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JOURNAL OF OPTIMIZATION AND DECISION MAKING

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JOURNAL OF OPTIMIZATION AND DECISION MAKING

An Analytical Model For Analysis of Steel-Concrete Composite Beams Under Monotonic and Repeated Loads

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Keywords	Abstract
Nonlinear analysis, Composite beams, Repeated loads, Slip, Numerical model	*This paper presents a numerical model for non-linear analyze steel-concrete composite beam subjected to monotonic and repeated loading with partial and full interaction. The model is constructed by a modified FORTRAN computer program. The nonlinear responsiveness for the composite beam is depending on dividing the element into fibers using a section layered method with the constituent materials hysteretic models. A derivation of the cyclic model for concrete, reinforcing bar and steel has been adopted. The behavior of the shear connectors under repeated load has also been derived. Since the slip between the components of composite beams is considered as a basic factor in the analysis, a slip model is adopted to estimate its amount. The numerical model is validated using experimental results. The results indicate that the presented numerical model can provide an effective tool for analyzing steel-concrete composite beam.*
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1. INTRODUCTION

The structural behavior of steel-concrete composite beams that combine tensile of steel beam and compressive property of concrete slab relies on the interaction between them. So, the connection largely influences the behavior of beam, and its simulation is a key matter in analysis of these structures. In the last years, many research studied the mechanical behavior of composite beams, more attention was on the steel-slab interface (Jianguo, et al., 2004) effective slab width (Aref 2007) numerical studies (Ikbal et al., 2009), improved shear connectors rules (Lawson, M., et al, 2017). Modelling of composite beam with shear connection (Jianguo, et al., 2004) and (Marzi, S. and Enrico. S. 2001). This work introduces a numerical model to analysis composite beam under monotonic and repeated load by including bond slip interfaces. The results have been evaluated, using pervious experimental results.

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2. MATERIAL PROPERTIES

2.1. Concrete

The cyclic behavior model under compression for concrete is shown in Figure 1 based on the monotonic stress-strain curve of (AL-Sulayfani, 1986). Cyclic model of concrete under compression in the current study is shown in Figure 2.

2.2. Steel

The monotonic envelope for the stress-strain relationship of steel was idealism as elasto plastic behaviors and the shape of the curve is assumed to be optimal in both tensile and compressive areas as shown in Figure 3.İn this paper Menegotto-Pinto model was adopted (Menegotto and Pinto 1973) as shown in Figure 4.
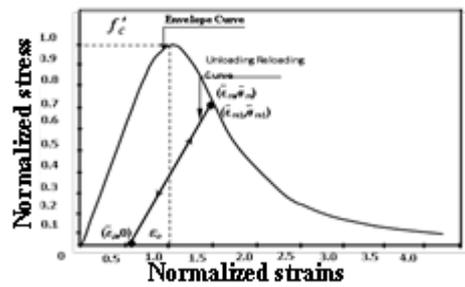
Figure 1. Cyclic model of concrete under compression
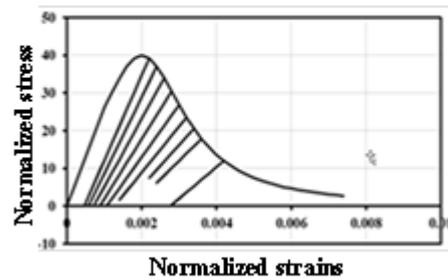
Figure 2. Cyclic model for compresion concrete (current study)
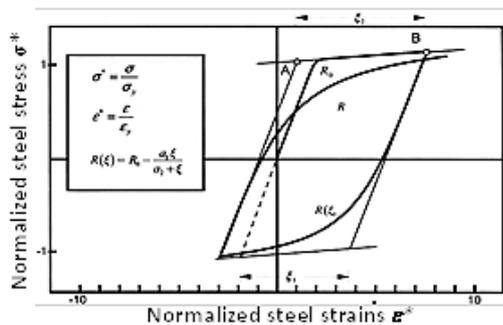
Figure 3. Menegotto and Pinto model
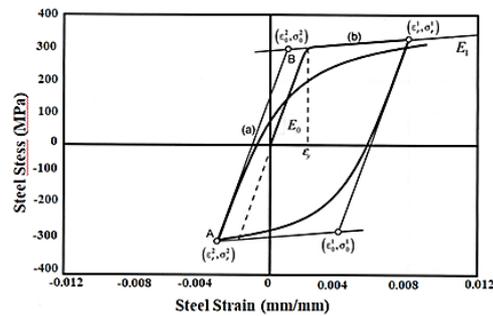
Figure 4. Cyclic model (current study)

2.3. Connectors

The flexural and slip behavior of composite beams are greatly affected by shear connectors feature ductility and stiffness. For shear connection consisting of headed studs the relationship defined by(Olgaard 1971) is used .Some curves representing the mechanical behavior of the headed studs are plotted in Figure 5. They were taking into account typical values of the two coefficients (α=0.558 and β=1 mm-1) in type A (α=0.989 and β=1.535 mm-1) in type B, or (α=0. 8 and β=0.7 mm-1) as in type C. In this study a derivation of model for stud connectors subjected to repeated loads has been presented in Figure 6.
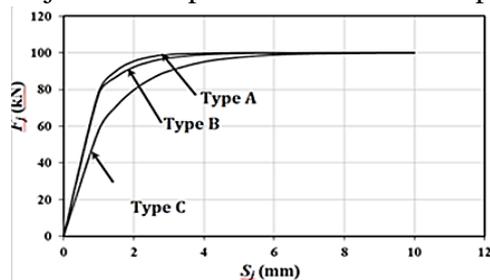
Figure 5. Constitutive relationship conne-ctors(Enrico S& Sherif, T 2004)
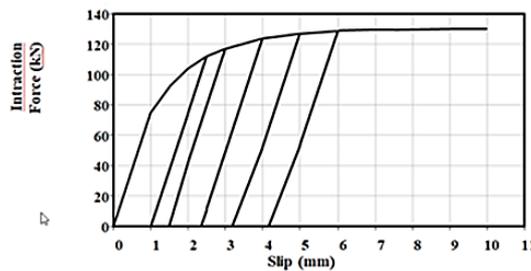
Figure 6. Cyclic model for connectors under repeated load (Current study)

3. PREDICTION OF INTERFACE SLIPS (JIANGUO & CAI, 2004)

The assumptions which were used in this study are : (i) The shear stress at the interface is commensurate to the slip,(ii) Same curvature for steel girder and concrete flange. (iii) For basically, section is symmetric about its vertical axis. For beam illustrated in Figure 7and from equilibrium ,the slip computed based on the Eqs.(1) and (2): Jianguo, and Cai (2004),

$$\varepsilon_{slip} = \frac{\alpha 1 \beta 1\, P(e^{-\alpha 1 x} - e^{\alpha 1 x - \alpha 1 L} - e^{-\alpha 1 x})}{2(1 + e^{-\alpha 1 L})} \tag{1}$$

$$\Delta\varphi = \frac{\varepsilon_{cs}}{h_c} = \frac{\varepsilon_{ss}}{h_s} = \frac{\varepsilon_s}{H} \tag{2}$$

4. NONLINEAR SECTIONAL ANALYSIS

The idea of the fiber section model is simple. The section is segmented into (n) fibers (equal area is not a necessity), concrete, structural steel or reinforcing steel can be assigned to a fiber.
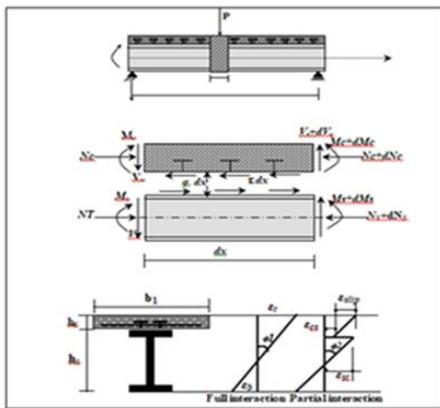
Figure 7. Calculated model for simply supported beam
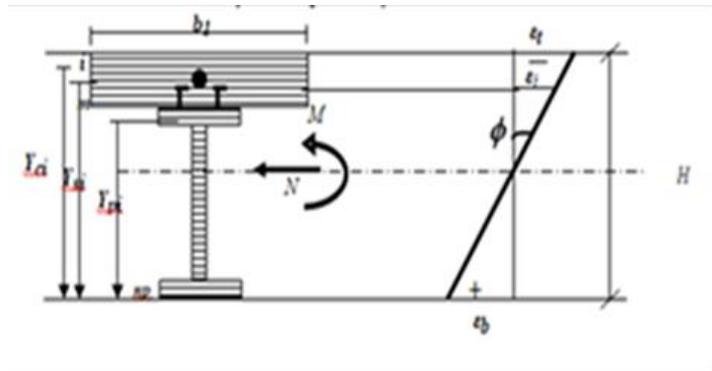
Figure 8. Section of simply supported beam

Assuming plane sections remain plane and from relevant constitutive models, fiber stresses are measured from strain fiber. To be an accurate analysis of the section, the internal stresses due to repeated impact loads must be calculated. Internal stresses require true distribution along the depth of section in order to achieve equilibrium and then it can be calculated the neutral axis and curvature, then modify the value of curvature after calculation of the value of slip between concrete and steel fragment. The steps of nonlinear analysis are summarized.

Step-1: The basis of analysis process is to get a balance between internal forces and moments with external forces and moments($N_{ext} = N_{int}$) and ($M_{ext} = M_{int}$). At the beginning must know external loads of axial force (N_{ext}) and moment (M_{ext}) affecting composite section, then divide the section into a number of layers to (m, n and n_p,) which represent the number of the concrete layers, elements of reinforced bar and number of steel section layers respectively as shown in" Figure 8.

Step-2: determine upper and lower strain layers of the section (ε_t) and (ε_b)

$$\varepsilon_t = \frac{\varepsilon_{t_{max}} + \varepsilon_{t_{min}}}{2} \quad \varepsilon_b = \frac{\varepsilon_{b_{max}} + \varepsilon_{b_{min}}}{2} \tag{3}$$

Step-3: determine the strain at the center of each layer of concrete section (n) , reinforced bar (m) and steel section (n_p) by the following equations:

$$\varepsilon_{ci} = \varepsilon_t - \frac{\varepsilon_t - \varepsilon_b}{H}(H - Y_{ci}) \;\; \varepsilon_{si} = \varepsilon_t - \frac{\varepsilon_t - \varepsilon_b}{H}(H - Y_{si}) \;\; \varepsilon_{pi} = \varepsilon_t - \frac{\varepsilon_t - \varepsilon_b}{H}(H - Y_{pi}) \tag{4}$$

Step- 4: Calculate the stress in each layer of concrete from the theoretical models of the material constitutive relationships for concrete, reinforced bar and steel section respectively, which corresponds to the strains calculated from step 4.

Step- 5: Calculation internal responses of internal axial force (N_{int}) and internal moment (M_{int}) as follows:

$$N\ int = \sum_{i=1}^{m} f_{ci} \cdot A_{ci} + \sum_{i=1}^{n} f_{si} \cdot A_{si} + \sum_{i=1}^{np} f_{pi} \cdot A_{pi} \tag{5}$$

$$M\ int = \sum_{i=1}^{m} f_{ci} \cdot A_{ci} \cdot (Y_{ci}) + \sum_{i=1}^{n} f_{si} \cdot A_{si} \cdot (Y_{si}) + \sum_{i=1}^{np} f_{pi} \cdot A_{pi} \cdot (Y_{pi}) \tag{6}$$

Step- 6: Comparing the computed internal force with the external force, if the difference between the two in what is permitted as in Eqution. (7) then going to step 7 or if not then must modify minimum or maximum strain in the upper layer(εt_{min}, εt_{max}).

$$\left(\left| \frac{Next_{int}}{N_{ext}} \right| \left| \% \right| \bigcirc \right), \left(\left| \frac{Mext_{int}}{M_{ext}} \right| \left| \% \right| \bigcirc \right) \tag{7}$$

If the N_{int} < Next then $\varepsilon t\ min$ modify to take the current value of εt .If the N_{int} > Next then ε_t max   modify to take current value of ε_t ,Then calculate the new value of ε_t by Eq. 3. Then going to the step or if not then must modify min or max strain in lower layer (εb_{min}, εb_{max}).

If Mint < Mext then $\varepsilon b\ min$ modify to take current value of εb ,If the M_{int} > M_{ext} then εb_{max} modify to take the current value of εb,Caculate the new value of εb from Eq. 3.

Step- 7: Comparing computed Mint with M_{ext} if the difference in what is permitted in Eq. 7.

Step 8: calculate the central strain ε_{cl} and the curvature ($\emptyset_1$)

$$\varepsilon_{cl} = \frac{\varepsilon_b + \varepsilon_t}{2} \qquad \varphi_1 = \frac{\varepsilon_t - \varepsilon_b}{H} \qquad \varphi_2 = \varphi_1 + \Delta\varphi \tag{8}$$

4.1. Flow Chart For Nonlinear Analysis of The Composite Section

The implementation of the model to enter numerical data on the number and description of cross sections of the engineering members of composite beam in the computer program, these include the number of data layers. The program calculates the strains and stresses at the center of each layer of concrete ,reinforced bar and steel section under the external loads to make a balance between them and responses of the Internal. The program calculates the value of the slip ,strain slip and strength of the connections at any distance from the length of the beam.

5. RESULTS AND DISCUSSION

5.1. Slip Effects Under Monotonic Load

A comparison with experimental beam tests by Abdel aziz,K. (1986) was involved in this study to assist validity of the numerical model in terms of mid-span deflection and slip of the connectors. Table 1. shows mechanical and geometrical characteristics of the cross section.A good agreement in terms of load–deflection was achieved between experimental and numerical technique as shown in Figure 9. Figure 10. shows slip distribution along left half of composite beam for two loaded levels and a decent agreement is observed.

5.2. Load-Deflection Curves Under Repeated Loads

Non-linear analysis conducted on composite beam. Table 2. demonstrates geometrical mechanical properties of cross section used in the analysis. Figure 11.displays the moment – deflection curve under repeated loads and Figure 12. shows load deflection curve. The increase of deflection is obvious in case of partial interaction compared with full interaction.

Table.1 The mechanical and geometrical properties of the cross section

Properties of materials	Section dimension
Concrete: E_c=33163MPa f'_c=35 MPa **Reinforced bar**: E_s=200 GPa f_y=350MPa f_u=375 MPa **Steel** E_s=200GPa f_y=350 MPa f_u=375) **Shear connectors**: Dia..= 19 mm Length=80 mm Space between pair = 650mm E_s=200GPa f_y=370 MPa	

Table 2. The mechanical and geometrical

Properties of materials	Section dimension
Concrete: E_c=2400(MPa) f'_c=25 (MPa) **Reinforced bar:** E_s=200000(MPa) f_y=245 (MPa) **Steel:** E_s=200 (GPa) f_y=245 (MPa) f_u=361 (MPa) **Shear connectors:** Dia.= 19 mm Length=80 mm Pair Space = 600mm E_s=200 (GPa) f_y=370 (MPa)	
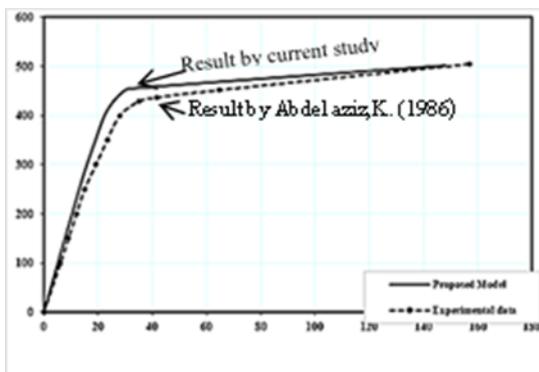
Figure 9. Load – Deflection curve for PI4
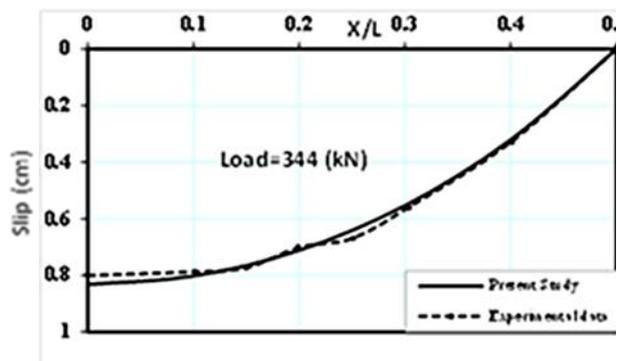
Figure 10. Slip distribution along PI4
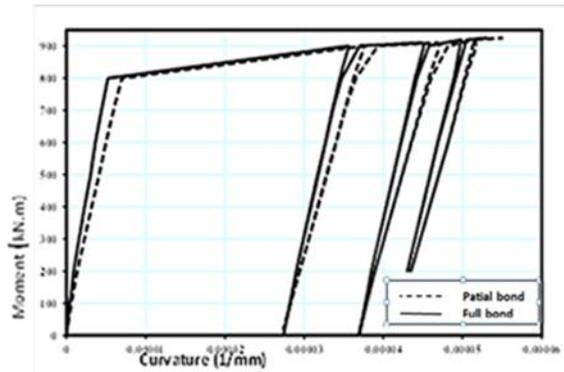
Figuer 11. Moment–curvature curve (current study)
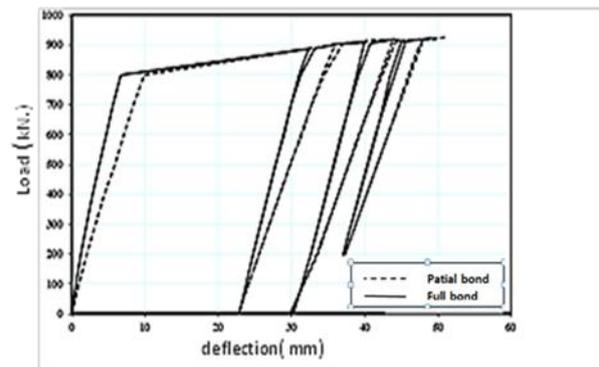
Figuer 12. Load–deflection curve (current study)

6. CONCLUSIONS

The following points can be summarized due to numerical study presented in this work:

A true replica of the materials stress-strain characteristics is the basic requirement for simulation of inelastic behavior up to the collapse of ductile structures. This computational technique allows the use of complex material models under repeated and cyclic loading and relates them with the structural behavior rather accurately. Since the stress distribution along the sections seems to be rather close to the real state. The method of layer section is proven to be efficient in a nonlinear analysis of concrete members.

The shear connectors that are used to connect elements together depend on slip that partially interacts to transfer of longitudinal shear. This results in the complexion of behavior of composite structures which is necessary to allow a slip in mathematical model. (Jianguo and . Cai 2004).

Conflict of Interest

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this paper.

Contribution of Authors

[Author 1's Dr.Ikhlas S. Sheet] Conceived and designed the study, collected and analyzed the data, and wrote the manuscript.
[Author 2's Dr.Bayar. J. Al-Sulafani]: research supervisor.

REFERENCES

Abdel-Aziz, K.,(1986). Modelisation et `etude experimental de poutres mixtes acier-beton aconnexion partielle ou espacee, Ph.D. Thesis, Institute National des Sciences Appliquées des cholar. Google Scholar

AL-Sulayfani, B.J. (1986). Contribution Du Comportement Desossatures En Beton Arme Sous Sollicitations Cycliques Analyse Non-Linear (Docteur). De 1`University De Nantes, https://scholar.google.co.uk/citations?user=ygyhqisAAAAJ&hl=en.

 Aref, A.(2007). Effective Slab Width Definition for Negative Moment Regions of Composite Bridges" Journal of Bridge EngineeringVol.12. https://ascelibrary.org/doi/abs/10.1061/%28ASCE%2910840702%282007%2912%3A3%283 39%29

Enrico S, Sherif, T ,(2004). Nonlinear analysis of steel-concrete Composite structures: state of the art. Journal of Structural Engineering, ASCE, Vol. 130. 24-34. doi:10.1061/(ASCE)0733-9445(2004)130:2(159)

Eurocode 4 (1994): Design of composite steel and concrete structures — Part 1-1: General rules and rules for buildings ENV 1994-1-1, https://www.phd.eng.br/wp-content/uploads/2015/12/en.1994.1.1.2004.pdf

Fabbrocino ,G., Cosenzc,G.(1999), Nonlinear Analysis of Composite Beams under Positive Bending, Computers and Structures, Vol. 70, PP. 77-89.doi:10.1016/S0045-79495(98)00173:4

Ikbal,N. Korkess,A. Yousifany, H. , & , Husain, H.(2009). Behavior of Composite Steel-Concrete Beam Subjected To Negative Bending. Engineering and technology journal, Vol 27, 53-71 https://www.iasj.net/iasj/article/28498.

Jianguo Nie; Jiansheng Fan; & C. S. Cai (2004): Stiffness and deflection of steel-concrete composite beams under negative bending. Journal of Structural Engineering, ASCE, Vol. 130, 1842-1851. doi: https://ascelibrary.org/doi/10.1061.

Lawson, R. and Aggelopoulos, E. Obiala and F. HanusC. Odenbreit and S. NellingernU. Kuhlmann and F. Eggert D. Lam, X. Dai and T. Sheehan 2017. "Development of improved shear connection rules in composite beams" - Final Rep. https://constructalia.arcelormittal.com/files/R&D%20report%20DISSCO%20en--6c334a425cf171309240b225dc8c61ec.pdf.

Marzi ,S and Enrico. S,2001. Analysis of steel concrete composite frames with bond-slip, Journal of Structural Engineering ASCE Vo.127, 1243-1250. https://web.archive.org/web/20040920122531id_/http://civil.colorado.edu:80/~spacone/Salari Spacone-ASCE-ST-11-2001.pdf

Menegotto,M. ,Pinto,P.E.1973. Method of analysis for cyclically loaded reinforced concrete plane frame including changes in geometry and non elastic behavior of elements under combined normal force and bending", Proceedings of IABSE symposium, Lisbon. https://www.e-periodica.ch/cntmng?pid=bse-re-001:1973:13::9.

Ollgaard,J. Slutter,R. Fisher.J. (1971). Shear strength of stud connectors in lightweight and normal weight concrete. Journal of Structural Engineering ASCE Vol.8, 711 https://core.ac.uk/download/pdf/228628783.pdf

The Role of Urban Connectivity in Progressing New Cities

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Keywords	Abstract
new cities, patterns of new cities, urban connectivity, upgrading policies, connectivity mechanisms	*As a result of environmental, social, and economic changes....etc., the master plans of cities, meeting the growing needs of individuals, expanded, deteriorated materially and environmentally, lost their connection with their current status. The research aims to determine the impact of urban connectivity in the progress of new cities, so it starts by identifying new cities, urban connectivity and its importance as a research topic. The problem of the research was:"there is a comprehensive lack of knowledge about the policies of upgrading new cities, activating the mechanisms of urban interconnection of new cities with existing cities within a unified and sustainable master plan". On its basis, of which the goal of the research was determined, in building a cognitive perception about the policies of development and redevelopment of new cities by activating the mechanisms of urban interconnection in them . The research adopted the descriptive-analytical approach in building the theoretical framework, and then applied it within the practical study, which included a description of two experiences of new cities (Almada and Kuala Lumpur), as cases embodying the types of urban connectivity and activating their mechanisms to connect new and existing cities in proportion to the specificity of their master plan.*

1. INTRODUCTION

The city performs different but related functions with regard to its connection with other satellite cities. Urban connectivity is important in explaining the growth of new centers, bringing about intellectual and dynamic changes or transformations. There is usually a dominance of a specific form of connectivity based on the patterns of (existing functions, movement, spaces between, the type of blocks and urban units, etc.). On this basis, the main idea of the research became to understand the meaning and contributions provided by the policies and mechanisms of urban connectivity that call for the upgrading of new cities. Therefore, the research aimed to build a clear cognitive vision about the policies of upgrading and redeveloping cities by activating the mechanisms of urban connectivity in them.

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In order to accomplish this, the study used to descriptive as well as analytic approach depending on the three axes as follows: The first axis began to provide a knowledge base for the new cities, which included defining the concept of new cities; and the second axis included the concept of urban connectivity, its elements, and principles, while the third axis concerned itself with investigating the policies of upgrading and redeveloping new cities in a way that enhances integration with the rest of the existing city's master plan master scheme. Then extract the theoretical framework and apply its features to selected models of projects that embody the types of urban connectivity and how to activate its mechanisms in upgrading the centers of these new cities and developing their master plans, down to the most important conclusions.

2. THE FIRST AXIS: THE CONCEPT OF NEW CITIES

(Noorloos, et al., 2018) indicated that new cities are environmentally friendly, smart, and based on large-scale enclaves that include a range of mixed land uses such as residential, commercial, along with technological centers, and economic zones, in a way that achieves social justice, embodies democracy, and meets the needs of all members of society. (Noorloos, 2018, p.1224-1225)

"New City" is a term that is used to refer to the new (cities, towns, neighborhoods, districts, and villages, etc..) that are institutionally different and share the adjective "New"; it can always be replaced with something newer. (Governa, et al., 2020, 1-5)

2.1. New Cities Styles

The concept of the "New City" is used in the sense of a town built directly, built on empty land and in proportion to the rest of the uses of the master plan ; there are several types of new cities according to their formation patterns, as follows:

First: Spatial Patterns: (Harris et al., 1945) indicated that the new cities develop in specific patterns in response to economic and social needs. They are as follows:

- Pattern of the central cities.   - The pattern of cities as transportation foci.
- Pattern of cities with specialized functions.   - Pattern of the clustered and compound cities.

Second: Functional patterns: which were referred to by (Prideaux, 2009), as follows:

- Industrial cities.   - Commercial cities.   - Political cities.
- Residential cities.   - Tourist cities.

2.2. New Cities Attributes

New cities are characterized by a set of basic characteristics, which are as follows:

* Manage the rapid growth of large cities by reducing the size of their population.
* Providing low-cost and affordable housing.
* Transfer of some industrial facilities from major cities to new ones.
* Prevention of the formation of slums in the vicinity of large cities.
* Reduce traffic congestion and environmental pollution such as air and water pollution. (Atash, 2000, p.67 & 75-76)

3. THE SECOND AXIS: THE CONCEPT OF URBAN CONNECTIVITY

The term "Connectivity " refers to any repetitive sequence of behavior that arises in one system and interacts with it in another system. (Rosenau, 1969, p.5), and (Cullen, 1971) describes the connectivity as the sequence and coherence in vision the urban landscape as integrated relationships between the constituent parts of the city and its spaces. (Cullen, 2012, p.7-8)

Howard, 1985 stated that urban connectivity is the combination of the countryside and the city within a design unit called "the Garden City of Tomorrow", being polycentric economically, socially and culturally integrated and interconnected with each other by means of urban axes. (Howard, 2003, p.37)

3.1. Elements of Urban Connectivity in New Cities

New cities are understood as spatial units that interact at various levels and scales in a hierarchical manner, the elements of which consist of the following:
 * Architectural elements.   * Natural elements.
* Nodes of various functions such as: (residential, commercial, industrial, religious, cultural, and natural areas). (Lynch, 1984) & (ALslik, et al., 2014, pp.41-48, pp.6)

3.2. Principles of Urban Connectivity in New Cities

(Remesar, 2012) identified five values that he considered necessary principles to enhance urban connectivity in the centers and spaces of new cities, predicated on the idea that is the main factor improving city centers is public space. These principles are embodied in: (James, et al., 2020, p7-21) & (Remesar, 2012, p.10-11)
 -         Motion - The   anchor – Multifunctionality. - Diversity. - Identity.
 continuity.   spaces.

4. THE THIRD AXIS: MECHANISMS FOR UPGRADING AND REDEVELOPING NEW CITIES

 (Sepe, 2022) stated that the urban upgrading and renewal of new cities is an integrated approach that combines vision and action to solve various problems related to disadvantaged urban areas through mechanisms as applied measures that achieve sustainable urban design: attracting the city's residents to places by providing all their material and moral needs, ensuring flexibility of places and adapting them to change, creating new movement axes that enhance the connectivity between people and place, the connectivity between the green and blue infrastructure and creating an appropriate balance with the gray ones to ensure environmental sustainability and economic renewal, creation of safe and inclusive public spaces, promoting movement connectivity between new cities and their surroundings and urban and rural areas by promoting sustainable transport and mobility, linking the new areas visually with each other and commensurate with the building heights of other neighboring cities. (Sepe, 2022, p.7-11).

5. THEORETICAL FRAMEWORK

The theoretical framework includes the most important elements of urban connectivity for the upgrading of new cities may be summarized in table 1. below.

Table 1. The theoretical framework of urban connectivity/source. the researchers

The main terms	The secondary terms	Indicators
New cities attributes	Analytical properties	- Easy access between the new city and the original center. -Distinguished planning or division, with wide and quiet streets and the availability of commensurate urban places. -Economic competitiveness in providing job and investment opportunities.
	structural properties	- The spatial connectivity between regions through open spaces. - Functional versatility within urban areas.
	Evaluative properties	- Accommodate the population increase in cities.
Types of urban connectivity	Generative continuity pattern	-The overlapping of building units with the space structure. (overlapping of buildings and roads)
	Organic pattern	-The rapid growth of the elements.
	Articulatory pattern	-provide articulated support axes that connect the new parts added with the whole.

	Motion pattern	-Enhancing the flow of movement and access to the rest of the new spaces and areas.
Principles of urban connectivity	At the level of organizing city centers	- Motion continuity. - Preservation of anchor spaces. -Multifunctionality.
Mechanisms of urban connectivity	Condensation	- The center should have a high density .
	multipolarity	-Moving away from one center of the urban fabric.
	articulation	-Urban axes as connecting parts between the newly developed regions.
	Spatial rhythm of morphological elements	- Repetition of urban patterns, balance between urban parts.

6. PRACTICAL STUDY

6.1 New Cities in the Almada Region

The new cities in the Almada region are divided into three, as follows:

A. Almada sprawl - an emerging centrality in the context of a dispersed city, where the urban functions of large catchment areas and good access conditions transform it into an attractive centrality within the urban scale **B.** Subrida suburban area - a semi-urban, semi-residential area consisting of single-family houses, and its origins are linked to the strong urban growth associated with the migration of people from the countryside to the city, while showing some characteristics of its rural past. **C.** Central Almada - a unified urban area, multifunctional and with good accessibility, linking it to other metropolitan areas. It is still the main urban center of the surrounding areas, with the greatest concentration of activities, commerce and services in it, although in some areas there are vacant, neglected spaces especially in the historic center. As in figure 5. (Remesar, 2012, p.13) The two patterns of continuous and organic connectivity have been activated to connect the center of Almada, its surrounding neighborhoods, and the emerging central areas, through the creation of motion and visual axes that make the city multi-centered with various functions, characterized by permeability in the possibility of multiple access, and thereby enhancing the continuity of occupancy of the place (24 hours). Some attempts to create these connections (e.g. Parque da Paz, bike lane to the Forum Almada shopping center), others are planned (e.g. pedestrian and bicycle connection between the center of Almada and the transport front), these connections must guarantee good walkability and suitable conditions for cycling along with along with sustainable public transportation. (Remesar, 2012, p.12-17) as in figure 1. below.

6.2 New Cities in Kuala Lumpur

These cities are characterized by a hinged or motor linkage pattern that serves to provide a network of pedestrian connections and spatial or hinged support axes that connect the new added parts with the urban environment within a dynamic unit of movement interconnected at the functional and spatial level. This is done by creating a transition zone that connects private and public spaces, as in "Jalan Tun Tan Cheng" is the main street that connects all other pedestrian routes at the intersection of "Jalan Tun HS Lee", "Jalan Petaling", "Jalan Hang Kasturi" and "Jalan Sultan". (Choo, 2017, p.1-6). As in figure 2. below.

Figure 1. Shows the dependence of the pattern of organic connectivity and the continuity sources: (Almada new centers master plan, google image)

Figure 2. Shows the articulated connectivity between the suburbs of Kuala Lumpur and the old historical center / source: (choo, 2017, p.4&6)

7. CONCLUSION

- Urban connectivity is important in explaining the growth of new centers, bringing about intellectual and dynamic changes or transformations.

- Urban connectivity has a set of elements in the light of which it operates at the level of the individual building as a part and the fabric as a whole, to achieve the desired goal and significance.

- The levels of upgrading the new cities towards sustainable development and linking the areas with each other according to the following levels:

* The social level: enhancing the sense of human belonging to space, enhancing social cohesion, minimizing the random spread of new functions that affect the concept of privacy within residential areas.

* The economic level: developing activities and jobs that help attract the population and increase the general income of the city, provide job opportunities in the new cities, and restore the traditional building materials, that harmonize with the local context or environment and economically inexpensive.

* The functional level: diversifying activities in urban areas to achieve inclusiveness and communication, reviving neglected areas and enhancing their livability, gradual movement or moving from public to private space.

Conflict of Interest

There is no conflict of interest between the authors during the creation of this study.

Contribution of Authors

The authors involved in this study contributed to all the aspects of the study.

REFERENCE

ALslik, G. M. R., & Majeed, F. A. (2014). Succession of Urban Structures of the City of Baghdad. Journal of Engineering, 20(12), 1-30. doi:https://doi.org/10.31026/j.eng.2014.12.11

Atash, F. (2000). New towns and future urbanisation in Iran. Third World Planning Review, 22(1), 67. doi: https://doi.org/10.3828/twpr.22.1.d24p30hk65524v20

Choo, H. (2017). Urban Pedestrian Linkages in the Heritage District of Kuala Lumpur, UIA, Seoul World Architects Congress. 1-6. https://scholar.google.com/scholar?q=Urban+Pedestrian+Linkages+in+the+Heritage+District+of+Kuala+Lumpur&hl=en&as_sdt=0,5

Cullen, G. (2012). Concise townscape. Routledge.doi: https://doi.org/10.4324/9780080502816

Governa, F., & Sampieri, A. (2020). Urbanisation processes and new towns in contemporary China: A critical understanding from a decentred view. Urban studies, 57(2), 366-382.doi: https://doi.org/10.1177/0042098019860807

Harris, C. D., & Ullman, E. L. (1945). The nature of cities. The annals of the American academy of political and social science, 242(1), 7-17. doi: https://doi.org/10.4324/9780203543047

Howard, E. (2003). Garden cities of to-morrow. Organization & environment, 16(1), 98-107.doi: https://doi.org/10.1177/1086026602250259

James, P., Magee, L., & Honeck, T. (2020). Principles for Better Cities: Towards Sustainable Development in Metropolitan Regions, Precincts and Places. https://researchdirect.westernsydney.edu.au/islandora/object/uws:58325/

Lynch, K. (1984). Reconsidering the image of the city (pp. 151-161). Springer US. doi: https://doi.org/10.1007/978-1-4757-9697-1_9

Pinto, A. J., & Remesar, A. (2012). Urban cohesion: a guiding concept for new urban realitites. Ambivalent Landscapes Sorting out the present by designing the future.https://www.researchgate.net/profile/Antoni-Remesar/publication/299885966_Urban_cohesion_a_guiding_concept_for_new_urban_realiti es/links/5706a7ba08ae04e9708c097b/Urban-cohesion-a-guiding-concept-for-new-urban-realities.pdf

Prideaux, B. (2009). Resort destinations. Routledge. doi: https://doi.org/10.4324/9780080939643

Rosenau, J. N. (1969). Toward the study of national-international linkages. Linkage Politics, 44-63. https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&q=Toward+the+study+of+nationa l-international+linkages&btnG=

Tuominen, P. (2023). Designing healthy and liveable cities: creating sustainable urban regeneration: by Marichela Sepe, Oxon & New York, Routledge, 2023, 272 pp.,£ 120 (hardback), ISBN 9780367566425. doi: https://doi.org/10.1080/17549175.2023.2260359

Van Noorloos, F., & Kloosterboer, M. (2018). Africa's new cities: The contested future of urbanisation. Urban studies, 55(6), 1223-1241. doi: https://doi.org/10.1177/0042098017700574

The Third Space In Interior Design

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Keywords	Abstract
Third space *Interior design* *Contempplative spaces* *Fourth place*	*After the recent Corona pandemic crisis ,it was necessary to pay attention to the means that give meaning to internal spaces and express human identity and requirements. The research paper discusses the third space in architecture as an inter-expressive space that combines two functions and its transformation into the concept of the fourth place by the concept of contemplative spaces that is reflected in the interior spaces in addition to the contribution of spaces in supporting social interaction as a basic need of its needs and how contemplative spaces can transform one's social interaction to presence with self and mind to a fourth place. In order to understand the third space, it was necessary to explore the theoretical frameworks on the topic, how it contributes to supporting the interior space, and what are the means to achieve the fourth place in architecture and interior design in particular, through discussing a number of descriptive projects elected for the purpose of clarifying the theoretical frameworks that contributed to shaping the concept at the level Interior design and architecture of interior spaces.*

1. INTRODUCTION

After the recent crisis of Corona pandemic, it was necessary to pay attention to express the identity of a person, as many people often see space that performs a specific function and raises a sense of appropriate use, so the success of architecture or it's beauty should happen through the effects of the internal space first, as well as the space interpretations that must be parallel to the formal, psychological and intellectual interpretations, and thus reflect the value of the building architecturally (Abusaada, 2018, p. 78) which includes the experience of the internal space with all its elements (such as materials, lighting, masses, decoration, etc.)

Plato defined space in terms of place by using the words (Chora) and (Topos) to denote space, while Aristotle noted that space takes precedence over all other things, he also sees it as a "container" of things and is prior to everything (Abusaada, 2018, p. 79).According to Heidegger, the space involves something like a bridge, and its purpose is to carry something from one place to another(Ibid. Source). Heidegger believes that the place from his point of view is in the detail perceived by the senses of existence in the world like an experience of self, mind and body, while others see that the structure of the place depends on the human experiences that occur in space (transforming space to a place through experience like contemplative practices)by enriching the human experience as important centers for our direct

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experiences in this world, while some others indicated the importance of places with a cultural and human dimension through personal, collective processes (Abusaada, 2018, p. 80).

Place is a term based on meaning created from interactions with the physical background, the given place writings focus on a powerful view of "social creation." This sense of place is not rooted in the physical surroundings, but rather in people's understanding of it, which is formed through interaction with that,Through lived experience, spaces become laden with meanings and become "places." (Raghani et al., 2022, p. 250), and thus we can focus on a specific concept of "third space" as a space that reflects social interaction and meaning which is expressed in the next section.

2. THIRD SPACE

The third space has been defined as the space in which an individual experience a transformative sense of self, identity, and relationship with others. (Krider et al., 2019), A hybrid or marginal space that can be transformative.Whereas (Collins English Dictionary) indicated a place to socialize outside the home.Another definition of Third spaces are designed to encourage social interactions, to create unique spaces, to foster connectivity and creativity, and to make use of spaces (Morisson, 2019). In his book The Great Good Place (1989-1990), Ray Oldenburg argues that the third spaces are important for civil society, democracy, civic participation, and the establishment of a sense of place. (Carmona et al., 2004). So, the third spaces are the "anchors" of community life that facilitate and foster broader and more creative interaction. In other words, "The third space is where you relax, and make new acquaintances." The American sociologist Ray Oldenburg formulated the concept of third space that is public and informal, in which a person meet different individuals, with whom he may enjoy sharing time. It provides interactive structure, in which people actually achieves an effective civil society, leading to the creation of special bonds.

2.1. Theoretical Origins of The Third Space

The third space is a theory of identity and community realized through language or education. Attributed to Homey K. bhabha Third space theory explains the uniqueness of each person, actor, or context as a "hybrid". (Nethersole, 2020) Third space theory emerges from the sociocultural tradition which are concerned with the constitutive role of culture in the mind. Third Space was recently used by Randall Bakker to represent the fusion of physical space (first space) and dimension (second space) in a networked space that can be inhabited by many simultaneously or remote users (Third space). (Kosari & Amoori, 2018) The hybrid concept of blurring reality and virtual into third space is extended by distributed presence, where participants in third space are in distributed physical spaces, essentially, in reference to a shared electronic social space. The Third Space expands the concept of the real and the virtual by proposing a hybrid space that allows remote participants to engage in social relationships with each other at a distance. (Nethersole, 2020). Edward Soja's theory of Third space where the first space represents the physical built environment, which can be mapped, quantified, and "seen" in the real world. The second space is conceptual space how that space is conceived in the minds of the people who inhabit it. It is the product of (re)imaging the social norms that determine how people may act or behave in that space. The third space is a 'real and imagined' space, a living space, the way people actually live and experience that urban space. This works in real space and is activated by projections of the second space. (Allen, 1997)

Through the foregoing the most important features of the third space is a neutral space between two functions that gives importance to the individual's position in society and helps him to feel entity and being as a basic need among human needs, this represented the pandemic as a psychological, physical, and health trauma presenting alot of pressure for the human being, in

which it sought to review thoughts,emotions, and the way one can act and, in order to enhance belonging, identity, and reflect values in which one believes.

2.2. Characteristics of Third Spaces

Other scholars (Kosari & Amoori, 2018) have summarized Oldenburg's view of the third space with eight characteristics: 1- Neutral ground: Occupants of third spaces are not constrained by the area financially, politically, legally.2-a leveling space: third spaces do not give importance to the position of the individual in society. It does not matter the socioeconomic status of an individual in a third location. 3- Conversation is the main activity: The tone of the conversation is usually light and goodwill are highly valued.4- Accessibility and accommodation: The third premises must be open and accessible to the occupants. that is providing the needs of its residents.5- The regulars: The third spaces include regular elements that help give the space a tone(to feel welcome and accommodated).6- A low profile: The third spaces are particularly useful. The interior of the third is devoid of extravagance or grandeur, and has a homely feel. they accept all kinds of individuals.7 - Occupants of Third spaces feel that a piece of themselves is rooted in the space, and they gain spiritual renewal by spending time there. according to (Jeffres et al., 2009), is that it "relieves the stress of the daily demands, providing the sense of inclusion and belonging associated with participation in the social activities of a group"

While others mentioned (Krider et al., 2019) that third spaces characterized by:regular, and frequent there naturally as its between work and home,Entertaining conversations the main purpose, It's a place of possibility,Equitable to all –a neutral ground public space or business where everyone is equal, It's human scaled–appeals to the senses, allows for close interaction, observation and comfort, Spirit of place (Genius Loci) has been tapped, giving it legitimacy and purpose.

The next section dicusses the idea of transforming third space to fourth place by experiencing self and mid through the concept of "contemplative practices" ,wehile the research focuses oon the notion of "contemplative spaces" as a practice that occurs in interior spaces.

3. CONTEMPLATIVE SPACES IN INTERIOR DESIGN

Contemplation has been defined as a form of private devotion, an act of considering with attention and a state of mystical awareness of God's being(Merriam Webster),while Oxford Dictionary defined as the act of thinking deeply about something, the act of looking at something in a calm and careful way and the intention or

Table 1. Theoretical formation of contemplative spaces(done by the author)

1	Exploring the Relationship Between Contemplative Spaces, Human Experience and Spiritual Architecture	2022	Inner peace	disassemble	
				regroup	
				Reuse	
			contemplative space(embodiment language)	garden in the middle of a dense area	
				a light source in a dark place	
				Scene framing	
			Spirituality	Finding meaning	Stimulating the senses
				Finding inner peace	
				Finding comfort	

#	Title	Year	Category	Subcategory	Detail
				spiritual healing	
			Contemplative process	Thinking process	
				Provide breathing space	
			effectiveness of the space	Day light	
				Healing nature	
				Positive focus	
				Using color, texture and materials	
				Adding different elements (fountains, winding paths)	
2	How Does Buddhist Contemplative Space Facilitate the Practice of Mindfulness	2022	From within mindfulness	atmosphere	Finding refuge
				comfort	
				solitude	
3	Impact of Contemplative Spaces and Sacred Geometry on Spiritual Development	2021	The importance of the spiritual side	Achieving contemplative architecture	Human spiritual development
					Accelerate recovery and spiritual journey
			Timeless architecture quality	improve the quality of life	
				Focus on the shape, aesthetics of the space	
				human need to establish contact with self	
				Stimulating the senses	
				Stimulating positive energy	
				From material to the post-material space	
4	Contemplative Architecture	2019	Benefits of mindfulness	Improve cognitive performance	
				Decrease stress levels	
				Enhancing mental and psychological health	
			Aspects of connection	With self	
				With nature	
				With light and day light	
5	Public Libraries as Contemplative Spaces	2019	aspects of contemplative practice	awareness	Stillness,Generative, CreativeActivist, Relational, Movement Ritual, cyclical
				connection	
		2019	Fourth place	Coliving place	

6	A Typology of Places in the Knowledge Economy			Coworking place
				Comingling place
7	Transcending Architecture	2015	Manifestations of contemplative architecture	Theatric mode
				Sanctuary mode
				contemplative mode
			mindfulness	Connect to nature
				serenity
				isolation

expectation or acceptation. A study in the aspects of contemplative architecture (Bermudez, 2015, p. 22)showed that there were three main aspects(as shown in fig.1):

a. architectural forms providing background for spiritual activities that people experience ritual performances facilitated by geometry rather than experience architecture itself. giving meaning and spirituality through its scale and its impressive but modest architecture.

b. architectural forms provide a boundary between the wider environment. i.e. separating the inner spiritual environment from the outside world, thus creating a contemplative atmosphere. The boundary between the two worlds creates an isolated, mythical experience.

c. This involves constructed formations that serve as the actual object of direct, purposeful meditative attention. the most famous example of a meditative pose is Mecca.

Contemplative spaces was crutial to focus on the important aspects of the contemplative space and its features, where meditation was associated with full mental focus (minfullness), by paying attention intentionally without issuing judgment, with an emphasis on the awareness of the present moment. Through solitude, calmness, and communication with the natural elements of space or the natural environment (Chen et al., 2022, p. 1), in addition to other intangible elements, including (the general atmosphere, comfort, and tranquility). The study emphasized that true mindfulness comes from within. (Ibid., pg. 19)

a.Taj Mahal as an example for theatical style	b.Al Khulafaa' Mosque s as an example of the Haram style (separation between inside and outside)	c.The Holy Kaaba as an example of the contemplative style
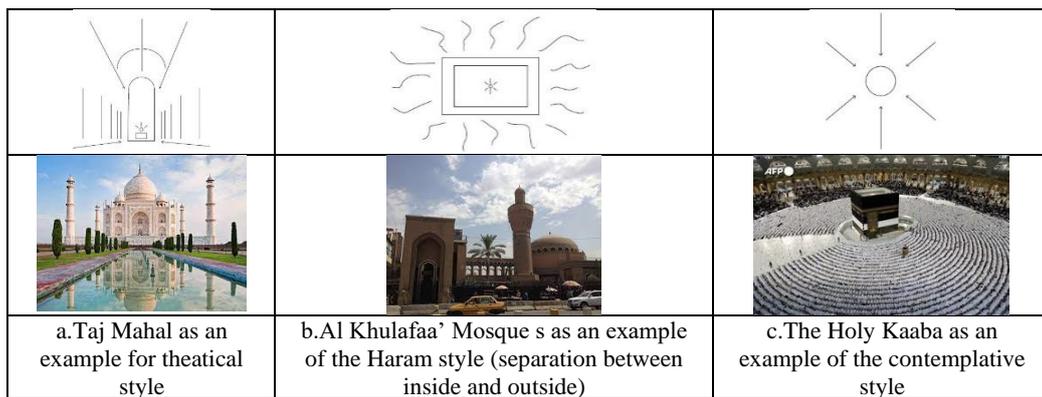
Figure 1. Aspects of contemplative architecture (modified by the author)

There are many scientifically proven benefits of practicing mindfulness, including improved cognitive performance, stress reduction, and improvements in mental and psychological health (Puranik et al., 2019, p. 646). Other studies have referred to (the tree of contemplative practices). In this perception, the roots of contemplative practice lie in two basic aspects:

awareness, Connection and communication. The different branches of this tree denote the different modes of meditative practice: static, generative, creative, activist, relational, kinetic, and ritual/cyclical. Therefore, practices such as mindfulness and meditation fall under the category of "static" practices, (Pyati, 2019; Chen et al., 2022).

Returning to the original idea of the research, the main axis of the research was concerned with the third space, which is a hybrid space that combines the material and immaterial worlds, or between the natural and the imagined, or between housing and working to be a social space that provides a common ground between the population, in which the conversation is an essential axis in its success.While (Morisson, 2019) proposed a new model in which it addresses the fourth space, which combines the first and second space (coliving), the second and third space (coworking), and the first and third space (comingling).
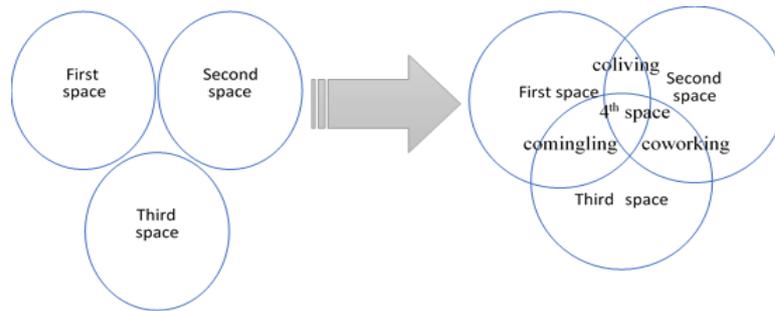
Figure 2. Transforming third space into fourth place (morisson model)
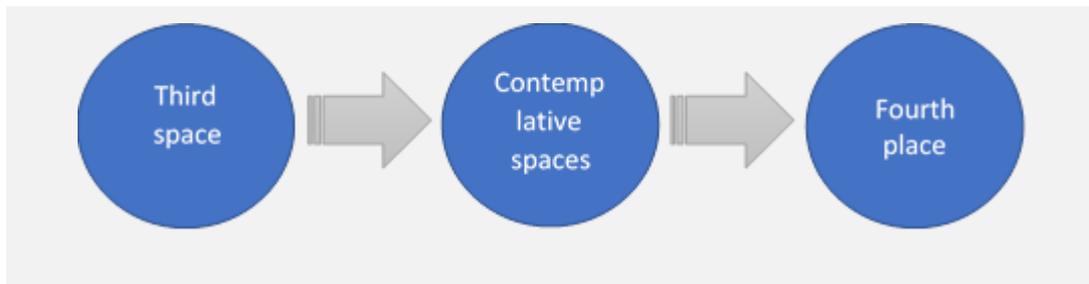
Figure 3. Transforming third space into a fourth place through contemplative spaces(done by the author)

4. CASE STUDY AND DiSCUSSiON OF THE SELECTED PROJECTS

The research used the descriptive method in obtaining the results for the research sample by analyzing contemporary global projects to obtain a table of basic vocabulary in the design of the third space through the reflective space.the first case was a contemporary place of worship (Mosque of the Late Mohamed Abdulkhaliq Gargash -UAE-2021)that is quietly skilled in its use of form, materiality, and controlled natural light to evoke a sense of calm, spiritual connection, and the worshiper's transition from the material world to the inner sense of existence. in the heart of Dubai, to promote an act of worship and a transitional journey so that the worshiper is ready for prayer and feels a sense of intimacy with the sacred. A series of spaces is created that allows the worshiper to move away from the crowded outside world and prepare for an inner experience. Natural light is used as a tool to enhance a sense of spirituality, a connection between man and the Creator. Scale also plays a role in creating this sense of sacredness.The use of pattern and materiality in this project enhances the user's experience during their journey from the outside to the courtyard and entering the building,with natural light in worship areas with great control and care to illuminate the main spaces and create a serene atmosphere and a sense of connection to the Creator. The double skin dome allows natural light to enter, filtering through the interior decorative leather, which incorporates the

same pattern. This filtered light creates a soft, naturally lit prayer space that is attuned to an introspective mind while praying.

Another case no. 2 (The Cambridge Mosque Trust-United Kingdom-2017)wood projects devoid of major forms such as the Cambridge Mosque demonstrate the enormous range of forms that modern timber construction can take. On an area of 2,340 square meters, the wooden construction accommodates a prayer room that can accommodate 1,000 worshipers, a café, and two apartments. The calm and focused atmosphere inside the building is created by 30 interconnected tree-like wooden columns. The geometry is guided by a historical Islamic pattern called "Nafas Al-Rahim". The pattern evokes the rhythm of breathing and thus life.

While case no.3 (Mosque haj benuah-Iraq-1974)is one of the controversial mosques in Iraq, which is located on the Karkh side of the city of Baghdad and in the Al-Alawi area. It was inaugurated in 1974, and used for its unique Islamic architecture and style. It contains paintings in Arabic calligraphy of verses from the Qur'an on its walls. The mosque has an oval dome, 36 m high and 25 m in diameter, and decorated with beautiful inscriptions. The mosque also has a high minaret, 55 m high, which is octagonal in shape, 3 m in diameter, and covered with the blue Karbalai kashi. There is an oval-shaped dome surrounded by a group of separate concrete ribs at the bottom resting on a "drum" that rises from a cubic block that encloses the space of the mosque's sanctuary. Next to the dome, a long, ribbed-shaped minaret element rises. The sanctuary block is surrounded by external galleries with pointed arches. Some of the mosque's surfaces were covered with colored bricks with a metallic luster, which is locally called "Karbalai". The aim of the design was to raise the artistic level and change the prevailing aesthetic circle. The composition as a whole repeats the formula of a design solution, in which the vocabulary of the imagined image is evoked by the memory in its perceptions of the building (the mosque), and the introduction of sculptural elements does not deviate from the spirit of modernity

5. CONCLUSION

The Corona pandemic played a positively influencing role on man's return to self ,being and contemplation of the psychological aspect of truth and spiritual need and reflection on the spaces that achieve identity and needs, as the third space reflected the social aspect of man's need for the other and social interaction ,the need for self-reflection and fulfillment. The research saw the contemplative space as an aspect that achieves social interaction on the one hand, and as an orientation that achieves communication with self and mind and the true identity of the individual, forming the fourth place that tries to reach coexistence that combines spirit, body, matter, nature, isolation, and interaction.the paper concluded that fourth place is acheived through contemplative spaces that is characterized by (comingling,colivingand that reflect connection,awareness,enhance effectiveness through:day light,positive focus using colors, textures ,local materials, caligraphy and orniments elemnts in interior spaces in order to find peace and meaning).The use of local materials in interior spaces to reflect the character of the local and natural environment, such as wood and local pressed bricks, The use of natural lighting and methods of manipulating lighting to provide a high spiritual atmosphere and connection with the Creator and the self, Focusing on decoration, inscriptions, and the arts of Arabic calligraphy, in addition to scale and materials. And Focusing on the expressive, abstract and sculptural aspect to obtain the architectural form and thus the internal space and its reflection through the architectural scale.

Sample1: Mosque of the Late Mohamed Abdulkhaliq Gargash -UAE-2021(www.archdaily.com)

Sample2: The Cambridge Mosque Trust-United Kingdom-2017 (www.archdaily.com)

Sample3: Mosque haj benuah-Iraq-1974(www.gettyimages.ca)

Figure 4. Case study samples

Conflict of Interest

Authors declare that there is no conflict of interest.

Contribution of Authors

The author involved in this study is Neda Khalil Ibrahim Al-arab; who contributed to all aspects of the study;the idea, design, inspection, data collection, literature review, critical review and analysis and interpretation sections of the study.

REFRENCES

Abusaada, H. (2018). The fifth dimension: Urban design-The atmospheres of the city https://www.academia.edu/36441662/%D8%A7%D9%84%D8%A8%D8%B9%D8%AF_%D8%A7%D9%84%D8%AE%D8%A7%D9%85%D8%B3_%D8%A7%D9%84%D8%AA%D8%B5%D9%85%D9%8A%D9%85_%D8%A7%D9%84%D8%AD%D8%B6%D8%B1%D9%8A_%D8%A3%D8%AC%D9%88%D8%A7%D8%A1_%D8%A7%D9%84%D9%85%D8%AF%D9%8A%D9%86%D8%A9_The_fifth_dimension_Urban_design_The_atmospheres_of_the_city_in_Arabic_

Allen, R. (1997). What Space Makes of Us: Thirdspace, Identity Politics, and Multiculturalism. https://www.semanticscholar.org/paper/What-Space-Makes-of-Us%3A-Thirdspace%2C-Identity-and-Allen/83ce25fdb30933feb1413a97eb5eebf07bf51651

Bermudez, J. (2015). Transcending architecture. The Catholic University of America Press. doi:https://doi.org/10.2307/j.ctt130h9f6

Carmona, M., Heath, T., Tiesdell, S., & Oc, T. (2004). Public Places Urban Spaces. Urban Design Quarterly, 90, 40. doi:https://doi.org/10.4324/9780080515427

Chen, A., Porter, N., & Tang, Y. (2022). How Does Buddhist Contemplative Space Facilitate the Practice of Mindfulness? Religions, 13(5).doi: https://doi.org/10.3390/rel13050437

Jeffres, L. W., Bracken, C. C., Jian, G., & Casey, M. F. (2009). The impact of third places on community quality of life. Applied Research in Quality of Life, 4(4), 333–345. doi: https://doi:10.1007/s11482-009-9084-8

Kosari, M., & Amoori, A. (2018). Thirdspace: The trialectics of the real, virtual and blended spaces. Journal of Cyberspace Studies, 2(2), 163–185. doi: 10.22059/JCSS.2018.258274.1019

Krider, K., Robinson, N., Aidlin, J., Aidlin, A., Design, D., & Francisco, S. (2019). Third Place: Architecture, Spirit and Community.https://arlingtonva.s3.amazonaws.com/wp-content/uploads/sites/31/2019/10/NPC19_FNL_compressed.pdf

Morisson, A. (2019). A typology of places in the knowledge economy: Towards the fourth place. Smart Innovation, Systems and Technologies, 100, 444–451. doi: https://doi.org/10.1007/978-3-319-92099-3_50

Nethersole, R. (2020). 6| Shards of Hegel: Jean-Paul Sartre's and Homi K. Bhabha's Readings of The Wretched of the Earth. Violence, Slavery and Freedom between Hegel and Fanon, 117.https://ebin.pub/violence-slavery-and-freedom-between-hegel-and-fanon-9781776146239-9781776146246.html

Puranik, P., Joshi, R., & Raverkar, A. (2019). Contemplative Architecture. 2(11). International Journal of Research in Engineering, Science and Management Volume-2, Issue-11, November-2019 www.ijresm.com , ISSN (Online): 2581-5792

Pyati, A. K. (2019). Public Libraries as Contemplative Spaces: A Framework for Action and Research. Journal of the Australian Library and Information Association, 68(4), 356–370. doi: https://doi.org/10.1080/24750158.2019.1670773

Raghani, S., Brar, T. S., & Kamal, M. A. (2022). Exploring the Relationship Between Contemplative Spaces, Human Experience and Spiritual Architecture. Architecture Engineering and Science, 3(4), 249. doi: https://doi.org/10.32629/aes.v3i4.1051

Soja, E., & Thirdspace, W. (1996). Journeys to Los Angeles and other real-and-imagined places. Malden, MA: Blackwell. doi: https://doi.org/10.1007/978-3-658-10438-2_

The Heritage Identity Within The Architecture of The Old City of Mosul

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Keywords	Abstract
heritage, local identity, traditional building characteristics	*The city of Mosul is considered one of the important Arab cities due to the richness of its history and its human, cultural, and architectural heritage; the traditional building in the old city represents the visible and tangible part of this history, which expresses the local heritage identity. Identity is one of the most important social links and expresses a wide range of concepts and thoughts. Generally, it can be defined as the characteristics by which a person, a group, or a culture can be distinguished from another. Architectural identity is a community's uniqueness and architectural distinction, which comes from the factors surrounding it, such as political, economic, environmental, social, and cultural factors. During the past couple of years, the old city of Mosul witnessed many construction operations concerning the last unfortunate events in the city. However, most of these reconstructions were planned or organized by non-governmental, specialized, or scientific agencies. Still, they resulted from individual efforts to bring life back to the old city. As a result, this research came to determine the most important architectural characteristics of the heritage identity of the old Mosul city buildings and within the various functional models such as residential, commercial, and religious buildings, using the help of previous studies and then classifying them in a unique table.*

1. INTRODUCTION

The heritage identity represents a great value legacy as it is a record of people's memory, and without this identity, nations become without memory or history. Therefore, we find countries with an outstanding and distinguished heritage and historical experience almost agree to adhere to their civilization and heritage and are proud of its vast grant in all intellectual, scientific, artistic fields, and architecture; the matter may even go beyond that, to find some newly developed countries racing to create themselves a heritage and identity that they perpetuate and boast of.

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1.2 Local Architectural Identity in the Old City of Mosul

Mosul is one of the ancient cities, as a great civilization was built on its land, attested to by history. It showed creativity in its great heritage, archaeological monuments, architectural arts, and majestic buildings throughout the ages. Still, after the recent war and the re-liberation operations, many of the heritage architectural models in the old city were exposed to devastation and destruction. This led to the possibility of losing a large part of the Mosulian local identity. Hence, this research came to try to identify the most important characteristics and features of the regional identity of Mosul city by reviewing the heritage models and what was mentioned in previous studies in this field and documentation models. It aims to identify the essential characteristics of heritage architecture and its determinants and then schedule it within an applicable and standardized table. The possibilities it provides for use in attempts to reconstruct the heritage buildings that have been exposed to ruin and destruction, as well as in contemporary constructive attempts that try to simulate the identity and architectural heritage of the region.

2. PREVIOUS STUDIES

The importance of documenting and defining the characteristics and elements of the architectural identity of the heritage buildings in the old city of Mosul today has become more necessary because of the devastation, destruction, and distortion large parts of these buildings suffered after the recent war on the city, in addition, the nature of most of the studies and researches that dealt with the topics of heritage architecture in the countries of the world in general, and the specialized ones in the local identity of the ancient city of Mosul came in a narrative and descriptive manner or for historical documentation only. Also, some specialized in a functional style without the other or dealt with one structural element or component. Such as the external facades, and among these studies is the study of "Rhythm in Traditional Facades a Lanes of the old Mosul City" by Alaane and Al-Botany; it dealt with the issue of the external facades of old buildings and their significant impact on defining an important image of the local heritage identity in the ancient city of Mosul, also what governs their formative elements in terms of relationships and systems, and on top of them came the concept of rhythm (Al-Ani & Al-Boutani, 2010).

In Al-juma'a study entitled "The Characteristics and Heritage Architectural Designs in Mosul", the study identified the planning style of the city of Mosul and the most important features and designs of its buildings, the nature of the various variables that passed through the city and affected the distinctive formation of its buildings and their reflection of the local heritage identity of the city (Al-juma'a, 1986). Some other studies specialized in the Mosulian house, such as Al-Tayib's study "Design Solutions in the Heritage Mosulian Houses", which identified some design principles and the architectural and decorative elements of the heritage Mosulian old house, in addition to the techniques and solutions that used (Al-Tayib, 2008). Likewise, Thanon's study "Popular Architecture of The Old City of Mosul - The Architecture of The Traditional House" and Mustafa's study "The Characteristics of Architecture Style of the Traditional Houses in the Mosul City" both came in the field of identifying the most essential characteristics of the traditional Mosulian house design and in the light of several levels, such as the level of primary and secondary components, the level of the spatial organization of spaces, the group of structural system and materials (Thanon, 2007) in addition to formal relationships, architectural treatments, and others (Mustafa, 2010).

3. RESEARCH PROBLEM

The need to identify the essential features and characteristics of the heritage buildings in the old city of Mosul and its various functional types, and the most important scientific and practical

fs for achieving this in the form of tables that are applicable and standardized to the extent to which the heritage identity is performed and the methods of its consolidation.

4. RESEARCH QUESTIONS

• What are the determinants and characteristics of the heritage architectural identity in the old city of Mosul?

• Are there clear criteria and determinants that are applied when attempting to rebuild heritage buildings that have been subjected to vandalism and destruction, and can these limitations be followed when trying to build new buildings in or outside the old area to obtain buildings that bear the spirit and the local heritage imprint of the city?

5. RESEARCH OBJECTIVE

To answer the research questions, this study came to define the most critical characteristics of the local identity of the heritage buildings in old Mosul city and the determinants of achieving them by relying on previous studies related to the title of the research and the essential writings in this field.

6. SPECIAL CHARACTERISTICS OF THE ARCHITECTURAL HERITAGE IDENTITY IN THE OLD CITY OF MOSUL

The different civilizations and cultures that the city of Mosul passed through had a significant impact on many aspects of the city, the most important of which was the architectural aspect, which made it characterized by a unique architectural character that distinguishes it from among Arab and Islamic cities (Mustafa 2013), and with time, this character has become a solid and inherited identity an explicit architecture for the residents, with its characteristics and advantages expressing the various cultural, social and economic aspects of the Mosulian community. We will discuss the most critical factors and vocabulary that formed precise determinants of the local architectural identity in the old city.

6.1 The Plan and Its Design Elements

Focusing on the actual heritage content and defining ways to consolidate the concept of identity is on two levels. The first is the planning level, which includes the shape of the urban, the signature of the particular unit within the public site, the formation of facade blocks and their protrusions, the fulfillment of religious and social requirements, and the second level is the design level; It includes the main architectural elements and their uses. And how to meet functional needs (Saydam, 2014).
At the level of the traditional Mosulian house, the mechanisms for achieving identity in it and its most important indicators were represented by the importance of the functional significant architectural elements according to the inherited model, such as the inner courtyard "alhosh" that opened to the top, the "Rahra" and basement, corridors, Iwan, rooms, etc. (Saeed & Salim, 2019). In religious and service buildings as well, conserving the inherited design scheme and signing the primary spaces for each functional style is essential to achieving heritage identity.
The plan of the dwelling mainly consists of an open courtyard surrounded by wings, corridors, and other service extensions. One of the wings includes an Iwan surrounded by a room on each side (Figure 1). In addition, the spatial organization pattern at the general level is the central pattern, while the spatial organization pattern for the detailed parts (Wings) is a triangular pattern (Thanon, 2007).
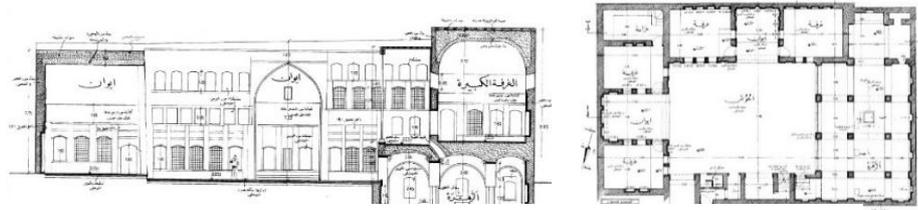
Figure 1. Plan and section for Al-Totnchi traditional house

The plans of mosques in Mosul were formed from the spaces of the chapel surrounded by arcades, the largest of which is the qibla arcade because it represents the chapel. As for the plans of the Khans, they consisted of rows of rooms arranged around open courtyards and some of them might add an upper floor with entrances, followed by a passage leading to the courtyard (Al-juma'a, 2020).

6.2 Facades and Their Details

The external facades of the buildings also constitute an important part of the old city landscape. The formed elements of these facades, with the relationships between them, their scales, and details, create a distinctive formative appearance for the alleys that form a large part of the local identity concept and define a distinct pattern for the shape of the alleys and neighborhoods. The characteristics of these facades were not by chance. Instead, they came as a result of many natural and social factors related to the personality of the Mosulian architect and builder and their cultural background. Thus, it was characterized by a unified character and homogeneous relationships in scales that led to the visual unity of the design. (Figure 2).

The design of the heritage buildings facades in Mosul was based on relationships and systems (relations of unity, diversity, gradation, and contradiction) and exchanged between them to achieve a harmonious rhythm, a distinctive architectural style, and a unique identity in the old city of Mosul (Alaane & Albotany, 2010).

As for the internal facades of the traditional dwelling, their formal characteristics were characterized by unity, rhythm, and human scale at the whole level and the whole's components (Figure 3). The Iwan, with its size and distinctive shape, was an essential element in organizing the facade of the traditional house. (Alaane, 2014).

Figure 2 & 3. External and internal façade of old Mosulian house

6.3 Building Materials and Structural System

Building materials are also considered one of the most important determinants of forming the heritage architectural identity in the world in general, and the materials available in each region were repeatedly used in construction at that time, thus creating an image of the features of heritage buildings and giving them their own local identity. Among the most important materials used in Mosul is Marble (Alfarsh); it Was used in the Mosulian house in several forms, so it came in the formation of entrances, window frames, marble columns, arches, floors, etc. Other materials, such as wood and iron, were used less. (Thanoun, 2001). The structural

system was also affected by the building materials. The basic approach in the construction was the load-bearing walls, and the column system was sometimes used on the ground floors (marble columns and arches); various dome types (Figure 4) roofed the rooms (Thanoun, 2001).

6.4 Architectural Elements

The various architectural elements, such as arches, minarets, domes, mihrabs, columns, entrances, windows, wall bands, and cantilevers (shanashil), constitute distinctive components of the heritage buildings in the old city of Mosul. They were used according to the functional or decorative need in the various functional and structural models of houses, mosques, khans, etc.; we will briefly explain these elements. Successively:

- Ceiling: The heritage buildings in old Mosul were characterized by roofing with a system of contracts without the use of iron, So using the domes as ceilings where the most common type. They came in different forms and names, such as al-tishet, al-bagdashi, and al-mahid (Thanoon, 2010). Their shapes varied according to their functions and structural treatments (Figure 4).

- Columns: Mosulian columns were distinct in their shape; the most famous was the marble columns (Figure 5), on which marble arches were decorated with motifs and pendants (Thanon, 2007).
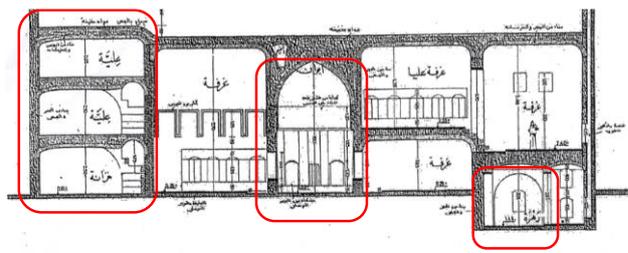
Figure 4. Various types of domes

Figure 5. Various shapes of columns

- Openings: The shapes of the openings, including entrances and windows, were linked to their locations within the façade (Al-Hayali 2006). The shapes of these windows and doors varied, as well as their names, decorations, and inscriptions employed on them (Figure 6) (Thanon, 2007).

- The wall bands: the enclosed zone at the bottom of the interior walls, with geometrical and plant motifs and inscriptions (Figure 7). Its importance was not only aesthetic but also served as a protection for the bottom of the walls from dampness, especially in the basement and rooms on the ground floors (Al-juma'a, 1991).
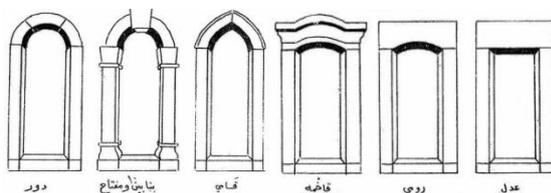
Figure 6. most famous traditional Mosulian entrances
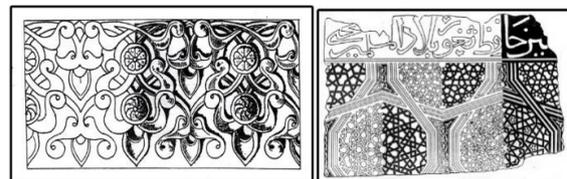
Figure 7. Sample of wall bands in al-Noria school and Yahya bin Al-Qasim shrine

- Al-Ashkhim: a distinctive element in Mosulian houses. It is a space left between rooms, narrow, closed, and has two openings, the first in the roof and the second in the court. It is used to store various materials such as grain and firewood.

- Minarets: They came with cylindrical bodies whose diameter gradually decreases toward the top and has prismatic bases (Al-Juma'a, 2020), as in the minaret of the Al-Nuri Mosque (Figure 8).

- The Domes: They came in two forms; the first is hemispherical domes above the Mihrab of the mosque, as in the dome of the Al-Mujahideen Mosque, and the second is the double conical domes, consisting of two internal muqarnas domes and external polygonal dome with a space between them (Al-juma'a, 2020), like the dome of Yahya bin Al-Qasim Shrine (Figure 9).
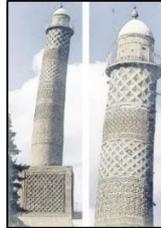
Figure 8. Al-Nori Mosque minaret
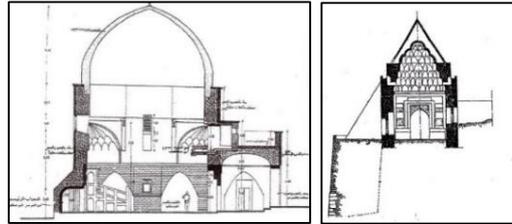
Figure 9. Types of mosques' domes

- Al-Mihrabs: Mosul mosques were distinguished by the diversity of their mihrabs. In prominent mosques, hollow mihrabs were used for the imam to get into to provide an additional row for worshipers, such as the mihrab of Al-Nuri Mosque Figure 10, While the flat mihrab was used in schools and shrines because there was no need for an additional row, such as the mihrab of Sheikh Fathi shrine (Figure 11). As for the secluded mihrab, which is considered one of the architectural innovations in Mosul, it was more common in shrines, such as the mihrab of Yahya bin Al-Qasim shrine (Figure 12) (Al-juma'a, 2020).

Figure 10. Al-Nuri Mos. mihrab

Figure 11. Sheikh Fathi mihrab
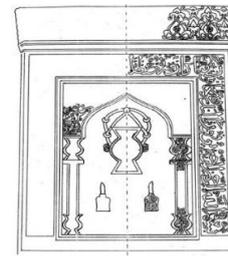
Figure 12. Yahya bin Al-Qasim mihrab

6.5 Architectural Details

The essential features of traditional Mosulian architecture are the architectural details and their different classifications that decorate the building units from inside and on the external facades. Foremost among them are the geometrical and plant motifs and their various subjects, artistic elements, and materials; marble and plaster decorations are the most famous (Figure 13). The ornaments with metal can be seen in windows, doors, cabinets, and furniture (Thanon, 2007). Among other details are the inscriptions and calligraphy, such as the Thuluth calligraphy, Kufic, and Syrianic calligraphy in the churches, in addition to the colors that appeared as a result of the colors of the used materials such as marble (Al-Farsh), stone (Hillan), and plaster, and what they specified of a homogeneous color plan that distinguishes heritage buildings (Al-juma'a, 2020).

Figure 13. Various kinds of ornaments

6.6 The Social Aspect Impacts

The social aspect of Mosul city greatly affected the building units' style and planning, even at the level of detail. The first manifestations of this influence were represented by the common walls between the buildings, which are only separated by narrow alleys. The interdependence between the members of the traditional Mosulian community was reflected in the way of interdependence between the units that make up the space; as one moves gradually from the space of the room to the open area of the house, the space of the alley, to the space of the mosque and all the way to the whole city. This indicates that the city forms a coordinated composition between its building shapes and what is required of them socially. (Al-Obaidi, 2012).

The houses were characterized by features reflecting the Mosulian conservative society, which prefers a high degree of privacy. The entrance is indirect, and the entry process is through a passage to an inner courtyard isolated from the outside, providing the house's residents with an internal environment to perform their daily work away from the eyes of strangers. In addition, the high parapet on the roofs provides privacy for the residents to sleep in the summer (Al-Dewachi, 1975).

6.7 Meet Environmental Requirements

The heritage buildings in the old city of Mosul adopted design ideas commensurate with the natural and climatic conditions of the region. Mosulian architects responded to this climate to reduce its impact to the maximum extent possible. At the level of the housing unit, there were several environmental treatments. For example, the horizontality of the dwellings; allowed the allocation of an open courtyard (Alhosh) to carry out the functions of ventilation and lighting (Al-Obaidi, 2012). The Iwan (a roofed space that opened from the front) formed a place for daily activities that protected from the sun in summer and rain in winter. The basement (al-Rahra) was an excellent place to sleep during the summer afternoon. The "Malqaf" element, directed towards the direction of the prevailing winds, succeeded in cooling and ventilating the basement. As for the roof, it was used for sleeping at night, in addition to the detailed climatic treatments such as the "Shanashils" and the corridors within the inner courtyards and the presence of perforated parapets that do not prevent the passage of air currents for the sleepers on the roof of the house in summer (Al-juma'a, 1986).

The following table is about the essential primary and secondary characteristics of the heritage identity within the architecture of the old city of Mosul, which the research concluded:

Table 1. Characteristics of the heritage identity within the architecture of the old city of Mosul

No	Primary features	Type	Secondary features
1	The plan and its design elements	Residential buildings (houses)	Inner courtyard (9Alhosh)
			Iwan
			Rooms
			Arcade (Riwaq)
			Basement and Al-rahra
		Religious buildings (mosques)	Court (Al-hosh)
			Arcades (Riwaqs)

#	Category					
				Room of Imam		
		Service buildings (khans)	Court (Alhosh)			
			Rooms			
			Corridors			
			Stable (in some Khans)			
2	Facades and their details	External	Entrances and Doors			
			Shanashil			
			Arches			
		Internal	Windows			
			Niches	Types from least to most profound	Kibale	
					Dolab	
					maktaba	
			Decorative compositions			
			Marble arches			
			Al-kawabil			
			Al-Kowa			
3	Building Materials and structural system	Building material	Mosulian marble (Al-farsh)			
			Stone (Hillan)			
			Plaster			
			Other materials, such as wood and iron			
		Structural system	Bearing wall			
			Columns system in specific locations on the ground floor (marble columns and arches)			
			Roofing with domes			
4	Architectural elements	Common elements in different functional types (religious, residential, service)	Vaults	Cradle vault		
				Bakdashi vault		
				Tisht vault		
			Columns	Marble columns	Cubed	
					Cylindrical	
					Octagonal	
					Al-dinga (short column)	
				Wooden columns	It was used for decorative purposes, such as the wooden columns at the front of some Iwans.	
			Openings	Doors and windows	Al-Adl	
					Al-door	
					Alkassami	
					Al-kakhma	
					Al- Rumi	
					Thu nabain wa miftah	
			The wall bands			
		Specific elements of religious buildings	Minarets	Cylindrical		
			Domes	hemispherical (at the mosques)		
				conical (in shrines)		
			Mihrabs	The hollow mihrab		
				The flat mihrab		
				The secluded mihrab		
5	Architectural Details	Ornament and motifs	geometrical			
			Plant			
		Calligraphy	Thuluth calligraphy			
			Kufic calligraphy			
			Syrianic calligraphy			

		Colors	
6	The social aspect impacts	High cohesion at the urban	
		Common walls between dwellings	
		Inward opening (al-hosh)	
		Indirect entrances	
		Absence of windows open to the outside and replacing them with Shanashils	
		High parapet	
7	Meet environmental reqirements	The appearance of	The open courtyard (Al-hosh) for ventilation and lighting
			The roofed Iwan which opens on one side to the courtyard.
			Al-Rahra for sleeping purposes in the summer
			Al-Malqaf element and its orientation towards the prevailing winds for cooling and ventilation of the basement
			Al-Shanashils and their materials

7. CONCLUSIONS

Maintaining the heritage identity of Mosul city, and its architectural heritage is now more urgent than ever. The recent war and its aftermath of destruction and devastation affected a large part of the heritage buildings in the old city, which threatened the loss of a large part of the Mosulians' history, heritage, and the most critical manifestations of their local identity.

Preserving the heritage architectural identity is done through several methods and strategies. First, it needs to identify the most important architectural characteristics of the old city and the features that form its identity. The research came up with a table that includes the most important primary and secondary factors that distinguish the old city's architecture.

This table can measure the extent to which the heritage identity is achieved within the reconstructed building models, and it can be applied to contemporary building models that try to draw inspiration from the local architectural heritage and come up with designs and structures that belong to the spirit of the place and mimic its identity and not just a reproduction of Western forms that are far from the identity and culture of our society.

The most crucial characteristic of identity came through several levels, including the level of the elements design, horizontal plan, and external facades and their impact on the creation of alleys identity with distinctive features such as Shanashil, vaults, archways, entrances, inscriptions ... etc., in addition to the unique traditional architectural elements, such as the element of al-Ashkhim in the residential houses, and the distinctive domes and niches in the mosques of Mosul.

The city of Mosul was also famous for its methods of construction and unique building materials such as AL- Hillan, Al- Farsh, and plaster, in addition to the distinctive shapes of the vaults, which reflected the culture of the population and their lives through its names such as cradle vault, and others, and showed the ingenuity of Mosul architecture and construction in its adoption of some creative design and construction solutions.

8. RECOMMENDATIONS

The research recommends increasing the cultural awareness for the inhabitants of the old city and all residents of Mosul, explaining the importance of their history and heritage and the great value it carries, which extends over the years.

The need to set standards and laws supervised by specialized governmental and engineering agencies to limit the random construction operations and the distorted reconstruction of some heritage buildings, especially in the old city, taking into consideration their great value and importance, and applying these laws to future projects that are established in the region and intend to simulate the architectural heritage of old Mosul and its local identity characteristics.

Conflict of Interest

The authors declare that there is no conflict of interest.

Contribution of Authors

The authors involved in this study are Sana Nabeel Najib and Dr. Ahmed Abdulwahid Thanon; who contributed to all aspects of the study, All authors contributed to the concept, design, inspection, data collecting, literature review, resources, and interpretation of the study.

REFERENCES

Mustafa, Muzahem, Muhammad, (2013), "The Local Identity of the City of Mosul in the Academic Urban Design Products", 2nd Engineering Conference, College of Engineering, University of Mosul, (Arabic), https://www.uomosul.edu.iq/public/files

Al-Juma'a, Ahmed, Qassem, (1986), "The Characteristics and Heritage Designs in Mosul and Their Impact on its Urban Growth", Al-Rafidain Arts Journal, No. 16, University of Mosul, Mosul, Iraq. (Arabic), https://archive.alsharekh.org/Articles/143/14526/324865

Mustafa, Mozahim, Mohammed, (2010), "The Characteristics of Architecture Style of the Traditional Houses in the Mosul City-Analytical Study", American J. of Engineering and Applied Sciences 3 (2), p 380-389, https://thescipub.com/pdf/ajeassp.2010.380.389.pdf

Al-Tayib, Abdullah, Y., (2008), "Designed Solutions of Mosul Traditional Houses - An Applied Experiment in Building a Traditional House", AL-Rafidain Engineering (AREJ), Volume 16, Issue 2, P 78-89, (Arabic), https://www.iasj.net/iasj/article/44571

Saeed, Marwa, Muhammad, and Salim, Shoresh, (2019), "Strategies for Preserving the Local Architectural Identity of the Mosul's House for the Post-War Period", Sulaimani Journal for Engineering Sciences, Vol. 6, Number 2, (Arabic), https://www.iasj.net/iasj

Saydam, M., Wahid, (2013), "Revival of Architecture Heritage Values in Modern Local Architecture - Gaza City as a Case study", Master Thesis, Faculty of Engineering, IUG, (Arabic), https://ketabpedia.com

Alaane, Talaat, and Albotany, Hussein, (2010), "Rhythm in Traditional Facades a Lanes of the Old Mosul City", *The Iraqi Journal of Architecture and Planning,* Vol. 9, Issue 19, P. 256-276, (Arabic), https://www.uotechnology.edu.iq/dep-architecture/IraqiArchMagazine/issues19-20-21/

Thanon, Ahmed, Abdulwahid, (2001), "The Impact of Building Materials on the Formation of the Traditional Mosul's House Style", 1st Scientific Conference on Architecture in Mosul, Mosul Studies Centre, (Arabic),

Aljuma'a, Ahmed, Qassem, (2020), "The ancient Arab city of Mosul, its reconstruction and development", (Arabic), https://www.baytalmosul.com/uploads

Thanon, Ahmed, Abdulwahid, (2007), "Popular Architecture of the Old City of Mosul the Architecture of the Traditional House", ICANAS 38, Ankara, Turkey, https://www.ayk.gov.tr

Al-Hayali, Omar, Adel, (2006), "The Formative Structure of the Traditional Alleys in the City of Mosul", An Unpublished Master's Thesis, Department of Architecture, University of Mosul, Mosul, Iraq, (Arabic).

Aljuma'a, Ahmed, Qassem, (1991), "Architectural Significances and their Civilizational Rooting", The Civilizational Encyclopedia of Mosul, Volume 3, P. 334, (Arabic).

Al-Obaidi, Ali, Mohammad, (2012), "The Architectural Formation of the City of Mosul during the Galilean Era", Mosuliya Illuminations Magazine, Issue 62, Mosul University, (Arabic), https://uomosul.edu.iq/public/files/datafolder_2700/_20190926_070633_380.pdf

Al-Dewachi, Saeed, (1975), "Mosuli House", Popular Heritage Magazine, Issue 6, Sixth Year, Baghdad, Dar Al-Hurriya for Printing, (Arabic).

Alanee, Talaat, Ibrahim, (*2014),* "The Attributes of Architectural Form of Traditional House Internal Facades of Mosul's Traditional House as a Case-study", *AREJ,* Volume 22, Issue 2, P. 16-28, (Arabic), https://www.scribd.com/document

Automated Body Postures Assessment From Still Images Using MediaPipe

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1.   INTRODUCTION

Human body posture is a very interesting research line in the last two decades at least. It is important in our daily life activities (Stenum et al., 2021). There are correct postures for almost every state of our bodies. Incorrect postures could be very harmful and should be detected and avoided. Automated pose assessment attracts a lot of attention using different technical methods like using wearable and unwearable sensors (Diraco, Leone, & Siciliano, 2013; Lawanont, Inoue, Mongkolnam, & Nukoolkit, 2018; Leightley & Yap, 2018), computer vision, and machine learning (Munea et al., 2020; Nicolae-Adrian, Claudiu, Ana-Maria, & Ciprian, 2021). Google's MediaPipe Pose is a part of a framework which offers a pre-trained machine learning model that detects body joints in an image and video. It is based on the convolutional neural network BlazePose. From an RGB image, MediaPipe predicts 33 body important locations termed posture landmarks (each of which consists of x, y, and z referring to the hip-point) (Bazarevsky et al., 2020).

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In this paper, we present a method for real time body pose assessment based on comparing the features of the trainee or learner video-frames (frame by frame) with the features of a reference standstill image and give proper text advice to the user to reach the best match with the reference pose in real time. This method could be application-independent and be applied to various activities. A side view posture was taken as an example for standing and sitting states. The reference image means the perfect posture that the trainee wants to reach and could be given by the trainer or selected from a confident reference.

1. PREVIOUS WORKS

(Jesmeen et al., 2023) have developed a real-time CNN-based system to recognize three sleep postures (right, left, and lying on back). They collected their own dataset to train the CNN, and provided 99.59% classification accuracy. (Chiang et al., 2022) proposed a posture recognition system for bedridden elderly patients using an RGB-Depth camera, where only four-3D joints were adopted. The system used OpenPose for 2D skeleton-joint detection. The recognition accuracy was about 95%. If the elderly person doesn't change his posture for a pre-given period, a warning message is sent to the medical staff. MediaPipe was used by (Kwon & Kim, 2022) to get the body posture landmarks for an exerciser doing (squat, push-up) exercise at home, where Open CV was adopted for video capturing via a webcam, posture estimation, body angle calculation, incorrect pose detection, and giving text messages for pose correction. An adaptive generative adversarial network (GAN) approach was produced by (Xu et al., 2022) for landmarks detection. DenseNet and KNN were combined by (Dittakavi et al., 2022) to produce a Pose Tutor for pose detection and correction. Human body posture detection and assessment can have a variety of applications. One of them is Yoga posture assessment (George, Dcouth, Jaimy, Daji, & Antony, 2022; Long, Jo, & Nam, 2022; Wu et al., 2022; Kothari, 2020). Another application is baby sleep monitoring (Khan, 2021). Head pose was analyzed by (Hammadi, Grondin, Ferland, & Lebel, 2022), while (Johnston et al., 2022) focused on Human motion. Body balance (Nguyen, Woo, Huynh, & Jeong, 2022), and fall detection (Han, Yang, & Huang, 2020) were investigated too. Sitting pose (Chen, 2019) and Workout assessment (Dawange, Chavan, & Dusane, 2021; Kwon & Kim, 2022) were studied also. Body language attracted (Piñero-Fuentes et al., 2021), while Islamic Prayer activity monitoring was implemented by (Gupta, 2020; Koubaa et al., 2020). A Pose Tutor (Dittakavi et al., 2022) was suggested too. It is well noted that each one of the previous works was tailored to a certain use, here we introduce a method that could be the first step to cross over many applications and could be applicable for various usages.

2. MATERIALS AND METHODS

We proposed a way that helps people to make self-assessment for their body posture using a selected reference pose image. It can be used for various types of postures and not limited to a certain use. The proposed setup consists of a webcam connected to a PC, as depicted in **Error! Reference source not found.**, that executes the proposed algorithm using Python program. The user needs to feed the PC with the reference pose image then the system will acquire the user pose-images via the webcam, and he will get the assessment of his posture and some advice for improvement for each frame of the video. The assessment and the correction advice are given as text messages along with some sketches added on the images.

Figure 1. The proposed setup

The suggested framework consists of two identical processing pipelines as shown in **Error! Reference source not found.**; one for the reference image and the other for the user video. The common last stage compares the extracted features from both lines and give the proper assessment in real time.
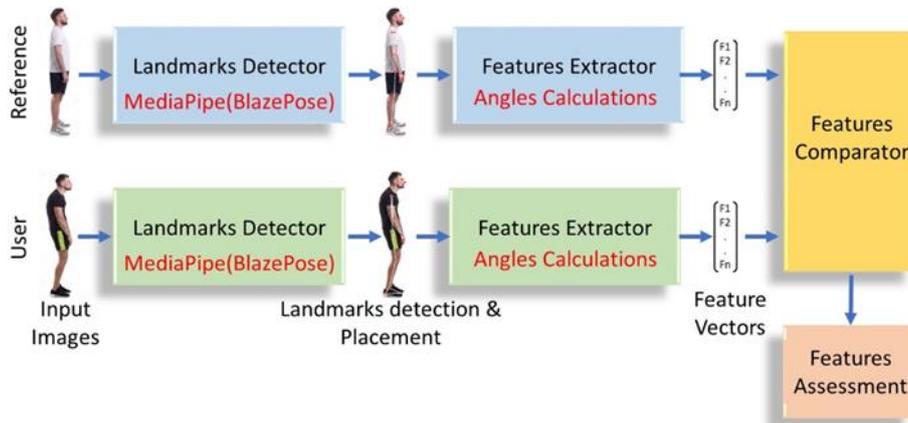
Figure 2. The suggested framework

3.1. Landmarks Detection

The input images are subjected to MediaPipe for landmarks detection. Google MediaPipe uses PlazePose to find 33 body landmarks with high accuracy. These landmarks can be projected on the original image. Each landmark is defined by three coordinates x, y and z and. The landmarks can also be connected with line-segments to form a skeleton shape for the original image as shown in **Error! Reference source not found.** which reflects the body posture in that image.
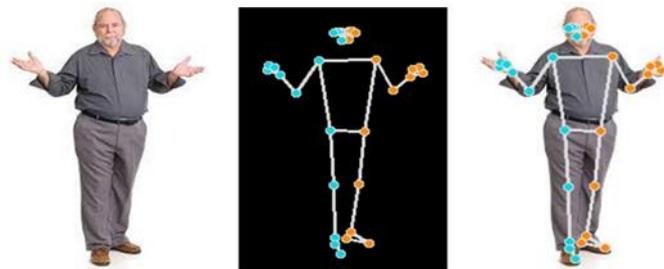
Figure 3. Image skeleton extracted using Mediapipe key points

3.2. Features Extraction

Seven handcrafted features were extracted from the detected landmarks for the right side of the body. These features were empirically chosen to produce distinguishable differences between the reference and the user poses. We adopted angle calculations between two vectors of the skeleton shape as presented in Table 2. The angles can be calculated from three vertices

Table 2. Postures' features for the right side of the body

	Features	2-Vertix- Angle	3-Vertix-Angle	
θ1	Head Tilt	Shoulder-Nose (φ1)	Hip-Nose-Ear	
θ2	Torso Alignment	-	Shoulder-Hip-Knee	
θ3	Arm Angle	-	Elbow- Shoulder-Hip	
θ4	Elbow Angle	-	Shoulder-Elbow-Wrist	
θ5	Wrist Angle	-	Elbow-Wrist-Index Finger	
θ6	Knee Angle	-	Ankle-Knee-Hip	
θ7	Foot angle	-	Knee-Ankle-Foot Index	
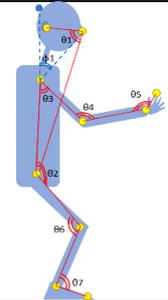
(landmarks) or from two landmarks using a third vertex lying on one of the cartesian axes of the image. Angle calculation from three vertices is not affected by image orientation since it is only related to the predicted landmarks of the body. The angle-dependent features may describe body posture with acceptable accuracy for many cases, and they aren't affected by body parts' length, width, or shape. We found these features are suitable to detect posture misleading from side view images for standing and sitting.

3.3. Features Comparison and Decision Making

The pre-last stage of the framework is the comparator, which compares the extracted features from each frame of the user video with those of the reference image. The comparison is done by subtracting each feature of the reference from its corresponding feature from the user. The result gave an indication of the deviation of each body part of the user body from its equivalent of the reference and direction of that deviation. The smaller the deviation the better performing. The last stage is the pose assessment which was accomplished by overlaying text and line sketches on the user video-frames. The sketches indicated the angle vectors for each feature in addition to line-arrows pointing to the direction of the required corrections. While the text messages were of two types, the difference angles that should be minimized in addition to an advice sentence as depicted in **Error! Reference source not found.**.

Figure 4. Sample of the trainee image overlayered with the pose assessment notice

3. RESULTS AND DISCUSSIONS

The proposed method was applied on side view posture for two main body situations as shown in **Error! Reference source not found.**. The first application is used to correct body posture and help people to avoid harmful standing postures. The second application is the sitting state which takes a lot of time of our lives and could lead to many unwanted consequences on our bodies. The results that were given by the presented framework were compared with the Man-made decisions and gave comparable results with some notes. The first note is that the torso and neck bowing cannot be detected precisely by using landmarks. The second note is the need

to align the camera coordinates with the reference image coordinates to extract more useful features. The third note is that the selection of the reference image is crucial.

Figure 5. An example for standing and sitting postures for three selected frames of the user video

Body rotation was not considered in this research, and it is left to future works. Anyway, the system works well regardless of image and video backgrounds, image size, age, or gender difference between the user and the reference as demonstrated in **Error! Reference source not found.**.

Figure 6. Age, gender, background, and image size differences has no effects on the operation

4. CONCLUSION

In this paper, we presented a human body posture assessment method using the convolutional neural network model BlazePose via MediaPipe in the detection of 33 body landmarks. These landmarks were used to extract discriminative handcrafted features. The assessment method was based on comparing the features of a reference image with each frame of the user video in real-time using a webcam. This method is applicable for many usages and doesn't depend on the opinion of the designer, it almost looks like the traditional training ways. A side view was experimented with the standing and sitting postures and showed comparable results. This method can be developed to be general by making the system more intelligent by detecting the body side and selecting the most suitable features, from pre-saved features, depending on the reference image body state.

Conflict of Interest

The authors declare that they have no conflicts of interest related to this research. The study was conducted without any external financial support, and there are no personal relationships or financial interests that could influence the research findings or interpretation.

Author Contributions

Mazin H. Aziz: Conceptualization, Methodology, Writing, Visualization, and Editing.

Hamed A. Mahmood: Methodology and Programming.

REFERENCES

Bazarevsky, V., Grishchenko, I., Raveendran, K., Zhu, T., Zhang, F., & Grundmann, M. (2020). BlazePose: On device Real-time Body Pose tracking. Retrieved from doi: https://doi.org/10.48550/arXiv.2006.10204

Chen, K. (2019). Sitting Posture Recognition Based on OpenPose. IOP Conference Series: Materials Science and Engineering, 677(3). doi: https://doi.org/10.1088/1757-899X/677/3/032057

Chiang, J.-C., Lie, W.-N., Huang, H.-C., Chen, K.-T., Liang, J.-Y., Lo, Y.-C., & Huang, W.-H. (2022). Posture Monitoring for Health Care of Bedridden Elderly Patients Using 3D Human Skeleton Analysis via Machine Learning Approach. Applied Sciences, 12(6), 3087. doi: https://doi.org/10.3390/app12063087

Dawange, S., Chavan, A., & Dusane, A. (2021). Workout Analysis Using Mediapipe BlazePose and Machine Learning. International Journal of Creative Research Thoughts (IJCRT), 9(12), 294–297.

Diraco, G., Leone, A., & Siciliano, P. (2013). Human posture recognition with a time-of-flight 3D sensor for in-home applications. Expert Systems with Applications, 40(2), 744–751. doi: https://doi.org/10.1016/j.eswa.2012.08.007

Dittakavi, B., Bavikadi, D., Desai, S. V., Chakraborty, S., Reddy, N., Balasubramanian, V. N., … Sharma, A. (2022). Pose Tutor: An Explainable System for Pose Correction in the Wild. 2022 IEEE/CVF Conference on Computer Vision and Pattern Recognition Workshops (CVPRW), 2022-June, 3539–3548. doi: https://doi.org/10.1109/CVPRW56347.2022.00398

George, S., Dcouth, J., Jaimy, S., Daji, E., & Antony, A. (2022). COMPUTER-ASSISTED TRAINING SYSTEM FOR YOGA AND PILATES USING COMPUTER VISION METHODS. Journal of Tianjin University Science and Technology, 55(06), 176–186. doi: https://doi.org/10.17605/OSF.IO/FXSQE

Gupta, R. (2020). Activity Monitoring of Islamic Prayer (Salat) Postures using Deep Learning. Roceedings - 2020 6th Conference on Data Science and Machine Learning Applications, CDMA, (October), 106–111. doi: https://doi.org/10.1109/CDMA47397.2020.00024

Hammadi, Y., Grondin, F., Ferland, F., & Lebel, K. (2022). Evaluation of Various State of the Art Head Pose Estimation Algorithms for Clinical Scenarios. Sensors, 22(18), 1–12. doi: https://doi.org/10.3390/s22186850

Han, K., Yang, Q., & Huang, Z. (2020). A two-stage fall recognition algorithm based on human posture features. Sensors (Switzerland), 20(23), 1–21. doi: https://doi.org/10.3390/s20236966

Jesmeen, M. Z. H., Bhuvaneswari, T., Mazbah, A. H., Chin, Y. B., Siong, L. H., & Aziz, N. H. A. (2023). SleepCon: Sleeping Posture Recognition Model using Convolutional Neural Network. Emerging Science Journal, 7(1), 50–59. doi: https://doi.org/10.28991/ESJ-2023-07-01-04

Johnston, S. H., Berg, M. F., Eikevåg, S. W., Ege, D. N., Kohtala, S., & Steinert, M. (2022). Pure Vision-Based Motion Tracking for Data-Driven Design - A Simple, Flexible, and Cost-Effective Approach for Capturing Static and Dynamic Interactions. Proceedings of the Design Society, 2(2015), 485–494. doi: https://doi.org/10.1017/pds.2022.50

Khan, T. (2021). An Intelligent Baby Monitor with Automatic Sleeping Posture Detection and Notification. Ai, 2(2), 290–306. doi: https://doi.org/10.3390/ai2020018

Kothari, S. (2020). Yoga Pose Detection and Classification Using Deep Learning (San Jose State University). doi: https://doi.org/10.32628/cseit206623

Koubaa, A., Ammar, A., Benjdira, B., Al-Hadid, A., Kawaf, B., Al-Yahri, S. A., … Ba Ras, M. (2020). Activity Monitoring of Islamic Prayer (Salat) Postures using Deep Learning. Proceedings - 2020 6th Conference on Data Science and Machine Learning Applications, CDMA 2020, 106–111. doi: https://doi.org/10.1109/CDMA47397.2020.00024

Kwon, Y., & Kim, D. (2022). Real-Time Workout Posture Correction using OpenCV and MediaPipe. The Journal of Korean Institute of Information Technology, 20(1), 199–208. doi: https://doi.org/10.14801/jkiit.2022.20.1.199

Lawanont, W., Inoue, M., Mongkolnam, P., & Nukoolkit, C. (2018). Neck posture monitoring system based on image detection and smartphone sensors using the prolonged usage classification concept. IEEJ Transactions on Electrical and Electronic Engineering, 13(10), 1501–1510. doi: https://doi.org/10.1002/tee.22778

Leightley, D., & Yap, M. H. (2018). Digital analysis of sit-to-stand in masters athletes, healthy old people, and young adults using a depth sensor. Healthcare (Switzerland), 6(1). doi: https://doi.org/10.3390/healthcare6010021

Long, C., Jo, E., & Nam, Y. (2022). Development of a yoga posture coaching system using an interactive display based on transfer learning. Journal of Supercomputing, 78(4), 5269–5284. doi: https://doi.org/10.1007/s11227-021-04076-w

Munea, T. L., Jembre, Y. Z., Weldegebriel, H. T., Chen, L., Huang, C., & Yang, C. (2020). The Progress of Human Pose Estimation: A Survey and Taxonomy of Models Applied in 2D Human Pose Estimation. IEEE Access, 8, 133330–133348. doi: https://doi.org/10.1109/ACCESS.2020.3010248

Nguyen, H. T. P., Woo, Y., Huynh, N. N., & Jeong, H. (2022). Scoring of Human Body-Balance Ability on Wobble Board Based on the Geometric Solution. Applied Sciences (Switzerland), 12(12). doi: https://doi.org/10.3390/app12125967

Nicolae-Adrian, J., Claudiu, A., Ana-Maria, V., & Ciprian, G. (2021). A systematic review of integrated machine learning in posture recognition. Timisoara Physical Education and Rehabilitation Journal, 14(27), 15–20. doi: https://doi.org/10.2478/tperj-2021-0009

Piñero-Fuentes, E., Canas-Moreno, S., Rios-Navarro, A., Domínguez-Morales, M., Sevillano, J. L., & Linares-Barranco, A. (2021). A Deep-Learning Based Posture Detection System for Preventing Telework-Related Musculoskeletal Disorders. Sensors, 21(15), 5236. doi: https://doi.org/10.3390/s21155236

Stenum, J., Cherry-Allen, K. M., Pyles, C. O., Reetzke, R. D., Vignos, M. F., & Roemmich, R. T. (2021). Applications of pose estimation in human health and performance across the lifespan. Sensors, 21(21). doi: https://doi.org/10.3390/s21217315

Wu, Y., Lin, Q., Yang, M., Liu, J., Tian, J., Kapil, D., & Vanderbloemen, L. (2022). A computer vision-based yoga pose grading approach using contrastive skeleton feature representations. Healthcare (Switzerland), 10(1), 1–12. doi: https://doi.org/10.3390/healthcare10010036

Xu, Z., Qu, W., Cao, H., Dong, M., Li, D., & Qiu, Z. (2022). An Adaptive Human Posture Detection Algorithm Based on Generative Adversarial Network. Computational Intelligence and Neuroscience, 2022. doi: https://doi.org/10.1155/2022/7193234

Face-Palm Print Recognition System Based On 2d Circular Wavelet Filter And Contourlet Transformation

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Keywords	Abstract
face recognition, palm print recognition, multi biometrics system, 2D circular wavelet filter, contourlet transformation	*The study proposes a multimodal biometric design that combines face and palm print recognition modules. To extract the features from the face data set, we proposed a novel 2-D circular wavelet filter that depends on HAAR filters and used the contourlet transformation in palm print data sets. The multimodal biometric design merges the features extracted from different types of unimodal system UBS by using a fusion level. Our proposed approach wants to decrease the time required to recognize a person depending on 2-D CDWT and enhance the accuracy of recognition by using the 2-D CDWT and contourlet transformations as pre-processing level in our approach, then the CNN model is applied to train and test our approach. Our data set was taken from 110 people which means 1100 pairs of images in 10 sessions. This approach's results look good and progressed over other most recent architectures by recording a precision of 99.3%, with a score-level fusion.*

1. INTRODUCTION

The human face has a piece of certain individual key information to identify someone compared with other people in the human community. The eye and brain is the most important part of the human system that can distinguish and analyze each face taking a quick look, so many algorithms are produced to improve a computer-based program for analyzing faces similar to the efficiency of the human system. A lot of ideas and algorithms were suggested by researchers to extract features and make true decisions for classification and discover the person's identity (s, 2023). An interesting algorithm for the biometric system has developed rapidly over the last few decades. This development of applications in the biometric system is gaining attraction among industries like video surveillance, criminal identification, and building access control (Kortli et al., 2020). Researchers tried to add modifications to increase the efficiency of biometric design and theories. The efforts are focused to find a new idea for recognizing humans by using the multi-type of features, so a multimodal biometric system (MBS) has been proposed (Hardalac et al., 2020). The contribution of our approach is to add a new pre-processing tool to enhance the extraction of the spatial and frequency information from the input image and then entered the extraction information into the CNN model instead of the image itself and used two types of data set as an MBS instead of UBS.

The 2-D CDWT is proposed like 2-DDWT which represents one of the efficient approaches in computer vision because it can extract both the spatial and frequency information of the input signal. Since it possesses several crucial mathematical qualities. in our study, the Haar filter is applied to find the features of the face.

2. REVIEW RELATED WORK

There are many issues and difficulties that appeared against UBS like Noisy data, Non-universality, inter-class similarities, spoof attacks, and intra-class variation. The UBS suffers from a very huge value of both False Acceptance Rate (FAR) and False Rejection Rate (FRR)(Oloyede & Hancke, 2016). So,the researchers suggested The MBS that solves many problems facing the UBS and enhances the model's performance to enhance the criteria like reliability, security, and precision of the system (Leghari et al., 2018). Channe gowda et.al.(Bc & Prakash, 2022) suggested a multimodal biometric recognition with DWT depending on face and signature data sets. The security solution depending on Discrete Wavelet Transform (DWT) and Multi input data samples model. Mansoura et.al. (Mansoura et al., 2019) depended on Adaptive Score Normalization, PCA, DCT, DWT, and SVD with the Euclidean, distance and applied to Face and Iris Recognition, the recognition rate (98.50%) needs a lot of time to calculate PCA, SVD, and Euclidean, distance. Regouid and et.al. (Regouid et al., 2019) suggested using three types of datasets (ECG, ear, and iris data sets) to recognize the person but increasing the dataset caused to increase in the processing time.So, another type of research tried to suggest a novel method to speed up of execution time of recognizing the human face. Preksha (Singhal & Kumar, 2022) proposed an algorithm to speed up the model by combining Principal Component Analysis (PCA) with Wavelet Transform. There are many important factors play a key role in choosing the suitable face recognition like: Time required for analysis and the memory space consumed in storage (Agrawal et al., 2021). In our approach, the pre-processing level is using a 2D circular wavelet Filter and Contourlet transformations. However, the fantastic development of deep learning and machine learning in the last few years, make many researchers use the Convolutional Neural Network (CNN) methods to enhance the precision of biomedical theories. A lot of studies into multimodal biometric technologies are described in Table 1 with different datasets and theories.

3. THE PROPOSED BIOMETRIC MODAL

In this study, we proposed an MBS by using face and palm recognition by implementing two sets of images.The Data set which is used in the proposed design consists of images of 110 subjects, each subject has 10 face images and 10 palm print images for different sessions. The basic blocks of our system are described in Figure 1. The pre-processing step in our study consists of a 2-D circular discrete wavelet transform (2-D CDWT) based on the Haar filter. The contourlet transformations are implemented on each palm print image. These operations are applied to every image on the training step.

Table 3. Multimodal systems and Their type of systems algorithm

Model	Year	Biometric used	algorithms
Channegowda AB (Bc & Prakash, 2022)	2022	Face, finger vein, and signature images.	DWT
E. Sujatha (Sujatha & Chilambuchelvan, 2017)	2018	Iris, Palm Print, Face, and Signature	DWT
M.Regouid, M. (Regouid et al., 2019)	2019	ECG signal, ear and iris	local descriptors
Nada Alay (Nada Alay, 2020)	2020	Face, Finger Vein, and Iris	Deep Learning

Inass Shahadha (Agrawal et al., 2021)	2020	High-Resolution Palm prints	GLCM
K. Gunasekaran (Tabassum et al., 2022)	2019	face, fingerprint, and iris	Deep learning machine
D.R.Nayak (Tarawneh et al., 2018)	2021	Ear and Face profile	CNN
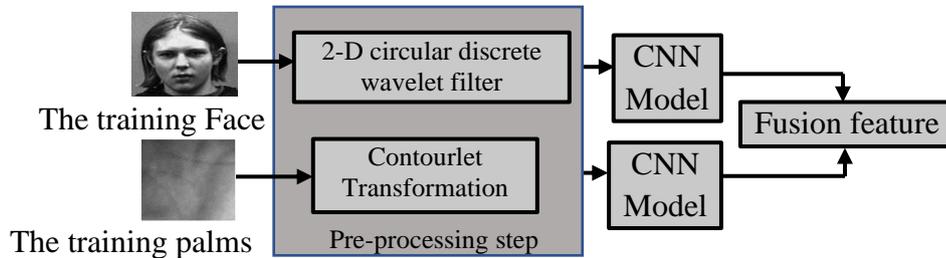
Figure 1. The proposed Multimodal Biometric System**.**

4. THE PROPOSED 2-D CIRCULAR DISCRETE WAVELET TRANSFORM FILTER

This study proposes a 2-D filter based on Digital Spectral Transformation (DST), which is described by (Tarawneh et al., 2018)

$$z^{-1} \xrightarrow{DST} \left(\frac{a+z_1^{-1}}{1+az_1^{-1}}\right)\left(\frac{b+z_2^{-1}}{1+bz_2^{-1}}\right) \tag{1}$$

The 1-D Haar filter is converted into 2-D version by DST as shown in the following equations:

$$H_0(z) = \frac{1}{\sqrt{2}} + \frac{1}{\sqrt{2}}z^{-1} \tag{2}$$

$$\because H_0(z) = \frac{1}{\sqrt{2}}(1+z^{-1})$$

$$H_0(z_1,z_2) = \frac{1}{2}\left(1+\left(\frac{a+z_1^{-1}}{1+a\,z_1^{-1}}\right)\left(\frac{b+z_2^{-1}}{1+b\,z_2^{-1}}\right)\right)\left(1+\left(\frac{a+z_1^{-1}}{1+a\,z_1^{-1}}\right)\left(\frac{b+z_2}{1+bz_2}\right)\right)*\frac{1}{2}\left(1+\left(\frac{a+z_1^{-1}}{1+a\,z_1^{-1}}\right)\right)$$

$$= \frac{1}{4}\left(1+\left(\frac{a+z_1^{-1}}{1+a\,z_1^{-1}}\right)\left(\frac{b+z_2^{-1}}{1+b\,z_2^{-1}}\right)\right)\left(1+\left(\frac{a+z_1^{-1}}{1+a\,z_1^{-1}}\right)\left(\frac{b+z_2}{1+b\,z_2}\right)\right)\left(1+\left(\frac{a+z_1^{-1}}{1+a\,z_1^{-1}}\right)\right)\left(1+\left(\frac{b+z_2^{-1}}{1+b\,z_2^{-1}}\right)\right) \tag{3}$$

The coefficients of 2D filter (a and b) are chosen to be 0.5. The 2-D CDWT provides three contributions: (1) Reduce the Dimensionality. (2) Data approximation can be specified by Multi-resolution analysis. (3) Feature extraction is more sensitive than other method (Singhal & Kumar, 2022).

5. CONTOURLET TRANSFORM

The contourlet transformation is used in many applications of image processing to calculate and determine the feature extraction effectively and more efficiently than DWT due to the multi resolution analysis. The contourlet transformation is applied to plam- print data to preserve the detail of images and give a high resolution results. The contourlet transform has five characteristics that make it more compact and efficient than the DWT: Multi level of resolution, Localization, The critical value of sampling, Directionality, Anisotropy (Wang et al., 2018).

6. THE CONVOLUTIONAL NEURAL NETWORK (CNN) MODEL

To apply the suggested our MBS by utilizing two traits (face, and palm print), the UM is built at first for each of input dataset then the output of each model is fused by using score level fusion as displayed in Figure 1. The CNN architecture in our design are built by multi-level of CONV2D layer as shown Table 2. The proposed MBS is built to increase the recognition accuracy in the design, simultaneously, enhancing the confidence system by applying different types of datasets as face, and hand patterns.

Table 2. The structure of CNN model in the proposed model

Layers	Configuration	Output size
input	1x 128x128	1x128x128
Conv2-D	16_3x3_st.0_pad 0, BN, Relu	16x128x128
Max pooling	2x2, st.2	16x64x64
Conv2-D	32_3x3_st.0_pad 0, BN, Relu	32x64x64
Max pooling	2x2, st.2	32x32x32
Conv2-D	32_3x3_st.0_pad 0, BN, Relu	32x32x32
Full1	2048	2048
Full2	2048	2048
Full2	256, SoftMax	256

7. FEATURE FUSION MODEL

Two sets of features are used in the proposed method which are concatenated into a single one with more discriminative power than either of the input function vectors using the fusion features model to determine whether the outputs fit or not. The feature-level is applied by using concatenation, summation, product, weighted, experimental and maximum method. In this study, summation method is chosen (Bai et al., 2018).

$$Z_1 = X^* + Y^* = W_x^T X + W_y^T Y = \begin{pmatrix} W_x \\ W_y \end{pmatrix}^T \tag{4}$$

8.RESULTS AND DISCUSSIONS

The system is implemented using Keras Python library for implementing the proposed model and run the code under GeForce RTX 3060 NIVIDIA GPU's. The data sets contain of face images and palm print image for 110 persons. The total sample images for training are 8800 pairs of images; 8800 (1100*8) for face images and 8800 images for palm print to train the model and the 22000 (11000*2) face data, 220(110*2) palm print data for validation and testing model.

Our suggested model displayed promising and reasonable results compared with the other researches. The incorporation of utilizing the 2-D CDWT and Contourlet technique shows significant results displayed in Table 3. The proposed technique also improved the accuracy rates. Although (Nada Alay, 2020)reach 100% accuracy rate but this approach used three type of data and this is needing a lot of memory space and more time for training deep model. So, our approach can perform an acceptable accuracy rate with only two types of data.

Table 3. Compare the result of our model with other MBS approaches

References	dataset	subject	Accuracy
(Bc & Prakash, 2022)	Face dataset, finger vein, and signature (ULBP)	40 subjects and 400 samples	92.5%
(Bc & Prakash, 2022)	Face dataset, finger vein, and signature (HOG)	40 subjects and 400 samples	95.8%
(T., 2021)	Palm print, face, Iris, finger print, and vein	--------------	94%
(Nada Alay, 2020)	Face, finger vein, and Iris dataset	SDUMLA-HMT dataset	100%
Our method	Face and palm print	110 subject and 10 sessions	95.39%
		520 subject and 10 sessions	99.3%

9. CONCLUSIONS

MBS depending on face and palm print data set are proposed. This research is considered the first one uses the 2-Dcircular wavelet filter in a MBS to decrease the time required for recognition and enhance the system performance. The data set consist of 1100 subjects. Each subject represents a pair of images, one image is face data and other image is palmprint data.

10. FUTURE WORK

In the future, we intend to do further studies to extend the proposed code by using three data sets aiming at increasing the verification and the security of the system, we can extend our approach and use another trait like finger vein.

Contribution of Authors

This paper presented a novel method based on using the 2D circular filter and countorlet transform as a preprocessing step of deep learning face recognition model. This modification enhanced the deep learning model to extract the most proper features and increase the accuracy of the system.

Conflict of Interest

There is no confliect of interest.

REFERENCES

Agrawal, P., Zabrovskiy, A., Ilangovan, A., Timmerer, C., & Prodan, R. (2021). FastTTPS: fast approach for video transcoding time prediction and scheduling for HTTP adaptive streaming videos. *Cluster Computing*,*24*(3),1605–1621.doi:https://doi.org/10.1007/s10586-020-03207-x

Bai, Y., Haghighat, M., & Abdel-Mottaleb, M. (2018). Kernel Discriminant Correlation Analysis: Feature Level Fusion for Nonlinear Biometric Recognition. *P2018 24th International Conference on Pattern Recognition(ICPR)*,3198–3203. doi:https://doi.org/10.1109/ICPR.2018.8546068

Bc, A., & Prakash, H. N. (2022). Image fusion by discrete wavelet transform for multimodal biometric recognition. *IAES International Journal of Artificial Intelligence (IJ-AI)*, *11*(1), 229–237. doi:https://doi.org/10.11591/ijai.v11.i1.pp229-237

Hardalac, F., Yaşar, H., Akyel, A., & Kutbay, U. (2020). A novel comparative study using multi-resolution transforms and convolutional neural network (CNN) for contactless palm print verification and identification. *Multimedia Tools and Applications*, *79*(31–32), 22929–22963. doi:https://doi.org/10.1007/s11042-020-09005-2

Kortli, Y., Jridi, M., Al Falou, A., & Atri, M. (2020). Face recognition systems: A survey. *Sensors (Switzerland)*, *20*(2). doi: https://doi.org/10.3390/s20020342

Leghari, M., Memon, S., & Chandio, A. A. (2018). Feature-Level Fusion of Fingerprint and Online Signature for Multimodal Biometrics. *2018 International Conference on Computing, Mathematics and Engineering Technologies (ICoMET)*, 2–5. doi: https://doi.org/10.1109/ICOMET.2018.8346358

Mansoura, L., Noureddine, A., Assas, O., & Yassine, A. (2019). Multimodal Face and Iris Recognition with Adaptive Score Normalization using Several Comparative Methods. *Indian Journal of Science and Technology, 12*(7),1–8. doi:https://doi.org/10.17485/ijst/2019/v12i7/140755

Nada Alay, H. H. A.-B. (2020). Deep Learning Approach for Multimodal Biometric Recognition System Based on Fusion of Iris, Face, and Finger Vein Traits. *Sensors*, *20*(19),

5523–5530. doi:https://doi.org/10.3390/s20195523.

Oloyede, M. O., & Hancke, G. P. (2016). Unimodal and Multimodal Biometric Sensing Systems: A Review. *IEEE Access*, *4*, 7532–7555. doi:https://doi.org/10.1109/ACCESS.2016.2614720

Regouid, M., Touahria, M., Benouis, M., & Costen, N. (2019). Multimodal biometric system for ECG , ear and iris recognition based on local descriptors. *Multimed Tools Appl*, *78*, 22509–22535. doi:https://doi.org/10.1007/s11042-019-7467-x

s, K. R. (2023). A Deep Learning Technique for Bi-Fold Grading of an Eye Disorder DR-Diabetic Retinopathy. *Data Analytics and Artificial Intelligence*, *3*(2), 113–115. doi:https://doi.org/10.1007/978-981-19-0151-5_32

Singhal, P., & Kumar, A. (2022). FACE RECOGNITION USING PCA AND WAVELET TRANSFORM. *Advances and Application in Mathematical Sciences*, *21*(5), 2795–2802.

Sujatha, E., & Chilambuchelvan, A. (2017). Multimodal Biometric Authentication Algorithm Using Iris, Palm Print, Face and Signature with Encoded DWT. *Wireless Personal Communications*, *99*(1), 23–34. doi: https://doi.org/10.1007/s11277-017-5034-1

T., V. (2021). Synthesis of Palm Print in Feature Fusion Techniques for Multimodal Biometric Recognition System Online Signature. *Journal of Innovative Image Processing*, *3*(2), 131–143. doi:https://doi.org/10.36548/jiip.2021.2.005

Tabassum, F., Imdadul Islam, M., Tasin Khan, R., & Amin, M. R. (2022). Human face recognition with combination of DWT and machine learning. *Journal of King Saud University - Computer and Information Sciences*, *34*(3), 546–556. doi:https://doi.org/10.1016/j.jksuci.2020.02.002

Tarawneh, A. S., Chetverikov, D., & Hassanat, A. B. (2018). Pilot Comparative Study of Different Deep Features for Palmprint Identification in Low-Quality Images. *Ninth Hungarian Conference on Computer Graphics and Geometry*, 1804–1810. doi:https://doi.org/10.48550/arXiv.1804.04602

Wang, Y., Peng, L., & Zhe, F. (2018). Face recognition using slow feature analysis and contourlet transform. *AIP Conference Proceedings*,*1955*, 040155–040161. doi:https://doi.org/10.1063/1.5033819

An Intelligent Method to Adapt the Distance Relay in Power System Fault Detection with Electric Vehicles Presence

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Keywords	Abstract
Electric Vehicles, ANN, Distance relay, Smart System, Faults Detection	*In this research paper, the effect of electric vehicles integration on performance of distance relay in the distribution system was studied. The number of electric vehicles integrated into the distribution system has been increased, and its effect on distance protection has been demonstrated using the MATLAB / Simulink software. The results showed that integrating these vehicles led to poor performance, due to the occurrence of over-reach in distance protection and the difficulty of fault location. To obtain distance protection that could be adapted to the condition of the system, smart adaptive distance protection was proposed based on artificial intelligence. Artificial neural networks were used to detect the faults and to issue a trip signal with an accuracy of 99.9%. Meanwhile, fuzzy logic was used to locate the fault with an error rate of 0.00036 when 30 electric vehicles were added. Thus, smart distance protection was obtained that was able to adapt its characteristics to the number of added vehicles and to detect and locate a fault with high accuracy.*

1. INTRODUCTION

Environmental pollution, which the world is suffering from today, has become a monumental problem due to emissions from the transportation and power generation sectors, factories, etc., which are the main sources of these emissions. Their dependence on fossil fuels as well as the high cost of these fuels have given rise to many of the problems that the world is witnessing today. It is necessary to turn to new policies to reduce the use of fossil fuels, and thus, reduce emissions resulting from their use (Habib, Kamran & Rashid, 2015). Electric vehicles are considered as one of the important solutions as the electrification of the transportation sector will lead to a reduction of emissions from internal combustion engines (Rezaee, Farjah & Khorramdel, 2013). Despite the advantages of electric vehicles, they have negative effects on the distribution system, and many researchers have conducted studies and literature reviews to investigate these negative effects.

A literature review was carried out by(Nour, Chaves-Ávila, Magdy & Sánchez-Miralles, 2020) on the effects of electric vehicle charging stations on the parameters of the distribution system in terms of voltage stability, losses, power factor and power quality, where the researchers concluded that adding these stations will reduce stability and the power factor, and increase losses in the system. Meanwhile, the research by (Utakrue & Hongesombut, 2018) deal with the effect of the addition of electric vehicle charging stations on power transformers and their life span. The effect on the level of failure following the addition of charging stations was studied by (Kumar & Saxena, 2019), who concluded that the addition of charging stations will lead to an increase in the faults level (short circuit level) and the demand for reactive power. The negative effects caused by the integration of electric vehicles will also negatively impact the protection system in the electric network because of the harmonics that these vehicles inject into the electric system. In (Etezadi-Amoli, Choma & Stefani, 2010) investigated the effects of the fast-charging (FC) of electric vehicles on the distribution system without compensation and in several different locations by studying the power flow and analyzing the faults, as well as the use of the necessary protection to protect the transformer from various fault currents. In (Gong, Ma, Zhang, Ding, Li, Yang & Liu, 2017) studied the effects of integrated electric vehicle charging stations (EVCSs) on the coordination and accuracy of protection relays in distribution networks, and developed the necessary solutions to avoid the effects of adding these stations. In (Goodarzi, sadat Nouprvar, Safaei & Mozaffari, 2019) the researchers employed the genetic algorithm to improve the coordination of the overcurrent relay in the event of the integration of electric vehicle charging stations, where the aforementioned algorithm can be used to select the optimal trip time for the overcurrent relay. By modelling and simulating a distribution system consisting of 33 buses using the MATLAB/Simulink program, the researchers found that the increased integration of electric vehicles (EVs) into the system will lead to an increase in short circuit levels and trip time.

In this paper, the effect of integrating fast-charging stations (FCS) into the distribution system on the performance of distance protection was investigated using MATLAB/Simulink software, after which, adaptive protection was designed using artificial intelligence (AI). This paper is divided into seven sections. The first section gives the introduction, the second section is on the electric vehicle charger model, the third section is concerning the effect of the charging station on distance protection, the forth present research method , the fifth is on artificial neural networks (ANN) ,the sixth section presents the simulation results, and the seventh section presents the conclusions.

2. ELECTRIC VEHICLE CHARGER MODEL

Before presenting the details on the protection of the distribution system, the type of charger used in the research should first be mentioned. When charging the batteries of electric vehicles, it is necessary for the alternating current to be converted to a direct current. Many technologies are available for charging the batteries of electric vehicles, such as conductive charging, wireless charging, and battery swapping. The charger can also be a single-phase or three-phase charger (Khudher, Aris, Mailah & Sahbudin, 2017), or it can be classified according to the direction of the power flow from and to the battery. In other words, the charger can be bidirectional or unidirectional (Nour et al., 2020). The charger used in this research paper was a six-pulse three-phase charger (as shown in Figure 1.) with a closed loop control using thyristors**.**
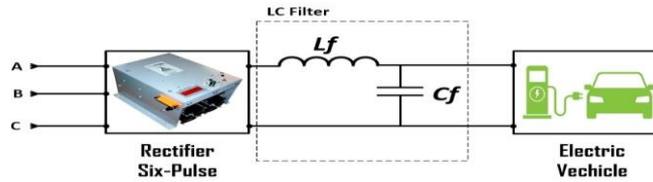
Figure 1. A six-pulse three-phase charger for charging an electric vehicle

Meanwhile, Figure 2. shows the control circuit of the three-phase charger, which controlled the operation of the thyristor by changing the firing angles so that the output remained constant to obtain a stable charge and a fast-charging process. As such, the proposed circuit provided charging at a constant current and voltage**.**
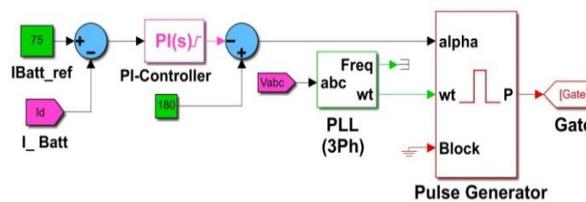
Figure 2. Control circuit of three-phase charger

3. EFFECT OF THE CHARGING STATION ON THE PERFORMANCE OF THE DISTANCE RELAY

The main objective of the distance relay is to protect the transmission lines and thus, protect and ensure the safety of the electrical system (Nasser & Arkan, 2019). The functioning of the distance protection depends on the measured impedance at the moment a fault occurs. Both the voltage and current signal are entered continuously into the distance protection, which works uninterruptedly to measure the impedance. When a fault occurs, the impedance that is seen by the distance protection will be less than the setting impedance, and thus the distance protection works to issue an trip signal to the circuit breaker to Isolate the faulty part from the network (Alsammak & Abdulhameed, 2018; Electric, 2017). However, there are other factors that affect the operation of the distance element, such as fault resistance, and flexible alternating current transmission systems (FACTS) (Alsammak & Janderma, 2019). The loads connected to the electrical network are divided into two types, linear and non-linear loads. Electric vehicle charging stations are considered non-linear loads since they work to convert the alternating current into a direct current using power electronic devices, as a result of the closing and opening operations of the power electronics switches, it leads to the generation of harmonics and thus distortion of current and voltage waves. In addition to reducing the power factor, reducing the voltage, increasing the losses in the system and increasing the load (Alsammak & Janderma, 2019; Khraiwish, Alshamasin, Kassasbeh, shiboul, Al-Qudah & Al-Busoul, 2009; Nour et al., 2020). The process of adding charging stations to the distribution system leads to an increase in harmonics, and consequently these harmonics lead to the wrong operation of the protection devices (Khraiwish et al., 2009).The impedance seen by the distance protection is greatly affected by the harmonics in the current and voltage, and this will result in poor performance and Maloperation of the distance protection. The current and voltage that determine the perceived impedance can be calculated in the normal case and at the moment of failure, as shown in the equations (1,2,3).
To calculate the seen impedance by the distance protection, the equation (1,2,3) is used:

$$|V_{rms}| = \sqrt{V_1^2 + (|V_i||_{h=5})^2 + (|V_i||_{h=7})^2 + ..} \tag{1}$$

$$|I_{rms}| = \sqrt{I_1^2 + (|I_i||_{h=5})^2 + (|I_i||_{h=7})^2 + ..} \qquad (2)$$

In order to calculate the seen impedance by the distance protection, the equation (3) is used.

$$Z_{relar} = \frac{|V_{rms}|\angle\theta}{|I_{rms}|\angle\varphi} \qquad (3)$$

where V_rms and I_rms, represent the voltage and current, respectively, including the existing harmonics, and Z_relay represents the impedance observed by the distance protection. As a result of the injection of these harmonics into the distribution system, an over reach of the distance protection occurs as the number of vehicles is increased.

4. RESEARCH METHOD

The network model shown in Figure 3. was proposed to show the effect of adding electric vehicles into the distribution system in two different scenarios. Artificial neural networks were used to detect the faults, while fuzzy logic was used to locate the faults.

1- For the system in a normal case without the addition of electric vehicles, the fault resistance values were 0Ω, 5Ω, 10Ω, and 15Ω, the fault location value was changed by 5% to 80%, the fault procedure was phased with the ground (single line to ground), while the resistance (R) and inductance will (X) were recorded.

2- The first scenario was applied with the addition of 30 electric vehicles.
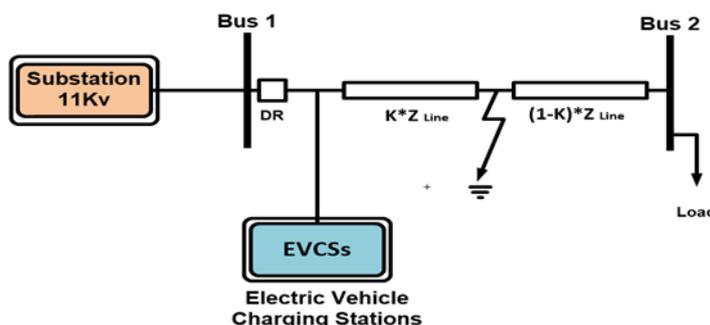
Figure 3. Model of proposed network for the study

Table 1. Data of the proposed system for the study

Element	Data
Substation	3 Phase, $V_{ph-ph} = 11Kv$, f=50 Hz
EV capacity	Charging current=75 A,V Battery=450 V , Pin=34 Kw
Transmission Line	R_1 [Ω/Km]= 0.0474, R_0=[Ω/Km]= 0.3073, L_1[H/Km]= 0.001011047, L_0[H/Km]= 0.003476, C_1[F/Km]=11.3 $* 10^{-9}$, C_0[F/Km]=8.14 $* 10^{-9}$, Line Length = 58.8 Km
Load	3 phase Yg , $V_{ph-ph} = 11Kv$, f=50 Hz S=11.2 KVA, PF=0.8944 lag

A- Case one

In this case, Fig.3 was represented in MATLAB. The fault (A-G) was applied for a period (t) of 1.3 seconds without the addition of any electric vehicle. This was the normal case of the system. The value of K was changed by 5% to 80% for variations in the value of the fault resistance (0Ω, 5Ω, 10Ω, 15Ω). All the readings that were obtained for the resistance (R/Ohm) and inductance (X/Ohm) were recorded, and then, the distance protection characteristics were plotted using the obtained resistance and inductance values. Figure 4 shows the characteristics of the distance protection in the normal case.
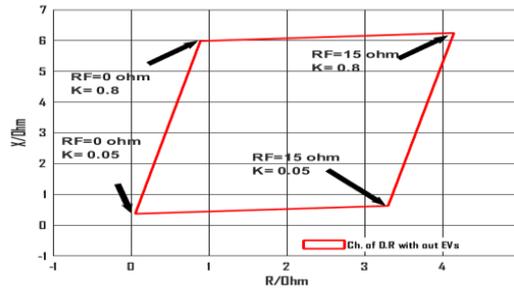
Figure 4. Characteristics of the distance protection in the normal case

B- *Case two*

30 electric vehicles were added to the distribution system, and the same scenario was repeated as in the first case. Figure 5**.** shows the distance protection characteristics in the second case, and the effect of adding 30 electric vehicles compared to the first case.
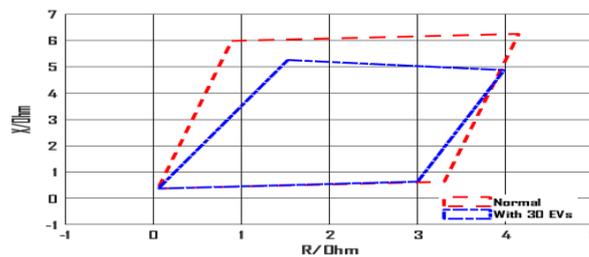
Figure 5. Characteristics of the distance protection with the addition of 30 vehicles compared to the normal condition

Figure 5. shows that the addition of 30 electric vehicles led to the occurrence of over-reach in the distance relay, that is, the apparent impedance in the case of the addition of electric vehicles was less than the impedance in the normal case, and this resulted in poor performance and problems in the selectivity of the circuit breakers that had to be separated At the moment of failure, the same applied to the location of the fault, which was difficult to determine as the process depended mainly on the value of the impedance.

5. ARTIFICIAL NEURAL NETWORKS (ANN)

One of the techniques of artificial neural networks (ANNs) is the feed forward neural network (FNN), which can be represented by equation (4):

$$Y = F(\sum_{i=1}^{n} I_i * w_i) \tag{4}$$

where Y represents the output of the feed-forward neural network; I_i, the number of entries for the network; and w_i, the bias weights of the neural network cells (Alnaib, Alsammak & Sabry, 2022). The previously mentioned cases were used to obtain the data for the training process to develop a model of the neural network that was responsible for issuing the trip signal, and another that was responsible for locating the fault using fuzzy logic. Given below is the training that was conducted on the data extracted from each of the cases.

A- *Case One*

The characteristics of the distance relay in Figure 4 were converted into a set of data, as shown in Figure 6, and this data was entered into the neural network as the training set. Thus, this data was ready to train the artificial neural networks. Figure 6 shows the characteristics of the relay in the form of points, in the normal case.
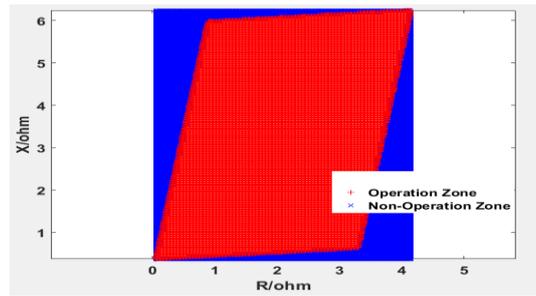
Figure 6. Characteristics of the distance relay, in the form of points, in the normal case.

After the training group had been obtained using MATLAB, the neural networks were trained using a classification algorithm, and the following training results were obtained by using the scaled conjugate gradient algorithm. as shown below in Table 2.

Table 2. describes the best training of the neural network for fault detection in the normal case

Number of hidden neurons	Training algorithm	Cross-entropy Error	Error	Epoch
40	Scaled conjugate gradient	0.0046	0.0009	364

B- Case Two

In the same way as in the first case, Figure 5 shows the characteristics that were obtained when 30 compounds were added into the system. These characteristics were also converted into data to be trained on the neural network, after which, the specifications of the neural network were as shown below in Table 3.

Table 3. describes the best training of the neural network for fault detection in the case of the addition of 30 vehicles

Number of hidden neurons	Training algorithm	Cross-entropy Error	Error	Epoch
20	Scaled conjugate gradient	0.0042	9.6e-4	408

6. FUZZY LOGIC

Fuzzy logic can be used in many modern applications. In this research, it was used as part of the proposed distance relay to locate faults, as the location of a fault is affected by the addition of electric vehicles. Fuzzy logic consists of four parts: Fuzzifier, Rules, Inference, and Defuzzifier (Alsammak & Janderma, 2019), as shown in Figure 7.
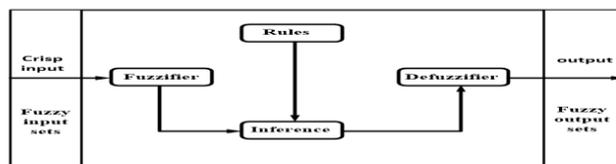
Figure 7. Basic structure of fuzzy logic

Fuzzy logic is trained using artificial neural network (ANN) algorithms. For this research, a hybrid algorithm, containing two types of training algorithms, namely, a back propagation and least square algorithm, was used. This adaptive neuro-fuzzy inference system used the Takagi-Sugeno type of inference mechanism (Alnaib, Alsammak & Sabry, 2022), where the inputs to the fuzzy logic were the impedance and angle of the protected line at the moment of failure. Below are the training results for the data obtained previously. The data obtained from the normal condition without the addition of electric vehicles was entered at the moment of failure.

There were two entries, namely, the value of the impedance (Z) and the angle. The fuzzy logic was trained using the system of attempts to obtain the lowest error rate. Table 5. shows the specifications of the fuzzy logic to obtain the lowest error rate, Figure 8. represents a three-dimensional form of the fuzzy logic model. An illustration of the fuzzy logic model used to locate the fault is given in Figure 9.

Table 5. Fuzzy logic specifications for locating the fault in the normal state

Input membership function type	No. of input membership function	Output membership function type	RMSE
Triangular	5	constant	0.00129
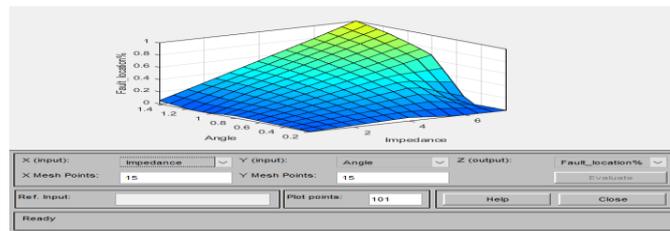
Figure 8. Three-dimensional figure showing the relationship between input and output
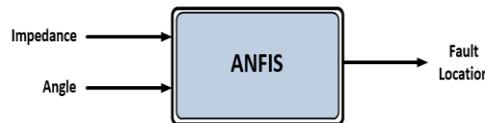
Figure 9. Illustration of the input and output of the fuzzy logic

30 electric vehicles were added to the distance phase, and, as shown in Figure 5, it occurred beyond the range of the phase and distance, and affected the accuracy of the fault location. Therefore, this effect was treated using fuzzy logic, as in the first case. The data was entered into the fuzzy logic, and in the same way, the specifications of the fuzzy logic model, which gave the lowest error rate, were obtained. Table 6. shows the specifications of the fuzzy logic for this case.

Table 6. Specifications of the fuzzy logic for the location of faults in the case of the addition of 30 vehicles

Input membership function type	No. of input membership function	Output membership function type	RMSE
Triangular	6	constant	0.00075

The distance relay was adapted to suit the condition of the system in the normal case and considering the presence of 30 electric vehicles. The addition of electric vehicles led to an increase in the total harmonic distortion (THD), and from the measurement of the harmonic distortion, it could be determined if these vehicles were connected to the system. Thus, the characteristics of the distance relay were chosen to suit the condition of the system, and it worked correctly in issuing the trip signal, in addition to determining the location of the fault with high accuracy. Figure 10 shows the structure of the proposed distance relay.
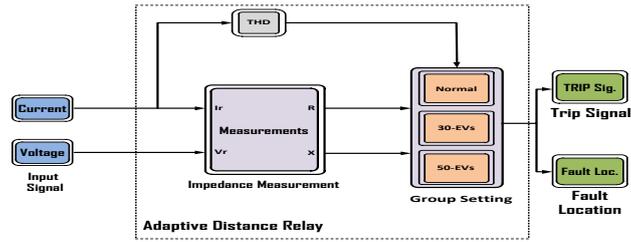
Figure 10. Structure of the proposed distance relay

7. SIMULATION RESULTS

On completion of the training of the neural networks on the training sets for each of the previously mentioned cases, and after obtaining the best specifications for the neural networks, the distance relay in the event of a ground fault (SLG) was tested regarding the issuing of the trip signal, as well as in determining the location of the faults for all the studied cases. The results were divided according to the two cases, namely, the normal condition and the addition of 30 vehicles. Each of the cases included displaying the condition of the ground fault (SLG) in terms of the status of the voltage, current and fault detection time, respectively, together with a table showing the fault locations that were predicted by the proposed distance relay and the error rate for each fault location. The ground fault (SLG) for the normal condition without the addition of any electric vehicle was achieved at a fault resistance of 7Ω, fault location of 70%, and time of 1.3 seconds. Figure 11. shows the ground fault current and the response of the distance relay in the release of the trip signal.
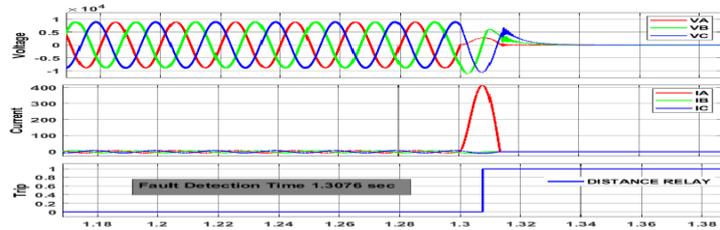
Figure 11. Ground fault phase at 1.3 sec

It was noted in Fig. 11 that the ground fault of the first phase occurred at 1.3 seconds, and the protection relay issued an trip signal to the circuit breaker for 7.6 msec to isolate the faulty part of the system. In the same manner as in the first case, the ground fault was applied, and the results, as presented below in Figure 12 , show the earth fault current and relay response with the addition of 30 electric vehicles.
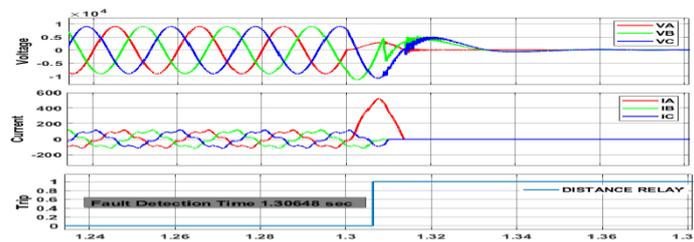
Figure 12. Ground fault phase at 1.3 sec with the addition of 30 vehicles

It was noted in Figure 12, that the ground fault of the first phase occurred at 1.3 seconds, and that the fault current was greater than the fault current in the first case. It was also noted that the protection relay issued a trip signal to the circuit breaker for 6.48 m-sec to isolate the faulty part of the system. The larger the number of vehicles connected to the system, the greater the fault current. To determine the location of the fault, tables were presented for locating the faults

for the two states (normal condition and addition of 30 EVs), at different locations and with a fault resistance of 5Ω. The error rate for a different set of fault locations when the fault resistance is (5 Ω) was from (3.02945e-6 to 114480292|) and the actual fault locations was (5%-80%) by 5% step and their predicted at the moment the faults occurred was (0.04999997 -0.798855197) .It can be seen from the result that the trained fuzzy logic model was able to predict the fault locations with high accuracy and at a very low error rate of less than 5%.

8. CONCLUSION

In this paper, the effect of the electric vehicle charging station on the performance of distance protection in the distribution system was studied, where a three-phase charger with a six-pulse controller was used. From the results, it was clear that the addition of electric vehicles led to increases in the fault current, current drawn from the system, and the harmonics in the drawn current. Also, the increase in the number of electric vehicles led to poor performance of the distance relay, where the value of the impedance apparent at the distance relay was less compared to the normal case, and this was known as over-reach that occurred for the distance relay. This resulted in a change in the characteristics of the distance relay as the number of electric vehicles increased. In this research, the relay was designed based on two cases (normal condition and addition of 30 vehicles. The error rate at the fault location (5%) was 3.02945e-06% in the normal case and 2.85874e-06% for the same location with the addition of 30 vehicles. While the accuracy of the artificial neural network model for fault detection was 99.9%.

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Conflict of Interest
Authors declare that there is no conflict of interest.

Authors Contributions

The authors involved in this study are Wisam Mohamed Najem, Dr.Shaker M.Khudher, Dr.Omar Sh. Al-Yozbaky; contributed to all aspects of the study. All authors contributed to the idea, design, inspection,resources, data collection, literature review, critical review and analysis and interpretation sections of the study.

REFERENCE

Alnaib, I. I., Alsammak, A. N. B. & Sabry, S. (2022) 'Protection Relay Performance Comparison for Faults Detection and Classification Based on ANN and ANFIS', in Norhaliza Abdul Wahab, Z. M. (ed.) Control, Instrumentation and Mechatronics: Theory and Practice. Springer, Singapore, pp. 545–555. doi: http://dx.doi.org/10.1007/978-981-19-3923-5_47

Alsammak, A. N. & Abdulhameed, M. I. I. (2018) 'Performance Improvement for Distance Relay Based Fuzzy Logic for All Prospective Faults', International Research Journal of Engineering and Technology, 05(08), pp. 1489–1495. https://www.irjet.net/archives/V5/i8/IRJET-V5I8255.pdf

Alsammak, A. N. & Janderma, M. S. A. (2019) 'Design a Fuzzy Distance Relay Including STATCOM Effects', International Research Journal of Engineering and Technology, 06(08), pp. 1072–1078. https://www.academia.edu/download/60631193/IRJET-V6I820220190918-80408-1klqbcz.pdf

Electric, G. (2017) 'MiCOM P40 Agile, Technical Manual'. https://data2.manualslib.com/pdf6/125/12426/1242532-ge/micom_p40_agile.pdf

Etezadi-Amoli, M., Choma, K. & Stefani, J. (2010) 'Rapid-charge electric-vehicle stations', IEEE Transactions on Power Delivery, 25(3), pp. 1883–1887. doi: http://dx.doi.org/10.1109/TPWRD.2010.2047874

Gong, C., Ma, L., Zhang, B., Ding, Y., Li, X., Yang, S., ... & Liu, H. (2017). Research on influence and resolution of the relay protections with electric vehicle charging station integrating into distribution network. International journal of hydrogen energy, 42(29), 18747-18753. doi: http://dx.doi.org/10.1016/j.ijhydene.2017.04.181

Goodarzi, M., sadat Nouprvar, B., Safaei, A., & Mozaffari, M. (2019, December). A Novel Algorithm for Improving the Overcurrent Relay Coordination with the consideration of EV Charging Station. In 2019 International Power System Conference (PSC) (pp. 280-286). IEEE. doi: https://doi.org/10.1109/PSC49016.2019.9081467

Habib, S., Kamran, M. & Rashid, U. (2015) 'Impact analysis of vehicle-to-grid technology and charging strategies of electric vehicles on distribution networks – A review', Journal of Power Sources, 277, pp. 205–214. doi: https://doi.org/10.1016/j.jpowsour .2014.2.020

Khraiwish, A. S., Alshamasin, M., Kassasbeh, R., shiboul, Y. A., Al-Qudah, Z., & Al-Busoul, M. (2009). The Effect of the Harmonics, the Fault Location and the Fault Resistance on the Performance of the Impedance-Type Distance Relay. American Journal of Applied Sciences, 6(4), 788. doi: https://doi.org/10.3844/ajassp.2009.788.796

Khudher, S. M., Aris, I. B., Mailah, N. F., & Sahbudin, R. K. (2017). Analysis of AC-To-DC uncontrolled converters harmonics for electric vehicles applications. Pertanika J. Sci. Technol, 25, 283-290. https://core.ac.uk/download /pdf/153830400.pdf

Kumar, R. & Saxena, D. (2019) 'Impact of Plug-In Electric Vehicles on Faulted Distribution System', Arabian Journal for Science and Engineering, pp. 1599–1614. doi: http://dx.doi.org/10.1007/s13369-019-04104-1

Nasser, A.&Arkan, S. (2019) 'Enhancement Effects of the STATCOM on the Distance Relay Protection', International Journal of Computer Applications, 182(40), pp. 10–14. doi: http://dx.doi.org/10.5120/ijca2019918461

Nour, M., Chaves-Ávila, J. P., Magdy, G., & Sánchez-Miralles, Á. (2020). Review of positive and negative impacts of electric vehicles charging on electric power systems. Energies, 13(18), 4675. https://www.mdpi.com/1996-1073/13/18/4675/pdf

Rezaee, S., Farjah, E. & Khorramdel, B. (2013) 'Probabilistic Analysis of Plug-In Electric Vehicles Impact on Electrical Grid Through Homes and Parking Lots', IEEE Transactions on Sustainable Energy, 4(4), pp. 1024–1033. doi: http://dx.doi.org/10.1109/TSTE.2013.2264498

Design of Fractional Order PID Controller Based on Genetic Algorithm Optimization for Vertical Take-Off and Landing Platforms

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Keywords	Abstract
PID Controllers, FOPID Controllers, Genetic Algorithms, Unmanned aerial vehicles, VTOL platforms	*This research studies the procedure of analyzing and designing of a fractional order PID controller (FOPID) with the genetic algorithm (GA) as an optimization method to control the pitch angle of vertical take-off and landing system (VTOL). The VTOL system has been manipulated in many areas because they have stable flight and simple necessities. The VTOL system has been modeled by taking the action of the torque of the rigid body then finding the equations of the angular motions. The transfer function of the current to the position dynamics of the VTOL has been found. The fractional order PID controller is considered as a modified type of the PID controller because it has fractional orders for the integral and derivative sections instead of being integers. The GA optimization method will be used to find the optimal values for the parameters of the controller, while three fitness functions will be used, including mean square error (MSE), integral time square error (ITSE) and integral square error (ISE). The performances of the controllers have been compared relating to the maximum overshot, rise time, settling time, and steady-state error. The results show that the ISE gives better behavior in terms of the transient and the steady state response specifications.*

1. INTRODUCTION

Conventional PID controller is considered as superior kind of feedback controls in many fields including industry and academic for many reasons involving its uncomplicated design and the ability to deal with the transient and steady state responses (S Dawood et al., 2018). However, it also has downsides including a less efficient performance (Shah & Agashe, 2016). Recently, researchers attracted to the analysis and design of the fractional order PID controllers. This controller was firstly proposed by (Zhao et al., 2005) and since then it has been used in numerous applications of many filed such as control application, material science, robotics, etc. (Mahmood et al., 2021). One of the challenging parts regarding the FOPID design is the selection of the tuning method (Shah & Agashe, 2016). In this work, GA optimization method has been used to select the optimal values for the Kp, Ki, Kd, μ and λ and applied on a (VTOL) system. UAVs considered as dynamically growing area of knowledge and have many

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applications in both military and civil fields including surveillance, firefighting, etc. (Lin et al., 2020; Zhang et al., 2014; Becker & Sheffler, 2016). The role of the controller is to keep the pitch angle as required by controlling the position of the propeller tilt angle. (Bauersfeld & Ducard, 2020). The aim of their study was to verify the effectiveness of the adaptive landing. The outline of the paper is organized as follow: Firstly, the model of the VTOL is presented. Secondly, a separate section for the FOPID is presented. Then, GA is discussed in details. Followed by a section for the results and discussion. Finally, a conclusion section is provided.

2. VERTICAL TAKE-OFF AND LANDING MODELING

The model of vertical takeoff and landing (VTOL) system has been built and used as a benchmark to evaluate and test the performance of different control systems. This system consists of a propeller actuator and a counterweight connected by a rod. This propeller actuator actually a fan with variable speed and by controlling its speed, the system can mimic the behavior of UAVs regarding the pitch angle. Figure (1) shows the free body diagram (FBD) of the VTOL device that rotates around its pitch axis.
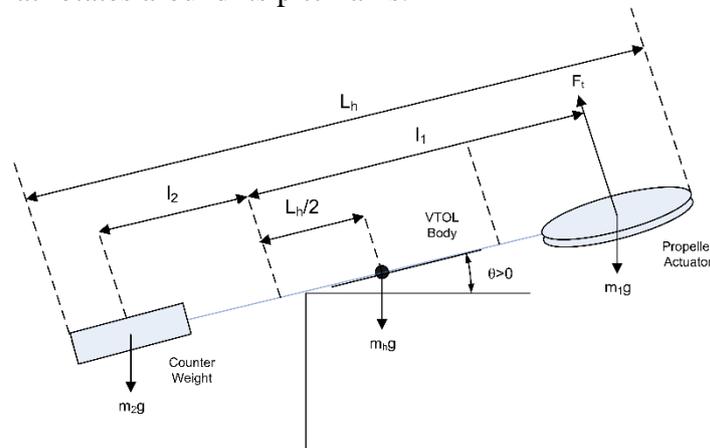
Figure 1. FBD of 1-DOF VTOL

The equations of torque acting can be summed and described by equation (1). While the equations that describe the angular motions in term of the thrust torque can be fully expressed by equation (2). Finally, the obtained transfer function of the current to position of the VTOL is shown in equation (3).

$$
\left.\begin{array}{c}
\tau t + m2\, g\, l2 \cos \theta(t) - m1\, g\, l1 \cos \theta(t) - \dfrac{1}{2}\, mh\, g\, Lh \cos \theta(t) = 0 \\[4pt]
\tau t = Ft\, l1 \\
\tau t = Kt\, Im \\[4pt]
Kt\, Im + m2\, g\, l2 \cos \theta(t) - m1\, g\, l1 \cos \theta(t) - \dfrac{1}{2} mh\, g\, Lh \cos \theta(t) = 0 \\[4pt]
Kt\, Ieq + m2\, g\, l2 - m1\, g\, l1 - \dfrac{1}{2} mh\, g\, Lh = 0
\end{array}\right\} \quad (1)
$$

$$
\left.\begin{array}{c}
J\,\ddot{\theta} + B\,\dot{\theta} + K\,\theta = \tau t \\
J\,\ddot{\theta} + B\,\dot{\theta} + K\,\theta = Kt\, Im \\[4pt]
J = \displaystyle\sum_{i=1}^{n} m_i\, r_i^2
\end{array}\right\} \quad (2)
$$

$$
P(s) = \frac{K_t}{J\left(s^2 + \dfrac{B}{J}s + \dfrac{K}{J}\right)} \quad (3)
$$

Table (1) sums up all the parameters and symbols that has been used and mentioned in equations (1, 2, 3) for the VTOL system.

Table 1. VTOL system parameters and values

Parameter	Symbol	Value	Unit
Equilibrium Current	I_{eq}	1.0	*A*
Torque-thrust Constant	K_t	0.0226	*(Nm)/A*
Moment of Inertia	*J*	0.0035	*Kgm²*
Viscous Damping	*B*	0.002	*(Nms)/rad*
Natural Frequency	w_n	2.52	*rad*
Stiffness	*K*	0.022	*(Nm)/rad*
Measured Torque-thrust Constant	K_{tid}	0.01	*(Nm)/A*
Measured Viscous Damping	B_{id}	0.006	*(Nms)/rad*
Measured Stifness	K_{id}	0.015	*(Nm)/rad*
Length of the setup	L_h	0.3	*m*

3. FOPID CONTROLLER

The characteristics of PID controllers can be more enhanced by appropriate manipulation of its integral and derivative actions. Therefore, beside tuning the basic gains, there are two extra parameters, the powers of the integral and derivative orders (Ibrahim Khather et al., 2018).

FOPID controllers are mainly depend on fractional calculus of two additional parameters, which are (λ and μ). These added gains aim to enhance controller's performance and robustness. The control action of the fractional order PID controller PIλDμ is specified as:

$$u(t) = kp. e(t) + ki. I^{-\lambda}. e(t) + kd. D^{-\mu}. e(t) \tag{4}$$

In which e(t) represents the tracking error signal of the system whereas u(t) is the control action signal. Implementing Laplace transformation on this equation, the control output for the fractional order PID controller can be stated as:

$$G_c(s) = kp + \frac{ki}{s^\lambda} + kd\, s^\mu \quad (\lambda\ \&\ \mu:\ 0-1) \tag{5}$$

4. GENETIC ALGORITHM

Genetic Algorithm (GA) is a random probability search engine that simulates genetic mechanism and natural selection (Cao et al., 2005). This algorithm starts with a random initialization of the elements creating the initial chromosome which is formed in this particular problem by five gain values of the FOPID controller (PIλDμ) that should be adjusted to achieve the desired behavior. Then, Genetic Algorithm executes iteratively to obtain the best values of these elements through three main stages of Mutation, Crossover and Selection (AIbrahim et al., 2019). Finally, the validity of each chromosome is assessed by calculating its fitness function which is a measure of the quality of the chromosome and compared with a stopping criterion (ε) (Gani et al., 2019). In this particular work, three objective functions are applied which are the ISE, ITSE and MSE which can be presented by:

$$\text{ISE} = \int_0^T \big(e(t)\big)^2 dt = \int_0^T \big(r(t) - y(t)\big)^2 dt \tag{6}$$

$$\text{ITSE} = \int_0^T t(e(t))^2 dt = \int_0^T t(r(t) - y(t))^2 dt \tag{7}$$

$$MSE = \frac{1}{n} \sum_{i=1}^{n} (e(t))^2 \qquad (8)$$

The fractional order PID optimized via genetic algorithm for vertical take-off and landing system is illustarted in figure 2 below. The reference position is fed as an input and the associated error between the actual and desired positions is calculated. Then, genetic algorithm is executed iteratively to generate the five controller's. Finally, the controller gives the control signal (u) as an input to the VTOL system to drive the actuators.
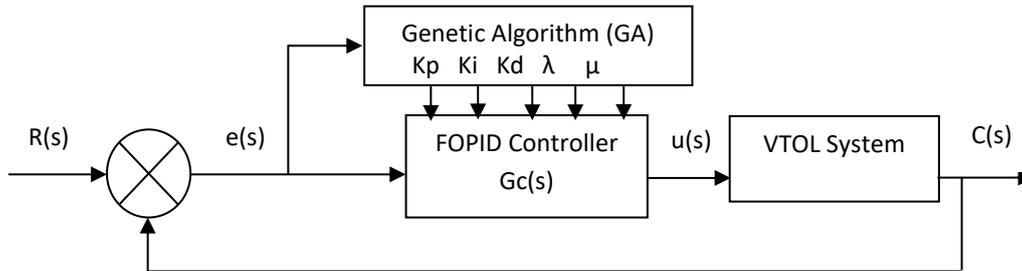
Figure 2. GA-FOPID controller.

5. SIMULATIONS AND RESULTS

In this section, many simulations have been attempted using MATLAB in order to obtain the optimal values for the FOPID controller's gains. Then, the response of the system has been analyzed in term of the maximum overshoot percent (MP %), rise time (Tr) and settling time (Ts) then compared for different fitness functions (ISE, ITSE and MSE). After running the GA optimization each selected fitness functions, the trend of the FOPID controller gains through generations are shown in figure (3a), (3b) and (3c) respectively.
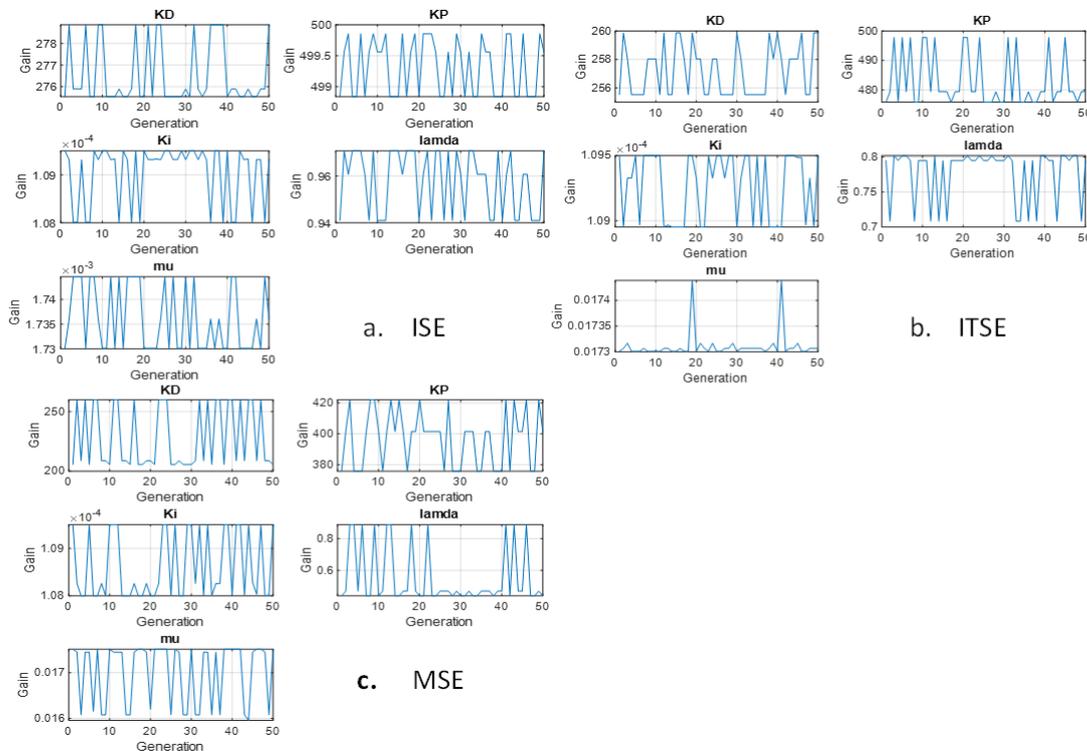
Figure 3. Parameter variation of the FOPID Controller for ISE, ITSE and MSE

The best five controller gain values resulted from the three fitness functions are shown in table (2)

Table 2. Performance characteristics for VTOL

GA-PID Parameters	ISE Fit. Function	ITSE Fit. Function	MSE Fit. Function
K_d	275.531	255.271	205.531
K_P	498.837	475.135	375.837
K_i	0.0001095	0.0001247	0.000114
Lamda	0.941	0.795075	0.441
Mu	0.0017301	0.016251	0.0175188

Finally, the step responses of the system for the three fitness functions have been summarized in figure (4). It can be noted that all the fitness functions have produced excellent responses with nearly no overshoot and fast transient and settling time. However, ISE fitness function yields the best overall response as shown in table (3).
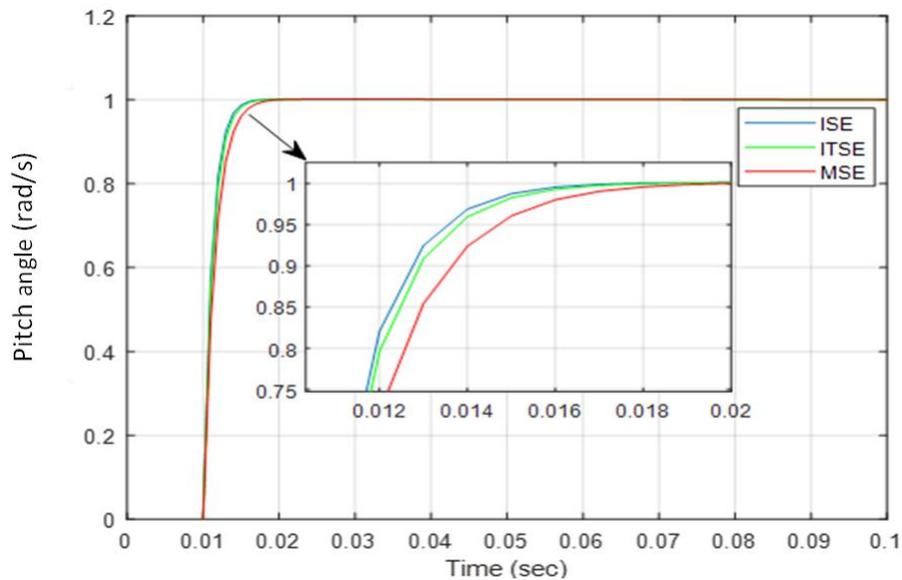
Figure 4. Pitch angle response for ISE, ITSE and MSE

Table 3. Performance characteristics for VTOL

GA-PID Controller Parameters	Values ISE Fit. Function	Values ITSE Fit. Function	Values MSE Fit. Function
T_r (sec)	0.00259	0.00274	0.00345
T_s (sec)	0.00445	0.00489	0.00599
MP %	0.12751	0.1422	0.167

6. CONCLUSION

In this study, FOPID controller has been analyzed and designed in order to control the tilt of VTOL system. For Optimization purposes, (GA) has been applied to select the optimal parameters for the FOPID controller which are (Kp, Ki, Kd, μ and λ). Three fitness functions have been considered which are ISE, ITSE and MSE. The obtained results have been compared in term of the rise time, settling time and the maximum overshoot for the three fitness functions.

The performances of all systems were satisfactory. However, the response of the MSE fitness function has produced the best performance.

Conflict of Interest

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this paper.

Contribution of Authors

[1st Author Ali Mahmood]: Derived the model of VTOL, and wrote the modelling section of the manuscript, contribuated in rsults discussion and analsis.
[2nd Author Mohammed Almaged]: Designed the PID controller in Matlab, produced output response, and wrote introduction and literature section, revised the mansucript.
[3d Author Abdullah I. Abdullah]: Designed the Genetic algorithm optimising technique, produced the best gain values, yielded Performance characteristics for VTOL system.

REFERENCES

AIbrahim, M., Kh Mahmood, A., Saleh Sultan, N., & Sultan, N. S. (2019). Optimal PID controller of a brushless DC motor using genetic algorithm. International Journal of Power Electronics and Drive System (IJPEDS), 10(2), 822–830. doi: https://doi.org/10.11591/ijpeds.v10.i2.pp822-830

Bauersfeld, L., & Ducard, G. (2020). Fused-PID control for tilt-rotor VTOL aircraft. 2020 28th Mediterranean Conference on Control and Automation, MED 2020, 703–708. doi: https://doi.org/10.1109/MED48518.2020.9183031

Becker, M., & Sheffler, D. (2016). Designing a high speed, stealthy, and payload-focused VTOL UAV. 2016 IEEE Systems and Information Engineering Design Symposium, SIEDS 2016, 176–180. doi: https://doi.org/10.1109/SIEDS.2016.7489294

Cao, J. Y., Liang, J., & Cao, B. G. (2005). Optimization of Fractional Order PID controllers based on genetic algorithms. 2005 International Conference on Machine Learning and Cybernetics, ICMLC 2005, 5686–5689. doi: https://doi.org/10.1109/ICMLC.2005.1527950

Gani, M. M., Islam, M. S., & Ullah, M. A. (2019). Optimal PID tuning for controlling the temperature of electric furnace by genetic algorithm. SN Applied Sciences, 1(8), 1–8. doi: https://doi.org/10.1007/S42452-019-0929-Y/FIGURES/12

Ibrahim Khather, S., Almaged, M., & Abdullah, A. I. (2018). Fractional order based on genetic algorithm PID controller for controlling the speed of DC motors. International Journal of Engineering & Technology, 7(4), 5386–5392. doi: https://doi.org/10.14419/ijet.v7i4.25601

Lin, K., Qi, J., Wu, C., Wang, M., & Zhu, G. (2020). Control System Design of A Vertical Take-off and Landing Unmanned Aerial Vehicle. Chinese Control Conference, CCC, 2020-July, 6750–6755. doi: https://doi.org/10.23919/CCC50068.2020.9188609

Mahmood, A., Almaged, M., & Abdulla, A. I. (2021). Antenna Azimuth Position Control Using Fractional Order PID Controller Based on Genetic Algorithm. IOP Conference Series: Materials Science and Engineering, 1152(1), 012016. doi: https://doi.org/10.1088/1757-899X/1152/1/012016

S Dawood, Y., K Mahmood, A., & A Ibrahim, M. (2018). Comparison of PID, GA and Fuzzy Logic Controllers for Cruise Control System. International Journal of Computing and Digital Systems, 7(05), 311–319. doi: http://dx.doi.org/10.12785/ijcds/070505

Shah, P., & Agashe, S. (2016). Review of fractional PID controller. Mechatronics, 38, 29–41. doi: https://doi.org/10.1016/J.MECHATRONICS.2016.06.005

Taşören, A. E., Gökçen, A., Soydemir, M. U., & Şahin, S. (2020). Artificial Neural Network-Based Adaptive PID Controller Design for Vertical Takeoff and Landing Model. European Journal of Science and Technology Special Issue, 87–93. doi: https://doi.org/10.31590/ejosat.779085

Zhang, B., Liu, W., Mao, Z., Liu, J., & Shen, L. (2014). Cooperative and Geometric Learning Algorithm (CGLA) for path planning of UAVs with limited information. Automatica, 50(3), 809–820. doi: https://doi.org/10.1016/J.AUTOMATICA.2013.12.035

Zhao, C., Xue, D., & Chen, Y. Q. (2005). A fractional order PID tuning algorithm for a class of fractional order plants. IEEE International Conference on Mechatronics and Automation, ICMA 2005, 216–221. doi: https://doi.org/10.1109/ICMA.2005.1626550

Crime Analysis and Forecasting Using Machine Learning

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1. INTRODUCTION

Crime is a human behavior that expresses the deliberate violation (caste) of the legal values that need to be protected in terms of the continuation of the social order or carelessness (negligence) against the rules to protect these values. Criminology or crime science is a scientific discipline that explains crime, examines the causes of criminal behavior, and deals with the prevention of crime and the fight against crime. Criminology examines criminality, the consequences of the crime, and the effects of crime on the victim and society. The existence of crime in a society is enough to make people in that community uneasy. For this reason, police units have a great responsibility to prevent crime since it may increase that intense crime is being committed in cases the lack of sufficient police force. It is crucial to predict crimes before they are committed to take precautions accordingly. At this point, machine learning can be effectively used in crime analysis and prediction, which provides parallelism with criminology.

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In this paper, we perform and compare various types of machine learning techniques to predict crimes. Our methods include decision stump, hoeffding tree, J48, logistic model trees, random tree, random forest, and REP tree. Furthermore, we discuss the results of Naive Bayes classifier as well as function-based methods which include support vector machine, simple logistic regression, and artificial neural networks. Finally, we discuss the results of lazy learning methods which include KStar, locally weighted learning, k-nearest neighbor, and ensemble methods. The other sections are organized as follows: Section 2 includes related studies including crime analysis. In Section 3, we introduce the dataset. Section 4 overviews machine learning methods. Section 5 summarizes the results and Section 6 concludes the study.

2. LITERATURE REVIEW

Jain et al. (Jain, Sharma, Bhaita, & Arora, 2017) used k-means clustering algorithms to detect crime-prone areas. Their method was considered to have promising value in the current complex crime scenario and can be used as a tool in crime detection and prevention by the police and law enforcement. Chun et al. (Chun, Avinash Paturu, Yuan, Pathak, Atluri, & Adam, 2019) aimed to find out whether a person would execute a crime in the near future and the level of seriousness of this crime. They used a deep learning method, and their method reached an accuracy of 99.7%. Zhang et al. (Zhang, Liu, Xiao, & Ji, 2020) performed and compared the random forest algorithm, the k-nearest neighbor algorithm, and support vector machine algorithms for crime prediction. They also performed the long short-term memory method (LSTM) which is a deep learning method to determine the most effective one. Their study achieved the best results with an accuracy of 59.9% when the LSTM method was used. Llaha et al. (Llaha, 2020) also used machine learning methods to analyze crime and take prevention. As a result of their study, it was observed that the decision tree method, which is one of the methods applied in classifying crime data, reached the most efficient result with an accuracy of 76%. Safat et al. (Safat, Asghar, & Gillani, 2021) used different machine learning algorithms to further analyze accurate crime prediction. In their study, different algorithms were applied and their efficiency was compared. As a result of their study, the XGBoost achieved maximum accuracy (94%). Tamir et al. (Tamir, Watson, Willett, Hasan, & Yuan, 2021) applied k-nearest neighbors, AdaBoost, random forest, and neural network methods to predict possible crimes and their locations. Their experimental studies showed that the neural network method with an accuracy of 90.77% achieved better results than other machine learning methods concerning different performance criteria.

3. DATA AND PREPROCESSING

The historical data on 62 different crimes that took place in 2019 in New York State was acquired from NYC open data (NYPD, 2020). The dataset includes 49,030 instances and 12 attributes. The features and their explanations are given in Table 1. We choose an equal number of instances for each class to obtain a balanced dataset. Furthermore, we removed the entries with missing values.

Table 1. Dataset description

Feature Name	Description
ARREST KEY	ID value that differs for each arrest
ARREST DATE	The date of the criminal's arrest
KY CD	Crime classification code for each crime type
OFNS DESC	Description of the crime classification code

LAWCATCD	Grade of offense: F(Felony), M(Misdemeanor), V(Violation), I(Infraction)
ARREST BORO	District of the arrest. B(Bronx), S(Staten Island), K(Brooklyn), M(Manhattan), Q(Queens)
ARREST PRECINCT	Police station where the arrest took place
AGE GROUP	Perpetrator's age within a category 1(-18), 2(18-24), 3(25-44), 4(45-64), 5(65+)
PERP SEX	Perpetrator's sex description
PERP RACE	Perpetrator's race description
XCOORDCD	X-coordinate the place where the crime took place
YCOORDCD	Y-coordinate the place where the crime took place

4. METHODOLOGY

This section summarizes the machine learning methods we implement for crime prediction. The methods are implemented using Waikato Environment for Information Analysis (WEKA) (Witten, Frank, Trigg, Hall, & Cunningham, 1999) which is a comprehensive application written entirely in Java and incorporates many machine learning and data mining methods developed by the University of Waikato.

Decision tree techniques are widely used for classification. In these methods, the data is classified as root nodes, internal nodes, and leaf nodes as if it were a tree (Song, & Ying 2015). In this study, the decision tree methods we implement are Decision Stump, Hoeffding Tree, J48 (C4.5), LMT, Random Forest, Random Tree, and REP Tree. On the other hand, Bayesian classifiers assign a particular instance defined by the feature vector to the most probable class (Rish, 2001). In this study, we performed Bayes Net, Naive Bayes, and Naive Bayes Updateable methods. We also performed function-based methods including Logistic Regression, Support Vector Machine, and Artificial Neural Networks. Furthermore, we apply lazy learning methods. The K-nearest neighbor (KNN) classifier (Dasarathy, 1991) is known as the basis of many lazy learning algorithms. The KNN method stores the entire training set and defers all efforts to inductive generalization until classification time (Wettschereck, Aha, & Mohri, 1997). In this study, the lazy learning methods we implement are KNN, K-Star, and LWL (Locally Weighted Learning) methods. Finally, we performed ensemble methods which are machine learning methods that create a set of classifiers and then make predictions by classifying new data points by taking the (weighted) vote of their predictions (Dietterich, 2000). In this study, the ensemble methods we implement are AdaBoost, Bagging, Logit Boost, Multi Scheme, Random Committee, Random Subspace, Stacking, and Vote.

5. RESULTS

Machine learning techniques performed in this study are compared and evaluated using accuracy, precision, recall, and F-measure metrics. We also applied 10-fold cross-validation to avoid overfitting. First of all, we evaluate the results of the tree-based methods. The accuracy, precision, recall, and F-measure values of the decision tree methods are listed in Table 2. The J48 method achieves remarkable results when compared to other decision-based methods based on accuracy, precision, recall, and F-measure values. On the other hand, the decision stump method has lower performance. Second, the accuracy, precision, recall, and F-measure values of the Naive Bayes classifier methods are listed in Table 3. The Bayes Net method has better results than Naïve Bayes and achieves 99.97% accuracy, and 1.0 precision, recall, and F-measure values.

Table 2. Results of decision tree methods

Method	Accuracy (%)	Precision	Recall	F-Measure
J48	99.99	1.000	1.000	1.000
LMT	99.98	1.000	1.000	1.000
Random Forest	99.98	1.000	1.000	1.000
REP Tree	99.98	1.000	1.000	1.000
Hoeffding Tree	98.99	0.990	0.990	0.990
Random Tree	97.37	0.974	0.974	0.974
Decision Stump	40.78	0.344	0.408	0.155

Table 3. Results of naïve bayes classifiers

Method	Accuracy (%)	Precision	Recall	F-Measure
Bayes Net	99.97	1.000	1.000	1.000
Naive Bayes	99.34	0.994	0.993	0.993

Table 4. Results of lazy learning methods

Method	Accuracy (%)	Precision	Recall	F-Measure
KStar	98.35	0.984	0.983	0.983
LWL	84.41	0.882	0.844	0.841
KNN	79.08	0.794	0.791	0.792

Table 5. Results of function-based methods

Method	Accuracy (%)	Precision	Recall	F-Measure
SVM	99.98	1.000	1.000	1.000
Simple Logistic	99.97	1.000	1.000	1.000
Logistic Regression	99.65	0.997	0.997	0.997
ANN	20.00	0.200	0.200	0.186

Table 6. Results of ensemble methods

Method	Accuracy(%)	Precision	Recall	F-Measure
AdaBoost	40.78	0.344	0.408	0.155
Bagging	99.98	1.000	1.000	1.000
Logit Boost	99.98	1.000	1.000	1.000
Multi Scheme	20.39	0.204	0.204	0.134
Random Committee	99.97	1.000	1.000	1.000
Random Subspace	99.97	1.000	1.000	1.000
Stacking	20.39	0.204	0.204	0.134
Vote	20.39	0.204	0.204	0.134

Third, the accuracy, precision, recall, and F-measure values of the lazy learning methods are listed in Table 4. The best results are obtained when the KStar is used and achieves an accuracy of 98.4%, a precision of 0.98, a recall of 0.98, and an F-measure of 0.98. On the other hand, the KNN has a lower performance and reaches an accuracy of 79.08%, a precision of 0.79, a recall of 0.79, and an F-measure of 0.79. Fourth, the accuracy, precision, recall, and F-measure values of the functions-based methods are listed in Table 5. While the ANN has the lowest performance, the SVM method achieves the best results. The SVM method achieves an

accuracy of 99.98%, and full precision, recall, and F-measure values. Finally, the accuracy, precision, recall, and F-measure values of ensemble methods are listed in Table 6. Bagging and Logit Boost achieve the best results with an accuracy of 99.98% and full precision, recall, and F-measure.

6. CONCLUSION

Crime is a type of behavior that causes bad effects on people. To eliminate these bad effects, predicting a crime before it happens improves social life in a good way. With the developing technology, crime prediction can be made with machine learning methods. This study aims to predict crime by using various machine learning methods. When the accuracy and time results of machine learning methods are evaluated, decision tree methods achieve 99.99% accuracies in about 2 seconds. Experimental results demonstrate that the machine learning methods achieved admirable performance in crime prediction. We believe that these methods will also enable the police units to develop a new strategy by saving time to prevent crime.

Conflict of Interest

Authors declare that there is no conflict of interest.

Contribution of Authors

[Author 1's Hilal Arslan]: Contributed to the study design, method implementation, and revised the manuscript for important content, research supervisor, and wrote the manuscript.
[Author 2's Aslınur Doluca Horoz]: Conceived to the idea and designed the study, collected and analyzed the data, literature review, and wrote the manuscript.

REFERENCES

Chun, S. A., Avinash Paturu, V., Yuan, S., Pathak, R., Atluri, V., R. Adam, N. (2019, June). Crime prediction model using deep neural networks. In Proceedings of the 20th Annual International Conference on digital government research (pp. 512-514). doi: https://doi.org/10.1145/3325112.3328221

Dietterich, T. G. (2000, June). Ensemble methods in machine learning. In International workshop on multiple classifier systems (pp. 1-15). Springer, Berlin, Heidelberg. doi: https://doi.org/10.1007/3-540-45014-9_1

Gardner, M. W., Dorling, S. R. (1998). Artificial neural networks (the multilayer perceptron)—a review of applications in the atmospheric sciences. Atmospheric environment, 32(14-15), 2627-2636. doi: https://doi.org/10.1016/S1352-2310(97)00447-0

Jain, V., Sharma, Y., Bhatia, A., Arora, V. (2017). Crime prediction using K-means algorithm. GRD Journals-Global Research and Development Journal for Engineering, 2(5), 206-209. https://grdjournals.com/uploads/article/GRDJE/V02/I05/0176/GRDJEV02I050176.pdf

Llaha, O. (2020). Crime Analysis and Prediction using Machine Learning. In 2020 43rd International Convention on Information, Communication and Electronic Technology (MIPRO) (pp. 496-501). IEEE. doi: https://doi.org/10.22214/ijraset.2023.50310

NYPD Arrests Data Historic 2006 - 2020, List of every arrest in NYC going back to 2006 through the end of the year 2020. [Online]. Available: https://www.kaggle.com/datasets/okettaeneye/nypdarrests-data-historic-2006-2020

Rish, I. (2001, August). An empirical study of the naive Bayes classifier. In IJCAI 2001 workshop on empirical methods in artificial intelligence (Vol. 3, No. 22, pp. 41-46). https://www.cc.gatech.edu/home/isbell/classes/reading/papers/Rish.pdf

Safat, W., Asghar, S., Gillani, S. A. (2021). Empirical analysis for crime prediction and forecasting using machine learning and deep learning techniques. IEEE Access, 9, 70080-70094. doi: https://doi.org/10.1109/ACCESS.2021.3078117

Song, Y. Y., Ying, L. U. (2015). Decision tree methods: applications for classification and prediction. Shanghai archives of psychiatry, 27(2), 130. doi: https://doi.org/10.11919/j.issn.1002-0829.215044

Tamir, A., Watson, E., Willett, B., Hasan, Q., Yuan, J. S. (2021). Crime Prediction and Forecasting using Machine Learning Algorithms. International Journal of Computer Science and Information Technologies, 12(2), 26-33. https://ijcsit.com/docs/volume12/vol12issue02/ijcsit2021120201.pdf

Wettschereck, D., Aha, D. W., Mohri, T. (1997). A review and empirical evaluation of feature weighting methods for a class of lazy learning algorithms. Artificial Intelligence Review, 11(1), 273-314. https://link.springer.com/article/10.1023/A:1006593614256

Witten, I. H., Frank, E., Trigg, L. E., Hall, M. A., Holmes, G., Cunningham, S. J. (1999). Weka: Practical machine learning tools and techniques with Java implementations. https://researchcommons.waikato.ac.nz/bitstream/handle/10289/1040/uow-cs-wp-1999-11.pdf?sequence=1&isAllowed=y

Zhang, X., Liu, L., Xiao, L., Ji, J. (2020). Comparison of machine learning algorithms for predicting crime hotspots. IEEE Access, 8, 181302-181310. doi: https://doi.org.tr/10.1109/ACCESS.2020.3028420

Ambiguity Multiple Target Detection with Frequency Modulated Continuous Wave Radar

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Keywords	Abstract
Radar, Signal, FMCW Radar	*In this study, FMCW radar system was used because it is Frequency Modulated and the signal emitted from the transmitting antenna uses a signal type called Linear Frequency Modulation (LFM) Chirp signal. Linear frequency modulation allows the frequency of the signal to increase or decrease linearly over time. Linear frequency modulation achieve to increase the range resolution, which is the radar's ability to distinguish between targets, and makes it more protected against electronic warfare techniques. Therefore, it is widely used in military applications. As in every radar system, range resolution is an important detail in FMCW radar systems. The modules used in the radar system have an effect on the range resolution separately, as well as the processing of the transmitted and received signals is of great importance. In a FMCW radar system designed within the scope of this study, an environment with more than one target was created to provide the best range resolution, and a modeling and simulation study was carried out to determine the distances, velocities and angular positions of ambiguity multiple targets by processing the transmitted and received signals with CA-CFAR and MUSIC algorithms.*

1. INTRDOUCTION

Frequency Modulated Continuous Wave (FMCW) radar systems are used to detect the position, speed, and distance of moving or stationary objects. FMCW radars are classified under the structure classification due to their unique structure and components, which include a transmitter antenna, receiver antenna, mixer, and Radar Control Board. Compared to pulse radars, FMCW radars have a simpler structure, lower production cost, and better range detection capability. They also overcome the limitation of continuous wave radars in detecting multiple targets (Ali & Erçelebi, 2017; Şeflek & Yaldız, 2020). In this study, Ambiguity Multiple Target Detection tecnique is used for the detection of multiple targets in a single radar measurement (Aulia, Suksmono & Munir, 2015). This technique is based on the principle of range-Doppler ambiguity, and its implementation in a FMCW radar system requires advanced signal processing techniques such as pulse compression, matched filtering, CFAR, MUSIC, and FFT.

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In the next parts of the study, the examination of the features of the FMCW Radar System, the examination of its general structure, the stages of the simulation carried out in the MATLAB software for ambiguity multiple target detection were mentioned with FFT, CFAR and MUSIC algorithms. Finally, the results obtained were evaluated and an idea was given about what the future works could be.

2. AMBIGUITY MULTIPLE TARGET DETECTION WITH FMCW RADAR

2.1. System Information

Frequency Modulated Continuous Wave (FMCW) radar is a type of radar that uses a continuous transmission of electromagnetic waves at a specific frequency, which is then modulated over time. By analyzing the frequency shift of the reflected wave, the range and velocity of the object can be determined. FMCW radar systems typically use a gradualy changing waveform as shown in Figure 1, in which the frequency of the transmitted wave is linearly swept over a specific range. This allows for a high range resolution and low probability of intercept by enemy radar systems.
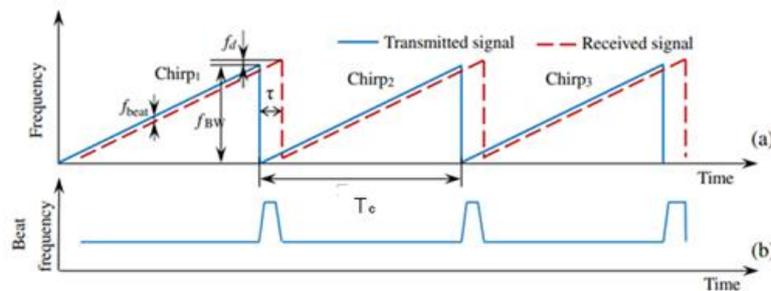
Figure 1. FMCW radar waveform principle for a single moving target the transmitted and received signal (a), the corresponding beat frequency (b)

FMCW radar has many advantages and is commonly used in various applications, including automotive radar and industrial process control. Military applications such as air defense and surveillance also rely on FMCW radar due to its ability to detect small and slow-moving targets, as well as its low POI. The FMCW radar system consists of a transmitter, receiver, modulator, demodulator, and antenna. The signal of FMCW radar can be modulated in four different types of signals including triangular, sinusoidal, square, and sawtooth. The system block diagram typically includes a transmitter, antenna, mixer, local oscillator, signal processor, display, and control unit as shown Figure 2. Overall, FMCW radar is a radar system that allows for accurate range and velocity detection, making it a valuable asset in a variety of fields.
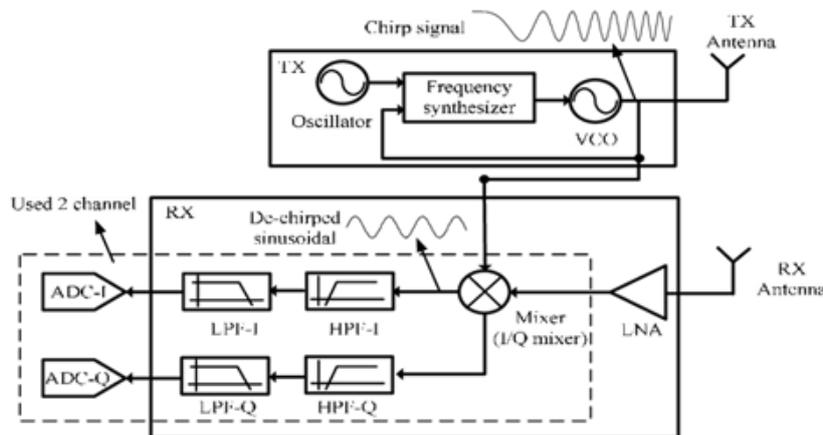
Figure 2. The block diagram of FMCW radar (sangdong, bong-seok, daegun and lee, 2015).

The System Block Diagram of FMCW Radar is typically includes the following components:
1. Transmitter: This component generates and amplifies the radio frequency (RF) signal that will be transmitted by the antenna. The signal is typically a continuous waveform that is frequency modulated (FMCW) to provide range information.
2. Antennas: These components transmit and receive the RF signals. The transmit and receive antennas can be separate or combined into a single element.
3. Mixer: This component combines the transmitted and received signals, creating an intermediate frequency (IF) signal.
4. Local Oscillator (LO): This component generates a reference frequency that is mixed with the received signal in the mixer.
5. Signal Processor: This component performs various signal processing functions on the IF signal, such as filtering, amplification, and demodulation. The signal processor also extracts range and velocity information from the IF signal.
6. Display: This component presents the radar data to the operator in a meaningful way, such as on a radar scope or map.
7. Control Unit : This component control the overall system, it contains all the parameters of the radar system and it communicate with the signal processing unit.

2.2. MATLAB Simualtion

The FMCW Radar Simulation for detecting Ambuguity Multiple Target on Matlab is follows steps :
1. It defines the parameters of the radar system as shown in Table 1, such as the speed of light, bandwidth, carrier frequency, number of ADC samples, number of chirps per frame, pulse repetition interval, and others.
2. It defines the two target according to informations in Table 2. It simulates the movement of two targets over time by calculating their locations at each point in the time axis. It sets up some variables such as range and velocity axis, and angle axis.
3. It simulates Transmitted Signal
4. It simulates Received Signal
5. It simulates Mix Signal with Transmitted and Received Signal
6. It simulates FFT Operations
7. Apply CA-CFAR Algorithm for detecting multiple target
8. Appy MUSIC Algorithm for detecting multiple target

Table 1. Parameters of FMCW radar

Parameters of FMCW Radar	
Center Frequency	24 GHz
Bandwith	150 MHz
Number of ADC Samples	256
Number of Chirps	256
Time Period	10 microsecond
Number of Transmitter Antenna	1
Number of Receiver Antenna	4
Range Resolution	1

Table 2. Target range, angle,velocity and coordinates

Target Informations	Range (m)	Angle (Degree)	Velocity(m/s)	Coordinate X	Coordinate Y
Target 1	50	-15	10	-12.941	48.2963
Target 2	100	10	-15	17.3648	98.4808

2.2.1. Transmitted Signal

Before generating the transmitter signal in MATLAB simulation code for FMCW radar, time delays between targets and transmitter-receiver pairs in a 3D space are calculated using the Euclidean distance formula. Arrays of transmitter and receiver locations and target locations over time are created, and delays are stored in cell arrays. Transmitter signal is then generated based on specified radar signal parameters in the parameters of FMCW Radar as shown in Figure 3 .
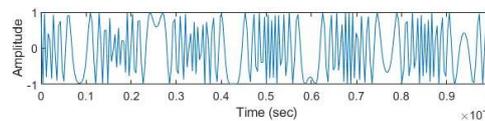
Figure 3. Tranmitted signal

2.2.2. Mixed Signal

In this part of the MATLAB Simulation Code, a mixed signal is generated by combining two target signals with the transmitted signal as shown in Figure 4. The code calculates the phase of the transmitted and received signals, as well as range and Doppler dependent frequencies for the two targets. A nested for loop is used to iterate over all the transmitter-receiver pairs, and the resulting mixed signal is stored in a cell array called "mixed".
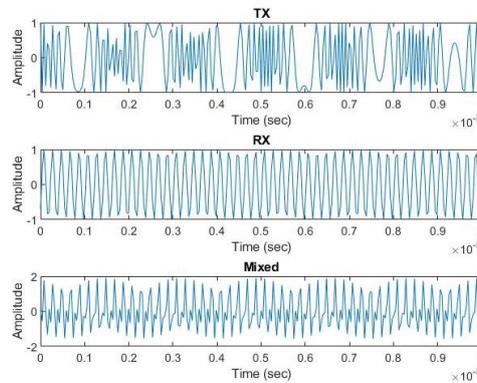
Figure 4. Transmitted, received and mixed signal

2.2.3. FFT Operations

The FFT part of code reshapes the mixed signal data and applies a 2D Fourier transform to create a Range-Doppler Map (RDM). It reshapes the mixed signal data into a 3D array called "RDC" and applies a 2D FFT on it using "fft2" and "fftshift" functions to create a 4D array called "RDM" with dimensions of number of ADC, number of Chirps, multiplying the number of receiver and transmitter antennas, number of CPI and plots the Range-Doppler Map using the "imagesc" function as shown in Figure 5. It also applies a colormap, sets the color axis limits and adds x and y labels.
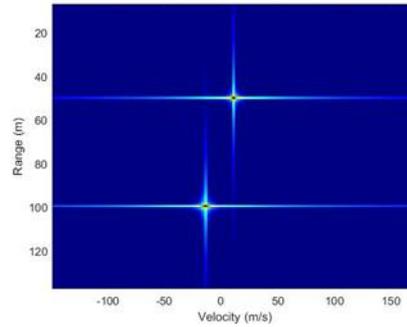
Figure 5. The range-velocity graph after FFT operations

2.2.4. CA-CFAR Algorithm

This part of code applies a Constant False Alarm Rate (CFAR) detection algorithm to a Range-Doppler Map (RDM) in order to identify target returns as shown in Figure 6. The CFAR algorithm compares the power of the target return to the power of the surrounding noise and decides if the target return is real. It defines the number of guard cells and training cells and the desired false alarm rate and also defines an SNR offset value in dB. The RDM data is passed in dB scale. It calls the "ca_cfar" function which takes in RDM data, number of guard cells, number of training cells, desired false alarm rate, and SNR offset as inputs, and returns the range-Doppler map with a CFAR mask applied to it, CFAR detected ranges, CFAR detected Doppler values and the threshold value. The CFAR algorithm used here is Cell Averaging CFAR (CA-CFAR) which compares the power of the target return to the average power of the surrounding noise.
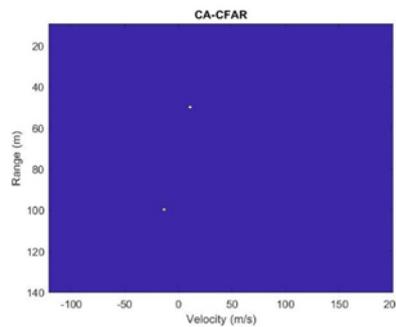
Figure 6. The range-velocity graph after applying CA-CFAR algorithm

2.2.5. MUSIC Algorithm

This part of code applies the Multiple Signal Classification (MUSIC) algorithm to the RDC data to estimate the angle of arrival (AoA) of the targets. MUSIC is a subspace-based technique that is used to estimate the AoA of multiple signals in a noisy Environment. It applies 1D FFT on the RDC along the range dimension and uses a for loop to iterate over all range bins, creating the matrix by summing the outer product of the signal vector for each snapshot and divide it by the number of snapshots and plot "MUSIC Sprectrum" as shown in Figure 7. It then applies the MUSIC algorithm to the created matrix using the estimator object and obtains the DOA estimates. It creates a new figure and plots the range-angle map using the "imagesc" function with the angle values and range values. It also applies a colormap, sets the color axis limits and plot "MUSIC Range-Angle Map" as shown in Figure 8.
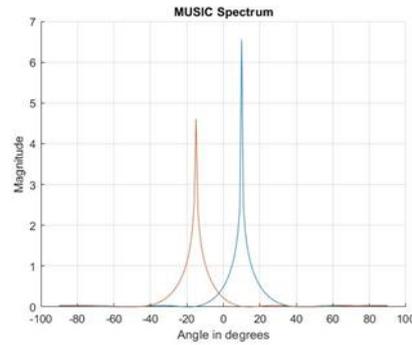
Figure 7. The spectrum graph for angle values of targets with MUSIC algorithm
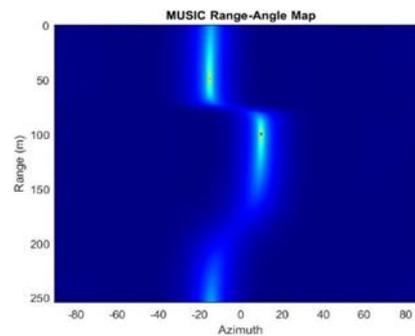
Figure 8. Range-Azimuth graph of targets with music algorithm

3. CONCLUSION

Some signal processing algorithms were applied in the simulation study for the detection of ambiguity multiple targets with FMCW radar in Matlab software. These are FFT, CA-CFAR and MUSIC algorithms. The Range and Velocity information of the targets were determined by the CA-CFAR algorithm. Azimuth angles of the targets were successfully determined with the applying MUSIC algorithm. The location information detected on the targets are Target1(-13.2,49.26), Target2(17.54,99.40). However, the defined target locations are specified as Target1(-12.94,48.30), Target2(17.36,98.48). When the actual and determined results related to the location are compared, it has been observed that there is a 1% margin of error. As a result of this study, it has been confirmed that the detection of ambiguity multiple targets can be successfully performed with FMCW Radar and the performances of CA-CFAR, MUSIC algorithms have been verified.

In future work, the different signal processing algorithms that are not used in this study and their performance for target detection can be examined. For example, in this study, the success of detecting target information can be measured by examining signal processing algorithms such as Order Statistic CFAR (OS-CFAR), Adaptive CFAR (ACFAR) and similar instead of CA-CFAR signal processing algorithm, which is one of the CFAR Signal Processing algorithms. This study would provide a more comprehensive understanding of their strengths and weaknesses. Additionally, it would be utility to see how these different algorithms perform under various conditions, such as different noise levels, target ranges, and clutter environments. Furthermore, some other techniques like Machine learning techniques, deep learning techniques can be used to improve the performance of target detection. These techniques can be used to detect target in noisy, cluttered and adaptive environment.

Conflict of Interest

There was no conflict of interest between the authors during the creation of this study.

Contribution of Authors

The authors involved in this study are Oğuzhan Çam, İlyas Çankaya; contributed to all aspects of the study. All authors contributed to the idea, design, inspection, resources, data collection, literature review, critical review and analysis and interpretation sections of the study.

REFERENCES

Ali, H., Erçelebi, E., (2017), "Design and implementation of FMCW radar using the raspberry Pi single board computer," *2017 10th International Conference on Electrical and Electronics Engineering (ELECO)*, PP: 1372-1374. https://ieeexplore.ieee.org/abstract/document/8266222

Aulia, S., Suksmono, A. B., Munir, A., (2015), "Stationary and moving targets detection on FMCW radar using GNU radio-based software defined radio," 2015 International Symposium on Intelligent Signal Processing and Communication Systems (ISPACS), Nusa Dua Bali, Indonesia, PP: 468-473. https://ieeexplore.ieee.org/document/7432817

Ivanov, S. I., Kuptsov, V. D., Fedotov, A. A., (2019), "The signal processing algorithm of automotive FMCW radars with an extended range of speed estimation", Journal of Physics: Conference Series, PP: 1236 https://iopscience.iop.org/article/10.1088/1742-6596/1236/1/012081

Mahafza, B. R., (2013), "Radar Systems, Analysis and Design using MATLAB®", Chapman & Hall/CRC.doi: https://doi.org/10.1201/9781420057072

Mumtaz, Z., Hanif, A., Hashmi, A., (2015), "Digital Signal Processing (DSP) Algorithms for CW/FMCW Portable Radar". https://www.researchgate.net/publication/348163927_Digital_Signal_Processing_DSP_Algorithms_for_CWFMCW_Portable_Radar

Sangdong, K., Bong-seok, K., Daegun, O., Lee, J., (2015), "An Effective Pre-processing Technique for Robust ESPRIT-Based Single-Tone Frequency Estimation against an I/Q Mismatch". doi: https://doi.org/10.5755/j01.eee.21.6.13757

Şeflek, İ., Yaldız, E., (2020), "Frekans Modüleli Sürekli Dalga Radarıyla Simüle Edilen Hayati Sinyallerin Temassız Tespiti", Avrupa Bilim ve Teknoloji Dergisi (Special Issue), PP: 72-77. doi: https://doi.org/10.31590/ejosat.802905

Parrish, K., (2010), "An Overview of FMCW Systems in MATLAB". https://www.researchgate.net/publication/260286270_An_Overview_of_FMCW_Systems_in_MATLAB

Modified Bi-Directional Cuk Converter For Cell Balancing Using PI And Fuzzy Logic Control Method

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Keywords	Abstract
Cell Balancing, Cuk Converter, Active Balance, Battery Equalization	*In this study, a modular and converter-based active balancing topology is presented. In the design, there are insulated cuk converter modules that perform bidirectional energy transfer corresponding to each battery cell connected in series. By designing an isolated bi-directional cuk converter circuit and equalization controller, five battery cells connected in series were tested separately in charging, discharging, and idle states. The PI control and fuzzy logic control (FLC) methods have been applied to the proposed topology and verified with the Matlab/Simulink program.*

1. INTRODUCTION

One of the most important functions of the battery management system is cell balancing. Balancing is the term used for the process of equalizing the SOC levels of each cell in series-connected battery cells to maximize battery capacity (Andrea, 2010). In the literature, there are various cell-balancing topologies under the main headings of passive and active balancing. Both passive and active balancing methods have their advantages and disadvantages. Passive balancing is simple and inexpensive in design but has low efficiency as energy is wasted. Excess energy is dissipated as heat through a resistor, so low balancing currents are used. Active balancing is complex and costly to design but highly efficient as excess energy is transferred to other cells. In active balancing, balancing can be done at very high currents compared to passive balancing. Active balancing topologies are very important in terms of energy efficiency. In active balancing, there are capacitive, inductive, and converter-based topologies. Converter-based topologies stand out due to their energy efficiency and balancing speed. In general, converter-based topologies are designed as cell-to-cell, string, and bus topologies. In cell-to-cell topology, energy is transferred between adjacent cells. In the string topology, energy is transferred from the cell to the battery pack and vice versa. In the bus topology, energy is transferred between a bus isolated from the battery pack and a cell (Andrea, 2020). In the bus topology, the bus voltage is low because it does not depend on the number of cells connected in series. The lower bus voltage allows cheaper DC-DC converters to be used. The same DC-DC converters can be used regardless of the number of battery cells connected in series. In other words, battery cells can be easily added to or removed from the designed system afterwards. Isolated DC-DC converters are bidirectional, and only DC-DC converters are connected to the bus (Andrea, 2020).

Because of these advantages, a bus-based topology is investigated in this study. When the literature is examined, in reference (Ling, Dan, Wang, & Li, 2015), a modified cuk equalizer for the energy bus-based distributed equalization network is proposed, and a synchronous control strategy is used to improve the equalization efficiency. In reference (Wu, Ling, & Tang, 2017), the dynamic equalization of an electric vehicle's battery during charging, discharging, and driving moments was examined, and a model-predictive control strategy was proposed to deal with changes in operating state. In reference (Zhong, Li, & Wang, 2019), the analysis and modeling of the modified isolated Cuk-based equalizer are presented, and an adaptive sliding-mode control (SMC) is proposed. In reference (Ling, Dan, Zhang, & Chen, 2014), a bidirectional flyback converter-based equalization circuit was designed, and the output power of the converter was regulated by a PI controller.

2. ANALYSIS AND DESIGN OF MODIFIED ISOLATED BIDIRECTIONAL CUK CONVERTER

A cuk converter is a DC-DC converter that can increase or decrease the voltage applied to its input and has reverse polarity at its output relative to the input (Bildirici & Karaarslan, 2017). The modified isolated bidirectional cuk converter circuit is shown in Figure 1 (Zhong, Li, & Wang, 2019). In order to realize the power transfer between the battery cells and the energy bus bidirectionally, the cuk converter circuit is modified to have a symmetrical structure. When we replace the diode in the cuk converter with a mosfet, the circuit simply becomes symmetrical. There are two MOSFETs with body diodes in the circuit that determine the direction of energy transfer. Four inductors are used to reduce di/dt when switches for different equalizers are turned on at the same time (Ling, Dan, Wang, & Li, 2015). The isolation between the battery string and the energy bus is provided by the C1a and C1b capacitors in the middle (Wu, Ling, & Tang, 2017).
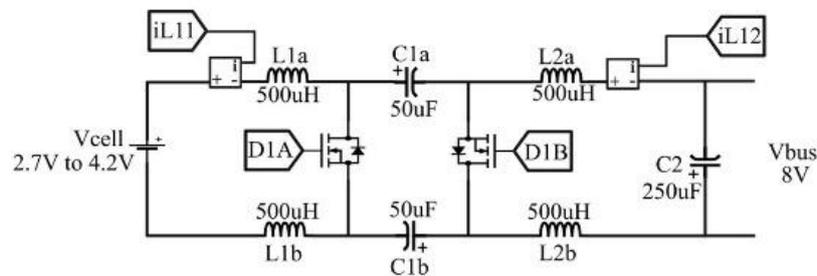
Figure 1. Modified isolated bidirectional cuk converter.

The modified cuk converter operates in Continuous Conduction Mode (CCM) in two different transfer modes: from battery side to bus side and from bus side to battery side. In the designed balancing system, the minimum and maximum voltages of the battery cells are determined between 2.7V and 4.2V in order to operate in the safe zone. In addition, the charge and discharge currents of the batteries are limited to 3A. Within these limits, the components in the circuit designed for efficient and stable operation of the converter in the CCM region (Karaarslan, 2018).

2.1 Fuzzy Logic Controller for Modified Isolated Bidirectional Cuk Converter

Due to its straightforward architecture, fuzzy logic control is frequently utilized in DC-DC converters. Fuzzy control rules are developed within the scope of certain criteria based on the system's behavior. If the converter's output is distant from the reference point, the duty cycle change must be big for the output to rapidly return to the reference point. If the converter's output approaches the reference point, a slight modification in the duty cycle will be sufficient. The duty cycle should stay constant if the output is steady and has reached the reference point.

The duty cycle change should be negative if the output exceeds the reference point. If the converter's output greatly exceeds the reference point, the duty cycle change must be negative and big to swiftly return the output to the reference point. Five fuzzy levels (NB) negative large, (NS) negative small, (Z) zero, (PS) positive small, and (PB) positive large are selected as fuzzy set values. Table 1 shows the rule base.

Table 1. The rules

		Change of error				
		NB	NS	Z	PS	PB
Error	**NB**	NB	NB	NB	NS	Z
	NS	NB	NB	NS	Z	PS
	Z	NB	NS	Z	PS	PB
	PS	NS	Z	PS	PB	PB
	PB	Z	PS	PB	PB	PB

The converter and fuzzy logic controller block diagram designed in Matlab/Simulink program is shown in figure 2 for mode-1(discharging) and mode-2(charging). In mode-1 energy transfers from cell to bus and in mode-2 energy transfers from bus to cell.
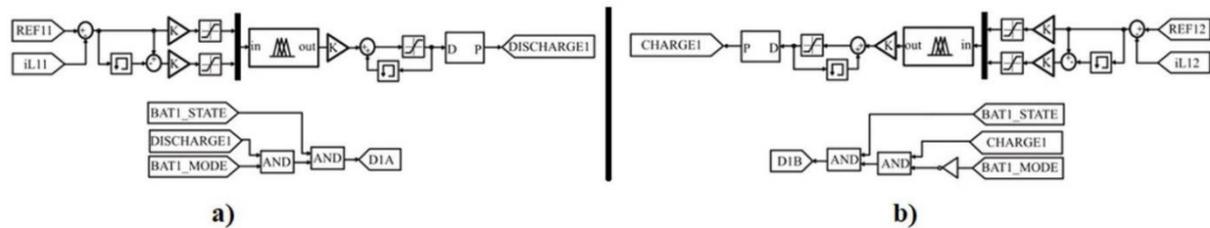
Figure 2. The cuk converter with FLC Matlab/Simulink block diagram; a) mode-1, b) mode-2

2.2 PI Controller for Modified Isolated Bidirectional Cuk Converter

Because of its simple implementation, the PI controller is one of the most popular controllers used to control DC-DC converters. The small signal model of the cuk converter is given in Equations 1.1, 1.2, 1.3, and 1.4. Using these equations, transfer functions for PI control design are easily obtained.

$$\dot{\hat{x}} = A\hat{x} + B\hat{u} \tag{1.1}$$

$$
\begin{pmatrix} \dot{\widehat{i_{L_1}}} \\ \dot{\widehat{i_{L_2}}} \\ \dot{\widehat{v_{C_1}}} \\ \dot{\widehat{v_{C_2}}} \end{pmatrix} =
\begin{pmatrix}
0 & 0 & \frac{D-1}{L_1} & 0 \\
0 & 0 & \frac{D}{L_2} & -\frac{1}{L_2} \\
\frac{(1-D)}{C_1} & -\frac{D}{C_1} & 0 & 0 \\
0 & \frac{1}{C_2} & 0 & -\frac{1}{RC_2}
\end{pmatrix}
\begin{pmatrix} \widehat{i_{L_1}} \\ \widehat{i_{L_2}} \\ \widehat{v_{C_1}} \\ \widehat{v_{C_2}} \end{pmatrix} +
\begin{pmatrix}
\frac{1}{L_1} & 0 & \frac{V_{C_1}}{L_1} \\
0 & 0 & \frac{V_{C_1}}{L_2} \\
0 & 0 & \frac{-I_{L_2}-I_{L_1}}{C_1} \\
0 & -\frac{1}{C_2} & 0
\end{pmatrix}
\begin{pmatrix} \widehat{v_g} \\ \widehat{i_z} \\ \widehat{d} \end{pmatrix} \tag{1.2}
$$

$$\hat{y} = C\hat{x} + E\hat{u} \tag{1.3}$$

$$
\begin{pmatrix} \widehat{v_o} \\ \widehat{i_i} \end{pmatrix} =
\begin{pmatrix} 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \end{pmatrix}
\begin{pmatrix} \widehat{i_{L_1}} \\ \widehat{i_{L_2}} \\ \widehat{v_{C_1}} \\ \widehat{v_{C_2}} \end{pmatrix} +
\begin{pmatrix} 0 & 0 \end{pmatrix} \tag{1.4}
$$

Equations 1.5, 1.6 and 1.7 are transfer functions for mode-1(charging). Figure 3 shows the Matlab/Simulink program block diagram of PI control.

$$Gvd = \frac{\widehat{v_o}}{\widehat{d}} = \frac{2.46e08s^2 - 2.4e12s + 3.395e15}{s^4 + 3937s^3 + 4.192e07s^2 + 8.631e10s + 9.522e13} \tag{1.5}$$

$$Gid = \frac{\widehat{i_i}}{\widehat{d}} = \frac{1.23e04s^3 + 1.116e08s^2 + 8.171e11s + 2.533e15}{s^4 + 3937s^3 + 4.192e07s^2 + 8.631e10s + 9.522e13} \tag{1.6}$$

$$Gvi = \frac{\widehat{v_o}}{\widehat{i_i}} = \frac{2.46e08s^6 + 2.691e11s^5 + 1.081e16s^4 + 5.298e18s^3 + 1.045e23s^2 + 2.319e26s + 3.375e29}{1.23e04s^7 + 1.187e08s^7 + 1.437e12s^5 + 8.244e15s^4 + 4.098e19s^3 + 1.336e23s^2 + 2.107e26s + 1.645e29} \tag{1.7}$$
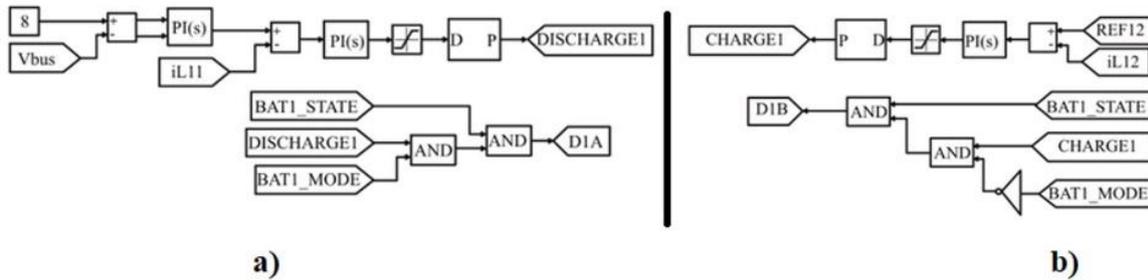
Figure 3. The cuk converter with PI control Matlab/Simulink block diagram; a) mode-1, b) mode-2

Kp and Ki values are determined by the PID tuner in the Matlab/Simulink program. The inner loop PI control parameters that control the reference current are $K_p = 2$ and $K_i = 950$. For the bus voltage to remain constant at 8 volts, the outer loop PI control parameters are $K_p = 0$ and $K_i = 166.6$. Equation 1.8 is transfer function for mode-2(charging). In mode-2, energy is transferred from the bus to the cell. The PI control parameters that control the reference current for this mode are $K_p = 0.31$ and $K_i = 9.71$.

$$Giz = \frac{\widehat{i_i}}{\widehat{i_z}} = \frac{1.805e14}{s^4 + 1.405e06s^3 + 4.195e07s^2 + 3.084e13s + 3.443e14} \tag{1.8}$$

3. SIMULATION RESULTS

The initial SOC (%) of each battery cell is 74, 74.1, 74.2, 74.5, and 74.6, respectively. Also, each battery cell has a nominal capacity of 2.6Ah and a nominal voltage of 3.7V. Figure 2 shows the SOC changes of battery cells in idle state, discharging state and charging state.
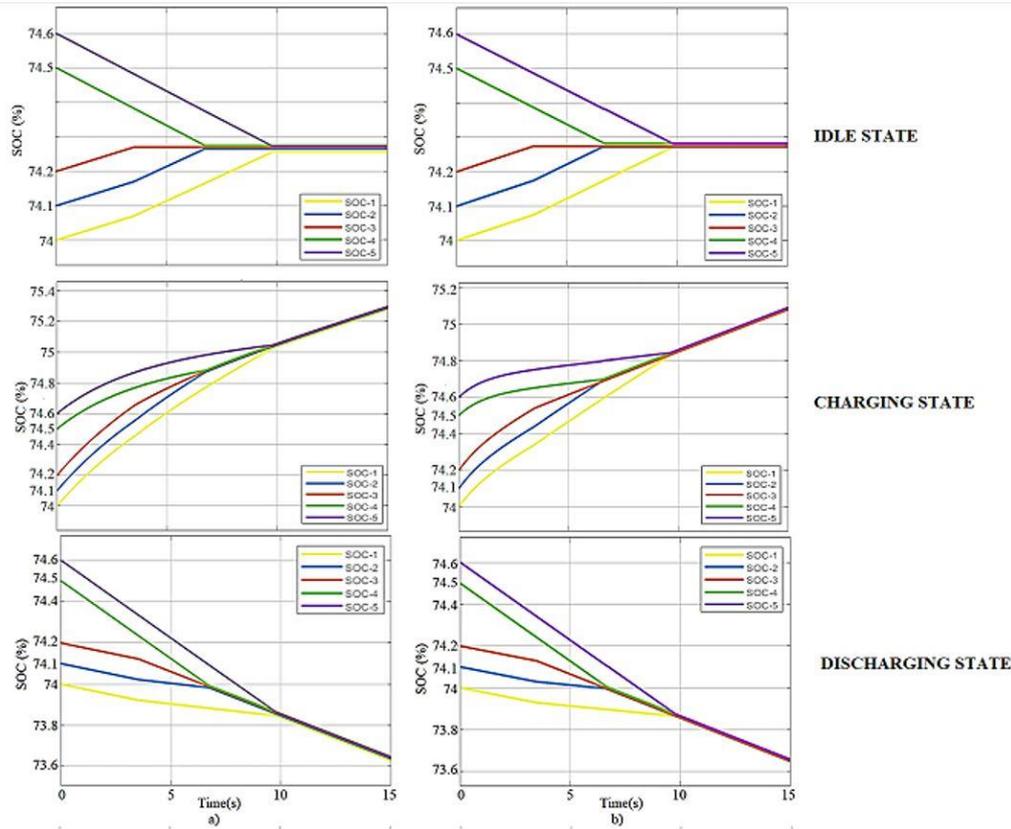
Figure 4. SOC changes at idle, charging and discharging state: a) PI control, b) FLC.

In Table 2, the balancing times of the systems designed with FLC and PI control methods are given comparatively in the three states of the battery pack.

Table 2. Balancing time comparison.

Method	Idle state	Charging state	Discharging state
PI Control	9.811s	9.828s	9.805s
FLC	9.808s	9.636s	9.775s

The waveform of the current change in the cells during the balancing process is shown in Figure 3. The charge-discharge currents of the cells are limited to a maximum of 3A. Initially, 3 cells with SOC values lower than the reference receive energy from the bus, while 2 cells with SOC values higher than the reference transfer energy to the bus. Battery cells that reach the limits of the calculated average SOC reference value are excluded from the energy transfer process as they have reached equilibrium. As the number of cells participating in the balancing process changes, the reference current values of the battery cells in the energy transfer process also change. The balancing module of the battery cell that reaches the reference SOC value is disabled, and the current in the transfer process becomes zero. When the balancing process is complete, the current values of all battery cells become zero since no energy is transferred.
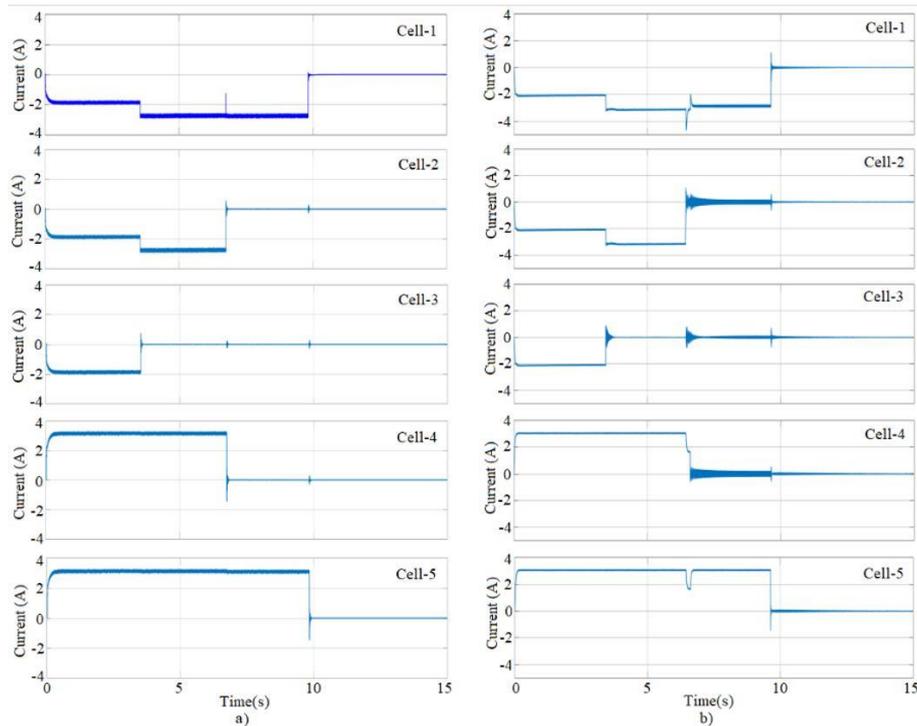
Figure 5. Cells' current variations in the balancing process; a) PI control, b) FLC.

Figure 3 shows the responses of the systems designed with PI control and FLC method to reference current changes. When compared to FLC, PI control has faster transient response and less maximum deviation from steady state. On the other hand, the FLC method has a faster rise and settling time.

Table 3. Simulation results of rise time and settling time

Parameters	Description	PI control rise time(s)	FLC rise time(s)	PI control settling time(s)	FLC settling time(s)
Cell-1	Cell Current 1	0.147	0.043	0.333	0.15
Cell-2	Cell Current 2	0.147	0.043	0.333	0.15
Cell-3	Cell Current 3	0.147	0.043	0.333	0.15
Cell-4	Cell Current 4	0.147	0.052	0.333	0.15
Cell-5	Cell Current 5	0.147	0.052	0.333	0.15

4. CONCLUSION

In this study, an active balancing topology is presented for balancing battery cells. Bus-based topology is created with modified isolated bidirectional cuk converter modules. Excess energy is transferred bidirectionally via a bus where the balancing modules are connected in parallel. In the balancing process, the energy that the converter modules will transfer is calculated and regulated by the balancing algorithm. The equalization system designed with five series-connected battery cells with different SOC values has been verified in the Matlab/Simulink program. As a result, the balancing process is carried out successfully with both control methods, and a comparative analysis is made.

Conflict of Interest

Author declare that there is no conflict of interest.

Contribution of Authors

REFERENCES

Andrea, D. (2010). Battery management systems for large lithium-ion battery packs, Artech house. https://ieeexplore.ieee.org/document/9100544

Andrea, D. (2020). Lithium-Ion Batteries and Applications: A Practical and Comprehensive Guide to Lithium-Ion Batteries and Arrays, from Toys to Towns, Volume 2, Applications, Artech House. https://ieeexplore.ieee.org/document/9219999

Ling, R., Dan, Q., Wang, L. & Li, D. (2015). Energy bus-based equalization scheme with bi-directional isolated Cuk equalizer for series connected battery strings, IEEE Applied Power Electronics Conference and Exposition (APEC), 3335-3340, Charlotte, NC, USA. doi: https://doi.org/10.1109/APEC.2015.7104831

Zhong, H., Li, J. & Wang, Y. X. (2019). A bus-based battery equalization via modified isolated cuk converter governed by adaptive control, Chinese Automation Congress (CAC), 2824-2828, Hangzhou, China. doi: https://doi.org/10.1109/CAC48633.2019.8996984

Ling, R., Dan, Q., Zhang, J. & Chen, G. (2014). A distributed equalization control approach for series connected battery strings, The 26th Chinese Control and Decision Conference (2014 CCDC), 5102-5106, Changsha, China. doi: https://doi.org/10.1109/CCDC.2014.6853089

Bildirici, M. & Karaarslan, A. (2017). Analysis of cuk converter using PI and OCC control method, 13th Int. Conf. Technical Phys. Probl. Eng., 2077-3528, Van, Turkey. http://mikrolit.com/PROCEEDINGS/B14.pdf

Karaarslan, A. (2018). Modeling and performance analysis of cuk converter using PI and OCC method, Int. J. Technical Phys. Probl. Eng, (10), (3), 1-5. http://www.iotpe.com/IJTPE/IJTPE-2018/IJTPE-Issue36-Vol10-No3-Sep2018/1-IJTPE-Issue36-Vol10-No3-Sep2018-pp1-5.pdf

Towards a Wearable Embedded System for Real Time Feedback in Health and Sports Applications Based on Bluetooth Wireless Sensor

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Keywords	Abstract
IoT *Embeded system* *Real time,* *Wireless sensor*	*Real-time feedback plays a vital role in sports and health applications, allowing athletes to improve their performance and people with medical issues to keep track of their health. This Paper suggests an embedded wearable device that uses Bluetooth technology to deliver real-time feedback. The system was designed as an example of Internet of Things (IoT) technology since it combines wireless connectivity, sensors, and microcontrollers. The wearable embedded system is supported by Bluetooth wireless making it possible for athletes to get rapid feedback on their vital signs and performance parameters, enabling real-time modifications and training schedule optimization. To evaluate the system's performance, experiments were conducted in both air and water environments. The objective is to examine how signal intensity and distance varied across these various media. The results showed that this system is feasible in the air for long distances and in water with and without turbidity for short distances.*

1. INTRODUCTION

The Internet of Things (IoT) is an interesting topic in the IT revolution of the most recent decade. This new model is hoped to be the following stage of the Internet that connects objects of the physical world with each other and links them with the virtual world (Khan et al., 2012; Zheng et al., 2011). Connecting devices has some challenges, such as power consumption, range, and security (Khan et al., 2012). These challenges are also crucial in a Wireless Sensor Area Network (WSAN), which is a network that comprises different kinds of sensors and actuators that are connected. These gadgets would then be able to gather, offer, and follow up on information gathered from the physical world. The Internet of Things has been used in different applications including health and sport (Khan et al., 2022; Abbasi-Kesbi et al., 2020; Memon et al., 2020). The Internet of Things has been used in different applications including health and sport (Khan et al., 2022; Abbasi-Kesbi et al., 2020; Memon et al., 2020). Most of the time, WSAN gadgets don't require electrical outlets and are relied upon to work proficiently with batteries as their source of energy.

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Most of the time, WSAN gadgets don't require electrical outlets and are relied upon to work proficiently with batteries as their source of energy. These limitations revoke Wi-Fi communication as a reasonable choice because of its high-power utilization. In order to reduce the power consumption of Wi-Fi, sleep mode must be activated on the device, a solution that creates additional restrictions of a sensor or actuator connecting through the Wi-Fi. These constraints prevent collecting data from a sensor and or actions from an actuator because of the device's sleep mode.

To use these devices to their full capability and to enhance a wireless environment, different methods of communication could be used. One of the options is to use Bluetooth Low Energy (BLE) as wireless communication technology. BLE allows for more power consumption, which permits sensors and actuators to keep them turned on and connected to the local gateway. In addition, it has many other features, including compatibility, cost efficiency, reliability, robustness, ease of use, and integration with different applications (Gupta & Mohammed, 2022). Low-cost and low-power consumption wearable devices have been designed to be used in different sports (Hagem et al., 2013; Hagem et al.,2015).

A considerable number of studies have been done about using different types of wireless technologies in designing wireless sensor systems to be used for different applications, including health and sports. One of the researchers performed a comparative study between multiple kinds of wireless protocols to design a short-range wireless communication about transmission time, complexity, and power consumption (Lee et al., 2007). Important research used Bluetooth Low Energy BLE as the communication standard to implement a home pool automation system using the WSN and compare the results with the Particle Photon Wi-Fi development board (Nilsson & Lindman, 2017). Another research developed a mobile electrocardiogram monitoring system by using a single chip electrocardiogram ECG signal acquisition module, a Bluetooth module, and a smartphone. The monitoring system can get the ECG signals, send the data through Bluetooth to the smartphone, and process and display the final data on the smartphone screen (Yu et al., 2012).

2. SYSTEM SPECIFICATION

The Red Bear Duo was designed to simplify the building process of Internet-of-Things (IoT) with dimensions of (40×20×13) mm. The board includes STMicroelectronics STM32F205 ARM Cortex-M3 @120MHz, 128 KB SRAM, and 1MB Flash Broadcom BCM43438 Wi-Fi 802.11n (2.4GHz only) + Bluetooth 4.1 (Dual Mode) combo chip On-board 16 Mbit (2 MB) SPI Flash Integrated chip antenna with the option to connect external antenna 18 I/O pins RGB status LED. The Bluetooth specifications chip on this board is: a small antenna of a 2 dBi peak gain with a frequency band (2402-2480) MHz is used. The output power is (class 1.5) with 9 dBm and sensitivity of -86 dBm with BER of 0.01% for the π/4-dqpsk (2Mbps). Figure 1 shows the Red Bear Duo board (Thumb-size website, 2016).

Figure 1. The redbear Due Wi-Fi & BLE module (Thumb-size website, 2016).

3. METHODOLOGY

The methodology is based on checking the BLE signal strength in air and water with distance. Some letters, such as the Hello word are sent every second, and the BLE firmware controller receives the data. The distance is calculated for successful communication, which means receiving the data exactly the same as at the transmitter side. The Duo is fixed on an athlete's arm, and the measurements are done with and without arm movement, which is the case for most sports. This is applied to air and water. In water, the methodology was based on using two different types of water, which are pure and turbid, and checking the signal strength in the two cases. A water tank with (50×100) cm is used to check the signal strength in water.
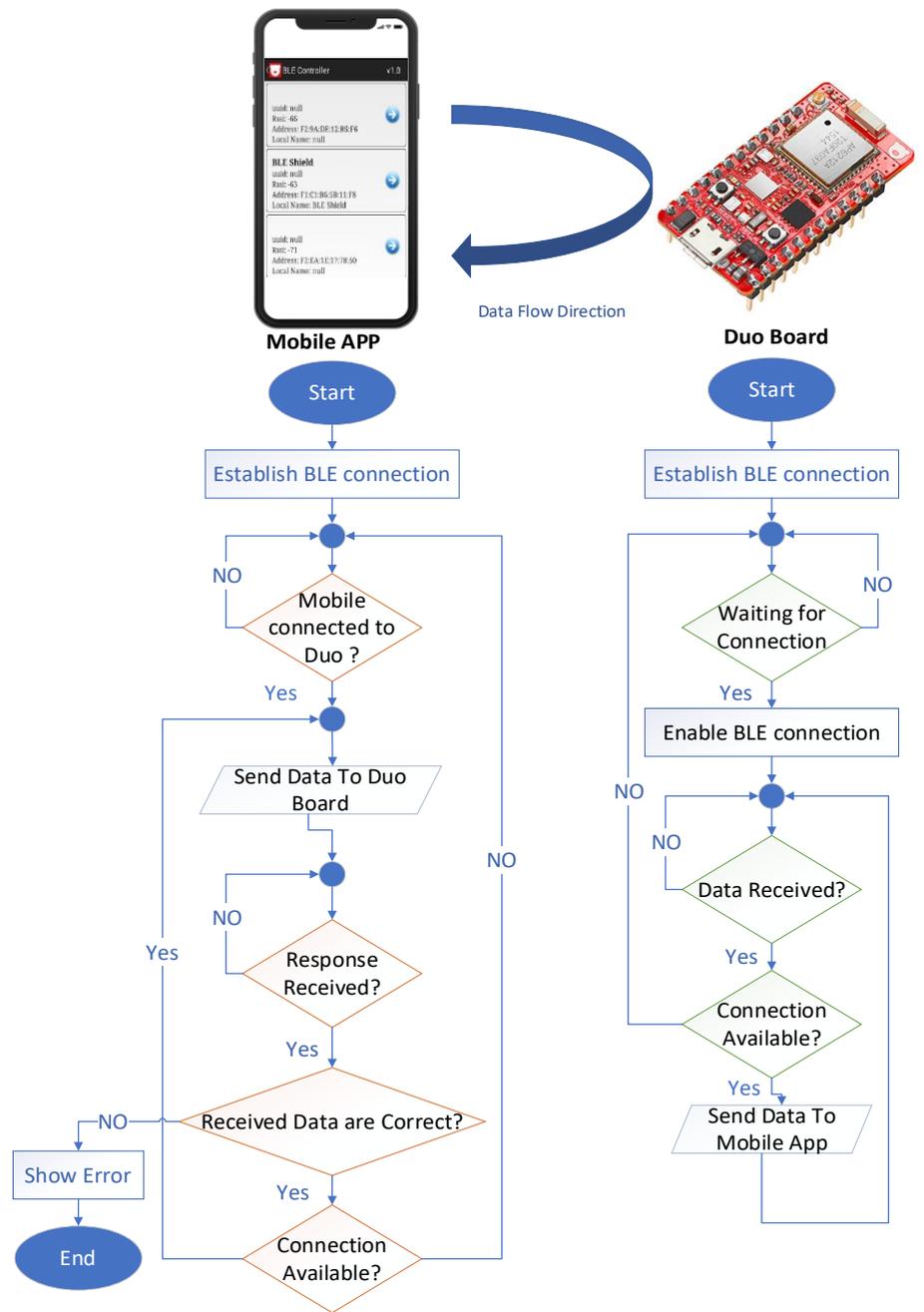
Figure 2. Proposed system algorithm.

The Duo is placed inside a plastic bag that is waterproof to protect the electronic components from damage by water. For displaying the data sent to the RedBear DUE and monitoring the

signal strength, the BLE Controller app which is available for Android and iOS smartphones is used. The app is designed by the RedBear Lab to work with most of the BLE boards. We modified the internal firmware code for the DUE to send the data, for instance, the "Hello" word every second and tested receiving the same data and displaying it on the BLE Controller app. The proposed algorithm is shown in Figure 2.

4. RESULTS AND DISCUSSION

Experiments are conducted in air and water to test the signal strength with distance for successful communication. In the air, the received signal is tested from the Due board when it is in a fixed location, on a person's arm while moving and without moving. The maximum distance that Due can handle receiving the complete data was 93 meters, as shown in Figure 3 which is considered a good distance for giving and receiving feedback between a coach and players in some sports such as running, volleyball, and basketball.

On the other hand, the Due module is tested in two cans of water containing pure water and turbid water respectively. The two water cans, the turbidity meter, and the ReadBear DUE are shown in Figure 4.
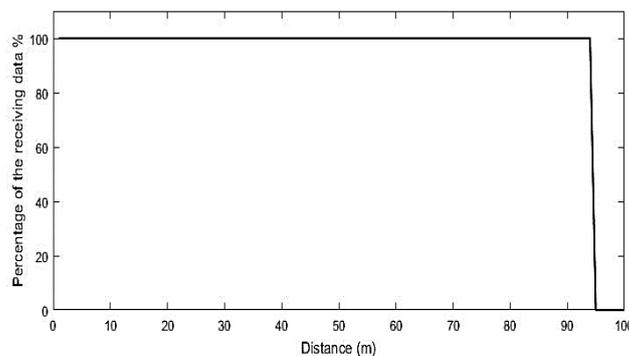
Figure 3. The percentage of received data with distance from the DUE board on a fixed location, on an arm with movement, and on an arm without movement.

The water turbidity does not mainly affect the DUE's board signal as shown in Table 1. Notice that the Aluminium Silicate Hydroxide (Al2Si2O5(OH)4), also called Kaolinite is added to get water with high turbidity with 430 NT compared with 1.5NTU for pure water.

Figure 4. The turbidity meter, two water cans containing pure water and turbid water respectively, and the redbear due board.

Table 1. The due's signal strength difference between the pure and turbid water.

DUE's signal strength inside water can containing pure water	-77 dB
DUE's signal strength inside water can contain highly turbid water	-71 dB

Then, the Due board is inserted inside a water tub with a dimension of (50×100) cm as shown in Figure 5. The signal strength is monitored at different depths and directions. Figure 6 shows the signal strength in pure water concerning the width W, the depth D, and length L of the water tub edges. When the distance exceeded 6 cm under the water, the signal dropped.

The results based on the graph above for the signal strength showed that Bluetooth technology cannot be used for long-distance communication in water. This is because of the high attenuation that the high frequency signals face in water [9-10]. However, for some water sports applications, such as swimming, some arrangements could be made by connecting the sensor on the swimmer's wrist, and communication could be established with the coach when the wrist was outside of the water. In this case, the communication will be air-to-air, which is proven to be successful over long distances in this paper.

Figure 5. Testing the Due board in a plastic bag running and stepping inside a water tub at 11°C and turbidity of 1.5 NTU.
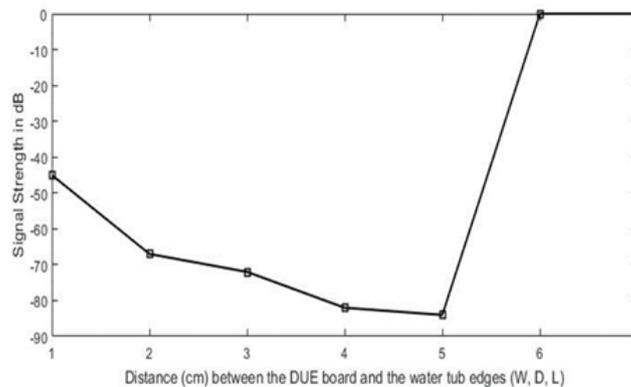
Figure 6. The signal strength of the due board inside the water tub.

5. CONCLUSION

The Bluetooth Low Energy BLE board's (RedBear DUE) performance is tested in the air and underwater. The air test is conducted in a fixed location, on a person's arm with and without moving in different directions with a 93 m successful communication range. Experiments are conducted in pure water and in turbid water to discover if turbidity is an effective factor in the RedBear Bluetooth signal strength. The results showed that the DUE board can be used in water with limited distances and depths because of the high-water attenuation for the 2.4 GHz frequencies. One of the best features of the RedBear board or any other BLE board is the low power consumption that enables any project to operate for a long time. Therefore, using the BLE board is very useful in sports and health applications, especially with the high need for using portable and small sensors to monitor the elderly and athletes in these two fields.

Conflict of Interest

There was no conflict of interest between the authors during the creation of this study. No financial support has been received and there are no conditions that provide financial or personal benefit.

Contribution of Authors

The authors involved in this study contributed to all aspects of the study. All authors contributed to the idea, design, inspection, resources, data collection, literature review, critical review and analysis, and interpretation sections of the study.

REFERENCES

Abbasi-Kesbi R., Nikfarjam A., Nemati M.,(2020).Developed wireless sensor network to supervise the essential parameters in greenhouses for internet of things applications. IET Circuits Devices Syst.,vol. 14 Iss. 8, pp. 1258-1264. doi: https://doi.org/10.1049/iet-cds.2020.0085.

Gupta, A., and Mohammed, I., (2016). Bluetooth low energy (BLE) fundamentals, Cypress Semiconductor. [Online]. [Accessed: Sep - 2023] https://www.embedded.com/design/connectivity/4442870/Bluetooth-low-energy--BLE--fundamentals.

Hagem R. M., Sabti H. A., Thiel D. V.(2015).Coach-Swimmer Communications Based on Wrist Mounted 2.4GHz Accelerometer Sensor. Procedia Engineering, vol. 112, pp. 512-516. doi: https://doi.org/10.1016/j.proeng.2015.07.234.

Hagem R. M., O'Keefe S. G., Fickenscher T., Thiel D. V. (2013). Self Contained Adaptable Optical Wireless Communications System for Stroke Rate During Swimming. in IEEE Sensors Journal, vol. 13, no. 8, pp. 3144-3151, doi: https://doi: 10.1109/JSEN.2013.2262933.

Khan, R., Khan, S. U., Zaheer, R., and Khan, S. (2012). Future Internet: The Internet of Things Architecture, Possible Applications and Key Challenges, *10th International Conference on Frontiers of Information Technology*, pp. 257–260. doi: https://doi.org/10.1109/FIT.2012.53

Khan A. N, Cha Y., Giddens H., Hao Y. (2022).Recent Advances in Organ Specific Wireless Bioelectronic Devices: Perspective on Biotelemetry and Power Transfer Using Antenna Systems. Engineering, vol. 11,pp. 27-41, doi: https://doi.org/10.1016/j.eng.2021.10.019.

Lee, J., Su, Y., and Shen, C., (2007). A Comparative Study of Wireless Protocols: Bluetooth, UWB, ZigBee, and Wi-Fi. *33rd Annual Conference of the IEEE Industrial Electronics Society (IECON)*, pp. 46-51, Nov. 5-8, Taipei, Taiwan. doi: https://doi.org/10.1109/IECON.2007.4460126

Memon S. F., Memon M., Bhatti S.(2020).Wearable technology for infant health monitoring: A surve . IET Circuits Devices Syst. , vol. 14 Iss. 2, pp. 115-129. doi: https://doi.org/10.1049/iet-cds.2018.5447 .

Nilsson E. Lindman T.(2017).Implementation and evaluation of Bluetooth Low Energy as a communication technology for wireless sensor networks ,*Bachelor thesis* [Innovative programming], pp.10. https://www.diva-portal.org/smash/get/diva2:1112860/FULLTEXT01.pdf

Thumb-size Cloud-ready Internet-of-Things (IoT) board with co-existing WiFi and BLE capability, (2016). [Online]. [Accessed: Sep - 2023] , https://github.com/redbear/Duo.

Yu, B., Xu, L., and Li, Y., (2012). Bluetooth Low Energy (BLE) Based Mobile Electrocardiogram Monitoring System. *Proceeding of the IEEE International Conference on Information and Automation*, pp. 763-767, Shenyang, China. doi: https://doi.org/10.1109/ICInfA.2012.6246921

Zheng, J., Simplot-Ryl, D., Bisdikian, C. and Mouftah, H. T. (2011) The internet of things [Guest Editorial]. *IEEE Communications Magazine*, vol. 49, no. 11, pp. 30–31. doi: https://doi.org/10.1109/MCOM.2011.6069706

Prediction of the Coefficient on Heat Transfer for Heat Transfer for Single –Phase Flow In A Annular Passage on Vertical Tube by Foeced Convection Heat Flow

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Keywords	Abstract
Turbulent zone, Forced convection, Developing flow, forced convection heat flow.	*The forced convection hypothesis poses a challenge to the employ of smooth vertical circular tubes due to the low heat flux wanted to prevent buoyancy effects by increasing the coefficient of heat transfer. Previous research on the turbulent zone has mainly focused on mixed convection, via limited studies on forced convective heat transfer. The aim of this study is to predict the behaviour of the coefficient of heat transfer under specific convection conditions. Prandtl number, and Reynold number. The turbulent zone in the turbulent developing zone was determined for all heat flows, and turbulent flow happened at all rates of mass flow for all heat fluxes. The Reynolds number increased with an increase in heat flux for the characteristics of heat transfer under isothermal flow. The experiments involved the use of water that had a Prandtl number between (2.09 and 2.12). Reynolds numbers varied between (28352.75 and 57442.32), while heat fluxes ranged from (424.62 to 2547.77 W/m^2). The tests were conducted at a single-phase to coefficient of heat transfer for annular passage of (2.09 to 3.64 $Kw/m^2.K$), with heat inputs ranging from (50 to 300 watts). The turbulent flow zone width was determined in the developing turbulent zone.*

1. INTRODUCTION

The flow within a tube that has turbulent and convective can either be due to forced convection or mixed convection. It is important to be able to differentiate between the two types because the Reynolds number varies significantly between them. This difference has significant.Both fully developed and developing flows had examined. While there has significant literature on transitional flow zones in vertical tubes, most of these studies focus on natural or mixed convection..The study examined the heat transfer through forced convection in the transition zone of vertical heat exchangers with a co-current flow, by Reynolds number between (4000 and 10000). However, depending on the inlet geometry and rate of heating, the transition to turbulent flow in the tubes occurred much earlier than a Reynolds number of (4000), (Everts et al.,, 2018; Ghajar et al., 1994; Bashir et al., 2019; Holman, 2012; Alsulaiei et al., 2023; SHAKIR, 2022a, 2022b; Shakir, 2020, 2021b, 2021a, 2022, 2023; SHAKIR, 2023) the study conducted a numerical analysis on forced

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convection, looking at laminar and turbulent flows on mini-channels by varying boundary conditions. They identified the area where quasi-turbulent and turbulent flows occur as the transition zone. So, this zone has been defined as the portion of the quasi-turbulent zone and turbulent flow zone. Since there were no empirical data from practical experiments, the study solely relied on predictive analysis through heat transfer equations. These equations were used for hypothetical setups that resemble real-world lab tests conducted under the same circumstances.The main goal of this research is to develop an advanced numerical iterative method that utilizes a prediction software to determine the characteristics of forced convection heat transfer and fluid flow.

NUMERICAL METHODOLOGIES

The equations that control the phenomenon are solved using the finite method on the Excel software algorithm, which also solves the temperature of the fluid and all wanted fluid properties. To predict the phenomenon, a program was employed that used over (700) correlations of heat transfer, and these correlations had then transmitted to the Excel software using an iterative technique. Figure.1 shows that heat movement only occurs at the solid-water boundary, which has why the 2-D array can be configured in such a way that the main effect on the wall line has perpendicular to the water flow, parallel to the water flow, as well as thermal conductivity, can be traced by the stages seen in Figure.1. (Shakir, 2020; Shakir, 2021b).

$$\delta^2 T / \delta y^2 + \delta^2 T / \delta z^2 = 0 \tag{1}$$
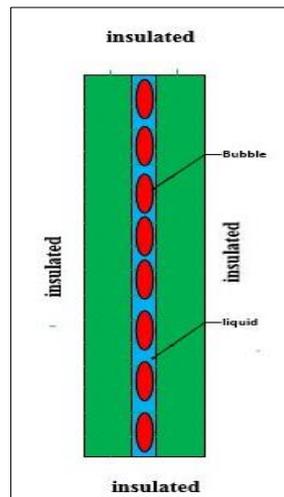
Figure 1. Test section

Which has temperature (T) was measured on the copper wall, while (y) is perpendicular to the axis of water flow, in order to calculate heat transfer using equation (1) by dividing it by the area of the square cell (0.05 m) squared. (Shakir, 2020; Shakir, 2021b).

$$T_{i,j} = \delta y^2 \left(T_{i+1,j} + T_{i-1,j} \right) + \delta z^2 \left(T_{i,j+1} + T_{i,j_1} \right) / 2 \, (\delta y^2 + \delta z^2) \tag{2}$$

2. MATHEMATICAL EQUATIONS

The flow temperatures, (T_L), at any axial location, (Holman, 2012)
$$T_L = T_{in} + (T_{out} - T_{in}/L) \, x \tag{3}$$
To get the area of tube flow, (Holman, 2012)
$$A = \pi/4 \left(D_{out}^2 - D_{in}^2 \right) \tag{4}$$
The hydraulic diameter can be found by:- (Holman, 2012)
$$D_h = D_{out} - D_{in} \tag{5}$$
To calculate the fluid of mean velocity by, (Holman, 2012)

$$u = m/\rho \, A \tag{6}$$

To obtain   the Re   by, (Holman, 2012)

$$Re = \rho u D_h /\mu \tag{7}$$

To get   the (Pr) by, (Holman, 2012)

$$Pr = C_p \mu / K_f \tag{8}$$

To obtain   the (St)   by, (Holman, 2012)

$$S_f = E_{st} R_e^{-0.205} P_r^{-0.503} \tag{9}$$

To obtain   the (E-St)   by, (Holman, 2012)

$$E_{st} = -0.0225 \, exp^{(-0.0225 \, (\ln Pr)^2)} \tag{10}$$

To obtain   the (Nu-T)   by, (Holman, 2012)

$$N_U = 0.023 \, R_e^{0.8} P_r^{0.4} \tag{11}$$

To obtain   the (h-T)   by, (Holman, 2012)

$$h_T = \rho \, u C_p S_t \tag{12}$$

3. RESULTS

The data seen in Figure 2 illustrates the Reynolds number plotted against the rate of mass flow. Through a polynomial curve fit of the forced convection heat transfer results for vertical upward and downward flows, a revised correlation for developing turbulent forced convection Reynolds number can be obtained, which takes into account the increase in Reynolds number with the rate of mass flow rate. Figure.2 indicates that this correlation has valid for Reynolds numbers ranging from (28352.75 to 57442.35). The increase in the temperature of liquid reduces the viscosity of a liquid, which in turn raises the Reynolds number. Additionally, the geometry of the inlet and outlet can be significantly affected the Reynolds number range mentioned.
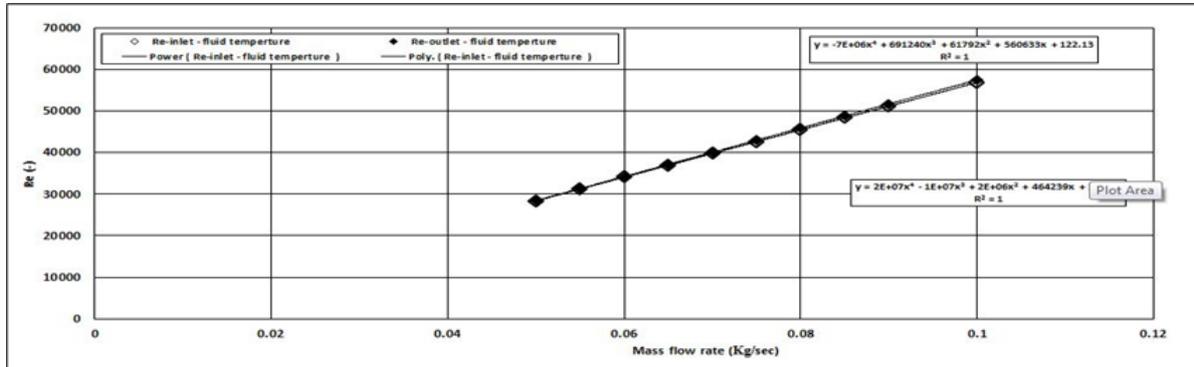
Figure 2.Variation to (Re) versus rate of mass flow

The information presented in Figure 3 demonstrates that the Reynolds number, as a function of the thermal entrance length (x/Di), is affected by forced convection and heat flux in upward and downward flows due to the reduction in viscosity caused by an increase in temperature. The Reynolds number remained relatively constant along the length of the tube until it reached the thermal entrance length, indicating that flow development occurred for all flow orientations and under forced convection conditions in vertical tubes. so Increasing the thermal entrance length had a significant impact on raising the Reynolds number for all inlet and outlet data. Additionally, (4) thermocouples are employed in this study to analyze by developing and turbulent flow in the range of (7.14 < x/Di ≤ 71.42), which has much smaller than the thermal entrance.
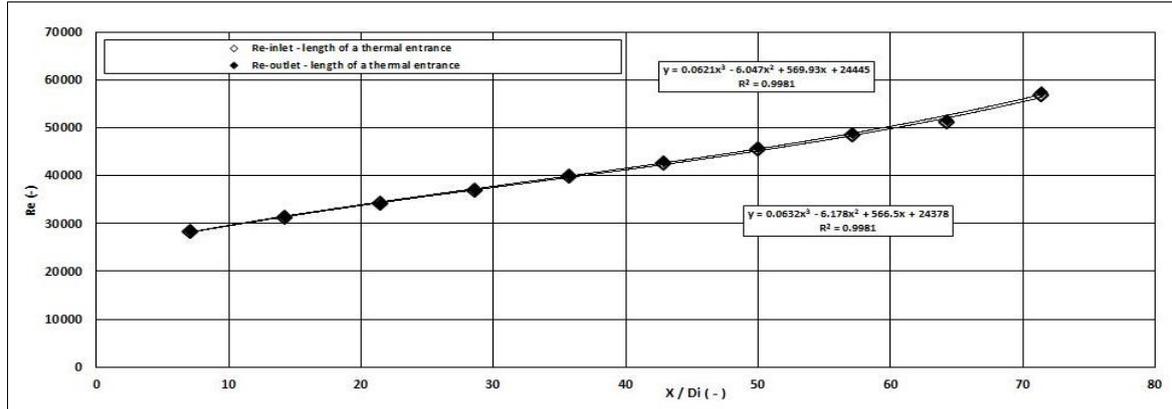
Figure 3.Variation to (Re) as a function of (x/Di)

Figure 4 illustrates the investigation of the relationship between the temperature of the fluid and the coefficient of heat transfer. The coefficient of heat transfer has been studied for both upward and downward flows and can be represented by a simple polynomial curve fit. The consequences of vertical upward and downward flows are reflected in this curve. The data obtained from the study show that at the outlet, a higher increase in temperature of the fluid (represented by the black line) occurred at a Reynolds number of (28339.98-57442.33), with a mass flow rate of (0.05-0.1 kg/s) and a heat flux of (424.62-2547.77 W/m^2). Similar rates of mass flow and heat fluxes, but different Reynolds numbers (28352.75-56844.02), were obtained at the inlet with data on the coefficient of heat transfer and the temperature of the fluid.
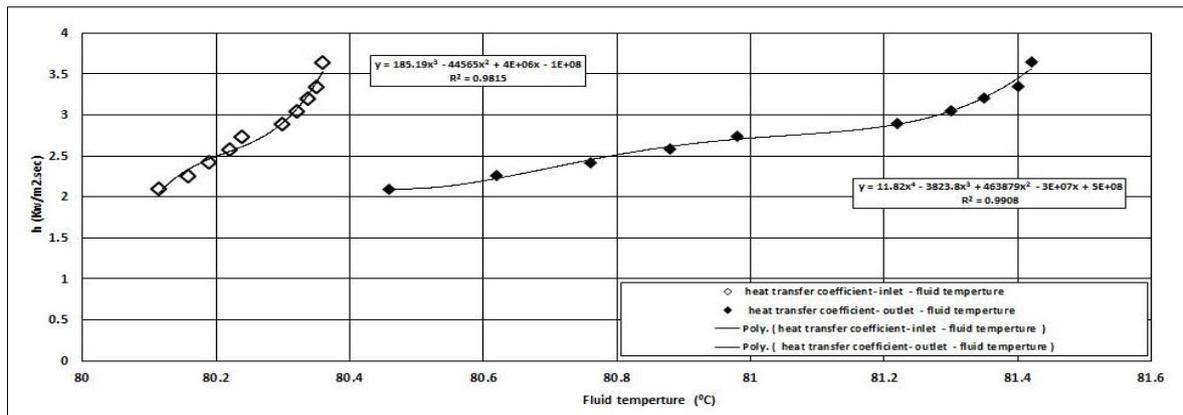
Figure 4. Variation of coefficient of heat transfer as function fluid temperature

The graph in Figure 5 shows the relationship between the temperature of the fluid and the velocity of the fluid, which was obtained by fitting third and second-degree polynomial curves to all the forced convection heat transfer data for the vertical upward and downward flow. For vertical upward flow, the temperature of the wall remained constant and was less than the uncertainty of temperature measurement, indicating that buoyancy effects are negligible and forced convection was the dominant heat transfer mechanism. This resulted in similar circumferential wall temperatures at a given location. A similar result was obtained for other heat flux and Reynolds number, as well as for downward flow. The similarity of the results for upward and for downward flow so confirmed that buoyancy effects can be ignored.
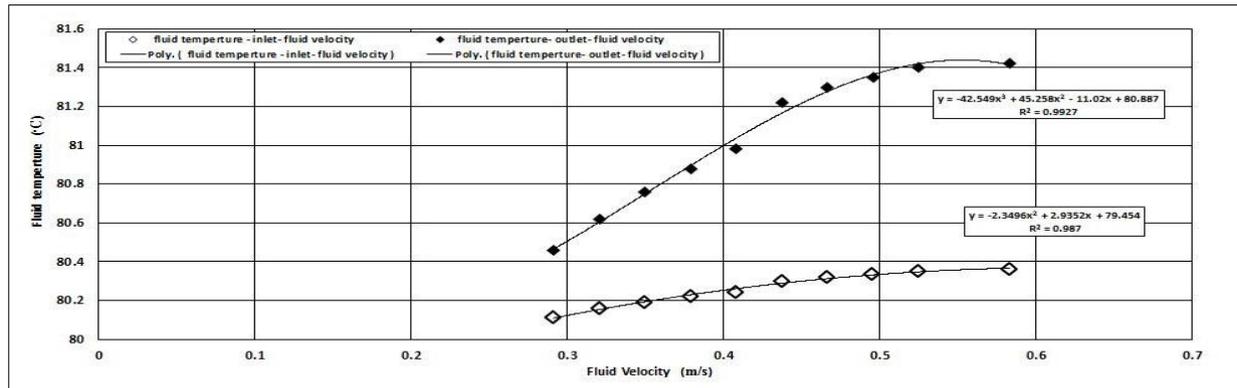
Figure 5. Variation of fluid temperature as function fluid velocity

4. CONCLUSIONS

The existing literature on predicting outcomes has noted that there has been a lack of research on internal forced convection in turbulent zone. To account for forced convection and minor buoyancy effects, predictions are made using a test section that was oriented both vertically downward and upward. In situations of pure forced convection, the transition range (Re) in the developing zone increased as heat flow increased, and it was turbulent. This paper suggests using uncertainty assessments in predicting (Re). Increasing heat flow by increasing temperature and by decreasing viscosity could be raised (Re). Predictions in this paper are made using a copper tube test section by Reynolds number ranging from (28,352.75 to 57,442.32). Pure forced convection resulted in the cessation of turbulent flow in the developing region at higher Reynolds numbers with an increase in heat flux. Furthermore, the width of the flow regime changed with different heat flux values, and equations were formulated to determine the boundaries of the turbulent flow regime in pure forced convection. The study discovered that, like isothermal flow, turbulent flow happened at different mass flow rates for all heat fluxes. However, Reynolds numbers increased with heat flux, which was attributed to the drop in viscosity as the temperature rise.

NOMENCLATURE

A	area of tube flow (mm^2)
C_p	specific heat of water,(kJ/(kg .K)
D_h	hydraulic diameter, mm
E-st	factor of Stanton number (-)
h_T	turbulent coefficient of heat transfer, (W/(m2.K)
K_f	thermal conductivity of fluid, (W/(m .K)
K_c	thermal conductivity of copper, (W/(m .K)
L	tube length (m)
m	mass water flow rate,(kg/s)
Nu	Nusselt number (-)
Pr	Prandtl number (-)
St	Stanton number (-)
Re	Reynolds number (-)
T	temperature,(C^o)
TL	Fluid temperature,(C^o))
Tin	Inlet temperature,(C^o))
Tout	Exit temperature,(C^o))

V	water velocity,(m/sec)
ρ	water density, (Kg/m2)
μ	dynamic velocity (Pa .S)

Conflict of Interest

The author participated in this study without any conflicts of interest, receiving no financial support and having no situations that could lead to financial or personal benefits.

REFERENCES

Alsulaiei, Z. M. A., Abid, H. J., Shakir, R., & Ajimi, H. S. H. (2023). Forecast Study on the Overall Coefficient for Passage of Single-Phase and Passage of Single-Phase in an Annular to Plain Tubes Heat Stream. IOP Conference Series: Earth and Environmental Science, 1223(1), 12028.doi: https://doi.org/10.1088/1755-1315/1223/1/012028

Bashir, A. I., Everts, M., & Meyer, J. P. (2019). Influence of inlet contraction ratios on the heat transfer and pressure drop characteristics of single-phase flow in smooth circular tubes in the transitional flow regime. Experimental Thermal and Fluid Science, 109, 109892. doi: https://doi.org/10.1016/j.expthermflusci.2019.109892

Everts, M., & Meyer, J. P. (2018). Heat transfer of developing and fully developed flow in smooth horizontal tubes in the transitional flow regime. International Journal of Heat and Mass Transfer, 117, 1331–1351. doi: https://doi.org/10.1016/j.ijheatmasstransfer.2017.10.071

Ghajar, A. J., & Tam, L.-M. (1994). Heat transfer measurements and correlations in the transition region for a circular tube with three different inlet configurations. Experimental Thermal and Fluid Science, 8(1), 79–90. doi: https://doi.org/10.1016/0894-1777(94)90075-2

Holman, J. P. (2012). Heat Transfer (ten editio). McGRAW-HILL'S. doi: https://doi.org/10.1002/aic.690180643

R.SHAKIR, R. S. (2022a). Investigate the Flow of Boiling Heat Transfer in a Complex Geometry Flat Channel University of Thi-Qar Journal for Engineering Sciences مجلة جامعة ذي 25–21 ,(1)12, قار للعلوم الهندسية. doi:http://www.doi.org/10.31663/tqujes.12.1.416(2022).

R.SHAKIR, R. S. (2022b). Pressure Drop Effect on Mini-Scale Heat Sink by Multi-phase: Review & Prediction. University of Thi-Qar Journal for Engineering Sciences مجلة جامعة 20–15 ,(1)12, ذي قار للعلوم الهندسية. doi: http://www.doi.org/10.31663/tqujes.12.1.415(2022)

Shakir, R. (2020). Boiling Heat Transfer in a Micro-Channel Complex Geometry. IOP Conference Series: Materials Science and Engineering, 928(2), 22129. doi: https://doi.org/10.1088/1757-899x/928/2/022129

Shakir, R. (2021a). INVESTIGATION OF SINGLE-PHASE FLOW CHARACTERISTICS IN A STAGGER PIN-FINS COMPLEX GEOMETRY. Journal of Engineering and Sustainable Development, 25(6), 74–81. doi: https://doi.org/10.31272/jeasd.25.6.8

Shakir, R. (2021b). Investigation of Single-Phase Flow Characteristics in an Inline Pin-Fins Complex Geometry. Journal of Physics: Conference Series, 1879(3), 32118. doi: https://doi.org/10.1088/1742-6596/1879/3/032118

Shakir, R. (2022). Study Of Pressure Drop and Heat Transfer Characteristics Of Mini-Channel Heat Sinks. The Iraqi Journal for Mechanical and Materials Engineering, 22(2), 85–97. doi: https://doi.org/10.32852/iqjfmme.v22i2.595

Shakir, R. (2023). Prediction study of the boiling flow of heat transfer in an array of in-line micro-pin-fins heat sink. AIP Conference Proceedings, 2845(1), 60003. doi: https://doi.org/10.1063/5.0157017

SHAKIR, R. (2023). GUESS HEAT TRANSFER COEFFICIENT OF FORCED CONVECTION FOR SINGLE-PHASE FLOW IN A SINGLE-PHASE PASSAGE ON A VERTICAL TUBE HEAT TRANSFER. Journal of Optimization and Decision Making, 2(1), 139–146. doi: https://dergipark.org.tr/en/pub/jodm/issue/76227/1283610

Effect of Metals on the Reflection Coefficent for Non-Invasive Glucose Sensing in the Millimeter Waveband

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Keywords	Abstract
Millimeter wave, Reflection coefficient, Non-invasive glucose detection, Glucose detection, Diabetes.	*Diabetes Mellitus is a chronic disease that affects more than 400 million people worldwide. Therefore, to minimize the side effects of the disease and to prevent hyperglycemia and hypoglycemia, it is important to determine and monitor the glucose level in blood. Invasive, minimal invasive and non-invasive methods are used to determine the glucose level in the blood. However, invasive and minimal invasive methods bring infectious and psychological risks and they are not cost-effective solutions. Besides, invasive methods cannot provide continuous monitoring of the blood glucose level and the risks for hyperglycemia and hypoglycemia during sleep cannot reduced. This situation has led researchers to determine the glucose level in the blood with a non-invasive method. In the search for non-invasive methods, the microwave and millimeter wave portion of the electromagnetic spectrum have significant potential. Complex permeability of blood for millimeter waveband is very sensitive to glucose concentration. In this study, materials such as brass, steel, aluminum and copper were used to re-reflect the signals applied to the glucose solution through the WR-28 adapter. It has been shown that with better reflection coefficient, glucose level can be distinguished more clearly and steel displays better reflection performance compared to other materials.*

1. INTRODUCTION

Non-invasive methods to measure blood glucose level are divided into four categories as electrochemical-based, optical based, electromechanical and electromagnetic-based methods (Sutradhar & Hazarika, 2022). Many studies have been conducted on various body fluids to determine glucose levels in tear fluid (Zhang et al., 2011), saliva (Malik et al., 2015), breath (Guo et al., 2012), and sweat (Gao et al., 2016) using electrochemical-based method. These studies showed a weak and lagging relationship between blood glucose levels and measured values.

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In electromagnetic-based methods, electromagnetic signals of different wavelengths are used and the relationship between the properties of the measured signal and the glucose level in the blood is investigated after interaction with the human body. A very broad variety of studies focusing on electromagnetic wavelengths have been found in the literature such as radiowave/microwave/millimeter wave, bioimpedance spectrograpgy and raman spectroscopy (Xue et al., 2022). Microwave and millimeter wave radiation offer lower energy per photon and less scattering, meaning they can go deeper in the tissue to reach areas with sufficient blood concentration and provide a more accurate glucose tracking (Gonzales et al., 2019). Microwave and millimeter wave band methods three basic techniques to detect and define blood parameters: transmission, reflection and resonance perturbation. The forward-based transmission method examines the attenuation and phase change in the transmitted signal due to glucose level change by measuring the S21-transmission coefficient. Reflection-based technique, on the other hand, changes the amplitude and phase of the reflected signal due to the change in permeability in the blood when the glucose level changes, and the change in the glucose level is monitored by measuring the S_{11}-reflection coefficient. The resonance perturbation method works as a subset of the reflection and transmission methods targeting to measure changes in resonant frequency, quality factor and 3dB bandwidth and correlate them with variations in dielectric properties of the tested medium (Gonzales et al., 2019). In the first study conducted in the millimeter waveband, the researchers measured the complex permeability of the glucose solution and showed the variation of the transmission coefficient in the 35 - 38 GHz range (Nikawa & Someya, 2001). There are studies by measuring the transmission and reflection coefficient from a waveguide positioned on the tested tissue to the waveguide using an active transmission port (Siegel et al., n.d., 2014). There is a study examining the changes in glucose level by compressing animal tissue using a pair of patch antennas facing each other at 58 - 62 GHz (Cano-Garcia et al., 2018). In another study, a study based on measuring the transmission coefficient at 60 GHz using two microstrip patch antennas was carried out (Saha et al., 2017). In another study, Hu et al. proposed a non-invasive glucose concentration estimation system using transmission amplitude and phase data at glucose concentrations ranging from 0-300 mg/dL in the 60-80 GHz band (Hu et al., 2019).

Researchers stated that the reflection coefficient data is effective in distinguishing the glucose level in the blood (Cano-Garcia et al., 2016; Göktaş et al., 2022; Hofmann et al., 2012; Nikawa & Someya, 2001). Studies have been carried out to obtain a better S_{11}-reflection coefficient. In this study, materials such as brass, steel, aluminum and copper were used to re-reflect the signals applied to the glucose solution through the WR-28 adapter. When the results obtained were examined, it was observed that the measurements made using steel gave better results. In the following sections of the study, information is given about how the S_{11}-reflection coefficient parameter is measured and the experimental setup. Finally, the obtained results are mentioned and an idea is given about what the future studies could be.

2. MATERIAL AND METHODS

Scattering parameters are the method that shows the circuit in a matrix structure without knowing which circuit elements the millimeter wave circuit consists of and its internal structure. In other words, it consists of the transition equations of a circuit defined as a black box.

Figure 1. Representative illustration of a 2 port circuit

In millimeter wave circuits, S parameters can be defined as the ratio of the voltage coming from any gate to the voltage reflected from the same gate. If V1+ is the sign applied to the system, some of this sign will be reflected as V1-, while some will exit the system as V2+. The reflection coefficient (S_{11}) is defined as the ratio of the amplitude of the reflected signal to the amplitude of the transmitted signal. To determine the S parameters, a fixed frequency wave is sent to each gate of the box and reflected and transmitted waves are measured at the other gates (Göktaş et al., 2022). In this way, in addition to the reflection coefficient parameter, the reverse voltage gain (S12), the forward voltage gain (S21) and the output gate voltage gain (S22) are calculated. In this study, the effect of different materials on the reflection coefficient was investigated. Materials such as brass, steel, aluminum and copper (Figure 2.(a)) were used to re-reflect the signals applied to the glucose solution (Figure 2.(b)) via the WR-28 adapter.

(a)   (b)
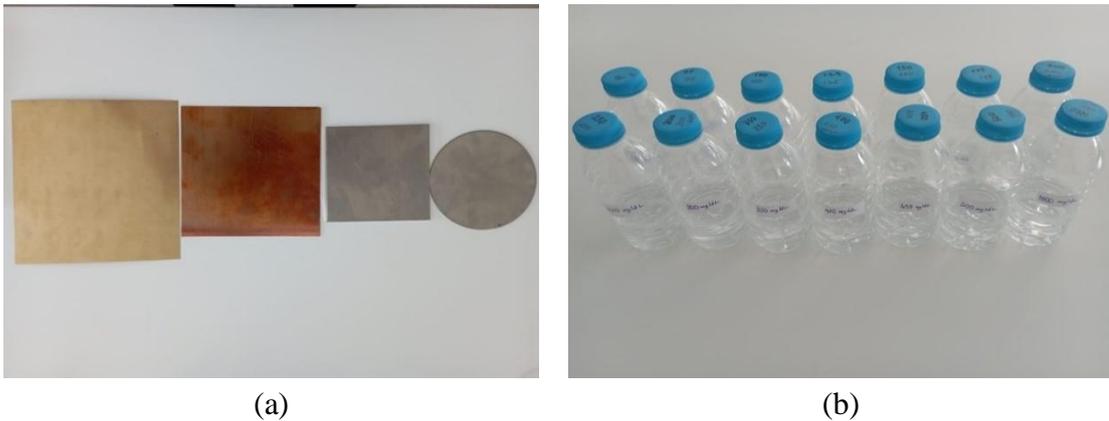
Figure 2. Solutions and reflective metals (From left to right brass, copper, aluminum and steel)

In the study using a vector network analyzer, the WR-28 adapter was placed under the sample cup. Metals were placed on the upper part of the sample cup in order to re-reflect the incoming signal. The experimental setup is shown in Figure 3. The measurements were repeated 20 times and the average of these measurements was taken. Solution densities used in the study are in the range of 50 - 20000 mg/dl.
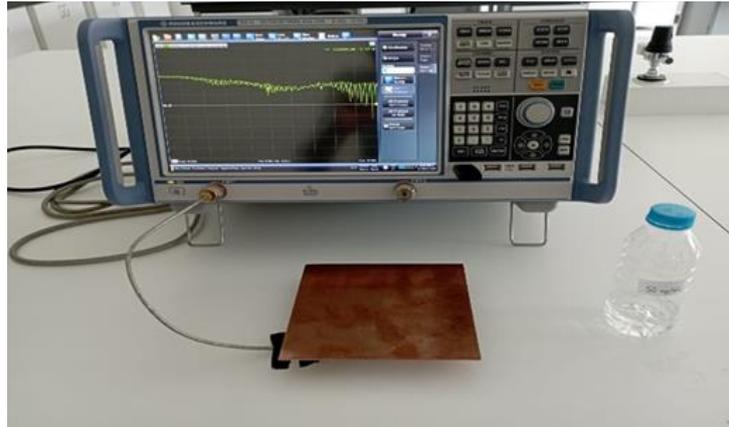
Figure 3. Experimental setup

3. RESULTS

Firstly, the effects of various metals on the reflection coefficient were examined and the results obtained are given in Figure 4 comparatively. Figure 4 shows the S11-reflection coefficient data obtained by placing the empty container and various materials on it. According to these data, the best results were obtained in steel, aluminum, brass and copper, respectively.
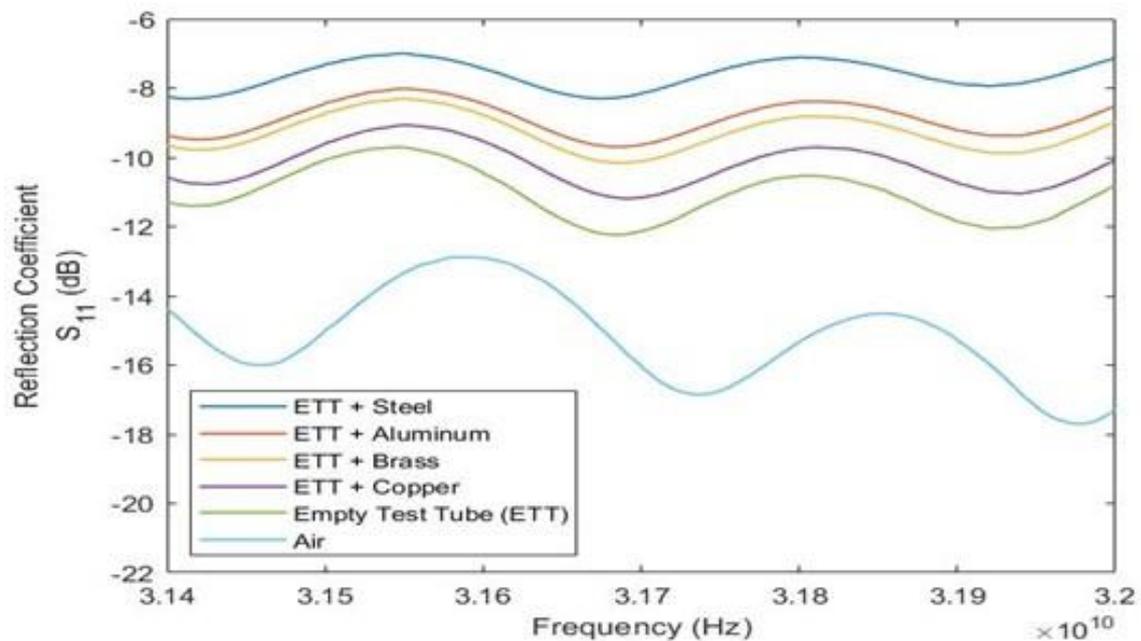
Figure 4. Reflection coefficient data obtained using empty container and reflective materials at 31 GHz.

Then, the graphical results of the measurements made using steel in solutions with different glucose densities are given in Figure 5. Since the operating range of the WR-28 adapter used in the measurement is between 28-40 GHz, the reflection coefficient data obtained at the center point between 31-34 GHz are presented. In the study, air and glucose solutions can be clearly distinguished. However, the difference in the change of glucose concentration in aqueous solutions is relatively small. These results show consistency when compared with other studies in the literature (Hofmann et al., 2012; Nikawa & Michiyama, 2007; Omer et al., 2018).
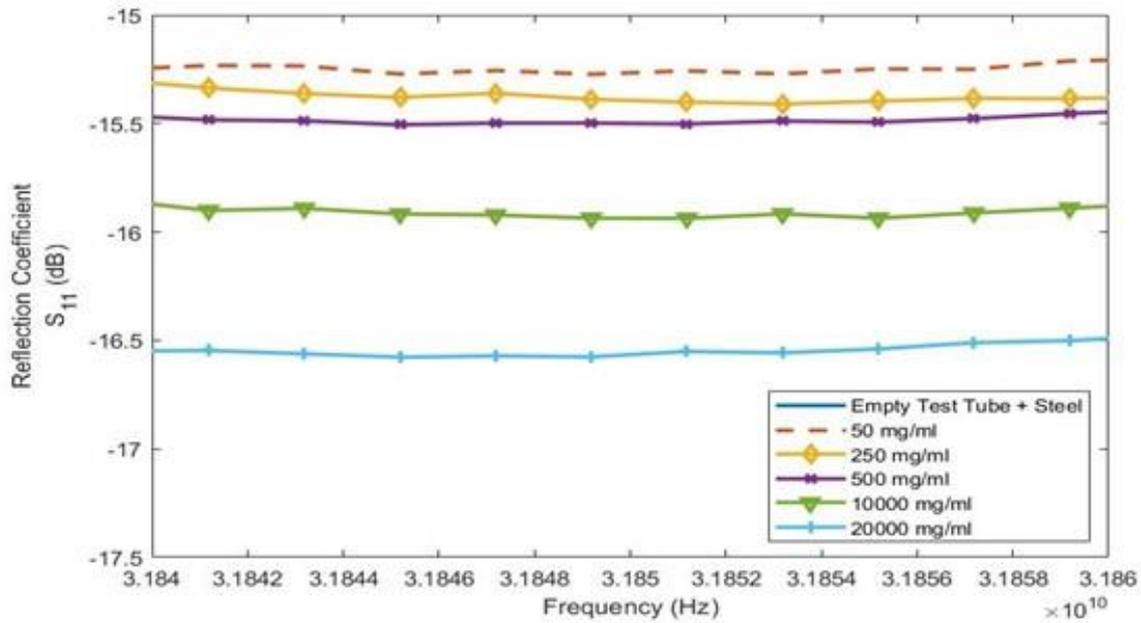
Figure 5. S_{11}-reflection coefficient data obtained using the WR-28 adapter and steel

4. CONCLUSION

This study showed that aqueous solutions with different glucose concentrations in the $30 - 35$ GHz frequency range can be distinguished by non-invasive methods of glucose level measurement in the mm-wave band. Besides, the effects of various metals on the S_{11}-reflection coefficient were investigated. The addition of glucose to water changes the complex permeability of the water. This has enabled the reflection coefficient to be discriminating for solutions with different concentrations. Our basic approach is to find a ratio between the blood glucose level and the measured signal. However, the signal loss is quite high due to the scattering of the transmitted signal. At this stage of the study, the effect of metals on the reflection coefficient for different glucose concentrations at mm-wavelength was investigated. It has been shown that if the reflection coefficient is obtained better, the glucose level can be distinguished more clearly. It has also been shown that steel has better reflective performance than other materials. As a future work, these results will guide the material selection for the antenna to be designed so that the reflection coefficient can be obtained better.

Conflict of Interest

The authors declare that they have no conflict of interest.

Contribution of Authors

The authors involved in this study are Ömer Faruk GÖKTAŞ, İlyas ÇANKAYA and Esra ŞENGÜN ERMEYDAN; contributed to all aspects of the study. All authors contributed to the idea, design, inspection, resources, data collection, literature review, critical review and analysis and interpretation sections of the study.

REFERENCES

Cano-Garcia, H., Gouzouasis, I., Sotiriou, I., Saha, S., Palikaras, G., Kosmas, P., & Kallos, E. (2016). Reflection and transmission measurements using 60 GHz patch antennas in the presence of animal tissue for non-invasive glucose sensing. 2016 10th European Conference on Antennas and Propagation, EuCAP 2016, 1, 10–12. doi: https://doi.org/10.1109/EuCAP.2016.7481178

Cano-Garcia, H., Saha, S., Sotiriou, I., Kosmas, P., Gouzouasis, I., & Kallos, E. (2018). Millimeter-Wave Sensing of Diabetes-Relevant Glucose Concentration Changes in Pigs. Journal of Infrared, Millimeter, and Terahertz Waves, 39(8), 761–772. doi: https://doi.org/10.1007/s10762-018-0502-6

Gao, W., Emaminejad, S., Nyein, H. Y. Y., Challa, S., Chen, K., Peck, A., Fahad, H. M., Ota, H., Shiraki, H., Kiriya, D., Lien, D. H., Brooks, G. A., Davis, R. W., & Javey, A. (2016). Fully integrated wearable sensor arrays for multiplexed in situ perspiration analysis. Nature, 529(7587). doi: https://doi.org/10.1038/nature16521

Göktaş, Ö. F., Çankaya, İ., & Ermeydan, E. Ş. (2022). Milimetre dalga bandinda invazif olmayan bir yöntem ile sivilarda glikoz seviyesinin belirlenmesi. 1235–1248. doi: https://doi.org/10.17482/uumfd.1125289

Gonzales, W. V., Mobashsher, A. T., & Abbosh, A. (2019). The progress of glucose monitoring—A review of invasive to minimally and non-invasive techniques, devices and sensors. In Sensors (Switzerland) (Vol. 19, Issue 4). doi: https://doi.org/10.3390/s19040800

Guo, D., Zhang, D., Zhang, L., & Lu, G. (2012). Non-invasive blood glucose monitoring for diabetics by means of breath signal analysis. Sensors and Actuators, B: Chemical, 173. doi: https://doi.org/10.1016/j.snb.2012.06.025

Hofmann, M., Bloss, M., Weigel, R., Fischer, G., & Kissinger, D. (2012). Non-invasive glucose monitoring using open electromagnetic waveguides. European Microwave Week 2012: "Space for Microwaves", EuMW 2012, Conference Proceedings - 42nd European Microwave Conference, EuMC 2012, 546–549. doi: https://doi.org/10.23919/eumc.2012.6459152

Hu, S., Nagae, S., & Hirose, A. (2019). Millimeter-Wave Adaptive Glucose Concentration Estimation with Complex-Valued Neural Networks. IEEE Transactions on Biomedical Engineering, 66(7), 2065–2071. doi: https://doi.org/10.1109/TBME.2018.2883085

Malik, S., Gupta, S., Khadgawat, R., & Anand, S. (2015). A novel non-invasive blood glucose monitoring approach using saliva. 2015 IEEE International Conference on Signal Processing, Informatics, Communication and Energy Systems, SPICES 2015. doi: https://doi.org/10.1109/SPICES.2015.7091562

Nikawa, Y., & Michiyama, T. (2007). Blood-sugar monitoring by reflection of millimeter wave. Asia-Pacific Microwave Conference Proceedings, APMC. doi: https://doi.org/10.1109/APMC.2007.4555070

Nikawa, Y., & Someya, D. (2001). Application of millimeter waves to measure blood sugar level. Asia-Pacific Microwave Conference Proceedings, APMC, 3, 1303–1306. doi: https://doi.org/10.1109/apmc.2001.985374

Omer, A. E., Shaker, G., & Safavi-Naeini, S. (2018). Non-invasive Glucose Monitoring at mm-Wave Frequencies. Journal of Computational Vision and Imaging Systems, 4(1). doi: https://doi.org/10.15353/jcvis.v4i1.325

Saha, S., Cano-Garcia, H., Sotiriou, I., Lipscombe, O., Gouzouasis, I., Koutsoupidou, M., Palikaras, G., Mackenzie, R., Reeve, T., Kosmas, P., & Kallos, E. (2017). A Glucose Sensing System Based on Transmission Measurements at Millimetre Waves using Micro strip Patch Antennas. Scientific Reports, 7(1). doi: https://doi.org/10.1038/s41598-017-06926-1

Siegel, P. H., Lee, Y., & Pikov, V. (2014). Millimeter-wave non-invasive monitoring of glucose in anesthetized rats. International Conference on Infrared, Millimeter, and Terahertz Waves, IRMMW-THz. doi: https://doi.org/10.1109/IRMMW-THz.2014.6956294

Siegel, P. H., Tang, A., Virbila, G., Kim, Y., Chang, M. C. F., & Pikov, V. (n.d.). Compact non-invasive millimeter-wave glucose sensor. 53–55.

Sutradhar, D., & Hazarika, D. (2022). A Review of Non-invasive Electromagnetic Blood Glucose Monitoring Techniques. Asian Pacific Journal of Health Sciences, 9(1), 98–105. doi: https://doi.org/10.21276/apjhs.2022.9.1.29

Xue, Y., Thalmayer, A. S., Zeising, S., Fischer, G., & Lübke, M. (2022). Commercial and Scientific Solutions for Blood Glucose Monitoring—A Review. In Sensors (Vol. 22, Issue 2). doi: https://doi.org/10.3390/s22020425

Zhang, J., Hodge, W., Hutnick, C., & Wang, X. (2011). Noninvasive diagnostic devices for diabetes through measuring tear glucose. In Journal of Diabetes Science and Technology (Vol. 5, Issue 1). doi: https://doi.org/10.1177/193229681100500123

Hassas Tarım Uygulamalarında İnovasyon

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Anahtar Kelimeler	Öz
Hassas tarım, Akıllı Teknoloji, Ürün verimliliği	*Dünya nüfusunun artması ile gıda tüketimide doğru orantılı olarak artmaktadır. Bu tarımsal üretimin verimli hale getirilmesini zorunlu kılmıştır. Tarımsal arazilerin kentsel yerleşime dahil edilerek imara açılması, tarımsal arazilerin giderek azalmasına neden olmuştur. Tarımsal üretim veriminin artırılması amacı ile yapılan bilinçsiz sulama ve kimyasal gübre kullanımı ise tarım arazilerini kullanılamaz hale getirmiştir. Bilişim teknolojilerinin tarıma uygulanabileceği fikri ile 1990'lı yılların başında ortaya çıkan ve akıllı teknoloji uygulamalarının dahil edildiği tarım, "hassas tarım" olarak adlandırılmış, ABD' de ve AB ülkelerinde yaygınlaşmış, ülkemizde ise yeni kullanılır hale gelmiştir. Hassas tarım olarak adlandırılan tekniklerin kullanılması ile gübre veriminin sağlanması, tarımsal zararlılara (yabani ot, zararlı haşere vb.) karşı kimyasal madde kullanımından tasarruf edilmesi, dron ve GPS(Global Positioning System) gibi farklı teknolojilerden faydalanılarak minimum insan gücü ve minimum kaynak kullanımı ile maksimum ürün verimliliği amaçlanmaktadır. Tarım arazilerinde fazla kullanımı çevre kirliliğine neden olabilecek kimyasalların ihtiyaca yönelik tespiti ve uygulanması, tarım alanlarının yeteri kadar sulanması, toprak analizi ile eksik toprak besin maddelerinin verilmesi sayesinde tarımsal arazilerin sürdürülebilirliği mümkün olacaktır. Bu çalışmada; Hassas tarım uygulamalarında kullanılan bilişim teknolojilerinin geliştirilip yaygınlaşması, söz konusu teknolojiye ulaşılabilirliğinin artırılmasında inovasyoun teknolojik durumu incelenmiş ve irdelenmiştir.*

Innovation in Precision Agriculture Applications

Keywords	Abstract
Precise Agriculture, Smart Technology, Productivity	*As the world population increases, food consumption also increases in direct proportion. This necessitated agricultural production to be made more efficient. The inclusion of agricultural lands in urban settlements and their opening to development has led to a gradual decrease in agricultural lands. Unconscious irrigation and use of chemical fertilizers to increase agricultural production efficiency have made agricultural lands unusable. Agriculture, which emerged in the early 1990s with the idea that information technologies could be applied to agriculture and included smart technology applications, was called "precision agriculture", became widespread in the USA and EU countries, and has just become used in our country. Ensuring fertilizer efficiency by using techniques called precision agriculture, saving on the use of chemicals against agricultural pests (weeds, pests, etc.), using different technologies such as*

drones and GPS (Global Positioning System) to maximize maximum productivity with minimum manpower and minimum resource usage. product efficiency is aimed. Sustainability of agricultural lands will be possible through the need-oriented detection and application of chemicals, the excessive use of which may cause environmental pollution in agricultural lands, adequate irrigation of agricultural fields, and the supply of missing soil nutrients through soil analysis. In this study; The technological status of innovation in the development and dissemination of information technologies used in precision agriculture applications and in increasing the accessibility of the technology in question has been examined and examined.

1. GİRİŞ

Dünyada hassas ve akıllı tarım uygulamaları gittikçe yaygınlaşmaktadır. Türkiye, Amerika Birleşik Devletleri, Almanya ve Hollanda bu uygulamalrda önemli yer tutmaktadırlar. Sözü geçen ülkelerin tarım üretiminde ilk sıralarda yer almaları tarımda teknolojiyi çok iyi bir şekilde kullanmaları ile mümkün olmuştur. Hassas tarım uygulamalarının ne kadar önemli olduğunu, Türkiye'de Konya ili kadar bir yüzölçümü olduğu halde günümüzde dünya tarımında 80 milyar Euro ihracata sahip olan Hollanda'ya bakarak anlayabiliriz (Yüksel ve Meral, 2020). Şekil-1 hassas tarım uygulamalarındaki süreçlere bir örnek olarak gösterilebilir.

Şekil 1. Hassas tasarım uygulamalarındaki süreçlere bir örnek (Yüksel ve Meral, 2020)

Günümüzde ilaçların ve gübrelerin insan sağlığına olumsuz etkileri bilinmektedir. İnsan sağlığının yanı sıra gerektiğinden fazla kullanılan ilaç ve gübreler toprak kirliliğine neden olmaktadır. Fazla sulama yapmak da fazla ilaçlama ve gübreleme gibi toprağın kullanılamaz hale gelmesine neden olabilir. Gelişen teknoloji tarım sektöründe de kullanılmakta, üretimi ve insan sağlığını olumsuz etkileyen tarımsal yanlışları engelleyebilmek için güçlü bir alternatif olmaktadır.

Sonuç olarak hassas tarım, tarımsal üretim ve işletmede; hem ekonomik hem de doğa kirliliğinin azalmasını amaçlayan metotdur (Tekin ve Sındır, 2006). Hassas tarım; yeni

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teknolojiler ışığında üretilen bilgiler ve bu bilgiler sayesinde üretilen yeni araçlar sayesinde geliştirilmiştir. Hassas tarımın bileşenleri; küresel konum belirleme sistemi (GPS), coğrafi bilgi sistemleri (Geographic Information Systems(GIS)), ürün izleme aletleri, bitki, toprak ve yabancı ot sensörleri, uzaktan algılama ve değişken düzeyli uygulama (Variable Rate Application(VRA)) şeklindedir.

2. KÜRESEL KONUM BELİRLEME SİSTEMİ

Hassas tarımın gelişmesindeki en önemli olay 1990 'lı yıllarda ortaya çıkan; Küresel Konum Belirleme Sistemi (Global Positioning System: GPS) olmuştur. GPS sistemi ile herhangi bir zaman diliminde, herhangi bir konumu belirlenebildiği görülmüştür (Brase, 2005; Aktaran ve Türkmen, 2015).

Hassas tarım kapsamında, hangi bölgede ne kadar verim elde edildiği GPS yardımı ile hasat esnasında belirlenip kayıt altına alınabilir ve GPS verilerinden elde edilen sonuçlara göre hasat edilen ürünün biyokütlesi ile elektromanyetik tarama yardımı ile toprakların verimleri karşılaştırılabilir. Toprağın daha verimli bir hale getirilmesi, topraktaki yabancı ot ve zararlıların engellenmesi gibi tarımsal üretim konularında HT yöntemleri ve araçları kullanılabilir. Mesela üreticiler, trafik sistemlerini kontrol etmede, sırt oluşturmada ya da önceki yıllarda yapılan ekim ve ilaçlamanın aynı yerlerde yapılmaması ve verimi artırmak için ekim ürünlerini yıllara göre sıralama konularından GPS yönteminden yararlanabilir. Yine zirai ilaç kullanımlarının sonuçlarını ve değişik ürünlerin, farklı alanlarda ne kadar verim getirdiğini tespit etmek adına verim haritaları oluşturularak bir sonraki yılın performansının artırmak için değerlendirmeler yapılabilmektedir. Ucuz olmayan ilaç, tohum gibi girdilerin yerli yerinde kullanılması, bir alanın farklı değerlendirilmesi gereken bölümlerinin ayrılması gibi hususlar da Hassas Tarımın amaçları arasında sıralanabilir (Türker , Akdemir, Topakcı, Tekin, Ünal, Aydın, Özoğul ve Evrenosoğlu, 2015). Şekil-2 toprağın kalite dağılımını göstermek için yapılan bir çalışma örneğidir.
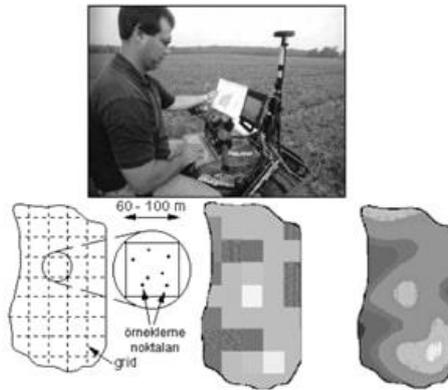
Şekil 2. Toprağın kalite dağılımını göstermek için yapılan bir çalışma örneği (Çorumluoğlu, Kalaycı ve Ceran, 2007)

3. COĞRAFİ BİLGİ SİSTEMLERİ

Coğrafi Bilgi Sistemleri (Geographic Information Systems); yer, mekân ve insan ile ilgili coğrafi dataların yeryüzündeki gerçek referansları ile beraber veri tabanında toplanması, bunlar üzerinde amaca yönelik farklı analizlerin gerçekleştirilmesi ve sonuçların grafikler, harita ve tablo şeklinde görüntülenmesi için dizayn edilmiş olan bir bilgisayar sistemidir (Fitzpatrick, 2000; Aktaran ve Ballı, 2021)

Coğrafi bilgi sistemlerinin ana işlevlerini gerçekleştirebilmesi için 5 ana başlığın birlikte bulunması gerekmektedir. Bahsi geçen bu ana başlıklar, bütününde coğrafi bilgi sistemlerini de

oluşturan; insanlar, yöntemler, yazılım, donanım ve veridir. (Türkmen, 2015). Şekil-3'de ilgili çalışma görünmektedir.

Coğrafi bilgi sistemleri hassas tarımı oluşturan en önemli unsurlardan birisidir. Hava durumu, mevcutta bulunan su kaynaklarının durumu, toprağın ve toprağın altındaki kayaçların durumu vb. konularda muhtevası geniş veri tabanı oluşturulması ve oluşturulan veri tabanındaki veriler aracılığı ile amaca uygun unsurların kullanılması yine coğrafi bilgi sistemleri ile mümkün olabilmektedir.

İmal edilecek Coğrafi bilgi sistemleri için GPS alıcıları sayesinde çok az yer kaplayacak bir bilgisayar ile farklı özellikte verilerin yer aldığı konum içeren enformasyonlar elde edilebileceği gibi, uzaktan algılamada entegre bir şekilde faydalanabilmek adına yer doğrulama bilgileri ile beraber bir araya getirilecek konum bilgilerinin elde edilmesi söz konusudur. Bütün bunlar haricinde, tarımsal alanların doğruluk payı yüksek, matematiksel haritalandırmalarının da oluşturulması mümkün olabilmektedir. GPS yöntemi ile, anında, zor olmayan ve doğruluk payı yüksek bir şekilde tarımsal alanın, matematiksel haritalandırılmasının oluşturulması, hassas tarımın tarımsal alanda ihtiyaç duyacağı ana konum bilgilerini oluşturma bağlamında da epey gereklidir (Çorumluoğlu, Kalaycı, ve Ceran, 2007).

CBS yöntemi sayesinde tarımsal ekonomi sahasında da birçok çalışma gerçekleştirilmesi mümkün olabilmiştir. Tarımsal alanın yapısının ve ürün yelpazesinin belirlenmesi, farklı yatırım türleri için ideal alanların hangi kısımlar olacağının tespit edilmesi, farklı işletme türlerinden ideal işletme türünün saptanması, muhtemel çevresel problemlere karşı alınabilecek önlemlerin sıralanması, tarımsal üretimle ilgilenenlerin nüfus yapılarının tespit edilmesi, tarımsal üretimi yapanların ve söz konusu ürünleri tüketenlerin niteliklerinin belirlenmesi, hane halkının demografik yapısının saptanması, üretici ve tüketici profilinin belirlenmesi, kırsal turizm varlıklarının neler ve hangi bölgelerde olduğunun tespit edilmesi, aktif olarak çalışan sanayi bölümlerinin satış potansiyellerinin saptanması, farklı tarımsal ürünleri ile ilgilenenlerin profillerinin çıkarılması, o bölgede ilk defa üretilen ürünlerin pazar alanlarının bulunması ve satış yöntemlerinin geliştirilmesi için sosyoekonomik ağın belirlenmesi, elde edilen bilgilerin hangi konularda kullanılacağının belirlenmesi, taşınmaz varlıkların kıymetlerinin belirlenmesi, taşınmaz varlıkların kıymetini azaltan ya da artıran etmenlerin belirlenmesi, tarım sigortaları muhtevasındaki arazilerin ve elde edilen ürünlerin belirlenmesi gibi çalışmalar gerçekleştirilebilmektedir (Akça ve Esengün, 2003).

2015 yılında Türkmen'in Eskişehir'de yapmış olduğu çalışmada, alandaki 300 noktadan toprak örneği alınmış ve analizi yapılarak su doygunluğu, verimi, kireç değerleri, organik madde içeriği vb. özelliklerine göre CBS yardımıyla haritalandırılmıştır.
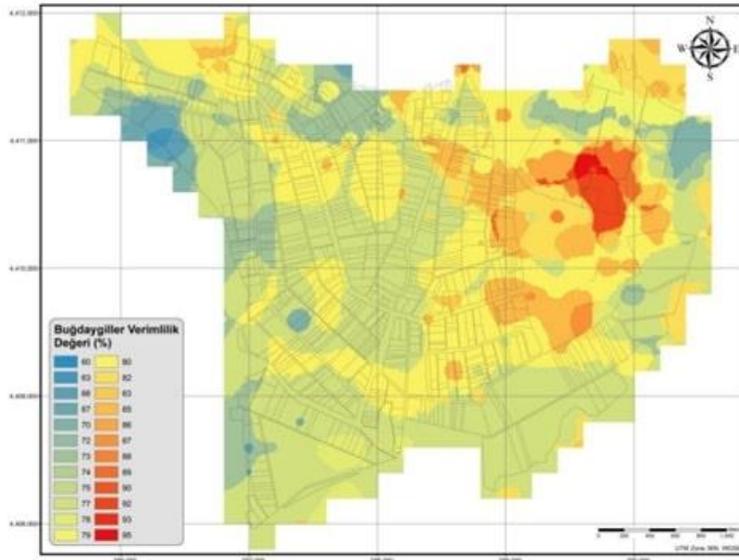
Şekil 3. Buğdayların çalışama alanında hangi yerlerde daha verimli olduğunu gösteren örnek bir çalışma (Türkmen, 2015)

Söz konusu çalışmada örnek alınan noktalardan oluşturulan değerlendirmeler kullanılarak sayısal haritalar üretilmiş ve bu tahmin haritaları sayesinde hangi buğday türünün, hangi bölgede daha verimli bir şekilde üretilebileceği tespit edilmiştir. Ağırlıklı çakıştırma (weighted overlay) analiz yöntemi kullanılarak toprak verimliliği etkileyen unsurların değerlendirilmesi yapılmak istenmiş, literatürde yapılan bir çalışma olmadığı için bütün unsurlar eşit ağırlıklı kabul edilmiş ve değerlendirme yüz puan üzerinden oluşturulmuştur.

Söz konusu çalışmaya göre elde edilen sonuç haritada toplam 1268 hektar çalışma alanının buğday ekimi için % 3.15'i (39.80 hektar) az verimli, % 80.08'i (1015.47 hektar) orta verimli, % 15.45'i (195.93 hektar) iyi verimli ve % 1.32'i (16.80 hektar) yüksek verimli olarak hesaplanmış olup, buğday ekim planı bu verilere göre hazırlanarak verim en üst düzeye çıkarılabilir.

4. BİTKİ, TOPRAK VE YABANCI OT SENSÖRLERİ

Tarım makinelerine ve tarımsal araçlara sensörler yerleştirerek tarımsal üretimin her katmanında, üretim boyunca makinelerin ve araçların birbiri ile temas halinde olması sağlanabilmektedir. Bahsi geçen donatılar sayesinde üreticilerin tarımsal alanlarda kullanmaları gereken su miktarı, zirai ilaç ve gübre miktarı belirlenebilmektedir. İklim koşulları, bitkinin ihtiyaç duyduğu besin ve mineraller, ekilecek yerin durumu, ideal hasat vakti vb. unsurlar değerlendirilerek ve bu konuda ayrıntılı veriler elde edilerek üretimin en verimli seviyeye ulaştırılması amaçlanır. Sonuç olarak, tarımsal üretim gerçekleştirenlerin; sensörler ve sensörlerden elde edilen bilgilerin değerlendirildiği akıllı teknoloji araçları sayesinde bütün üretim alanını kontrol altında bulundurmaları ve arazinin takibini gerçekleştirebilmeleri, insan gücünü ve üretim için gerekli tüm malzemelerin ekonomik bedellerini en az seviyeye çekerek hem kaliteli hem de nicelik olarak fazla ürüne sahip olma fırsatına erişebilmeleri mümkün olabilmektedir (Kılavuz ve Erdem, 2019).

Sensörler toprak sıcaklığı ve nemi, topraktan farklı seviyelerde bağıl nemin ve hava sıcaklığının belli zaman aralıklarıyla ölçülmesini sağlar. Son yıllarda çok farklı tarım sensörleri(duyarga) icat edilmiştir. Toprak nem sensörlerinin geliştirilmesi aşamasında yapılan gözlemlerde söz konusu donatıların kullanılması durumunda su tasarrufuna neden olunduğu buna karşılık elde edilen verimde bir azalma olmadığı tespit edilmiştir. Nötron saçılma yönteminin maliyetinin fazla olması, tecrübeli eleman istihdamını ve fazla güvenlik önlemi alınmasını gerektirmesi ve

benzeri toprak nem sensörlerinin de maliyetinin fazla olması, üreticilerin tercih etmemesinin nedenlerinden olduğu belirlenmiştir. Bu sebeple bu donatıları kullanmadan önce üretim ortamına göre şekillendirilmesi amacıyla kalibrasyon yapılması ve sayısal sonuçların yapılacak kalibrasyon baz alınarak değerlendirilmesinin uygun olacağı önceki araştırmaların bir sonucudur (Karaca, Tekelioğlu ve Büyüktaş, 2017)

Yabani otların tespit edilip önlem alınması için tasarlanmış sensörler de bulunmaktadır. Bu sensörler; yabani otların varlığını belirler ve bu verileri bilgisayardan aldığı direktifler doğrultusunda açma-kapama yöntemine göre çalışan uygulama kısmına iletmektedirler. Böylece yabani otun varlığı hissedildiği andan itibaren, alanda bulunan yabani ota yönelik herbisit uygulaması yapılabilecek ve yabani otların olduğu bu bölgelere uygulanabilecektir (Çavuşoğlu ve Kitiş, 2014).

Zamanımızda pek çok yabani ot sensörleri satışa çıkarılmıştır. Tian ve arkadaşları; Yabani otun bulunduğu bölgeleri, doğruluk payı yüksek bir şekilde saptayan yabani ot sensörü ve yabani otlarla mücadele etmek için tasarlanmış ilaçlama sistemi icat etmişlerdir(Titan ve ark., 1999). Purdue Üniversitesi, Medlin ve arkadaşları tarafından icat edilen çok amaçlı görüntüleme sistemi (PUMIS) kullanılarak mısır bitkisi ile yabani otların ayrımı gerçek zamanlı olarak yapılabilmiş ve sistem tarafından yapılan ilaçlama hedefe tam olarak ulaşmıştır (Medlin ve ark, 2003). Feyaerts ve Gool 2001 yılında, bir çalışma yapmış ve bu çalışmada çok işlevli görüntüleme sistemi sayesinde tarımsal alandaki yabani otları belirlemişlerdir. Geliştirilen donatılar ve algoritmalar yardımı ile kültür ve yabani ot ayrımı yapılmasında % 86 gibi bir rakamla başarılı olunmuş, sistemsel yabani ot ilaçlanmasında ise hedefe yönelik % 90 oranda yabani otlarda azalma meydana gelmiştir. LaMastus ve arkadaşları homojen bir şekilde büyüyen bitkilerde yabancı otların belirlenmesi amacıyla çok bantlı (4 bant) kamera sistemi kullanmıştır (LaMastus ve ark, 2000). Sonuç olarak yetiştirilen bitki türüne ve yabani ot çeşitlerine göre % 69-88 oranında doğruluk payı kazanılmıştır. Varner ve ark. 2000 yılında, soya bitkisinin aralarında kazık otu yetiştirmiş ve uzaktan algılama yolu ile bu bitkileri tanımlamayı denemişlerdir. Uzaktan algılama yolu ile elde edilen bu görüntülerde, kontrollü bir şekilde sınıflandırma yaparak % 78- 86 doğruluk seviyesinde yabani otları tespit etmişlerdir (Güler ve Kara, 2005).

Görüntülerin aslı gerçekliğinde tespit edildiği görüntü sensörleri ve bitki gelişimi aşamalarını elektronik ortama geçirmeyi hedefleyen lidar sensörler, maddeler arasında ısı farklılıklarını ölçen ve bu ısı farklarına göre sınıflandıran termal sensörler, Ultraviolet Radaition A(UVA) dalga boyunda yansıma ölçebilen multi spektral ve hiperspektral sensörler kullanılmaktadır. Nitekim UVA dalga boyu yansımalarını ölçebilen sensörlerin daha fazla kullanıldığı bilinmektedir (Türkseven ve ark., 2016). Şekil-4 toprağın nemini ölçen ve yetersiz olduğu durumlarda uyarı veren bir bitki sensörü göstermektedir.

Şekil 4. Toprağın nemini ölçen ve yetersiz olduğu durumlarda uyarı veren bir bitki sensörü

5. UZAKTAN ALGILAMA

Uzaktan algılama, bir nesne ile temas kurmadan, bu nesnenin nicelik ve nitelik özellikleri hakkında bilgi sahibi olmak olarak tanımlanır. Bunun için hava fotoğrafları, radarlar, çeşitli yer gözlem-ölçüm platformları ve uydular kullanılır (Uzun, 2010).

Uzaktan algılama teknikleri; tabiatta gerçekleşen pek çok farklılıkları, anında ve doğruluk payı yüksek bir şekilde tespit edilmesini sağlamaktadır. Daha çok alanların farklı olarak değerlendirilmesi için, alanlardaki bitkilerin tespit edilebilmesi için, tarımsal arazilerin saptanmasında ve hasat veriminin öngörülmesinde, mera, ormancılık, jeoloji, erozyon takibi, toprak, madencilik alanlarında yaygın olarak kullanılmaktadır. Söz edilen alanlarda, uzaktan algılama sayesinde var olan değerlerin tespit edilmesini ve yine uzaktan algılama yöntemi ile bu değerlerin haritalandırılmasını sağlamaktadır (Çavaş, 2007).

Hassas tarımda, uzaktan algılamanın kullanıldığı yerler;

- Tarımsal ürünün tespit edilmesi
- Tarımsal ürünün değişimini takip etme
- Tarımsal üretim hasat veriminin öngörülmesi
- Tarımsal üretimde meydana gelebilecek zararların saptanması
- Tarımsal alandaki toprağın nemini ve toprağın türünü belirleme, türlere göre tanımlanması
- Tarımsal aktivitelerin organize edilmesi
- Tarımsal alanın kontrol altında bulundurulması
- Tarımsal sigortadır (Tunca, 2014).

Uzaktan algılamanın çalışma biçimi; yerküredeki bütün varlık veya unsurların farklı dalga boylarındaki elektromanyetik radyasyonu aksettirme ya da iletmedeki farklılıklarının, bu varlık ve unsurların saptanmasında kullanılması esasındadır. Böylece yerküredeki bütün varlık ve unsurların değişik elektromanyetik enerji dalga boylarına karşı yaptığı tepkime kendine has olacağı için hepsinin farklı bir parmak izi olur. Mesela, çevremizde algıladığımız renkler esasında, varlıkların kendilerine ait niteliklerinden ötürü elektromanyetik enerjinin gözle görünür dalga boylarının bulunduğu elektromanyetik çeşitlilik bölgesindeki dalga boylarının birazını absorbe ettikten sonra aksettirdiği bölümüne verilen adlardır. Bunun gibi, bitkilerin yapraklarında bulunan klorofil maddesinin elektromanyetik radyasyonun mavi ve kırmızı dalga boylu enerjilerinin çoğunu absorbe etmesi nedeni ile yeşil dalga boyunu fazlaca aksettirir ve sonuç olarak bitkiler yeşil olarak algılanırlar. Bitkilerin; hassas tarım uygulamalarında ister görünür dalga boyları olsun isterse de kızıl ötesi dalga boylarındaki elektromanyetik enerjinin her zamanki aksettirme özelliklerine kıyasla değişiklik göstermesi halinde, bitkinin su tutma durumu, sağlıklı olup olmadığı, besine ihtiyaç duyup duymadığı gibi başlıklar üzerinden son durumunun tespiti, sadece çok bantlı ve değişik vakitlerde oluşturulan uzaktan algılama görüntüleri ile imkân dahilindedir (Çorumluoğlu ve ark., 2007).

6. DEĞİŞKEN DÜZEYLİ UYGULAMA (VRA)

Önce kararsız (örneğin arazide bulunan yabancı otlar), sonra girdiler (örneğin herbisit, alev, lazer, vb.) tespit edildikten sonra bu kararsızlık göz önüne alınarak gerekli alanlara, gerekli niceliklerde müdahale edilmesine değişken düzeyli uygulama denir (Çavuşoğlu ve Kiriş, 2014). Hassas tarım; gelişmiş teknolojiler yardımı ile tarımsal alanın tümüne uygulanan bilindik sabit düzeyli uygulama yöntemleri yerine, alanın az bir kısmına ait toprak ve bitki niteliklerinin (topraktaki su miktarı, topraktaki bitki besin elementlerinin seviyesi, toprak muhteviyatı, tarımsal ürün halleri, verim, vb.) tespit edilmesi yöntemiyle değişken düzeyli uygulamayı baz almaktadır (her bir alanda gerektiği düzeyde gübre veya zirai ilaç uygulanması, değişik derinliklerde toprak işleme, farklı normlarda ekim, değişik seviyelerde sulama ve drenaj)

(Tekin ve Sındır, 2006). Değişken girdi uygulaması için öncelikle değişkenlik belirlenmeli ve bunlar kullanılmak üzere nicelikli hale getirilmeli ve uygulamadaki değişkenliğe neden olan unsurlar belirlenmelidir. Sorunların ortadan kalkması için yapılması ön görülen yöntemler doğru bir şekilde belirlenmeli ve seçilen uygulamanın ekonomik sonuçları detaylı bir şekilde araştırılmalıdır. Değişken girdi uygulamasında seçilecek prosedür ve metotlar net bir şekilde ekonomik olarak kar elde edilmesi yönünde olmalıdır (Üngör ve Akdemir 2016). Son olarak günümüz teknolojisinde artık akıllı robotik uygulamalarda mevcuttur (Soygüder ve Alli, 2011; Soygüder ve Alli, 2012; Soygüder et al, 2015; Soygüder et al, 2010¸ Soygüder ve Abut, 2015; Soygüder ve Abut, 2022; Soygüder ve Abut, 2019; Soygüder ve Alli, 2010; Soygüder ve Alli, 2010).

7. SONUÇ

Hassas tarım teknolojilerinden faydalanmak isteyen üreticiler, üretimin başında gelişime açık ve birbirleri ile uyum sağlayacak teknolojilerin birini ya da ikisini kullanarak ilerleyen zamanlarda bütün bu teknolojilerin üzerine imar edebileceği tümden bir uygulamayı kanıksaması doğru olacaktır. Bu sebeple, hassas tarımın uyarlanabileceği, zamandan ve paradan tasarruf sağlayacak veya çevre yönetimini geliştirebilecek ve tarımsal deneylerin düzenlenebileceği farklı birçok kullanım yönteminin var olduğunu anımsamak gereklidir. Hassas tarım teknolojisi gelişim/geliştirilme aşamasındadır. Tarımsal bilgilerin kaydedilmesi, takibinin yapılması, bu bilgiler doğrultusunda hareket edilmesi hassas tarımın en önemli yöntemidir. Bu çalışmada; sudan, gübreden, insan gücünden tasarruf edilebilecek, çevre kirliliğini azaltabilecek, sürdürülebilirliği sağlayabilecek hassas tarım teknolojilerinin geliştirilebilmesi ve söz konusu teknolojilere ulaşılabilirliğin artırılması milli kazanım bakımından öemli bir gereklilik olduğu sonucuna varılmıştır.

Çıkar Çatışması: Yazarlar, bu araştırmayla ilgili herhangi bir çıkar çatışması bulunmadığını beyan ederler.

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KAYNAKÇA

Abut, T., & Soygüder, S. (2015, May). Motion control in virtual reality based teleoperation system. In 2015 23nd Signal Processing and Communications Applications Conference (SIU) (pp. 2682-2685). IEEE. doi: https://doi.org/10.1109/SIU.2015.7130441

Abut, T., & Soyguder, S. (2022). Two-loop controller design and implementations for an inverted pendulum system with optimal self-adaptive fuzzy-proportional–integral–derivative control. Transactions of the Institute of Measurement and Control, 44(2), 468-483. doi: https://doi.org/10.1177/01423312211040301

Abut, T., & Soyguder, S. (2019, September). Sliding Mode Control of the Haptic-Teleoperation System Based on a Real and Virtual Robot. In 2019 International Artificial Intelligence and Data Processing Symposium (IDAP) (pp. 1-7). IEEE. doi: https://doi.org/10.1109/IDAP.2019.8875990

Ballı, Y., & Bağdatlı, C. (2021). İç Anadolu bölgesinde şebekeden deşarj edilen atıksu miktarlarının yıllar bazındaki değişim seyri ve coğrafi bilgi sistemleri (CBS) yardımıyla mekansal analizi (Master's thesis). Nevşehir Hacı Bektaş Veli Üniversitesi. http://hdl.handle.net/20.500.11787/6400

Çavaş, G. (2007). Uzaktan algılama sistemleri yardımı ile hassas tarım uygulamaları ve Türkiye'de uygulama olanakları Accurate agriculture practices with the help of remote detection

systems and practice possibilities in Turkey (Master's thesis). http://dspace.trakya.edu.tr/xmlui/handle/trakya/222

KİTİŞ, Y., & ÇAVUŞOĞLU, O. (2016). Elektromanyetik Işınlarla Yabancı Ot Kontrolü. Meyve Bilimi, 3(1), 29-36. https://dergipark.org.tr/tr/pub/meyve/issue/19546/208123

Çorumluoğlu, Ö., Kalaycı, İ., & Ceran, M. B. (2007). Bilgi Toplumlarinda Modern Tarım Yaklaşımı: Hassas Tarımda Uydu Ve Bilgi Sistemi Teknolojileri (GPS, Uzaktan Algılama ve CBS). https://www.researchgate.net/publication/270274701_Bilgi_Toplumlarinda_Modern_Tarim_Yaklasimi_Hassas_Tarimda_Uydu_Ve_Bilgi_Sistemi_Teknolojileri_GPS_Uzaktan_Algilama_ve_CBS

Güler, M., & Tekin, K. A. R. A. (2005). Hassas Uygulamali Tarim Teknolojisine Genel Bir bakiş. Anadolu Tarım Bilimleri Dergisi, 20(3), 110-117. https://dergipark.org.tr/en/pub/omuanajas/issue/20234/214257

Karaca, C., Tekelioğlu, B., & Büyüktaş, D. (2017). Sürdürülebilir tarımsal üretim için toprak nem sensörlerinin etkin kullanımı. Academia Journal of Engineering and Applied Sciences, 2, 33-41. https://www.researchgate.net/publication/321832018_Surdurulebilir_Tarimsal_Uretim_icin_Toprak_Nem_Sensorlerinin_Etkin_Kullanimi_Efficient_Use_of_Soil_Moisture_Sensors_for_Sustainable_Agricultural_Production

KILAVUZ, E., & Erdem, İ. (2019). Dünyada tarım 4.0 uygulamaları ve Türk tarımının dönüşümü. Social Sciences, 14(4), 133-157. https://dergipark.org.tr/en/pub/nwsasocial/issue/49791/511386

Korkmaz, D., Akpolat, Z. H., Soygüder, S., & Alli, H. (2015). Dynamic simulation model of a biomimetic robotic fish with multi-joint propulsion mechanism. Transactions of the Institute of Measurement and Control, 37(5), 684-695. doi: https://doi.org/10.1177/0142331214565710

Soyguder, S., & Alli, H. (2012). Computer simulation and dynamic modeling of a quadrupedal pronking gait robot with SLIP model. Computers & Electrical Engineering, 38(1), 161-174. doi: https://doi.org/10.1016/j.compeleceng.2011.11.007

SOYGUDER, S., & ALLI, H. (2010). Dynamic model and fuzzy-pd type control of four-legged quadrupedal robot with a pronking gait. In Mobile Robotics: Solutions and Challenges (pp. 567-574). doi: https://doi.org/10.1142/9789814291279_0069

SOYGUDER, S., & ALLI, H. (2010). Fuzzy logic control of a hexapod robot with bounding gait. In Emerging Trends In Mobile Robotics (pp. 509-516). doi: https://doi.org/10.1142/9789814329927_0063

Tekin, A., & Sındır, K. O. (2006). Tarımsal Üretimde Hassas Tarım Uygulamaları. XI Türkiye'de Internet Konferansı, 21-23.

Tunca. (2014). Uzaktan Algılamanın Tarımda Kullanımı ve Uydu Verileri Tabanlı Vejetasyon İndeksi Modelleri ile Tarımsal Kuraklığın Takibi ve Değerlendirilmesi, Geçit Kuşağı Tarımsal Araştırma Enstitüsü, Gıda Tarım ve Hayvancılık Bakanlığı sunumu.

Türker, U., Akdemir, B., Topakcı, M., Tekin, B., Ünal, İ., Aydın, A., Özoğul, G., Evrenosoğlu, M. (2015). Hassas Tarım Teknolojilerindeki Gelişmeler, Türkiye Ziraat Mühendisliği VIII. Teknik Kongresi.

Türkmen, E. (2016). Hassas Tarım Uygulamalarında Coğrafi Bilgi Sistemleri Kullanımı (Doctoral dissertation). Anadolu University, Turkey.

Uzun, B. (2010). Fotosentetik aktif radyasyon ölçümlerinde LED ve fotodiyotların hassas tarım açısından kullanılabilirliği üzerine bir araştırma. https://dergipark.org.tr/en/download/article-file/1543466

Üngör, M. G., & Akdemir, B. (2016). Meyve bahçeleri için değişken miktarlı tarımsal girdi uygulama programının geliştirilmesi. Journal of Agricultural Faculty of Gaziosmanpaşa University (JAFAG), 33(Ek Sayı), 143-151. https://dergipark.org.tr/en/pub/gopzfd/issue/65806/1024240

Yüksel ,A., Meral, A. (2020). Hassas Tarımda CBS (Coğrafi Bilgi Sistemleri), UA (Uzaktan Algılama), GPS (Küresel Konum Belirleme) ve İHA (İnsansız Hava Araçları) Teknolojilerinin Kullanımı. Tarımda Yenilikçi Yaklaşımlar, Sürdürülebilir Tarım ve Biyoçeşitlilik, İksad Publishing House, 173-195. https://www.researchgate.net/publication/348768181_HASSAS_TARIMDA_CBS_COGRAFI_BILGI_SISTEMLERI_UA_UZAKTAN_ALGILAMA_GPS_KURESEL_KONUM_BELIRLEME_ve_IHA_INSANSIZ_HAVA_ARACLARI_TEKNOLOJILERININ_KULLANIMI

The Effect of Semi-Conductor Analogue Electronic Technology on the Development of Other Science Areas

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Keywords	Abstract
Semiconductor, Diode, Transistor, Chip, Technology	*In this study, a brief analysis of the semiconductor era, the development of science and technology, made of semiconductor germanium, silicon and other materials was made. It is seen that analog electronics, which is used as a basic technology, contributes greatly to the development of other fields of science. In other technologies developed depending on this basic area, the pyramid structure is given according to the signal processing techniques and the order of development. Design techniques have been added to this pyramid depending on the signs used by the systems. The designs of the systems are generally determined according to the signal processing techniques, and the processes for modelling, simulation and standard production are determined. In this, system design techniques signal processing techniques, testing, durability, and stages until the production stage are defined together.*

1. INTRODUCTION

There have been many important developments and inventions in science over the last century. However, no invention of the semiconductor has been as influential as the diode and transistor. The diode and transistor did not radically change electronics and other related sciences and technologies. The transistor, the active part of electronic circuits, was invented in 1947 by John Bardeen and Walter Brattain of the William Shockley team at the Bell Telephone Research Laboratories (Jaeger & Blalock, 2016). The team received the Nobel Prize in 1956 for their work. Jack Kilby and Robert Noyce produced the microchip, the next stage of the transistor, from semiconductor for the first time in 1959 (Jaeger & Blalock, 2016). Thus, the packaging of semiconductor transistors entered a new stage. This stage is the placement of a large number of transistors in a small volume and a new breakthrough in the field of circuit systems. The development of this microchip technology has led to a very significant technological change in the field of circuits and systems. This very significant development accelerated the development of electronics and then computers and all other electronic systems. This technological change has forced some of the other fields of science to change and has influenced some other fields of science.

The first application of the semiconductor transistor was in 1953 when Texas Instruments produced radios (Jaeger & Blalock, 2016). Thus began the semiconductor world or the Ge-Si era. The production of Ge-Si Microchips led to a revolutionary development in the electronics industry. The main ones are the production of computers using semiconductor chips, the production of semiconductor logic gates and the digital electronics era. The production of many different memories such as RAM and ROM designed by these logic gates and then the production of microprocessors as chips can only be counted as the main ones. This new digital technology and computer technology has affected and continues to affect all kinds of business areas. This semiconductor technology and science has entered every field of industry. Chips continue to spread rapidly in our daily lives. Today, they are being further developed and used for different purposes, even in humans or people consisting of biological structures. It is estimated that they will be used much more widely in bio-hybrid systems in the coming years. Perhaps the materials from which the chips are made are nowadays obtained not only from Ge-Si but also from many other elements. But the end goal is the same. In the future, the Ge-Si era will soon be replaced by quantum chips. Because it is given in many open sources that they are working intensively in these areas. The quantum era will close an era in technology and science and start a new era. Therefore, we think that quantum systems or chips are very important.

Technology Level

In this study, it has been tried to determine the current state of use and the trend of the technology as a forecast for the future, which is basically produced from electronic science and technology. For this purpose, the systems were evaluated according to their signaling characteristics in general. While making this evaluation, only very basic features were considered. These include the signal used by the system, the basic structure of the system and the design technique. On the other hand, the marking used in the design, model checking and testing for mass production, and then certification procedures to obtain a production permit were considered.

Analog Technology (AT)

Analog systems or technologies form the basis of today's technologies. The general meaning of this is that all systems that do not use digital signals are called analog systems. The area where it is very commonly used is more commonly used as analog electronics. However, if it is evaluated as the signal it produces or uses, it would not be wrong to use it as the name given to large and small systems that produce or process analog signals. The biggest negative aspect of these analog systems is that the signal used is the use of the same signal continuously from one end to the other. As a result, continuous amplification and filtering noise is very effective (Jaeger & Blalock, 2016).

Digital Technology (DT)

It is used as the name given to systems that process or generate digital signals. In these systems, while the digital signal leaves a system or unit, the signal itself is regenerated. The signal produced in analog systems, or the signal itself entering the system is used without being renewed or reproduced as the original. In this respect, digital systems have advantages over analog systems. However, the negative aspects of these systems are the delay time delays are very high. Working at very high frequencies creates problems or work. With analog systems, they operate at higher frequencies (Jaeger & Blalock, 2016).

Hybrid Systems Technology (HS)

Hybrid systems are dynamic systems consisting of the combination of many different systems. There are many examples such as automobiles, electric-gasoline, gasoline-LPG, gasoline-LPG-electric (Grossman, Nerode, Ravn & Rischel, 1993).

Process Control (PC)

Process control systems are systems built to meet the needs of industry. These systems are based on classical logic and analog electronics (King, 2016).

Operation Control Technology (OT)

Operation control technologies are systems developed for the needs of industry. While the beginning of these systems consisted of analog electronics and classical logic systems, today all kinds of technologies suitable for the purpose are used (Gubbi, Buyya, Marusic & Palaniswami, 2013).

Information Technology (IT)

Information systems are systems that developed after the invention of computing systems. Today, they are widely used in every field (Fox, 2020). It represents the development of software-based systems, especially those that developed after operational technology.

Internet of Things (IoT)

It is known as the Internet of Things or "Industry 4.00". The purpose of these systems is to minimize the human resources working in the sectors, to increase productivity to the highest level, and to reduce costs to the lowest level (Tripathy & Anuradha, 2019).

Cyber Physical Systems (CPS)

Cyber physical systems are a combination of many systems (Lee and Seshia, 2017). Europeans refer to a sub-section of CPS as IoT. However, the US does not set any limits for CPS. Therefore, it can consist of many different systems, large and small. Robots working in a group in a factory and all robots working in the factory are good examples of these. Again, more than 2000 systems used in passenger airplanes and all electronic systems in automobiles are current examples of this field (Alur, 2017).

Systems of Systems (SoS): SoS are systems that are composed of many independent systems. They can operate both independently and in concert with other systems, or they can operate as a single system. An example is the control of intercontinental missiles with nuclear warheads. Where the missile passes over land, it is controlled by radar systems on land, at sea it is controlled by ship radars, in the air it is sometimes controlled by aircraft radars, and again by applications. Each system is controlled independently and receives feedback. All systems in the system of systems are combined and controlled in a single system structure (Jamshidi, 2009).

Modelling and Simulation (MS)

Modeling is the definition of mathematical system equations of a system or the definition of mathematical ratios for the work to be used appropriately (Birta and Arbez, 2007). Simulation is the operation of these mathematical relations, time base, and frequency plane or ratio equations by computer in the appropriate plane to be used. The more realistic the ratio equations are organized, the more accurate the results are. In other words, simulation results are obtained depending on the success of the mathematical equations (Kinser, 2022).

Model Checking (MC)

It is the testing of the finished product or model with a large number of variables using model logic techniques. This testing process consists of a structure depending on the variables used in

the product. For example, testing a passenger airplane is very different from testing a smartphone. Their variables are also different (Baier and Katoen, 2008).

Reliability Engineering and Testing Certification Process (RE)

RE engineering is the final testing process performed by manufacturing organizations before a finished product is tested for conformity
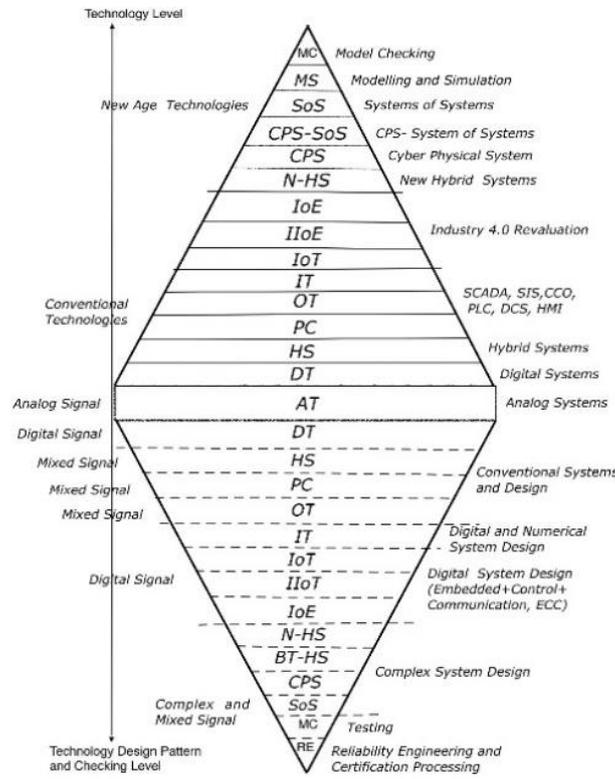
Figure 1. Analog electronics-based systems, signals, and classification

to standards. This is the stage before official corporate production authorization is obtained (Kapur, and Pecht, 2014). In figure 1, all fields of science and engineering have developed and are developing completely dependent on the development of analog electronics.

2. CONCLUSION

In this study, the contribution and development of semiconductor analog electronics to other fields of science is given in historical order. While making this ranking, other fields of science and technology produced from analog electronics, which is the basic technology, are also given. The basis of analog electronics is Semiconductor science. In the development of this science, semiconductor electronic components (diodes, transistors, FETs, etc.) and chips are produced from the combination of physics, materials, chemistry, machinery, and many other fields. In the next 25 years, we expect very serious developments in quantum science and quantum technologies. This will lead to the commercialization of quantum computers, quantum computing systems, quantum communication systems, quantum electronics and quantum chips. This will open up new horizons in science and technology and usher in a new era. The next industry will be called the "quantum era" or industry 6.00. The next developments will be in the field of quantum biology and artificial synthetic biology in the field of biology. In this period, everything will be produced in organic form. This period will be called the "biology era".

Conflict of Interest

The author declare that there is no conflict of interest.

Contribution of Authors

Abdurrahman HAZER: Wrote the manuscript and contributed at all stages of the article.

Remzi YILDIRIM: Performed the experiments and analyze the results. Wrote this manuscript.

REFERENCES

B.K. Tripathy, J. Anuradha, (2019). "Internet of Things (IoT)", CRP Press 2019 https://www.routledge.com/Internet-of-Things-for-Things-and-by-Things/Chaudhuri/p/book/9781032401829

Baier, C., & Katoen, J. P., 2008. "Principles of model checking". MIT press. https://books.google.com.tr/books?id=5dvxCwAAQBAJ&printsec=copyright&redir_esc=y#v=onepage&q&f=false

E. A. Lee and S. A. Seshia, (2017) "Introduction to Embedded Systems - A Cyber-Physical Systems Approach", Second Edition, MIT Press. https://books.google.com.tr/books/about/Introduction_to_Embedded_Systems.html?id=MgXvLFE7HIgC&redir_esc=y

Fox, R., (2020). "Information Technology: An Introduction for Today's Digital World". CRC Press. https://www.routledge.com/Information-Technology-An-Introduction-for-Todays-Digital-World/Fox/p/book/9780367820213

Grossman R. L., Nerode A., Ravn A.P., Rischel H., (1993, October). "Hybrid Systems", Sprinder-Verlag doi: https://doi.org/10.1007/3-540-57318-6

Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M., (2013). "Internet of Things (IoT): A vision, architectural elements, and future directions". Future generation computer systems, 29(7), 1645-1660. doi: https://doi.org/10.1016/j.future.2013.01.010

Jaeger, R.C., Blalock, T.N. (2016, March). "Microelectronic Circuit Design Fifth edition", MCGraw Hill. https://books.google.com.tr/books/about/Microelectronic_Circuit_Design.html?id=XqtZCgAAQBAJ&redir_esc=y

Jason Kinser, 2022, "Modeling and Simulation in Python", Green Tea Press. https://allendowney.github.io/ModSimPy/

Kapur, K. C., & Pecht, M., 2014. "Reliability engineering" (Vol. 86). John Wiley & Sons. https://www.google.com.tr/books/edition/Reliability_Engineering/RHMJEAAAQBAJ?hl=tr&gbpv=1&dq=Reliability+engineering&pg=PA183&printsec=frontcover

King, M., (2016, July). "Process control: a practical approach". John Wiley & Sons. DOI:10.1002/978047097656

L. G. Birta, G. Arbez, (2007). "Modelling and Simulation", Springer. doi: https://doi.org/10.1007/978-1-84628-622-3

Mo Jamshidi, (2009). "Systems of Systems Engineering: innovations for the 21st century", J. Wiley and Sons https://www.google.com.tr/books/edition/Systems_of_Systems_Engineering/YvxUon2vAfUC?hl=tr&gbpv=1&dq=Systems+of+Systems+Engineering:+innovations+for+the+21st+century&pg=PA33&printsec=frontcover

Rajeev Alur, (2017). "Principles of Cyber-physical Systems", MIT Press https://www.google.com.tr/books/edition/Principles_of_Cyber_Physical_Systems/cPrKEAA AQBAJ?hl=tr&gbpv=1&dq=Principles+of+Cyber-physical+Systems&pg=PA6&printsec=frontcover

Using Space Syntax to Analyze the Location of the Central Library A Comparative Study Between Designed and Cumulative Universities

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Keywords	Abstract
space syntax, designed universities, cumulative universities, Central Library location	*The research dealt with the study of the location of the central library within the urban structure of universities, due to the importance of the central library, and the fact that it stands on top of other libraries, as well as that it represents the backbone of the university institution. The current research aims to verify the suitability of the library's location for its function, and whether there is a difference between the two types, one designed and the other accumulative in design. In order to achieve the goal of the research, ten samples of universities were selected as a case study for this purpose, and their plans were analyzed and the properties of the space installation were measured for each of them using space syntax analysis. we conclude that the designed universities showed better results for the location of the library and its relationship with the complete complex, as it showed that choosing the location of the library was appropriate for its function. We can also conclude that there are no significant differences between the universities in terms of the location of the library, and that the additions made to the universities that have grown cumulatively did not significantly affect their initial design.*

1. INTRODUCTION

Given the importance of the central library, and being on top of other libraries, as well as being the backbone of the university institution, and the most important supporting buildings for colleges and educational institutions, and by reviewing the history of universities to select the case studies, it became clear that there are two types designed and accumulative growth, So the research aims to verify the suitability of the library's location for its function, and whether there is a difference between the two types, to achieve the goal of the research, ten samples were selected from universities of different sizes, designs, and locations around the world, as case studies.

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This research provides a look into the spatial properties of the library's location were plans analyzed and the characteristics of the spatial structure measured for each of them using the space syntax analysis, and then the results of the analysis were compared to reach the final conclusions and to answer the research question.

2. UNIVERSITY DEFINITION

The university is a source of knowledge of the world, and manpower with high skills for professions in the whole world, and it differ in their functions, goals, mission, programs, qualifications required for faculty members, criteria for accepting students, duration of study, and the type of certificate they grant (Assié-Lumumba, 2005; Alemu, 2018).

2.1 Types of Universities

The university can be classified into two categories: (Abbas, 2011)

1. The integrated type: the location of the university is intertwined with the fabric of the city, so it is limited. In this category, the university mainly provides academic facilities, while it depends partially or entirely on the housing and service facilities provided by the city.
2. The campus type: In this class, all academic and residential university facilities, as well as service facilities, are combined together within one integrated site, and these universities are often outside cities, and are not in centers due to the difficulty of providing sufficient space for all these facilities. The research dealt with the first type of universities for study.

2.2 University Environments

The university environment is the place through which science and academic knowledge are acquired, training and rehabilitation is received, skills are developed, and all activities and events are practiced, And peaceful coexistence among members of society. There are three systems of the university environment that work together and cannot be separated from each other (Al-Jumaili, 2012)

1) The first pattern: This is the spread of the specialized and public educational spaces of the university on the site with a central gathering of the public auxiliary spaces.

2) The second pattern: This is a dispersed community of colleges independent of each other and separate teaching departments. Each department is unique in its educational and service spaces, administrative structures, and other recreational spaces.

3) The third pattern: in which the educational spaces and public assistance are linked together by an urban organization.
From what was mentioned above, it can be said that there are universities that are designed, that is, the basic design idea of their campus follows one of these three patterns. It may move from one style to another depending on the places where these changes occur and the way the buildings are connected and their relationship with each other.

2.3 Campus Planning Patterns

The urban patterns of the campus structure can be determined depending on the quality of the internal structure of the university and the characteristics of its constituent elements, spaces and their relationship with the surroundings. The internal structure of the campus complex can be

divided into seven types (Grid, Linear, Central, Central-Multi, Radial, Organic, irregular geometry) (Calvo-Sotelo, 2014). From this classification, it is clear that the diversity and changes in the patterns of the urban structure of the university campus, which may be in accordance with the requirements of place and time, and the variables of social and economic life, etc., The current research does not focus on a specific planning pattern for the university campus, given that the planning pattern does not affect the relationship of the buildings with each other, "the functional connection of all parts of the campus by virtue of their presence within one university campus" (Altalib & Aljaberi, 2017), as important as the fact that these planning patterns are designed or cumulative in growth.

3. DEFINITION OF THE UNIVERSITY CENTRAL LIBRARY

The university central library is not a place where sources of information such as books, periodicals, etc. are collected, but it is more important and comprehensive than this concept. The university central library embodies a message that is to serve university education and scientific research, by supporting curricula and courses, developing the ability to obtain information, and developing and advancing scientific research (Al-Shawani, 2020)

3.1 Library Location at The University

The library has a great priority in the university, as it can be said that it is the most used building among the university buildings. The researcher (Al-Dabbagh, 1993) points out that choosing the right place for the library is of great importance, especially when constructing a building for it, because this place has a major role in its activity and its success in attracting readers and the important characteristics of an effective library site are (Accessibility which means ease of access, Centralization which reinforces the importance of the library as a symbol of education and makes it a dominant building on the site, Legibility which means distinctive location of the library, as well as its clear entrance, and its location within other auxiliary spaces such as the student club, the cafeteria, and the great hall, which are often organized around an open space in the center of the university, confirm the generality of the use of these buildings).It is clear from the foregoing that the library, in order to function efficiently and effectively, must achieve the characteristics mentioned above, and to achieve these characteristics, the site must be designed.

4. SELECTED UNIVERSITY AS CASE STUDIE

4.1 History of Universities

By reviewing the historical file of a group of universities, we found that there are universities whose campuses were designed from the beginning with the determination of their future expansion, while there is another group that was cumulative in its future growth and expansion. Five universities were chosen for both types (designed and Cumulative) as study cases.

5. METHODOLOGY

Space syntax refers to a group of space configuration analysis techniques (Spatial Configuration), and the set of theories that link space with society, as researchers were able to link the spatial Configuration to where people are, how they move, how they decorate and adapt

space, and how they talk about it, and thus allow the interpretation of space phenomena from a social point of view (Hillier, 2014). The Space Syntax method works with three basic elements: the axial line, the convex space, and the isovist field. The main idea of these basic space elements is that humans move in lines, interact in convex spaces, and see changing scenes when moving around the built environment this tools can understand space shapes by converting space layout into a series of defined spaces, lines of sight, and visual locations.

The analysis of Configuration properties includes the following analyzes: convex space analysis, axial analysis, and visual analysis (van, 2011). Except squares, most urban public space (streets, roads, paths, avenues, pavements, or boulevards) is linear. Therefore, we can represent each spatial element of the street network as an axial sightline which indicates the movement paths. The axial map represents the maximum optical kinetic extension of any point in one dimension, as it consists of the least number of straight lines that cover all the system (van Nes & Yamu, 2021).

Connectivity is a local measurement that aims to determine the relationship between each street with the other streets that directly adjacent to it. The high value means it contains many connections with the streets that are directly connected to it, while the low value means it contains the fewest connections (Hillier& Hanson, 1984) Integration is a measurement that aims to 'predict' the pedestrian movement in the street and determined whether it is dense or segregated (Ozbek et al, 2014). As there is a relationship between the presence of people and integration, a high value of integration means the presence of a large number of people in the space, while a low value of it means the absence of people and the space is more isolated and private (Dettlaff, 2014).

Control is a local measure that depends on the relations between space and the spaces directly neighboring to it. Control value means the degree to which a space access to these spaces. A high value means strong control and density of pedestrians, while a low value means little control and isolation. (Lamprecht, 2020).

6. RESULTS

The differences between the designed and accumulative universities were examined by using Depthmap. The results of the analysis showed that the library location in the designed universities is as follows: The value of integration (Global measurement) is very high for four universities and relatively high for one university. As for the value of connectivity (Local measurement), it was very high for three universities and medium for two. The control value (Local measurement) was very low for three universities and medium for two (Fig. 1, table 1)

The results of the analysis showed that the library location in the cumulative universities is as follows: The value of integration (Global measurement) is very high for four universities and relatively high for one university. As for the value of connectivity (Local measurement), it was high for one university, medium for two universities, and low for the other two universities. The control (Local measurement) was low for three universities, medium for one university, and high for the other university (Figure 2, table 2).

Table 1. (Integration, Connectivity, Control) Value for designed universities

	Designed Universities	Variables	Library Location	Maximum	Minimum	Mean
1	Qatar University	Integration	2.12	2.12	0.57	1.345
		Connectivity	21	21	1	11
		Control	2	9.7	0.39	5.045
2	Princess Noura University	Integration	0.926	1.01	0.432	0.721
		Connectivity	13	15	1	8
		Control	4.2	5.15	0.25	2.7
3	University of Baghdad	Integration	0.84	0.84	0.366	0.603
		Connectivity	4	5	1	3
		Control	1.29	3.366	0.16	1.763
4	University of Kufa	Integration	1.01	1.62	0.31	0.965
		Connectivity	12	19	1	10
		Control	3.78	7.29	0.25	3.77
5	University of Iowa	Integration	3.36	3.56	1.1	2.33
		Connectivity	20	34	1	17.5
		Control	4.6	11.6	0.1	5.85

	Designed Universities	Integration	Connectivity	Control
1	Qatar University			
2	Princess Noura University			
3	University of Baghdad			
4	University of Kufa			

| 5 | University of Iowa | | | |
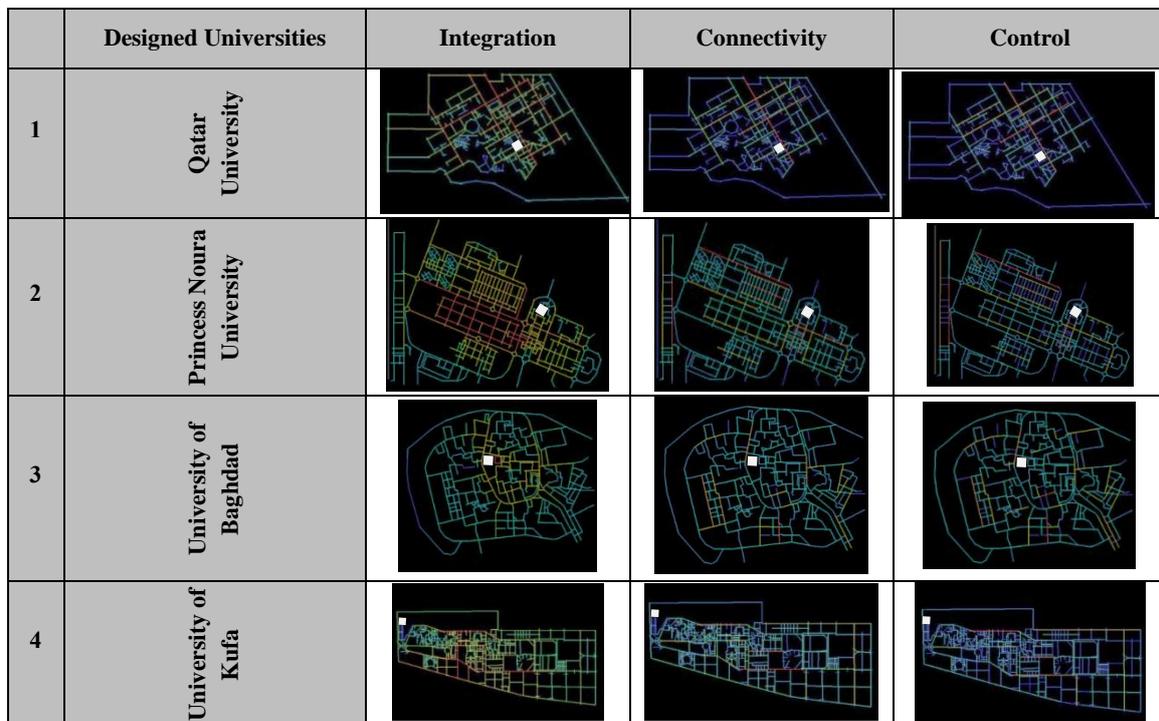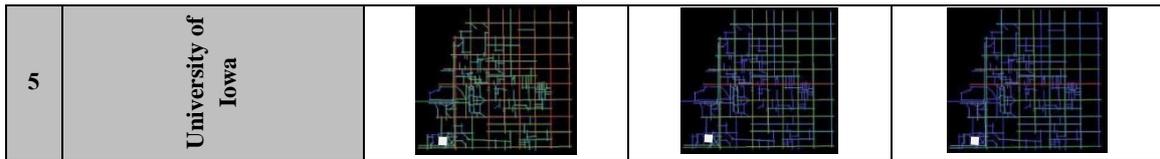
Figure 7. Global integration & local (connectivity, control) axial analysis by using depthmap

Table 2. (Integration, Connectivity, Control) Value for cumulative universities

	Cumulative Universities	Variables	Library Location	Maximum	Minimum	Mean
1	University of Mosul	Integration	1.125	1.272	0.357	0.8145
		Connectivity	13	15	1	8
		Control	3.26	4.97	0.11	2.54
2	Weber state university	Integration	0.566	0.869	0.36	0.6145
		Connectivity	6	15	1	8
		Control	1.6	6.16	0.14	3.15
3	University At Albany Uptown Campus	Integration	1.154	1.191	0.45	0.8205
		Connectivity	16	27	1	14
		Control	4.8	10.6	1	5.8
4	SJSU Timeline University	Integration	2.37	2.5	0.9	1.7
		Connectivity	11	21	1	11
		Control	4.8	8.44	0.09	4.265
5	University of Miami	Integration	1.44	1.9	0.57	1.235
		Connectivity	6	18	1	9.5
		Control	1.11	8.46	0.30	4.38

	Cumulative Universities	Integration	Connectivity	Control
1	University of Mosul			
2	Weber state university			
3	University At Albany Uptown Campus			
4	SJSU Timeline University			

5	University of Miami			
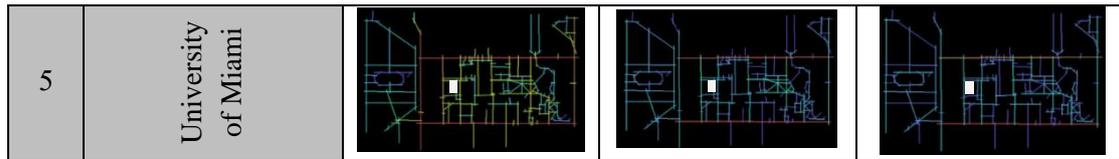
Figure 8. Global integration & local (connectivity, control) axial analysis by using depthmap

7. CONCLUSIONS

The results of the analysis showed that the library site integration is high for all universities, and from this we conclude that the library site represents the destination for the university where there are a large number of people. But the value of the integration of the library site in the designed universities is higher than that of the cumulative universities. With regard to connectivity, the results showed that the designed universities have relatively high connectivity, which means that the library site is contains many connections with the streets that are directly connected to it. As for control, the results showed a low value for most universities and for the two types, which means that accessibility and pedestrian density from neighboring sites are low. Accordingly, we conclude that the designed universities showed better results for the location of the library and its relationship with the complete complex, as it showed that choosing the location of the library was appropriate for its function. We can also conclude that there are no significant differences between the universities in terms of the location of the library, and that the additions made to the universities that have grown cumulatively did not significantly affect their initial design.

Conflict of Interest

Authors declare that there is no conflict of interest.

Contribution of Authors

Shaymaa Kh. Abdulqader: Conceived and designed the analysis; Collected the data; Wrote the paper. Eman Kh. Al-Moula: Data analysis & Wrote the paper. Noor Y. Al- Tamer: Data analysis.

REFERENCES

Abbas, Z., E. (2011) " Visual chaos of the formal order of the university buildings: Case study- University of Technology ", Iraqi Journal of Architecture, Volume 7, Issue 22-23-24. (Arabic)

Al-dabbagh, A., H. (1993), "Characteristics of spatial relations between university buildings and their impact on student movement", a thesis as part of the requirements for obtaining a master's degree in Architectural Engineering, University of Technology, Baghdad. (Arabic)

Alemu, S., K. (2018) "The Meaning, Idea and History of University/Higher Education in Africa: A Brief Literature Review", FIRE: Forum for International Research in Education, Vol. 4, Iss. 3, 2018, pp. 210-227. doi: https://doi.org/10.32865/fire20184312

Al-Jumaili, S., K., (2012) "The effect of organizing the university environment on increasing its efficiency and directing economic resources", Journal of Planning and Development, Issue 25, Institute of Urban Planning and Regional for Postgraduate Studies, University of Baghdad. (Arabic)

Al-Shawani , S., A. (2020) "The Central Library of Chahrimu University: a field study of its problems and ways to solve them", Journal of Literature Al-Rafidain, Issue 80. (Arabic)

Altalib, T.,H. & Z., O. (2017) " Construction Policies on Campus An Analytical Study of the Policy of Construction Planning on Kufa Campus", Journal of Engineering, Volume 23 June 2017, p8. (Arabic)

Calvo-Sotelo, P. C. (2014) "From typological analysis to planning: modern strategies for university spatial quality", CIAN-Revista de Historia de las Universidades, 17(1), p.44-47. https://e-revistas.uc3m.es/index.php/CIAN/article/view/1968

Dettlaff, W. H. (2014), "Space syntax analysis - methodology of understanding the space", PhD interdisciplinary Journal, vol. 1, p.288, https://www.academia.edu/45350775/Space_syntax_analysis_methodology_of_understanding_the_space

Hillier, B., (2014) "Spatial Analysis and Cultural Information: The Need for Theory as Well as Method In Space Syntax Analysis", In :Paiou, E., Lieberwirth, U., Polla, S.(Eds.), Inter Disciplinary Approaches to the Interpretation of Pre Historic and Historic Built Environments, De Gruyter, Boston, p19. doi: https://doi.org/10.1515/9783110266436.19

Hillier, B.; Hanson, J. (1984) "The Social Logic of Space"; Cambridge University Press: Cambridge, UK, p103

Lamprecht, M. K. (2020) "PEDESTRIAN MOVEMENT AND SPACE SYNTAX MEASURES. THE EXAMPLE OF THE CITY CENTRE IN ŁÓDŹ, POLAND". Studia Miejskie, 37, p32. http://cejsh.icm.edu.pl/cejsh/element/bwmeta1.element.ojs-doi-10_25167_sm_2087/c/2087-3134.pdf

Ozbek, M., Gulec, Ozer, D. (2014), "Spatial Integration and Accessibility Considering Urban Sustainability Patterns: Historical Islands of Istanbul" The Sustain-able City IX (2 Volume Set), WIT Press, p1651, doi: https://doi.org/10.2495/SC141402

van Nes, A., (2011) "The One - and Two Dimensional Isovoists Analysis in Space Syntax", Exploring the Visual Landscape: Advances in Physiognomic Landscape Research in the Netherlands, Delft University Press, Netherlands, vol. 2, p166, doi: https://doi.org/10.7480/rius.2.211

van Nes, A., Yamu, C. (2021) "Analysing Linear Spatial Relationships: The Measures of Connectivity, Integration, and Choice. In: Introduction to Space Syntax in Urban Studies", Springer, Cham, p36. doi: https://doi.org/10.1007/978-3-030-59

Global and Local Robot Navigation Combination for Mobile Robot Obstacle Avoidance

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Keywords	Abstract
Mobile robot navigation, local path planning, global path planning, Adaptive Neuro-Fuzzy Inference System, dynamic obstacle avoidance.	*Nowadays, robots can be seen in different areas of life. Mobile robots can perform tasks that are too risky for a human. An essential issue in the mobile robot was addressed: driving the robot until it reaches its destination. A combination of global and local mobile robot navigation has been proposed to address the challenge of dynamic obstacle avoidance. A-star is utilized to discover an initial way between the and goal points. The ANFIS model is called when the obstacle is near the mobile robot to anticipate the collision. There are three inputs and two outputs in the adaptive neuro-fuzzy inference system. The inputs include the angle, distance, and relative speed between the mobile robot and any obstacles. The outputs are recommendations for a mobile robot's steering angle and speed. According to the simulation findings, the model can avoid static and moving obstacles in a static known environment. The proposed system achieves avoiding multiple obstacles. Compared with recent research, the proposed model shows the enhancement in path length, speed, and time required for mobile robot traveling.*

1. INTRODUCTION

Robot applications have spread widely and clearly in many applications (Anaz et al., 2023), where we can see robots in agricultural, industrial, and domestic applications. For this reason, the technologies used in robotics are developing remarkably and clearly, and these technologies depend significantly on the robot's applications. For example, the techniques used in robots that operate indoors are different from the technologies used in robots that operate outdoors. There are many common technologies, even if the applications are different. One type of robot is the mobile robot. Autonomous mobile robots can be defined as robots that can move from one point to another without human guidance when there is information about the surrounding environment or part of it available(Chatterjee et al., 2013). There are two categories for mobile robot navigation.

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The global and local navigation (Yosif et al., 2021). A-star (A*) is One of the well-known algorithms that is used to find the path between two points in a static environment and the absence of dynamic obstacles(Duchoň et al., 2014).The A* is used by(Guruji et al., 2016) for mobile robot path planning, where the robot moves toward the target. As soon as it reaches a critical distance from the obstacle the controller calls the algorithm to find the path from the current position to the goal. The author in (Shahad M.Majeed, 2021) used A* to find the shortest path from start to goal with the help of image processing. The researchers in (Al-Arif et al., 2012) compare Dijkstra and A* algorithms and found that A* consumes less processing time. The work in (Hernández and Giraldo, 2018) compares A* and PRM, whereas A* finds a shorter path RPM. There are many techniques used for mobile robot local navigation, one of these methods is the Adaptive Neuro-Fuzzy Inference System (ANFIS). This method combined fuzzy logic, which has a fast response, and neural networks, which are characterized by accurate results. The authors (Singh et al., 2009) suggested ANFIS makes a decision when the obstacle becomes very near to the robot. The ANFIS has four distance inputs from the robot to the obstacle in various orientations. whereas ANFIS suggests a mobile robot steering angle to avoid the obstacle. the authors (Pandey et al., 2016) introduced mobile robot navigation using ANFIS but for a static environment only. The distance between the robot and the obstacle is the input for ANFIS, and the output is a recommended steering angle for the mobile robot. (Gharajeh & Jond, 2020) use the ANFIS to avoid obstacles in the path of the mobile robot, whereas there are three inputs represented by distance on the right, left, and front of the mobile robot. The output is the steering angle suggested by ANFIS to avoid obstacles. The same idea was introduced by (Samadi Gharajeh and Jond, 2022) The input of ANFIS is three distance sensors and the output is the steering angle of a mobile robot, In this paper, we took the advantage of the two types of navigation and this let us to combine the two types of mobile robot navigation. The initial path is generated by using the A* algorithm. The benefit from the second type is avoiding dynamic obstacles which pose a danger to the robot within the path that we found through global navigation.

2. PROPOSED METHOD

The first step in mobile robot navigation is reading the environment around the mobile robot. Defining the locations of stationary obstacles in the environment is known as reading the environment. The environment reading contains the positions of the start and target points. The A* algorithm is used to find the initial path between two points to avoid static obstacles. The ANFIS is called if the dynamic obstacle becomes close to the mobile robot. The proposed method includes two main parts. The first one is the generation of a path (initial path) between the target and the first point. The second one is the dynamic obstacle avoidance stage. Figure 1 includes the main parts of the proposed system.
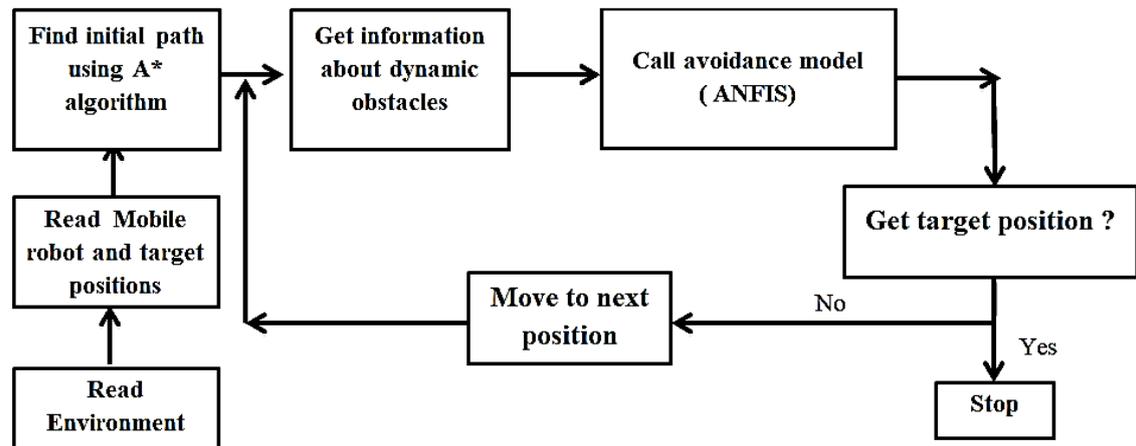
Figure 9. Proposed system

2.1 A* Algorithm

The problem of mobile robot path planning is still a research challenge, especially for an autonomous mobile robot. The question is answered through path planning " how should I get to where I am going ", there is no mention of time in path planning (Gasparetto et al., 2015). A* is a heuristic algorithm that finds the shortest path between two points. A* is found from the Dijkstra algorithm(Yosif et al., 2022). Robotics and video games employ the A* algorithm to determine the route between two locations in a two-dimensional space. The heuristic property of A* can be achieved by the fitness function declared in the following :

$$f(n) = g(n) + h(n) \tag{1}$$

Whereas g(n) is the total cost from the start point to the current point, and h(n) is the cost from the current point to the target point. Figure 2 explains the basis of the A* algorithm. The A* algorithm provides a shorter path length and requires less time when compared to the RRT algorithm.
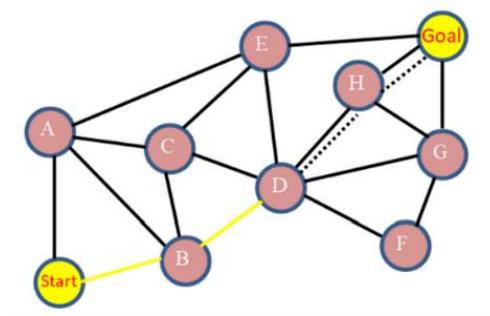
Figure 2. A* path planning example

2.2 Adaptive Neuro-Fuzzy Inference System (ANFIS)

The Adaptive Neuro-Fuzzy Inference System (ANFIS) combines Fuzzy logic and Neural networks. Whereas the rules of fuzzy logic are trained as a neural network. The ANFIS has multi inputs but one output (Gharajeh and Jond, 2020). Takagi-Sugeno fuzzy inference system combined with an artificial neural network to form ANFIS(Shafiullah et al., 2022). The Adaptive Neuro-Fuzzy Inference System consists of five layers in addition to input and output layers (Chen and Chang, 2018). The following figure 3 shows the main layers of the ANFIS system. The proposed model includes three inputs and two outputs. At the ANFIS input side, there are three inputs which are represented by angle, distance, and relative speed, all these

criteria are between mobile robot and obstacle(s). The output of the model is two attributes which are represented by the suggested new mobile speed and steering angle. Figure 4 describes the ANFIS-suggested model.
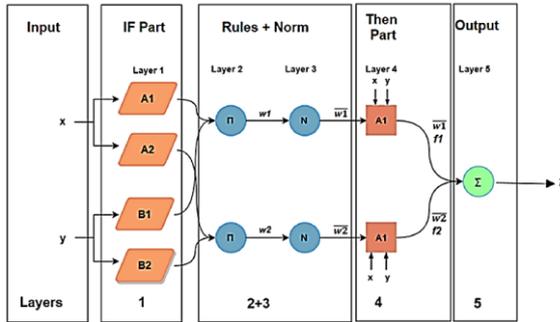
Figure 3. Structure of ANFIS model with two inputs(Armaghani and Asteris, 2021)
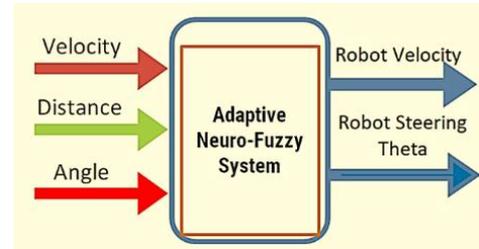
Figure 4. ANFIS proposed system

Five memberships have determined for each of the inputs and outputs, the rule can be generated by training a 5000 data record data set. The robot's velocity, distance from obstacles, and angle with those obstacles are the first three of each data row's five parts; the remaining two items are the two gANFIS outputs. The data ranges include an angle from -90 to 90, and distances from 1 to 120 cm, speeds from 1 to 50 cm/sec. the same ranges for output speed and angle. Three major sections make up the data set. The first part includes 4000 records. these records are used for training the ANFIS model. The remaining parts are subdivided into two parts, 500 samples for validating the model and another 500 records for testing. The test error for speed training is 0.7128, the validation error is 0.9582, and the speed training error is 1.0266. Here, Gaussian membership is employed. The test error is 3.93, the cross-validation error is 3.08, and the angle training error is 1.766. Figures 5 and 6 depict training, testing, and inspection. Figure 7 displays the ANFIS block diagram.

(a) Training speed

(b) testing speed

(c) checking speed
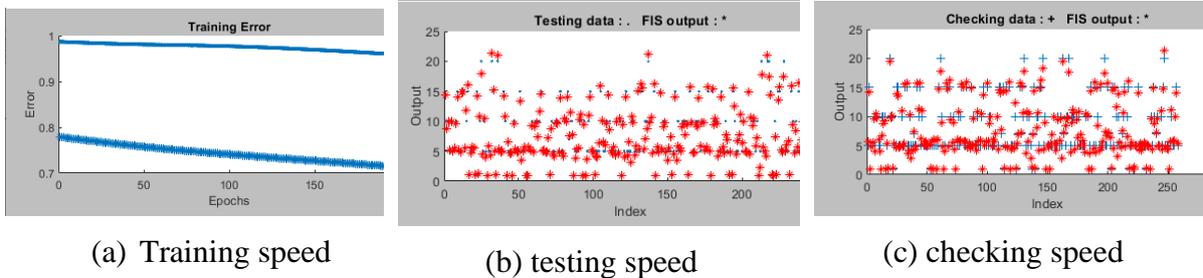
Figure 5. **A**daptive neuro-fuzzy systems model for mobile robot speed

(a) Training Steering Angle

(b) Testing steering Angle

(a) Checking steering Angle
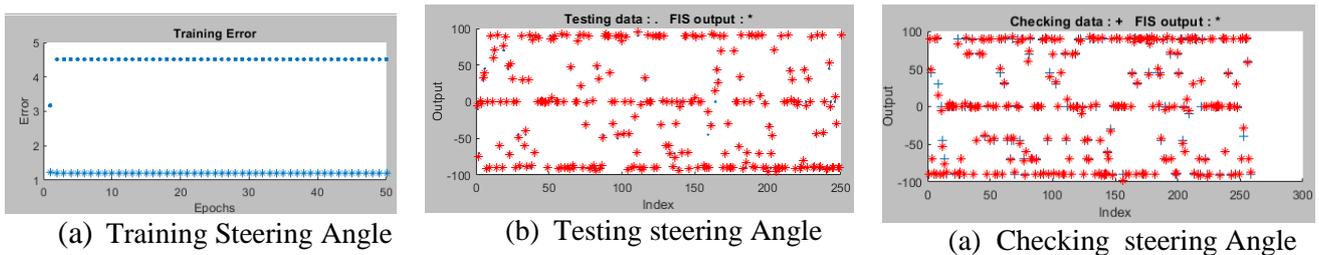
Figure 6. Adaptive neuro-fuzzy systems model for mobile robot steering angle
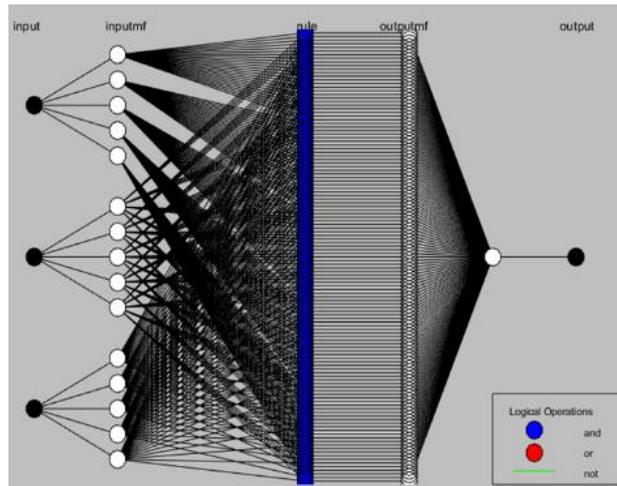
Figure 7. Adaptive neuro-fuzzy systems model block diagram

3. RESULTS AND DISCUSSIONS

The proposed environment dimension is 500 X 500 cm. each centimeter is represented by 1 pixel, therefor the area dimension in the simulation workspace is 500 X 500 pixels. Two types of environments have been proposed, the first type is the free environment which has dynamic obstacles only with no static obstacles. The second type of environment has both static and dynamic obstacles. Three dynamic challenges are presented in Scenario 1. The mobile robot and its path are in the direction of the first and second dynamic obstacles. The initial obstruction has a -150-degree angle. The angles of obstacles 2 and 3 are -37° and -90°, respectively. The mobile robot begins avoiding it at point A in Figure 8 and returns to the path at point B. The mobile robot is traveling away from obstacle 2 once it reaches the beginning path at point B. Another obstacle (obstacle 3) is advancing toward the mobile robot as it goes from point B. The third obstacle is facing the mobile robot and is moving in a -90-degree angle. The most significant issue in this situation is the constant monitoring of the environment from point B to point C. In this instance, the mobile robot starts using the avoidance approach. The system calls the avoiding model once more, despite the mobile robot being in the avoidance strategy at a particular location C. The mobile robot resumes its starting journey at point D toward the objective after completing the third obstacle avoidance. After navigating obstacles, the robot covered 356 lengths. From start to finish, the robot needs 35 seconds. Figure 8 displays the details and traits we discovered for this situation. In terms of the locations of the mobile robot and the dynamic impediments, the second situation, which will be detailed shortly, is comparable to the first. In this scenario, the robot moves at a speed of 60 cm/sec while the dynamic obstacles move at speeds of 25 cm/sec, 25 cm/sec, and 15 cm/sec, respectively. The robot moves away from the third dynamic obstacle while it is coming directly into it in order to avoid a collision. Because the mobile robot and obstacle move more quickly than in the prior example, the steering angle is steeper than it was. The specifics of this case are shown in Figure 9. Three dynamic obstacles are part of a different scenario that is used in this situation (scenario 3). With a 35 cm/sec velocity, the initial obstacle travels toward the mobile robot from the upper right corner. The second dynamic obstacle is moving toward the mobile robot and its path at an angle of -45 degrees and a speed of 40 cm/sec. In contrast to obstacle 2, obstacle 3 is moving in the opposite direction at the same speed. The three moving objects provide a visible threat and collision risk as they reach the mobile robot. The recommended path has a length of 546 cm, and there is a 530 cm displacement between the starting point and the objective. After overcoming obstacles, the robot covered 660 meters. The robot needs 16 seconds to get from

the start of the journey to the destination. As shown in Figure 10. Table 1 lists the features of the situations. The ANFIS responds to the system in 1.3 milliseconds.
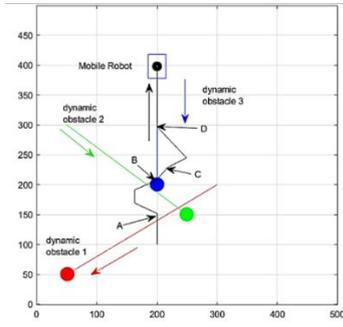
Figure 8. Three dangerous dynamic obstacles- (scenario 1)
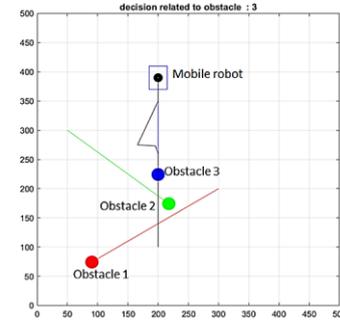
Figure 9. One dangerous obstacle and two safe obstacles, (scenario 2)
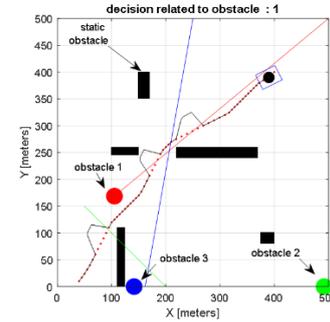
Figure 10. Environment with static and three dangerous dynamic obstacles (scenario 3)

Table 4. Characteristic of applied scenarios

Characteristic	Scenario 1	Scenario 2	Scenario 3
Initial path length using A* (cm)	300	300	546
Duration of the generate initial route (sec)	0.6	0.6	8
Direct distance from the start to the end points	300	300	530
Path length after avoidance(cm)	356	330	660
Velocity of obstacle 1 (cm/s)	9	27	35
Velocity of obstacle 2 (cm/s)	8	24	40
Velocity of obstacle 3 (cm/s)	5	14	40
Velocity of robot(cm /s)	10	60	60
Relative velocity 1 - (cm /s)	16	61	94
Relative velocity2 - (cm /s)	16	82	82
Relative velocity3 - (cm /s)	15	70	100
Time from start to goal	35	9 sec	8 sec
No of iterations	78	72	115

4. COMPARISON WITH OTHER WORK

This work is compared with another paper that includes a static environment only and the second environment contains include dynamic obstacles. The first paper used a combination of neural networks and particle swarm optimization (PSO). This work, introduced by Pandey et al., 2020, uses a feedforward neural network to suggest a steering angle for a mobile robot depending on the distance between the robot and the obstacle which is neural network input. The PSO is used to optimize the path. in comparison to our work, we get a better model in terms of path length and time response. as clear in Figure 11(a) and table
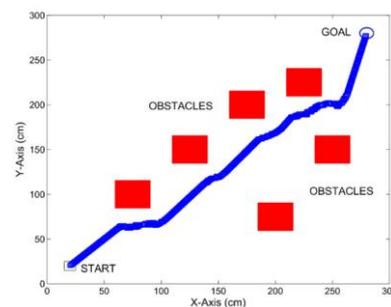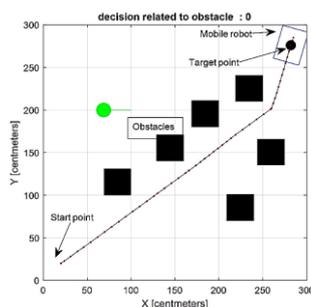
(a) Proposed method   (b) Neural network and PSO (Pandey et al., 2020)

Figure 11. Testing proposed method and Neural network –PSO (Pandey et al., 2020)

Table 2. Comparison between Neural network PSO and the proposed method

Characteristics	Neural network – PSO (Pandey et al., 2020)	Proposed method
Path length	410 cm	387 cm
Traveling Time	39 sec	10 sec
Tiem required to find the initial path	0	5 sec
Total elapsed time	39	15 sec
Path length reduction ration	6 %	
Total time reduction ration	62	

5. CONCLUSIONS

A combination of global and local mobile robot navigation has been proposed to address the challenge of dynamic obstacle avoidance. The A* is a global path-planning navigation algorithm that is used to find the initial path from the start point of a mobile robot to its target. The local path planning is represented by Adaptive Neuro-Fuzzy Inference System to avoid dynamic obstacles in the path of the mobile robot. The proposed method shows the ability to avoid dynamic and static obstacles. The main challenge is the ability to avoid more than one obstacle at the same time. The proposed method compared with the other two papers that used static and dynamic obstacles respectively, the proposed method achieved better results and performance in terms of path length, speed, and response time.

Conflicts of Interest

The authors declared that there is no conflict of interest.

Contributions of Authors

The first and second authors contributed to designing the proposed system and collecting the results. The third author corrected and revising the language, giving appropriate directions on how to write, and analyzing and discussing the results contributed to collect all the information in this paper.

REFERENCES

Armaghani, D.J., Asteris, P.G., 2021. A comparative study of ANN and ANFIS models for the prediction of cement-based mortar materials compressive strength. Neural Comput & Applic 33, 4501–4532. doi: https://doi.org/10.1007/s00521-020-05244-4 .

Chatterjee, A., Rakshit, A., Singh, N.N., 2013. Mobile Robot Navigation, in: Vision Based Autonomous Robot Navigation, Studies in Computational Intelligence. Springer Berlin Heidelberg, Berlin, Heidelberg, pp. 1–20. doi: https://doi.org/10.1007/978-3-642-33965-3_1

Chen, Y.-H., Chang, C.-D., 2018. An intelligent ANFIS controller design for a mobile robot, in: 2018 IEEE International Conference on Applied System Invention (ICASI). Presented at the 2018 IEEE International Conference on Applied System Innovation (ICASI), IEEE, Chiba, pp. 445–448. doi: https://doi.org/10.1109/ICASI.2018.8394280

Duchoň, F., Babinec, A., Kajan, M., Beňo, P., Florek, M., Fico, T., Jurišica, L., 2014. Path Planning with Modified a Star Algorithm for a Mobile Robot. Procedia Engineering 96, 59–69. doi: https://doi.org/10.1016/j.proeng.2014.12.098

Gasparetto, A., Boscariol, P., Lanzutti, A., Vidoni, R., 2015. Path planning and trajectory planning algorithms: A general overview. Motion and operation planning of robotic systems 3–27.

Gharajeh, M.S., Jond, H.B., 2020. Hybrid Global Positioning System-Adaptive Neuro-Fuzzy Inference System based autonomous mobile robot navigation. Robotics and Autonomous Systems 134, 103669. doi: https://doi.org/10.1016/j.robot.2020.103669

Guruji, A.K., Agarwal, H., Parsediya, D.K., 2016. Time-efficient A* Algorithm for Robot Path Planning. Procedia Technology, 3rd International Conference on Innovations in Automation and Mechatronics Engineering 2016, ICIAME 2016 05-06 February, 2016 23, 144–149. doi: https://doi.org/10.1016/j.protcy.2016.03.010

Pandey, A., Kumar, S., Pandey, K.K., Parhi, D.R., 2016. Mobile robot navigation in unknown static environments using ANFIS controller. Perspectives in Science 8, 421–423. doi: https://doi.org/10.1016/j.pisc.2016.04.094

Pandey, A., Panwar, V.S., Hasan, M.E., Parhi, D.R., 2020. V-REP-based navigation of automated wheeled robot between obstacles using PSO-tuned feedforward neural network. Journal of Computational Design and Engineering 7, 427–434. doi: https://doi.org/10.1093/jcde/qwaa035

Samadi Gharajeh, M., Jond, H.B., 2022. An intelligent approach for autonomous mobile robots path planning based on adaptive neuro-fuzzy inference system. Ain Shams Engineering Journal 13, 101491. doi: https://doi.org/10.1016/j.asej.2021.05.005

Shafiullah, M., Abido, M.A., Al-Mohammed, A.H., 2022. Artificial intelligence techniques, in: Power System Fault Diagnosis. Elsevier, pp. 69–100. doi: https://doi.org/10.1016/B978-0-323-88429-7.00007-2

Shahad M.Majeed, I.A.A., 2021. Path Planning with Static and Dynamic Obstacles Avoidance Using Image Processing. International Transaction Journal of Engineering Management, 12A8A: 17. doi: https://doi.org/10.14456/ITJEMAST.2021.148

Singh, M.K., Parhi, D.R., Pothal, J.K., 2009. ANFIS Approach for Navigation of Mobile Robots, in: 2009 International Conference on Advances in Recent Technologies in Communication and Computing. Presented at the 2009 International Conference on Advances in Recent Technologies in Communication and Computing, IEEE, Kottayam, Kerala, India, pp. 727–731. doi: https://doi.org/10.1109/ARTCom.2009.119

Singh, N.H., Thongam, K., 2019. Neural network-based approaches for mobile robot navigation in static and moving obstacles environments. Intel Serv Robotics 12, 55–67. doi: https://doi.org/10.1007/s11370-018-0260-2

Yosif, Z., Mahmood, B., Al-khayyt, S., 2021. Assessment and Review of the Reactive Mobile Robot Navigation. Al-Rafidain Engineering Journal (AREJ) 26, 340–355. doi: https://doi.org/10.33899/rengj.2021.129484.1082

Yosif, Z.M., Mahmood, B.S., Saeed, S.Z., 2022. Artificial Techniques Based on Neural Network and Fuzzy Logic Combination Approach for Avoiding Dynamic Obstacles. JESA 55, 339–348. doi: https://doi.org/10.18280/jesa.550306

Production Planning and Loading on CNC Machines

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Keywords	Abstract
	The most important step in a production process is the correct work flow planning. The production planning process is the creation of a plan with steps such as which goods will be produced and how much will be produced, when will be produced, what will be the capacity need, determination of the necessary machines and workforce, and the most appropriate job assignment by bringing the appropriate jobs and personnel to the machines. Today, many companies use various methods for production planning, which we divide into two as long-term planning and short-term planning. In this study, it is aimed to emphasize the importance of production planning and to do business planning correctly. The increasing competitive environment has made it necessary to plan the production correctly, which is the most important place for a company. The study was evaluated by making short-term production planning for Küçükpazarlı Aviation company, which produces machining in the aviation sector in the mainland. The current works and the qualifications of production in the enterprise were determined, and the classical method, Gantt method and Johnson method were tried. Three methods were examined and the Gantt method was chosen as the most suitable scheduling method among the methods. The aim of this study is to ensure timely delivery performance by making the right business plan of the company. The results obtained were compared and analyzed with the current classical situation in the enterprise. As a result, more successful results of the applied Gantt method in production planning than the current classical method were obtained and examined.

1. INTRODUCTION

Developing fast technology, market competitive environment affects the share of companies in the business world. One of the methods used for production planning is ERP (Enterprise Resource Planning). It is one of the requirements brought by technology. Integrating the company's data and departments into ERP will be the most important investment the company has made for the future. Corporate systems trying to adapt to developments mean commercial software packages that allow uninterrupted information flow, which reflects the physical reality and functionally available opportunities moment by moment in an environment where

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environmental conditions are constantly changing, can show the results depending on possible scenarios according to the new situation, and enable the right decisions to be taken. Fui-Hoon,F.,2002). In other words, ERP allows all components of an organization to be seen as a whole. In other words, it allows an institution to carry out its own business processes in an integrated structure, while also supporting and monitoring the part of the work that goes beyond the boundaries of the institution (Genoulaz, at all., 2005). The ERP system is an integrated software that provides a holistic perspective to all business processes of companies and creates a bridge between all business processes. This software can also be expressed as the interface associated with all units fed from a database used in all units of the company (Ehie at all, 2005). It enables the most accurate planning with the least error for short-term production planning. It is very important in this method that the data entered into the ERP system is correct.

In the study by Halil İbrahim Koruca et al., flexible workflow editor module was developed and gantt chart scheduling representation was made (Koruca at all,2010). In the study conducted by Gülçin Bektur et al., the method of assigning the workforce to the tasks, shifts and leave days with the goal programming model was made, taking into account the skills, seniority levels, preferences of the employees and the demands of the system (Bektur and Hasgül, 2013). In the study conducted by Erçin Tevfik Öztuncel, a scheduling method integrated into Uyumsoft database was used for the capacity study of the enterprise (Öztuncel, 2007). In the study conducted by Tuğçe Kaçar et al., they used a package program and Gantt method for job scheduling (Kaçar and Olgun, 2020). In the study conducted by Osman Demirdöğen and his friend, researches were made and methods were mentioned in order to be able to load the work correctly, and a study was conducted by entering the determined constraints and purpose into the WINQSB package program (Demirdöğen and Güzel, 2009).

2. PRODUCTION PLANNING

Production planning decisions include decisions such as workforce level, sequencing of production decisions, and job loading (Graves, 1999). Production planning according to the definition of APICS (American Production and Inventory Control Society); It is a function that determines the levels or limits of future manufacturing activities or quantities (Yamak, 1993). Production planning according to the definition of APICS (American Production and Inventory Control Society); It is a function that determines the levels or limits of future manufacturing activities or quantities (Yamak, 1993). Production planning performs the following functions: Using the available production resources and possibilities in the best way, carrying out the works with the least expense, reaching the desired quality and quantity in a short time and getting the most efficient result (Yelken and Demir, 1978). Production planning; It is related to many different activities such as determining the production and stock level, sequencing the processes with minimum cost, supplying the raw materials in a way that will not disrupt the production, purchasing new workbenches, commissioning additional buildings and so on (Yıldız, 2000). The processes are carried out in order and according to the details determined in the production systems. On the other hand, control initiates and supervises the processes by means of information feedback in order to achieve the goals (Alptekin, 1994).

2.1. Machine Capacity

While preparing production programs, the actual and maximum capacity of the machines in the factory should be known. Maximum capacity of a machine; It can be calculated based on measures such as working speed, durability, reliability. For example; In case of working 24 hours a day in 3 shifts and 30 days a month in an enterprise; It is seen that there is a suitable capacity of 24 x 30=720 hours/month. This capacity is only the capacity of a machine. In the enterprise, machines can work alternately in accordance with a certain production process and

workflow. If the machine works 12 hours a day and 30 days a month, the machine capacity; 12 x 30 = 360 hours/month. In this case, 720/360=2 machines are needed to do the same job. As a result, in the planning of machine capacity, the number of shifts of the enterprise determines the number of machines to be used in daily production (Ödeniyazov, 2006).

3. TECHNICS

3.1. Classic Method

This classical method, which is done completely manually, causes a high margin of error. Momentary inattention allows situations such as incorrect examination of the list.

Table 1. Order list used in the classical method

Part No	Bench	Order Opening Date	Open Quantity	Contract Term	The Shipment Date
111A532..	X	12.12.2022 00:00	22	21	21.12.2022 00:00
112A533..	X	12.12.2022 00:00	22	21	19.1.2023 00:00

Table 2. Bench program in classical method

X Bench						
Production Completed		File	Part No	Quantity	The Shipment Date	Note
1. Operation	2. Operation					
		x	112A533..	22	30.11.2022 00:00	A surface -B surface
		x	111A532..	22	29.12.2022 00:00	

The parts requested according to the list in the bench production programs are sent to the raw material area by the warehouse together with their files. In the program, the parts groups whose production turn is approaching are pulled from the raw material area to the sides of the bench by the relevant operator. (See Fig 1)

3.2. Gantt Method

A Gantt timeline chart is used to track work in progress. It is also used for project scheduling. It shows which jobs are on schedule and which are ahead or behind schedule. In practice, there are many versions of the chart (Wikipedia, 2022). The steps followed for the Gantt Method performed on excel during the implementation phase are as follows: Step 1: Create a data range that includes the track name, start date, and duration:

Table 3. Part name, duration and start date

Part No	Duration (Day)	Starting Date
112A533..	0,43	7.12.2022 00:00
111A532..	1,68	7.12.2022 10:20

Table 4. Time calculation table

Quantity	Set up Time	Run Time	Duration (Hour)	Duration (Day)
22	0,5	0,33	7,76	0,43
22	1	1,33	30,26	1,68

The time calculation is calculated by taking into account the set time and processing time withdrawn from the system: Time (Hour) = Setting Time + (Processing Time*Amount). Since

the daily working time is 18 hours (2 shifts * 9 hours), the day is calculated by dividing the hourly working time by 18. This calculation is given in Table 4. The Start Date shown in Table 3 is calculated cumulatively. The process continues with the other piece being taken to the bench immediately after the first piece is finished on the bench. Step 2: Add a bar chart and data series: Regular forecasting is required which is a time consuming task (https://know-base.net/7581270-gantt-chart-in-excel, 2022).

3.3. Johnson Algorithm

Johnson algorithm is also known as Johnson Ranking Algorithm. It gives the best solution for a group of jobs to run sequentially on two machines (wikipedia, Johnson Algorithm, 2022). Flow Time: The time a job or service spends on the workstation is called flow time. This time is the sum of all the preparation times required at the workstation, the processing time, the time spent switching between productions, the delay times due to input exhaustion. Delay = time to complete work – time to deadline (Topoyan, 2022)

5. CONCLUSION

The classical method and the Gantt and Johnson Method have been tried and compared. It has been determined that the classical method used allows for shipment delays, it is a method that we cannot see the forward plan due to its being completely manual, and the Johnson Method causes shipment delays because it creates a plan based on time rather than shipment dates. The Gantt Method was chosen as the most suitable method among the three methods. Thus, we started the continuation process with a method where we can plan the production area more easily and systematically. We have become so that we can more easily catch up with the speed in the industry. Errors arising from the planning process, which are completely manual and have a high margin of error, have been minimized. With the Gantt method, which is one of the scheduling methods and was chosen because of its success in the study, delays in shipments and unnecessary workloads on the counter and personnel were prevented. As a result, instead of a system in which the human burden is lightened and dependent on the initiative of the person; a system in which more accurate planning was made has been started.

REFERENCES

Alptekin, Ü. (1994). Konfeksiyon İşletmelerinde Üretim Planlaması ve Optimizasyon Çalışmaları (Yüksek Lisans Tezi). İstanbul Teknik Üniversitesi Fen Bilimleri Enstitüsü, İstanbul, s.12.

Altındaş, M. (2011). Üretim Çizelgeleme ve Bir Uygulama. (Yüksek Lisans Tezi). Bozok Üniversitesi, Yozgat.

Botta-Genoulaz, V., Millet, P. A., & Grabot, B. (2005). A survey on the recent research literature on ERP systems. Computers in industry, 56(6), 510-522. doi: http://dx.doi.org/10.1016/j.compind.2005.02.004

Demırdöğen, O., & Güzel, D. (2009). ÜRETİM PLANLAMA VE İŞ YÜKLEME METOTLARI. Ataturk University Journal of Economics & Administrative Sciences, 23(4). . https://dergipark.org.tr/tr/download/article-file/29720

Ehie, I. C., & Madsen, M. (2005). Identifying critical issues in enterprise resource planning (ERP) implementation. Computers in industry, 56(6), 545-557. doi: http://dx.doi.org/10.1016/j.compind.2005.02.006

Öztuncel, E. T. (2007). Sonlu kapasiteli çizelgeleme ve bir uygulama (Doctoral dissertation). Sakarya Universitesi, Turkey.

Fui-Hoon, F. (2002). Enterprise Resource Planning Solutions and Management, Travers, J.

Graves, S. C. (1999). Manufacturing planning and control. Massachusetts institute of technology, 1-26. https://www.researchgate.net/publication/246760677_Manufacturing_Planning_and_Control

Bektur, G., & Hasgül, S. (2013). KIDEM SEVİYELERİNE GÖRE İŞGÜCÜ ÇİZELGELEME PROBLEMİ: HİZMET SEKTÖRÜNDE BİR UYGULAMA. Afyon Kocatepe Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi, 15(2), 385-402. https://dergipark.org.tr/en/pub/akuiibfd/issue/1618/20270

KORUCA, H., ÖZDEMİR, G., AYDEMİR, E., & ÇAYIRLI, M. (2010). BİR SİMÜLASYON YAZILIMI İÇİN ESNEK İŞ AKIŞ PLANI EDİTÖRÜ GELİŞTİRİLMESİ VE İŞLEMLERİN GANTT ŞEMASINDA ÇİZELGELENMESİ. Gazi Üniversitesi Mühendislik Mimarlık Fakültesi Dergisi, 25(1). https://dergipark.org.tr/en/pub/gazimmfd/issue/6683/88454

Ödeniyazov, S. (2006). Bir Tekstil İşletmesinde Üretim Ve Pazarlama Planlaması (Türkmenbaşı Tekstil Kompleksinde Bir Örnek Uygulama), (Yüksek Lisans Tezi). Selçuk Üniversitesi Sosyal Bilimler Enstitüsü İşletme Anabilim Dalı, Konya.

Tekbaş, H. (2011). Esnek sipariş tipi üretim sistemlerinde müşteri siparişlerinin çizelgelenmesi (Doctoral dissertation). İstanbul Teknik Üniversitesi Fen Bilimleri Enstitüsü.

OLGUN, M. O., & KAÇAR, T. (2020). Bir Metal Fabrikası İçin İş Çizelgeleme Yazılımı Hazırlanması. Bilecik Şeyh Edebali Üniversitesi Fen Bilimleri Dergisi, 7(1), 421-443. doi: https://doi.org/10.35193/bseufbd.589585

Yamak, O. (1993). Üretim yönetimi: sistemler, ilkeler ve teknikler. Alfa.

Yelken, N., & Demir, H. (1978). Üretim planlaması ve kontrolü. Ege Üniversitesi.

Yıldız, S. (2000). Sanayi İşletmelerinde Ana Üretim Planlama ve Bütünleşik Üretim Planlama Uygulaması. (Doktora Tezi). Atatürk Üniversitesi.

Yrd. Doç. Dr. Mert Topoyan, Üretim Çizelgeleme, 2022.

https://tr.wikipedia.org/wiki/Gantt_%C3%A7izelgesi#cite_note-1 , Gantt çizelgesi, 2022.

https://tr.know-base.net/7581270-gantt-chart-in-excel , 2022.

www.cengizpak.com.tr/ İş Sıralama Kuralları –201/Johnson Algoritması , 2022.

Application of Multi-Criteria Decision-Making Methods in Supplier Selection

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Keywords	Abstract
	The problem of supplier selection is significant in the defense industry, as in all sectors, for companies to carry out their production in a healthy way and to deliver products on time. Since the defense industry is a critical sector that directly regarding the country's security, fast and safe supply is directly related to the country's defense. This study discusses the selection problem of the suppliers used for the surface processing of the parts of a company operating in the defense industry. Expert decision-makers evaluate the criteria determined, and it is aimed to select the most suitable supplier with Fuzzy AHP (Analytic Hierarchy Process) and Fuzzy TOPSIS methods.

1. INTRODUCTION

Businesses must establish an effective supplier management system to ensure continuity in increasingly competitive conditions. Supply management encompasses all processes from raw material supply to the final product stage. The performance exhibited in these processes significantly contributes to ensuring the enterprises' continuity. Several factors, such as quality, time, and price, influence the decision-making process for selecting suppliers. There are numerous criteria involved in exploring alternative suppliers to enhance the business potential of enterprises (Özçelik & Eryılmaz, 2019). Supplier selection criteria vary based on the sector and product structure of the enterprises. The multitude of criteria impacting the selection process, along with the growing number of suppliers, contributes to the complexity of the supplier selection problem (Deste & Serve, 2021). The selection of a supplier forms the basis for predicting and evaluating partnership-building capabilities for supplier collaboration. Companies should implement appropriate supplier selection strategies to identify potential partners in the globalizing world order (Hsu et al., 2013). The presence of diverse expert decision-makers and a variety of criteria has led to the utilization of Multiple Criteria Decision Making (MCDM) techniques in addressing the selection problem. Numerous studies in supplier selection utilize multi-criteria decision-making methods. Karabayır and Botsalı (2022) identified seven primary criteria and twenty-four sub-criteria for selecting suitable suppliers in the construction industry. They applied Fuzzy AHP to weigh decision criteria and Fuzzy TOPSIS to list alternatives. To and Kritchanchai (2022) employed the Fuzzy TOPSIS method to select sustainable suppliers for a hospital, conducting sensitivity analysis to validate their results.

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Gupta (2022) utilized the fuzzy AHP-TOPSIS method for supplier selection in the Indian automobile industry, highlighting economic sustainability as the paramount criterion. Arslankaya and Çelik (2021) utilized Fuzzy AHP and Fuzzy MOORA methods to determine green criteria for steel sheet raw material suppliers in the steel door manufacturing sector. Tsai and Phumchusri (2021) employed Fuzzy AHP in selecting raw material suppliers for a nano SIM card connector manufacturer. Kılınçcı and Önal (2011) used Fuzzy AHP for supplier selection of the washing machine company. Çakar and Çavuş (2021) utilized the Fuzzy TOPSIS method to choose suppliers for Sütaş Süt, newly entered into the Macedonian milk market.Astanti et al. (2020) employed various versions of Fuzzy AHP for supplier selection in the glove manufacturing industry in Indonesia. Özen and Borat (2020) used the IATF 16949:2016 standard and risk analysis in selecting suppliers for an automotive supplier industry company, conducting sensitivity analyses with AHP, Fuzzy AHP, and Fuzzy TOPSIS methods. Javad et al. (2020) used BWM and Fuzzy TOPSIS methods to select suppliers based on their green innovation capabilities in a steel company. Manivel and Ranganathan (2019) utilized Fuzzy AHP and Fuzzy TOPSIS methods for hospital pharmacy supplier selection, categorizing criteria into Supplier, Product Performance, and Service Performance dimensions. Galankashi et al. (2016) applied the Balanced Scorecard–Fuzzy Analytic Hierarchical Process (BSC–FAHP) model in the automobile industry, proposing a new BSC model while evaluating four suppliers across different perspectives. Awasthi et al. (2017) employed the Fuzzy AHP-Fuzzy VIKOR integrated method, identifying economic, quality, environmental, social, and global risk sustainability criteria.Deshmukh and Vasudevan (2019) determined eight primary criteria and forty sub-criteria, both traditional and green, for supplier selection in plastic manufacturing. Mondragon et al. (2019) aimed to use AHP and Fuzzy AHP methods for technology and supplier selection in the textile industry, based on twelve criteria for production technology. Azimifard et al. (2018) utilized AHP and TOPSIS methods in the Iranian steel industry

In this study, Fuzzy AHP and Fuzzy TOPSIS methods were used by considering the surface process supplier selection problem of a company operating in the defense industry. It aims to select the most suitable supplier by considering four alternatives in line with the ten criteria. After expert decision-makers evaluated the criteria, the alternatives were assessed according to these criteria. The fundamental aim of this research is to investigate the utilization of Fuzzy AHP and Fuzzy TOPSIS methodologies in supplier selection within academic literature, thereby contributing to the existing body of knowledge. The structure of this study encompasses four distinct sections. Section 1 explores the inherent significance of the supply chain. Section 2 elucidates the methodologies employed in this study. Transitioning to Section 3, a comprehensive analysis of the practical application of these methodologies is presented. Finally, Section 4 encapsulates the conclusive findings of the study, concurrently highlighting gaps in the current literature and suggesting potential avenues for future research.

2. MATERIAL AND METHOD

The methods used are discussed in detail in this section.

2.1. Fuzzy AHP

Chang's extended analysis method consists of 4 steps (Chang, 1996).

Step 1: The linguistic variables of the decision makers were converted into triangular fuzzy numbers using the scale in Table 1.

Table 1. Fuzzy analytical hierarchy process importance scale and definition

Absolutely More Important	(3.5, 4, 4.5)
Very Strongly More Important	(2.5, 3, 3.5)

Strongly More Important	(1.5, 2, 2.5)
Weakly More Important	(0.66, 1, 1.5)
Just Equal	(1, 1, 1)
Weakly More Important	(0.66, 1, 1.5)
Not Strongly More Important	(0.4, 0.5, 0.66)
Very Weakly More Important	(0.285, 0.33, 0.4)
Not Absolutely Important	(0.22, 0.25, 0.285)

The fuzzy synthetic extent value for criterion i is calculated using Equation (1).

$$Si = \sum_{j=1}^{m} M_{gi}^{j} \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right]^{-1} \tag{1}$$

The fuzzy value of Si in the equation represents the synthesis value of i. purpose, M_{gi}^{j} represents the expanded value for all purposes. $\sum_{j=1}^{m} M_{gi}^{j}$ value is obtained by fuzzy addition in Equation (2).

$$\sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j \right) \tag{2}$$

Then $\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right]$ value is obtained by fuzzy addition in Equation (3).

$$\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{i=1}^{m} l_i, \sum_{i=1}^{m} m_i, \sum_{i=1}^{m} u_i \right) \tag{3}$$

To find $\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right]^{-1}$ the inverse of the vector is calculated with the help of Equation (4).

$$\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right]^{-1} = \left(\frac{1}{\sum_{i}^{n} ui}, \frac{1}{\sum_{i=1}^{n} mi}, \frac{1}{\sum_{i=1}^{n} li} \right) \tag{4}$$

Step 2: Calculated synthesis values are compared, and weight values are calculated from these values. The possibility degree of equality of two fuzzy numbers ($M2 \geq M1$) with $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$ is calculated according to Equation (5).

$$V (M_2 \geq M_1) = sup_{y \geq x} [\min \mu M_1 (x), \mu M2 (y)] \tag{5}$$

The membership function equation is expressed as in Equation (6).

$$V (M_2 \geq M_1) = \begin{cases} 1 & , \quad m2 \geq m1 \\ 0 & , \quad l1 \geq u2 \\ \frac{l1-u2}{(m2-u2)-(m1-l1)} & , \quad \text{otherwise} \end{cases} \tag{6}$$

In V ($M_2 \geq M_1$), the intersection point d, μM_1 and μM_2 equals the ordinate of the d point. The point "d" here is the ordinate of the largest intersection point. The graphical representation of the comparison is shown in Figure 1 (Kaptanoğlu and Özok, 2006).
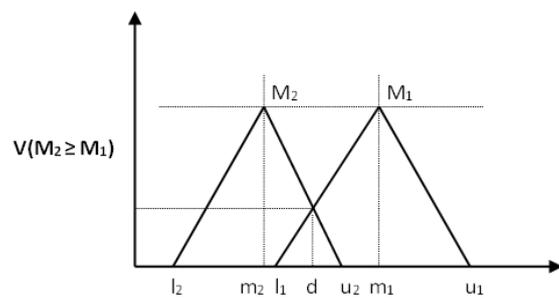
Figure 1. M1 and M2 intersection point

Step 3: The possibility degree of a convex fuzzy number greater than Mi (i = 1,2, . . . , k) values out of k convex fuzzy numbers is expressed as in Equation (7).

$$V(M \geq M_1, M_2, \ldots, M_k) = V[(M \geq M_1) \text{ and } (M \geq M_2) \text{ and } (M \geq M_k) = \min V(M \geq Mi)$$

(i = 1,2, . . . , k)   (7)

For all k values k = 1, 2, . . . , Assuming, n and k ≠ i, d′(Ai) = min $V(S_i \geq S_k)$ the weight vector is calculated according to Equation (8). A_i (i = 1,2, . . . , n) n elements.

$$W' = (d'(A_1), d'(A_2)\ldots.d'(A_n))^T$$ (8)

Step 4: Normalization is performed by adding all the elements of the vector and dividing each element by this sum. With the normalization process, the weight vector is obtained as normalized as in Equation (9). W is a non-fuzzy number of real numbers.

$$W = (d(A1), (A2), \ldots., (An))T$$ (9)

2.2. Fuzzy TOPSIS

Chen (2000) will explain the step-by-step algorithm of the Fuzzy TOPSIS method.

Step 1: The linguistic variables of the criteria and alternatives are converted into triangular fuzzy numbers using Table 2.

Table 2. Linguistic variables for the criteria and alternatives

Very low (VL)	(0,0,1)	(0, 0, 1)
Low (L)	(0,0.1,0.3)	(0, 1, 3)
Medium low (ML)	(0.1,0.3,0.5)	(1, 3, 5)
Medium (M)	(0.3,0.5,0.7)	(3, 5, 7)
Medium high (MH)	(0.5,0.7,0.9)	(5, 7, 9)
High (H)	(0.7,0.9,1.0)	(7, 9, 10)
Very high (VH)	(0.9,1.0,1.0)	(9, 10, 10)

In the fuzzy TOPSIS method, the triangular fuzzy number equivalent of verbal expressions is defined as r= (a; b; c). Decision makers (K) perform their evaluations among $A_1, A_2, \cdots, A_m$ alternatives, taking into account the decision criteria defined with $C = \{Ci \backslash i = 1,2,\cdots,n\}$. $\widetilde{D}$ fuzzy decision matrix consists of $\tilde{x}_{ij}$ elements as shown in Equation (10), and these elements are the alternatives of $A_i(i = 1,2, \cdots, m)$ according to C_j (j = 1,2,$\cdots$,c) criteria. W is the matrix of the decision criteria formed by the $\tilde{w}$ i elements, which indicate the importance weights of the Cj (j = 1,2,$\cdots$,c) criteria.

$$x\tilde{i}j = \frac{1}{K}[x\tilde{i}j^{\,1} + x\tilde{i}j^{\,2} + \cdots + x\tilde{i}j^{\,K}]$$ (10)

$$D = \begin{bmatrix} \tilde{x}11 & \cdots & \tilde{x}1n \\ \vdots & \ddots & \vdots \\ \tilde{x}m1 & \cdots & \tilde{x}mn \end{bmatrix}$$

$$W = [\tilde{w}_1, \tilde{w}_2, \ldots, \tilde{w}_n]$$

The fuzzy decision matrix is normalized using Equation (11).

$$R = [\tilde{r}ij]_{mxn} \rightarrow (rij^L, rij^M, rij^U) = (\frac{l_{ij}}{u_j^+}, \frac{m_{ij}}{u_j^+}, \frac{u_{ij}}{u_j^+}), i=(1,2,..,m) ; j \; j \in K_m$$ (11)

$$u_j^+ = max_i(u_{ij}) \quad ; \quad j \in Km$$ (12)

Step 2: The weighted normalized fuzzy decision matrix is calculated by Equation (13) by multiplying the importance weights of the criteria with the normalized triangular fuzzy number values.

$$V_{ij} = W_j * r_{ij} \tag{13}$$

Step 3: The fuzzy positive ideal solution is determined as *A*+ and the fuzzy negative ideal solution as *A*−. The values of *A*+ of the fuzzy positive ideal solution are calculated by Equation (14) and by Equation (15).

$$V_j^+ = max_i\{V_{ij4}\} \tag{14}$$

The fuzzy positive ideal solution (*A*+) elements are as follows.

$$A^+ = (V_1^+, V_2^+, .., V_n^+) \tag{15}$$

The *A*− values for the fuzzy negative ideal solution are calculated by Equation (16) and by Equation (17).

$$V_j^- = min_i\{V_{ij1}\} \tag{16}$$

The fuzzy negative ideal solution (*A*−) elements are as follows.

$$A^- = (V_1^-, V_2^-, .., V_n^-) \tag{17}$$

Step 4: According to the criteria of the alternatives, the distance values *A*+ to the fuzzy positive ideal solution and *A*− to the fuzzy negative ideal solution are calculated. The distance of the fuzzy positive ideal solution *A*+ value is calculated by Equation (18).

$$d^+ = \sum_j^n d(\bar{v}_j, \bar{v}_j^*) \quad i = 1,2,\ldots, m \tag{18}$$

The distance of the fuzzy negative ideal solution *A*− value is calculated by Equation (19).

$$d^- = \sum_j^n d(\bar{v}_j, \bar{v}_j^*) \quad i = 1,2,\ldots, m \tag{19}$$

Equation (20) using the vertex method, d (…) is the measure of the distance between two fuzzy numbers..

$$d(\widetilde{m}, \ \tilde{n}) = \sqrt{\frac{1}{3}[(m_1 - n_1)^2 + +(m_2 - n_2)^2 + (m_3 - n_3)^2]} \tag{20}$$

Step 5: The proximity coefficient CCi values for all alternatives are calculated by Equation (21).

$$CCi = \frac{d_i^-}{d_i^+ + d_i^-} \tag{21}$$

The CCi value should be between [0, 1] shown in Table 3. As the CCi value approaches 1, A+ indicates that it is close to the ideal solution, while A- indicates that it is far from the ideal solution value. As the closeness coefficient value approaches 0, it shows that while A- is close to the ideal solution, it is far from A+ ideal solution value (Chen et al., 2006).

Table 3. Closeness coefficient evaluation

Closeness Coefficient (CCi)	Assessment status
$CC_i \in [0,0.2)$	Do not recommend
$CC_i \in [0.2,0.4)$	Recommend with high risk
$CC_i \in [0.4,0.6)$	Recommend with low risk
$CC_i \in [0.6,0.8)$	Approved
$CC_i \in [0.8,1.0)$	Approved and preferred

3. CASE STUDY

This study addresses the supplier selection challenge within the surface processes of a defense industry company. Through a simultaneous survey, three expert decision-makers evaluated four alternative suppliers against ten distinct criteria. This section presents an illustrative application. The study employed the Fuzzy AHP Chang Extended Analysis Method and Fuzzy TOPSIS Methods for evaluation. The criteria considered for supplier selection are as follows: price availability, return time for offers, diversity in field of activity, technical competence, production capacity, appropriate product ratio, prompt delivery, industry awareness, and customer relationship. The Fuzzy AHP analysis identified appropriate product ratio and prompt delivery as crucial factors in supplier selection. Furthermore, all alternatives were evaluated against these criteria, and the cumulative weight vector is presented in Table 4.

Table 4. Alternative assessments

Criteria Wi Supplier	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	∑Wi
	0.085	0.173	0.008	0.157	0.147	0.190	0.190	0.000	0.033	0.017	
A1	0.523	0.762	0.000	0.332	0.685	0.456	0.516	0.000	0.504	0.683	0.542
A2	0.000	0.000	0.041	0.000	0.000	0.336	0.179	0.439	0.198	0.000	0.105
A3	0.000	0.000	0.313	0.278	0.000	0.208	0.306	0.561	0.099	0.000	0.147
A4	0.477	0.238	0.646	0.391	0.315	0.000	0.000	0.000	0.198	0.317	0.207

According to the combined weights in Table 4, the best supplier ranking is A1-A4-A3-A2. According to the Fuzzy TOPSIS method; given in Table 5 di* and di- are calculated from the distances of the alternatives from FPIS and from FNIS for all criteria.

Table 5. di* and di- values of alternatives

	di*	di-
A1	2.627	8.084
A2	7.042	3.680
A3	6.381	4.363
A4	4.302	6.545

After calculating the distances from FPIS and FNIS, the closeness coefficients of each alternative are calculated using Equation (21) shown in Table 6. According to Table 3; A1 and A4 are approved suppliers, A2 is high risk and A3 low risk.

Table 6. Closeness coefficients

	CCI	Ranking
A1	0.755	1
A2	0.343	4
A3	0.406	3
A4	0.603	2

4. CONCLUSION

This study used a methodology in a fuzzy framework to evaluate the supply chain. Since many factors affect supplier selection, decision-makers are quite indecisive in their selection decisions. Fuzzy logic was used to minimize this uncertainty. Ten criteria affecting the selection were determined, and the most important criteria were the appropriate product ratio and fast delivery. Businesses need to give importance to supplier selection to make a profit. Supplier performance should be measured at regular intervals, and the suppliers' capabilities, the advantages they provide, and the characteristics of the suppliers should be checked. As a result of the application of Fuzzy AHP and Fuzzy TOPSIS methods, supplier rankings A1-A4-A3-A2

were the same from largest to smallest. According to the fuzzy TOPSIS method, A1 and A4 are acceptable suppliers, while A2 and A4 suppliers are in the non-preferred range. Despite the similarities in outcomes produced by both methods, they diverge in certain aspects. For instance, the Fuzzy TOPSIS method considers the distances to both positive and negative ideal solutions as a basis for ranking alternatives. Conversely, the Fuzzy AHP method determines the priorities of alternatives by calculating synthesis values derived from pairwise comparisons. In prospective research, the study can be enhanced by employing methodologies tailored to address heightened levels of uncertainty, such as q-rung orthopair fuzzy-based approaches. The study's robustness can be assessed through the execution of various sensitivity and scenario analyses. Enhancing the study's robustness can be achieved by administering multiple surveys to decision-makers concurrently, as opposed to utilizing a single survey.

Conflict of Interest

The authors declared that there is no conflict of interest.

Contribution of Authors

All authors contributed to literature review, data collection, analysis and interpretation.

REFERENCES

Arslankaya, S., Çelik, M. T. (2021). Green supplier selection in steel door industry using fuzzy AHP and fuzzy Moora methods. *Emerging Materials Research*, 10(4), 357-369. doi: https://doi.org/10.1680/jemmr.21.00011

Astanti, R., Mbolla, S., Ai, T. (2020). Raw material supplier selection in a glove manufacturing: Application of AHP and fuzzy AHP. Decision Science Letters, 9(3), 291-312. doi: https://doi.org/10.5267/j.dsl.2020.5.005

Awasthi, A., Govindan, K., Gold, S. (2018). Multi-tier sustainable global supplier selection using a fuzzy AHP-VIKOR based approach. International Journal of Production Economics, 195, 106-117. doi: https://doi.org/10.1016/j.ijpe.2017.10.013

Azimifard, A., Moosavirad, S.H., Ariafar, S. (2018). Selecting sustainable supplier countries for Iran's steel industry at three levels by using AHP and TOPSIS methods. Resources Policy, 57, 30-44. doi: https://doi.org/10.1016/j.resourpol.2018.01.002

Çakar, T., Çavuş, B. (2021). Supplier selection process in dairy industry using fuzzy TOPSIS method. Operational Research in Engineering Sciences: Theory and Applications, 4(1), 82-98. doi: https://doi.org/10.31181/oresta2040182c

Chen, C.T. (2000). Extensions of the TOPSIS for group decisionmaking under fuzzy environment, Fuzzy Sets and Systems, 114(1), 1-9. doi: https://doi.org/10.1016/S0165-0114(97)00377-1

Chen, C.T., Lin, C.T, Huang, S.F. (2006). A Fuzzy Approach For Supplier Evaluation and Selection in Supply Chain Management, Int. J. Production Economics, C:CII, 289 -301. doi: https://doi.org/10.1016/j.ijpe.2005.03.009

Chang, D. Y. (1996). Applications of the extent analysis method on fuzzy AHP. European journal of operational research, 95(3), 649-655. doi: https://doi.org/10.1016/0377-2217(95)00300-2

Deshmukh, A. J., Vasudevan, H. (2019). Supplier selection in plastic products manufacturing MSMEs using a combined traditional and green criteria based on AHP and fuzzy AHP. In Proceedings of International Conference on Intelligent Manufacturing and Automation (pp. 593-600). Springer, Singapore. doi: https://doi.org/10.1007/978-981-13-2490-1_55

Deste, M., Sever, S. (2021). Kumaş Tedariğinde Tedarikçi Seçim Kriterlerinin Sürdürülebilirlik Çerçevesinde Belirlenmesi Yönelik Tekstil Sektöründe Bir Araştırma, Journal of Vocational and Social Sciences of Turkey, 3, 6, 108-126. doi: https://doi.org/10.46236/jovosst.952818

Galankashi, M. R., Helmi, S. A., Hashemzahi, P. (2016). Supplier selection in automobile industry: A mixed balanced scorecard–fuzzy AHP approach. Alexandria Engineering Journal, 55(1), 93-100. doi: https://doi.org/10.1016/j.aej.2016.01.005

Gupta, A.K. (2022). Framework for the Selection of Sustainable Suppliers using Integrated Compensatory Fuzzy AHP-TOPSIS Multi-criteria Approach. In 2022 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM) (pp. 0772-0775). IEEE. doi: https://doi.org/10.1109/IEEM55944.2022.9989663

Hsu, C.W., Kuo, T.C., Chen, S.H., Hu, A.H. (2013). Using DEMATEL to Develop a Carbon Management Model of Supplier Selection in Green Supply Chain Management. J. Clean. Prod. 56, 164–172. doi: https://doi.org/10.1016/j.jclepro.2011.09.012

Javad, M.O.M., Darvishi, M., Javad, A.O.M. (2020). Green supplier selection for the steel industry using BWM and fuzzy TOPSIS: a case study of Khouzestan steel company. Sustainable Futures, 2, 100012. doi: https://doi.org/10.1016/j.sftr.2020.100012

Karabayır, A., Botsalı, A.R. (2022). Supplier Selection Among Different Scale Construction Companies Using Fuzzy AHP And Fuzzy TOPSIS. El-Cezeri, 9(1), 35-48. doi: https://doi.org/10.31202/ecjse.933617

Kılınçcı, Ö., Önal, S. A. (2011). Fuzzy AHP approach for supplier selection in a washing machine company. Expert systems with Applications, 38(8), 9656-9664. doi: https://doi.org/10.1016/j.eswa.2011.01.159

Manivel, P., Ranganathan, R. (2019). An efficient supplier selection model for hospital pharmacy through fuzzy AHP and fuzzy TOPSIS. International Journal of Services and Operations Management, 33(4), 468-493. doi: https://doi.org/10.1504/IJSOM.2019.101588

Mondragon, A.E.C., Mastrocinque, E., Tsai, J. F., Hogg, P. J. (2019). An AHP and fuzzy AHP multifactor decision-making approach for technology and supplier selection in the high-functionality textile industry. IEEE Transactions on Engineering Management, 68(4), 1112-1125. doi: https://doi.org/10.1109/TEM.2019.2923286

Özçelik, T.O., Eryılmaz, S.A. (2019). Traktör imalatında çok kriterli karar verme yöntemleri ile tedarikçi seçimi. Avrupa Bilim ve Teknoloji Dergisi, 498-512. doi: https://doi.org/10.31590/ejosat.590418

Özen, M., Borat, O. (2020). Otomotiv Yan Sanayi Sektöründe Tedarikçi Seçiminde Ahp, Bulanık Ahp ve Bulanık Topsis Yaklaşımı. İstanbul Ticaret Üniversitesi Fen Bilimleri Dergisi, 19(38), 152-171. Retrieved from https://dergipark.org.tr/tr/pub/ticaretfbd/issue/58122/847239

Saaty, T.L. (1990). How to make a decision: the analytic hierarchy process. European Journal of Operational Research, 48 (1), 9-26. doi: https://doi.org/10.1016/0377-2217(90)90057-I

To, S., Kritchanchai, D. (2022). Sustainable Supplier Selection in a Hospital Using the Fuzzy TOPSIS method: a Case Study. doi: https://doi.org/10.46254/EU05.20220478

Tsai, C.K., Phumchusri, N. (2021). Fuzzy analytical hierarchy process for supplier selection: A case study in an electronic component manufacturer. Engineering Journal, 25(8), 73-86. doi: https://doi.org/10.4186/ej.2021.25.8.73

Evaluation of Renewable Energy Alternative for Ankara and Selection of Appropriate Power Plant Location

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Keywords	Abstract
	In this context, the most suitable renewable energy type in terms of efficiency for the capital Ankara, which is thought to have a high renewable energy resource potential, was determined by using the multi-MOORA method.

1. INTRODUCTION

Today, with the increasing population growth and developing industry, the need for energy is increasing day by day. Non-renewable energy resources such as coal, oil and natural gas play a major role in meeting the energy demand. Although the use of these energy sources seems to be more advantageous in terms of both material and transportation and storage, it actually causes great harm to the environment and is constantly reduced through consumption, to be completely depleted one day. Therefore, while meeting this energy need, it will be more beneficial to use renewable energy in terms of protecting the environment and being sustainable. Various studies are carried out in the world for the use of renewable energy. In line with these studies, the installation of Solar Energy, Wind Energy, Hydrogen Energy, Bioenergy, Geothermal Energy, Hydroelectric Energy, Wave Energy and Nuclear Energy plants is increasing day by day. The purpose of these power plants is to increase the energy to be obtained. (TSKB Danışmanlık Hizmetleri, 2022)
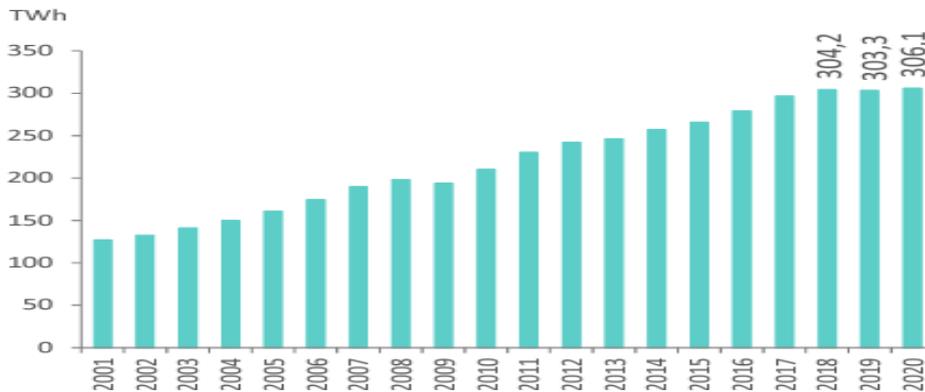

Figure 10. Total electricity demand

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2. METHODOLOGY

Multi-Criteria Decision Making (MCDM) is a set of methods that form a sub-branch of Decision Science and incorporate different approaches. Decision making is the study of identifying and choosing alternatives based on the decision maker's values and preferences. MCDM analysis is a method frequently used in emerging decision-making problems.

2.1 Multi-MOORA

(Brauers & Zavadskas, 2010) The article of Project management by MULTIMOORA as an instrument for transition economies introduced MOORA (Multi-Objective Optimization on the basis of a Ratio Analysis) combining Ratio System and Reference Point Approach in 2006. (Rouyendegh & Erkan ,2010) Then they improved MOORA to Multi-MOORA by adding Full Multiplicative Form and employing Dominance Theory to obtain a final integrative ranking based on the results of these triple subordinate methods. (Brauers & Zavadskas, 2010). The MOORA method has been successfully applied in solving many problems in recent years. Examples of these studies are logistics center selection, bank branch location selection, port planning, road design optimization, selection of production systems, ranking of performances of European Union members according to Lisbon strategies, material selection, apartment evaluation in perimeter blocks, corporate resource planning system selection, procurement. chain strategy selection, selection of smart production systems, selection of wireless networks, solution of multi-criteria problems, optimization of welding process parameters, selection of treatment technology, application of privatization, determination of indoor conditions, evaluation of regional development, selection of academic unit managers, performance evaluation of coal enterprises, banks financial performance evaluation studies can be shown. (Bulut, 2017)

The method briefly consists of 4 steps:

Step 1: The MOORA method first establishes a matrix (x_{ij}) in which the criteria are the columns, and the alternatives are the rows. Where i represents the number of criteria and m represents the number of alternatives.

$$X = \begin{pmatrix} x_{11} & \cdots & x_{1m} \\ \vdots & \ddots & \vdots \\ x_{n1} & \cdots & x_{nm} \end{pmatrix} \tag{3.1}$$

Step 2: Normalize the given data. It calculates the normalized performance value of each alternative according to its corresponding purpose. (i alternatives , j corresponding purpose)

$$x_{ij}^* = \frac{x_{ij}}{\sqrt{\sum_1^n x_{ij}^2}} \tag{3.2}$$

Step 3: Ratio Method, Reference Point and Full Multiplicative approaches are applied sequentially or by choosing one or both of them. Alternative rankings are obtained as a result of the approaches used.

Step 4: According to the MOORA method applied at this stage, the rankings obtained from the Ratio Method, Reference Point and Full Multiplicative Form applications are put side by side and analyzed. At the end of the methods, after the rankings are evaluated together using the Multi-MOORA method and a dominance comparison is made, the ranking is done. The main purpose here is to guide the decision maker by identifying the dominant alternatives.
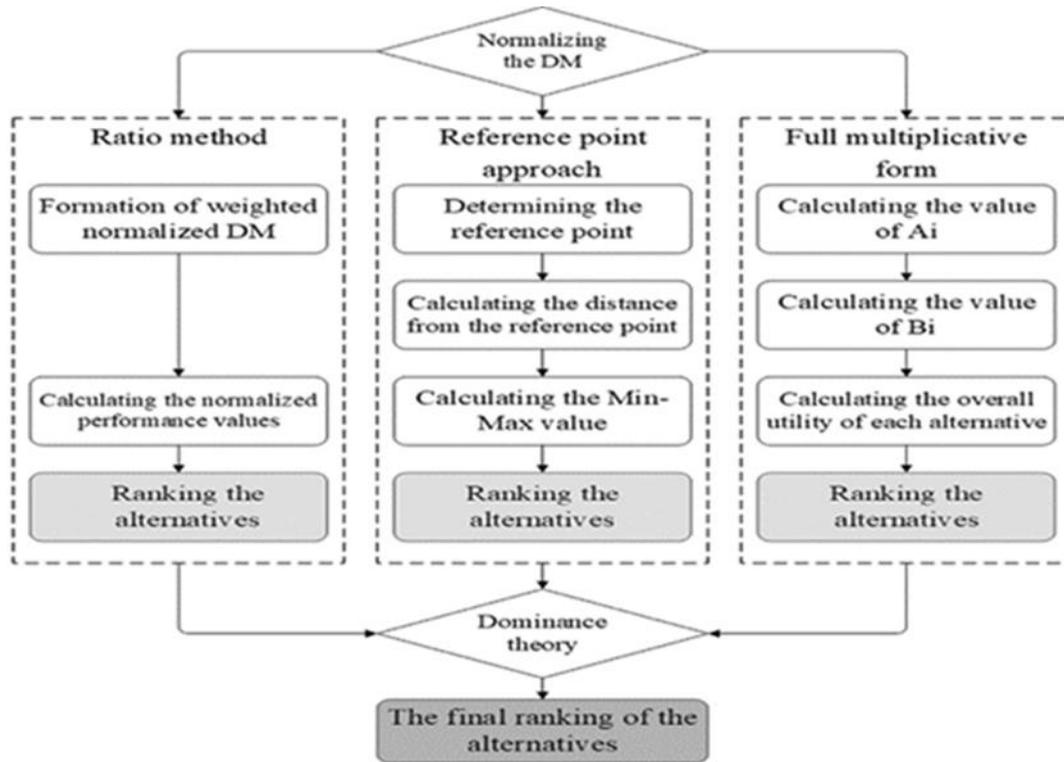
Figure 2. Multi-MOORA method

3. CASE STUDY

In the study, potential renewable energy sources for Ankara were determined as solar energy, wind energy, biomass energy, hydroelectric energy, and geothermal energy, respectively. These types of energy are alternatives in the decision problem and have been evaluated within the framework of four main criteria and fifteen sub-criteria. The necessary data for the evaluation of the sub-criteria were obtained from both literature reviews and the opinions of experts with the help of a survey.

Table 5. Main criteria and alternatives

PURPOSE	MAIN CRITERIA	SUB CRITERIA	ALTERNATIVES
Determining the most suitable type of renewable energy for Ankara	TECHNICAL (B1)	Energy Efficiency (B11)	Solar Energy (A1)
		Land Use (B12)	
		Capacity Factor (B13)	
		Build Time (B14)	Wind Energy (A2)
		Resource Potential (B15)	
	ECONOMIC (B2)	Investment Cost (B21)	
		Operation & Management Cost (B22)	Hydroelectric Energy (A3)
		State Support Rate (B23)	
		Economic Life (B24)	
		Electricity Production Cost (B25)	Biomass Energy (A4)

		Payback Period (B26)	
	ENVIRONMENT (B3)	Greenhouse Gases Emission (B31)	
		Sound and Visual Pollution (B32)	Geothermal Energy (A5)
	SOCIAL (B4)	Employment Opportunities (B41)	
		Social Acceptance (B42)	

In order to evaluate renewable energy alternatives, it is necessary to create the main criteria table first. Data on alternatives and criteria are shown in Table 2.

Table 6. Main criteria and their alternatives

Criteria	Alternatives				
	Solar Energy (A1)	Wind Energy (A2)	Hydroelectric Energy (A3)	Biomass Energy (A4)	Geothermal Energy (A5)
Energy Efficiency (%)	25	12,5	22,5	20	27,5
Land Use (km2/MW)	0,04	0,05	8,1	20	0,007
Capacity Factor (%)	30	18	34	46	42
Build Time (Year)	4	1	1	2	2
Resource Potential (1-10 Scoring)	5,6	2,6	3,2	4,2	4,4
Investment Cost ($)	4550	3005	2040	3370	3920
Operation & Management Cost ($/kW/y)	30	60,86	14,85	99,4	112,6
State Support Rate (cent/kWh)	13,3	7,3	7,3	13,3	10,5
Economic Life (Year)	25	25	30	20	25
Electricity Production Cost ($/KWh)	0,125	0,07	0,08	0,1	0,05
Payback Period (Year)	1,85	0,9	11,8	1,92	5,7
Greenhouse Gases Emission (gCO$_2$/kWh)	85	26	26	45	50
Sound and Visual Pollution (1-5 Scoring)	1	3	2	3	2,6
Employment Opportunities (person/kWh)	4,76	4,51	4,19	3,78	4,11
Social Acceptance (1-5 Scoring)	4,2	2,6	2,2	3,2	3,2

The results obtained in the Ratio Method, Reference Point and Full Multiplicative Form applications applied in the MOORA method are done in this step with the help of Multi-MOORA dominance rankings.

Table 7. Multi-MOORA dominance ranking

	Ratio Method	Reference Point	Full Multiplicative Form	Multi-MOORA
A1	1	2	1	1
A2	3	1	3	3
A3	4	4	4	4
A4	5	5	5	5
A5	2	3	2	2

In the dominance ranking made according to the Multi-MOORA result, it was concluded that the most ideal energy type for Ankara province was solar energy (A1).

Table 8. Multi-MOORA result

	Multi-MOORA
A1	1
A2	3
A3	4
A4	5
A5	2

4. CONCLUSION

In this study, it was tried to determine the most suitable renewable energy type for Ankara, which has a high renewable energy source potential. For this purpose, multiple MOORA, which is one of the multi-criteria decision-making methods, was used to determine the renewable energy type. The most ideal energy was found according to the Multi-MOORA method.

Renewable energy alternatives for Ankara have been determined as solar energy, wind energy, geothermal energy, hydroelectric energy, and biomass. In order to find the most suitable type of energy among these alternatives, 15 sub-criteria were evaluated under 4 main criteria. Among these criteria and alternatives analyzed using the multi-MOORA method, solar energy was determined as the most suitable type of energy. In conclusion, this study is an important step to evaluate the renewable energy potential of Ankara province and to meet its energy needs in a sustainable way in the future. In addition, this study can be evaluated in terms of energy policies and infrastructure planning of Ankara province. The establishment of solar power plants in these suitable areas will be an important step in terms of sustainable energy production and environmental protection.

In addition, this study may inspire similar analyzes for other provinces and regions, so that the efficient use of renewable energy resources can be encouraged. For example, if it is considered to invest in a renewable energy facility in Ankara, this research can make a great contribution to the selection of the facility. As can be seen in the research details, the most suitable renewable energy facility for Ankara is solar energy. The clear determination of suitable locations within Ankara for the installation of solar power plants, which emerged towards the conclusion of the study, will also contribute to the people concerned with the subject.

Conflict of Interest

Authors declare that there is no conflict of interest.

Contribution of Authors

Furkan Algül (1st Author):

- Conducted in-depth research on renewable energy sources, focusing on their efficiency and potential for Ankara.
- Led the application of the Multi-MOORA method, utilizing decision-making tools for the selection of the most suitable renewable energy type.
- Contributed significantly to the formulation of the methodology section, detailing the steps of the Multi-MOORA method.
- Responsible for gathering and analyzing data related to technical, economic, environmental, and social criteria for renewable energy alternatives.

Müşerref Nur Koruk (2nd Author):

- Collaborated closely with the 1st author in the identification and evaluation of potential renewable energy sources for Ankara.
- Played a key role in the collection of data from literature reviews and expert opinions for the assessment of sub-criteria.
- Contributed to the formulation of the main criteria table, specifying the technical, economic, environmental, and social aspects for evaluation.
- Actively participated in the application of the Multi-MOORA method, including the Ratio Method, Reference Point, and Full Multiplicative Form applications.

Babek Erdebilli (Advisor):

- Provided guidance and supervision throughout the research project as the advisor.
- Offered expertise in decision science and Multi-Criteria Decision Making (MCDM) methods, particularly in the application of Multi-MOORA.
- Assisted in the design of the research methodology, ensuring the robustness of the decision-making process.
- Reviewed and contributed to the interpretation of results, ensuring the conclusions align with the research objectives.

REFERENCES

TSKB Danışmanlık Hizmetleri. (2022, Ekim 12). *Aylık Enerji Bülteni* https://www.tskb.com.tr/uploads/file/enerji-bulteni-ekim-20221121.pdf

Rouyendegh, B. D., & Erkan, T. E. (2010). Ankara'da Bulunan 4 Yildizli Otellerin, Vza-Ahs Sirali Hibrit Yöntemiyle Etkinlik Değerlendirmesi. Gazi Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi, 12(3), 69-90 doi:https://dergipark.org.tr/en/pub/gaziuiibfd/issue/28321/300956

Brauers, W. K. M., & Zavadskas, E. K. (2010). Project management by MULTIMOORA as an instrument for transition economies. Technological and Economic Development of Economy, 16(1), 5-24. doi:https://doi.org/10.3846/tede.2010.01

Bulut, T. (2017). MULTIMOORA yöntemi ile farklı illerdeki organize sanayi bölgelerinin yabancı yatırımcılar açısından optimal yer seçimi olarak değerlendirilmesi. Finans Politik ve Ekonomik Yorumlar, (624), 41-52. https://dergipark.org.tr/en/pub/fpeyd/issue/48021/607315#article_cite

Determination of Suitable Sites of Water Harvesting Dams in the Northeastern of Nineveh Province

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Keywords	Abstract
Water harvesting, Dam, Nineveh, HEC-HMS	*The increasing of water demand resulting of population growth, climate change, and the water policies of neighboring countries of Iraq led to the needing to specify other sources of water in the arid and semi-arid areas of Iraq. The aim of this study is to harvest the rainwater that produced by the catchment area of seasonal Al-Khoser river. The Easter side of Mosul city is divided by the stream flow of this river then combined to Tigris river inside of Mosul city. Three sites of rainwater harvesting dams (RWHDs) were chosen in the catchment of this river. The storage volumes of RWH reservoirs were estimated using HEC-HMS model. The elevation-Area-Storage curves of those RWH reservoirs were identified with live storage, dead storage, flood storage, and outlet capacities (sluice gate, bottom out let and spillway). The results of the study showed that sufficient quantities of surface runoff water are available in the Al-Khoser Basin, which can be stored (dead and live storage) in those three reservoirs 0.96, 1.60, and 2.5 MCM.*

1. INTRODUCTION

Rainwater harvesting (RWH) is an old-new technique that can ensure the availability of water for arid and semi-arid region (Al- Ansari, et al., 2013). By this technique, reservoirs of small earth dams can be established to store the surface runoff of a selected catchment area. This surface runoff is produced by rainwater and may represent as the rainfall that is neither infiltrated into the soil nor retained on the land surface (Chow et al., 1988). Rainfall water productivity can be significantly improved by applying a RWH technique based on availability of a surface reservoir (Zakaria, et al., 2013, P.1665). The success of RWH systems depends on several factors, including rainfall, catchment characteristics and socio-economic factors (Ndeketeya & Dundu, 2021). A number of researchers including Derdour et al., 2018; Darji et al., 2019, have used HEC-HMS to simulate the rainfall-runoff process and to estimate the direct runoff of their study area. They conclude that HEC-HMS model has the advantage over other models and recommended it for runoff simulation.

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Other researchers have studied the selection of suitable sites for reservoirs, their size, and type for rainwater-harvesting techniques to be used to suit diverse goals such as water supply, limited power generation, and supplementary irrigation (Al-Ansari et al., 2013). Skhakhfa & Ouerdachi, 2016, they studied the efficiency of HEC-HMS model in wadi Ressoul, Algeria. The results of measuring runoff approved the results of the model. Al-Aqeeli et al., 2021 proposed two reservoirs on the Greater Zab River along the border between Iraq and Turkey. The aim of their study was to show the importance of exploiting the appropriate sites for construction of dams on the borders of riparian countries, a multi-reservoir system was designed across the border of two riparian countries. In addition, simulation models that express the possible operating mechanisms for this system were created.

The current study aims to explore three sites of Al Khoser watershed for proposed rainwater harvesting dams and to determin their aspects.

2. METHODOLOGY

2.1 Study Area

The basin of Al Khoser seasonal river (652 km2) is located at 45 km northeast of Mosul city in Nineveh Governorate, Iraq (Figure 1-a), the Basin has a length of 39 km, average slope of 0.06 m/m, and a maximum land elevation of 1260 (m.a.s.l.) (Figure 1-b).

The slope and topography are varied in the study area where steep slope is in the northern part of the basin while it is almost flat at south part Most of the study area is usually cultivated mainly with Barley crop, Wheat comes in second place during the winter, in addition to olive trees.
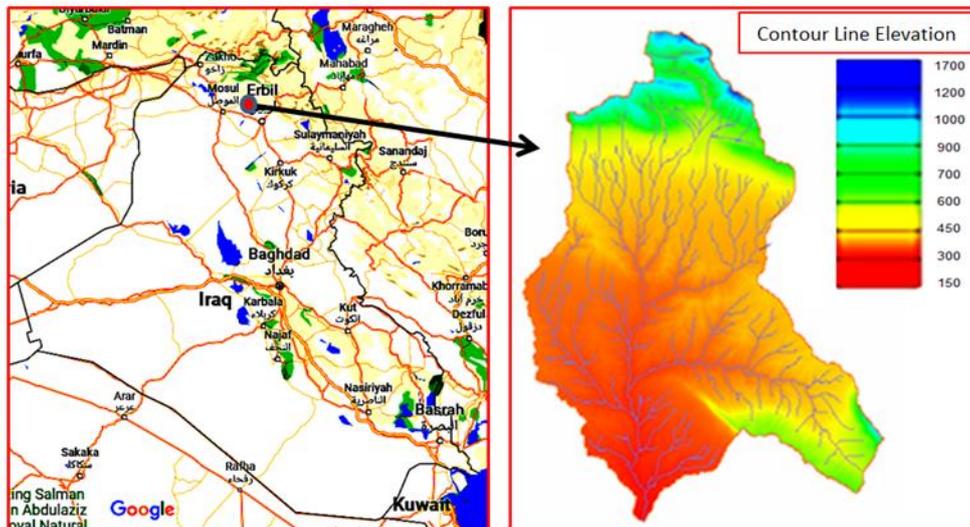
Figure 1-a. Locatation of al khoser basin at Nineveh, Iraq, source: google map

Figure 1-b. Elevation of al-khoser main basin

The study area includes some scattered pastures, and a limited part of urban (residential) areas. The soil of the main part of the study area is of the type: Silty Clay Loam, Silty Clay, Silty Loam and about 18% of the area is limestone (Al-Naqib, 1980; Ezzedine, M. 2005).

2.2 Rainfall of the Study Area

The daily rainfall data of Mosul station was relied on which was the nearest stations to the studied area. The total annual rainfall varied during the study period (1985-2020). The minimum total annual rainfall was about 97 mm during the season (2007-2008), while the

average total annual rainfall was about 342 mm during the season (2007-2008), the maximum total annual rainfall reached 618 mm during the season (2018-2019).

2.3 Framework

Al-Khoser river basin was selected and divided into three sub-basins, which necessitated the design of three dams at the outlets of these basins. the HEC-HMS was used in order to estimate the discharge and the volume of surface runoff. The design of these RWH included the determination of elevation-area-storage curve, dead, live, flood storage, and the capacities of their outlets. Results of Basin (2B) was adopted as a sample of calculations.

2.4 Location Sites of Harvesting Dams

Al-Khoser basin was divided into three sub-basins, (Table 1). The connections of selected RWHDs were presented in figure 2.

Table 1. The main and sub-basins of al-khoser seasonal river locations

Dam No	1	2	3	4
Basin No	1B	2B	3B	4B
Area (km2)	652	167.81	121.67	173.83
Length (km)	39.00	21.27	17.97	21.29
X-coordinate	338171.1	338325.8	341050.6	338723.2
Y-coordinate	4037318.4	4055154.7	4053914.4	4046955.9
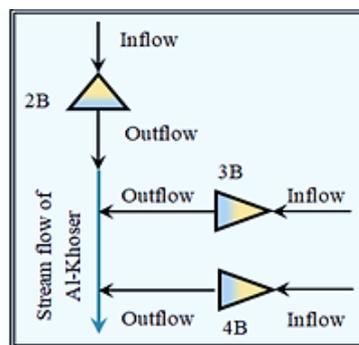
Figure 2 . The conviction style of the three RWHDs

2.5 Simulation Model

Digital elevation model (DEM) is used to select the suitable location of rainwater harvesting dams. The Global Mapper (GM) model and watershed modelling system (WMS) were used to investigate the cross sections of the valleys, where the dams will be constructed. Delineate catchment areas can be satisfy by WMS model based on DEM data of the study area (Al-Ansari, et al., 2013).

2.6 Runoff Model

For each selected dam site, the total depth of daily rainfall was provided to the HEC-HMS in order to estimate the runoff hydrograph for individual rain storm and the volume of surface runoff .

2.7 HEC-HMS Model

HEC-HMS is a physically based, semi-distributed hydrologic model developed to simulate the hydrologic response of a watershed (Scharffenber et al., 2010). HEC-HMS was developed to estimate direct runoff of Al-Khoser watersheb based on the selected following methods:

2.7.1 The exponential loss method

This method is modeling the infiltration rate reduction as an exponentially decreasing function of accumulated infiltration (HEC-HMS Technical Reference Manual, 2000). The potential loss rate (It) may express as follows:

$$It = (LR + II) * PRt^{ER} \tag{1}$$

$$II = 0.2 * IIR * (1 - CML/IIR)^2 \tag{2}$$

$$LR = ST/RTL^{0.1*CML} \tag{3}$$

where PRt = precipitation rate (mm/hr) at time *t*, ER = precipitation exponent, LR = loss rate coefficient at the beginning of the time interval, II = incremental increase in the loss rate coefficient during the first IIR (mm) of accumulated loss, It. If (It) is greater than IIR, II = zero, CML is the accumulated loss (mm) (HEC-1 Flood Hydrograph Package Users Manual, 1998), (HEC-HMS Technical Reference Manual. 2000).

2.7.2 *Transform Method*

Clark's model start with the continuity equation:(Technical Reference Manual. 2000)

$$\frac{dS}{dt} = It - Ot \tag{4}$$

In which $\frac{dS}{dt}$ = change of water storage; I = the average inflow; Ot= the out flow at t of time.

The storage at time t (for linear reservoir model) is related to outflow as:

$$S(t) = R * O(t) \tag{5}$$

where R =constant linear reservoir parameter.

The basin storage coefficient, R, is an index of the temporary storage of precipitation excess in the watershed as it drains to the outlet point.

$$\frac{R}{Tc+R} = 0.65 \tag{6}$$

Time Concentration (Tc) of clark model was over estimated, so Kirpich formula was used

$$Tc = 0.00013 * L^{0.77} * S^{-0.385} \tag{7}$$

Where: Tc= Time of concentration, (hr). L= Length of channel from the farthest point to the outlet of the watershed, (km). S= Slope of the longest hydraulic length.

2.8 Model Calibration and Applications

The HEC-HMS model was calibrated (manual and optimized) using observed data (Table 2). The match between observed (II) and simulated hydrograph of the direct runoff was very acceptable in terms of shape, volume and discharge of the runoff (Figure 3) so it was considered. The final parameters values for optimized calibration of the HEC-HMS model were recorded (Table 3). The statistical criteria that evaluate the performance of the HEC-HMS model were recorded (Table 4), showing that the results of HEC-HMS model is very close to the observed data. In the first step of application process, the locations of the proposed RWH dams were selected based on the DEM of the study area in addition to the hydrological and dams were selected based on the DEM of the study area in addition to the hydrological and geological conditions, then HEC-HMS was applied for each selected dam in order to estimate direct runoff volume that inters the reservoir of the selected dam. The procedure was applied for each individual rainfall storm of the average rainfall seasons which occurred in 2000-2001 of the study period 1985–2018.

Table 2. Observed hydrographs data of season 2003-2004 at the al-khoser watershed (Ezz-Aldeen, M., 2005)

Rainstorm No.	date	Rainfall Depth (mm)	Intensity mm/hr	Peak Runoff (m³/sec)	Peak Sediment (Kg/m³)
I	19/2/2003	19	0.9-8.0	32	2.6
II	22/2/2003	18	2.0-3.5	51	3.2
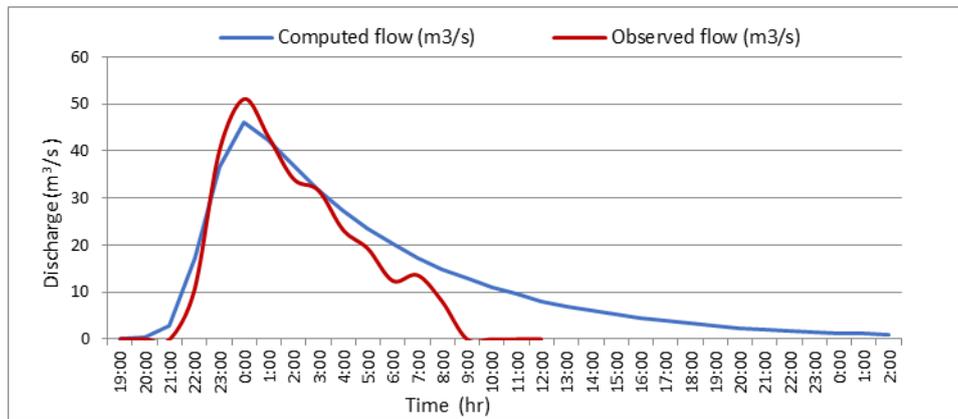
Figure 3. Comparison between computed and observed direct runoff hydrograph

Table 3. Optimized calibration results for HEC-HMS model using Clark - exponential methods

Method	Parameter	Units	Intial values	Optimized values	Objective Function Sensitivity
Clark U. H.	Storage Coefficient	HR	5.500	6.6145	1.32
Clark U. H.	Time of Concentration	HR	4.500	3.2942	1.12
Exponential	Coefficient Ratio		0.650	0.95	4.48
Exponential	Exponent		0. 85	0.79890	-2.06
Exponential	Initial Coefficient	(MM/HR)^(1-x)	0.700	0.89975	-5.57
Exponential	Initial Range	MM	0.0	0.0	0.00

Table 4. Statistical criteria results using Clark - exponential method

Statistical criteria	Value	Unit
Nash–Sutclife Efficiency (NSE)	96.4	%
Root Mean Square Error (RMSE)	1.5	m3/S
Mean Absolut Error (MAE)	2.3	m3/S
Observed peak Discharge	51	m3/S
Simulated peak Discharge	46	m3/S

3. DAMS HYDROLOGICAL ASPECTS

Hydrological aspects of the three RWHDs included elevation-area-storage curves, dead storages, live storages, flood storages, and the capacities of the outlets.

3.1 Elevation-Area-Storage Curves

WMS was used to identify the elevation-storage curves for the three RWHDs. This relation was adopted to specify the relationship between the elevation and area of storage. Figure 4 show the elevation-storage curves of RWHD that located in 2B.
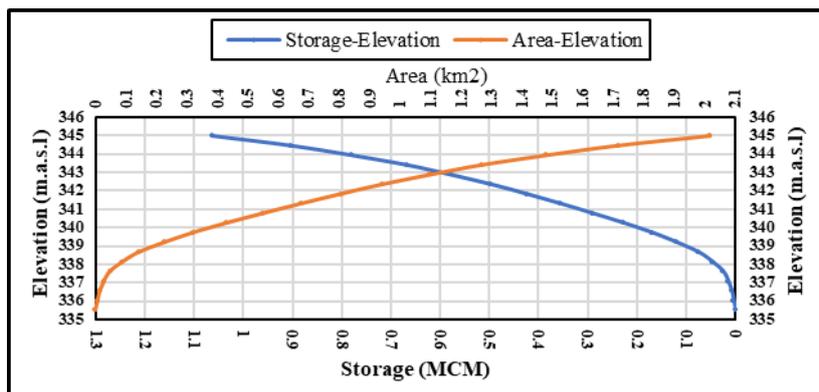
Figure 4. Elevation-Area-Storage curve of RWHD that located in 2B

3.2 Dead Storage

The dead storages of RWHDs were specified based on amounts of sedimentation that observed at the out let of main basin, in addition to the economic reservoir life is 25 years. The dead storage for each RWHD was calculated. Table 5 shows the calculation of dead storage for the reservoir of 2B basin.

Table 5. Calculation of dead storage for 2B reservoir based on clark and exponential methods

| Date	Dayly Runoff Discharge (MCM)	Sediment Equation S=0.0661*Q^0.942 (Mkg\day)	Suspended Load (SL) (Mkg\month)	Not.
1-31/10/2000	0	0	0	Oct.
24/11/2000	3.2	0.197720973		
30/11/2000	3.8	0.232465018	0.430185991	Nov.
01/12/2000	20.4	1.132069467		
15/12/2000	23.4	1.288257849		
16/12/2000	5.7	0.340592887		
22/12/2000	1.9	0.121000552		
23/12/2000	3	0.186058571	3.067979326	Sept,
27/01/2001	16.8	0.942850429	0.942850429	Jan.
16/02/2001	18.1	1.011427312	1.011427312	Feb.
13/03/2001	38.5	2.059232893		
21/03/2001	5.2	0.312375245		
29/03/2001	1.3	0.084632291		
30/03/2001	3.8	0.232465018	2.688705446	Mar.
08/04/2001	1.5	0.096845495		
13/04/2001	17.8	0.995628	1.092473495	Apr.
15/05/2001	1.8	0.114992141	0.114992141	May
			9.348614139	SL Mkg/year
			7029.033187	SL m3/year
			8434.839825	Total L m3/year
			210870.9956	Total L m3/25year
			0.210870996	Total L MCM/25year

The sedimentation amounts were distributed arbitrary to the three sub-basins of RWHDs according to area percentage of each sub-basin relative to the main basin. According to this procedure, the following mathematical equations (8, 9, and 10) were identified for 2B, 3B, and 4B respectively. The mathematical equations carfuly describe the relation between susbended load and discharge of runoff.

$$S = 0.0661 * Q^{0.942} \tag{8}$$

$$S = 0.0649 * Q^{0.942} \tag{9}$$

$$S = 0.0649 * Q^{0.942} \tag{10}$$

3.3 Live Storage

To determine the live storage of RWHDs, the average year of the rain series was used in HEC-HMS to specify the daily runoff for this time series, daily runoff was converted to monthly runoff. The monthly water demand at downstream of basin 2 was estimated to be 0.4829 MCM. The Tabulation Method (Table 6) was used to calculate the live storage for reservoir of 2B basin.

Table 6. Calculation of live storage for reservoir of 2B basin

Month	Inflow (MCM)	Demand (MCM)	Deficit (MCM)	Surplus (MCM)	Acc. Deficit (MCM)	Acc. Surplus (MCM)	Water wasted (MCM)
10	0	0.4828	-0.4829		-0.4829		
11	0.2193	0.4828	-0.2636		-0.7465		
12	1.8834	0.4828		1.4005		1.4005	
1	0.579	0.4828		0.0961		1.4966	
2	0.6247	0.4828		0.1418		1.6384	
3	1.7675	0.4828		1.2846		2.923	
4	0.6642	0.4828		0.1813		3.1043	3.1045
5	0.0565	0.4828	-0.4264		-0.4264		
6	0	0.4828	-0.4829		-0.9093		
7	0	0.4828	-0.4829		-1.3922		
8	0	0.4828	-0.4829		-1.8751		
9	0	0.4828	-0.4829		-2.358		

3.4 Flood Storage

To determine the flood storage, the highest wave rain observed was used within the time series adopted of rain. 50.000 cubic meters for the three RWHDs were store in reservoir while the remaining water is released to downstream by spillway.

3.5 Capacities of Outlets

The capacities of sluice gates were determined based on the inflow rates for the sub-basins which represent the water requirements at the bottom of the three RWHDs. The capacity of bottom out let and spillway were specified based on the highest flood storm in the highest rainy year. The highest rainall depth was 43.5 mm during season 2000-2001. The volumes of water product at the outlets of 2B, 3B, and 4B were 1.4322, 1.0384, and 1.4386 MCM. According to this methodology, the capacity of the bottom out let was inserted 0.1 MCM. The spillway capacity was calculated based on the highest wave in the highest rainy year. As mentioned previously, 50,000 cubic meters of this wave were reserved, the rest of this wave represents the capacity of the bottom out with spillway.

3.6 The Elevations

The elevations of dead storage (sluice gate), live storage (spillway), and flood storage of RWHDs were identified using elevation-area-storage curves. In addition, dam crest, dam base were identified. The elevations of dam crest for RWHDs were determined by add the free board (F.B) of each dam to the head of water (H) in the reservoirs using equation 16.

$$F.B = 4\%(H + F.B) \tag{11}$$

4.0 HYDROLOGIC ASPICTS OF RWHDs

the hydrologic aspicts of the three harvisting dams were inserted in Table 7.

Table 7. Hydrologic aspicts of the three harvisting dams

Details of RWHDs	2B	3B	4B
Dead storage (MCM)	0.210870996	0.152429177	0.213443999
Live storage (MCM)	0.75	1.447570823	2.28656
Flood storage (MCM)	0.05	0.05	0.05
Elevation of sluice gate (m.a.s.l)	340.0	339.8	301.3
Elevation of spillway (m.a.s.l)	344.650	344.8	306.8
Elevation of Flood storage (m.a.s.l)	344.814	345.2	307.1
Elevation of dam crest (m.a.s.l)	345.2015	345.583	307.479
|Elevation of dam base (m.a.s.l)	335.5	336	298
Head of water (m)	9.314	9.2	9.1
Free board (m)	0.3875	0.383	0.379
Head of dam (m)	9.714	9.583	9.479
Capacity of sluice gate (MCM)	0.4829	0.350	0.495
Capacity of bottom outlet (MCM)	0.1	0.1	0.1
Capacity of spillway (MCM)	1.2822	0.8884	1.2886

5.0 RESULTS and DISCUSION

5.1 Runoff Results

The estimated runoff volumes that enters the selected reservoirs were produced by rainfall of season 2000-2001. The results of Table 8 showed that there are appropriate quantities of water worth considering that can be stored in the selected dams reservoirs, then, to be employed for various purposes to achieve the water demand in a semi-arid environment where there is no surface water available.

Table 8. Harvested runoff of selected Basins, over the 2000-2001 (average rainfall season)

ID of RWHDs	2B	3B	4B
The annual Volume of surface runoff (MCM)	5.7946	4.1948	5.9479

The average annual quantities of surface runoff were 5.7946, 4.1948 and 5.9479 MCM in basins 2, 3 and 4 respectively with a total of 15.9373 MCM. The hydrological conditions are similar for the three selected basins, however, the area of basin 4 was the main reason that lead the surface runoff of basin 4 greater than each of basins 2 and 3.

The total rainfall depth for the average rainfall season is about 263.4 mm, the mimimum and maximum rainfall dept were 5.7 and 43.5 mm respictivily that produced runoff with volume of 0.047 and 1.4322 MCM with 1.3 and 38.5 m³/sec of peack runoff discharge respictivily for the basin 2B. while same rainfall depths gave the followin results: for basins 3B, Runoff volumes

were 0.0295 and 1.0384 with peack runoff discharge of 0.9 and 27.9 m3/sec respictivily. While for basins 4B, the runoff volumes were 0.0422 and 1.4386 MCM with peack runoff discharge of 1.3 and 39.9 m3/sec respictivily.

5.2 Hydrologic Aspicts of RWHDs Results

The results shows that the dead storage volumes of the three reservoirs of basins 2B, 3B and 4B will reach up to 0.210870, 0.152429, and 0.213443 MCM. The topography of the seasonal Al-Khoser River catchment, in addition to the conditions of construction rainwater harvesting dams are combined to be the dominant factors that determine the Hydrologic aspects of RWHDs. The results shows that there is an abundance of water harvested from basins of Al-Khoser River during the average rainy season (2000-2001). The live storage of selected reservoirs of basins 2B, 3B, and 4B reach up to 3.1045, 2.250, and 3.184 MCM respectively. However, as a result of the dominant factors, it is not possible to store the entire live storage due to limited capacity storage of the reservoirs in addition it is not possible to increase the height of the dam due to a limited depth of the valley at the dam site. Therefore the maximum volume of live storage of reservoir 2B, 3B, and 4B that can be stored reach up to 0.7500, 1.447570, and 2.286560 MCM respectively. The capacity of bottom out let and spillway were specified based on highest rainall depth for the study period (1985-2020) which was found to be 43.5 mm during season 2000-2001. The volumes of water product from this highest rainy at the outlets of 2B, 3B, and 4B were 1.4322, 1.0384, and 1.4386 MCM, based on clark and exponential methods of HEC-HMS model. Accordingly, the capacity of the bottom out let was inserted 0.1 MCM. The spillway capacity was 50,000 cubic meters based on the highest wave in the highest rainy year. The Capacity of sluice gate of selected RWHDs reach up to 0.4829, 0.350, and 0.495 MCM for the reservoirs 2B, 3B, and 4B respectively. The spillway elevations of the three selected RWHDs reach up to 344.650, 344.8, and 306.8 m.a.s.l, while the flood elevation reach up to 344.814, 345.2, and 307.1 m.a.s.l. The spillway capacity of reservoirs 2B, 3B, and 4B reach up to 1.2822, 0.8884,and 1.2886 MCM respectively.

6. CONCLUSION

The volumes of water harvested are larger than the capacity of the dams reservoirs that can be constructed at the outlets of the selected basins during the average rainy season 2000-2001. In the present study, the main basin was divided into three sub-basins. The spacing between these three reservoirs helps to achieve maximum benefit to the people living on the study area. The most important of RWHDs, which is increasing job opportunities, as the availability of water contributes effectively to the agricultural production of crops of national income.

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Conflict of Interest

The authors declare that they have no competing interests. Confict of Interest- None, and the research was not funded.

Contribution of Authors

Saleh Mohammed Saleh Zakaria: Conceived and designed the analysis, performed the computer simulations, developed needed model, and wrote the paper.**Yousif H. Al-Aqeeli:** Contributed mathmatical calculation, analysis tools, , and wrote the paper**. Ali A. Abdulmawjood :** Performed the text mining analysis and Collected the data.**, Omar M. A Mahmood Agha:** statistical analysis

REFERENCES

Al-Ansari, N., Ezz-Aldeen M., Knutsson, S., and Zakaria, S., 2013. Water Harvesting and Reservoir Optimization in Selected Areas of South Sinjar Mountain, Iraq. Journal of Hydrologic Engineering, Vol. 18, No. 12, 1607-1616, doi: https://doi.org/10.1061/(ASCE) HE. 1943-5584.000071

Al-Aqeeli, Y.H., Altaiee, T.M. and Abdulmawjood, A.A., 2021. Proposition of a Multi-Reservoir System Across the Border of Riparian Countries and Specifying Its Operational Outputs by Formulating Simulation Models. Water Resources Management, 35(15), pp.5225-524, doi: https://doi.org/10.1007/s11269-021-02996-z

Al-Naqib, S. Q. 1980. Geology of Atrush area. M.Sc. Thesis, University of Mosul, Mosul, Iraq, https://uomosul.edu.iq/en/ engineering-colleges/

Chow, Ven Te, Maidment, David R., Mays, Larry W., 1988. Applied Hydrology, Library of Congress Cataloging-in-Publication Data, IV. Series. GB661.2.C43 1988 627 87-16860 ISBN 0-07-010810-2, (Book).

Darji, K., Khokhani, V., Prakash, D., Mehmood, K., Pham, B., Final, M., 2019. Rainfall-Runoff Modelling Using HE-CHMS Model: J.of Emerg. Technol. Innov. Res. JETIR 6, 10, http://www.jetir.org/papers /JETIR 1905F33.pdf

Derdour, A., Bouanani, A., Babahamed, K., 2018. Modelling rainfall runoff relations using HEC-HMS in a semi-arid region: A case study in Ain Sefra watershed. J. of water and land development, No. 36 (I–III): 45–55, doi: https://doi.org/10.2478/jwld-2018-0005.

Ezz-Aldeen, M., 2005. A Conceptual model for flow and sediment routing for a watershed northern Iraq" , PhD thesis, mosul university , https://uomosul.edu.iq/en/engineering-colleges/

HEC-1 Flood Hydrograph User's Manual, June 1998, Us Army Corps Of Engıne-ers Hydrologıc Engıneerıng Center (HEC) 609 Second Street Davis, CA 95616-4687, https://www.hec.usace.army.mil/publications/ComputerProgramDocumentation/HEC-1_UsersManual_(CPD-1a).pdf

Ndeketeya, A., Dundu M., 2021. Application of HEC-HMS Model for Evaluation of Rainwater Harvesting Potential in a Semi arid City, Water Resources Management (2021)35:4217–4232, doi: https://doi.org/10. 1007 /s11269-021-02941-0

Scharffenberg w., Fleming m. 2010. HEC-HMS v3.5: User's manual. Davis, CA. USACE,. pp. 318. https://www.hec.usace. army.mil/ software/hec-hms/documentation/ HEC-HMS_Users_Manual _3.5 .pdf

Skhakhfa I. D., Ouerdachi, L., 2016. Hydrological modelling of wadi Ressoul watershed, Algeria, journal of water and land development, 2016, No. 31 (X–XII): 139–147, PL ISSN 1429–7426, doi: http://dx.doi.org/10.1515/jwld-2016-0045

USACE, 2000. Hydrologic Modeling System HEC-HMS Technical Reference Manual. http://www.hec.usace.army.mil

Zakaria, S., Al-Ansari, N., and Knutsson, S., 2013. Wheat yield scenarios for rainwater harvesting at Northern Sinjar Mountain, Iraq. J. of Natural Science, V.5, No.10, 1057-1068. doi: http://dx.doi.org/10.4236/ns.2013.510130

Advances In Synthesis and Energy Applications of Conductive Polymers

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Keywords	Abstract
	This study provides a thorough summary of the latest advancements in conductive polymer manufacturing techniques and their diverse range of energy applications. Because of their distinctive electrical, optical, and electrochemical characteristics, conductive polymers have attracted a lot of attention and are now considered cutting-edge materials for energy-related technologies. The paper investigates a variety of synthesis methods, including chemical, electrochemical polymerization, plasma polymerization, nano sized production etc. The focus is on adjusting synthesis parameters, such as dopants, functional groups, and nanostructured structures, to modify the characteristics of conductive polymers for certain energy uses. Furthermore, the important functions that these polymers play in a variety of energy conversion and storage technologies are thoroughly examined in this article. Elucidating their roles in improving energy density, cyclic stability, and power output, it highlights their importance in supercapacitors, batteries, and energy harvesting systems. In summary, this article presents a detailed on the synthesis techniques and diverse energy applications of conductive polymers, purposing to guide researchers, engineers, and practitioners toward harnessing for the development of energy technologies.

1. INTRODUCTION

Today, the amount of energy used and produced by a society can be counted as an indicator of the level of welfare reached by developed countries. Consumption of natural resources continues at a faster rate to provide the energy needed for the sustainability of the economy and the development of other countries (Özkan et al., 2019). Fossil fuels are the most widely used energy source. There are studies on the possibilities of renewable, sustainable, and environmentally friendly energy sources due to the limited availability of fossil fuels and the damage they cause to the environment (Barreto et al., 2003). Ongoing scientific research is being driven by the growing demand for energy, particularly from renewable sources like sunlight, wind, nuclear, wave, and geothermal heat, etc. These renewable energy sources do, however, vary with time and place. To deal with this variability, using energy harvesters in conjunction with converters has shown to be a workable solution. Conductive polymers (CPs) are defined as a class of organic materials with electrical and optical properties similar to inorganic semiconductors. Materials science has been progressed in many technological applications, especially in electronic technology, with conductive polymer materials. The Nobel Prize in Chemistry was awarded to the discoverers of conductive polyacetylene in 2000

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(Shirakawa et al., 2003). Although conductive polymers are at the forefront of their conductivity properties, they also have unique electronic, magnetic, wetting, optical properties, mechanical, and microwave absorption properties of these materials. Because of these features, it has many usage areas such as electronic devices, sensors, a catalyst, energy, and biomedicine etc. (Das & Prusty, 2012). These superior properties are the result of their chemical structure. They are conjugated and have a backbone of neighbouring sp2 hybridized orbitals. Therefore, delocalized π electrons are located throughout their backbone structure. Nevertheless, conjugation alone is not enough for conductivity. A dopant is required to alter the band structure of the semiconducting molecular structure backbone. The added dopant allows electrical transport by causing hole or electron mobility in the polymeric structure (Vandesteeg, 2007). In the CPs studies, primarily polyaniline (PANi) as well as poly(3,4-ethylenedioxythiophene) (PEDOT), polypyrrole (PPy), Polythiophenes (PTs) and polyphenylene vinylene (PPV) are investigated.

2. SYNTHESIS METHODS OF CPS

The main aim in the synthesis of CPs is to preserve the conjugated structure of the monomer during the synthesis process. This makes both monomer selection and polymerization process selection important. Most of the CPs monomers are chosen electron-rich molecules such as pyrroles, thiophenes. Such monomers are widely used as they undergo linear polymerization. CPs are synthesized by using many methods such as chemical, electrochemical polymerization, photochemical, concentrated emulsion, and plasma polymerization. The most widely used of these synthesis methods are chemical and electrochemical methods. However, recently, research on the synthesis and application of nanostructured CPs has also increased. Chemical method in the synthesis of CPs occurs through reduction or oxidation of the monomers followed by polymerization of the respective monomers. To obtain the desired quality and weight polymer, the oligomers and/or low molecular weight polymers must be sufficiently reactive and soluble in the medium to polymerize. In addition, it allows the specific oxidant selection to selectively generate cation radicals at the appropriate position on the selected monomer. The advantage of this method, the mass production cost is acceptable. There are also disadvantages of this synthesis method such as not being able to control the oxidation step and the obtained product containing impurities (Kumar et al., 2015). Electrochemical reaction carries out oxidation of the monomer in the supporting electrolyte solution. By applying an external potential, a reactive radical cation is produced. After the first oxidation step, two methods are possible for the formation of the polymer. In the first method, the radical cation of the monomer can combine with the monomer to form a dimer. In the second method, two radical cations can combine to form a dimer, also. Next, the synthesized dimer is oxidized again and then initiates electroactive polymer formation (Naveen et al., 2017; Zhang et al., 2018). The advantages of this polymerization are that the reaction rate and doping method can be controlled. Besides, it is a simple, selective, reproducible method and easy to control the film thickness and molar mass. The disadvantage of this method is that the products obtained by this method are insoluble polymers, also (Kumar et al., 2015; Zhang et al., 2018).

In concentrated emulsion method polymerization method, there are two phrases that do not mix with each other. The monomer phase is dispersed as an emulsion in the dispersion phase. By using various emulsifiers, the monomer phase is stably emulsified in the dispersion phase. In emulsion polymerization, water is generally used as the emulsion medium. The monomer is dispersed in this medium with the help of an emulsifying agent. The polymerization initiator is a water-soluble substance and produces free radicals. The emulsifier is an active substance and contains hydrophilic and hydrophobic groups (Awuzie, 2017). The desired product is precipitated and then purified. The emulsifier has two important advantages in emulsion polymerization. The first is to influence the polymerization locus and thereby increase the

molecular weight of the product. The second is to improve the solubility, conductivity and processability of the synthesized polymers (Palaniappan & John, 2008).

Plasma polymerization is one of the new processes to produce thin films from a group of organic and organometallic materials. These films are rather high cross-linked. Therefore, they are insoluble in water, thermally and chemically stable, and have high mechanical strength. In addition, these films can easily adhere to surfaces such as polymers, glass, or metal (Biederman, 2004). As a result of these extraordinary properties, CPs synthesized by this method have been widely used in some applications such as in membrane systems, biomedical materials, electronics, optical devices, etc. (Kumar et al., 2015).

When CPs are designed and synthesized in nanoscale, many characteristic properties are improved. Therefore, they have better device performance in energy applications compared to their bulk solid CPs. Until now, some synthesis strategies have been improved to produce many CPs materials. Two main synthesis strategies, template-based and template-free, are applied, taking into account "morphology control" and "size control" of nano sized CPs (Yin & Zheng, 2012). In template-based synthesis is a significant and effective method for the synthesis of nano CPs with the wanted shape and controlled dimensions. This synthesis strategy means a process using nanostructured materials as templates, providing the spatial confinement function to encourage 1D or 0D growth of CPs on their inner pores and/or outer surfaces supported by some physical and chemical measures (Zhang et al., 2018). In the template-free synthesis strategy, nanostructured CPs are produced without any templates. Therefore, it is thought a simple and economic method compared with the template-based strategy. In this process, the nanostructured CPs can be synthesized by controlling the reaction conditions, such as temperature, a molar ratio of dopant to monomer, pressure, etc. (Zhang et al., 2018).

3. ENERGY APPLICATION OF CPS

Due to the attractive properties of CPs, these materials make them promising candidates for applications in high-performance energy devices. Therefore, this advanced material plays an important role as electrodes, catalysts, electrode/catalyst support, and so on in energy conversion and storage applications such as solar cells, fuel cells, lithium-ion batteries, supercapacitors. Remarkable advances in these applications of CPs are reviewed in this section, where information on the relations between the material structures and some device performances are given below.

3.1 Solar Cell

Solar cells, one of the effective and promising devices, convert sunlight energy into electrical energy. In recent years, organic or hybrid photovoltaic devices, including polymer solar cells (PSCs), hybrid solar cells (HSCs), and organic tandem solar cells (OTSCs), have been attractive because of their advantages such as light weight, flexibility, thin, cost-effective production, etc. It is interesting compared to the silicon solar cells sold, and research are increasing day by day. Nowadays, the progress on the synthesis of CPs as well as the fabrication of especially 0D or 1D CPs materials and improved performance, has paved a way for next generation solar cells types (Roncali, 2011). PSCs consist of an anode, a cathode, an n-type layer, and a p-type layer. In addition, to produce PSCs, it is obligatory to use transparent anode with organic-based materials. CPs can be used in these layers. For example; PTh derivatives (P3HT, P3OT, etc.), are the commonly used p-type materials, whereas fullerene and its derivatives are the most significant n-type materials (Murad et al., 2020). In addition, CPs materials play an important role in the construction of HSC, also. In this solar cell, p-type electron donor is generally used CPs, whereas n-type electron acceptor are used inorganic semiconductors such as ZnO, TiO_2, CdS, Si, etc., (Yin & Zheng, 2012). The efficiency of this solar cell was higher than the organic solar cell. Such a combined design has been a more effective design than the case in solar cells

containing only organic or only inorganic. The OTSC structure is more complex than other organic solar cells. Its architecture includes the stacking of two subcell units. The first subcell is designed to capture short-wavelength energetic photons, whereas the second subcell is also designed to receive long-wavelength energetic photons (Zheng et al., 2015). Therefore, the OTSCs demonstrate the potential to come through a wide solar spectrum and solve associated problems concerning the thickness of the active organic absorbing layers in single junctions because of low carrier mobility (M. Li et al., 2017). For OTSC, examples of the large band gap polymers are given poly[2-methoxy-5-(3′,7′-dimethyloctyloxy)-1,4-phenylene vinylene], P3HT, and poly((2,7-(9,9-dioctyl)-fluorene)-alt-5,5-(4′,7′-di-2-thienyl-2′,1′,3′-benzothia-diazole) whereas examples of the small band gap polymer material poly(5,7-di-2-thienyl-2,3-bis(3,5-di(2-ethylhexyloxy)phenyl)-thieno[3,4-b]pyrazine) (PTBEHT) is given. All large band gap polymers can be used complementary with PTBEHT (Hadipour et al., 2008; Li et al., 2013). In another study carried out TiOx was coated as a dense and homogeneous film on the BHJ solar cell. Smooth and sharp interfaces in the TiO_x/PEDOT: PSS interconnect layer have been found to produce a unified direction of the electric field located throughout the tandem cells. They found that an organic tandem cell with $TiO_{1.76}$/PEDOT: PSS interconnect layer provides a power conversion efficiency of 20.27%. This efficiency is a remarkable result among organic solar cells so far (Zheng et al., 2022).

3.2 Fuel Cells

Fuel cells convert the chemical energy of a fuel directly into electricity by electrochemical reactions. Fuel cells that use polymeric material in their structure are fuel cells with polymer electrolyte membranes such as proton exchange membrane fuel cells (PEMFC) and direct methanol fuel cells (DMFC). In fuel cells with a polymer electrolyte membrane, the proton exchange membrane is the most important part. This membrane both prevents the separation of anode and cathode and prevents the mixing of reactant gases. In addition, this membrane is selectively permeable. As they carry protons from the anode to the cathode, they prevent electron passage. This polymeric membrane should be good chemical, mechanical and thermal stability, high proton conductivity, low cost, and meet the needs of the fuel cells (Gubler & Scherer, 2010). Commercially, perfluorosulfonic acid polymers materials such as Nafion (Du Pont, USA), Flemion (Asahi Glass, Japan), and Aciplex (Asahi Kasei, Japan) are used as membranes in polymeric fuel cell systems (Saito et al., 2004). Various organic membranes have been researched and improved with high performance compared with the commercial product. One of them is the development of a CP based PEM (Kausar, 2017). CPs based fuel cell operating at high temperatures has been identified as an up-and-coming resolution to meet technical problems. Some examples of literature, Polybenzimidazole (PBI), acid-doped PBI (Jensen et al., 2005), poli(2,5-benzimidazol) (Asensio et al., 2003), poly(etheretherketone) (PEEK) / poly (benzimidazole) (PBI) (Kerres et al., 1999), SPEEK/PANI (X. Li et al., 2006; Nagarale et al., 2006) have been successfully used as membranes for fuel cell systems. These membranes have high conductivity, thermal stability, and mechanical properties. They can be operated at higher temperatures than Nafion's operating temperature.

3.3 Lithium Ion Batteries

CPs are very up-and-coming materials for organic-inorganic composites in lithium-ion batteries because of their lightweight, multi-cycle working, high electrical conductivity, and high coulombic efficiency. These problems are overcome by the use of conductive polymers in the case of poor conductivity and insufficient cycling life problems, which are encountered only in batteries made of inorganic materials. CPs materials with inorganic matters could be proper as an electrode (Sengodu & Deshmukh, 2015). In addition, nanostructured PCs have a high specific capacity and have good cycling performance, so they are very attractive to use as

electrodes in Li-ion battery applications (Malta et al., 2003). To get better the entrapment of polysulfide, Cui et al. used encapsulated carbon/sulphur particles with PEDOT: PSS. This work provided an efficient alternative to trap polysulfides and minimize the resolution of polysulfides from cathodes. In addition, as a result of this study, it was determined that the discharge capacity in the 150th cycle was above 600 mA h g^{-1} (Yang et al., 2011). In another study, the performance of Li-ion battery was investigated when silicon-PANI composite is used as anode. The result is a high-performance Li-ion battery with a current density of 6.0 A g^{-1}, a capacity protection of over 90%, and a cycle life of 5,000 cycles (Wu et al., 2013).

3.4 Supercapacitors

Supercapacitors are the most interesting energy storage devices that can be used in application areas such as electric transportation vehicles and uninterruptible power supplies. Compared to lithium-ion batteries, these energy storage devices have higher specific power. CPs are used as electrodes in composite structure in supercapacitors (Das & Prusty, 2012). Multiple or binary composites based on nano sized PPy, PANI and PEDOT have very good performance in supercapacitors at electrodes (Gao, 2017). Wang et al. investigated the nanostructured PEDOT/ nano cellulose fiber composite in supercapacitors. The PEDOT was covered as a thin layer on nano cellulose fibers. The composite shows high specific capacitance (90 F g^{-1}) with 1.7 Ω equivalent series resistance and capacitance retention of 93% after 15,000 cycles with high cycling stability. In addition, it has 1.5 mW h cm^{-3} and 1470 mW cm^{-3}, volumetric energy, and power density, respectively (Wang et al., 2016). In another study was studied the supercapacitor performance of the carbon-PANI composite using a core-shell model of nanoporous carbon derived from a metal-organic framework and a CP. These nanocomposites showed a specific capacitance value in the range of 300–1100 F g^{-1}, high specific energy of 21 W h kg^{-1}, high specific power of 12 kW kg^{-1}, and excellent capacitance retention of 86% after 20,000 cycles (Salunkhe et al., 2016).

4   CONCLUSION

In conclusion, this comprehensive investigation of the synthesis processes of conductive polymers and their use in energy storage and energy harvesting applications highlights their critical role in expanding the field of contemporary energy technologies. This discussion of synthesis processes has demonstrated the adaptability and tunability of these materials, providing a range of ways to customize their characteristics, like conductivity, stability, and morphology, to meet particular application needs. The enormous potential of conductive polymers is highlighted by the insights gained from their use in energy devices, such as solar cell, fuel cell, batteries, supercapacitors, etc. They have the potential to improve energy practice performance, cyclic stability, and power delivery by acting as active materials, electrodes, or conductive additives.

The future of conductive polymers essentially consists of ongoing improvement, a wider range of applications, sustainable production techniques, functional integration into different technologies, the creation of sophisticated composites, and getting past commercialization and regulatory obstacles. Together, these paths open the door for conductive polymers to be widely used in various sectors and technologies.

Conflicts of Interest

The authors declared that there is no conflict of interest

Contribution of Authors

Designed the study, and wrote the manuscript: M. S. Akkuş, Research mentor, supervision: B. Yeşilata

REFERENCES

Asensio, J. A., Borrós, S., & Gómez-Romero, P. (2003). Enhanced conductivity in polyanion-containing polybenzimidazoles. Improved materials for proton-exchange membranes and PEM fuel cells. *Electrochemistry Communications*, *5*(11), 967-972. doi: https://doi.org/10.1016/j.elecom.2003.09.007.

Awuzie, C. I. (2017). Conducting polymers. *Materials Today: Proceedings*, *4*(4), 5721-5726. doi: https://doi.org/10.1016/j.matpr.2017.06.036.

Barreto, L., Makihira, A., & Riahi, K. (2003). The hydrogen economy in the 21st century: A sustainable development scenario. *International Journal of Hydrogen Energy*, *28*(3), 267-284. doi: https://doi.org/10.1016/S0360-3199(02)00074-5.

Biederman, H. (2004). *Plasma polymer films*. World Scientific. Imperial College Press, ISBN:1-86094-467.

Das, T. K., & Prusty, S. (2012). Review on Conducting Polymers and Their Applications. *Polymer-Plastics Technology and Engineering*, *51*(14), 1487-1500. doi:https://doi.org/10.1080/03602559.2012.710697.

Gao, Y. (2017). Graphene and Polymer Composites for Supercapacitor Applications: A Review. *Nanoscale Research Letters*, *12*(1), 387. doi: https://doi.org/10.1186/s11671-017-2150.

Gubler, L., & Scherer, G. G. (2010). Trends for fuel cell membrane development. *Desalination*, *250*(3), 1034-1037. doi: https://doi.org/10.1016/j.desal.2009.09.101.

Hadipour, A., de Boer, B., & Blom, P. W. M. (2008). Organic Tandem and Multi-Junction Solar Cells. *Advanced Functional Materials*, *18*(2), 169-181. doi: https://doi.org/10.1002/adfm.200700517.

Jensen, J. O., Li, Q., He, R., Pan, C., & Bjerrum, N. J. (2005). 100–200 C polymer fuel cells for use with NaAlH4. *Journal of alloys and compounds*, *404*, 653-656. doi:https://doi.org/10.1016/j.jallcom.2005.02.091.

Kausar, A. (2017). Overview on conducting polymer in energy storage and energy conversion system. *Journal of Macromolecular Science, Part A*, *54*(9), 640-653. doi:https://doi.org/10.1080/10601325.2017.1317210.

Kerres, J., Ullrich, A., Meier, F., & Häring, T. (1999). Synthesis and characterization of novel acid–base polymer blends for application in membrane fuel cells. *Solid state ionics*, *125*(1-4), 243-249. doi:https://doi.org/10.1016/S0167-2738(99)00181-2.

Kumar, R., Singh, S., & Yadav, B. C. (2015). Conducting polymers: Synthesis, properties and applications. *International Advanced Research Journal in Science, Engineering and Technology*, *2*(11), 110-124. doi: https://doi.org/10.17148/IARJSET.2015.21123.

Li, K., Li, Z., Feng, K., Xu, X., Wang, L., & Peng, Q. (2013). Development of Large Band-Gap Conjugated Copolymers for Efficient Regular Single and Tandem Organic Solar Cells. *Journal of the American Chemical Society*, *135*(36), 13549-13557. doi: https://doi.org/10.1021/ja406220a.

Li, M., Gao, K., Wan, X., Zhang, Q., Kan, B., Xia, R., Liu, F., Yang, X., Feng, H., & Ni, W. (2017). Solution-processed organic tandem solar cells with power conversion efficiencies> 12%. *Nature Photonics*, *11*(2), 85-90. doi: https://doi.org/10.3390/ma10070780.

Li, X., Chen, D., Xu, D., Zhao, C., Wang, Z., Lu, H., & Na, H. (2006). SPEEKK/polyaniline (PANI) composite membranes for direct methanol fuel cell usages. *Journal of Membrane Science*, *275*(1-2), 134-140. doi: https://doi.org/10.1016/j.memsci.2005.09.018.

Malta, M., Louarn, G., Errien, N.,Torresi, R. M. (2003). Nanofibers composite vanadium oxide/polyaniline: Synthesis and characterization of an electroactive anisotropic structure. *Electrochemistry communications*, *5*(12), 1011-1015. doi: https://doi.org/10.1016/j.elecom.2003.09.016.

Nagarale, R. K., Gohil, G. S., & Shahi, V. K. (2006). Sulfonated poly (ether ether ketone)/polyaniline composite proton-exchange membrane. *Journal of Membrane Science*, *280*(1-2), 389-396. doi: doi.10.1016/j.memsci.2006.01.043.

Naveen, M. H., Gurudatt, N. G., & Shim, Y.-B. (2017). Applications of conducting polymer composites to electrochemical sensors: A review. *Applied materials today*, *9*, 419-433. doi: https://doi.org/10.1016/j.apmt.2017.09.001.

Özkan, G., Akkuş, M. S., & Özkan, G. (2019). The effects of operating conditions on hydrogen production from sodium borohydride using Box-Wilson optimization technique. *International Journal of Hydrogen Energy*, *44*(20), 9811-9816. doi: https://doi.org/10.1016/j.ijhydene.2018.12.134.

Palaniappan, S., & John, A. (2008). Polyaniline materials by emulsion polymerization pathway. *Progress in polymer science*, *33*(7), 732-758. doi: https://doi.org/10.1016/j.progpolymsci.2008.02.002.

Murad, R., A., Iraqi, A., Aziz, S. B., N. Abdullah, S., & Brza, M. A. (2020). Conducting polymers for optoelectronic devices and organic solar cells: A review. *Polymers*, *12*(11), 2627. doi: https://doi.org/10.3390/polym12112627.

Roncali, J. (2011). Single Material Solar Cells: The Next Frontier for Organic Photovoltaics? *Advanced Energy Materials*, *1*(2), 147-160. doi: https://doi.org/10.1002/aenm.201000008.

Saito, M., Arimura, N., Hayamizu, K., Okada, T. (2004). Mechanisms of Ion and Water Transport in Perfluorosulfonated Ionomer Membranes for Fuel Cells. *The Journal of Physical Chem. B*, *108*(41), 16064-16070. doi: https://doi.org/10.1021/jp0482565.

Salunkhe, R. R., Tang, J., Kim, J., Yamauchi, Y. (2016). Ultrahigh performance supercapacitors utilizing core–shell nanoarchitectures from a metal–organic framework-derived nanoporous carbon and a conducting polymer. *Chemical Science*, *7*(9), 5704-5713. doi: https://doi.org/10.1039/C6SC01429A.

Sengodu, P., & Deshmukh, A. D. (2015). Conducting polymers and their inorganic composites for advanced Li-ion batteries: A review. *RSC advances*, *5*(52), 42109-42130. doi: https://doi.org/10.1039/C4RA17254J.

Shirakawa, H., McDiarmid, A., & Heeger, A. (2003). Twenty-five years of conducting polymers. *Chemical communications*, *2003*(1), 1-4. doi: https://doi.org/10.1039/B210718J.

Shrivastava, A. (2018). *Introduction to plastics engineering*. William Andrew. Elsevier.978-0-323-39500-7.

Vandesteeg, N. A. (2007). *Synthesis and characterization of conducting polymer actuators* [PhD Thesis, Massachusetts Institute of Technology]. https://dspace.mit.edu/handle/1721.1/38514.

Wang, Z., Tammela, P., Huo, J., Zhang, P., Strømme, M., & Nyholm, L. (2016). Solution-processed poly (3, 4-ethylenedioxythiophene) nanocomposite paper electrodes for high-

capacitance flexible supercapacitors. *Journal of Materials Chemistry A*, *4*(5), 1714-1722. doi: https://doi.org/10.1039/C5TA10122K.

Wu, H., Yu, G., Pan, L., Liu, N., McDowell, M. T., Bao, Z., & Cui, Y. (2013). Stable Li-ion battery anodes by in-situ polymerization of conducting hydrogel to conformally coat silicon nanoparticles. *Nature com.*, *4*(1), 1943. doi: https://doi.org/10.1038/ncomms2941.

Yang, Y., Yu, G., Cha, J. J., Wu, H., Vosgueritchian, M., Yao, Y., Bao, Z., & Cui, Y. (2011). Improving the Performance of Lithium–Sulfur Batteries by Conductive Polymer Coating. *ACS Nano*, *5*(11), 9187-9193. doi: https://doi.org/10.1021/nn203436j.

Yin, Z., & Zheng, Q. (2012). Controlled Synthesis and Energy Applications of One-Dimensional Conducting Polymer Nanostructures: An Overview. *Advanced Energy Materials*, *2*(2), 179-218. doi: https://doi.org/10.1002/aenm.201100560.

Zhang, Q., Dong, H., & Hu, W. (2018). Electrochemical polymerization for two-dimensional conjugated polymers. *Journal of Materials Chemistry C*, *6*(40), 10672-10686. doi: https://doi.org/10.1039/C8TC04149K.

Zheng, Z., Wang, J., Bi, P., Ren, J., Wang, Y., Yang, Y., Liu, X., Zhang, S., & Hou, J. (2022). Tandem organic solar cell with 20.2% efficiency. *Joule*, *6*(1), 171-184. doi: https://doi.org/10.1016/j.joule.2021.12.017.

Zheng, Z., Zhang, S., Zhang, M., Zhao, K., Ye, L., Chen, Y., Yang, B., & Hou, J. (2015). Highly Efficient Tandem Polymer Solar Cells with a Photovoltaic Response in the Visible Light Range. *Advanced Materials*, *27*(7), 1189-1194. doi: https://doi.org/10.1002/adma.201404525.

Review of Microgrid Energy Management Techniques on Virtual Power Plant System

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Keywords	Abstract
	The growing energy supply and demand are slowly changing the nature of power transmission and distribution, and the application of virtual power plant (VPP) has already gained traction in countries like Sweden, Germany, and Belgium. The dynamic nature of the VPP platform to connect multiple microgrids within the same geographical location, and to some degree, large-scale nationwide energy resources make it a state-of-the-art technological innovation. The platform has been applied for distributed energy resources (DERs) and dispatchable generation units such as combined heat and power (CHP) to monitor and control energy production and consumption, which also includes the integration of renewable energy sources (RES) into the energy mix. The energy management system (EMS) is one of the function modules in the control system of the VPP and can regulate energy stored and discharged from the energy storage system (ESS), generally, microgrids are known to connect regions far away from the main grid and can operate on islanding mode or on-grid, and they largely facilitate electrification of remote areas as energy production is done onsite. Therefore, in this review control strategies for energy management systems are analyzed and compared, e.g., Multi-Agent System (MAS), and Model Predictive Control (MPC), i.e., chance-constrained optimization, with the main emphasis being on minimizing costs and facilitating micro-grid stability through economical dispatch of energy generational units.

1. INTRODUCTION

The future grid network also referred as the smart grid of the future is envisioned to accommodate variety of energy sources. In the scheme of availing energy to meet increasing demand, modern power transmission and distribution challenges are inevitable, for instance, integration of more RESs into the grid can potentially results in unexpected supply shortages depending on the weather conditions, which poses grid reliability issues such as power losses and prolonged outages, such issues can be contained by use of adaptive EMS methods to control PV production, energy stored in the battery and energy from diesel generators as per the set network constraints. Currently, the modern trends and the impact of climate change has forced the adoption of cleaner ways of generating electricity, and renewables are the best alternative to combat climate change, however integration of these resources is the main hurdle as power

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output is stochastic, in order to solve the emerging issues in smart grid systems, Scientists and the global energy community are at the helm of providing tools and software platforms meant for smooth energy transition, that is, a modernized grid network with increased RES and controllable loads which include roll out of electric vehicles, and improved demand response strategies, for instance using an EMS with the view of reducing carbon emissions, and applying intelligent IoT-driven systems, which can act as hubs for generating consumption data for households through a Multi-agent System (Omarov & Altayeva, 2018). The control methods are crucial for the diagnostic and predictive maintenance of energy systems, (Raju et al., 2016) MAS, control technique has been applied to model a microgrid with penetration of renewable energy sources, by use of multi-agent approach various energy sources have been modelled as agents participating in energy sharing through a collaborative approach. All agents are designed to meet grid requirements, in terms of supply and demand, in case violation of energy balance equation is violated, the Independent System Operator (ISO) steps in by assessing the stability of the grid, at the same time ensuring physical delivery of power without power quality setbacks, such as voltage sag, voltage swell and harmonics. MPC method uses long-short term memory (LSTM) neural network to predict load consumption pattern on hourly basis, by considering the generation of wind or photovoltaic forecasted information. The method can complement the solution strategy of having a reduced economic dispatch cost for a VPP platform, and the optimal scheduling problem is then solved by an advanced version of particle swarm optimization (PSO) algorithm (Chang et al., 2020). MPC method has been used for microgrid control through an EMS platform to optimally control flexible loads, heating systems and generation sources (Parisio et al., 2017), the user is given access to the control system and can view demand forecast, energy prices and all the microgrid constraints. According to (Grosso et al., 2014) chance constrained MPC (CC-MPC) has been used to calculate probabilistic modelling of system disturbances without violating system constraints specified within the model, meanwhile (Velarde et al., 2017) gives a detailed analysis of a two stage CC-MPC for unit commitment.

This paper review covers two techniques that have been uniquely identified in literature for micro-grid control, the two methods will be compared with reference to their existing case studies. This study forms the foundation on which VPP concept can be developed as a solution for renewables integration into the grid network.

2. FUNCTIONALITY OF THE CONTROL METHODS

The control method applied for micro-grid control is chosen depending on the problem at hand, MAS is actualized using software agents, which are instantiated in a distributed system, the agents are programmed in a way that they collaborate to solve problems beyond their individual capacity. MAS is part of distributed artificial intelligence (DAI), whereby the agents are sociable and autonomous and can reach each other through a unified communication language (Olivares, 2014). In regard to the MPC method, its various sub-techniques, i.e., multi-scenario, tree-based, and chance constrained model predictive control, they mostly end up with similar results (E.C.A, 2016). Generally, MPC method applicability is suitable for many industries, especially when solving problems associated with non-linearities and constraints that involve manipulated variables and latency. Additionally, MPC is a model-oriented method with a step-by-step algorithm that provides a feedback mechanism. The algorithm transits through three parts, i.e., predictive model, rolling optimization, and feedback correction (Parisio et al., 2014).

2.1 Multi Agent System Deployment

Normally, electrical substations are monitored using Supervisory Control and Data Acquisition (SCADA) system, which has wide geographical coverage, its centrality ensures remote monitoring of power distribution systems, and they are capable of reporting to the maintenance

crew in real time to correct erroneous equipment and reduce power outage durations. However, the use of sensors mostly results in erroneous reporting and false alarm, which wastes a lot of time and operational resources for the utility providers. In comparison to the use of MAS approach, little to no error is an achievable fit, as the agents are distributed across the network, offering certainty on the operational nature of the equipment and instant reportage, as the agents are autonomous and when affected the source and the cause is identified with absolute certainty. Apparently, a micro-grid can be on-grid or islanded as per the state of the Breaker. The agent platform contains multiple energy agents representing unique power equipment, storage sources and generation units. A Circuit Breaker is modelled as a Switch Agent, Load Agent includes sensitive and critical loads, adjustable loads, and curtailable loads, also Generator Agent that include CHP, Non-dispatchable generation, Solar and small dispatchable generation (DG), etc. Consequently, Storage Agent considers thermal storage and Battery Storage. The agents are developed in an agent platform, for the demonstration purpose Java Agent Development Environment (JADE) is used to model MAS approach. JAVA upholds standards for intelligent agents as specified by Foundation of Intelligent and Physical Agent (FIPA), meanwhile JADE provides an environment that allows agents to execute without privy to the complex nature of operating system in use, and agents can be found in more than one computer in a network topology, and the communication among the agents is enabled by use of same type of code; used for sending and receiving messages, additionally JADE executes in a Java Virtual Machine (JVM), which live in a container that constitute a platform responsible for balancing of power in the micro-grid. The Agent Management System (AMS) has oversight over the agent platform and keeps a record of directory of agent identifiers (AIDS) together with agent states, AMS assigns each agent a unique identity. While the DF provides a channel for agents to be aware of other agents distributed in the platform. On the same note, the message transport service (MTS) maintains communication channel amongst the agents during task execution. MAS and IoT components interaction on the Multiagent System platform (Omarov & Altayeva, 2018), the Switch Agent connects the micro-grid and the utility grid, and the state of all the agents are recorded in the agent management system, and sensor variables such as temperature, air quality, humidity and illumination status are processed by respective controllers, which are connected to the central coordinator agent.

2.1.2 MAS Use Case Description

MAS method has been tried in multiples scenarios, and research shows effectiveness of the method in controlling a solar microgrid with JADE agents, (Raju et al., 2016) discusses multiagent system modelling of solar microgrid in Matlab and use of MACSimJX as a communication link between Matlab and JADE environment. MAS system architecture for West Virginia Super-Circuit (WVSC) physical Project (Chouhan et al., 2013), control is achieved by various agents instantiated in the distribution network, command and decision making starts at the substation agent and subsequent involvement of all the agents in the power distribution system. In real physical systems, MAS has been successful in fault identification within the transmission network, with an aim to show zones that are faulty in real time. WVSC is one such example, whereby agents have been designated to aid in faulty regional demarcation, the agents include Switch agent, zone agent and recloser agent. WVSC consists of many zones interlinked through intelligent electronic devices. Figure 1 shows the scale of WVSC project.
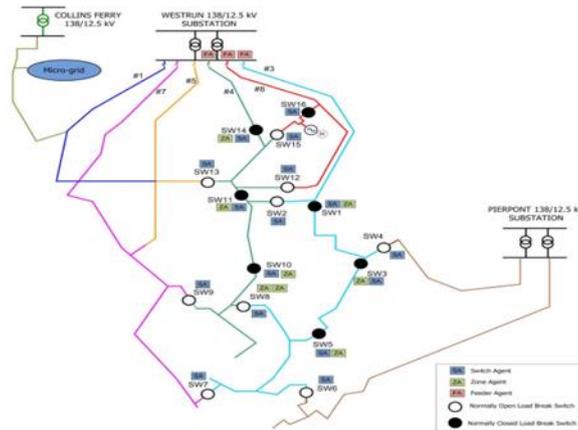
Figure 1. The WV MAS controlled super circuit (Chouhan et al., 2013)

The use of MAS for control purposes facilitates grid resiliency and with the view of incorporating renewable energy sources, the method can easily balance supply and demand in real-time through the defined agents. Each of the agents is fully aware of its environment and they are connected one level above the other, for example, Switch Agent obtains voltage and current RMS values with a resolution of 16 samples per cycle (Chouhan et al., 2013), meanwhile, the Zone agent is above the switch agent, and is able to gather all the information concerning all the switch agents and exchanges the information with other zone agents, at the same time flags the faults that occur within the specified zones. Finally, the recloser agents ensure the safety of the feeder lines and monitor the situation by closing and opening the feeder lines.

2.2 Model Predictive Control

The objective of MPC is to minimize costs by dispatching network resources at the least cost, this way the consumers get energy at low tariffs, at the same time ensuring stability of the network as top priority to the system operator. The MPC approach has a set of simplified steps and due to its feedback mechanism concept, stochastic nature of renewables can be modeled as a forecast model input to the objective function to derive continuous set-points for dispatch of the network resources.

2.2.1 Model Predictive Control Mathematical Modelling (Grosso et al., 2014)

In the mathematical problem formulation, the CC-MPC approach is used to solve equation 1, and the essential part is minimizing the objective function by use of expected values and decision variables.

$$\underset{u[k:k+N-1]}{\text{Min}} \sum_{i=k}^{k+N-1} \mathbb{E}\left[J\big(x(i), u(i)\big)\right] \tag{1}$$

Objective function shown in equation 1 is subject to the following constraints,

$$x(i+1) = Ax(i) + Bu(i) + E\omega(i) \tag{2}$$

$$\mathbb{P}[x_{min} \leq x(i+1) \leq x_{max}] > 1 - \delta_x \tag{3}$$

$$u(i) \in U, \qquad \forall i \in \mathbb{Z}_0^{N-1} \tag{4}$$

Whereby; $\mathbb{E}$ represents the expected value of the loss function and $\mathbb{P}$ is the probability operator, and N is required for the computation of the controller, while $\delta_x \in (0,1)$ is the penalty applied when the constraint is out of bounds. Also x_{max} and x_{min} represent the upper bound and lower bound respectively. Additionally, disturbances are modeled as Gaussian random variables, x being a normal variable with mean $\bar{x}$, and $\sigma_{x(k)}$ being the standard deviation indicated as $x(k) = N(\bar{x}, \sigma_{x(k)})$. For CC-MPC deterministic equivalent is obtained by equation 5 below.

$$\mathbb{P}[x(i+1) \geq x_{min}] \geq 1 - \delta_x \tag{5}$$

Variable x is standardized by applying Z score to establish the relationship between the data point and the mean divided by the standard deviation, as shown by the manipulations below.

$$Z = \frac{x(i+1) - \bar{x}(i+1)}{\sigma_{x(i+1)}} \tag{6}$$

$$\mathbb{P}(Z \geq = \frac{x_{min} - \bar{x}(i+1)}{\sigma_{x(i+1)}} \geq 1 - \delta_x \tag{7}$$

This can further be written as,

$$\mathbb{P}(Z \leq = \frac{x_{min} - \bar{x}(i+1)}{\sigma_{x(i+1)}} \leq \delta_x \tag{8}$$

$$\varphi(\frac{x_{min} - \bar{x}(i+1)}{\sigma_{x(i+1)}} \leq \delta_x \tag{9}$$

And $\varphi(.)$ is for the probability distribution function, which shows whether the random value, i.e., x takes an equal value at $\mathbb{P}(x)$.

$$\frac{x_{min} - \bar{x}(i+1)}{\sigma_{x(i+1)}} \leq \varphi^{-1}(\delta_x) \tag{10}$$

$$\bar{x}(i+1) \geq x_{min} - \varphi^{-1}(\delta_x)\delta_{x(i+1)} \tag{11}$$

Finally, the deterministic equivalent of the lower and upper bound of the chance constraints can be expressed as shown by equation 10 and 11, respectively.

2.2.2 CC-MPC Use Case Description

Application of CC-MPC method has been realized in a microgrid owned and run by HyLab, the system consisted of a photovoltaic field represented by an electronic power source that supplies power to the load, the remaining power in case of oversupply is stored in a battery, there is also an electrolyzer that can supply power when the overall demand is not met. Additionally, the Hydrogen Path available onboard serves two purposes, the first path produces and stores hydrogen while the second path feeds the fuel cell with hydrogen to supply the grid with power. Both the fuel cell and the electrolyzer are of proton exchange membrane (PEM) and hydrogen is in the form of metal hydrides to facilitate storage. Additionally, energy transfer is enabled by converters that connect multiples devices in the system topology.

The results were gotten from the simulations that employed a nonlinear model (Valverde et al., 2013), and generally applied prediction horizon, N=5, sampling time 30s and simulated for a period of 36 hours, the HyLab linear model constituted the internal model of the controller. Furthermore, disturbances used in the simulation exercise were from the registered real demand of May 23,2014 as shown in figure 2.
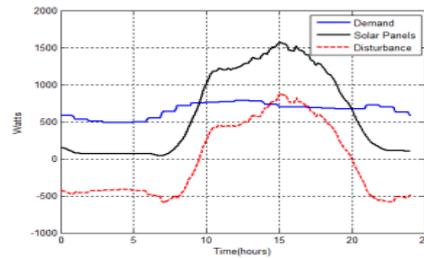
Figure 2. Energy demand, solar PV production and disturbance as of May 23,2014

The appication of CC-MPC factors in the failure probabilty of $\delta\_x<1\%$, and the disturbances follow a normal function whereby $\mu=0.3020$ and $\sigma=0.5245$ as per historical data of May 23, 2013, exactly one year before the simulation was carried out. It was found that the average tracking error of the desired point for the State of Charge (SoC) of the battery was 6.88% and the one corresponding to the metallic hydrogen or (metallic hydrides level) MHL was 2.2%. In literature, when traditional MPC control strategy is compared with the robust control method in this case CC-MPC, there is a world of a difference in terms of computational time, and cumulative final cost.

3. DISCUSSION

The two methods are generally used for the micro-grid control and to some extent are candidates for application of VPP, in terms of DERs scheduling and curtailment planning especially when the highest percentage of generation is obtained from renewables. MAS method application basis emerges from the limitation of SCADA systems, which typically can suffer huge errors emanating from system noise that corrupts the accuracy of measurements, through an agent managed approach such errors can be minimized to a confidential interval suitable for the micro-grid stability. (Luo et al., 2017) MAS and MPC method have been used together to coordinate and optimize the micro-grid, the two methods work in synchronicity to control the microgrid, while the agents use a consensus algorithm as a distribution control strategy. The MPC obtains network information and using rolling optimization external disturbances are minimized, however if MAS is used alone limitations exist and performance of the micro-grid in regard to power delivery would not be effective as much (Parisio et al., 2014), since a lot of constraints such as DG, storage dynamics and curtailments are not considered. It is for this reason MPC method is preferred for multiple DGs and storage systems connected to the micro-grid, research also shows the method has a profound effect in storage systems economical dispatch, as operational and cost constraints are factored in the optimization time horizon. The performance of MPC method has also been comprehensively discussed in (Fernández et al., 2020), meanwhile tunning parameters have been clearly outlined to indicate decrease and increase impact on the MPC controller, additionally design fundamentals of a MPC controller have been applied to a renewable penetrated micro-grid.

4. CONCLUSION

It is imperative to note that depending on the magnitude of the scale of control, MAS and MPC can be chosen, in case the application is on a small-scale MAS method can be applied by instantiating socially, autonomous agents that can take care of their individual needs without violation of the micro-grid energy demand and supply constraints. The two methodologies encompass the working principle of a VPP that intends to dispatch DGs with minimal cost while maximizing cost function for participants who entirely form the prosumer class, and by virtue of storage becoming indispensable part of the grid network infrastructure, the set points to discharge and charge must be considered to avoid battery degradation and CC-MPC methods by far show high performance in literature as modeling is specifically done to incorporate Wind and PV generation.

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Conflict of Interest

The authors have no known competing interests as far as preparation of this article is concerned.

Authors Contribution

First author identified critical control methods and mathematical modeling. Second author, supervised this work and provided utmost guidance during preparation of the manuscript.

REFERENCES

Chang, W., Dong, W., Zhao, L., & Yang, Q. (2020). Model Predictive Control based Energy Collaborative Optimization Management for Energy Storage System of Virtual Power Plant. 2020 19th International Symposium on Distributed Computing and Applications for Business Engineering and Science (DCABES), 112–115. doi: https://doi.org/10.1109/DCABES50732.2020.00037

Chouhan, S., Ghorbani, J., Inan, H., Feliachi, A., & Choudhry, M. A. (2013). Smart MAS restoration for distribution system with Microgrids. 2013 IEEE Power & Energy Society General Meeting, 1–5. doi: https://doi.org/10.1109/PESMG.2013.6672945

Fernández, F. J. V., Segura Manzano, F., Andújar Márquez, J. M., & Calderón Godoy, A. J. (2020). Extended Model Predictive Controller to Develop Energy Management Systems in Renewable Source-Based Smart Microgrids with Hydrogen as Backup. Theoretical Foundation and Case Study. Sustainability, 12(21), 8969. doi: https://doi.org/10.3390/su12218969

Grosso, J. M., Maestre, J. M., Ocampo-Martinez, C., & Puig, V. (2014). On the Assessment of Tree-Based and Chance-Constrained Predictive Control Approaches applied to Drinking Water Networks. IFAC Proceedings Volumes, 47(3), 6240–6245. doi: https://doi.org/10.3182/20140824-6-ZA-1003.01648

Luo, S., Hu, C., Zhang, Y., Ma, R., & Meng, L. (2017). Multi-agent systems using model predictive control for coordinative optimization control of microgrid. 2017 20th International Conference on Electrical Machines and Systems (ICEMS), 1–5. doi: https://doi.org/10.1109/ICEMS.2017.8056293

Omarov, B., & Altayeva, A. (2018). Towards Intelligent IoT Smart City platform Based on OneM2M Guideline: Smart Grid Case Study. 2018 IEEE International Conference on Big Data and Smart Computing (BigComp), 701–704. doi: https://doi.org/10.1109/BigComp.2018.00130

Parisio, A., Rikos, E., Tzamalis, G., & Glielmo, L. (2014). Use of model predictive control for experimental microgrid optimization. Applied Energy, 115, 37–46. doi: https://doi.org/10.1016/j.apenergy.2013.10.027

Parisio, A., Wiezorek, C., Kyntaja, T., Elo, J., Strunz, K., & Johansson, K. H. (2017). Cooperative MPC-Based Energy Management for Networked Microgrids. IEEE Transactions on Smart Grid, 8(6), 3066–3074. doi: https://doi.org/10.1109/TSG.2017.2726941

Raju, L., Appaswamy, K., Vengatraman, J., & Morais, A. A. (2016). Advanced energy management in virtual power plant using multi agent system. 2016 3rd International Conference on Electrical Energy Systems (ICEES), 133–138. doi: https://doi.org/10.1109/ICEES.2016.7510630

Valverde, L., Rosa, F., Del Real, A. J., Arce, A., & Bordons, C. (2013). Modeling, simulation and experimental set-up of a renewable hydrogen-based domestic microgrid. International Journal of Hydrogen Energy, 38(27), 11672–11684. doi: https://doi.org/10.1016/j.ijhydene.2013.06.113

Velarde, P., Valverde, L., Maestre, J. M., Ocampo-Martinez, C., & Bordons, C. (2017). On the comparison of stochastic model predictive control strategies applied to a hydrogen-based microgrid. Journal of Power Sources, 343, 161–173. doi: https://doi.org/10.1016/j.jpowsour.2017.01.015