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Emotion Recognition Based on Interval Type-2 Fuzzy Logic from Facial Expression

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ABSTRACT Automatic recognition of facial emotion plays an effective and important role in Human–Computer Interaction (HCI). There are various emotion recognition approaches have been proposed in the literature. The analytic face model consisted of a 26-dimensional geometric feature vector. These properties are used effectively to identify facial changes resulting from different expressions. The variation and uncertainties of these features make the emotion recognition problem more complicated. For decreasing these complications, we propose a distance-based clustering and uncertainty measures of the base new method for Emotion Recognition from Facial Expression using automatically selects 19 diagnostics of Action Units (AUs) in a 2D facial image using Type-2 Fuzzy inference system. The proposed system includes an automated generation scheme of the geometric facial feature vector. The proposed system has classified six facial expressions using the MUG Facial Expression database. The experimental results show that the proposed model is very efficient in uncertainty management policy and recognizes six basic emotions with an average precision rate of 86.175%.

KEYWORDS: Action Unit, Emotion Recognition, Facial Expression Recognition, Human–Computer Interaction, Interval Type-2 Fuzzy System

1. INTRODUCTION

In recent decades, facial expression and emotion recognition have become an important nonverbal communication step in the human-computer interface (HCI) that has attracted the attention of scientists. They are considered one of the most important ways of recognizing one's feelings, intentions or mood. Such as behavioral and neuroscience researchers there are several applications that use emotion recognition system. Identification of facial expression landmarks is an important key factor for recognition of emotion in human machine interaction. Feature extraction and classification are two significant steps in emotion recognition [1] [2]. Feature extraction refers to the acquisition of the feature vector in which features such as pixel positions, color, shape, and region of the image to be analyzed are represented. A classification module is recognized the intensity of emotional attributes into one of several emotions classes [3]. Feature selection and classifier design greatly affect the performance of a feeling-fully system. Several methods have been used to for facial feature extraction. Commonly used techniques are includes Principal Component Analysis [4], Active Contour [5], Gaussian Mixture Models [6], Neural Network [7], Deep Learning Network [8-11], Independent Component Analysis [12], Gabor Filter [13], Support Vector Machines [14] and Fuzzy logic [15-17],[21-23]. Similar characteristics of a particular emotion can be seen in facial expressions of different emotions. These are problems of uncertainty on emotion classification management. Therefore, it is difficult to have unique facial features. Although different methods have been utilized for facial expression and emotion

recognition system. In this paper, Fuzzy Logic techniques have been used because of the reasoning function is understandable and also similar to human logic. The uncertainties can be handled with this method using the primary and secondary membership distributions of each measurement [26], [27]. Interval type 2 fuzzy logic (IT2FIS) methods are used to associate standard facial actions with specific uncertainties and automatic facial expression recognition rules form. The IT2FIS method provides an alternative approaches to recognize emotion from facial expression and measurement of their intensity using Ekman´s AUs (Action Units), FAPs (Facial Animation Parameter) and FDPs (Facial Definition Parameter) of MPEG-4 standard [28]– [31]. Ekman et al. conducted a meticulous study of facial expression and concluded that there are six basic expressions, these include happiness, sadness, disgust, anger, surprise and fear and also stated that facial expressions were universal and innate [32]–[34]. The Facial Action Coding System (FACS) is a human observer based system developed to detect changes in facial features or facial muscles [35]. It is an important step towards effectively recognizing facial features expression from the faces of different people. Emotion recognition system includes three stage. These are face detection, feature extraction and classification. Geometric and appearance properties-based data are common types of features used to recognize facial expression. The main purpose of this study is to present an automatic facial expression recognition and classification method using type2 fuzzy logic rules using only geometric facial features. Six emotions (Anger, Disgust, Fear, Happiness, Sadness and Surprise) proposed by Ekman were chosen for the proposed recognition system [30], [33] [36]. These emotions recognized with using IT2FIS system. Membership function parameters have a significant effect on the precision of fuzzy inference systems. In order for the membership functions to achieve a higher performance in emotion recognition system, type2 fuzzy membership functions are preferred. Thus, it is more effective than type1 in eliminating the uncertainties. The type-2 fuzzy cluster is modeled by primary and secondary membership and has the potential to handle uncertainty. Because of this feature, it has attracted our attention about using it for emotion classification. The decision-making process here aims to lead the individual emotion class to a specific fuzzy measurement group.

The main contributions and the basic philosophy of the proposed method are explained below.

- The paper provides an alternative approach for facial expression and emotion recognition using soft computing techniques.
- A robust and simple solution to recognize emotion from face images is presented.
- A fully automatic facial expression recognition method has been developed using only geometric facial features.
- The proposed system was evaluated with Interval type-2 fuzzy logic classifiers.
- Implementation of algorithms based on the different AUs (Action Units) for measuring facial emotions and their intensities are presented.

- The tune of input parameters for membership functions are used Euclidian distance calculation between all AUs contribute in a weighted linear way to the total intensity of the emotion.
- Instead of 66 feature points, to decrease the complexity and increase the robustness and simple, only 19 facial feature points are considered where most of the emotions are observable.

The rest of the paper is organized as follows: Section 2 describes the knowledge-based of a framework for facial feature extraction. Section 3 presents segmentation and key features extraction techniques of the most important geometric features measurements of Fiducial Facial Points. Section 4 describes the architecture of Facial Features Extraction methodologies involved in applying 19 data to the IT2FIS for clustering the features data into basic six emotion zones. Section 5 introduce the Preliminaries on Type-2 Fuzzy Sets and philosophies of proposed emotion classification using IT2FIS. In section 6, the measurements of facial features and Fuzzification of facial features process is introduced. In section 7, Fuzzy Inference Engine for Emotion classification is expressed. The experiments and emotion recognition are discussed in Section 8. Finally, we draw conclusions and identify future work in Section 9.

2. KNOWLEDGE-BASED FRAMEWORK

The Knowledge-based framework used in the interpretation of emotional intensity uses reference points such as FAPs and AUs. Evaluating and interpreting the distances between these points according to fuzzy rules allows modeling facial expression definition and indexing in the emotional classification. Figure 1 shows the structure of a knowledge-based framework used to design the type 2 fuzzy logic system. It is utilized relationships between the measured facial AUs, FAPs and their corresponding mathematical description. These are important parameters to recognize facial expressions with fuzzy classifier which provides interpretation of emotional intensity. The measurement of the emotion intensity, the geometric displacement of these reference points and the distance between points generated are taken into account. With the implementation of the proposed method, semantic analysis of facial actions can be developed with an expert system and fuzzy logic systems. Six basic facial expressions (happiness, sadness, disgust, surprise, anger and fear) were tested using the proposed approach. The proposed system includes two classes. These are *Face Model* and *Emotion Model*. The *Face Model* class represents a variety of approaches that allow the definition of facial features. *Emotion* Model is obtained with rule-based modeling for emotion recognition and indexing and also represents the class in which basic facial actions (AUs, FAPs) or actions of facial muscles occur. The advantage of the proposed method is that it allows parameter transformations based on interrelated and interactive work of knowledge classes representing emotions.

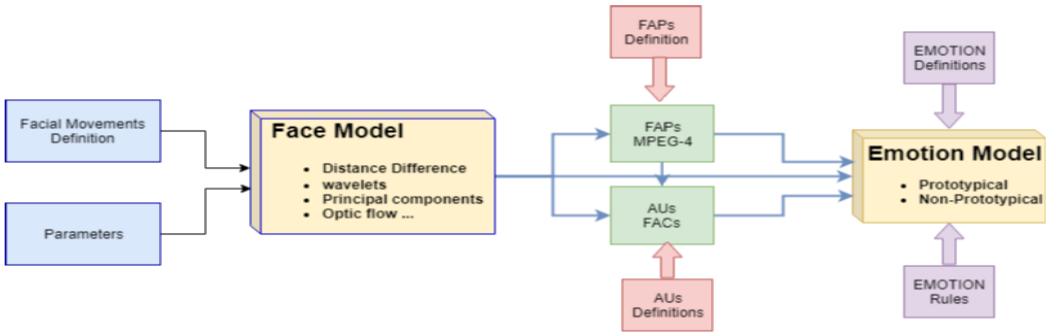


Figure 1. FAPs and AUs based emotion knowledge database structure.

3. GEOMETRIC MEASUREMENTS OF FIDUCIAL FACIAL POINTS

Facial features may provide sufficient information to recognize various facial expressions. The extracted features (from eyes area, eyebrows, lips, etc.) play an important role in providing the necessary information to recognize emotions. The contraction of facial muscles is represented and encoded by AUs of facial features that can be removed on the skin surface. In the proposed system, the face model based on the analysis of nineteen FDPs was used to determine the input parameters in the fuzzy logic system. The set of feature points selected FDPs with the suitable number of associated FAPs used in the proposed method is visualized in figure 2. The facial fiducial reference points are represented the Distance-Class of FDPs. The distance between two feature points (two red points) is combined with a blue line. These two points were calculated by Euclidean calculation method. For example, D1 represents the distance between points 1(Eyebrow left Outer) and 7 (eye Left Outer). Table 1 represents the measurement distances of the proposed model.

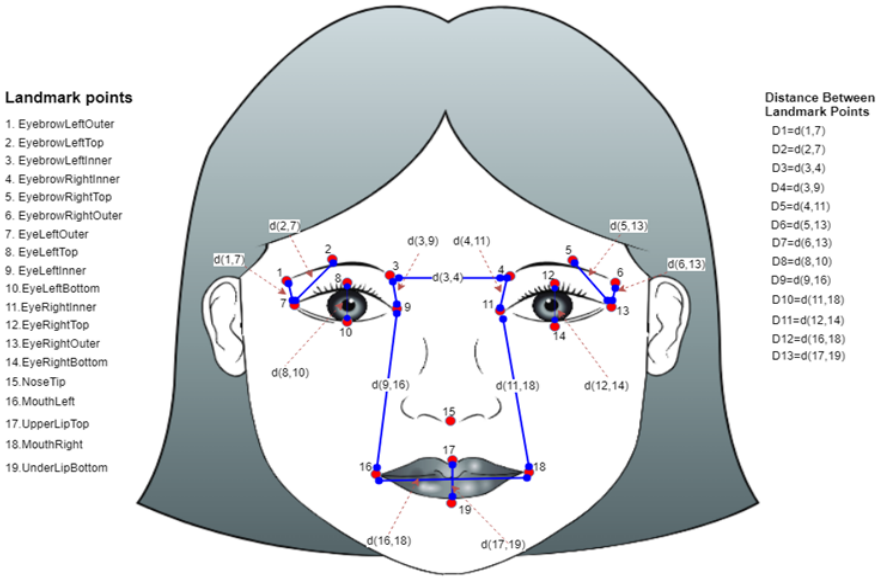


Figure 2. Visualization of feature points with specific emotions and distance vector.

The proposed facial model includes nineteen FDPs and thirteen distances between the fiducial reference points that modeled by the MPEG-4 standard and are represented by the equation D (x, y).

The thirteen-distance information selected for this model and the geometric definitions of these distances and their relations with FAPs are shown in Table 1.

Table 1. The definition of Geometric Measurements using Fiducial Facial Points.

Distance	Measurements	Measurement Name
D1	dist(1,7)	Eyebrow left outer-Eye left outer
D2	dist(2,7)	Eyebrow left top- Eye left outer
D3	dist(3,4)	Eyebrow left inner- Eyebrow right inner
D4	dist(3,9)	Eyebrow left inner- Eye left inner
D5	dist(4,11)	Eyebrow right inner- Eye right inner
D6	dist(5,13)	Eyebrow right top- Eye right outer
D7	dist(6,13)	Eyebrow right outer- Eye right outer
D8	dist(8,10)	Eye left top- Eye left bottom
D9	dist(9,16)	Eye left inner-Mouth left
D10	dist(11,18)	Eye right inner-Mouth right
D11	dist(12,14)	Eye right top- Eye right bottom
D12	dist(16,18)	Mouth left-Mouth right
D13	dist(17,19)	Upper lip top-Under lip bottom

4. AUTOMATIC FACIAL FEATURES EXTRACTION

In a basic sense, the system of emotion recognition consists of three main stages. These are Face Detection, Feature Extraction, and Classification stages. Facial feature extraction is one of the most complex and time-consuming stages in emotion recognition. The procedures performed at this stage have a great importance in obtaining accurate results on face recognition being robust and accurate. Many precise and effective algorithms have been recommended for this purpose. It is necessary to specify which properties are valuable for emotion recognition. We mentioned these features in the previous section. In the next steps, we'll cover the steps on how to get these features.

4.1 FACE DETECTION

The first step of the proposed method is to define the face image boundaries from the input images. One of the most notable detectors of research and algorithms focusing on facial recognition is designed by Viola and Jones [37]. Viola and Jones are known in the literature as object recognition methods. It has been found to have good performance in use as a real-time face detector. In our experiments we used these methods to extract the face region. The Viola-Jones philosophy involves two basic stages: Haar-like features extraction which is given by the summed difference of intensity (between the black and white) rectangular regions and Adaboost classifier [37], [38].

4.2 FACIAL FEATURE EXTRACTION

First of all, the exact accuracy of emotion recognition will depend on the results obtained at this stage. It is necessary to identify which features are valuable from the face region or which features are important for emotion recognition. The features used for recognition of basic emotions (Anger, Disgust, Fear, Happiness, Sadness, and Surprise) are attributes of regions of Eyes, Mouth, Eyebrows, Nose, and Lips. In this work, we used Active Shape Models (ASM) algorithm [39], [40] to extract the features of these regions. It is creating facial landmark's corresponding points and statistical of facial shape.

Nineteen facial landmarks are extracted using ASM. These are illustrated in Figure 2. To classify facial expressions, a feature vector was created using equation (1).

$$\vec{F}_{i,j} = (f_1, f_2, \dots, f_n), f = (x, y) \quad (1)$$

In (1), i and j denote the i-th landmark set for the j-th facial expression, n the number of extracted landmarks, and f = (x, y) the Cartesian coordinate for the landmark, respectively.

4.3 CLASSIFICATION

After obtained the feature vector with using eq. (1), the basic emotion proposed in [36] needs to be classified. Several classifiers have been proposed to recognize the emotions as mentioned before. In this work, we used Type 2 fuzzy inference system to evaluate and classify the facial expression and emotion recognition. The definition of membership function and fuzzy rules are the main factors that have a significant influence on emotion recognition more accurately. The graphical representation of our proposed emotion recognition system has been shown in Figure 3.

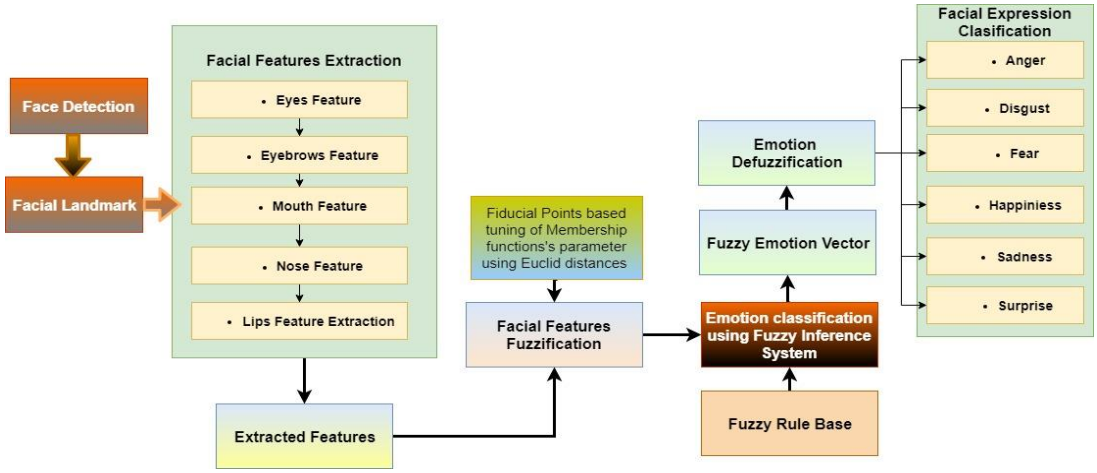


Figure 3. The graphical representation of the proposed emotion recognition system.

First of all the facial expression classification start with face detection stage. After that facial landmarks and feature of expected regions which play a vital role in the proposed system are extracted. Haar-like cascading features and Viola-Jones object detection algorithm were used for this process. The fundamental process of fuzzy reasoning is the fuzzification of inputs. In fuzzification stage, the measurements variables between fiducial points and AUs, given in Table 1, are considered as inputs. The range values of fuzzy logic membership functions were determined by considering measurements between FAUs obtained from face geometry. A fuzzy inference system was designed and a set of rules for fuzzy emotions was created. A separate set of rules was created for each basic emotion based on their own analysis of facial expressions. In the final stage, it is seen as the result of a fuzzy combination of AUs, which is the defuzzification phase of fuzzy logic, corresponding to a particular emotion classification. More details about fuzzy reasoning will be included in the next section.

5. PRELIMINARIES ON TYPE-2 FUZZY

In this section, a general overview of some terminologies related to type-1 (T1FS) and type-2 fuzzy sets (T2FS) and a scheme for emotion recognition using interval type-2 fuzzy inference system (IT2FIS) have been presented. These terminologies will be used throughout the paper. The concept of T2FS, which is presented as an extension of T1FS, enables us to deal with numerical and linguistic uncertainties. The concept of the T2FS was introduced by Zadeh [41], [42]. In its robustness for controlling nonlinear systems with variation and uncertainties, the fuzzy type-2 method has proven to be a strong tool for controlling complex systems [43]. The presence of uncertainties in a nonlinear system control uses the highest and lowest values of the parameters, extending the type-1 fuzzy method. Uncertainty is a characteristic of information, which may be incomplete, inaccurate, undefined, inconsistent, and so on. The uncertainty is represented by a region called the footprint of uncertainty (FOU). This is a bounded region that uses an upper and lower type-1 membership function. Here we would like to emphasize the Interval type-2 fuzzy inference system.

An interval type-2 fuzzy set denoted by $\tilde{A}$ is expressed in Equation (2) or (3).

$$\tilde{A} = \{(x, y), \mu_{\tilde{A}}(x, y) | \forall_x \epsilon X, \forall_u \epsilon J_x \subseteq [0\ 1]\} \quad (2)$$

Hence, $\mu_{\tilde{A}}(x, u) = 1, \forall_u \epsilon J_x \subseteq [0\ 1]$ is considered as an interval type-2 membership function.

$$\tilde{A} = \int_{x \epsilon X} \int_{u \epsilon J_x} 1/(x, u)\ J_x \subseteq [0\ 1] \quad (3)$$

where $\int \int$ donate the union of all acceptable x, u and J_x is just the interval of $[\bar{\mu}_{\tilde{A}}(x), \underline{\mu}_{\tilde{A}}(x)]$. $\bar{\mu}_{\tilde{A}}(x)$ and $\underline{\mu}_{\tilde{A}}(x)$ are denoted upper and lower membership functions.

6. FUZZIFICATION OF FACIAL FEATURES

In this case, the inputs of the fuzzy set convert into suitable linguistic variables. The membership functions consist of one or several types-2 fuzzy sets. A numerical vector x of the fuzzifier maps converts into a type-2 set $\tilde{A}$. The outputs of the type-2 fuzzy sets are considered a singleton. In a singleton fuzzification, the inputs are crisp values on nonzero membership. Input variables, in particular, FAPs of indexed facial expressions taken from MUG databases [44], accept the difference in the distances between standard reference points. It should be noted that the difference in distance is the difference between a neutral face and AUs on the face of the person performing any action that expresses any emotion. In this work we consider thirteen inputs. These are distances between fiducial facial AUs. The high number of fuzzy logic inputs can affect the number of rules to be created and can lead to complexity of the process. If we examine the face in two classes, the change between some points on the face to be right and left will yield similar mathematical results. One of these similar points or the average of these similar points may be considered. This reduces the number of inputs of fuzzy logic and reduces complexity. Therefore, search area decreases to find better parameters and it can fully

adjust the parameters of the MFs. In the last step, in this study, we reduced these inputs to seven and considered the average calculation method. These are listed in the following table 2.

Table 2. Input parameter of feature points with specific emotions and average vector from figure 2 and table 1.

Average Distances	Face fiducial points	
	Left side of face	**Left side of face**
D1-7	d(6,13)	d(6,13)
D2-6	d(2,7)	d(5,13)
D4-5	d(3,9)	d(4,11)
D8-11	d(8,10)	d(12,14)
D9-10	d(9,16)	d(11,18)

In order to achieve the desired purpose, the measurements we calculated for Mouth Opening, Eye Opening and Eyebrow constriction are coded to SMALL, MEDIUM and LARGE fuzzy cluster. Gaussian, Z-Shape and S-Shape membership functions are selected for SMALL, MEDIUM and LARGE Fuzzy sets, respectively. The functions of Gaussian, Z-Shape and S-Shape membership functions are shown in the Equations. (4) - (6) respectively.

$$\text{Gausian}(x, \sigma, \mu) = e^{-\frac{(x-\mu)^2}{2\sigma^2}} \tag{4}$$

$$Z\_Shape(x,a,b) = \begin{cases} 1, & x \le \boldsymbol{a} \\ 1 - 2\left[\frac{x-a}{b-a}\right]^2, & a < x \le \frac{a+b}{2} \\ 2\left[b - \frac{x}{b-a}\right]^2, & \frac{a+b}{2} \le \boldsymbol{x < b} \\ 0, & x \ge \boldsymbol{b} \end{cases} \tag{5}$$

$$S\_Shape(x,a,b) = \begin{cases} 0, & x \le \boldsymbol{a} \\ 2\left[\frac{x-a}{b-a}\right]^2, & a < x \le \frac{a+b}{2} \\ 1 - 2\left[\frac{x-b}{b-a}\right]^2, & \frac{a+b}{2} \le x < b \\ 1, & x \ge \boldsymbol{b} \end{cases} \tag{6}$$

The parameters given herein; x is any continuous feature; in addition, a, σ, μ and b are membership function parameters. These parameters have a significant effect on the obtained performance. S / Z memberships are functions that are suitable for the selection of emotion classes in cases where the reference range of the parameters used as input for emotion recognition is lower or higher. For intermediate functions and normally distributed data, we select the Gauss membership function. It is known that the basic blocks used for type-2 FIS are the same as those used with type-1. A type-2 FLS includes a fuzzifier, a rule base, a fuzzy inference engine, and an output processor. The output processor includes a type-reducer and defuzzifier. The type-reducer is the main distinctive point between type-1 and type-2 fuzzy systems. A type-1 fuzzy set output is generated from the type-reducer or a crisp number is generated from the defuzzifier [43] [45]. The type reducer is added because of its association

with the nature of the membership grades of the elements [46]. Figure 4 illustrates the block diagram of proposed fuzzy system structure using the mentioned input.

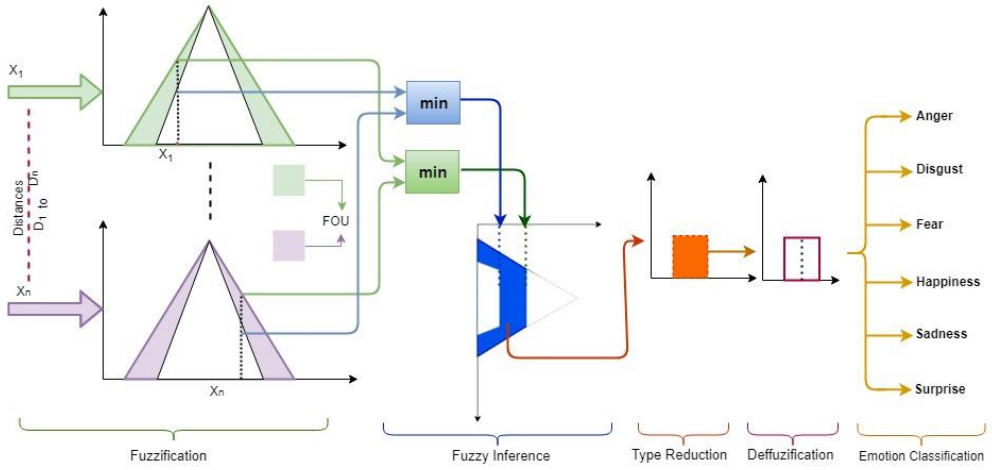


Figure 4. Structure of a type-2 fuzzy logic system.

7. FUZZY INFERENCE ENGINE FOR EMOTION CLASSIFICATION

After obtaining distance classes on natural facial image. These values are used for fuzzy emotion inference through fuzzification and membership function definition process. The inference engine is an interface that processes input values according to certain rules and produces output type-2 fuzzy sets. It is necessary to compute the intersection and union of type-2 sets and implement compositions of type-2 relations. The desired behavior is defined by a set of linguistic rules. By checking various images, we developed fuzzy rules for emotion recognition and experimented with many facial images of different emotions, testing the integrity and accuracy of these rules, and checking whether these rules would recognize real emotions. It is necessary to set the rules adequately to achieve the desired result. For instance, a type-2 fuzzy logic with p inputs ($x_1 \in X_1, \ldots x_p \in X_p$) and one output (y ∈ Y) with M rules has the following form.

R^{ℓ}: IF x_1 is $\tilde{F}_1^{\ell}$ …and x_p is $\tilde{F}_p^{\ell}$ THEN y is $\tilde{G}^{\ell}$, $\ell = 1 \ldots . M$

The knowledge bases for each controller consist of several rules related to the emotion classifications. Two examples of fuzzy rules for emotion recognition using the fuzzy values of facial features as precursors are shown below.

- Rule 1: If (*D1-7* is LARGE) and (*D2-6* is LARGE) and (*D4-5* is LARGE) and (*D8-11* is LARGE) and (*D13* is LARGE) and (*D12* is SMALL) then (Emotion is Surprise)
- Rule 2: If (*D2-6* is MEDIUM) and (*D3* is SMALL) and (*D4-5* is SMALL) and (*D9-10* is LARGE) and (*D8-11* is SMALL) then (Emotion is Disgust)

In these experiments, Mamdani-type implication operators for fuzzy emotion recognition were selected and used minimum t-norm operation. The rule firing strength $F^i(x)$ for crisp input vector is given by the type-1 fuzzy set

$$F^l(x') = \left[\underline{f}^{\,l}(x'), \overline{f}^{\,l}(x')\right] \equiv [\underline{f}^{\,l}, \overline{f}^{\,l}] \tag{7}$$

where $\underline{f}^{\,l}$ and $\overline{f}^{\,l}$ are the lower and upper firing degrees of the $l\ th$ rule, computed using Equations (8) and (9).

$$\underline{f}^{\,l}(x') = \underline{\mu}_{\tilde{F}_1^l}(x_1') * \ldots * \underline{\mu}_{\tilde{F}_p^l}(x_p') \tag{8}$$

$$\overline{f}^{\,l}(x') = \overline{\mu}_{\tilde{F}_1^l}(x_1') * \ldots * \overline{\mu}_{\tilde{F}_1^l}(x_p') \tag{9}$$

The given $*$ in the equation represents the t-norm, which is the $prod$ operator. The single combined type-2 fuzzy set is processed with the type reducer and the defuzzifier. Type-1 fuzzy set output is generated with the type reducer method. These outputs are converted into the crisp output through the defuzzifier. The defuzzifier combines the output sets to obtain a single output using one of the existing type reduction methods. Many methods can be used for type reduction. Centroid type reduction, height type reduction, and center of set are the most commonly used [47]. In these experiments a center of sets (cos) type reduction method was used. This method expressed as Equation (10).

$$Y_{cos}(x) = [y_l, y_r] = \int_{y^1 \in [{y_l}^1, {y_r}^1]} \ldots \int_{y^1 \in [{y_l}^M, {y_r}^M]} \int_{f^1 \in \left[\underline{f}^{\,1}, \overline{f}^{\,1}\right]} \ldots \int_{f^M \in \left[\underline{f}^{\,M}, \overline{f}^{\,M}\right]} \Big/ \frac{\sum_{i=1}^{M} f^i y^i}{\sum_{i=1}^{M} f^i} \tag{10}$$

The values of f_i and y_i which are associated with y_l are donated to ${f_l}^i$ and ${y_l}^i$, respectively, and the values of f_i and y_i which are associated with y_r are donated to ${f_r}^i$ and ${y_r}^i$ respectively, $\underline{f}^{\,i}$ and $\overline{f}^{\,i}$ are the lower and upper firing degrees of the $i\ th$ rule and and M is the number of fired rules. These points are given in Equations (11) and (12).

$$y_l = \frac{\sum_{i=1}^{M} {f_l}^i {y_l}^i}{\sum_{i=1}^{M} {f_l}^i} \tag{11}$$

$$y_r = \frac{\sum_{i=1}^{M} {f_r}^i {y_r}^i}{\sum_{i=1}^{M} {f_r}^i} \tag{12}$$

The average of y_l and y_r are used to defuzzify the output of an interval singleton type-2 fuzzy logic system as given in Equations (13).

$$y(x) = \frac{y_l + y_r}{2} \tag{13}$$

8. EXPERIMENTAL RESULTS AND DISCUSSION

This section presents the results of facial features extraction and classification of facial expressions into six basic emotions showing the accuracy of the proposed methodologies. We employ the publicly available and well-known MUG database [44] for our research purpose. This database consists of

numerous (86 subjects) face images performing facial expressions. MUG is a high quality face database with pictures of six emotional expressions. Some examples of the MUG image set are shown in Figure 5. The system's performance accessed using this database sample images. The performance of the proposed algorithms is evaluated in two stages. Evaluation of proposed feature extraction algorithms constitutes the first stage and evaluating the final sensitivity of the proposed fuzzy emotion recognition system constitutes the second stage. To evaluate our algorithms for feature extraction, we experimented on 175 (25x7 for each of emotion) randomly selected front-face images from the MUG facial expression databases. These 175 images have different emotions and expressions; these include natural, happy, sad, fear, angry and other facial features. As a result, we thoroughly evaluate the proposed feature extraction algorithms with these different test images. Table 3 reports the average sensitivity of selected feature extraction algorithms as an example of the test images described above. We employ the automatically selected features obtained by using the Viola-Jones philosophy to estimate the intensities of the 19 selected AUs. The differences of the extracted Euclidean distance features between the neutral and any expressive frames are used for AU intensity estimation are the parameters of system inputs. The results obtained are summarized in Table 3. Seven examples are shown in this table. The first example is a naturel face image. These data are used for a range of the membership functions. The other images represent 6 different emotion classes and are exemplary of the automatically acquired properties of the images. The distances used here are arranged according to the structure in figure 2. For example, D10 is represented the distance between the Eye right inner and Mouth right. Other distances have been obtained with this logic.

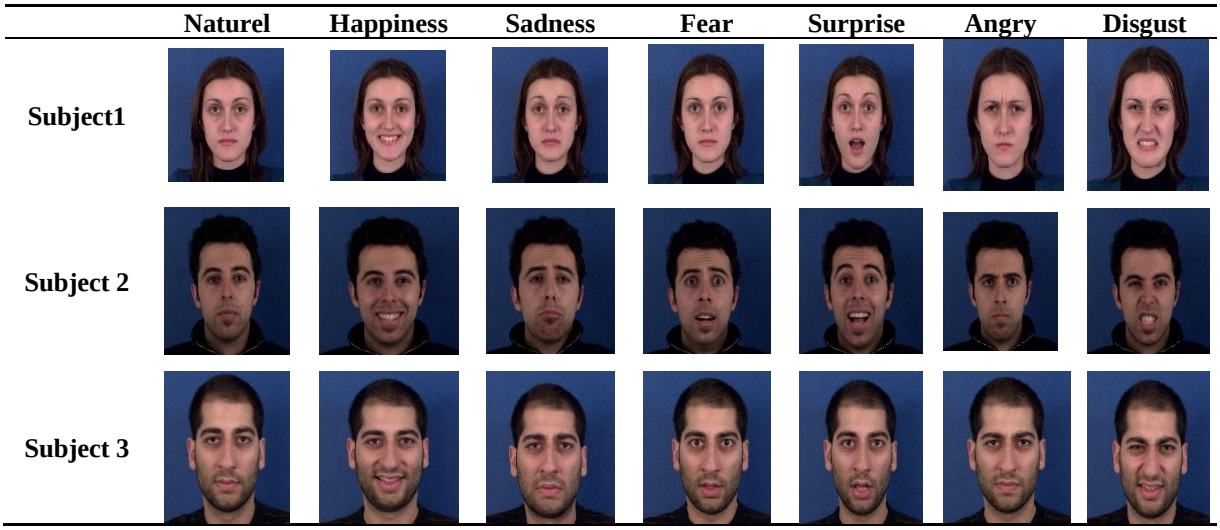
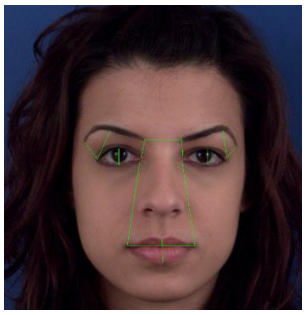
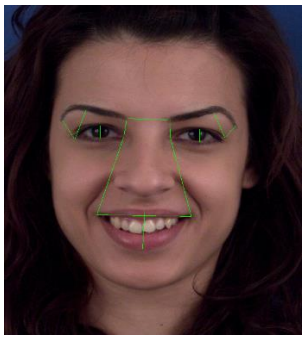
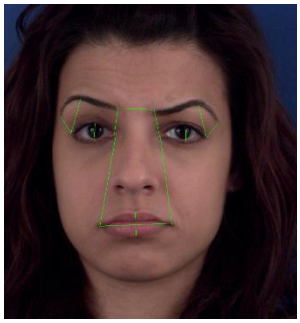


Figure 5. Examples from MUG database that show six basic emotional expressions

The second part of the experimental results focus on determining the classification accuracy obtained using the proposed IT2FIS based classification method. The result of emotion recognition and classification accuracies using the IT2FIS have been presented in table 4. The experimental results were tested using 25*7 samples and focused on determining the classification accuracy obtained by the proposed IT2FIS based classification method. The accuracy of classification provided by IT2FIS was

found to be highest (90.25%) for happiness and least (80.27%) for anger, which was 86.175% with an average recognition rate. It is worth noting that the current method for emotion recognition is significantly higher in performance and accuracy.

Table 3. Examples of facial features detection results and distances between specified fiducial points using proposed methods.

Emotion	Image	Length (pixel)		Start		End	
				x	y	x	y
Natural		D1	49.21	278	384	308	423
		D2	72.49	308	356	338	422
		D3	84	418	378	502	378
		D4	43.93	408	375	417	418
		D5	42.11	501	379	504	421
		D6	60.53	596	359	604	419
		D7	34.71	604	393	627	419
		D8	38	357	399	357	437
		D9	198.13	376	427	405	623
		D10	197.29	502	429	532	624
		D11	35	561	400	561	435
		D12	154.01	378	621	532	622
		D13	54.04	456	606	458	660
Happiness		D1	46.64	281	407	305	447
		D2	67.67	307	383	329	447
		D3	80.06	411	403	491	406
		D4	35.35	404	406	409	441
		D5	43.01	495	404	496	447
		D6	60.17	582	389	604	445
		D7	32.02	606	419	626	444
		D8	28	357	419	357	447
		D9	179.98	350	445	403	617
		D10	175.85	497	450	538	621
		D11	29	554	427	554	456
		D12	190.04	349	616	539	620
		D13	87.09	441	604	445	691
Sadness		D1	45.79	293	394	317	433
		D2	80.08	315	357	337	434
		D3	76.03	418	378	494	380
		D4	56.57	409	377	417	433
		D5	60.21	495	381	507	440
		D6	71.07	590	370	607	439
		D7	39.21	609	409	633	440
		D8	36.13	365	411	368	447
		D9	203.04	378	432	413	632
		D10	193.62	508	437	533	629
		D11	39.05	562	417	564	456
		D12	155.17	377	626	532	632
		D13	51.04	454	602	456	653
Fear		D1	47.51	250	394	274	435
		D2	87.82	276	349	288	436
		D3	79.23	382	385	461	391
		D4	49.16	376	386	380	435
		D5	51.79	461	394	470	445
		D6	79.25	563	360	577	438
		D7	42.52	577	406	605	438
		D8	39.01	327	412	328	451
		D9	218.23	346	438	377	654
		D10	207.39	471	443	495	649

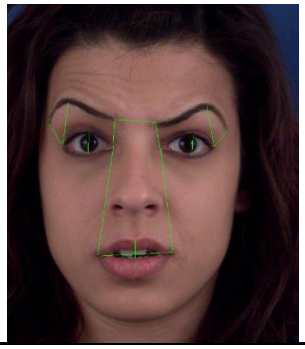
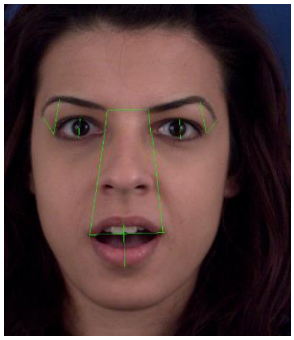
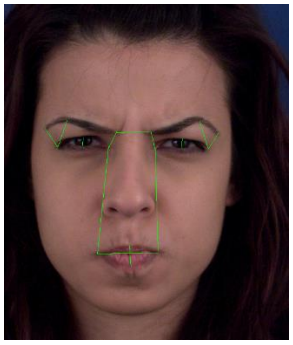
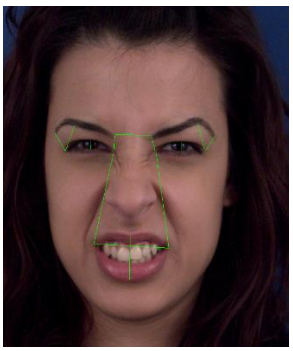
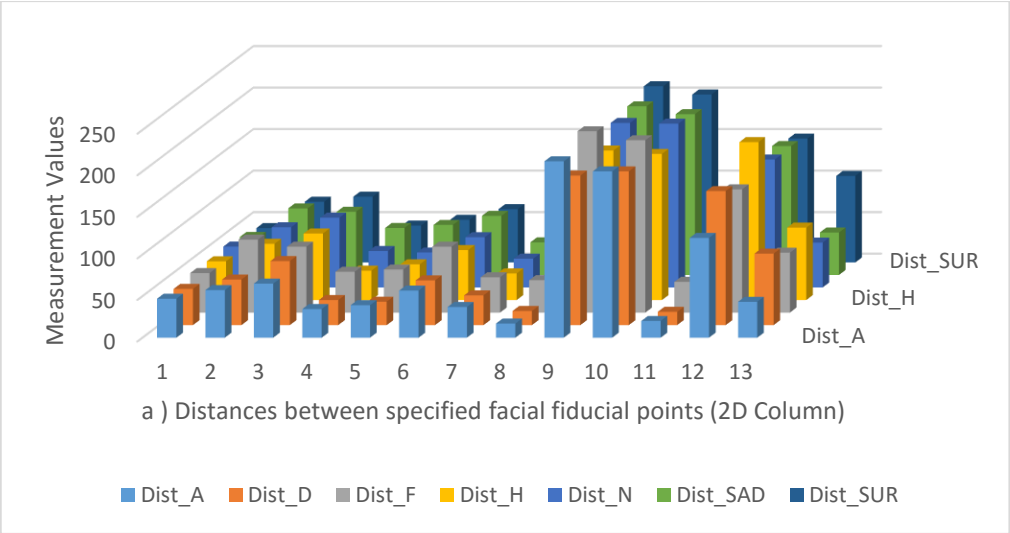
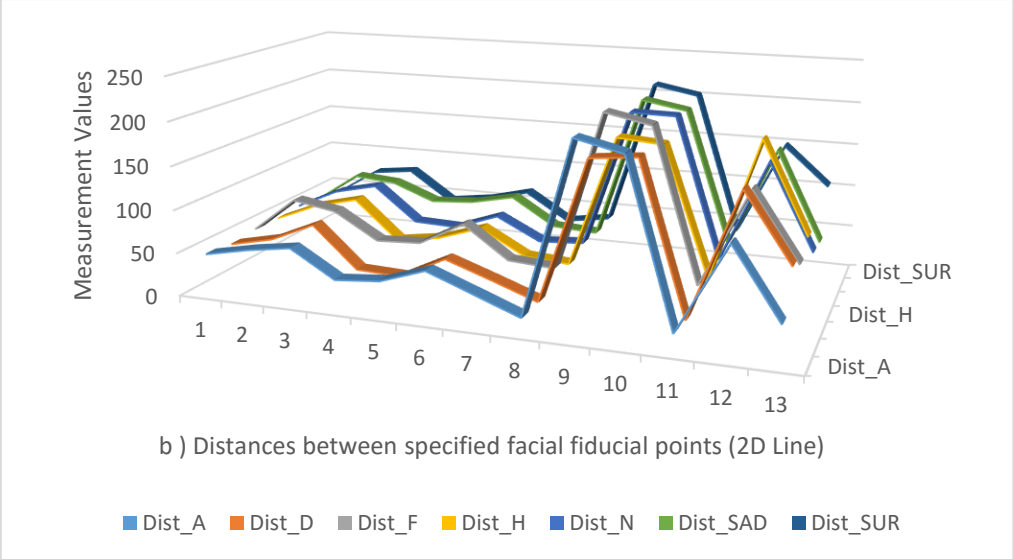
		D11	37.05	533	417	535	454
		D12	148.22	348	648	496	656
		D13	72.01	420	625	421	697
Surprise		D1	41.34	263	400	285	435
		D2	72.99	284	364	296	436
		D3	79.03	393	383	472	385
		D4	44.28	386	385	391	429
		D5	51.25	473	385	478	436
		D6	64.13	576	369	588	432
		D7	32.21	590	406	609	432
		D8	40.11	334	402	337	442
		D9	212.13	356	430	386	640
		D10	202.20	480	435	502	636
		D11	40.05	535	405	537	445
		D12	149.08	356	635	505	640
		D13	104.04	423	602	426	706
Angry		D1	46.87	263	402	289	441
		D2	57.26	288	386	307	440
		D3	65.03	403	409	468	411
		D4	34.44	389	409	404	440
		D5	39.05	471	408	480	446
		D6	56.62	567	389	584	443
		D7	36.89	584	412	604	443
		D8	17.03	337	420	338	437
		D9	212.15	366	438	388	649
		D10	200.06	480	444	485	644
		D11	20.09	531	423	533	443
		D12	120.02	366	646	486	648
		D13	43.15	429	632	432	675
Disgust		D1	43.57	278	412	301	449
		D2	54.78	301	399	321	450
		D3	77.01	407	418	484	419
		D4	30.15	403	420	406	450
		D5	28.16	483	422	491	449
		D6	53.85	581	395	595	447
		D7	35.81	597	420	618	449
		D8	17.03	354	429	355	446
		D9	179.96	361	452	403	627
		D10	184.98	493	452	520	635
		D11	16	547	432	547	448
		D12	161.21	361	626	522	634
		D13	86.01	437	609	438	695

Table 4. Confusion matrix of the proposed IT2FIS classification system tested for the six basic emotions.

Emotions	IT2FIS-Based Recognized Emotion From Facial Expression					
	Happiness (%)	**Sadness (%)**	**Fear (%)**	**Surprise (%)**	**Angry (%)**	**Disgust (%)**
Happiness	**90.25**	1.3	1.5	4.60	1.30	1.05
Sadness	1.32	**87.53**	2.58	1.72	2.34	4.51
Fear	1.79	1.16	**90.14**	4.69	0.97	1.25
Surprise	5.67	1.86	3.6	**85.07**	1.67	2.13
Angry	1.62	8.61	4.92	1.85	**80.27**	2.73
Disgust	1.98	7.52	2.88	1.23	2.6	**83.79**



(**a**) Distances between specified facial fiducial points (2D Column)



(**b**) Distances between specified facial fiducial points (2D Line)

Figure 4. Examples of one subject (person) for six facial emotions' distances between specified facial fiducial points. (a) Figure demonstration of 2D Line, (b) Figure demonstration of 2D column.

Figure 4 illustrates an example of the facial features that occur in the detection of six basic facial expressions using the IT2FIS classifier, and the Euclidean distance between these features. While the horizontal axis shows 13 different distance information, the vertical axis shows the measured value of

emotion recognition distance information. These graphs should be read in such a way that Euclidean distance measurements change as emotions change. This information was used to determine the input parameters of the proposed classifier. An overall assessment of the accuracy of all tests performed to recognize six basic emotions is shown in Table 4. From this table, it is concluded that the system performance is high and the proposed method is applicable.

9. CONCLUSIONS AND FUTURE WORKS

In this paper, we present a completely automated system for facial geometric features detection and facial emotion recognition classification is proposed. We introduce different techniques to detect facial geometries and facial landmark extraction based on the proposed platform. Then, 19 motion-based feature sets containing emotional information were selected using automatic feature selection methods. We used derived AUs intensity and distinctive of AUs combinations to identify six basic emotions that use specific community classifiers for each emotion category. These are density of AUs that was well estimated by high accuracy. These feature sets were subsequently employed as inputs to an array of IT2FIS to estimate the diagnostic facial emotion. We calculated the Euclidean distances between the face motion points we obtained. For achieving a higher performance for the proposed fuzzy emotion recognition system, we determined the average set of points in the right and left regions of the face showing similar distances (for example distance of D1 and D7). Then we used both the average of these distances and the distances which is not similar to each other in length for the input of the classifier. Finally, the number of inputs used is reduced from 13 distances to seven input parameters calculated in 19-point sets. The aim is to reduce complexity and to make the rules of the designed expert system more understandable. The performance and accuracy of our proposed techniques evaluated by 175 samples from MUG emotional image database in order to see the reliability of the proposed methods. The off-line evaluation results using the MUG database indicated that the proposed ensemble models consistently outperform the IT2FIS-based classification and have achieved an averaged recognition accuracy of 86.175% for the recognition of the six basic emotions. The best recognition accuracy was observed for Happiness facial expression (>90%) and lowest recognition accuracy rate was observed for angry (80.27%).

In the future, we aim to improve emotion recognition performance and sensitivity by developing robust and real-time applicable algorithms with the use of the proposed algorithm for the removal of related facial features and minimizing the effects of disturbances such as head movements or external illumination conditions changes on the 3D image. In addition, optimization techniques on 3D face image databases will be developed to improve the robustness and efficiency of the IT2FIS proposed expert system. Finally, we also aim to incorporate other optimization algorithms such as Particle Swarm Optimization, Genetic algorithm (PSO), for optimizing parameters of membership functions.

REFERENCES

[1] C. Silva, A. Sobral, and R. T. Vieira, "An automatic facial expression recognition system evaluated by different classifiers," no. October, 2014.

[2] R. Contreras, O. Starostenko, and V. Alarcon-aquino, "Facial Feature Model for Emotion Recognition," pp. 11–21, 2010.

[3] O. Starostenko, R. Contreras, V. A. Aquino, and L. F. Pulido, "A Fuzzy Reasoning Model for Recognition of Facial Expressions," vol. 15, no. 2, pp. 163–180, 2011.

[4] A. J. Calder, A. M. Burton, P. Miller, A. W. Young, and S. Akamatsu, "A principal component analysis of facial expressions," *Vision Res.*, 2001.

[5] M. H. Siddiqi, R. Ali, A. M. Khan, E. S. Kim, G. J. Kim, and S. Lee, "Facial expression recognition using active contour-based face detection, facial movement-based feature extraction, and non-linear feature selection," *Multimed. Syst.*, 2015.

[6] S. Ulukaya and Ç. Eroğlu Erdem, "Estimation of the neutral face shape using Gaussian mixture models," in *ICASSP, IEEE International Conference on Acoustics, Speech and Signal Processing - Proceedings*, 2012.

[7] D. Filko and G. Martinovic, "Emotion Recognition System by a Neural Network Based Facial Expression Analysis," *Autom. – J. Control. Meas. Electron. Comput. Commun.*, 2013.

[8] S. Jirayucharoensak, S. Pan-Ngum, and P. Israsena, "EEG-Based Emotion Recognition Using Deep Learning Network with Principal Component Based Covariate Shift Adaptation," *Sci. World J.*, 2014.

[9] Z. Yin, M. Zhao, Y. Wang, J. Yang, and J. Zhang, "Recognition of emotions using multimodal physiological signals and an ensemble deep learning model," *Comput. Methods Programs Biomed.*, 2017.

[10] A. T. Lopes, E. de Aguiar, A. F. De Souza, and T. Oliveira-Santos, "Facial expression recognition with Convolutional Neural Networks: Coping with few data and the training sample order," *Pattern Recognit.*, 2017.

[11] V. K. N. K. Kamlesh Pai, M. Balrai, S. Mogaveera, and D. Aeloor, "Face Recognition Using Convolutional Neural Networks," in *Proceedings of the 2nd International Conference on Trends in Electronics and Informatics, ICOEI 2018*, 2018.

[12] J. J. Lee, M. Zia Uddin, and T.-S. Kim, "spatiotemporal human facial expression recognition using fisher independent component analysis and Hidden Markov Model," 2009.

[13] J. Ou, X. B. Bai, Y. Pei, L. Ma, and W. Liu, "Automatic facial expression recognition using Gabor filter and expression analysis," in *ICCMS 2010 - 2010 International Conference on Computer Modeling and Simulation*, 2010.

[14] C. F. Chuang and F. Y. Shih, "Recognizing facial action units using independent component analysis and support vector machine," *Pattern Recognit.*, 2006.

[15] A. Halder *et al.*, "Reducing uncertainty in interval type-2 fuzzy sets for qualitative improvement in emotion recognition from facial expressions," in *IEEE International Conference on Fuzzy Systems*, 2012.

[16] A. Konar, A. Chakraborty, A. Halder, R. Mandal, and R. Janarthanan, "Interval type-2 fuzzy model for emotion recognition from facial expression," in *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 2012, vol. 7143 LNCS, pp. 114–121.

[17] A. Chakraborty, A. Konar, U. K. Chakraborty, and A. Chatterjee, "Emotion recognition from facial expressions and its control using fuzzy logic," *IEEE Trans. Syst. Man, Cybern. Part ASystems Humans*, vol. 39, no. 4, pp. 726–743, 2009.

[18] M. Ilbeygi and H. Shah-Hosseini, "A novel fuzzy facial expression recognition system based on facial feature extraction from color face images," *Eng. Appl. Artif. Intell.*, vol. 25, no. 1, pp. 130–146, Feb. 2012.

[19] A. Halder, R. Mandal, A. Chakraborty, A. Konar, and R. Janarthanan, "Application of general type-2 fuzzy set in emotion recognition from facial expression," in *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 2011, vol. 7076 LNCS, no. PART 1, pp. 460–468.

[20] A. Halder, R. Mandal, A. Konar, A. Chakraborty, and R. Janarthanan, "Emotion recognition from facial expression using general type-2 fuzzy set," in *2011 International Conference on Recent Trends in Information Systems, ReTIS 2011 - Proceedings*, 2011, pp. 263–268.

[21] A. Halder, R. Mandal, A. Konar, A. Chakraborty, and R. Janarthanan, “Emotion Recognition from Facial Expression using General Type-2 Fuzzy Set,” pp. 263–268, 2011.
[22] N. Esau, E. Wetzel, L. Kleinjohann, and B. Kleinjohann, “Real-Time Facial Expression Recognition Using Model Fuzzy Emotion,” 2007.
[23] S. Ghosh and G. Paul, “A Type-2 Approach in Emotion Recognition and an Extended Type-2 Approach for Emotion Detection,” Fuzzy Inf. Eng., vol. 7, no. 4, pp. 475–498, Dec. 2015.
[24] N. Esau, E. Wetzel, L. Kleinjohann, and B. Kleinjohann, “Real-time facial expression recognition using a fuzzy emotion model,” in IEEE International Conference on Fuzzy Systems, 2007.
[25] D. Y. Liliana, B. T., and R. W. M., “Fuzzy Emotion Recognition Using Semantic Facial Features and Knowledge-based Fuzzy,” *Int. J. Eng. Technol., vol. 11, no. 2, pp*. 177–186, Apr. 2019.
[26] J. M. Mendel, “Fuzzy sets for words: a new beginning,” 2004.
[27] J. Mendel, “Type-2 Fuzzy Sets, A Tribal Parody [Discussion Forum,” *IEEE Comput. Intell. Mag.*, 2010.
[28] R. J. Davidson *et al.*, “How are emotions distinguished from moods, temperament, and other related affective constructs?,” *Nat. Emot. Fundam. Quest. Ser. Affect. Sci.*, 1994.
[29] P. Ekman, “All Empotions Are Basic,” in *The Nature of Emotion*, 1994.
[30] P. Ekman, “Moods, Emotions, and Traits,” *The Nature of Emotion: Fundamental Questions*. 1994.
[31] P. Ekman, R. J. Davidson, M. Ricard, and B. A. Wallace, “Buddhist and psychological perspectives on emotions and well-being,” *Curr. Dir. Psychol. Sci.*, 2005.
[32] P. Ekman and W. V Friesen, “Facial action coding system: A technique for the measurement of facial movement.,” *CA Consult. Psychol. Press. Ellsworth, PC, Smith, CA (1988). From Apprais. to Emot. Differ. among unpleasant Feel. Motiv. Emot.*, 1978.
[33] P. Ekman and W. V. Friesen, *The Facial Action Coding System.* 1978.
[34] P. Ekman and W. V Friesen, *Unmasking the face: A guide to recognizing emotions from facial clues*. 2003.
[35] A. Majumder, L. Behera, and V. K. Subramanian, “Emotion recognition from geometric facial features using self-organizing map,” *Pattern Recognit.*, vol. 47, no. 3, pp. 1282–1293, 2014.
[36] P. Ekman, “Facial expression and emotion,” *Am. Psychol.*, 1993.
[37] P. Viola and M. J. Jones, “Robust Real-time Object Detection,” 2001.
[38] P. Viola and M. Jones, “Rapid object detection using a boosted cascade of simple features,” 2005.
[39] K. W. Wan, K. M. Lam, and K. C. Ng, “An accurate active shape model for facial feature extraction,” *Pattern Recognit. Lett.*, 2005.
[40] Y. H. Lee, Y. Lee, D. S. Yang, J. H. Park, and Y. Kim, “Facial feature extraction using enhanced active shape model,” in *2013 International Conference on Information Science and Applications, ICISA 2013*, 2013.
[41] L. A. Zadeh, “Soft computing and fuzzy logic,” *IEEE Softw.*, vol. 11, no. 6, pp. 48–56, 1994.
[42] L.A.Zadeh, “A fuzzy -algorithmic approach to the definition of complex or imprecise concepts,” no. 8, pp. 249–291, 1976.
[43] M. Dirik, O. Castillo, A. F. Kocamaz, M. Dirik, O. Castillo, and A. F. Kocamaz, “Visual-Servoing Based Global Path Planning Using Interval Type-2 Fuzzy Logic Control,” *Axioms 2019, Vol. 8, Page 58*, vol. 8, no. 2, p. 58, May 2019.
[44] “The MUG Facial Expression Database | Multimedia Understanding Group.” [Online]. Available: https://mug.ee.auth.gr/fed/. [Accessed: 06-Jul-2019].
[45] O. Castillo, P. Melin, J. Kacprzyk, and W. Pedrycz, “Type-2 Fuzzy Logic: Theory and Applications,” in *2007 IEEE International Conference on Granular Computing (GRC 2007)*, 2007, pp. 145–145.
[46] O. Castillo and P. Melin, “Hybrid intelligent systems for time series prediction using neural networks, fuzzy logic, and fractal theory,” *IEEE Trans. Neural Networks*, 2002.
[47] J. M. Mendel, “Advances in type-2 fuzzy sets and systems,” *Inf. Sci. (Ny).*, 2007.

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Global Vision Based Path Planning for AVGs Using A* Algorithm

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ABSTRACT One of the most studied problems in robotics is robot path planning. Many strategies have been invented. Image processing and machine vision technology also have been utilized in this regard. Studies are still underway to improve path planning methods. This paper proposes an implementing visual servoing-based technique using the A* algorithm to achieve efficient searching capabilities of path planning in complicated maps with a combination of LabVIEW and MATLAB software. The proposed algorithm is divided into three parts. Firstly, the environment model or robot motion environment is conducted. In this stage, the visual information extracted from a single ceiled camera. Secondly, the position and orientation of the objects (robot, obstacles etc.) under the visibility of the camera are generated from visual information. Thirdly, the A* algorithm is used as a path planning method. This algorithm is not guaranteed the generated path to be safe and desirable with obstacle-free. To solve this problem image processing techniques are utilized. This gives an effective improvement and high performance to A* in a complex environment and gives a safe path as a comparison to the traditional version of A*. The experimental results, considering the optimal path lengths and execution time, show that the proposed design is more effective and faster to generate the shortest path.

KEYWORDS: A* Algorithm, AVGs, Image Processing, Path Planning, Visual Servoing

1. INTRODUCTION

Path planning is a heavily studied because of its application in the field of industrial and daily manipulator of mobile robot research. The fundamental purpose is to find an optimal, safe, and collision-free path between the starting to the target point [1]. During the last two decades, a great deal of research focuses on the path planning problem [2-8]. To perform a task with the mobile robot finding a feasible solution in critical applications in real-life, one needs to solve path planning and path tracking problems efficiently [9, 10]. The environment type (static or dynamic) and path-planning algorithms are two important factors in solving the path planning problem. The path planning algorithms can be classified into two categories: global (off-line) or local (on-line) algorithms [11-13]. Global path planning methods required the environment model (robot map) to be static and completely known. There are many algorithms designed for global path planning such as A* [14,15] which is an extension of the Dijkstra algorithm[16,17], Genetic algorithm (GA) [18-21], Probabilistic Road Map (PRM) [24], Rapidly Exploring Random Tree (RRT) [25], Bidirectional-RRT (BRRT) [26, 27], Artificial Potential Fields (APF) [28, 29], Fuzzy Type 1 and Fuzzy Type 2 path planning algorithm [30-32]. Traditionally, different sensing techniques enable the robot to detect obstacles such as infrared detectors, laser scanner, ultrasonic sensors [33-35]. These sensors may cause systematic and unsystematic errors when the robot is moving. Systematic errors are often caused by the encoder, sensor, and physical design of the robot

parts. However, non-systematic errors are often caused by external causes such as slipping, hitting, and falling.

On the other hand, vision sensors provide low-cost motion control and effective in decreasing errors, as mentioned. They are also useful robotic sensors that allow for non-contact measurement of the environment. The information provided by vision sensors in a feedback loop known as visual servoing. It is classified into a position based, image-based, and hybrid based visual servoing (VS) system. The proposed method using VS is designed to extract the position and orientation information of interest objects. The main advantage of the visual servoing [36-38] is that it requires fewer sensor data, suitable to control multiple robots, internal and external sensors on robots generally are not needed, in terms of scalability; it provides more operating area by increasing imagining devices and so on. For these regards, various approaches have been used. These are background subtraction based, feature-based, gradient-based, statistical model-based, template-based, and optical flow object detection methods [39, 40].

The aim of this paper is how to combine visual servoing and A* based on an effective mobile robot path planning. Many experiments have been carried out to test the validity of the proposed technique. The results have shown that the system is effective and fast.

This paper is organized as follows. Problem formulation, image analysis, and environment model are described in section 2. Path planning and shortest path algorithm are discussed in section 3. The experimental results are presented in section 4. Finally, the paper conclusion is given in section 5.

2. MATERIAL AND METHODS

2.1 Environment Model

In the overall design, the proposed method uses only one non-contact sensor (overhead camera). Information to generate the desired robot path is extracted from image frames that acquire from this sensor. The robot poses estimated at each location from image frames using feature extraction and template-matching based methods. The work environment is configured as shown in Figure 1.

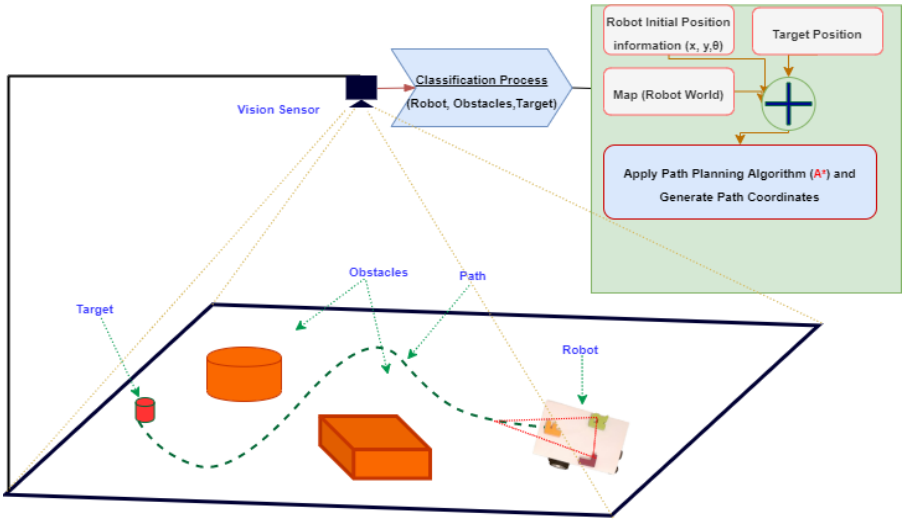


Figure 1. Overall system configuration block diagram

The base infrastructure hardware component has consisted of a mobile robot motion environment, a mobile robot, an overhead camera, and a host computer system. The implemented software component includes both LabVIEW and Matlab image processing tools and control modules. First, the classification process of the position and orientation of the robot, target, and obstacles are handled. Secondly, the initial parameters of the path planning algorithms are determined. In this stage, A* path planning algorithms have been considered. Three inputs parameters are required for the A* algorithm. These are the robot map, robot starting, and target point parameters. Several mathematical equations are required to obtain these input parameters.

The robot marks parameters and target parameters such as color and shape are initialized. These marks properties are template images as shown in Figure 2.

Figure 2. LabVIEW VI implementation of template matching system

Robot localization and position information were obtained using these templates (R, L, and F). Each template is uniquely identified by an onboard geometric pattern. To obtain an accurate representation of the boundaries of the obstacles, the proper selection of a color threshold value is essential for image analysis. The process of obtaining the robot map by determining the robot's initial position information, targets, and obstacles are shown on the image in figure 3. Detailed information about these processes is given in [41].

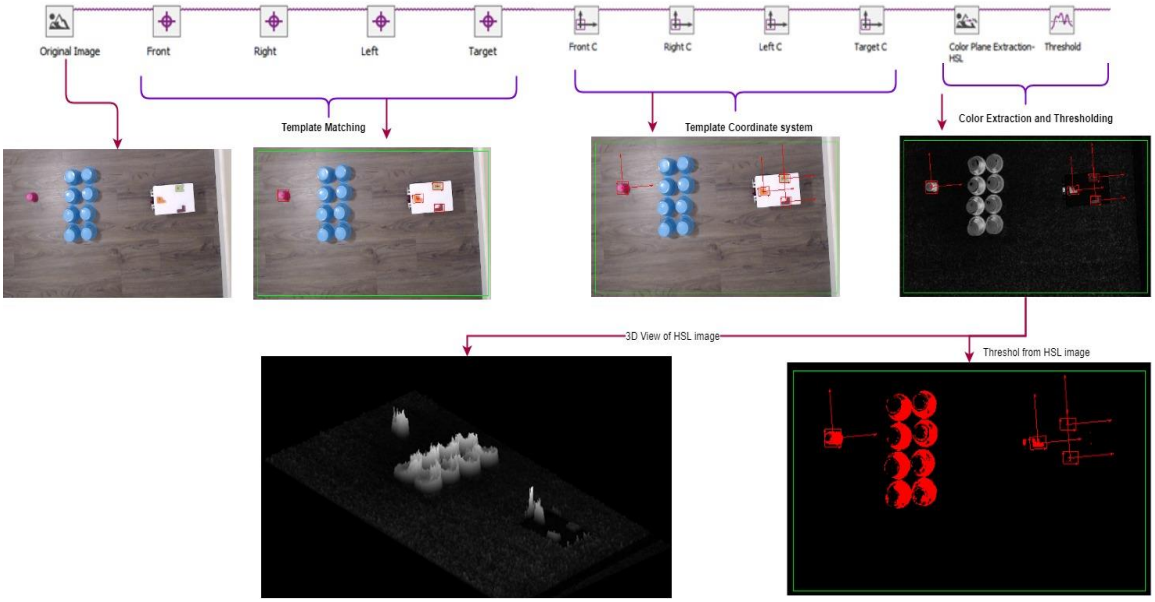


Figure 3. Image conversion process

After determining the initial position of the mobile robot and the target point, other calculations are performed. The required parameters are characterized in Figure 4.

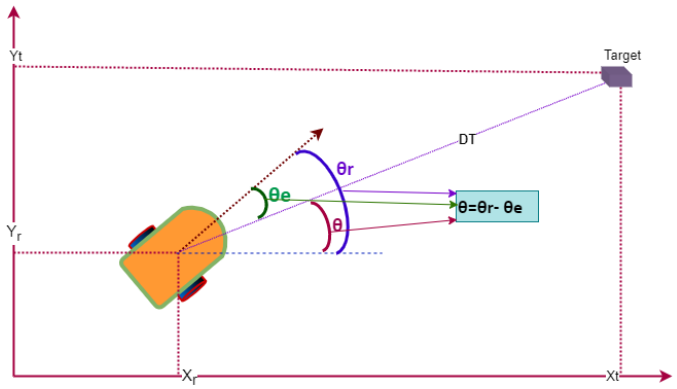


Figure 4. Path planning algorithm virtual inputs (angle to the goal (θ=θr- θe), distance from the target (DT))

The initial position information and target coordinates of the mobile robot are graphically represented in this figure. The equations used to obtain the input parameters are calculated as follows.

$$e_x = X_t - X_r = DT * \cos(\theta r)$$
$$e_y = Y_t - Y_r = DT * \sin(\theta r) \quad (1)$$

The positioning error computations are calculated as in (1). Where, DT corresponds to the current distance between the mobile robot and target, which is expressed in Equation (2).

$$DT = \sqrt{(e_x)^2 + (e_y)^2} \quad (2)$$

The robot current angle (θr) according to the target is computed as in Equation (3).

$$\theta r = tan^{-1} \frac{e_y}{e_x} \quad (3)$$

The error of the angle is given in Equation (4).

$$\theta e = \theta r - \theta \quad (4)$$

These are the planning algorithm's initial parameters.

3. A* ALGORITHM

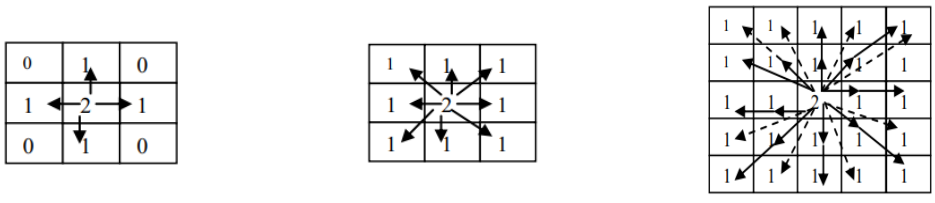
A star algorithm proposed by Haret et al.[17]. The A* algorithm is a practical search algorithm for path-finding and graph traversals in the real-world problem, which is a class of intelligent search algorithms in the Uniform Cost Research (UCS) philosophy developed based on Dijkstra [42] algorithm that it can find the shortest path. The key of the A* algorithm is to establish the evaluation function given in (5).

$$f(n) = g(n) + h(n) \tag{5}$$

where f(n) represents the expected cost from source to goal via node n, g(n) represents the exact cost of the path from the starting point to any vertex n, and h(n) represents the heuristic estimated cost from vertex n to the goal. The specific domain information in the problem is the heuristic function, which is an estimated distance of the node n to the goal. The Euclidean distance (ED) between the node n and the goal is usually taken as the value of $h(n)$that is an estimated cost of reaching the goal. When the value of $g(n)$ is constant, the value of $f(n)$is mainly affected by the value of $h(n)$ which is the cost value from the successor node to the destination node corresponds to the Manhattan distance (heuristic). The algorithm is optimal as a graph search using both an open and a closed set of nodes while ensuring acceptability and consistency. When using the A * algorithm, it is necessary to model the problem as a standard graphical search algorithm.

In our experiments, the converted binary images (pixel graph) are used as a searching node. All regions of the acquired image pixels are searched one by one to find the shortest path, and the unobstructed path from the source to the destination is determined. All black pixels are defined as obstacles; all white pixels are defined as a free node. The total cost constitutes the evaluation function's cost calculated between the free nodes.

The higher resolution of the map, the better results, but undesirable because it increases computational time in real-time applications [43]. Each pixel of the reduced resolution map is taken as a corner, and the connection paths between the pixels are taken as the edge. Robot motion is regarded in three possible matrix connections as shown in figure 5. These are rectilinear, rectilinear, diagonal, and many moves. All possible movements are indicated by 1, and impossible movements by 0. For increasing the rotational flexibility of the robot, the Cardinality of numbers in the matrix can be increased, but the addition of these can result in more calculation costs. In our experiments, the "Rectilinear and Diagonal" matrix was used.



a) b) c)

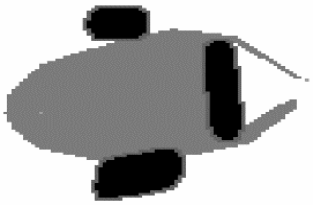
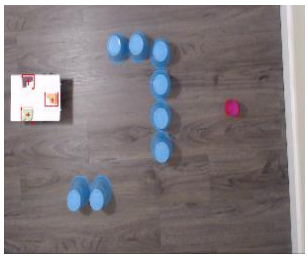
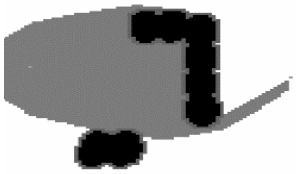
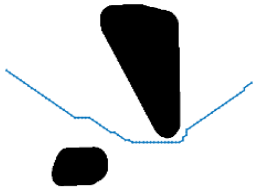
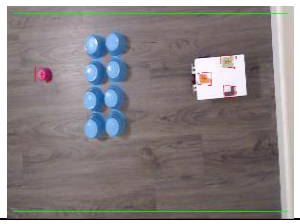
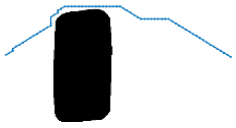
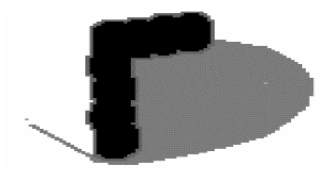
Figure 5. Connection matrices (a) Rectilinear, b) Rectilinear and Diagonal, c) Many Moves)

4. SIMULATION RESULTS

In order to verify the effectiveness of the proposed algorithm, LabVIEW and Matlab software are implemented practically in real-time. We tested the algorithm for the various test cases. In all test cases it is observed that the algorithm is able to generate a soft and suitable solution. It is more convincing to propose the algorithm to be used in real-world mobile robot tracking experiments. In the experiments,

first of all the ceiling camera configuration set up and visual information for a planner are obtained. The main parameters include mobile robot initial position information, target position, and obstacles position. The experimental study was carried out in two stages. In the first stage, the environment map, which is normally applied to image processing and sharp transitions are eliminated. In the second stage, convex hull method was applied to the maps of the environment in order to eliminate situations such as the local minimum and to minimize a collision. Experiments were carried out in structured environments as shown in figure 6.

As a binary image which is a 2D matrix of elements that can only hold two values where the white pixels (values 1) correspond to the free space and the black pixels (values 0) correspond to an obstacle area, it suffices to represent a fill grid with only two color levels, since the robot can only move within the free space. The obstacle-free path and other operations obtained by using this algorithm are shown on eight experimental results (see Figure 6).

Exp.	**Initial color Image**	**Expansion and path searching**	**Path**
1			
2A			
2B			
3			
4A			

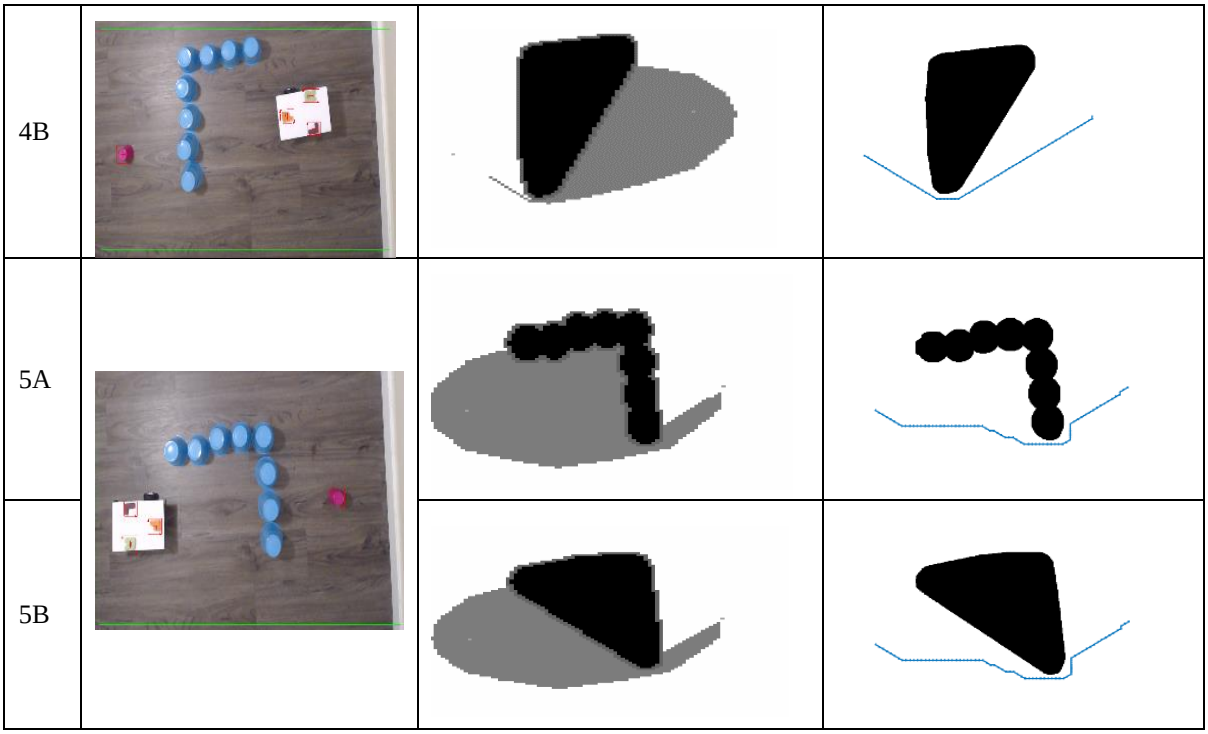


Figure 6. Experimental Sample Results using A* algorithm (A in (2, 4, 5) are the normal environments; B in (2, 4, 5) are convex hull applied maps.

To check the result of the experiments, the system is considered algorithm processing time and path length. The optimum path between the start and goal obtained by using A* path searching algorithm are marked as shown in figure 6. To obtain a feasible path that the robot can follow, it is aimed to reduce the possibility of collision during the movement of the robot by using dilatation and convex hull operation.

For this reason, the obstacle boundaries have been extended to the radius (half dimension) of the actual robot and the robot's safe operation without collision has been realized. In this case, the environment map has been changed so that the free space near the obstacles can be regarded as a disability area at distances below the radius. In the test cases, it is observed that the algorithm was able to find a feasible path solution to use by any robotic controller to move the robot physically. The execution time and path lengths obtained from the experiments are summarized in Table 1.

Table 1. Path Lengths (PL-px) and Execution Time (ET-sc) obtained in different configuration spaces

	Experiments							
	1	**2A**	**2B**	**3**	**4A**	**4B**	**5A**	**5B**
PL-(px)	757,00	800,56	793,29	762,02	756,91	736,88	785,20	770,20
ET-(sc)	5,00	3,91	4,51	8,05	3,98	3,42	5,19	3,28

As seen from the table, the convex hull method applied maps were completed in a shorter time and resulted in less path cost. All experiments have been successfully completed. Both execution and path length were evaluated together. It should be pointed out that these planning periods are the times taken

for path planning on the acquired image of the real environment. The path cost is more critical parameter. Because of robot to be operated in a real environment will spend time and energy according to the obtained path costs. In this case, it is stated that the path cost parameter is more critical in terms of enabling the robot to operate efficiently.

5. CONCLUSIONS

This paper performs real-time path planning algorithm of an indoor wheeled mobile robot using a single ceiling camera is implemented. The contribution here is the development of the A * algorithm in complex environments for mobile robot path planning. The predictive function of an improved A * algorithm is used as an intuitive function to improve search efficiency and smoothness of the path using image processing operation. To optimize and secure the path created with A *, image processing widening application (dilatation, convex body) implemented. The generated path is located as near as possible to the obstacle (s), by a distance determined by the robot radius. As a result, short travel distances for the robot were made possible in a short time by consuming less power along the way. This project has shown that a robot can be directed to move in an indoor environment without hitting any obstacles, even if it does not have any internal sensors. The system also takes into account the robot's information, such as the turning radius, depth, and width. The overall system is experimentally verified under the same conditions by using LabVIEW and Matlab software together. The results are convenient and reliable for the mobile robot to follow the path created.

REFERENCES

[1] X. Dai, S. Long, Z. Zhang, and D. Gong, "Mobile robot path planning based on ant colony algorithm with a∗ heuristic method," *Front. Neurorobot.*, 2019, doi: 10.3389/fnbot.2019.00015.

[2] A. Cherubini, F. Chaumette, and G. Oriolo, "A position-based visual servoing scheme for following paths with nonholonomic mobile robots," in *IEEE/RSJ International Conference on Intelligent Robots and Systems*, Sep. 2008, pp. 1648–1654, doi: 10.1109/IROS.2008.4650679.

[3] E. A. Elsheikh, M. A. El-Bardini, and M. A. Fkirin, "Practical Design of a Path Following for a Non-holonomic Mobile Robot Based on a Decentralized Fuzzy Logic Controller and Multiple Cameras," *Arab. J. Sci. Eng.*, vol. 41, no. 8, pp. 3215–3229, Aug. 2016, doi: 10.1007/s13369-016-2147-x.

[4] T. T. Mac, C. Copot, T. Tran, and R. De Keyser, "Heuristic approaches in robot path planning: A survey," *Rob. Auton. Syst.*, vol. 86, pp. 13–28, 2016, doi: 10.1016/j.robot.2016.08.001.

[5] J.-Y. Jhang, C.-J. Lin, C.-T. Lin, and K.-Y. Young, "Navigation Control of Mobile Robots Using an Interval Type-2 Fuzzy Controller Based on Dynamic-group Particle Swarm Optimization," *Int. J. Control. Autom. Syst.*, vol. 16, no. 5, pp. 2446–2457, Oct. 2018, doi: 10.1007/s12555-017-0156-5.

[6] R. Kala, A. Shukla, R. Tiwari, S. Rungta, and R. R. Janghel, "Mobile robot navigation control in moving obstacle environment using genetic algorithm, artificial neural networks and A* algorithm," in *2009 WRI World Congress on Computer Science and Information Engineering, CSIE 2009*, 2009, doi: 10.1109/CSIE.2009.854.

[7] R. Lagisetty, N. K. Philip, R. Padhi, and M. S. Bhat, "Object detection and obstacle avoidance for mobile robot using stereo camera," in *Proceedings of the IEEE International Conference on Control Applications*, 2013, doi: 10.1109/CCA.2013.6662816.

[8] K. Zheng, D. F. Glas, T. Kanda, H. Ishiguro, and N. Hagita, "Supervisory control of multiple social robots for navigation," in *ACM/IEEE International Conference on Human-Robot Interaction*, 2013, doi: 10.1109/HRI.2013.6483497.

[9] J. Han and Y. Seo, "Mobile robot path planning with surrounding point set and path improvement," *Appl. Soft Comput.*, vol. 57, pp. 35–47, Aug. 2017, doi: 10.1016/j.asoc.2017.03.035.

[10] B. K. Patle, D. R. K. Parhi, A. Jagadeesh, and S. K. Kashyap, "Application of probability to enhance the

performance of fuzzy based mobile robot navigation," *Appl. Soft Comput.*, vol. 75, pp. 265–283, Feb. 2019, doi: 10.1016/j.asoc.2018.11.026.

[11] R. Kala, A. Shukla, and R. Tiwari, "Robotic path planning in static environment using hierarchical multi-neuron heuristic search and probability based fitness," *Neurocomputing*, vol. 74, no. 14–15, pp. 2314–2335, Jul. 2011, doi: 10.1016/j.neucom.2011.03.006.

[12] M. Dirik, O. Castillo, and A. Kocamaz, "Visual-Servoing Based Global Path Planning Using Interval Type-2 Fuzzy Logic Control," *Axioms 2019, Vol. 8, Page 58*, vol. 8, no. 2, p. 58, May 2019, doi: 10.3390/AXIOMS8020058.

[13] G. Antonelli, S. Chiaverini, and G. Fusco, "A Fuzzy-Logic-Based Approach for Mobile Robot Path Tracking," *IEEE Trans. Fuzzy Syst.*, vol. 15, no. 2, pp. 211–221, Apr. 2007, doi: 10.1109/TFUZZ.2006.879998.

[14] F. Duchoň *et al.*, "Path Planning with Modified a Star Algorithm for a Mobile Robot," *Procedia Eng.*, vol. 96, pp. 59–69, 2014, doi: 10.1016/j.proeng.2014.12.098.

[15] G. Klančar, A. Zdešar, S. Blažič, and I. Škrjanc, *Wheeled Mobile Robotics, From Fundamentals Towards Autonomous Systems*. Butterworth-Heinemann, © 2017 Elsevier Inc., 2017.

[16] S. A. Fadzli, S. I. Abdulkadir, M. Makhtar, and A. A. Jamal, "Robotic Indoor Path Planning using Dijkstra ' s Algorithm with Multi-Layer Dictionaries," pp. 1–4, 2015.

[17] P. Hart, N. Nilsson, and B. Raphael, "A Formal Basis for the Heuristic Determination of Minimum Cost Paths," *IEEE Trans. Syst. Sci. Cybern.*, vol. 4, no. 2, pp. 100–107, 1968, doi: 10.1109/TSSC.1968.300136.

[18] S. Salmanpour, H. Monfared, and H. Omranpour, "Solving robot path planning problem by using a new elitist multi-objective IWD algorithm based on coefficient of variation," *Soft Comput.*, vol. 21, no. 11, pp. 3063–3079, 2017, doi: 10.1007/s00500-015-1991-z.

[19] P. Sudhakara, V. Ganapathy, and K. Sundaran, "Genetic algorithm based optimization technique for route planning of wheeled mobile robot," in *Proceedings of the 4th IEEE International Conference on Advances in Electrical and Electronics, Information, Communication and Bio-Informatics, AEEICB 2018*, 2018, doi: 10.1109/AEEICB.2018.8480937.

[20] A. Elshamli, H. A. Abdullah, and S. Areibi, "Genetic algorithm for dynamic path planning," in *Canadian Conference on Electrical and Computer Engineering*, 2004.

[21] AL-Taharwa, "A Mobile Robot Path Planning Using Genetic Algorithm in Static Environment," *J. Comput. Sci.*, vol. 4, no. 4, pp. 341–344, Apr. 2008, doi: 10.3844/jcssp.2008.341.344.

[22] C. Lamini, S. Benhlima, and A. Elbekri, "Genetic Algorithm Based Approach for Autonomous Mobile Robot Path Planning," *Procedia Comput. Sci.*, vol. 127, pp. 180–189, 2018, doi: 10.1016/j.procs.2018.01.113.

[23] Jianping Tu and S. X. Yang, "Genetic algorithm based path planning for a mobile robot," in *International Conference on Robotics and Automation (Cat. No.03CH37422)*, 2003, vol. 1, pp. 1221–1226, doi: 10.1109/ROBOT.2003.1241759.

[24] L. E. Kavraki, P. Svestka, J.-C. Latombe, and M. H. Overmars, "Probabilistic roadmaps for path planning in high-dimensional configuration spaces," *IEEE Trans. Robot. Autom.*, vol. 12, no. 4, pp. 566–580, 1996, doi: 10.1109/70.508439.

[25] J. Bruce and M. Veloso, "Real-time randomized path planning for robot navigation," in *IEEE/RSJ International Conference on Intelligent Robots and System*, 2002, vol. 3, pp. 2383–2388, doi: 10.1109/IRDS.2002.1041624.

[26] E. Dönmez, A. F. Kocamaz, and M. Dirik, "Bi-RRT path extraction and curve fitting smooth with visual based configuration space mapping," in *IDAP 2017 - International Artificial Intelligence and Data Processing Symposium*, 2017, doi: 10.1109/IDAP.2017.8090214.

[27] R. Sadeghian, S. Shahin, and M. T. Masouleh, "An experimental study on vision based controlling of a spherical rolling robot," in *Iranian Conference on Intelligent Systems and Signal Processing (ICSPIS)*, Dec. 2017, pp. 23–27, doi: 10.1109/ICSPIS.2017.8311583.

[28] T. Weerakoon, K. Ishii, and A. A. F. Nassiraei, "An Artificial Potential Field Based Mobile Robot Navigation Method To Prevent From Deadlock," *J. Artif. Intell. Soft Comput. Res.*, vol. 5, no. 3, pp. 189–203, Jul. 2015, doi: 10.1515/jaiscr-2015-0028.

[29] E. Rimon and D. E. Koditschek, "Exact robot navigation using artificial potential functions," *IEEE Trans. Robot. Autom.*, vol. 8, no. 5, pp. 501–518, Oct. 1992, doi: 10.1109/70.163777.

[30] J.-Y. Jhang, C.-J. Lin, C.-T. Lin, and K.-Y. Young, "Navigation Control of Mobile Robots Using an Interval Type-2 Fuzzy Controller Based on Dynamic-group Particle Swarm Optimization," *Int. J. Control. Autom. Syst.*, vol. 16, no. 5, pp. 2446–2457, Oct. 2018, doi: 10.1007/s12555-017-0156-5.

[31] T. W. Liao, "A procedure for the generation of interval type-2 membership functions from data," *Appl. Soft Comput.*, vol. 52, pp. 925–936, Mar. 2017, doi: 10.1016/j.asoc.2016.09.034.

[32] A. Pandey, R. K. Sonkar, K. K. Pandey, and D. R. Parhi, "Path planning navigation of mobile robot with obstacles avoidance using fuzzy logic controller," *2014 IEEE 8th Int. Conf. Intell. Syst. Control*, pp. 39–

41, 2014, doi: 10.1109/ISCO.2014.7103914.
[33] A. Pandey, "Multiple Mobile Robots Navigation and Obstacle Avoidance Using Minimum Rule Based ANFIS Network Controller in the Cluttered Environment," *Int. J. Adv. Robot. Autom.*, vol. 1, no. 1, pp. 1–11, 2016, doi: 10.15226/2473-3032/1/1/00102.
[34] K. Srinivasan and J. Gu, "Multiple Sensor Fusion in Mobile Robot Localization," in *Canadian Conference on Electrical and Computer Engineering*, 2007, pp. 1207–1210, doi: 10.1109/CCECE.2007.308.
[35] A. Shitsukane, W. Cheruiyot, C. Otieno, and M. Mvurya, "Fuzzy Logic Sensor Fusion for Obstacle Avoidance Mobile Robot," *IST-Africa Week Conf.*, no. May, pp. 1–8, 2018.
[36] S. R. Bista, P. R. Giordano, and F. Chaumette, "Combining line segments and points for appearance-based indoor navigation by image based visual servoing," in *IEEE International Conference on Intelligent Robots and Systems*, 2017, doi: 10.1109/IROS.2017.8206131.
[37] F. Bonin-Font, A. Ortiz, and G. Oliver, "Visual Navigation for Mobile Robots: A Survey," *J. Intell. Robot. Syst.*, vol. 53, no. 3, pp. 263–296, Nov. 2008, doi: 10.1007/s10846-008-9235-4.
[38] E. Dönmez, A. F. Kocamaz, and M. Dirik, "A Vision-Based Real-Time Mobile Robot Controller Design Based on Gaussian Function for Indoor Environment," *Arab. J. Sci. Eng.*, vol. 43, no. 12, pp. 7127–7142, Dec. 2018, doi: 10.1007/s13369-017-2917-0.
[39] Y. Yoon, G. N. DeSouza, and A. C. Kak, "Real-time tracking and pose estimation for industrial objects using geometric features," in *Proceedings - IEEE International Conference on Robotics and Automation*, 2003, doi: 10.1109/robot.2003.1242127.
[40] A. Elgammal, D. Harwood, and L. Davis, "Non-parametric model for background subtraction," in *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 2000, doi: 10.1007/3-540-45053-x_48.
[41] M. Dirik, "Development of vision-based mobile robot control and path planning algorithms in obstacled environments," Inonu University, 2020.
[42] L. M. S. Bento, D. R. Boccardo, R. C. S. Machado, F. K. Miyazawa, V. G. Pereira de Sá, and J. L. Szwarcfiter, "Dijkstra graphs," *Discret. Appl. Math.*, vol. 261, pp. 52–62, May 2019, doi: 10.1016/j.dam.2017.07.033.
[43] R. Kala, A. Shukla, and R. Tiwari, "Fusion of probabilistic A* algorithm and fuzzy inference system for robotic path planning," *Artif. Intell. Rev.*, vol. 33, no. 4, pp. 307–327, Apr. 2010, doi: 10.1007/s10462-010-9157-y.

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The effect of STEM application on 21st-century skills of middle school students and student experiences

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ABSTRACT This study aims to reveal the effect of the STEM approach on 21st-century skills of middle school students and to determine their experiences about STEM. This application, which lasted 6 weeks with 7th-grade students, was realized with 35 students. In the study, by using the explanatory mixed-method, firstly, quantitative data was taken and qualitative data were tried to be explained. In the first stage of the study, the pre-test and post-test results were examined in the group by using a dependent group t-test. "Multidimensional 21st Century Skills Scale" was used as a pre-test and post-test tool. In the second stage of the study, student experiences for STEM applications were revealed using the semi-structured interview form, which is one of the qualitative data collection methods. In the findings of the study, it was seen in the results of the analysis that the STEM approach contributed positively to 21st-century skills. Besides, a significant difference was observed between the pre-test and post-test in five sub-dimensions in the scale. However, in the results of the interviews, it was stated that the students were enjoyable to study with STEM, increased communication within the group, and encouraged the student to research and think. It was also observed that some students had difficulties during the application, complained about the lack of time, and had difficulty in designing.

KEYWORDS: 21st Century Skills, Science, Semi-Structured Interview, STEM, Success.

1. INTRODUCTION

Rapidly advancing scientific and technological developments; has revealed the need to keep up with this development in individuals and communities. These needs bring some skills that people should have. These skills also called 21st-century skills are called problem-solving, critical thinking, collaboration, entrepreneurship, etc. [1]. There are different opinions about what 21st-century skills are in the literature. Learning and innovation skills (creativity, innovation, critical thinking, problem-solving, communication, collaboration), knowledge, media, and technology skills (information literacy, media literacy) and technology literacy and life-career skills (flexibility, adaptability, assertiveness, self-management, social and intercultural skills, productivity, responsibility, leadership) [2]. In addition to these, while seeing different skills in the literature, there is a common tendency of these skills. The 21st-century skills focused on this research are listed as "Information and Technology Literacy Skills", "Critical Thinking and Problem-Solving Skills", "Entrepreneurship and Innovation Skills", "Social Responsibility and Leadership Skills" and "Career Awareness".

The need to keep up with rapid changes in the 21st century brought innovations in the field of education. Depending on the needs of the current period, changes may occur in the content, goals, and form of education provided to individuals [3]. Countries that want to exist in global competition need

to keep up with innovative understanding. This has revealed the necessity to adapt the educational needs of individuals to these innovations [4]. Individuals who will form the workforce in the future must be competent in the fields of science, technology, engineering, and mathematics [5]. Many disciplines should be applied together to raise individuals with a new hundred years of skills [6]. Since STEM (Science, Technology, Engineering, and Mathematics) education approach also offers an interdisciplinary field of study, it has an important place in raising individuals with 21st-century skills [7]. STEM as an educational approach; In the United States, it aims to teach science, technology, mathematics, and engineering fields in connection with each other at all levels of education [8-9].

When the literature is examined, research on the integration of 21st-century skills with technology, specific lessons/subjects (egg environmental science), skills (critical thinking, creativity, etc.) or curriculums stands out [10-12]. In the national literature, the pre-service teachers' 21st century determining their skills [13], determining the technology, tools, or methods that affect the 21st-century skills of their students [14-16] and how 21st-century skills are defined and There are researches to explain the classification [16-18]. Regarding the effect of STEM on skills, teachers and prospective teachers generally gain 21st-century skills [19-20] and scientific process skills [21-22]. Its effect has been investigated. However, STEM s students in the 21st century. Investigating the effect of gaining skills will contribute to the literature.

STEM education covers skills in science, technology, and mathematics. This education has two main purposes [23]. The first is employment, and the second is to train students with competencies in these fields. When the literature is examined, STEM applications; rather than being context-based and problem-solving-oriented, it has been observed that it is addressed towards the ability to produce and use technology [24]. STEM approach is stated to be evidence-based and problem-solving based [25]. Besides, establishing a relationship with daily life, which is the basis of the constructivist approach, is one of the results provided by the STEM approach in students.

Individuals and societies should also keep pace with this differentiation towards the needs of a different world. STEM-related fields in Turkey, unfortunately, very few studies carried out that increasing the number of STEM-related studies in Turkey is of great importance [26]. Considering the studies in the literature in the last 5 years, it is seen that STEM education has become widespread at the secondary level. As of the 2017-2018 academic year in the updated curriculum in Turkey was inserted into the STEM education programs. This situation requires having some skills with it. In this context, STEM education aims to provide individuals with these skills. In this context, the opinions of students who personally experienced the STEM approach on the effect of this approach on 21st-century skills are important. The study aims to reveal the effect of 21st-century skills according to the opinions of middle school students studying with the STEM approach and to determine their experiences about STEM. In this context, research questions;

1. What is the effect of STEM approach on 21st-century skills according to the opinions of middle school students?

a. What impact does it have on information and technology literacy skills?

b. What is its effect on critical thinking and problem-solving skills?

c. What is the impact on entrepreneurship and innovation skills?

d. What effect does it have on social responsibility and leadership skills?

e. What is its effect on career awareness?

2. What are the experiences of secondary school students towards the STEM approach?

a. What are the difficulties encountered in the STEM approach according to the opinions of the secondary school students?

b. What are the positive aspects of the STEM approach according to the opinions of secondary school students?

2. METHOD

Since qualitative and quantitative data are used together in this study, a mixed research method was used. Mixed research; is a research approach in which the researcher integrates two sets of data, where he gathers both quantitative and qualitative data to understand research problems, and then draws out the advantages of integrating these two sets [27]. Qualitative and quantitative data must be supportive of each other in a strong mixed pattern study [28]. In the study, a descriptive mixed research design, which is one of the mixed research patterns in which qualitative data is collected [29] to explain the quantitative data, was used. For this reason, the study consists of two stages.

In the first stage, a longitudinal survey model from a quantitative research pattern was used. In longitudinal survey studies, repeated measurements are made at different times to examine the variations of the research variables based on time [30]. With this technique, in the seventh-grade science course, the "Interaction of Light with Matter" unit was handled with a STEM approach for six weeks. Quantitative data were obtained by applying “Multidimensional 21st Century Skills Scale” to these students as a pre-test and a post-test at the end of the practice. In the second stage of the study, interview technique, one of the qualitative data collection types, was used. The most frequently used interview in qualitative research is a mutual and interactive form of communication-based on a predetermined and preferred way of asking and answering questions [31]. In this context, after six weeks of STEM application, the interview technique was used with volunteer students.

2.1 PARTICIPANTS

The study 7th grade students in the 2019-2020 academic year in a secondary school district in the north of Turkey participated. The sample of the study consists of 35 students, 20 males, and 15 female students.

2.2 APPLICATION PROCESS

The application in the "Interaction of Light with Matter" unit of the 7th-grade science course took six weeks in total. STEM activity papers were distributed to the students. During the process, they were asked to design engineering that solved a problem situation related to each subject. Classes were divided into seven groups of five students, and activities were conducted in the form of group work. The problem situation was presented through a story in STEM activity papers distributed to students at the beginning of each subject. While searching for a solution proposal for the problem situation, students were provided to learn the concepts related to the subject. Then students were asked to make their designs as a group in the lesson. After all the groups completed their designs, each group explained their design and explained to their classmates how they came up with a solution. Below are the activity and the gains related to the subject held every week.

Table 1. Activities and subject gains

Week	Activities	Gains
1.	Designing a sweater that suits every environment	She discovers that light can be absorbed by matter as a result of interaction with matter.
2.	Designing a color wheel	It concludes that white light is a combination of all light colors.
3.	Designing a solar panel	It gives examples of innovative applications of solar energy in daily life and technology. Discusses the ideas about how solar energy will be used in the future.
4.	Designing a periscope	Observes the mirror types and gives examples of usage areas.
5.	Designing a stove with a hollow mirror	Compares the images formed in flat, pit, and hump mirrors.
6.	Designing a telescope	Determines the focal points of thin and thick-edged lenses by experimenting. It gives examples of the usage areas of lenses in daily life and technology.

Below are some products that students in the application process have produced.

Figure 1. Products of students who carry out the application

2.3 COLLECTION OF DATA

In the first stage of the research, “Multidimensional 21st-century skills scale” developed by [32] was used. The scale developed in the 5-point Likert type; consists of a total of five sections: Information and Technology Literacy Skills, Critical Thinking and Problem-Solving Skills, Entrepreneurship and Innovation Skills, Social Responsibility and Leadership Skills, and Career Awareness. The answer options of the items in the scale were arranged as "5 = I totally agree", "4 = I agree", "3 = I have no idea", "2 = I do not agree" and "1 = I strongly disagree". This scale prepared for 21st-century skills of students consists of 41 items in total. The Cronbach's Alpha reliability score of the scale is 0.86. The scale was applied to the same study group twice in total as pre-test and post-test. In the second stage of the study, the interview form was used as a data collection tool. This form was applied to 12 students who wanted to participate in the interview voluntarily among the students who participated in the STEM application. The questions used in the form are as follows.

1. What are the shortcomings of the STEM application you think (What are the points you see as a disadvantage)

2. What are the pros of STEM application applied in your opinion? (What are the points you see as an advantage)

2.4 DATA ANALYSIS

The analysis stage of the study consists of two stages, quantitative and qualitative analysis.

a) QUANTITATIVE ANALYSIS

The data obtained from the scale were entered SPSS 23 program before and after the application. A dependent group t-test was used to evaluate the group internally, that is, to learn the effect of STEM approach on 21st-century skills. Data were tested at $p < .05$ significance level.

b) QUALITATIVE ANALYSIS

After six weeks of STEM application, students were interviewed. Voluntarily, a semi-structured interview was held with the students in the group. Voice recording was taken during the interview. Based on volunteering, the data of the 12 students who participated in the interview were listened to by the researchers and transferred to the computer environment. Conversation recordings are added directly to the Microsoft Word program without making any changes in the transfer process. All structured interview records were collected one after the other and interesting statements were determined and the codes of the study were drawn. Later, the authors grouped these codes to be related to each other and created the categories. The last relevant categories are grouped and themes are created.

3. FINDINGS

In this section, the findings related to the results of the analysis carried out to determine whether the STEM application differs from the 21st-century skills in terms of Information and Technology Literacy Skills, Critical Thinking and Problem-Solving Skills, Entrepreneurship and Innovation Skills, Social Responsibility and Leadership Skills and Career Awareness. It was evaluated.

3.1 THE EFFECT OF STEM APPROACH ON 21ST CENTURY SKILLS

Dependent groups t-test was used to determine whether seventh-grade students who taught science lessons with the STEM approach differ significantly according to 21st-century skills variables. The results of the students' pretest and posttest are presented in Table 2.

Table 2. Dependent groups t-test results of the 21st-century skills scale

		N	*X*	*ss*	*Sd*	*t*	*p*
21st Century Skills Scale	Pre-Test	35	2.999	.188	34	-19.66	**.00**
	Post-Test	35	3.878	.282			

A statistically significant difference was observed between the pretest scores of students (X = 2.999, S = 0.188) and posttest scores (X = 3.878, S = 0.282) in favor of the posttest [t (34) = -19.66, p = 0.00]. This finding shows that the STEM approach used has a significant effect on students' 21st-century skills. The dependent group t-test scores of these scores were calculated to determine whether there were significant differences in the five sub-dimensions included in the 21st-century skills scale used. The results of these dimensions are given below as separate tables.

Table 3. Dependent groups t-test results related to information and technology literacy skills

		N	*X*	*ss*	*Sd*	*t*	*p*
Information and Technology Literacy Skills	Pre-Test	35	3.099	.307	34	-14.88	**.00**
	Post-Test	35	3.975	.201			

A statistically significant difference was observed between the pre-test scores (X = 3.099, S = 0.307) and the post-test scores (X = 3.975, S = 0.201) in favor of the post-test [t (34) = -14.88, p = 0.00]. This finding shows that the STEM approach used has a significant effect on students' Information and Technology Literacy skills. Dependent groups t-test results of "Critical Thinking and Problem Solving" skills, another dimension of the scale, are given in Table 4.

Table 4. Dependent groups t-test results related to critical thinking and problem-solving skills

		N	*X*	*ss*	*Sd*	*t*	*p*
Critical Thinking and Problem Solving Skills	Ön Test	35	2.023	.291	34	-20.38	**.00**
	Son Test	35	4.047	.423			

A statistically significant difference was observed between the pre-test scores (X = 2.023, S = 0.291) and the post-test scores (X = 4.047, S = 0.423) in favor of the post-test [t (34) = -20.38, p = 0.00]. This finding shows that the STEM approach used has a significant effect on students' Critical Thinking and Problem-Solving Skills. Dependent groups t-test results of "Entrepreneurship and Innovation" skills, one of the other dimensions of the scale, areas in Table 5.

Table 5. Dependent groups t-test results for entrepreneurship and innovation skills

		N	*X*	*ss*	*sd*	*t*	*p*
	Pre-Test	35	2.714	.257	34	-10.25	.00

Entrepreneurship and Innovation Skills	Post-Test	35	3.617	.395			

A statistically significant difference was observed between the pre-test scores (X = 2.714, S = 0.257) and the post-test scores (X = 3.617, S = 0.395) in favor of the post-test [t (34) = -10.25, p = 0.00]. This finding shows that the STEM approach used has a significant effect on students' Entrepreneurship and Innovation skills. Dependent groups t-test results of "Social Responsibility and Leadership" skills, one of the dimensions of the scale, are given in Table 6.

Table 6. Dependent groups t-test results related to social responsibility and leadership skills

		N	***X***	***ss***	***sd***	***t***	***P***
Social Responsibility and Leadership Skills	Pre-Test	35	3.350	.575	34	-3.33	**.002**
	Post-Test	35	3.742	.505			

A statistically significant difference was observed between the pre-test scores (X = 3.350, S = 0.575) and post-test scores (X = 3.742, S = 0.505) in favor of the post-test [t (34) = -3.33, p = 0.002]. This finding shows that the STEM approach used has a significant effect on students' "Social Responsibility and Leadership" skills. Dependent groups t-test results of "Career Awareness" skills, one of the dimensions of the scale, are given in Table 7.

Table 7. Dependent groups t-test results related to career awareness

		N	***X***	***ss***	***sd***	***t***	***P***
Career Awareness	Pre-Test	35	3.809	.581	34	-2.20	**.035**
	Post-Test	35	4.009	.361			

A significant difference was observed between the pre-test scores (X = 3.809, S = 0.581) and post-test scores (X = 4.009, S = 0.361) of students [t (34) = -2.20, p = 0.035]. This finding shows that the STEM approach used has a significant effect on students' Career Awareness skills.

3.2 STUDENTS' EXPERIENCES ABOUT STEM APPROACH

This section includes qualitative findings obtained as a result of a semi-structured interview. Here, the interview records of the students about their STEM activities were analyzed and the themes, categories, and codes formed as a result of the analysis are presented in Table 8.

Table 8. Theme, category and code information of qualitative data

Theme	**Category**	**Code**	**f**	**Example Student Discourses**
The advantages of STEM activities	21st-century skills	Career Consciousness (Feeling like an Engineer)	2	*S3: I felt like an engineer.* *S10: I always thought I was an engineer while researching and designing.*
		Critical thinking and problem solving	7	*S11: I like to think with my friends to solve the problem given by our teacher. I couldn't get used to it, but then I started to like it.* *S12: When I came to class, I was talking to my friends this time about how the teacher would present a problem. We were curiously waiting.*
		Communication and collaboration (belonging to the group and communication)	5	*S2: It was so much fun working with the group. We did not want to breathe* *S4: I'm bored when the activities force. But my teacher and group friends helped. We did this job easier with the group*
		Entrepreneurship and innovation	3	*Q5: We were also designing in technology design lesson, but the designs in science lesson were useful* *Q10: We were researching and deciding which design to make*

		Information and technology literacy (Knowledge transfer-research)	8	*S3: It was fun to use the information I learned and researched* *S8: We researched on the internet in the parts we had difficulty*
	Learning Environment	Fun lesson	6	*S10: I didn't get used to it at first, but then it was fun.* *S7: The lesson was very enjoyable. Time has passed like water.*
		Positive attitude towards science	6	*S6: With this application, my interest in the course has increased. I don't understand how time passes. Everything was perfect.* *S9: Although I got used to it in the first place, I liked it later. We should even use it in other lessons. I will ask my math teacher to use STEM.*
The difficulties encountered	Time-consuming Events	Insufficient time	7	*S5: Time was not enough. We need extra time. Sometimes we even designed during recess.* *S5: Activities take a lot of time. I had a little difficulty.*
		Practice problem	4	*S7: I had a hard time using this activity for the first time.* *S9: Although I got used to it in the first place, I liked it later*
	Compelling Designs	Design challenge	5	*S2: But sometimes it was when we had a hard time making designs.* *S8: We used the internet when we had difficulty in design.* *S7: It has forced me to combine different designs.* *S1: I had difficulty in designing.*

When the students' views about the process were taken into consideration, the first theme was about the advantages of the activities. Under this theme, 21st-century skills and learning environment categories are included. These findings were determined that STEM activities contributed to students gaining 21st-century skills. Besides, these activities were found to make the learning environment more enjoyable and to provide students with a positive attitude towards science. In the second theme, students are faced with difficulties regarding STEM activities. The students stated that they had difficulty in completing the activities related to this process in time and design.

4. RESULT AND DISCUSSION

21st-century skills are embedded in new curricula with programs updated by MEB. For this purpose, the STEM approach is important. When the research results are examined, it was revealed that STEM activities positively affected the 21st-century skills of middle school students. When each sub-dimension of the 21st-century skills was examined separately, it was determined that there was a significant difference between the pre-test results of the students in all sub-dimensions in favor of the post-test. This result can be said that STEM activities increase students' information and technology literacy, critical thinking and problem-solving skills, entrepreneurship and innovation skills, social responsibility and leadership skills, and career awareness. When student discourses are examined, it is seen that it supports these results. The students stated that STEM activities developed critical thinking and problem-solving skills, strengthened the cooperation and communication aspects of the group, they felt like engineers during the activities, this process enabled them to make various designs, and they gained information and technology literacy by developing research and transferring information. We can explain this result as follows: During STEM activities, students encounter a problem situation in each activity and seek solutions for it. Acquiring this skill is essential. Because of the person; He can use his many skills such as creativity, critical thinking, and cooperative work when he takes action to solve a problem situation [26]. In this process, the student begins to actively think about the problem he faces while looking for a solution and conducts critical thinking by conducting research inquiry at

every stage of the process (research, proposing a solution, designing, etc.). While doing these, working with group friends develops students' cooperation and communication. It needs a variety of researches, both while proposing a solution to the problem and at the design stage, which enables them to transfer research and the information they acquire using technology. Because STEM education aims to use individuals' knowledge and skills with practical applications and to integrate them with daily life problems [33]. The process also offers students the opportunity to design. As a result of these design studies, students realize that the information they have when they reach a product works and wants to have more information [34]. However, these designs are effective in structuring scientific knowledge, creating a potential for students, and serving as a bridge for science learning [35]. Many studies in the literature emphasize that STEM education is the most appropriate approach to improve 21st-century skills [36-38].

Researches related to STEM and 21st-century skills were generally conducted with teachers and prospective teachers, and STEM activities were effective in gaining many 21st century skills of teachers and prospective teachers [19,20,40] and science teachers. He determined that there is a moderate positive relationship between 21st-century skills competence perceptions and attitudes towards STEM [41]. He argues that after the research they conducted with 7th-grade students, many skills aimed at individuals in the 21st century can be gained with STEM education [42]. When the effect of STEM activities on students is analyzed, it increases the academic success [43-45], in which students improved their scientific process skills [34], and their creative thinking skills [46] and it is emphasized that they have gained a positive attitude towards STEM [42,45].

At the end of the research, students stated that STEM activities make the learning environment more enjoyable and positively affect their attitudes towards science. Similarly, they stated that STEM positively improves middle school 5th-grade students' attitudes towards science and explained that this is because students make mini designs and obtain a product [47]. STEM applications increase students' interest in science subjects and their desire to learn [48]. However, another finding obtained in the research is that students have difficulty in raising and designing time during STEM activities. Since the process of researching and designing is unfamiliar with the students, and extra material, equipment, computer, internet, etc. for the learning environment may be due to the need. To prevent or minimize the time loss that may occur during the lesson, it is necessary to arrange the learning environment in advance, to have the necessary technological equipment and the necessary infrastructure ready for use, to check in advance, to determine the layout of the groups and to have the materials to be used ready [42]. Besides, the application of STEM activities from time to time during the education period may help these students to overcome these difficulties.

As a result, STEM activities develop 21st-century skills of secondary school students. Because STEM activities by nature require many skills such as research, using technology, working with a group,

creating products, and making presentations, and therefore students have the opportunity to develop these skills in learning environments where this approach is frequently used [42]. Besides, STEM practices contribute to the positive attitude of students towards learning science and to make the learning environment more fun. However, according to the opinions of the students who experience this STEM approach, it is determined that there may be difficulties during the process of raising and designing time in this process, and it is foreseen that these difficulties can be overcome with the plans and precautions taken before the implementation.

In future research, 21st-century skills can be handled separately, the effects of STEM applications (eg Argumentation supported STEM, Problem-based or project-based STEM applications) integrated with different methods on 21st-century skills can be investigated and these skills can be investigated with each other and other components of the learning environment their relationship can be examined. Besides, teachers who want to practice STEM in their classrooms; It is recommended that they behave meticulously in time planning and do not ignore the importance of doing STEM activities in improving students' skills.

5. REFERENCES

[1] National Research Council. (2011). *Successful STEM education: A workshop summary*. Washington, DC: National Academies Press.

[2] Partnership for 21st Century Skills-P21. (2009). *P21 framework definitions*. Retrieved from http://www.p21.org/storage/documents/P21_Framework_Definitions.pdf. Date of Access: 03/05/2020.

[3] Aydemir, E, Kaysi, F, Gülsecen, S. (2019). Estimation of Turkish Language Exam Results of University Students According to Exam Preparation Levels. *Alphanumeric Journal, 7* (2), 351-356.

[4] Kaysi, F., & Aydemir, E. (2017). Evaluation of Interaction Dimensions in Distance Education Processes. *Journal of Social Sciences, 4* (11): 1-10.

[5] Organisation for Economic Co-operation and Development (OECD). (2017). PISA 2015 collaborative problem-solving framework. Paris: OECD Publishing. https://www.oecd.org/pisa/pisaproducts/Draft%20PISA%202015%20Collaborative%20Problem%20Solving%20Framework%20.pdf. Date of access: 10/05/2020.

[6] Yildirim, B (2018). Mus Alparslan University STEM Education Report - STEM Education for the Goals of 2023, 2053, and 2071. www.alparslan.edu.tr//IcerikDosya?link=2f9aeaf8ecf00870f840c297c8649b19518d6f0b. Date of Access: 01/05/2020.

[7] Roberts, A. (2012). A justification for STEM education. *Technology and engineering teacher, 71*(8), 1-4.

[8] Bybee, R. W. (2011). "Scientific And Engineering Practices In K-12 Classrooms: Understanding "A Framework For K-12 Science Education". *Science and Children, 49*(4), 10-16.

[9] MEB (Ministry of National Education) (2016). STEM education report. Ankara: Ministry of National Education, General Directorate of Innovation and Educational Technologies (YEGITEK).

[10] Afandi, A., Sajidan, S., Akhyar, M., & Suryani, N. (2018). Pre-Service Science Teachers' Perception About High Order Thinking Skills (HOTS) in the 21st Century. *International Journal of Pedagogy and Teacher Education, 2*(1), 107–114.

[11] Halverson, A. (2018). *21st-century skills and the "4Cs" in the English language classroom*. Retrieved from http://hdl.handle.net/1794/23598. Date of Access: 09/05/2020.

[12] Louis, R. C. (2012). *A case study exploring technology integration and incorporation of 21st-century skills in elementary classrooms.* College of Professional Studies Northeastern University, Boston, Massachusetts.

[13] Gunuc, S., Odabasi, H. F., & Kuzu, A. (2013). Defining 21st Century Student Features by Prospective Teachers: A Twitter Application. *Journal Of Theory & Practice In Education (Jtpe), 9*(4).

[14] Gulen, B. (2013). *Investigation of Secondary School Students' 21st Century Learning Skills and Information Technologies and Support Levels According to Gender and Grade Level.* Unpublished Master's Thesis, Gazi University Institute of Educational Sciences, Ankara.

[15] Kotluk, N., & Kocakaya, S. (2015) Digital stories in the development of 21st-century skills: Investigation of secondary school students' views. *Journal of Education and Teaching Research, 4*(2), 354-363.

[16] Yalcin, S. (2018). 21st-century skills and tools and approaches used to measure these skills. *Journal of Ankara University Faculty of Educational Sciences, 51*(1), 183-201.

[17] Ekici, G., Abide, O. F., Canbolat, Y., & Ozturk, A. (2017). Analysis of data sources for 21st-century skills. *Journal of Research in Education and Teaching., 6*(1), 1-12.

[18] Murat, A. (2018). *Examination of science teacher candidates' 21st-century skills competence perceptions and their attitudes towards STEM*. Unpublished Master Thesis. Firat University, Elazig.

[19] Deveci, I. (2018). Entrepreneurial Traits of STEM Awareness of Science Teacher Candidates. *Kastamonu Education Journal, 26*(4), 1247-1256.

[20] Eroglu, S., & Bektas, O. (2016). Views of STEM Education Science Teachers About STEM-Based Course Activities. *Journal of Qualitative Research in Education 4*(3), 43-67.

[21] Gokbayrak, S., & Karisan, D. (2017). Investigation of Sixth Grade Students' Opinions About STEM Based Activities. *Journal of Field Education Research, 3* (1), 25-40.

[22] Tarkin-Celikkiran, A., & Aydin-Gunbatar, S. (2017). Examination of the opinions of chemistry teacher candidates about STEM applications. *Yuzuncu Yil University Journal of Education, 14*(1), 1624-1656.

[23] Thomasian, J. (2011). Building a science, technology, engineering, and math education agenda: An update of state actions. Washington, DC: National Governors Association (NGA), Center for Best Practices. Retrieved from http://www.nga.org/files/live/sites/NGA/files/ pdf/1112STEMGUIDE.pdf. Date of Access: 08/05/2020.

[24] Bati, K., Caliskan, I., & Yetisir, M. I. (2017). Computational thinking and integrated areas approach in science education (STEAM). *Pamukkale University Journal of Education, 41*, 91-103.

[25] Freeman, S., Eddy, SL., McDonough, M., Smith, MK., Okoroafor, N., Jordt, H., & Wenderoth MP.(2014). *Active learning increases student performance in science, engineering, and mathematics.* Proc Natl Acad Sci USA 111, 8410–8415.

[26] Akgunduz, D., Ertepinar, H., Ger, A. M., Kaplan Sayi, A., & Turk, Z. (2015). STEM education workshop report: a comprehensive assessment of Turkey STEM education: Istanbul Aydin University STEM Center and Education.

[27] Creswell, J. W. (2019). *Introduction to mixed-method researches*, 2nd Edition.. (Ed., M. Sözbilir) Pegem Academy.

[28] Tashakkori, A., & Creswell, J. W. (2007). Exploring the nature of research questions in mixed methods research. *Journal of Mixed Methods Research, 1*(3), 207-211.

[29] Creswell, J. W., & Clark, V. L. (2011). *Designing and conducting mixed methods research*. Thousand Oaks, CA: Sage.

[30] Buyukozturk, S., Cakmak, E., Akgun, O. E., Karadeniz, S., & Demirel, F. (2018). *Academic research methods in education (25. Edition).* Pegem Academy, Ankara.

[31] Stewart, C. J., & Cash Jr, W. B. (1985). *Interviewing: Principles and practices*. Dubuque, IA: Wm. C.

[32] Cevik, M. & Senturk C. (2019). Multidimensional 21st-century skills scale: Validity and reliability study. *Cypriot Journal of Educational Sciences. 14*(1), 011–028.

[33] Wang, H., Moore, T. J., Roehrig, G. H., & Park, M. S. (2011). STEM integration: teacher perceptions and practice. *Journal of Pre-College Engineering Education Research, 1*(2), 1–13.

[34] Yamak, H., Bulut, N., & Dundar, S. (2014). 5. The Effect of STEM Activities on the Scientific Process Skills and Attitudes of Science to Grade 5 Students. *Gazi University Journal of Gazi Education Faculty, 34*(2), 249-265.

[35] Fortus, D., Dershimer, R. C., Krajcik, J. S., Marx, R. W., & Mamlok-Naaman, R. (2004). Design-based science and student learning. *Journal of Research in Science Teaching, 41*(10), 1081-1110.

[36] Bybee, R. W. (2010). Advancing STEM education: A 2020 vision. *Technology and Engineering Teacher, 70*, 30-35.

[37] Ejiwale, J. A. (2012). Facilitating teaching and learning across STEM fields. *Journal of STEM Education: Innovations and Research, 13*(3), 87.

[38] Ostler, E. (2012). 21st century STEM education: A tactical model for long-range success. *International Journal of Applied Science and Technology, 2*(1), 28-33.

[40] Hacioglu, Y. (2017). *The Effects of Science, Technology, Engineering, and Mathematics (STEM) Education Based Activities on Pre-Service Science Teachers' Critical Thinking Skills.* Unpublished Master's Thesis, Gazi University, Institute of Educational Sciences, Ankara.

[41] Murat, M. (2018). *The effect of the flipped class model on fifth-grade students' 21st-century skills and scientific epistemological beliefs.* Unpublished Master Thesis. Mugla Sitki Kocaman University, Institute of Educational Sciences, Mugla.

[42] Ozcan, H. & Koca, E. (2019). The effect of teaching pressure issue with STEM approach on the academic achievement and attitudes of STEM students to 7th-grade students, *Education and Science, 44* (198), 201-227.

[43] Cevik, M. (2018). Impacts of the project-based (PBL) science, technology, engineering, and mathematics (STEM) education on academic achievement and career interests of vocational high school students. *Pegem Journal of Education and Training, 8*(2), 281-306.

[44] Cotabish, A., Dailey, D., Robinson, A., & Hughes, G. (2013). The effects of a STEM intervention on elementary students' science knowledge and skills. *School Science and Mathematics, 113*(5), 215-226.

[45] Toma, R. B., & Greca, I. M. (2018). The effect of integrative STEM instruction on elementary students' attitudes toward science. Eurasia Journal of Mathematics, *Science and Technology Education, 14*(4), 1383-1395.

[46] Kakarndee, N., Kudthalang, N., & Jansawang, N. (2018). The integrated learning management using the STEM education for improve learning achievement and creativity in the topic of force and motion at the 9th-grade level. *AIP Conference Proceedings, 1923*(1), 030024.

[47] Moore, T.J., Stohlmann, M.S., Wang, H.-H., Tank, K.M., & Roehrig, G.H. (2013). Implementation and integration of engineering in K-12 STEM education. In J. Strobel, S. Purzer, & M. Cardella (Edt.), *Engineering in precollege settings: Research into practice.* Rotterdam, the Netherlands: Sense Publishers.

[48] Doppelt, Y., Mehalik, M. M., Schunn, C. D., Silk, E., & Krysinski, D. (2008). Engagement and achievements: a case study of design-based learning in a science context. *Journal of Technology Education, 19*(2), 22-39.

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Recommendation of a New Device for Calculation of Non-Planning Areas

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ABSTRACT Area calculation is frequently used in engineering areas as well as especially in the construction sector. It is used in the effectiveness and efficiency research of companies, in the design and management of work areas and warehouses. In the marketing sector, it is used to deliver independent areas. The success of the delivery process is measured by customer satisfaction. In engineering services, area calculation is frequently used during the design phase. The designs of logistics storage areas and residential independent areas can be exemplified in the design of independent area. It is very important to calculate the right area when making these designs. Large area calculation devices are used in geographical area calculations and the appearance of historical monuments of restoration works. Laser scanners, drones and drones are used in the app. It is not appropriate to use these devices in small areas, such as specified areas. It is more suitable to use devices that measure single-axis length in the account of independent areas of industrial and residential structures. The simple area account is multiplied by data from two axis measurements. Individual measurement and calculation errors occur in manual measurements. Mistakes made in the production process cause serious economic problems. At the same time, companies suffer from prestige losses. A system is needed to eliminate these errors. For this reason, the idea of designing a device that can measure and calculate with a multi-axis measurement has emerged. Measuring, mapping and calculating planar and non-planar independent areas can be made with the developed device. Thus, practical and accurate calculation and mapping can be done at low cost. The laser distance sensor connected to the microcontroller is made with the help of a stepper motor and an area account with 360° scanning of the area. 20 different areas were calculated both by making a single-axis measurement and with the help of the device. These calculations were compared with single-axis measurements made with the help of civil engineers and error rates were obtained. As a result of the study, it was observed that the device made measurements with an average error of 3.64%. The lowest error rate was 1.50%, while the highest error rate was 6.04%. It is thought that better results will be achieved by using different equipment and methods in the design of the device. It is believed that it has the potential to pave the way for work to be done in many areas.

KEYWORDS: Laser Distance Measurement, Area Calculation, Non-Planar Areas, Construction.

1. INTRODUCTION

The laser scanning system, which appeared in architectural and restoration works in the 20th century, is often used today. It is applied in the determination of cultural heritage, in the determination of damage measurements, in documenting restoration works, measuring large-scale structures, geological surveys and land measurements. There are many projects and scientific studies using laser scanning system in our country. The method works as recording the return data of the distance sensors after each shot and mapping all data as punctuation. Istanbul Technical University School of Foreign Languages study [1], Tozman Cave [2], Harput Castle Bath [3] etc. such as this method was used. Thus, the desired map is

created from the points obtained. In order to clearly create the appearance of the structure, it is necessary to map from different points. An integrated look is achieved with the maps assembled. Another purpose of laser scanner systems is to demonstrate the defining properties of geometric shapes and areas. It is simple and easy to measure and calculate two-dimensional systems that produce three-dimensional mapping.

In the construction sector, the delivery process follows the production process. There is a contract between the employer and the contractor to create works. There are disagreements about the gross and net square meters of independent areas planned to be delivered under this work contract. The parties also have a sales contract for these independent areas. The cost of independent areas is multiplied by gross measurement values and unit prices. If it is determined that the net area committed by the employer is not carried out, a refund request is made. Studies on the accuracy of this request are limited. Single-axis distance meters are used in the delivery of independent areas. In particular, technical personnel such as engineers and architects are helped by the employer. However, disagreements occur due to individual measurement and calculation errors.

In the logistics sector, it is actively used in the execution of storage activities. In addition, the removal of net areas of logistics warehouses is an important topic in planning. It is important to detect empty areas when filling storage areas with different types of products. As in many sectors, individual single-axis measurements are technical errors. As a result of these errors, economically permanent damage sparked by serious return costs. It is seen how efficient and effective individual single-axis measurements are on a sectoral basis. Efficiency and effectiveness need to be increased, technological development must be captured and margins of error should be reduced. The need to calculate and map measurements of planar and non-planar independent areas has emerged.

2. LITERATURE

There are many areas scanning and calculation devices in the literature. With laser scanner and UAV, planar and non-planar terrain can be scanned and area edify. The study, "Researching Earth Laser Scanners and Location Accuracy", describes how three-dimensional information transfer is used in engineering and architectural studies. It is explained how it is used in relief and restoration works in the preservation of historical and cultural heritage. The laser scanner uses the cloud system as a working principle. A mapping system is created by identifying and transferring the data obtained from the scan as an object. Thus, an architecturally immense base is created [4]. In the study called "Basesal Laser Scanner Systems Used in Engineering Applications", accuracy and reliability tests of laser scanners used as measurement technology in all areas were carried out. It has been revealed how the laser scanner works. Then the coordinates obtained from laser scanners were converted to the desired coordinate system. Positive and negative results were discussed [5]. In the study called "Scanning Non-Planar Areas with UAV", it was thoroughly investigated to create a mapping system by scanning large areas

for different purposes. The study, which usually includes a purpose for the military and defense industries, has an important place in the literature to explain the transfer of large areas to the cloud system. Area scanning is carried out through Unmanned Aerial Vehicles. Thus, large areas are scanned for a short time and the map is created [6].

3. PURPOSE AND JUSTIFICATION

It is aimed to make a practical calculation using the automation system for the low cost and accurate calculation of building independent areas. When considering the cost option, different quality single-axis measuring devices are introduced in production by different companies. The aim of this study is to design a device that can calculate by measuring the two axes at the same time. Area measuring devices are mostly used for scanning and mapping large terrain. In addition, they are used in the process of removing the architecture and restoration works. These studies are carried out on large areas. Single-axis planar measuring instruments used in the application cannot make a clear measurement. Area measuring devices cannot be used in closed structures and small sizes. Personal measurement and calculation errors occur in single-axis measuring devices. The main purpose of this study is to create a device that can perform both two-axis measurements and calculate area as a result of measurement in order to pass all these glitches and errors. In experimental studies, measurements will be made with the device that is created. The numerical values of the selected venues in architectural projects, the results of a single-axis measurement and the results obtained from the device will be examined comparatively.

4. DEVICE DESIGN

4.1 EQUIPMENTS

Arduino UNO control card was decided to be used due to easy programming and economic timing of the device when planning the prototype. A stepper with a gearbox was used to ensure a 360° rotation. In order to measure distance, the laser distance sensor is preferred because it can measure point. The following are the features of the components mentioned:

- LIDAR-Lite v3 is a distance sensor developed by Garmin for spot measurement up to 40 meters. The drone is used for 2D/3D scanning in automation systems such as robots. Simple output pins are quite easy to use thanks to the Arduino library with I2C and PWM features. [7].
- Connections can be easily connected to rotating systems thanks to the rotary connector named "Flange Slip Ring - Rotary Connector 22mm Diameter 12 - 240V 2A Adafruit". It allows you to make connections that provide 360 degree smooth rotation thanks to the electromechanical mechanism that finds it inside. Up to 12 cables can be connected. Tested for rotation up to 300 RPM, each cable can carry 240V 2A DC or 240V AC. It comes with 12 15 cm cables [8].
- 28BYJ-48 engine; Operating voltage is 5V, step angle 5.625°, internal resistance is 130 Ohm, 100 Hz frequency and a gearbox unipolar step pert. It is often used in simple and mid-level automation projects. A stepper motor driver with four LED and four control pins is used to

control the stepper engine. It is possible to use it with many microcontrollers so that it is possible [9].

- Arduino UNO control card is used to read data from the laser sensor and control the stepper motor. Arduino UNO contains a TTmega328 microcontroller running at 16 Mhz. The card has a operating voltage 5V and has 14 digital input-output pins and six analog input pins [10].

4.2 PROTOTYPES AND FEATURES

The above-mentioned equipment is assembled and developed codes are installed on the control card. It is tested and prepared for measurement as a result of calibration operations.

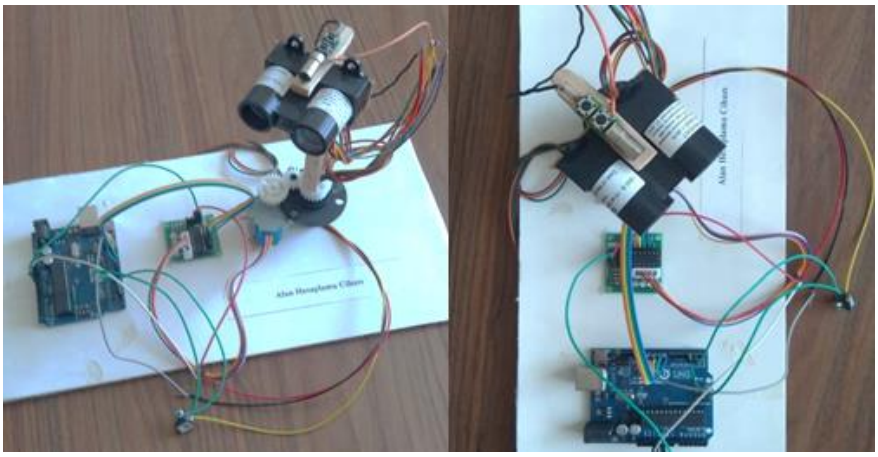

Figure 1. Produced Area Calculation Device Prototype

The prototype shown in Figure 1 has a Lidar Lite v3 sensor that rotates 360 degrees thanks to a flanged connector on the stepper motor. With 455 step motions of the stepper motor, the lidar sensor is provided for a lap. Thus, measurements were performed with angle accuracy of 360/455=0.8 degrees. With each distance measurement, the two sides with an angle of 0.8 degrees were formed by known triangles. The sum of the areas of these triangles is the total area. In addition, the data obtained using an interface developed on the Visual Studio 2017 platform was analyzed and the shape of the area contained in it was carried out.

5. FINDINGS

First of all, the area was accounted for with the help of existing single-axis devices. Measurements were made with the device that was then created, area map was drawn and area calculation was made. By comparing the data obtained, the error rate of the device in the calculation was determined. As a result of the calculations, the device was found to have measurements with an average error of 3.64%, including the lowest error rate of 1.5% and the highest 6.04% in the calculation of non-planar areas. Shown in Table 1. The measurements made by the prototype developed in Figure 2 show the maps created by the interface program.

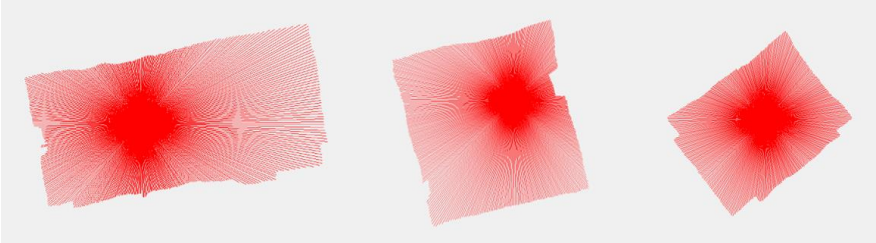

Figure 2. Maps created with interface

Table 1. Comparing Single-Axis Measurement and Device Measurements

Queue	Independent Area	Single-Axis Measurement	Measurement with device	Error Quantity	Error Rate
1	Room 1	10,83	10,32	0,51	4,71%
2	Room 2	11,17	10,94	0,23	2,06%
3	Room 3	10	9,73	0,27	2,70%
4	Room 4	28,86	27,39	1,47	5,09%
5	Room 5	17,32	17,11	0,21	1,21%
6	Room 6	20,26	19,76	0,5	2,47%
7	Housing-1	11,92	11,29	0,63	5,29%
8	Housing-2	8,76	8,62	0,14	1,60%
9	Housing-3	6,76	6,46	0,3	4,44%
10	Housing-4	12,56	12,35	0,21	1,67%
11	Housing-5	22,45	21,32	1,13	5,03%
12	Housing-6	20,21	19,04	1,17	5,79%
13	Housing-7	9,78	9,48	0,3	3,07%
14	Housing-8	13,58	12,96	0,62	4,57%
15	Housing-9	5,86	5,73	0,13	2,22%
16	Housing-10	18,47	17,54	0,93	5,04%
17	Housing-11	12,93	12,28	0,65	5,03%
18	Housing-12	8,65	8,24	0,41	4,74%
19	Housing-13	7,12	6,98	0,14	1,97%
20	Housing-14	6,46	6,19	0,27	4,18%
				Average Error Percentage:	%3,64

The data shows that the device makes fewer errors in smaller areas. In large areas, increasing error rate has been found to be effective in exceeding the correct measuring capacity of the distance sensor. Due to exceeding distance capacity, the error rate increases in area calculation. Therefore, sensors that are more featured should be selected depending on the size of the area to be measured.

6. DISCUSSION AND RESULT

The need for area calculation is frequently seen in the areas of construction, logistics and defense industry. Every move that increases the efficiency of work and production in these sectors creates a benefit to the national economy. We need to be able to create a product that meets the need, is economical, quality and captures the technology of the age. Many systems are used in the application for area scanning and calculation. Although the targeted area scanning and area calculation can be done with existing laser scanners and UAV, the calculation of the structure-independent internal areas is not useful and economical with existing systems. Internationally produced devices for area calculation do not fully meet the current need and cause high costs.

It is aimed to produce an original technology that will contribute to the economy of the country by creating a more economical, desired quality area measurement and calculation device than foreign devices. In this developed system, it is aimed to calculate the structure independent internal areas correctly by considering the quality-cost balance. The current technology is very costly due to its high foreign exchange values. The components to be used to create this device are foreign capital. However, it is possible to sell at a higher price than the costs of the equipment that makes up the device with the added value that occurs by achieving the desired targets. With the system created, all units needed in the public or private sector area account will be able to make area calculations without the need for technical personnel. The current ongoing length measurement equipment will eliminate individual measurement errors and eliminate job and cost loss.

Due to its specialization in the public sector, a budget is created using the "Direct Procurement" method for measurement and calculation. The subject of expertise is created by an external report. However, this need will be met with the developed device. Checks will be carried out without the need for additional confirmation, eliminating a serious financial burden on the public. In terms of private sector construction, logistics and defense industry, production efficiency will be increased by making more use of less cost. In the construction sector, disputes will be avoided, especially in the delivery of finished independent areas. Warehouse planning in the logistics area will be opened to easy construction. The device appeals to all sectors that interact indirectly with the aforementioned sectors and sectors. This creates a serious area.

As a result of the area measurements, a result of the targeted result was revealed. The error rate increases in the calculation of areas above capacity due to the selection of the distance sensor in accordance with the specified budget. With increasing budget and the use of more equipped materials, a more efficient and effective device design will hope.

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REFERENCES

[1]. S. Safkan, H. Hamarat, Z. Duran, U. Aydar, M.F. Çelik, "Yersel Lazer Tarama Yönteminin Mimari Belgelemede Kullanılması", *V. Uzaktan Algılama ve Coğrafi Bilgi Sistemleri Sempozyumu*, İstanbul, 2014.

[2]. U. Avdan, E. Pekkan and R. Çömert, "Mağara Ölçümlerinde Yersel Lazer Tarayıcıların Kullanılması (Tozman mağarası örneği)", *Harita Teknolojileri Elektronik Dergisi*, vol. 5, no. 2, 2013, pp. 16-28.

[3]. T. Uzun and Y. Spor, "Yersel Lazer (nokta bulut) Tarama Yöntemi ile Rölöve–Restitüsyon-Restorasyon Projesi Hazırlama Süreci ve Bir Örnek: Elazığ Harput Kale Hamamı", *Tasarım Kuram Dergisi*, vol. 15, no. 28, 2019, pp. 1-26.

[4]. K. Gümüş and H. Erkaya, "Yersel Lazer Tarayıcılar ve Konum Doğruluklarının Araştırılması", Yıldız Teknik Üniversitesi, Fen Bilimleri Enstitüsü, Master dissertation. 2008.

[5]. K. Gümüş and H. Erkaya, "Mühendislik Uygulamalarında Kullanılan Yersel Lazer Tarayıcı Sistemler", 11. Türkiye Harita Bilimsel ve Teknik Kurultayı, Ankara. 2007.

[6]. Ç. Seylan, Ö.S. Bican and F. Semiz, "İnsansız Araçlarla Düzlemsel Olmayan Alanların Taranması", *Savunma Bilimleri Dergisi*, vol. 11, 2012, pp. 107-117.

[7]. Garmin Ltd (2016). Lidar Lite v3 Operation Manual and Technical Specification, https://static.garmin.com/pumac/LIDAR_Lite_v3_Operation_Manual_and_Technical_Specifications.pdf, Access date: 19.05.2020.

[8]. Adafruit. Slip Ring with Flange. https://www.adafruit.com/product/1196, Access date: 19.05.2020.

[9]. Kiatronics. 28BYJ-48 Stepper Motor. https://pdf.direnc.net/upload/28byj-48-reduktorlu-step-motor-datasheet.pdf, Access date:19.05.2020.

[10]. Arduino. Arduino UNO. https://store.arduino.cc/usa/arduino-uno-rev3, Access date:19.05.2020.

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Al-Jazari: The Ingenious Inventor of Cybernetics and Robotics

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ABSTRACT In early civilizations, technology has developed independently from philosophical ideas and scientific theorems. Different civilizations have participated in the evolution of technologies throughout history. Technological developments are elaborated by successive civilizations and transmitted with written documents. There have been many scientists who have made an extraordinary contribution to technological development. Al-Jazari (1136-1206) was one of the scholars who were trained in this state. He was an inventor and mechanical engineer who invented ingenious inventions in robotics and control them with the hydraulic and gear systems. In addition, the crankshaft, which is the most important mechanical device after the wheel, is one of the invention with high technological significance invented by Al-Jazari. He has drawn many mechanically proper designs in his hand-written book. It is understood from this book he was one of the pioneers of cybernetics and robotics. In this study, firstly, a short description of the biography of this inventor is given and its place in the history of technology is emphasized. Then, the subject of cybernetics science was discussed. The effect of the cybernetic on the machines invented by Al-Jazari is shown here. The control of the developed robot systems is related to cybernetic philosophy and methodology. A set of ideas bearing on the self-regulation of action and emotion such as cybernetic is described. In the last chapter, the structures that form the milestones of today's technology history, from the machines invented by Al-Jazari, are discussed. Finally, information is given about why Al-Jazari was a master and pioneer in cybernetics and robotics.

KEYWORDS: Al-Jazari, Cybernetic and Robotic, Crankshaft, Hydraulic and Gear System

1. INTRODUCTION

Technological developments have evolved with the contributions of different civilizations and nations throughout history. The contribution of advanced societies to technology in terms of philosophical analysis and rational thinking is faster. Technological developments at large scales are detailed by successive civilizations and turned into written documents. Those who survive from these documents are well-defined and defended civilizations. One of them is the forgotten masterpieces of Muslim technological devices in Al-Jazari's hand-drawn mechanical systems. He pioneered many modern technological concepts, but unfortunately due to the lack of communication, his work and mechanical devices were not well recognized for a long time [1-4].

Al-Jazari, a Muslim scholar, mechanical engineer, and inventor who is remembered for his design of water-raising machines and many automata, which worked by waterpower hydraulically. His full name was Badi Al-Zaman AbulI-Izz Ibn Ismail Ibn Al-Razzaz Al-Jazari. Al-Jazari is his nickname. The name of the region where he lived in the name of the region between the Euphrates and the Tigris, which is known as “el-Cezire”. He had lived during the 12th century and drawn many mechanical special designs in his hand-written book [3-5]. Prof Eilhard wiedemann (1852-1928) is the first scientist to bring his book to the world of science. The first person to talk about this scientist in Turkey is the

historian Ibrahim Hakkı Konyalı [6]. The most comprehensive study on Al-Jazari was done in 1974 by Donald R. Hill. Donald Hill has translated his book (The Book of Knowledge of Ingenious Mechanical Devices) from the original Arabic to English, and added some explanations [7]. The Cultural Ministry of Turkey was printed in its original form in Turkish Language 1990 [8]. This book includes a whole range all the terminology of devices and machines, with a multiplicity of purposes. Al-Jazari spent nearly 25 years in Diyarbakır. One of his creation is a water pump using a crank-slider-like system, which was the first known machine to use a crank [9-11]. After searching the literature and consider the book written by this engineer, a glance through brings to one's mind the question of who is the leader in cybernetics and robotics in terms of controllable handy mechanical devices closest to today's technological level. Considering the resources that reach us as a written document, the book of Al-Jazari is actually regarded as the technological accumulation of the Islamic period. In the Muslim civilization, it is seen that, technological development and vending machines that served many social purposes compared to other civilizations [12]. These are important evaluations to understand who owes the origin of today's technology. They built further advances in the history of technology with their original ideas to make technology better. The book of Al-Jazari has an important written source identity in order to understand the technological level of the time. It is unique in reflecting the current technological level of humanity. It is accepted that Muslims climbed to the top of technological developments with the work of Al-Jazari [13]. A significant study on Al-Jazari has been given by Wiedemann [14]. It is understood that Al-Jazari's book concentrates more on engineering design than social and cultural situations. Considering the Physical descriptions of the robots he made, it is possible to build Al-Jazari's devices even today, because he has written in Arabic and understandable to every aspect of the elements and their common operations [15]. The best of technological advances were brought together in a book written by Al-Jazari and translated by Hill during the Medieval Islamic period [7]. Jazari has provided visual and intellectual descriptions for the further development of technology, with work on hand-drawn mechanical devices in his book.

The aim here is to help researchers, engineers, and scholars to demonstrate key scientific and technological principles of the Muslim civilization in a hands-on and minds-on fashion that is accessible to younger audiences. Also, it is aimed to highlight the technology history of Al-Jazari's system used in lifting water to show its place and importance in today's technology and the internal combustion engine and piston structure we use today.

This paper is organized as follows. Al-Jazari and Technology are described in section 2. The subject of cybernetics is discussed in section 3. Section 4 include the inventions of Al-Jazari. Finally, the paper conclusion is given in section 5.

2. AL-JAZARI AND TECHNOLOGY

This section will highlight the success of Al-Jazari, who designed devices for humanity about 800 years ago, but unfortunately has not been revealed until recently, showing the importance of automatic mechanical devices powered by water pressure and wind energy. In his technology, cybernetics may be considered as the core of the automation of robotic and mechanical devices. He expressed his ideas and opinions on objective grounds, with drawings that anyone can convince. The hand-drawn mechanical devices in his book and the comparisons with today's robots will give at first glance the machines that are powered by water power. These drawings gave rise to servo-mechanical thoughts and, as a result, cybernetics, which has emerged as a science in recent years. In the 19th Century, his thoughts and drawings gave intuitional feelings towards mechanization. Al-Jazari's inventions were the prototypes for many of the technological tools that we use daily. For instance, four-stroke engines, gears system, crankshafts, pneumatic and hydraulic systems, automats and control systems; these are all the technological innovations that we are used in our daily technology had been invented by him [16]. Al-Jazari has implemented all the experience and experimental works in his original designs of mechanical devices although calculations were not available at that time. These innovations was the most important work of engineering written before the Renaissance centuries later [12]. The best of the technological developments were gathered in his book named as “Kitab fi ma'rifat al-hiyal al-handasiya” which was translated by Hill [5] as “The Book of Knowledge of Ingenious Mechanical Devices” where here he described 100 types of mechanical devices and instructions on how to do them. These and many other inventions are described in scrupulous detail in his Book. The robots or automation was developed by Al-Jazari 250 years before Leonardo da Vinci, with some excellent examples. Hill emphasized that this work contributed significantly to the advancement of civilization and that mechanical technology was studied in all areas. The work of Al-Jazari has an invaluable place in the history of human technological developments. It is an exception because its book contains not only detailed drawings but also a description of the working mechanisms of the devices [4,13,14,17]. The most remarkable and sophisticated of all invented machines in terms of historical sources of today's technologies are briefly explained below.

Crankshaft and crank-slider mechanism

The crankshaft was first invented by Al-Jazari who employed it in water-rising machine which he incorporated with a crank-connecting rod the mechanism in twin-cylinder pump. The crankshaft, defined by Al-Jazari, converts the rotary motion into linear reciprocating motion and forms the basic mechanism of modern machines such as the steam engines, internal combustion engines, and automatic controls. He used the crankshaft with a connecting rod and crank-driven double-acting piston push and suction pump with a crank slider mechanism in water elevation machines. In Al-Jazari's work, some important concepts were seen in both design and manufacturing [5]. Innovations such as the use of wood stencils, models for creating paper use designs, casting of metals in the closed mold with sandpaper powder to achieve water tightness [18].

Segmental gear

A segmental gear is a piece for receiving or communicating reciprocating motion from or to a cogwheel, consisting of a sector of a circular gear. The segment gear is an interesting part is has encountered in Al-Jazari's water-raising machines. It was not so sophisticated in the use of gears that appeared in Europe before the mid-fourteenth century [18,19].

Saqiya chain pumps

Pumps are ingenious and most important ideas, which are components in water-raising machines introduced by Al-Jazari in 1206. His water-raising mechanism was connecting the main gear to a suction able to dual motion. He also had achieved the double-action suction pump with valves and reciprocating piston in his invention. He had used this system hydraulic power to pump water to another drain system. He used the flowing water river to move a turbine with the help of a water absorption system and several gears [18,20]. The first known use of the crankshaft was in the chain pump, one of Al-Jazari's Sativa machines. The implementation of this system is aimed to minimize intermittent operation to maximize the efficiency of the Saqiya chain pump. This system used as a saqiya chain pump for hydropower driven water elevation [18,19].

Automata

Automata are strong and consistent structures that are caused by the urge to represent the mechanism by mechanical means. Automata are another activity of Al-Jazari that is used for various devices such as hydropower driven and automatically moving peacocks, humanoid robots, automatic doors, water clocks. Al-Jazari is credited with creating the earliest forms of a humanoid robot. Al-Jazari's automaton was originally a boat with four automatic musicians that floated on a lake to entertain guests [20]. Automata, which is mechanically powered by water power, is considered to be the ancestor of Europe's detailed water clocks. It is noteworthy that this mechanical technology is a product of not only the construction of instruments but also water-raising culture. Fountains and musical automata where water flow varies from one large tank to another at hourly or half-hour intervals are other vending machines defined by Al-Jazari. In addition, Al-Jazari made various water clocks and candle clocks. The elephant water clock was an important medieval invention invented by him. He invented the monumental water-powered astronomical clocks displaying moving models of the Sun, Moon, and stars [14,18].

3. CYBERNETICS

Cybernetics was first used as a term by Norbert Wiener in 1948 as a common view of general science of control and communication in animals and machinery [21]. Communication refers to information transfer and control tools to produce desired changes using information [22]. Cybernetics is the science that studies systems that act like living things [23]. Depending on how the model and control actions are used, it is aimed to direct the systems to the most appropriate target. Cybernetics can be used to understand, model and design any system. Researchers are interested in the science of cybernetics turned to developing machines to study the functional mechanisms of living systems and to make them autonomous or act as living systems [24]. Over the years, cybernetics has found application

in many fields and has made natural progress through the application of various modern sciences to real-world problems, the development of theories and methods [22, 25].

Cybernetics is an interdisciplinary science. Control theory, communication theory, operations research, Mathematics, logic, semiotics, physiology, and others are the fields of cybernetics. Interdisciplinary communication enables the rapid realization of new results in order to combine efforts in different disciplines and focus on uniform solution of similar problems [26]. In 1948, a new synthetic science emerged with the integration of results from different sciences, also known as Wiener cybernetics (see Fig. 1) [21].

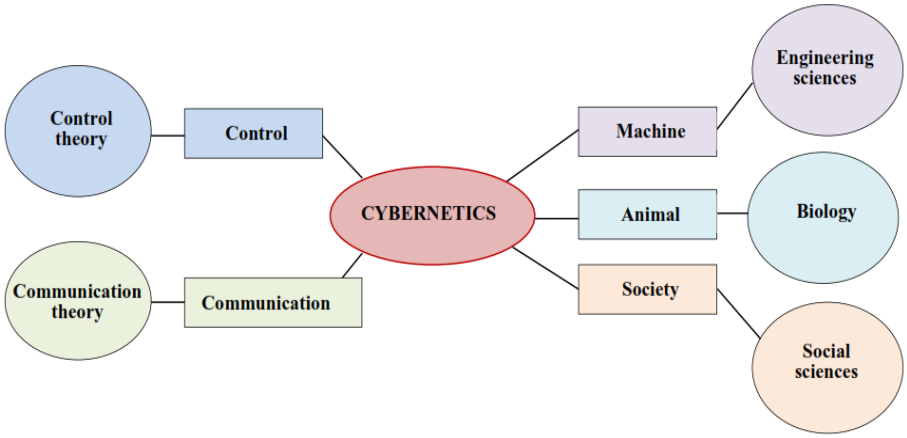

Figure 1. The phylogenesis of Wiener's cybernetics ([21])

Cybernetics attracts the attention of hundreds of private research centers, and scientific journals through worldwide at the present time. The technology of electronics, automated machines, telecommunication, and the science of robotics are all products of Cybernetics.

When talking about cybernetics and robotics in Anatolia, Al-Jazari should come to mind. Although the science world has heard of cybernetics from the Wiener, Al-Jazari has had a profound impact on this science going back to 800 years ago. Research in the field of control theory that emerged in the 1206s led to the emergence of other meta-sciences, namely cybernetics and system analysis. Automatic machines made by Jazari, the first scientist to study cybernetics and robotics in terms of the world history of science, formed the cornerstones of today's mechanical and cybernetics sciences. Al-Jazari has created milestones of today's technology by using science and technology in an extraordinary way according to the conditions of the time, and the importance of the balance or adjustment system in the machines that it has made has inspired today's automatic control science. Cybernetics or different cybernetics types are shown chronologically in the table below. The rest of this table can be viewed in [23] this source. The concept of "hydropower cybernetic" is mentioned here for the first time. The main reason for using this concept is that I understand from my literature research that Al-Jazari has realized the cybernetics philosophy with "hydroelectricity" and does not use it as a concept.

Table 1. Different types of cybernetics

Type	Authors	Period
Hydropower Cybernetics	Al-Jazari	the 1136-1206's
Cybernetics	N. Wiener W. Ashby S. Beer	the 1948-1950's
Second-order cybernetics	M. Mead G. Bateson H. Foerster	the 1960-1970's
Autopoiesis	H. Maturana F. Varela	the 1970's
Homeostatics	Yu. Gorsky	the 1980's
Conceptual cybernetics of third and fourth orders	V. Kenny R. Mancilla S. Umpleby	the 1990-2010's
Neo-cybernetics	B. Sokolov R. Yusupov	the 2000's

Cybernetics has always received a wide variety of evaluations by experts. Şen [2, 12] states that Al-Jazari is an indisputable pioneer and scientist in the initiation of today's cybernetic and robotic studies, and has no rival in any culture. Akman [27] drew attention to the different balance principles used by Al-Jazari on a wide variety of machines. The machines working on the principle of balance and power are used with hydro-mechanical effects and stated that an automatic system is used between the buoy and the hoists.

When the machines made by Al-Jazari are examined, the transmission of the work done with water power, the devices with the hydro-mechanical system it creates, and the feedback that it provides with the interaction between the pulleys and the gear wheels, constitutes the scope of the definition of cybernetics. Not only was it possible to install automatic systems, but Al-Jazari realized the automatic balance of these systems not with electric power, magnet power or electromagnetic power, but with water power and pressure power [28, 29].

It is understood that the devices made by Al-Jazari operate with hydraulic and mechanical cybernetic systems, and in some, they use interactive structures using gear wheels between the buoys and pulleys. He has made an important contribution to automation by developing automatic balance systems with water and pressure power [30]. Al-Jazari was able to use the conditions of his life in the best way and introduced himself in the modern era with the cybernetic system he made in his field. Although electricity and electromagnetic power are not available and have limited possibilities, Jazari has made devices that work with magnificent hydro-mechanical systems, taking advantage of water power and pressure [31].

Jazari expressed his philosophy as follows. "Techniques that cannot be translated into practice will fall between right and wrong". It is understood from this philosophy and the book he wrote that it is possible to say that all the vending machines he invented were created with the principles of balance.

This situation can be confirmed from the sources mentioned above. Consequently, considering all these evaluations, it is possible to say that Jazari is one of the pioneers of cybernetics.

4. INVENTIONS OF AL-JAZARI

Al-Jazari technology had three different goals: creativity, aesthetics, and vending machines that offer practical solutions for people's daily use. Al-Jazari has described the best mechanical devices he has invented and designed throughout his life in his book. The book contains many mechanical devices and descriptions on how to make them. The descriptions of the construction were very convincing. Even today, it is possible to redesign the original inventions of Al-Jazari inspired by personal information, comments or writings. The automation history that Al-Jazari invented the first robotics, water clocks and other mechanical devices dates back to 1206. The machines described in the book are classified into six categories; the first three categories consist of ten chapters and the last three categories consist of 5 chapters [5, 18].

1. Water and candle clocks (10 chapter)
2. Vessels and figures suited for drinking sessions (10 chapters)
3. Pitchers and basins for phlebotomy and washing before prayers (10 chapters)
4. Fountains perpetual flutes (10 chapters)
5. Five water raising machines (5 chapters)
6. Five miscellaneous devices (5 chapters)

Details about these machines and their drawings is given in [2, 4, 10, 11, 18, 32].

Al-Jazari's most interesting machine is a water lifting machine that uses Piston, cylinder, valve and wind energy with the importance it gives to today's technology. This system takes advantage of wind energy, which has an important role in the development of the machine's steam engine and pumping machines, and is converted into mechanical energy through panels radially placed around an axle. More information about the working principle of this machine is given below.

4.1 Water-Raising Machines

When people were supplying water from wells and rivers as the water source, Al-Jazari invented mechanical devices that helped create a water supply system. Al-Jazari invented five machines and introduced his most important ideas and components in these water elevation machines in 1206. Al-Jazari successfully operated the invented devices with great precision and accuracy. This system, which forms a few foundations of mechanical engineering today, consists of four main devices. This vehicle had a high economic value as well as an advanced technological value under the conditions of that day.

Many believe that the two-stroke piston, the ancestor of the two-stroke engine, was the invention of the 20th century. If gas was used instead of water or air power, this vehicle, which has today's engine working principle, was originally developed by Al-Jazari in the 12th century. This two-cylinder vehicle with two-stroke pistons moving left and right is actually a two-stroke suction pump. It is an oscillating and grooved rod connected by two-piston rods operated by a water wheel operated through the pump-gears system. Pistons operating in cylinders are horizontally opposite each other is a single outlet

system, each of which has suction and discharge pipes operating with a valve. The water pump facility of Al-Jazari is shown in Figure 2. It takes action by using the natural flow heat of a water and pumps the water upwards.

Figure 2. Wind- or water-powered flume-beam sweep

The water wheel in the stream creates a uniform rotational movement that continues on a shaft with the force applied by the water to the tracks. A gearwheel connected to the shaft transfers this movement to another gearwheel with an axle shaft connection. A crankshaft, which is movably connected with the axle shaft, mechanically converts the rotary movement into the thrust movement. Important points that stand out in this design, which is the first source of mechanical energy that replaces human or animal power; energy was obtained from the water wheel, the circular motion was converted to linear motion and the efficiency was doubled by using two reciprocating pistons.

Al-Jazari invented suction pipes, suction pump, double-acting pump and double-cylinder piston suction pump and used these mechanisms and crankshaft connecting rod. This pump is driven by a water wheel by means of a gear system by driving an oscillating slit rod to which the rods of the two pistons are connected. The pistons are equipped with horizontal opposite cylinders, suction and discharge pipes, each of which operates with a valve. Distribution pipes are connected to the center of the machine to create a single outlet to the irrigation system.

This water-raising machine, which has a direct importance for the development of modern engineering, is remarkable for the following reasons: It has an important place in modern engineering due to its characteristics such as the first known use of a real suction pipe, the conversion of rotation to the reciprocating motion through the crank-connecting rod mechanism, the first application of the double-acting principle.

With this invention, Al-Jazari succeeded to invent;

- A gear that drives water to operate other devices.
- Using a unique gear combination, he was able to change the direction of movement from vertical to horizontal.

- By connecting the main gear to a suction pump, it was able to create a piston-like bidirectional movement. These are shown in the Figure 3.

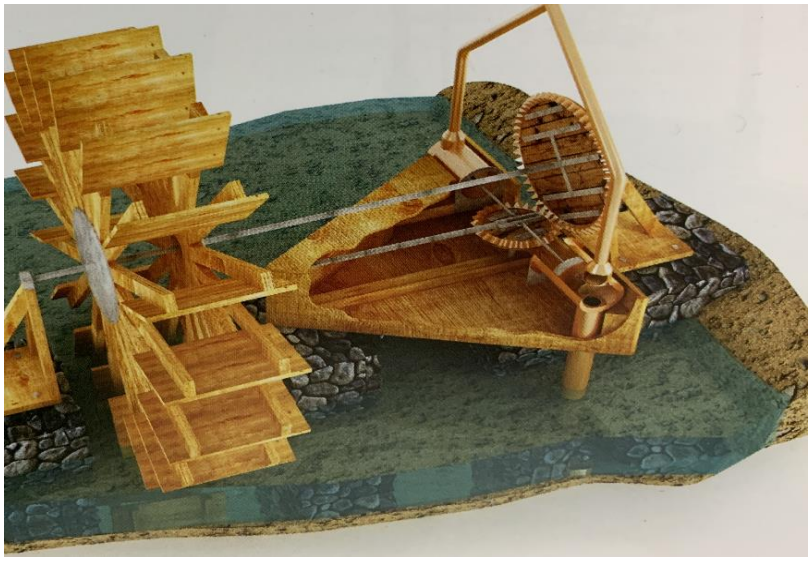

Figure 3. water-raising machine (include Piston, cylinder, valve) ([6])

The double-action suction pump with valves and reciprocating piston is implemented in this invention. This pump was used to pump water into another drain system using hydraulic power. He used the flowing water river with the help of several gears to move a turbine. He used cylinders and a caps to create the hydraulic effect. The visualized form of this piston mechanism is shown below.

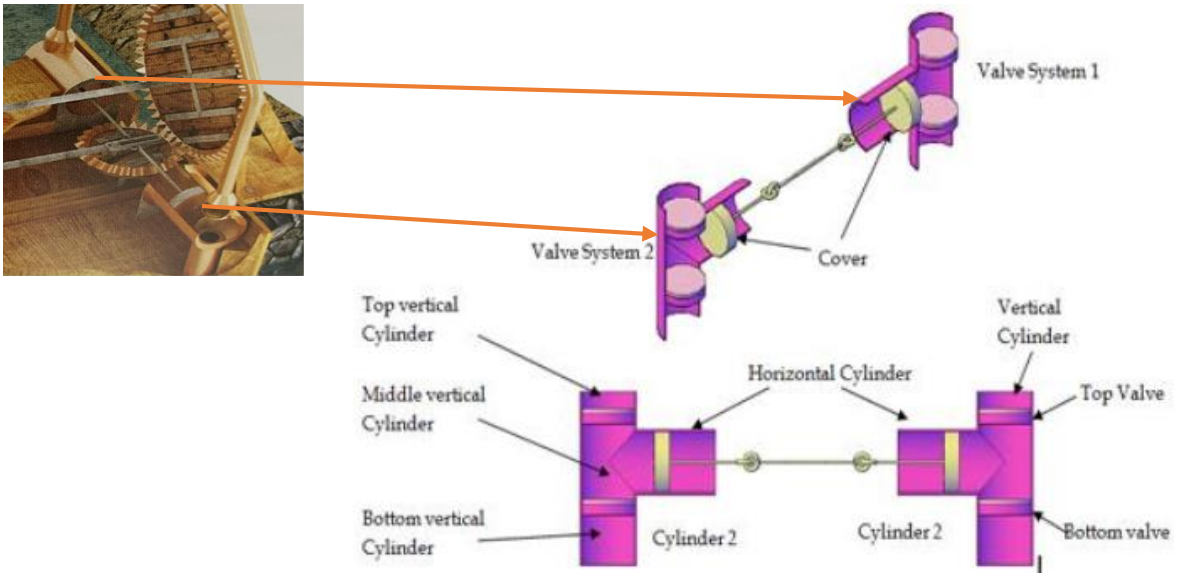

Figure 4. An illustration of hydraulic and gear system [20]

The material used is a copper suction pump that is resistant to corrosion and does not pollute the water. Gears were made of mulberry wood. Al-Jazari's creativity in using and manipulating water and air pressure power can be seen from this system. He automatically performed the flow of water from the pump source to a pipeline. This system is fully automated without the need to use manpower. The working principle of the system is briefly as follows.

The shaft of the wheel installed in the water rotates a gear wheel in the vertical position. It rotates a gear wheel in a horizontal position. The vertical shaft in the axis of this wheel is bedded from two places at the bottom of the wheel. When the horizontal impeller rotates, the pin on it makes a circular motion. This movement, as seen in figure 4, moves back and forth to the end of the special slit rod. The arms connected to both sides of this slotted end act on the pistons of the fixed cylinders. Each of the pistons is pushed to the bottom of its cylinder while the other is pulled to the mouth. In this arrangement, the cylinders act as suction and compression pump. Thus, while each piston moves towards the mouth of the cylinder, it creates an airless gap at the bottom of the cylinder. The flap of the suction pipe at the bottom opens and the flap of the discharge pipe at the top closes. The piston moves back after the water is filled from the suction pipe to the cylinder. The lower flap is closed and the upper flap opens so that the water is pressed up. In this vehicle two cylinders are operated mutually. This system is the first form of today's double-acting pumps. The mechanism that moves the piston rods is the first form of the lever-connecting rod mechanism used in today's engines. This extraordinary machine is regarded as an ancestor of today's double-acting coveralls, crankshaft and steam machines, in terms of working principle.

5. CONCLUSIONS

Al-Jazari, who lived in the 12th century, is the father of robotics and cybernetics, which works hydraulically with water power. He has made a significant contribution to modern technology, has made many inventions that work with water and air pressure power. This is the first person to produce and use mechanical gears and hydraulics, Al-Jazari lived before Leonardo da Vinci. It deserved to be one of the pioneers of cybernetics with the feedback control balance system used in the mechanisms it established. The transfer of technological developments among civilizations can be permanent if they are in the form of written documents. Al-Jazari made drawings of his designs in his handwritten book, translated (to English) by Donald Hill in its original form. Al-Jazari's book is an important resource in the history of automata, mechanics, mechatronics, automatic control, robotics and cybernetics.

The purpose and functioning of the machine given in his book are important for our technology. He describes, step by step, the manufacture of its component parts, setting out, assembly and fitting, joints and connections, and testing. He was a master craftsman, fully conversant with all branches of his trade. If we list what Al-Jazari has brought to science;

- He has developed automatic machines, robots, and hydro-mechanical systems by making mechanical tools powered by water power.
- He has developed the cybernetics science by using the automatic-control-balance system together.
- By making use of the water pressure, the lifting force of the fluid, the flow rate of the water, and the shifting of the center of gravity, automatic moving machines have been developed.
- The crankshaft and piston mechanism used in today's motor vehicles were used by Al-Jazari.

- Using a unique gear combination, he was able to change the direction of movement from vertical to horizontal.
- Al-Jazari invented suction pipes, suction pump, double-acting pump and double-cylinder piston suction pump and used these mechanisms and crankshaft connecting rod.
- Carburetor float circuits used in pressure valves, composite containers, hydraulic pumps and gasoline engines used in today's industrial hydraulics are designed based on the drawings of Jazari.

In the 12th century, humanoid, entertainment and cooperative multiple robots made by Al-Jazari became an inspiration for today's robots. In today's technology, robots that can imitate human abilities with artificial intelligence are being developed and the history and importance of cybernetics science is better understood. It is important to interpret the works of Al-Jazari today and to emphasize the methods of Jazari as physical programming in robotic programming.

The main aim of this article is to report the importance of Al-Jazari in our technology history and to emphasize the importance of the machines invented in today's technology. At the same time, it is aimed to show why the genius engineer who lived in Anatolian lands was one of the pioneers of robotics and cybernetics. Our belief in our civilization and cultural values increases with the works of Al-Jazarî. The devices of this scientist, who reached us through inheritance, are important in that they show where the origins of civilizations are based.

REFERENCES

[1] G. Sarton, *Introduction to the History of Science*. Robert E. Krieger Publishing Company,Malabar, FL, USA, 1950.

[2] Z. Şen, "Ancient water robotics and Abou-l Iz Al-Jazari," *Water Sci. Technol. Water Supply*, vol. 13, no. 3, pp. 699–709, 2013, doi: 10.2166/ws.2013.031.

[3] S. Al-Hassani, "Al-Jazari: The Mechanical Genius," *MuslimHeritage. com*, 2001.

[4] S. Al-Hassani, "The Machines of Al-Jazari and Taqi Al-Din | Muslim Heritage," *Muslim Heritage*, 2006. .

[5] I. al-R. al-Jazarī, *The Book of Knowledge of Ingenious Mechanical Devices*. 1973.

[6] D. Çalışkan, *Cezeri'nin Olağanüstü Makineleri*. babil kitap, 2019.

[7] R. V Jones, "The Book of Knowledge of Ingenious Mechanical Devices," *Phys. Bull.*, vol. 25, no. 10, pp. 474–474, Oct. 1974, doi: 10.1088/0031-9112/25/10/040.

[8] Cultural Ministry of Turkey, *Olaganüstü Mekanik Araçların Bilgisi Hakkında Kitap (The Book of Knowledge of Ingenious Mechanical Devices)*. 1990.

[9] A. A. Bin, M. Yazid, M. Fahmi, and A. Ruskam, "The Mechanical Engineer: Abu'l-'Izz Badi'u'z-Zaman Ismail ibnu'r-Razzaz al Jazari."

[10] M. Dirik, "Bilgisayar/Sibernetik/Özdevinimli Makinalar Sahasindaki lcatlanyla Cizreli Ebu'I-Iz -," in *Cizre Sempozyumu*, 2012.

[11] B. Çirak and A. Yörük, "MEKATRONİK BİLİMİNİN ÖNCÜSÜ İSMAİL EL-CEZERİ VANGUARD OF MECHATRONIC SCIENCE ISMAIL AL-JAZARI," *Siirt Üniversitesi Sos. Bilim. Enstitüsü Derg.*, vol. 4, pp. 175–194, 2015.

[12] Z. Şen, "How to Improve the Science and Engineering Education in Islamic Countries ?," vol. 1, no. 3, pp. 121–131, 2018, doi: 10.26701/uad.484662.

[13] G. Sarton, *Introduction to the History of Science*. Robert E. Krieger Publishing Company, Huntington, New York, 1975.

[14] E. Wiedeman, *Über die Uhren im Bereich der islamischen Kultur (German Edition):* saxoniabuch, 2017.

[15] M. Yavuz, M. Hasançebi, and F. Hasançebi, "The effect of STEM application on 21st-century skills of middle school students and student experiences," *J. Soft Comput. Artif. Intell.*, vol. 1, no. 1, pp. 29–41, 2020.

[16] "Medieval robots: How al-Jazari's mechanical marvels have been resurrected in Istanbul | Middle East Eye." https://www.middleeasteye.net/discover/medieval-robots-turkey-how-science-genius-al-jazari-brought-mechanical-marvels-istanbul (accessed Jun. 01, 2020).

[17] H. Invented, "AL-JAZARI," pp. 1–14, 2020.

[18] D. Hill, *A History of Engineering in Classical and Medieval Times*. Routledge, 1996.

[19] L. White, "Technology and Invention in the Middle Ages," *Speculum*, vol. 15, no. 2, pp. 141–159, 1940, doi: 10.2307/2849046.

[20] A. R. Amirul Akmal Bin Mohammad Yazid, Mohd Fahmi Bin Md Salleh, "The Mechanical Engineer: Abu'l –'Izz Badi'u'z – Zaman Ismail ibnu'r – Razzaz al Jazari," *Semin. Relig. Sci. Muslim Contrib.*, vol. 69, no. 4, pp. 59–61, 2014, doi: 10.1246/nikkashi1948.69.59.

[21] N. Wiener, *Cybernetics; or, Control and communication in the animal and the machine.* M.I.T. Press, 1948.

[22] N. Wiener, "Cybernetics, Second Edition: or the Control and Communication in the Animal and the Machine." p. 212, 1965.

[23] D. A. Novikov, *CYBERNETICS: From Past to Future*. Heidelberg: Springer, 2016. – 107 p., 2015.

[24] C. S. Carver and M. F. Scheier, "Cybernetic Control Processes and the Self-Regulation of Behavior," in *The Oxford Handbook of Human Motivation*, 2012.

[25] N. H. Siddique, R. Mitchell, M. O'Grady, and H. Jahankhani, "Cybernetic Approaches to Robotics," *Paladyn, J. Behav. Robot.*, vol. 2, no. 3, pp. 109–110, 2012, doi: 10.2478/s13230-012-0006-3.

[26] H. G. Johnson and N. Wiener, "Cybernetics: Control and Communication in the Animal and the Machine.," *Econ. J.*, 1949, doi: 10.2307/2226579.

[27] T. Akman, "Sekiz Yüzyıl Önce Otomatik Makine Yapan Türk Bilgini Ebül -İz," *Bilim ve Tek.*, vol. 7, no. 77, pp. 1–6, 1974.

[28] Metin Eriş & Ahmet Ağırakça, Ed., *The Bright Age Show as Dark*. Zero Books, 2016.

[29] M. Dirik, "The Place of Abu al - Iz in Cybernetics," *Mardin Artuklu Üniversitesi Yayınları*, p. 245, 2016.

[30] M. K. Atilla bir, "Pioneers of Automatic Control Systems," 2006. https://muslimheritage.com/pioneers-of-automatic-control-systems/ (accessed May 31, 2020).

[31] G. A. Hassaan, "Innovation of mechanical machinery in medieval centuries part IV : Mechanisms , gear trains and cranes," *Int. J. Adv. Res. Comput. Sci. Technol.*, 2014.

[32] K. V Raju, S. Manasi, A. Roots, and S. Development, *Water and Scriptures*. 2017.