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Integration of Artificial Intelligence into Space Design

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Abstract

Increasing air pollution day by day causes deterioration of air quality. This situation leads to continuous changes in emissions and pollutant concentrations released into the atmosphere. These changes accelerate with the increase in industrialisation, urbanisation and fossil fuel consumption. Therefore, regular monitoring of these emissions is of great importance. However, although traditional air quality measurement stations provide a wide range of data, these cannot perform detailed analyses at the local scale. The aim of this study is to examine how a solution to this problem can be produced using artificial intelligence. In this direction, a Arduino based artificial intelligence supported equipment and software has been analysed. The developed device can measure air quality parameters such as $PM_{2.5}$, PM_{10}, CO, CO_2, CH_4, humidity and temperature in a time-dependent manner. Thanks to the artificial intelligence supported software, the effect of any design on micro air quality can be easily analysed. In the findings section of the study, the design of the device, the data collection process and the results obtained for emission estimation will be discussed in detail. In this study, the integration of Arduino device designs into spatial design and the discipline of landscape architecture has been evaluated. At the end of the study, it will be discussed how the developed artificial intelligence supported system can be integrated into landscape architecture designs.

Keywords: Artificial intelligence, arduino software, robotic design, design

Yapay Zekanın Mekân Tasarımına Entegrasyonu

Öz

Her geçen gün artan hava kirliliği, hava kalitesinin bozulmasına neden olmaktadır. Bu durum, atmosfere salınan emisyonların ve kirletici konsantrasyonlarının sürekli değişmesine yol açmaktadır. Sanayileşme, kentleşme ve fosil yakıt tüketiminin artmasıyla birlikte bu değişimler daha da hızlanmaktadır. Bu nedenle, bu emisyonların düzenli olarak izlenmesi büyük önem taşımaktadır. Ancak geleneksel hava kalitesi ölçüm istasyonları, geniş çapta veri sağlasa da mikro ölçekte yeterince detaylı analiz yapamamaktadır. Bu çalışmanın amacı, yapay zekâ kullanılarak bu soruna nasıl bir çözüm üretilebileceğini incelemektir. Bu doğrultuda, geliştirilen Arduino tabanlı yapay zekâ destekli bir ekipman ve yazılım incelenmiştir. Geliştirilen cihaz, $PM_{2.5}$, PM_{10}, CO, CO_2, CH_4 nem ve sıcaklık gibi hava kalitesi parametrelerini zamana bağlı olarak ölçebilmektedir. Yapay zekâ destekli yazılım sayesinde, herhangi bir tasarımın mikro hava kalitesine etkisi kolaylıkla analiz edilebilmektedir. Yapılan bu çalışma kapsamında ise Ardunio cihaz tasarımlarının mekân tasarımına, peyzaj mimarlığı meslek disiplinine nasıl entegre olabileceği değerlendirilmiştir. Çalışmanın sonuç bölümünde, cihazın tasarımı, veri toplama süreci ve emisyon tahminine yönelik elde edilen sonuçlar detaylı olarak ele alınacaktır. Çalışmanın sonunda ise geliştirilen yapay zekâ destekli sistemin peyzaj mimarlığı tasarımlarına nasıl entegre edilebileceği tartışılacaktır

Keywords: Yapay zeka, arduino yazılımı, robotik tasarım, tasarım

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1.Introduction

Technology is always developing something for people that can facilitate their work and activities. Therefore, technology facilitates everything that is done. This developing technology encourages the development of many various technologies to facilitate human activities (Siregar et al., 2022).

Among the most critical concerns of the changing world order and rapidly growing world economy are climate change, carbon emissions, the rate of fossil fuel consumption and air pollution (Xu et al., 2022). Air quality measurement is of great importance for environmental health and human health. Today, these measurements are taken by large measuring stations in cities, infrared measuring devices, or various similar measuring devices. This measurement varies according to the purposes and emissions to be measured. It is a very costly process to make these systems at large scales. It is now important to make these measurements at micro scales as well as making measurements at large scales. These measurements also play an important role in taking measures to combat climate change.

The atmosphere is polluted and threatens the future due to the non-stop emission production of mankind for its own welfare. These emerging threats lead to a reduction in life expectancy (Remy et al., 2011; Lelieveld et al., 2015; Tomson et al., 2021), increased respiratory and heart disease (Xing et al., 2016; Yang et al., 2020; Guercio et al., 2022; Gladson et al., 2022; Zhu et al., 2023) ve cancer (Nielsen et al., 2017; Tomson et al., 2021; Xue et al., 2022) has caused an increasing number of people to be exposed to various diseases day by day (Kalivitis et al., 2022).

Air pollution arises from the joint influence of significant emissions and unfavorable weather conditions. Those responsible for air quality strive to safeguard public health by implementing emission controls. Enhancements in air quality can be influenced by alterations in meteorological patterns, which is synonymous with changes in climate. As we move into a period marked by swiftly shifting climatic conditions, it becomes imperative to effectively oversee air quality and gain deeper insights into how climate change affects air quality, given its profound societal implications (Jacob and Winner 2009).

Air pollution forecasting provides information on pollution levels to enable policy makers to take the necessary measures to reduce the effects of pollution. For example, traffic restrictions can be introduced to avoid periods of high pollution. The Air Quality Index (AQI) serves as a common indicator of air pollution severity. It is constructed as a segmented linear function based on specific pollutant concentrations (Méndez et al., 2023). A higher AQI value signifies highly polluted air, which poses significant health risks. The AQI enables continuous monitoring of current air quality conditions (Gupta et al., 2023).

Consequently, there has been a growing focus on research into predicting air quality across fields such as environmental science, statistics, and computer science. Presently, reducing carbon emissions, enhancing air quality, and addressing climate change are among the foremost challenges to economic and societal progress. Reliable forecasts of air quality are indispensable components of meteorological services and play a crucial role in ongoing air quality management, as well as in assessing pollutant emissions and

variations in air quality. Enhancing the precision of air quality predictions can expedite progress towards achieving goals of cleaner air and carbon neutrality. Thus, fully leveraging the supportive capabilities of machine learning models in the task of air quality forecasting is imperative (Zhang et al., 2024). A comprehensive examination of these studies yields the following insights:

- Demonstration of the relationship between artificial intelligence and design on an applied prototype,
- How a device created with artificial intelligence can help in design professional disciplines.

In this study, Estrada (2018) combined AI applications with design and landscape architecture. Through data processing, an integrated technical-natural system, and a real-time response system beyond human capacity, his work contributed to the discipline of landscape architecture. AI and design have increasingly converged in various fields today (He, 2025). Lu-Yao and Yi-Ping (2023) integrated AI with design to propose a landscape design model aimed at enhancing the artistic quality of rural landscapes and supporting rural development. Similarly, Shi (2024) argued that AI applications would significantly contribute to design. Their study emphasized that AI-based approaches are more precise compared to traditional software for tasks such as measurement, mapping, and digitization.

These studies demonstrate that the integration of AI into design processes has moved beyond theoretical discussion and is now supported by practical applications. AI's role in design spans a wide spectrum, from data analysis and decision support systems to simulations and automated design proposals. Today, AI algorithms accelerate design processes, reduce error rates, and offer more innovative solutions, indicating that this technology will become even more widespread in the future. Particularly in fields such as landscape architecture, urban planning, and industrial design, AI-supported models enhance efficiency, sustainability, and intelligence in design processes.

In the global order, many solution proposals, devices and measuring stations are being developed, especially for problems such as climate change and air pollution. The cost of these devices varies according to the production time content. However, in general, the production cost is quite high. In this case, artificial intelligence applications that add strength to its power day by day come into play. The follow-up of this change has become as important as its importance. Increasing air pollution due to anthropogenic effects affects the whole world. Each country that makes these measurements has mobile or fixed measurement stations. Although general measurement stations are very important, there is also a need for micro-scale emission measurements. Because it is very difficult to determine what causes emissions in the micro area using general station data. However, the production of micro-scale devices is quite costly. Thanks to these measurements and data, these studies can be integrated into future landscape designs since micro-scale measurements can be made. In the findings of the study, the creation of the device and estimation of emission data will be explained in detail.

1.1. Artificial Intelligence (AI) in Design

Among the professions most affected by the changes in the world, "those related to design" occupy an important place. Artificial Intelligence (AI) in Design refers to the use of AI in design processes and provides great

innovations and productivity increases in various industries. In the architecture industry, which is considered as a highly skilled and complex sector today, AI has great potential to increase the knowledge and skills of architects, to review designs faster and to expand their design capacities (Rafsanjani and Nabizadeh 2023). Today, when a machine displays human-like abilities such as analyzing, finding solutions and acquiring knowledge, we call it AI. However, these abilities are used in different ways than we learn (Ameen et al., 2022). Almost the entire global population (99 per cent) is exposed to pollution levels that exceed WHO (World Health Organization) limits, with middle- and low-income countries being most affected (WHO, 2021). Undoubtedly, air quality significantly affects the well-being and daily lives of individuals. The continuous advancement of social sciences and technology, coupled with the relentless progress of commercialisation, inevitably leads to fluctuations in air quality (Zhang et al., 2024). AI is increasingly being integrated into the design process, revolutionising the way designers work and the designs they create. AI has the potential to enhance the creativity and intuition of human designers, streamline the design process and improve the overall quality of designs. Today, AI plays a crucial role in automation and seamlessly bridges the physical and digital realms across diverse scientific, technological, and engineering disciplines. The global AI market was valued at US$93.53 billion in 2020 and will reach US$997.77 billion in 2028 (Howarth, 2021).

In recent times, AI has significantly aided various industries and creative domains. AI has started to take over certain professions, with robots now handling tasks such as grocery delivery and factory assembly lines, while AI assistants manage scheduling and customer service inquiries. Interestingly, there has been a growing appreciation for visual artworks generated by AI, as well as for essays and poems "authored" by AI, which mimic or assemble human compositions (Miller, 2019; Minerva and Giubilin 2023).

AI has become an important transformation tool in architecture and landscape architecture. The relationship between AI and the professional discipline of architecture can be summarised as follows.

- Parametric design,
- Acquisition and optimisation of architectural measurement data,
- Data analysis and management,
- Estimation of data,
- Visualisation with artificial intelligence-supported design tools,
- Provision of site analysis and planning data,
- Provision and estimation of ecological, environmental, sustainable data,
- 3d modelling and simulation and
- Robotic applications are only some of them.

In the combination of all these, innovative solutions emerge. The time management of the designer and the reduction of the application time are among the important effects of this union. AI, robotic applications and design are combined within the scope of this study (Figure 1).

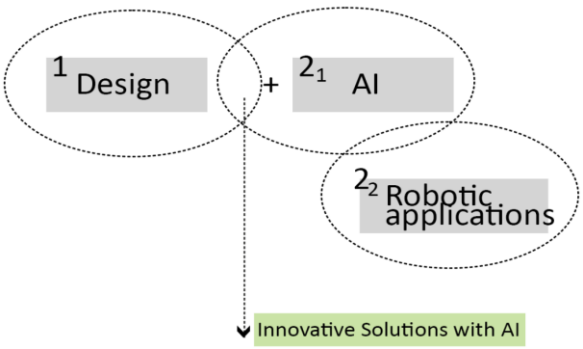

Figure 1. Relationship between design and AI (Designed by the author)

2. Material and Method

2.1. Ardunio Software and Artificial Intelligence (AI)

The Arduino Uno is a microcontroller board based on the ATmega328P. It attributes 14 digital input/output pins (including 6 PWM outputs), 6 analog inputs, and operates with a 16 MHz ceramic resonator (CSTCE16M0V53-R0). Equipped with a USB port, power input, ICSP header, and reset button, it includes all necessary components to asist the microcontroller. Powering options include connection to a computer using USB or using an AC-DC adapter or battery. The name "Uno," meaning "one" in Italian, symbolizes the initial release of version 1.0 of the Arduino Software (IDE). This board and the 1.0 IDE marked the standard versions of Arduino; newer iterations are now available. As the inaugural USB Arduino board, the Uno serves as the foundational model for the Arduino platform (Arduino Uno Rev3, 2024) (Figure 2). Its robust processor capability and versatile connectivity options make it proper for a wide range of projects. Arduino's open-source framework facilitates user development of custom hardware and software, fostering innovation in projects (Figure 2).

The Arduino Uno can be described as an open-source platform for physical computing. It is more than just a development tool; Arduino encompasses hardware, a programming language, and a comprehensive integrated development environment (IDE) (Mahalakshmi and Vigneshwaran, 2017; Hasibuan et al., 2021).

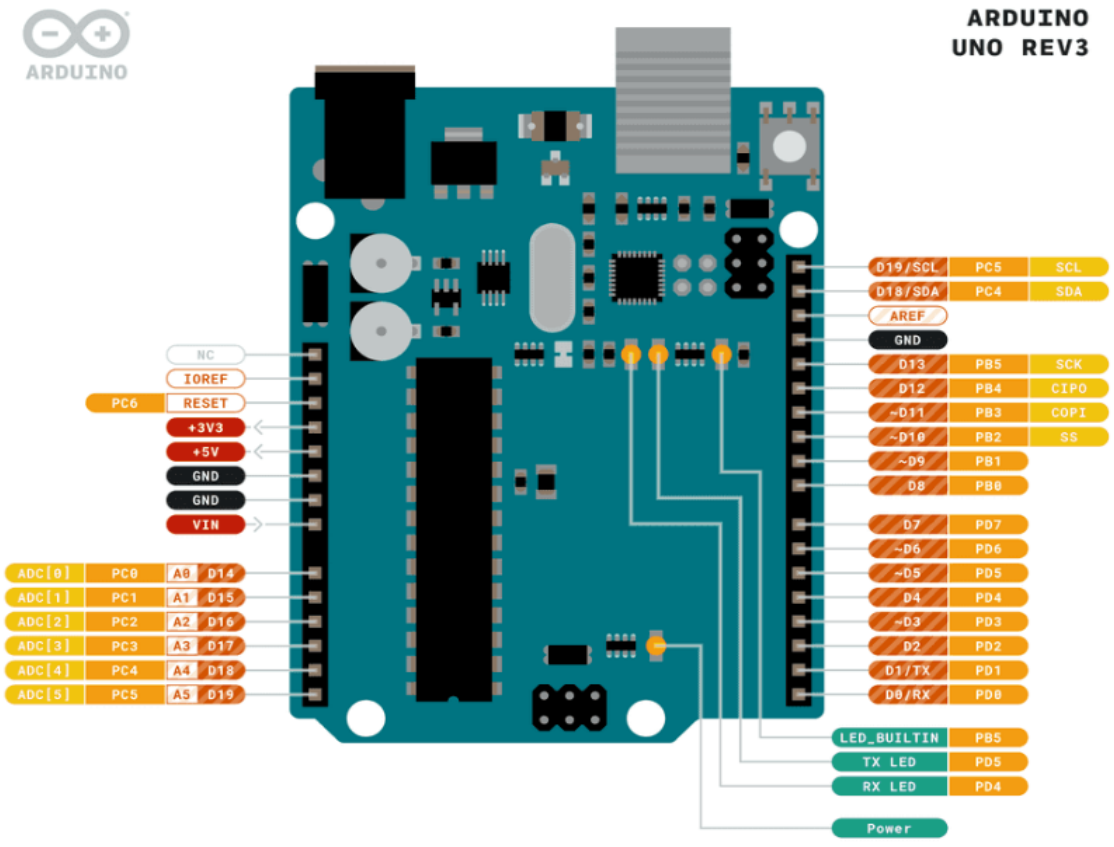

Figure 2. Arduino Uno Pinout Diagram (Ardunio.cc, URL-1).

Arduino is a microcontroller board bundled with an combined software suite tailored for programming embedded systems. This hardware lineup features boards equipped with AVR processors and is distinguished by its uncomplicated and open-source hardware design. Arduino includes a bootloader operating on AVR and a framework that facilitates the management of Input/Output (I/O) ports (Marhoon and Taha, 2018; Murad et al., 2021) (Figure 3-4).

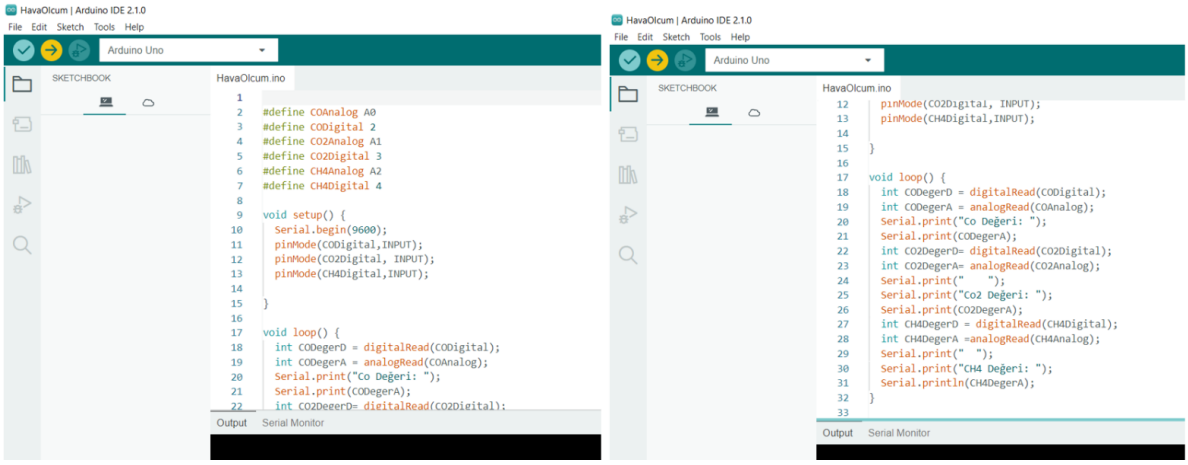

Figure 3. Ardunio IDE Software

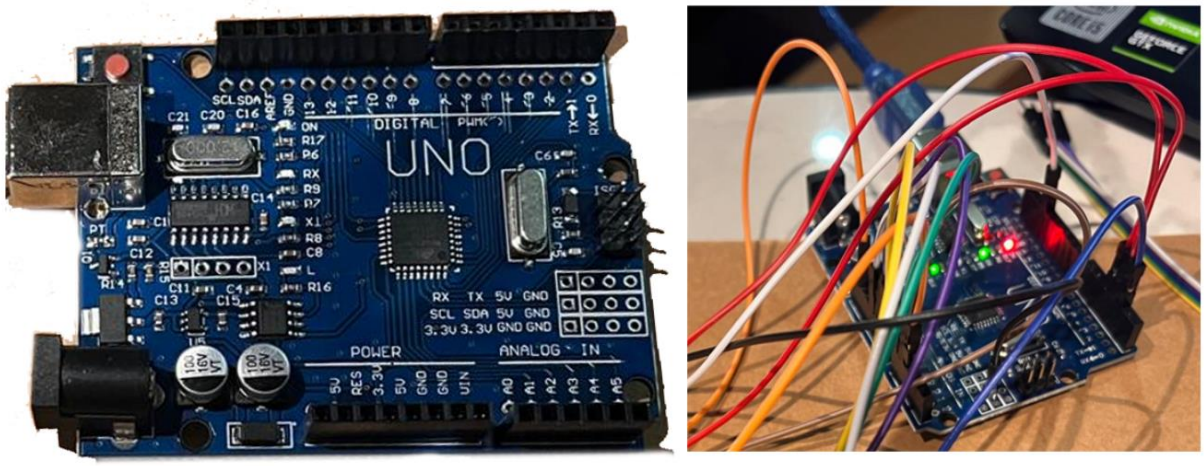

Figure 4. Arduino Uno Rev3 Pinout

The Arduino platform attracts attention with its easy-to-use structure that appeals to a wide range of users. These cards, preferred in many projects, especially accelerate the prototype development process and allow users to create their own projects. Arduino Uno, the most popular model of Arduino, was also used in this study. Arduino Uno is one of the most preferred Arduino models with its wide usage area and user-friendly structure. This model is widely used especially in education and rapid prototyping projects.

2.2. Creating the Measurement Device with Arduino Software and Artificial Intelligence (AI)

In the first stage of the production process of the device, breadboard (test board) was used

to learn the working principles of the microcontroller, gas sensors, modules and other components. C, C++ and Java programming languages were used in the software development process. The software of the device was created to collect data from CO_2, CO, HVOC, TVOC, $PM_{2.5}$, PM_{10} gas sensors, temperature and humidity sensors and GPS module. The creation of this process is given in Figure 5.

The sensors of the measuring device are enclosed in a box to protect them from external weather conditions etc. While creating this design, 3D scanners were used, and the box of the device was also produced with the help of a 3D printer. A screen that can show the measurements is placed on the top of the device.

There are numerous scientific studies combining Arduino and air quality research. Among them, Kelechi et al. (2022) used Arduino software along with an air quality measurement device to develop a low-cost air quality monitoring system. In another study, an Arduino-based design was utilized to develop wind power technology. However, research integrating Arduino design within the field of landscape architecture is quite limited. There is a gap in the literature on this subject. This study is expected to serve as a reference for future research in this field.

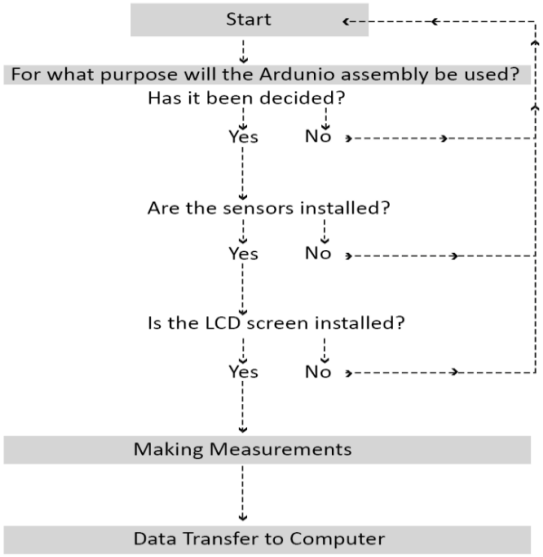

Figure 5. Flow diagram

2.3. Gas sensor modules

$PM_{2.5}$, PM_{10}, CO, CO_2, CH_4, Humidity, Temperature sensors were used. This device simultaneously measures them and instantly reflects these measurements on the screen. It repeats and records the data obtained by repeating the data to the micro-SD card. After all these processes are completed, the device installation is completed, and it is ready for measurement (Figure 6).

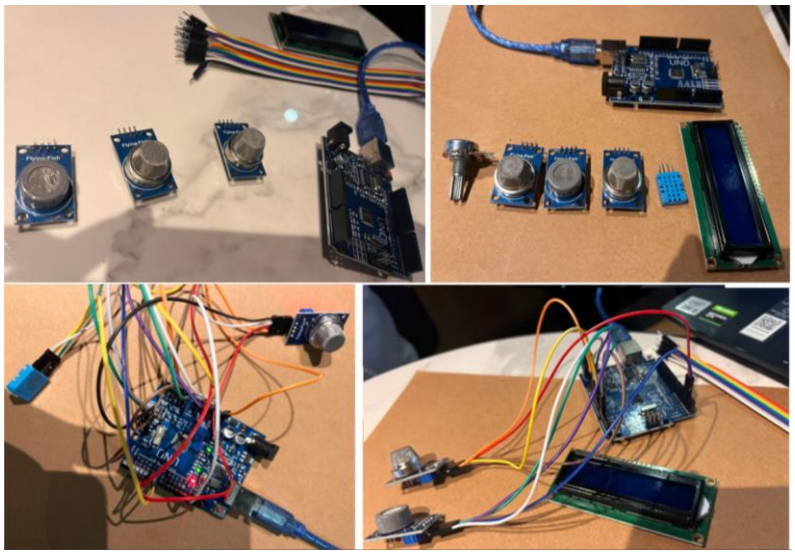

Figure 6. Input devices

After all these processes, the necessary checks were carried out, and the final status on the software was successful (Figure 7). Comparative analyses were conducted using an infrared device to evaluate the reliability of the measurement results and determine the suitability of the device for micro-measurements. During these comparisons, simultaneous measurements were taken from the same measurement point using an infrared device with a 95% confidence level. After verifying the reliability of the measurements, further studies were carried out.

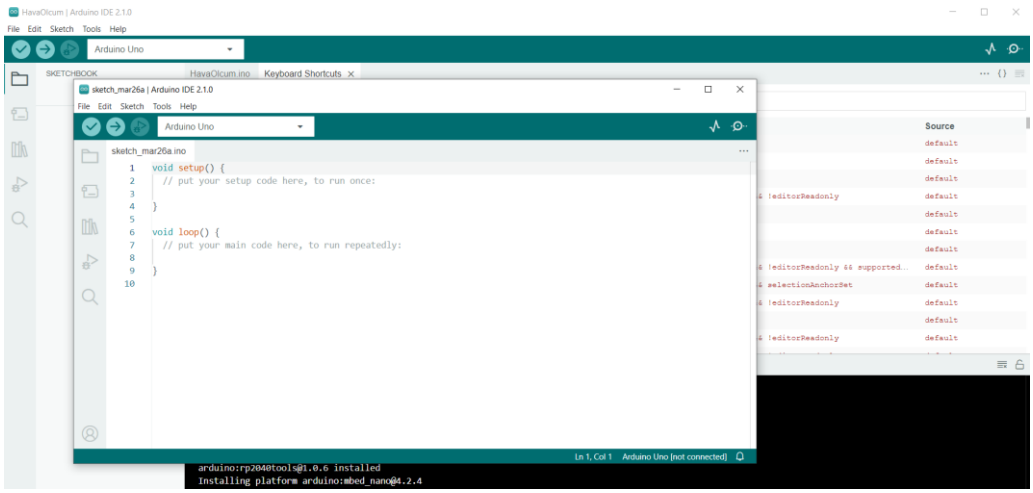

Figure 7. Operation of the device and data transfer (Ardunio IDE, 2024)

4. Results and Discussion

The relationship between artificial intelligence (AI) and design provides a major transformation in design. AI offers architects faster, effective and creative solutions through advanced algorithms used in the design stages. This enables the design of innovative structures both aesthetically and functionally. AI-supported simulations and analyses help to develop optimised designs in terms of energy efficiency, sustainability and building safety. In addition, automation and robotic construction techniques expand the horizons of architecture, enabling buildings to be constructed with complexity and precision not previously possible. This integration increases the ability of architects to turn imagination into reality, while at the same time making construction processes more sustainable and economical.

AI is revolutionising the design professions. In architecture, landscape architecture, urban planning and various other fields, AI has the potential to provide more sustainable, efficient and innovative solutions by accelerating design processes. This technological transformation not only changes the way designers work, but also radically redefines design itself. The air quality measurement device created within the scope of this study was created primarily for the professional disciplines of landscape architecture and interior architecture. AI and robotic applications were combined for the device and the device was completed as a result of the study. This device is among the important examples that can explain the relationship between AI and "design".

The benefits of this device made within the scope of the study for design professional disciplines with the use of AI are as follows.

- Thanks to the cooperation of "AI" and "design", a device that can measure air

quality has been solved in a more economical way.

- The fact that "AI" and "design" are also closely related to robotic applications has supported the device to be an example for the professional discipline.
- It has enabled Ardunio Software to be an example for landscape architecture and other design professions.

It is expressed through the applied example of how the relationship between AI and design can be. It is foreseen that this statement can be a source of inspiration for many future studies. Ardunio IDE Software and microcontroller used in this study are used in many professional disciplines (Anand et., al. 2016; Hidayanti et., al. 2020; Hasibuan et., al. 2021; Siregar et., al. 2022; Ozsoy, 2023). Within the scope of this study, it was evaluated how it could be integrated into design professional disciplines. This evaluation consists of application and production stages. The basic principle of the study is summarised in Figure 8.

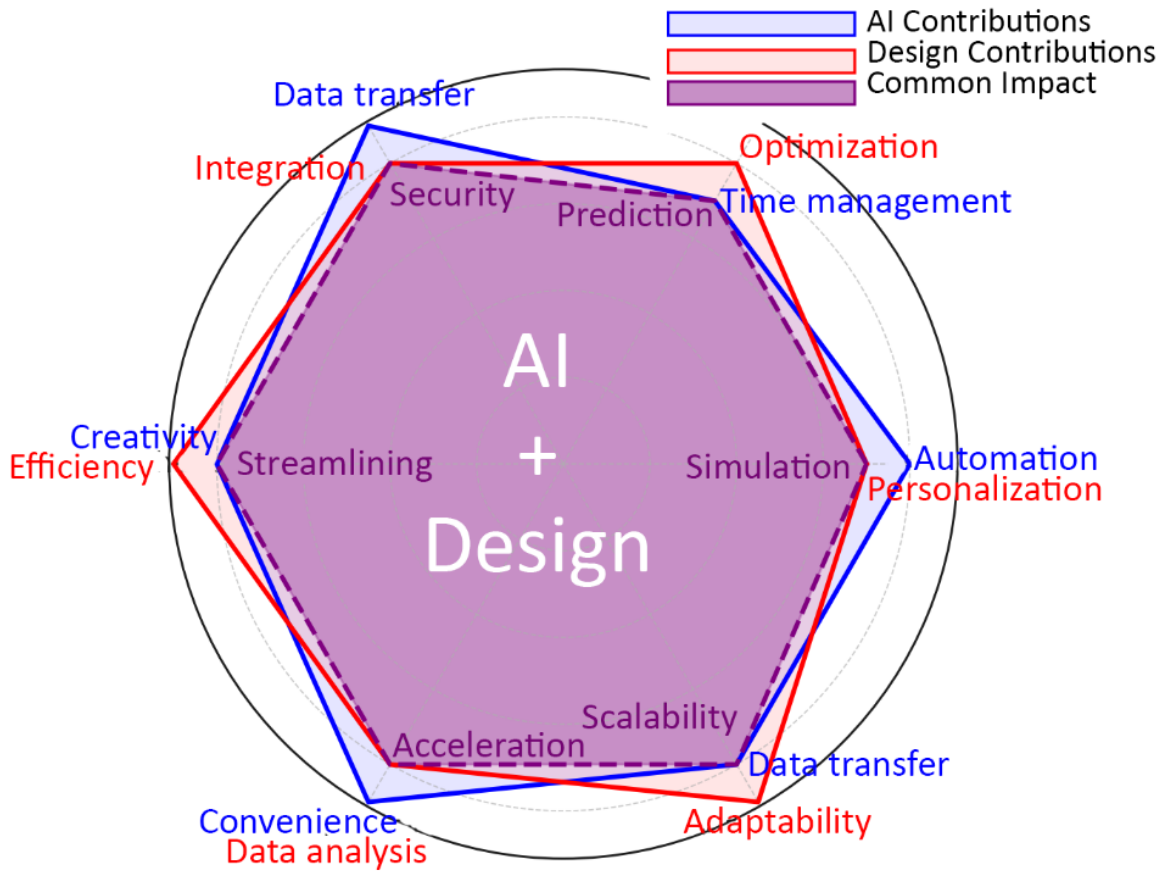

Figure 8. Relationship diagram between AI and design (Designed by the author)

5. Conclusion

In conclusion, the relationship between artificial intelligence (AI) and design is dynamic and constantly evolving. AI can play an important role in the design process by automating routine tasks, building models and suggesting design elements based on data and user feedback. This collaboration between humans and AI has the potential to increase efficiency, productivity and creativity. However, it is crucial to establish clear methods to recognise the intellectual property rights of AI models to creators and designers

working with these models, and to ensure transparency and accountability in the design process. As AI evolves, it is critical that designers keep abreast of the latest developments and best practices in AI-enabled design. This includes learning how to effectively integrate AI tools into business processes, how to interpret and improve AI-generated designs, and how to communicate the benefits and limitations of AI-assisted design to clients and stakeholders. By embracing AI and remaining flexible, designers can harness its potential to create innovative and effective designs that fit the changing needs of users and businesses.

Author contribution

Onur, M: Study planning, literature review, software, method analysis, visual design, and writing.

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Conflict of Interest Statement

All the authors declare no conflict of interest.

Ethical Standards:

No Ethics Committee Approval is required for this study.

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