EDUCATIONAL GAME PLATFORM FOR PRESCHOOL CHILDREN

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A Graduation Project Report

Electrical Electronics Engineering Department

JUNE 2024

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A Report Presented in Partial Fulfilment of the Requirements for the Degree Bachelor of Science in Electrical Electronics Engineering

ESKISEHIR OSMANGAZI UNIVERSITY

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ABSTRACT

Computer vision technology has rapidly and comprehensively developed, embedding itself deeply in many areas of our lives. Its transformative role in our daily routines becomes more evident with its continuous advancement and widespread adoption. This integration of technology into nearly every aspect of our lives is also manifesting in education. It has become particularly important to introduce and integrate technology into the lives of preschool children. This project aims to create a gaming platform designed for preschool children that seeks to enhance their cognitive, emotional, and motor skills. Given the significant impact of visual elements on learning, an educational game platform utilizing image processing will be beneficial in capturing children's attention and supporting their educational processes. By developing a user-friendly interface, the system will be easily accessible to children, making learning both fun and accessible. This work will provide an impressive educational tool that prepares preschool children for a future where digital literacy is crucial by combining traditional learning methods with the latest technology.

Keywords: *preschool, education, computer vision, image processing*.

ÖZET

Bilgisayarla görme teknolojisi, günümüzde hızlı ve kapsamlı bir gelişme göstermiş, hayatımızın birçok alanında derinlemesine yer edinmiştir. Bu teknolojinin hayatımızdaki dönüştürücü rolü, onun sürekli gelişimi ve yaygınlaşması ile daha da belirgin hale gelmektedir. Teknolojinin hayatımızın hemen her alanına entegre olması eğitimde de kendini göstermekte ve özellikle okul öncesi dönemde çocukların teknoloji ile tanışması ve bu sürece entegre edilmesi önemli bir konu haline gelmektedir. Bu projede de okul öncesi dönemdeki çocuklara yönelik onların bilişsel, duygusal ve motor becerilerini geliştirmeyi amaçlayan bir oyun platformu amaçlanmıştır. Görselliğin öğrenme üzerindeki etkisi büyük olduğundan görüntü işlemeyi kullanan eğitici oyunlar içeren bir platform, çocukların dikkatini çekmek ve onların eğitim süreçlerini desteklemek açısından faydalı olacaktır. Kullanıcı dostu bir arayüz geliştirilerek, çocukların sistemi kolayca kullanabilmesi ve öğrenmenin eğlenceli ve erişilebilir hale gelmesi sağlanacaktır. Bu çalışma, geleneksel öğrenme yöntemleri ile en son teknolojiyi birleştirerek, dijital okuryazarlığın önemli olduğu bir geleceğe okul öncesi çocukları hazırlayan etkileyici bir eğitim aracı sağlayacaktır.

Anahtar Kelimeler: *okul öncesi, eğitim, bilgisayarla görme, görüntü işleme.*

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LIST OF SYMBOLS AND ABBREVIATIONS

Abbreviation	**Explanation**
3D:	Three-Dimensional
API:	Application Programming Interface
AR:	Augmented Reality
bitmap:	Bitmap Image File
gif:	Graphics Interchange Format
GNU:	GNU's Not Unix
IEC:	International Electrotechnical Commission
IEEE:	Institute of Electrical and Electronics Engineers
ISO:	International Organization for Standardization
jpg:	Joint Photographic Experts Group
LANs:	Local Area Networks
midi:	Musical Instrument Digital Interface
mp3:	MPEG Audio Layer III
PEP:	Python Enhancement Proposal
png:	Portable Network Graphics
SDL:	Simple DirectMedia Layer
wav:	Waveform Audio File Format

1. INTRODUCTION

In today's rapidly advancing technological world, the integration of early childhood education with modern technology holds great importance [1]. The primary goal of our project is to create an interactive learning platform for preschool children using image processing techniques. This platform aims to develop essential learning skills such as shape and color recognition and physical activity. By leveraging advanced image processing technologies, we aim to provide an engaging and effective educational experience without requiring additional equipment.

In the first game, various shapes are displayed on the screen, and children are asked to identify the correct shape using hand gestures. Similarly, the second game focuses on color recognition, where children indicate the correct color with hand movements. The third and fourth games encourage physical activity by allowing children to interact with virtual balloons and balls, enhancing their motor skills and coordination.

This project is realized using Python programming language, incorporating popular and effective libraries such as OpenCV and MediaPipe for image processing. These technologies enable the system to accurately detect and respond to children's interactions in real-time. Current educational tools for children often use touch screens or augmented reality (AR) applications [2]. However, these solutions typically require specialized hardware and can be cost-prohibitive. This project aims to develop a system that operates solely with image processing techniques, eliminating the need for additional hardware.

By integrating such innovative technologies, the platform not only enriches the learning experience but also introduces young children to the possibilities of modern technology. A user-friendly interface is developed to ensure that children can easily use the system, making learning fun and accessible. Upon completion, this project will provide an impressive educational tool that prepares preschool children for a future where digital literacy is crucial by combining traditional learning methods with the latest technology. This platform will enhance children's learning processes while helping them acquire digital literacy skills at an early age and integrate into technology safely.

2. REQUIREMENTS SPECIFICATION

Computer vision is a rapidly growing field dedicated to the analysis, modification, and high-level understanding of images. Its goal is to determine what is happening in front of a camera and use this understanding to control a computer or robotic system, or to provide people with new images that are more informative or aesthetically pleasing than the original camera images [3]. The aim of this project is to teach children colors, numbers, and shapes, as well as to promote physical activity. During this project, the OpenCV and MediaPipe libraries and the Python programming language will be used.

The application should be designed to track users' hand movements and provide immediate feedback on whether their actions are correct or incorrect. Hand and body movements need to be detected accurately and promptly. Since the users will be preschool children, the application platform should be easy to understand and simple to use. Various games in multiple categories will be designed to capture the users' attention. To increase motivation, positive or negative feedback will be incorporated to keep the users engaged in the game.

The application aims to provide educational and physical activity benefits to the users. It will focus on tracking the movements of a single hand to ensure that only one user is engaged with the game at any given time. The application must operate with minimal errors and maximum performance. It should also be designed to be expandable and adaptable. The platform should be tested thoroughly, and performance analyses should support the development process.

In this project, hand recognition systems will operate based on a combination of various variables and factors. These variables affect the system's accuracy, efficiency, and generalization capability. Successful recognition depends on correctly adjusting these variables and may require access to specific hardware.

- **Physical Requirements**

Software and Equipment: The project will utilize a computer for image processing and will be designed using MediaPipe, OpenCV, and the Python programming language.

- **Performance and Functionality Requirements**

The system should quickly track hand movements, minimize error rates, and operate with maximum efficiency. The goal is to achieve at least 80% accuracy.

- **Economic Requirements**

During the development phase, costs have been kept low by using basic computer hardware and existing resources. The use of free and open-source software tools ensures the project's budget remains economically sustainable. Measures will be taken to handle potential future cost increases, supporting the project's sustainability and success.

- **Environmental Requirements**

The development environment has been designated as a school. The facilities provided by the school were utilized during this phase. No specific environmental requirements were necessary, but elementary school students will be needed for testing the application.

- **Health and Safety Requirements**

A user-friendly design must be created to ensure that children can use the application safely and comfortably. Attention should be given to aspects such as a simple and understandable interface design, safe camera positioning, and screen time usage.

- **Manufacturability and Maintainability Requirements**

Standard components that are easily available on the market should be used during project development. This ensures the production process is simple and cost-effective. The application should be updated regularly to keep the software secure and functional.

3. STANDARDS

- **PEP 8 (Python Enhancement Proposal 8):** The Python code is written in compliance with PEP 8 coding standards to ensure readability and consistency.

- **ISO 9241-210 (Ergonomics of human-system interaction - Human-centered design for interactive systems):** The user interface is designed following these standards to ensure safe and effective interaction for children.

- **IEEE 802.11 (Wireless LANs):** Wireless communication protocols are selected according to IEEE 802.11 standards, and the system's data transmission is configured accordingly.

- **ISO/IEC 25010 (System and software quality models):** To ensure the reliability and quality characteristics of the software, ISO/IEC 25010 standards are applied.

4. THEORETICAL BACKGROUND

Our project aims to develop an interactive learning platform for preschool children. This platform is designed to enhance children's hand-eye coordination, motor skills, and fundamental cognitive abilities. The technologies utilized in this project include image processing and motion detection.

4.1 Detection Methods

Image processing involves the analysis and manipulation of electronic image data. This project utilizes image processing techniques focused on real-time hand gesture detection and tracking. The libraries used for these purposes are MediaPipe and OpenCV.

4.1.1 MediaPipe

MediaPipe Holistic has the ability to simultaneously detect and track the key components of the human body. These components include body posture, facial landmarks, and hand landmarks, and they work on real-time video or image data [4].

MediaPipe Holistic integrates the capabilities of MediaPipe Pose, MediaPipe Face Mesh, and MediaPipe Hands to provide a holistic solution. This system utilizes machine learning models and computer vision techniques to accurately predict full-body posture, identify facial landmarks such as eyes, nose, and mouth, and track hand positions and movements. The capabilities provided by MediaPipe Holistic enable developers to create projects that involve full-body tracking, augmented reality experiences, fitness analysis, gesture recognition, and interactive applications. This comprehensive toolkit offers a powerful method for understanding and interacting with human body movements and facial expressions in real-time scenarios.

4.1.2 OpenCV

OpenCV (Open-Source Computer Vision Library) is a comprehensive open-source software library designed for developing computer vision and machine vision applications [5]. It is widely recognized in the field of computer vision for its robust and versatile toolkit, making it suitable for both beginners and professionals.

OpenCV covers core functions necessary for image and video processing, including reading, writing, resizing, and color conversion of images. It is also excellent for camera capture and video streaming, providing instant video acquisition from cameras for live image processing. These features make it possible to create dynamic and responsive applications, which are crucial for real-time image manipulation. In addition to these functions, OpenCV offers a wide range of image transformations and filtering techniques that facilitate tasks such as image editing, enhancement, and restoration. Continuously evolving with new features and performance improvements, OpenCV keeps pace with the latest developments in the field.

4.2 Hand Tracking Method

The ability to detect hand shapes and movements plays a critical role in enhancing user experiences across various technological fields and platforms. This capability is particularly valuable for applications such as sign language interpretation, gesture control, and augmented reality, as it enables seamless integration of digital content with the physical world. While humans naturally possess this skill, real-time hand detection in computer vision is challenging due to issues such as occlusion caused by fingers, palms, and hand overlaps, as well as the lack of distinct patterns.

MediaPipe Hands offers an advanced solution for tracking and capturing the complex movements of hands and fingers. Using machine learning techniques, it can accurately predict the positions of 21 3D hand landmarks from a single data frame. Although many state-of-the-art approaches require high-performance desktop systems, this approach achieves real-time performance on mobile phones and can process multiple hands simultaneously. By providing this hand detection functionality to the broader research and development community, we anticipate an increase in innovative use cases and the emergence of new applications and research areas.

4.2.1 Palm Detection Model

Differentiating hands based solely on visual features is more challenging compared to identifying faces, which have distinctive patterns around the mouth and eyes. However, accurate hand positioning can be achieved by incorporating additional contextual cues such as the arm, torso, or the person themselves.

To overcome the difficulty of recognizing open hands, a palm detector was trained instead of a hand detector. This choice stems from the fact that predicting bounding boxes for rigid objects like palms and fists is easier. Additionally, in cases where two hands overlap, such as a handshake, palms are relatively smaller objects, making non-maximum suppression effective. To reduce the number of bounding boxes, a square bounding box approach was used to model palms, reducing the number by 3 to 5 times. An encoder-decoder feature extractor was applied to enhance the awareness of the general scene context, including small objects. Lastly, focus loss was adjusted during training to address scale variations encountered in hand detection.

4.2.2 Hand Landmark Detection Model

After successfully detecting palms in the entire image, the subsequent hand landmark model determines the precise locations of 21 3D hand joint coordinates within the identified hand regions. The hand landmarks are illustrated in Figure 1. This model captures a reliable intrinsic representation of hand position, unaffected by self-occlusion or partially visible hands.

To obtain accurate ground truth data, a total of 30,000 real-world photos, each annotated with 21 3D coordinates, were meticulously used (with the Z-value derived from the depth map, if available). Additionally, a highly accurate synthetic hand model was created against various backgrounds, ensuring comprehensive coverage of possible hand positions. This synthetic model provides valuable supervision for mapping accurate 3D coordinates and enhances our ability to understand hand geometry.

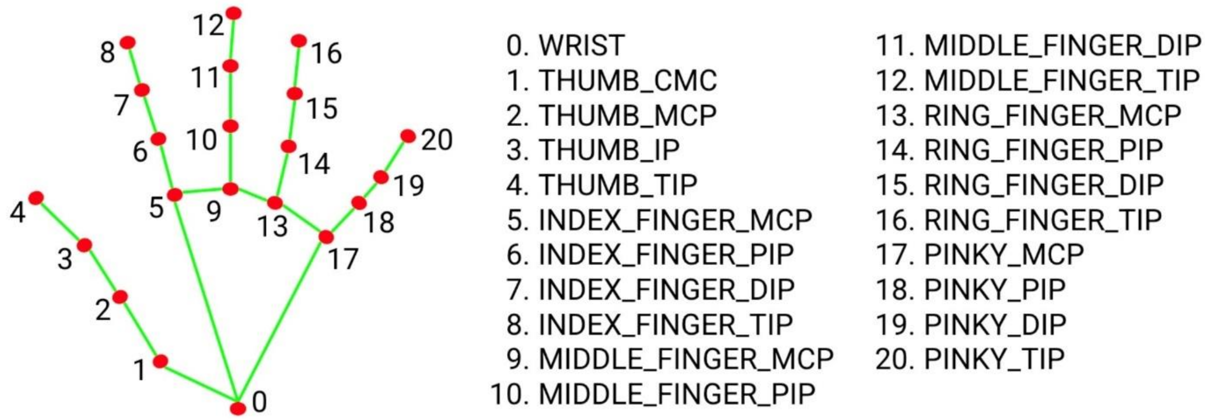

***Figure 1**. Hand Landmarks [6]*

4.3 PyGame

PyGame is a library developed by Pete Shinners for creating interactive games and multimedia applications using the Python programming language. Built on top of the Simple DirectMedia Layer (SDL), PyGame is capable of running on multiple platforms including Windows, GNU/Linux, and Mac OS. It supports various image formats (.jpg, .gif, .png, .bitmap) and audio formats (.mp3, .wav, .midi).

PyGame provides numerous functions for handling input devices such as keyboards, mice, and joysticks. It allows the developer to define the image processing loop, granting greater control over the game dynamics. With its straightforward API, PyGame makes game development accessible and is ideal for both beginners and experienced developers.

5. SUITABILITY OF EDUCATIONAL GAMES FOR CHILDREN'S DEVELOPMENT AND THE PROJECT

The purpose of this project is to create a game platform that supports the physical, cognitive, and emotional development of children aged 2-6. Two educational and two physical games have been developed, tracking hand movements using MediaPipe and OpenCV technologies. Children in this age group develop physical skills involving large muscle groups and fine motor skills [7]. Therefore, in Physical Game 1, children are asked to pop green balloons floating down while avoiding red balloons. Physical Game 2 is a volleyball game that encourages physical activity and interaction with the opponent player. Children in this age range are in Piaget's preoperational stage, where symbolic thinking, imagination, and language skills develop, although logical thinking is still limited [8].

Educational games are designed to support children's cognitive development. In Educational Game 1, children are asked to select the correct shape from two options and receive "Correct" or "Wrong" feedback based on their choice. In Educational Game 2, they are asked to select the correct color from two options and similarly receive feedback. These games aim to enhance children's color and shape recognition skills.

Children aged 2-6 begin to develop self-concept and enhance their social skills, such as empathy, sharing, and collaboration [9]. The volleyball game included in the project supports children's social interactions and collaboration, providing a competitive and cooperative experience as they try to reach the set score. Experts have identified fundamental criteria for programs suitable for children's development [10]. Programs should be age-appropriate and tailored to the child's developmental level; thus, our games are suitable for children aged 2-6. Children can control the flow of games and use the platform independently. Games should allow children to control the direction, flow, speed, and exit from the platform. Our games have clear and simple instructions; supported verbally and visually, allowing children to play the games independently. Contents should progress from simple to complex; therefore, our games are kept at simple levels. Programs should be free of violence; our games contain no violence and promote positive social values. Additionally, technical features of the program should be good, incorporating color, sound, and animation; our games include colorful graphics, sound effects, and animations.

6. METHODOLOGY

6.1 System Hardware

In this project, while creating a game platform for preschool children, only a standard personal computer is used as hardware. The built-in webcam of the personal computer is utilized to recognize and track the children's hand movements.

6.2 Software

The software component involves the use of OpenCV and MediaPipe, both implemented in the Python programming language. The flowchart of project is shown in Figure 2.

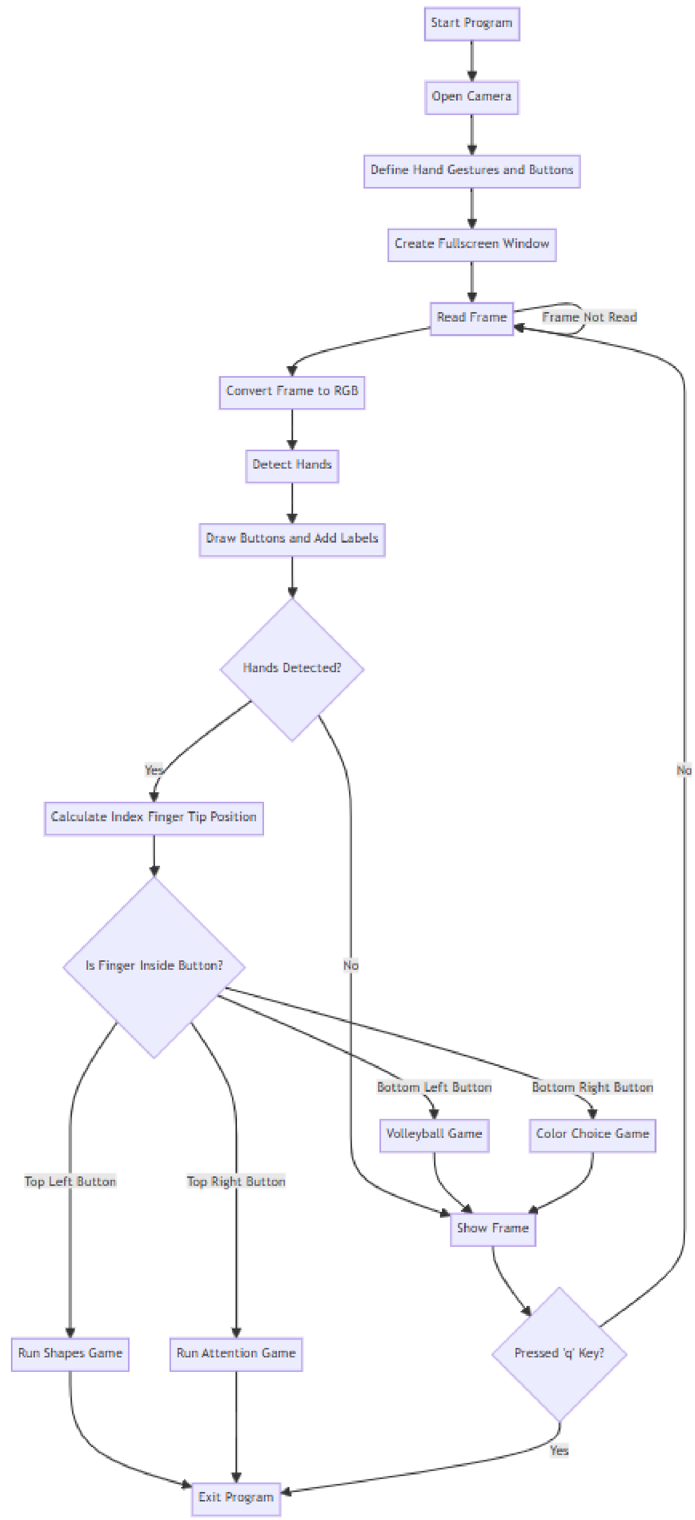

Figure 2. *Flowchart of the Project*

T-T1

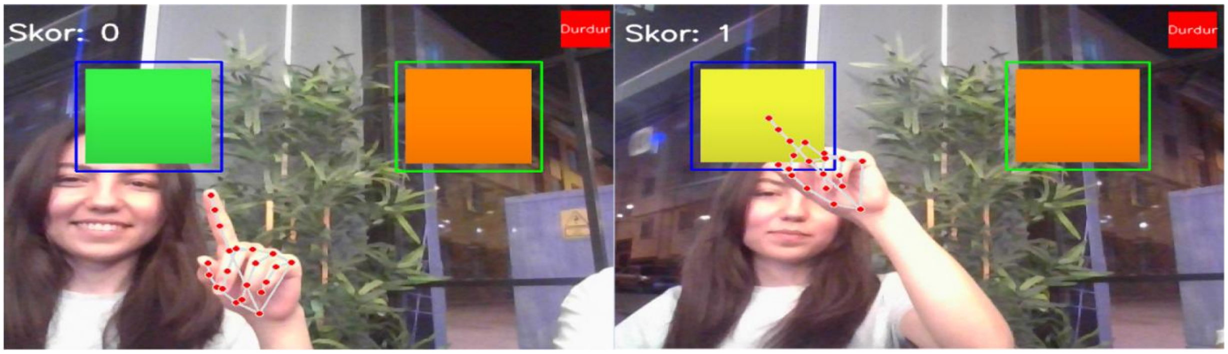

***Figure 3**.Educational Game 1- True*

The T-F coding indicates whether the game is educational or physical. T signifies an educational game, while F denotes a physical game. The other T-F symbols indicate “true or false,” and the numbers represent which game it is. In this game, the expression (T-T1) refers to the section where a correct choice is made in educational game number 1, as shown in Figure 3. In the game, the user will be asked to point to the desired shape with their finger among two shapes. Based on the choice made, the user will receive feedback in the form of "correct" or "incorrect." The user will be required to select the desired shape with their index finger, and at this stage, the selection of a second hand will not be accepted; only a single user will be able to play.

T-F1

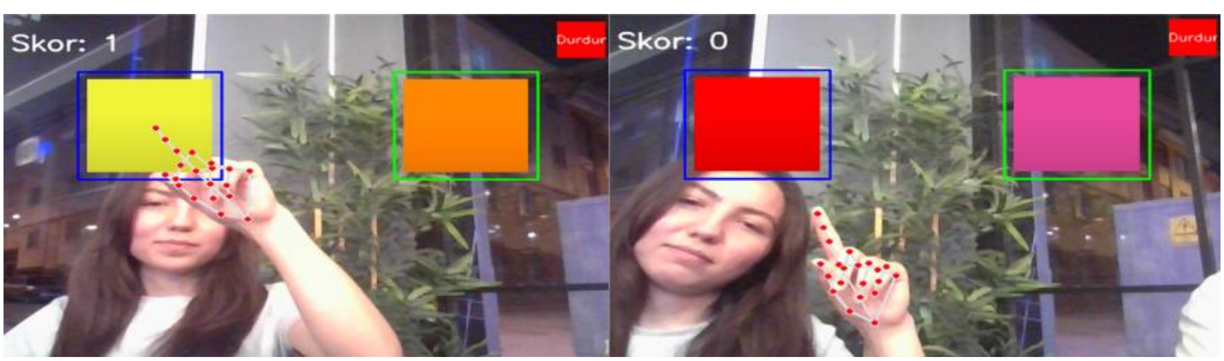

***Figure 4.** Educational Game 1- False*

T indicates an educational game. F1 indicates an incorrect choice was made in the first game. At this stage, the user is in the first educational game, and if they make a selection that does not match the given command among the displayed shapes, the user will be notified of the incorrect choice with an audible "Incorrect choice" warning. The selection is shown in Figure 4. The game will open in the same manner, displaying two options, and the user will be asked to make a selection based on the given command. If the user selects the option that does not match the command with their index finger, they will be informed that they have made an incorrect choice.

T-T2

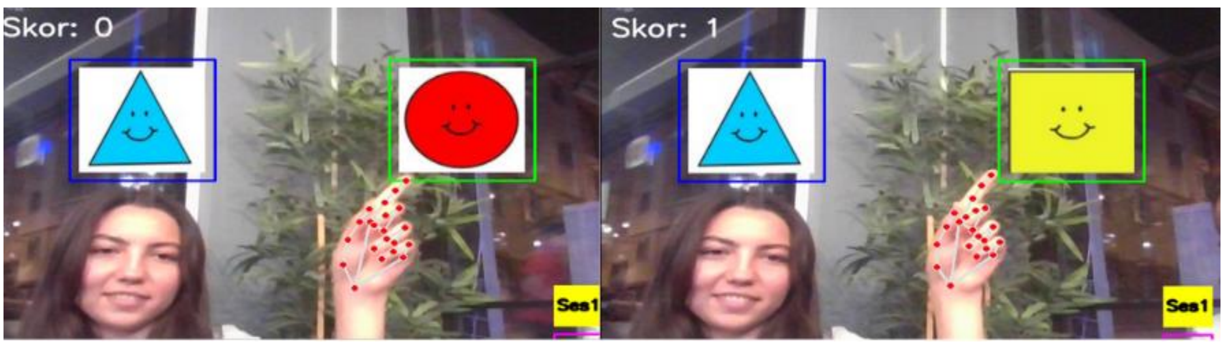

Figure 5. *Educational Game 2- True*

The user has made a correct choice in the second educational game. In this game, the user will be asked to select the correct color with their index finger from two presented colors. Similar to the other games, only a single user will be allowed to play, and the user will need to indicate the correct visual with their index finger. Upon making the correct choice, the user will receive feedback with the "Correct choice" command. The selection is shown in Figure 5.

T-F2

Figure 6. *Educational Game 2- False*

The user has made an incorrect choice in the second educational game. In this game, the user will select the color that does not match the given command from two visuals. If the user selects the incorrect color with the user's index finger, an audible "Incorrect choice" warning will be given. The selection is shown in Figure 6.

P-G3

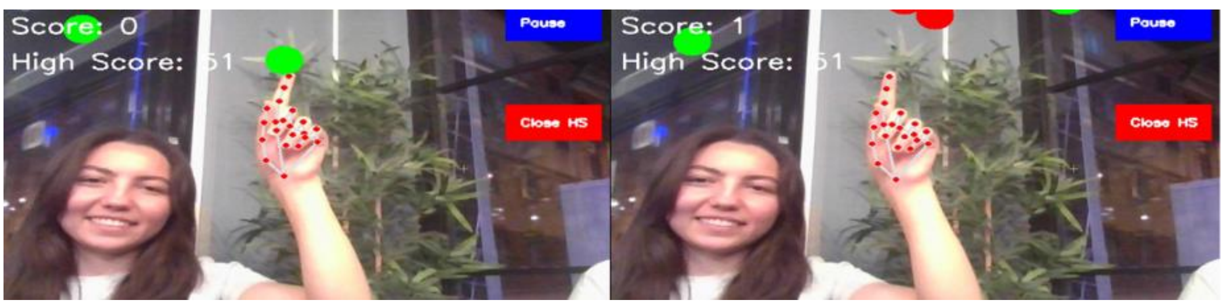

Figure 7. *Physical Game 1- True*

P code indicates that the user is playing a physical game. G3 indicates that we are selecting green balloons in the third game. In this game, among the balloons flowing down, which are red and green, the user is required to select the green balloons with their index finger while avoiding the red ones. When the user selects green balloons, their score increases by 1 point, and when they select red balloons, their score decreases by 1 point. This is illustrated in Figure 7. There will be no feedback on whether the user is making correct or incorrect choices; however, it is important how much score the user can achieve within the given time. This game aims to encourage physical activity, and the goal is to achieve the highest score within the allotted time.

P-R3

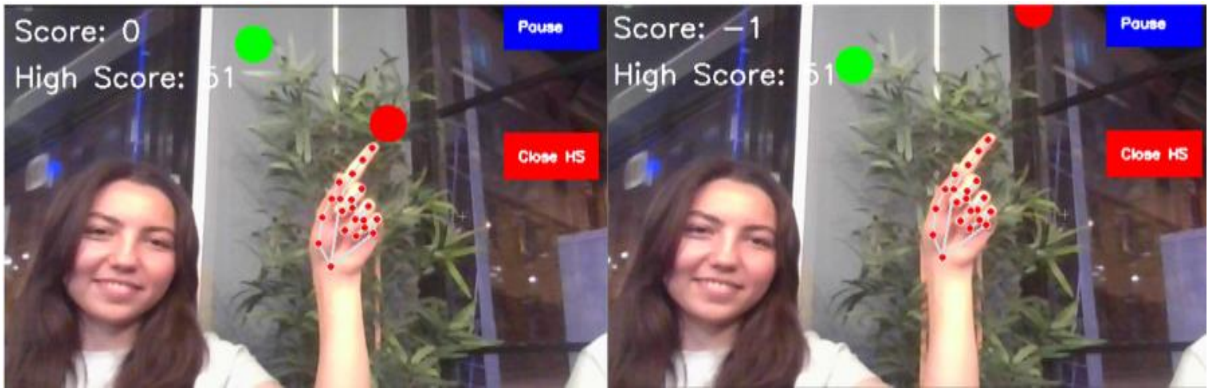

Figure 8. *Physical Game 1- False*

P- code indicates that we are playing a physical game. R3 indicates that we are selecting red balloons in the third game. When we select a red balloon among the flowing balloons with our index finger, our score will decrease by 1 unit. This is illustrated in Figure 8. The objective of this game is to avoid selecting red balloons.

P-4

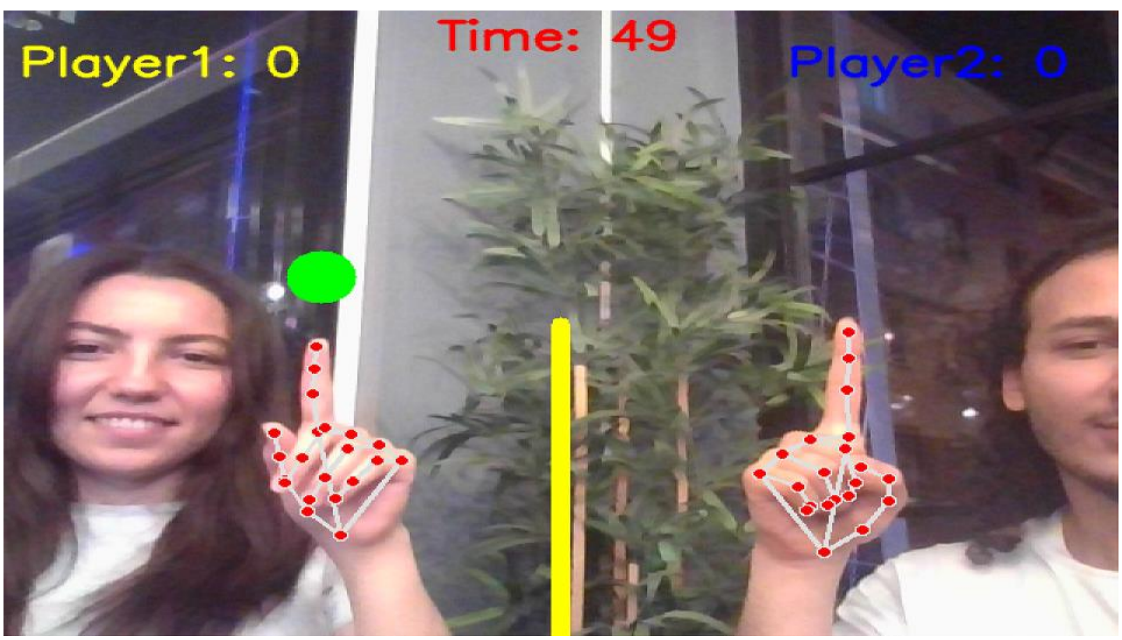

Figure 9. *Physical Game 2*

This is the final game on the gaming platform, and it is a physical one. Essentially, the game is designed to aim at sending the ball over to the opposite side using the yellow bar, which represents the net. The visual representation of the game is shown in Figure 9.

The Voice Feedback Option

- At this stage, voice feedback will be provided to increase user motivation. There are options for Female-Male and Turkish-English.
- F-T coding indicates a Turkish-speaking woman. Users who select this option will receive feedback from a woman in Turkish based on their choices.
- M-T Coding indicates a Turkish-speaking man. Users who select this option will receive feedback from a man in Turkish based on their choices.
- F-E coding indicates an English-speaking woman. Users who select this option will receive feedback from a woman in English based on their choices.
- M-E Coding indicates an English-speaking man. Users who select this option will receive feedback from a man in English based on their choices.

7. EXPERIMENTS

In our project, experiments were conducted in four different environments by varying the distance and light intensity. Ten participants, each with different height, weight, and gender, were selected to test the system's robustness and generalizability. The algorithms for each game were developed and tested separately to achieve high game dynamics and accuracy rates. Following the optimization process, comprehensive tests were conducted to evaluate the overall performance of the software platform and ensure smooth integration. Participants performed tasks evaluating shape recognition, color recognition, and motor skills coordination twice in each of the four different environments. These tasks included:

I. Shape recognition: Participants were shown various shapes on the screen and asked to identify the correct shape with hand movements.

II. Color recognition: Participants were shown different colors on the screen and asked to indicate the correct color with hand movements.

III. Motor skills and coordination: Participants interacted with virtual balloons and balls to evaluate their motor skills and coordination.

The experiments were conducted in four different environments:

- Environment 1: Short distance to the camera
- Environment 2: Long distance to the camera
- Environment 3: High ambient light
- Environment 4: Low ambient light

The collected data were analyzed in terms of detection accuracy and response times to determine performance differences arising from environmental factors or participant characteristics. The system demonstrated consistent high accuracy across different environments. This experimental phase confirmed the effectiveness of our educational game platform in various real-world scenarios and provided guidance for future improvements.

7.1 Participants

Before the experiment, participants were provided detailed information about the rules and how to play each game. There were a total of 10 participants, including 6 males and 4 females with varying hand sizes. The participants are shown in Figure 10.

Figure 10. *Participants*

7.2 Experimental Results

In the tables, abbreviations like G-1, G-2, G-3, and G-4 represent the games. The checkmark symbol (✓) indicates that the desired task in the game was successfully completed, while the cross symbol (✗) represents an unsuccessful hand detection.

Table 1. *Experimental Results in The Short Distance*

ENVIRONMENT- 1 (SHORT DISTANCE)				
USERS	*G-1*	*G-2*	*G-3*	*G-4*
User 1	✓	✓	✓	✓
	✓	✓	✓	✗
User 2	✓	✓	✗	✓
	✓	✓	✓	✓
User 3	✓	✓	✓	✓
	✓	✓	✓	✗
User 4	✓	✓	✗	✓
	✓	✓	✓	✓
User 5	✓	✓	✓	✓
	✓	✓	✓	✗

User 6	✓ ✓	✓ ✓	✓ ✓	✓ ✓
User 7	✓ ✓	✗ ✓	✓ ✗	✓ ✓
User 8	✗ ✓	✓ ✓	✗ ✓	✓ ✓
User 9	✓ ✓	✗ ✓	✓ ✓	✓ ✓
User 10	✓ ✓	✓ ✓	✓ ✓	✓ ✗
Correct Response (%)	**95**	**90**	**80**	**80**

The data in Table 1 represent the results of experiments conducted at a short distance. In this environment, it is observed that most users generally recognized and responded to or performed the desired tasks correctly. However, some users had lower success rates, especially in games G-3 and G-4. This could be due to the need for rapid tracking of hand movements required in games G-3 and G-4. Nevertheless, overall, a high level of accuracy was achieved at a short distance.

Table 2. *Experimental Results in The Long Distance*

ENVIRONMENT- 2 (LONG DISTANCE)				
USERS	*G-1*	*G-2*	*G-3*	*G-4*
User 1	✓ ✓	✓ ✓	✓ ✓	✓ ✗
User 2	✗ ✓	✓ ✓	✗ ✓	✓ ✓
User 3	✓ ✓	✓ ✓	✓ ✓	✓ ✗
User 4	✓ ✓	✓ ✓	✗ ✓	✓ ✓
User 5	✓ ✓	✓ ✓	✗ ✓	✓ ✗

User 6	✓ ✓	✓ ✓	✓ ✓	✓ ✓
User 7	✓ ✓	✗ ✓	✓ ✗	✗ ✗
User 8	✗ ✓	✓ ✓	✗ ✓	✓ ✓
User 9	✓ ✗	✗ ✓	✓ ✓	✓ ✓
User 10	✓ ✓	✗ ✓	✓ ✓	✓ ✗
Correct Response (%)	**85**	**85**	**75**	**70**

Table 2 shows the results of experiments conducted at a long distance. In this environment, it was observed that users had lower success rates in recognizing and performing the correct tasks, especially in game G-4 and in some cases in game G-3. These results may reflect the difficulty in detecting and tracking hand movements from a distance. However, in other tasks, users generally performed well.

Table 3. *Experimental Results in The High Light*

ENVIRONMENT- 3 (HIGH LIGHT)				
USERS	*G-1*	*G-2*	*G-3*	*G-4*
User 1	✓ ✓	✓ ✓	✓ ✓	✓ ✗
User 2	✗ ✓	✓ ✓	✗ ✓	✓ ✓
User 3	✓ ✓	✓ ✓	✓ ✓	✓ ✓
User 4	✓ ✓	✓ ✓	✗ ✓	✓ ✓
User 5	✓ ✓	✓ ✓	✓ ✓	✓ ✗

User 6	✓ ✓	✓ ✓	✓ ✓	✓ ✓
User 7	✓ ✓	✓ ✓	✓ ✗	✓ ✗
User 8	✓ ✓	✓ ✓	✓ ✓	✓ ✓
User 9	✓ ✗	✗ ✓	✓ ✓	✓ ✓
User 10	✓ ✓	✗ ✓	✓ ✓	✓ ✗
Correct Response (%)	**90**	**90**	**85**	**80**

Table 3 contains the results of experiments conducted under high light conditions. In this environment, generally, most users correctly recognized and responded to or performed the desired tasks. However, some users had lower success rates, especially in games G-3 and G-4. This could be due to the requirement for rapid tracking of hand movements in these games. However, overall, high accuracy was achieved even under high light conditions.

Table 4. *Experimental Results in The Low Light*

ENVIRONMENT- 4 (LOW LIGHT)				
USERS	*G-1*	*G-2*	*G-3*	*G-4*
User 1	✓ ✓	✓ ✓	✓ ✓	✓ ✗
User 2	✗ ✓	✓ ✓	✗ ✓	✓ ✓
User 3	✓ ✗	✓ ✓	✓ ✓	✗ ✗
User 4	✓ ✓	✗ ✗	✗ ✓	✓ ✓
User 5	✓ ✓	✓ ✓	✗ ✓	✓ ✗
User 6	✓ ✓	✓ ✓	✓ ✗	✓ ✓

User 7	✓ ✗	✗ ✓	✓ ✗	✗ ✗
User 8	✗ ✓	✓ ✓	✗ ✓	✓ ✓
User 9	✓ ✗	✗ ✓	✓ ✓	✓ ✓
User 10	✓ ✓	✗ ✓	✓ ✓	✓ ✗
Correct Response (%)	**75**	**75**	**70**	**65**

Table 4 contains the results of experiments conducted under low light conditions. In this environment, particularly in games G-1 and G-2, it is observed that most users had lower success rates. This may indicate that low light conditions make it more challenging to detect and track hand movements. However, in other games, generally, users achieved a lower level of accuracy overall.

8. PROJECT PLAN

In our project, which spanned a total of 107 days from the beginning of February to the end of May, we systematically completed various phases to ensure a comprehensive and well-structured approach. The preliminary work began in February and continued through April, during which extensive literature research, technology learning, and initial algorithm development were conducted. By mid-April, we transitioned into the software development phase, focusing on creating and refining our gesture recognition algorithms.

Throughout this period, key tasks included the design and coding of the games, interface design, and thorough testing of the software to ensure accuracy and user-friendliness. The experimental phase began in mid-May, where we tested the platform in various environments and with a diverse group of participants. This phase was crucial for collecting data, analyzing performance, and making necessary adjustments based on user feedback.

The project culminated in the writing of the thesis and the preparation of the presentation and poster, ensuring that all findings and methodologies were well-documented and communicated effectively. This detailed timeline and the breakdown of activities are depicted in the Gantt chart, providing a clear overview of the project's progress and the meticulous planning involved in each stage. The Gantt diagram for the project is shown in Figure 11, illustrating the start and end dates of all tasks.

ID	Task	Start Date	Due Date	Duration	2024					
					F	M	A	M	J	J
1	**Project Initiation**	07/02/2024	09/04/2024	59 days						
1.1	Literature Research	07/02/2024	21/02/2024	14 days						
1.2	Learning Python	22/02/2024	18/03/2024	25 days						
1.3	Learning Computer Vision	15/03/2024	28/03/2024	13 days						
1.4	Learning OpenCV	24/03/2024	04/04/2024	11 days						
1.5	Learning Mediapipe Holistic	28/03/2024	05/04/2024	8 days						
1.6	Determining Games on Platform	05/04/2024	09/04/2024	4 days						
2	**Design Phase**	09/04/2024	06/05/2024	1 month						
2.1	Overall Game Platform Design	09/04/2024	30/04/2024	21 days						
2.2	Algorithms of Games Design	01/05/2024	06/05/2024	5 days						
2.3	User Interface Design	05/05/2024	06/05/2024	2 days						
3	**Software Development**	04/05/2024	05/06/2024	1 month						
3.1	Coding the Application	04/05/2024	03/06/2024	31 days						
3.2	Development of Game Mechanics	04/05/2024	01/06/2024	27 days						
3.3	Integration of Components	01/06/2024	05/06/2024	4 days						
4	**Testing and Validation**	05/06/2024	10/06/2024	5 days						
5	**Thesis Writing and Presentation Preparation**	15/05/2024	15/06/2024	1 month						

Figure 11. *Gantt Diagram of The Project*

9. CONCLUSION

We have made significant progress towards our goals in our project. Firstly, we successfully developed a game platform aimed at supporting the cognitive, emotional, and physical development of preschool children aged 2-6. By utilizing modern technologies such as MediaPipe and OpenCV, we created games that enhance various skills including shape and color recognition, motor skills, and coordination. These games were meticulously designed to align with the developmental needs of children in this age group and aimed to be both fun and educational.

During the experimental phase of our project, we conducted tests in four different environments where factors such as camera distance and ambient lighting were varied. This allowed us to assess how robust our system is under different conditions and evaluate its generalizability. The results of these tests demonstrated consistent high accuracy rates, indicating the effectiveness of our algorithms and the overall design of the platform.

However, despite our achievements, there are areas that require improvement. Particularly, occasional errors stemming from variability in camera performance have been observed, especially under low-light conditions. To address this issue, we plan to enhance hardware components and further optimize our algorithms.

Additionally, while our project has successfully met many of the initially defined design specifications, there are still some aspects that need further attention. For instance, although we have developed games supporting various developmental skills, there may be opportunities to expand the scope of activities offered to cater to a wider range of learning needs.

In the future, we plan to continuously improve our platform based on feedback from testing and evaluations. This includes implementing enhancements to address any identified issues during the experimental phase and exploring additional features and functionalities to enhance the overall user experience. By iteratively improving our design and incorporating user feedback, we aim to create a game platform that effectively meets the educational needs of preschool children while providing a fun and engaging learning environment.

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