Play to Heal: An Interactive Maze Game Controlled by Hand Gestures Using MediaPipe and OpenCV for Hand Rehabilitation

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نموذج حقوق الملكية الفكرية لمشاريع التخرج في قسم علوم الحاسوب

يتم قراءة وتوقيع هذا النموذج من قبل الطلاب المسجلين لمشاريع التخرج في قسم علوم الحاسوب

تعود حقوق الملكية الفكرية لمشاريع التخرج ونتائجها (مثل براءات الاختراع أو أي منتج قابل للتسويق) إلى جامعة العلوم والتكنولوجيا الأردنية، وتخضع هذه الحقوق إلى قوانين وأنظمة و تعليمات الجامعة المتعلقة بالملكية الفكرية وبراءات الاختراع.

بناءا على ما سبق أوافق على ما يلي:

1) أن أحفظ كافة حقوق الملكية الفكرية لجامعة العلوم والتكنولوجيا الأردنية في مشروع التخرج.
2) أن ألتزم بوضع اسم جامعة العلوم والتكنولوجيا الأردنية و أسماء جميع الباحثين المشاركين في المشروع على أي نشرة علمية للمشروع كاملا أو لنتائجه. و يشمل ذلك النشر في المجلات و المؤتمرات العلمية عامة أو النشر على المواقع الإلكترونية أو براءات الاختراع أو المسابقات العلمية.
3) أن ألتزم بأسس حقوق التأليف المعتمدة في جامعة العلوم والتكنولوجيا الأردنية.
4) أن أقوم بإعلام الجهة المختصة في الجامعة عن أي اختراع أو اكتشاف قد ينتج عن هذا المشروع و أن ألتزم السرية التامة في ذلك و أن أعمل من خلال الجامعة على الحصول على براءة الاختراع التي قد تنتج عن هذا المشروع.
5) أن تكون جامعة العلوم والتكنولوجيا الأردنية هي المالك لأي براءة اختراع قد تنتج عن هذا المشروع و تشمل هذه الملكية حق الجامعة في إعطاء التراخيص و التسويق و البيع كمؤسسة راعية و داعمة لكافة الأنشطة البحثية. و يكون حق للطالب شمول اسمه على براءة الاختراع كأحد المخترعين، و في حال تم إعطاء تراخيص أو تسويق و بيع لأي من منتجات المشروع يمنح المخترعون بما فيهم الطالب نسبة من الإيرادات حسب تعليمات البحث العلمي في جامعة العلوم والتكنولوجيا الأردنية.

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تاريخ ....

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***Abstract*—The exercises used in traditional hand physiotherapy are usually monotonous and might also result in decreased patient engagement and motivation. As more people become interested in technology-assisted rehabilitation, there is a demand for interactive, cheap, and affordable solutions that can increase patient engagement and not compromise the therapeutic value. This paper describes a hand-controlled rehabilitation game with adaptive features, which helps in hand physiotherapy by playing a game. The proposed system can enable the user to play a game based on playing a maze by controlling the game by making hand movements, which are detected through the use of a basic webcam, and this offers a contactless and interactive experience that is easily usable at home and in the clinical setting. The system combines real-time hand movement with MediaPipe and OpenCV to correctly recognize and analyze hand movements. It includes an adaptive difficulty system, which automatically adjusts the levels of difficulty in the game in accordance with the performance of the user, thus providing them with personalized rehabilitation and permanent interest. Key performance indicators that will be used to assess the proposed system are responsiveness, accuracy, and usability. The ease of the hand movements required makes the system affordable and usable by people with various degrees of motor disabilities. We hope that our proposed game will offer a tool that can be an interesting and effective solution for hand rehabilitation, and we also hope that our game design will be able to combine the effect of therapeutic benefit with the fun of the game.**

***Index Terms*—Hand Rehabilitation, Gesture-Based Interaction, Physiotherapy Games, Computer Vision, MediaPipe, Human-Computer Interaction.**

To achieve cost effectiveness of the system through the use of available resources at the university. Dr. Dana El-Rushaidat already has all the necessary equipment. We are in the process of investigating the use of a VR headset that our maze game can be implemented in for immersive experiments in the future, and extra funding is not necessary at this point.

Possible future implementations of the system using a VR-based environment can make rehabilitation sessions more realistic and more immersive.

I. PROJECT GOALS AND OBJECTIVES

The overall objective of the project is to design an interactive user-adaptive hand rehabilitation system that would make the patient more motivated and active in the physiotherapy process. The presented system is based on the principles of hand gesture recognition and computer vision in order to convert the conventional rehabilitation activities into an engaging, efficient therapeutic experience so that patients are inclined to comply with exercises and record some progress.

The objectives of this project are specific, and they include:

- To develop and execute an interactive game that uses MediaPipe and OpenCV, whereby hand gestures are the main control system, by designing and implementing a rehabilitation game in the form of a maze.
- To transform therapeutic hand movements into a game-based activity, facilitating a fun and inspiring physiotherapy, and keeping the rehabilitation effectiveness.
- To create an adaptive difficulty system that can dynamically change the level of difficulty of the game according to the performance of the user and give him a personalized rehabilitation experience and a feeling of improvement with time.
- To trace and analyse user performance data to determine the effectiveness of the proposed system in helping hand rehabilitation.

II. INTRODUCTION

Physiotherapy of the hands is significant for the rehabilitation of individuals whose motor abilities are impaired due to neurological diseases, injuries, or inactivity [9], [10]. It involves repetitive training aimed at restoring hand strength, coordination, and functional movement, which often requires a prolonged period [19]. Although clinically important, traditional hand rehabilitation can be monotonous and unengaging, negatively affecting patient motivation, engagement, and adherence to therapy programs over the long term [2], [13]. Recent advances in computer vision (CV) and human-computer interaction (HCI) have enabled the transformation of rehabilitation exercises into interactive and engaging forms [11], [16]. Specifically, exergames, or game-based rehabilitation systems, have been shown to enhance patient motivation, promote repetitive practice, and provide quantifiable performance feedback. Nevertheless, many current rehabilitation systems rely on technical equipment such as wearable sensors, motion-tracking gloves, depth cameras, or invasive devices, which can be costly, cumbersome, and unsuitable for home use [14].

The other significant constraint of the existing rehabilitation games is that they use standard levels of difficulty, which are not able to adjust to the actual performance of the user [8]. Rehabilitation cannot be effective in a short period; it should be gradually introduced according to the motor abilities of the patient. Exercise that is either too simplistic can lead to little or no improvement, and one that is too challenging can demoralize and lose interest. As such, adaptive rehabilitation systems that can change the difficulty in real time according to the current performance of the user are necessary as long as optimum therapeutic outcomes are sought.

This paper is a gesture-based, adaptive rehabilitation system that will be proposed to assist in general hand physiotherapy based on a regular web-based camera. The system requires vision-based hand tracking in real-time using MediaPipe and OpenCV in order to facilitate natural and non-contact interaction without wearable and invasive devices. Directional controls in an interactive maze-based game are mapped to hand gestures; the result is that the patients are able to engage in therapeutic movements in a manner that is intuitive and engaging.

The proposed system will implement a methodology for observing user performance using quantitative indicators such as reaction time, gesture accuracy, and level completion time, which are commonly employed measures in gesture-based rehabilitation and exergame systems. Based on these metrics, a dynamic game difficulty adjustment mechanism will be introduced to ensure that the game is neither too difficult nor too easy for the user, as adaptive rehabilitation strategies have been shown to improve user engagement and therapy effectiveness [4]. The system will be developed in a non-virtual reality environment with a modular architecture, which can be extended in the future to immersive technologies if necessary.

The experimental evaluation is expected to demonstrate that the proposed system is responsive during user interaction and capable of adapting to different performance levels, making it suitable for users with varying degrees of motor impairment [9].

The main contribution of this work lies in the integration of real-time vision-based hand tracking [8], interactive game-based rehabilitation, and performance-based adaptive difficulty adjustment within a single low-cost and non-invasive framework. To the best of our knowledge, this approach has not been explored in this integrated manner before, offering a promising and engaging alternative to existing fixed and hardware-dependent rehabilitation solutions.

A. REVIEW AND ANALYSIS OF RELATED WORK

In this section, the previous research concerning the topic of gesture-based rehabilitation, game-based therapy, and vision-based interactive systems of hand physiotherapy will be reviewed.

1) Gesture Recognition to Hand Rehabilitation.: A number of studies have aimed at enhancing hand gesture recognition, especially in clinical populations like post-stroke patients. The authors used one-shot and transfer learning methods in [1] to overcome the limitation posed by small clinical datasets. Although the proposed solution was highly accurate at gesture recognition with minimal training data, it did not support an interactive rehabilitation environment and adaptive feedback systems, as well as gesture classification.

In the same way, most available studies on gesture recognition are concerned with enhancing their strength and accuracy in classification. Nevertheless, these methods, in the majority of cases, are not coupled with therapeutic play or real-time feedback about rehabilitation, which restricts the practical effectiveness of such methods in the case of prolonged rehabilitation.

2) Based and Exergame rehabilitation systems.: Exergames are also known as game-based rehabilitation, which has been extensively investigated as a way to make patients more motivated and engaged. In [10], the authors tested a home-based rehabilitation system that used video games with Functional Electrical Stimulation (FES) with post-stroke patients. Those outcomes proven enhanced engagement and quality of movement, but the system was based on wearable sensors and invasive hardware, diminishing ease of use and deployment.

In [6], the study of hand rehabilitation exergames on elderly users with the Leap Motion Controller was carried out. Though higher motivation and better performance were claimed, the system required specialized hardware and lacked in adaptive difficulty and gesture-based directional control.

On the whole, these papers prove the usefulness of gamification in rehabilitation and mention shortcomings in terms of hardware dependency and deficits in personalization.

C. Gesture-Controlled Rehabilitation Vision-based.

The recent developments in computer vision have made possible gesture-controlled rehabilitation devices based on the ordinary webcams. In [11], the authors tested various hand gestures in order to determine the best ones that could be used to control rehabilitation exergames by using MediaPipe and OpenCV. Discomfort in gestures and accuracy in recognition were studied by the research, but the system had no adaptive difficulty or performance-driven intelligence; it used fixed game logic.

A gesture-driven rehabilitation game was also proposed in [12]. The game uses MediaPipe as well as OpenCV to enable a user to play an inspired 2048 game using hand gestures. However, the system did not include the use of machine learning-based gesture modeling and the adjustment of game difficulty based on user performance, although it showed that an interaction based on the use of a web camera was possible, and increased user participation.

In addition to that, a number of vision systems have confirmed the feasibility of real-time hand tracking systems like MediaPipe. However, most such implementations are based on fixed gameplay and do not imply real-time performance monitoring and adaptive rehabilitation programs.

D. Adaptive and Immersive Rehabilitation Technologies.

Adaptive and immersive rehabilitation technologies have become the subject of more and more research. A detailed review in [5] has put the significance of personalization and intelligent design of systems in hand rehabilitation into perspective and also revealed issues concerning robustness and real-time tracking. Nonetheless, the review failed to give a definite adaptive or interactive rehabilitation model.

In [7] the use of augmented reality in therapeutic systems was discussed, and it was revealed that immersive environments may increase patient engagement and rehabilitation outcomes. Nevertheless, these systems were mainly cognitive/social rehabilitation oriented, other than adaptive motor training, and in most cases, the systems needed special equipment.

Table I presents the significant research on hand rehabilitation with the usage of gesture recognition and interactive systems. It also contrasts the methodologies, key findings, and limitations of both studies, pointing to the gap in the availability of non-invasive, adaptive rehabilitation systems and accessible systems that inspired the suggested work.

E. Research Gap

Although existing studies demonstrate the effectiveness of gesture recognition, game-based rehabilitation, and vision-based interaction, several limitations remain. Most systems either focus solely on gesture recognition accuracy or provide static rehabilitation games without personalization. Many approaches rely on specialized hardware, wearable sensors, or invasive devices, limiting accessibility and scalability. Moreover, adaptive difficulty adjustment based on real-time user performance is rarely implemented in vision-based rehabilitation games.

To address these gaps, the proposed work introduces an accessible, non-invasive hand rehabilitation system that integrates real-time vision-based hand tracking, interactive maze-based gameplay, and performance-driven adaptive difficulty adjustment using only a standard webcam. This unified approach aims to extend beyond recognition-focused and static exergame systems by providing personalized, adaptive, and engaging rehabilitation experiences.

TABLE I: Summary of Related Work

Paper	Methodology	Results	Limitations
[1]	One-shot and transfer learning for post-stroke hand gesture recognition	High recognition accuracy with limited training data	No interactive rehabilitation or adaptive feedback
[2]	FES-assisted video game therapy with wearable sensors	Improved engagement and hand movement quality	Invasive hardware and wearable devices required
[3]	MediaPipe and OpenCV for gesture-based exergame control	Identified comfortable and accurate gestures for therapy	Static difficulty without performance-based adaptation
[4]	Gesture-controlled rehabilitation game using webcam input	Real-time interaction and increased user engagement	No machine learning or adaptive difficulty mechanism
[5]	Review of AI-based hand rehabilitation systems	Highlights importance of personalization in rehabilitation	No proposed interactive system
[6]	Exergames using Leap Motion Controller	Higher motivation and improved performance in elderly users	Requires specialized hardware and lacks adaptivity
[7]	Augmented reality-based therapeutic systems	Enhanced engagement through immersive environments	Focus on cognitive/social therapy rather than motor training
[8]	Vision-based gesture-controlled rehabilitation systems	Confirms feasibility of webcam-based hand tracking	Static game logic and no adaptive intelligence

B. *Significance of work*

The significance of this work lies in addressing key practical limitations of existing hand rehabilitation solutions, particularly those related to accessibility, cost, and long-term usability. Unlike traditional rehabilitation approaches that often rely on specialized equipment, wearable devices, or frequent clinical visits [12]. The proposed RWHRS adopts a vision-based hand tracking approach that operates using a standard webcam. This design enables a low-cost, non-invasive, and easily deployable rehabilitation solution suitable for home-based therapy environments.

Contrary to most contemporary rehabilitation platforms, which focus on either gesture recognition or static game-based exercise, the proposed rehabilitation system shall make use of adaptive difficulty adjustment based on real-time user performance. The concept of adaptable rehabilitation has been discovered to improve user engagement and therapeutic outcome, taking into consideration the tailored adjustment of task difficulty to suit the capabilities of the user [19]. The proposed system shall make use of this adaptive rehabilitation approach that aims to sustain user motivation and assist in the recovery of their motor [3], [20]. The relevance of this research work is in its ability to cover several important deficits that are found to have existed in other related research work on hand rehabilitation systems [5]. In traditional rehabilitation systems, there is the need for regular hospital sessions, equipment, or the use of wearable and invasive sensors, which can be cumbersome, expensive, and even hindering to patients in adhering to long-term rehabilitation programs [2], [10], [13], [14]. This system will provide an easy-to-use and non-invasive system by using a vision-based tracking system of the hand by the standard webcam, which can be applied in domestic settings.

Unlike most modern rehabilitation platforms that rely on static gesture recognition or fixed game-based exercises [5], the proposed system integrates adaptive difficulty adjustment based on real-time user performance. The use of adaptation techniques in rehabilitation platforms has been shown to promote user engagement with the system , thus improving motivation towards the rehabilitation processes [18].

III. APPROACH AND METHODOLOGY

The presented work will be based on an interactive rehabilitation model grounded in computer vision, integrating real-time hand gesture recognition and game-based feedback. The system will be developed to prompt repeated therapeutic hand movements through an interactive series of mazes, as repetitive task-oriented activities are a key factor in effective motor rehabilitation [18].

A. ***System Overview***

The suggested system will consist of four key phases: video capture, hand landmark detection, gesture interpretation, and game control. Real-time video of the user's hand will be captured using a standard RGB webcam. The captured frames will be processed to identify hand landmarks, which will then be mapped to standard rehabilitation movements. These movements will eventually be translated into control commands for the interactive maze-based game.

- **Hand Detection and Landmark Extraction.**
  The MediaPipe Hands framework will be used to perform hand landmark detection and tracking, enabling the identification of a single hand and the extraction of 21 three-dimensional landmarks corresponding to the major joints of the hand and fingers. MediaPipe will employ a convolutional neural network (CNN)-based palm detector along with a lightweight hand landmark regression model, making it suitable for real-time applications . Figure 1 will present a graphical representation of the MediaPipe hand landmarks utilized in this work.
  The extracted landmarks will be used to provide accurate spatial information regarding finger locations and overall hand position, enabling robust gesture recognition regardless of variations in lighting conditions and background complexity.
- **Gesture Recognition and Mapping.**
  According to consultations with general physiotherapy guidelines, a set of elementary therapeutic hand movements will be defined, such as left, right, upward, and downward motions, which are commonly used in basic hand rehabilitation exercises. Gesture recognition will be achieved by analyzing the relative positions and angles of selected hand landmarks. These extracted features will be compared against predefined threshold values in order to classify the current hand gesture.
  All recognized gestures will be mapped to movement commands within the maze-based game, enabling the user to navigate the game environment solely through hand movements, without the need for external controllers or wearable devices [3], [4].
- **Interaction and Feedback in a Game.**
  The maze-based game will be implemented to provide immediate visual feedback in response to the recognized hand gestures. Real-time communication will ensure that hand movements are continuously translated into in-game actions, thereby facilitating repetition and sustained user engagement, which are essential elements in effective motor rehabilitation [20]. The interactive feedback loop will be designed to enhance user motivation and adherence to therapy, offering a more engaging alternative compared to traditional physiotherapy exercises [12].

B. *Tools and Technologies*

The following tools and libraries are used to implement the system:

- The Python system approach and processing.
- Video capture and frame processing using OpenCV.
- MediaPipe hand detector and landmark extractor.
- Maze interaction and feedback Game engine/custom game logic

The approach would allow a low-cost, camera-based rehabilitation that would not need wearable sensors; thus, it is affordable and is simple to implement in non-clinical settings.

C. *Dataset*

The proposed system is based on a collection of hand gesture images captured using a standard RGB webcam and a custom-built dataset. Gesture data will not be obtained from publicly available datasets; instead, it will be collected specifically for the target rehabilitation movements to ensure relevance and accuracy for the intended therapeutic tasks. Data collection will be conducted ethically and in the best interest of the participants by consulting the Institutional Review Board (IRB), and appropriate protection will be provided upon approval.

The video stream will be processed on a frame-by-frame basis, and hand landmarks will be extracted using the MediaPipe Hands framework. MediaPipe detects 21 anatomical hand landmarks corresponding to major joints and fingertip positions in each video frame [15]. These landmarks are represented as normalized coordinates and serve as the primary feature set for model training and inference [11]. The normalization process improves robustness against variations in hand size, camera distance, and lighting conditions.

The MediaPipe hand landmark model used in this work is illustrated in Fig. 1. Each landmark is assigned a specific index to enable accurate identification of detected hand points.

The hand landmarks are represented by red points, while the connections between them are shown using green lines.

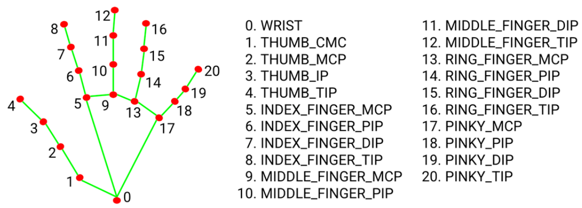


Fig. 1: Pipeline of the proposed hand gesture recognition system, illustrating hand landmark extraction using MediaPipe [15].

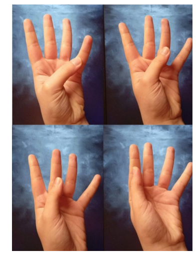
The data are encoded such that each sample corresponds to a fixed therapeutic hand movement. Four fundamental directional gestures commonly used in hand rehabilitation are considered: forward, backward, leftward, and rightward movements . For each direction, a representative hand pose image is defined to clearly describe the intended movement, as illustrated in Fig. 2. Specifically, one image represents the forward movement, another represents the backward movement, while the remaining images illustrate the leftward and rightward movements, respectively. These images are used solely as visual aids to explain gesture definitions and do not constitute the full dataset.

Multiple samples for each gesture class are collected to capture natural variations in gesture execution across different users. The collected dataset is divided into training and testing subsets. The model is trained to learn the relationship between hand landmark patterns and their corresponding gesture labels. During evaluation, unseen samples are used to assess classification accuracy and overall system robustness

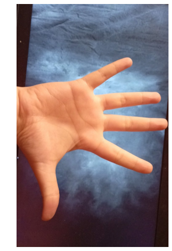
All data are collected during controlled interaction sessions, and no personal or identifiable information is recorded. The system adheres to ethical research practices and is suitable for rehabilitation settings, as it is trained, validated, and evaluated exclusively using anonymized gesture data.

Representative examples of the hand gesture images corresponding to the four defined directional movements are shown in Fig. 2, while the associated rehabilitation movements tracked using MediaPipe hand landmarks are illustrated in Fig. 3.

The data presented in Fig. 2 and Fig. 3 are for testing and illustration purposes only. The final dataset will be collected after obtaining Institutional Review Board (IRB) approval. All datasets used in the illustration of these figures will be discarded and re-collected once IRB approval is officially granted.



(a) Forward hand movement



(b) Rightward hand movement

(c) Backward hand movement

(d) Leftward hand movement

Fig. 2: Representative hand gesture images corresponding to the four defined directional rehabilitation movements.

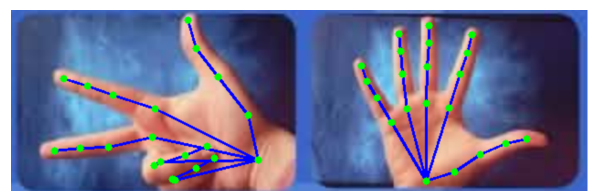


Fig. 3: Example of hand gesture images collected for the dataset. The applied pipeline ensures high accuracy and effective tracking of the rehabilitation movements.

D. Model

The suggested system comprises a two-step modeling strategy:

Step 1—Pre-trained Hand Landmark Detection Model: For the first step, a pre-trained hand landmark detection model is used, such as MediaPipe Hands. This model is static and does not require any training. Its sole function is to process an input frame and output 21 hand landmarks (x, y coordinates) for the detected hand. This stage is purely a feature extraction step and does not involve gesture classification

The Gesture Classification Model is the initial step to be taken. Step 2- Gesture Classification Model: The second step involves classifying gestures. In this case, one feeds the model with sequences of frames (and the landmarks of the hands that they represent) and labels such as forward, backward, left, and right. This model is aimed at acquiring the temporal and spatial behavior of the hand movements to correctly categorize the gestures.

To this end, we suggest the application of CNN + LSTM or BiLSTM architecture. The CNN fraction obtains spatial representations of every frame or landmark representation, whereas LSTM (or BiLSTM) obtains temporal relationships throughout the series of frames. This assembly of the model can not only comprehend the static posture of hands but also the dynamic movement with time, and this is essential in correctly identifying gestures over time through the right model [16] [17].

It should be mentioned that, until the given stage, we have applied the statistical pipeline (Step 1) using the ready-to-use hand landmark model. Future work is intended to be conducted with the classification of gestures model (Step 2), which will be trained on human gesture sequences based on hand landmarking. This step-by-step method enables us to initially prove the hand landmark extraction task before moving on to the more difficult task of the temporal gesture learning task[1].

E. Storyboard

In Unity, the system is used to create a rehabilitation environment that can be interacted with to enable users to train hand gestures in a game-based scenario. The game storyboard registers the order of user interactions and the flow of the application, and how hand gestures, which are registered with the help of MediaPipe, are embedded into the game.

There are four principal scenes in the storyboard:

Start Scene: This interface is the first one that the user sees upon opening the game. It offers the choice of either proceeding to a new session in Fig. 4.

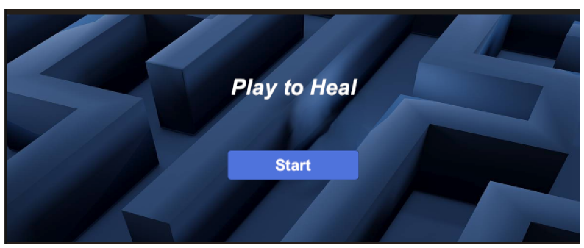


Fig. 4: Initial start screen of the rehabilitation system, illustrating the user interface before beginning the gesture-based exercises.

Create an account/log in: The user has a chance to create a new account or log in using their already registered user. This action will make sure that personal improvement can be followed in the course of time in Fig. 5.

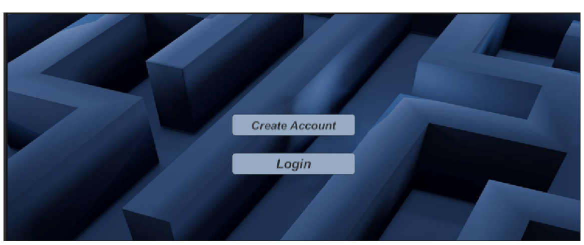


Fig. 5: Create an account and login interface for the system, allowing users to register or access the rehabilitation platform before starting the exercises.

User Information Scene: In this case, the user can give personal information, which includes name, age, and gender. The name is only applied in the model to monitor the developments of the rehabilitation session. In the study, all the data remain confidential, and the research and analytical processes are conducted in accordance with the ethical principles; only age, gender, and the sequences of the hand gestures are used in Fig. 6.

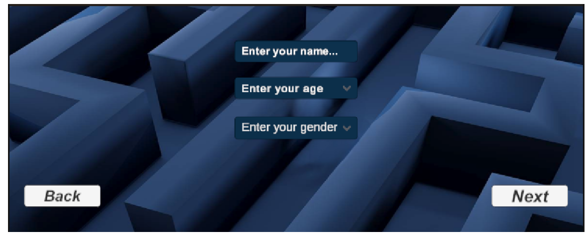


Fig. 6: Information screen providing guidance and instructions to the user before starting the rehabilitation exercises.

Maze Navigation Scene: The users are guided through a maze by the use of the keyboard arrow buttons. This scene will be used as an early interface to the future control of hand gestures. It will eventually be combined with the hand gesture pipeline to enable gesture-based navigation, instead of using the keyboard in Fig. 7.

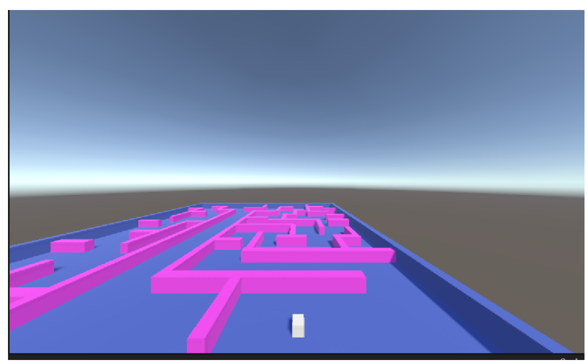


Fig. 7: The test maze environment is used to evaluate hand gesture control and interaction accuracy within the rehabilitation game.

This character is a representation of the first maze setup to be deployed as a first validation activity to test the patients. This maze is given to all patients in order to assess their fundamental interaction skill, orientation, and accuracy to their responses within the system. In this step, the navigation is done with the help of keyboard arrow buttons to form a baseline judgment prior to introducing hand gesture-based control. The findings obtained in this maze act as a guide on which the progress of patients at the advanced stages of the rehabilitation process can be tracked in Fig. 8..

[1] https://drive.google.com/drive/folders/1oPL7ZiJgsdffEFtdgDJUXLCpk6zJ4I7P?usp=sharing

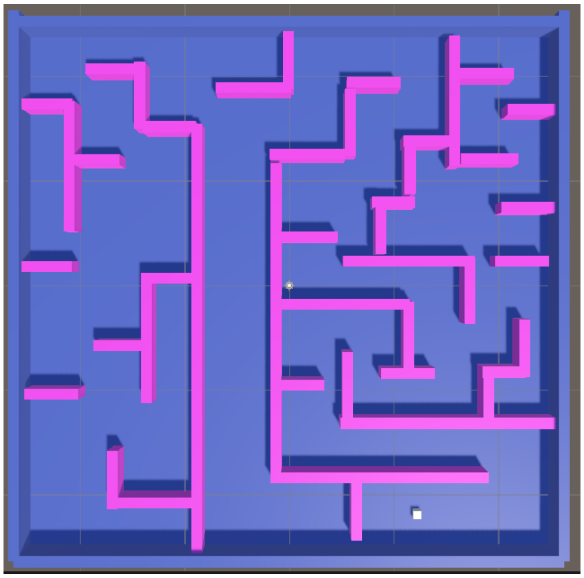


Fig. 8: The initial test maze was used as the first navigation task for patient evaluation, designed to assess interaction accuracy before integrating hand gesture control.

To make the process clear, a flowchart of the whole process, starting with the user input and the gesture-based interaction is given in the storyboard in Fig. 9.

The entire storyboard, with all the screen layouts and the sequence details, can be examined at the next link [2]: .

This architectural design makes every part of the game interconnected with the rehabilitation pipeline and keeps the unambiguous distinction between user tracking to rehabilitation and the data utilized to analyze the research.

The development of the maze environment was supported by our university through continuous guidance and supervision. We would like to acknowledge Dr. Mohammad Al-Wedian for his role in directing and supporting this work.

F. Location and Safety Considerations

The proposed system for rehab will be applicable in a controlled environment such as a clinic or a rehab center or even a home setting that will be supervised. A proper environment will be ensured around the user so that there are no cases of collision or fall due to accidental movements of the hands. The system will make use of vision-based non-invasive methods for hand tracking through the help of conventional webcams.

Additionally, personal and identifiable data shall not be gathered. Users shall be shown how to perform low-risk therapy movements by hand. The visual feedback system of the software shall aid in executing the movements correctly and shall help prevent the possibility of injury.

This proposal is submitted to JUST IRB with research number 1-2026. The search is approved by the Faculty Research Committee. We have applied the consent form for approval

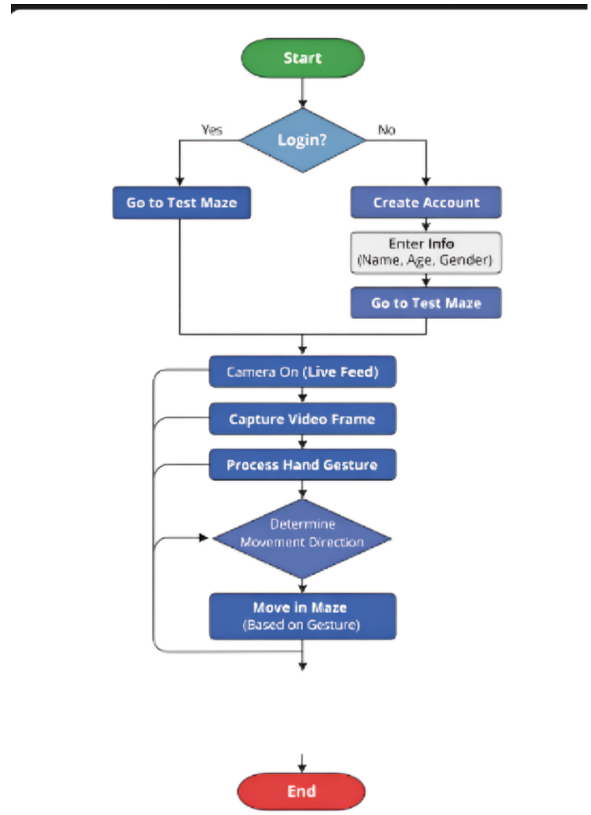


Fig. 9: Flowchart illustrating the sequence of actions in the hand gesture-controlled maze game, from account creation or login to frame processing and character movement in the maze.

of data collection and, in the future, for data testing in the following Google form: [3] of data collection and, in the future, for data testing in the following Google form: [4]. The hand gesture movements used in this system were kindly provided by Dr. Ahmed Bwa'neh.

G. Expected Results/Outputs

It is anticipated that the proposed system will be able to successfully identify predefined therapeutic hand gestures in real time, leveraging the accuracy of the MediaPipe-based hand landmark detection framework . A static gesture recognition pipeline will be implemented as an initial stage, which is expected to demonstrate high accuracy and reliability, forming a strong foundation for the interactive rehabilitation system , . The output of this process will be gesture classification corresponding to specific rehabilitation movements, which will then be mapped to control actions within the maze-based game.

[2] https://drive.google.com/drive/folders/1oPL7ZiJgsdffEFtdgDJUXLCpk6zJ4I7F?usp=sharing

[3] https://docs.google.com/document/d/1xnwsPMSFxNK9vss7BFA2jwJ3HNIBl4_Qy_Pw_EJLTfA/edit?usp=sharing

[4] https://docs.google.com/document/d/1xnwsPMSFxNK9vss7BFA2jwJ3HNIBl4_Qy_Pw_EJLTfA/edit?usp=sharing

At this stage, the model will operate using a fixed detection pipeline; however, future work will focus on training the system using custom-labeled images for each therapeutic movement to ensure optimal alignment with the game mechanics and rehabilitation objectives. Performance metrics such as gesture classification accuracy, response time, and overall system robustness will be evaluated using the collected dataset. Ultimately, the system is expected to provide a non-invasive, adaptive, and interactive rehabilitation tool suitable for both clinical and home-based settings, supporting patient engagement and contributing to gradual motor recovery.

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