

A Hybrid Mirror Therapy and Gamified Rehabilitation System for Stroke Patients Using a Force-Sensitive *Flappy Bird* Interface[★]

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Abstract. Stroke rehabilitation is often hindered by the repetitive and uninspiring nature of traditional therapy, leading to low patient motivation and suboptimal recovery. This paper presents a novel hybrid rehabilitation system that combines the established principles of Mirror Therapy (MT) with a gamified, sensor-driven interface to address these challenges. The system uses force-sensitive resistors (FSRs) integrated into a rubber gripper to control a *Flappy Bird*-inspired game, transforming repetitive motor exercises into engaging interactions. Simultaneously, the system preserves the visual feedback mechanisms central to MT, enabling neuroplastic gains through visual-motor coupling. Our approach aims to enhance patient motivation, promote adherence to rehabilitation routines, and provide real-time feedback for clinical insights. Initial evaluations suggest that this system offers a promising, low-cost, and portable solution for stroke patients experiencing hand weakness, while maintaining the therapeutic benefits of MT.

Keywords: Haptic feedback · Stroke rehabilitation · Virtual reality · Mirror Therapy · Gamification.

1 Introduction

Stroke remains a leading cause of long-term disability worldwide, with many survivors facing significant muscular and neurological impairments. Rehabilitation is the most effective treatment option, promoting neuroplasticity and preventing further neural degradation. However, adherence to rehabilitation programmes remains a challenge due to a lack of patient motivation. Despite the consequences of chronic paralysis, nerve damage, or muscle weakness, many patients still struggle

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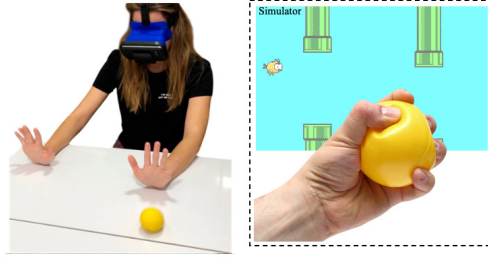


Fig. 1. Concept of the proposed system: the user is controlling a *Flappy Bird* game with a sensor-embedded gripper, while receiving stimulation from virtual mirror therapy.

to understand the importance of rehabilitation. Moreover, traditional rehabilitation methods are often repetitive and uninspiring, further hindering patient engagement.

Mirror Therapy (MT) has been widely accepted as an effective, non-invasive rehabilitation technique. It creates a visual illusion of movement in the affected limb using real-life mirrors, helping improve motor recovery in hemiparetic limbs. However, MT suffers from limitations such as a lack of engagement due to the absence of real-time feedback, and its reliance on mirrors, which may not be easily accessible for some patients.

This paper proposes a hybrid rehabilitation system that combines the benefits of MT with gamified exercises to address these challenges. The system integrates force-sensitive resistors (FSRs) in a rubber gripper to control a *Flappy Bird*-inspired game, as shown in Figure 1. The game engages patients while preserving the effectiveness of MT by allowing the user to focus on both the reflected limb and the game, maintaining the illusion necessary for neuroplastic stimulation.

The remainder of the paper is organised as follows: Section 2 discusses related works in the field of stroke rehabilitation and the integration of gamification and biofeedback. Section 3 outlines the design and development of the proposed hybrid system, including its hardware and software architecture. Section 4 presents the results of initial evaluations and user feedback. Finally, Section 5 concludes the paper and outlines directions for future work.

2 Related Works

In recent years, efforts to modernise rehabilitation have focused on integrating gamification and biofeedback mechanisms to increase patient adherence and improve therapeutic outcomes. Our research group developed an interactive therapeutic system that uses a force-sensitive rubber gripper to control a *Flappy Bird*-inspired game with data logged in real time for medical analysis [3]. Their

approach highlights the value of transforming repetitive motor tasks into engaging activities, demonstrating how affordable sensor-driven interfaces can motivate patients while providing time-stamped interaction data for therapy optimisation. However, while this system offers promising groundwork, it does not explicitly address the visual-motor coupling that mirror therapy leverages for neuroplasticity.

For better function of Mirror Therapy (MT), Mr. Bruno Ferreira and Prof. Dr. Paulo Menezes explored a sensor-based hand rehabilitation game that incorporates haptic feedback to reinforce proper motion [2]. Their findings suggest that real-time feedback loops enhance motor learning and task accuracy, key components in stroke rehabilitation. This results in improved engagement in MT. However, due to their system’s lack of any visual illusion mechanism, it seems not able to fully exploit bilateral transfer of mirror neuron activation—mechanisms which are central to the effectiveness of MT.

The limitations of gamified approaches have also been examined in the context of traditional MT. Our research team identified that while MT is widely supported as a non-invasive tool for stroke rehabilitation, it often suffers from poor long-term adherence due to its repetitive and passive nature [13]. Without interactive feedback or motivational elements [8, 11, 6, 7, 4, 10], patients may disengage despite the clinical benefits. This gap suggests a need for hybrid systems that can retain MT’s neurological benefits while actively sustaining user interest.

Expanding on this need, a virtual reality (VR) rehabilitation system was introduced in [9] by using a smart glove for upper limb therapy. Their work exemplifies how immersive environments can enhance engagement and neuroplastic stimulation through task-specific training. Yet, as with many VR-based systems, barriers such as hardware cost, setup complexity, and accessibility can limit adoption, particularly in underserved or home-based care settings.

Building upon these insights, our proposed system bridges these gaps by offering a hybrid model that merges the visual illusion of traditional mirror therapy with low-cost, sensor-enabled gameplay. By allowing users to view their reflected limb while engaging in force-controlled interaction, our approach delivers both the neurological stimulation of MT and the motivational benefits of gamification without requiring expensive immersive technologies. This positions the system as a scalable, accessible solution for stroke rehabilitation, balancing engagement, feedback, and medical validity.

3 Methodology

This section describes the design and development of the proposed hybrid rehabilitation system, describing the interaction between the sensor-embedded gripper with a Unity [12]-based *Flappy Bird* game and a virtual mirror therapy interface. The system aims to enhance motor rehabilitation by combining visual-motor stimulation with gamified feedback.

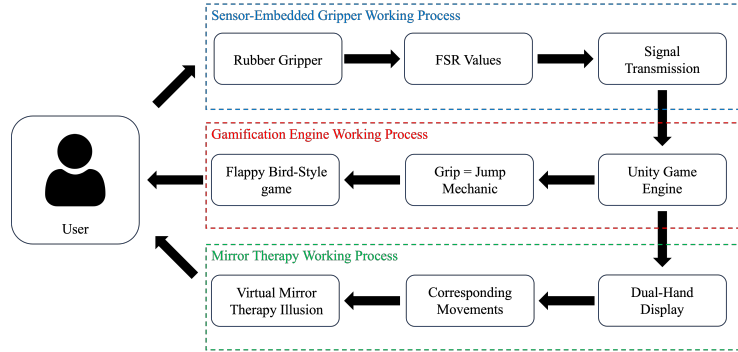


Fig. 2. System overview illustrating the integration of the sensor-embedded gripper, gamification engine, and mirror therapy components.

3.1 System Overview

As shown in Figure 2, the proposed system consists of three main components:

- A Sensor-Embedded Gripper: equipped with a force-sensitive resistor (FSR) to detect grip strength in real time.
- Virtual Mirror Therapy Interface: displays two virtual hands within the game view, allowing the illusion of bilateral hand movement for neuroplastic stimulation.
- A Gamification Engine: translates grip strength into a jump within the *Flappy Bird* interface.

The system is designed for use with a VR headset in conjunction with a rubber gripper to allow users to perceive movements in both hands while engaging with the game, as shown in Figure 3.

3.2 Hardware Architecture

The hardware architecture is centered around the sensor-embedded gripper, which acts as the “controller” to the *Flappy Bird* inspired game. The working process and methods for adaptive rehabilitation are as follows:

- Sensor-Embedded Gripper: A rubber gripper embedded with a force-sensitive resistor (FSR) captures the grip strength in real time from the user, as shown in Figure 3-a. The hardware schematics are shown in Figure 3-b. The FSR’s analog signal is translated to digital by using an Arduino Nano board [1] and transmitted to a Unity application. The system interprets values above a set threshold as valid jumps, mimicking traditional *Flappy Bird* mechanics.
- Data Analysis & Report: Grip force data is logged in real time, analysed for consistency and improvement, and summarised in a report sheet. The report contains the following information: measured force over time; game score;

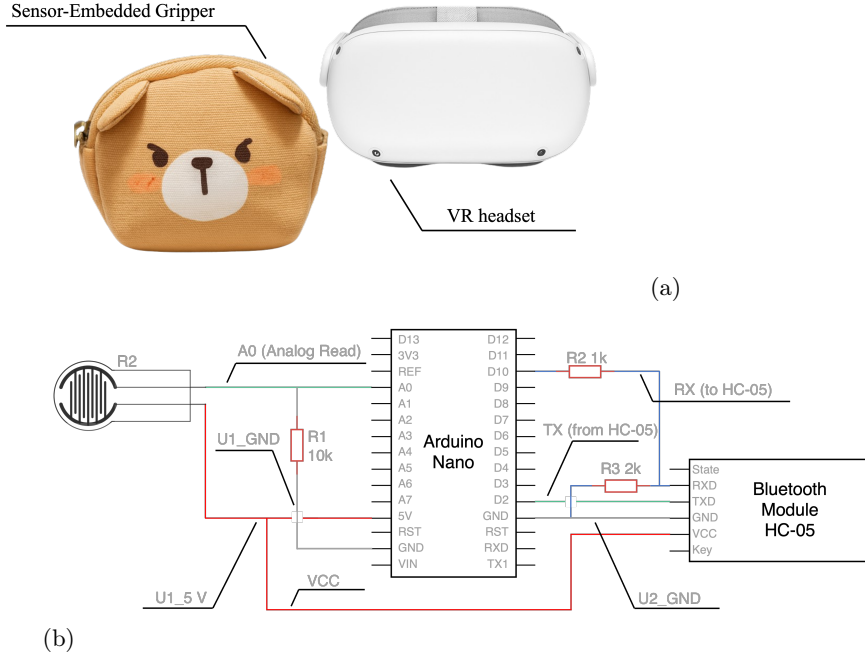


Fig. 3. Hardware configuration and physical setup of the proposed rehabilitation system: (a) real images of the main hardware components utilised by the system; (b) electrical schematic displaying the connection between a FSR sensor, Arduino NANO, and Bluetooth Module HC-05 in the sensor-embedded gripper.

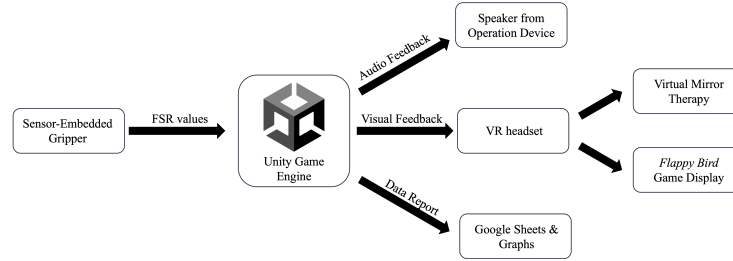


Fig. 4. Software architecture, including the input and outputs of the hybrid solution.

time. This report can be accessed by the user or potential medical personnel who use this system for additional data for diagnosis. Most importantly, this data is quantitative, allowing users to observe their results. This an essential part in progress recognition, leading to greater motivation and engagement.

- **Strength Calibration:** Before the user engages with rehabilitation, the system initiates a strength calibration sequence. The user is asked to squeeze the gripper with maximum effort. Based on this input, the system will set the

threshold to around 50-70% of the perceived force, ensuring accessibility and optimal training across different varying strength levels and recovery stages.

3.3 Software Architecture

As shown in Figure 4, the software architecture is centred around the Unity game engine, which acts as the core processing unit, linking the user’s grip input from the rubber gripper to both the gamified feedback system and virtual mirror therapy interface. The working process and methods for the integrated system are described as follows:

- Unity Game Engine: The Unity game engine links the input from the sensor-embedded gripper to control a character within the *Flappy Bird* inspired game. In addition, it is responsible for virtual mirror feedback, by synchronising the movement of the pair of virtual hands, it provides visual feedback that follows the physical action of the user.
- Virtual Mirror Therapy: To adopt the methods of conventional therapy, two virtual hands are displayed, one corresponding to the active limb, and another mimicking and mirroring the movement. This is shown alongside the game interface through a VR headset. This setup allows users to focus on the illusion of bilateral movement while engaging with the game, enhancing motor cortex stimulation.
- Gamified feedback: Gameplay elements such as score, progression, and visual/auditory feedback are built into the Unity application. These components are simple, yet effective methods in engaging and motivating the user, essential for long-term commitment to therapy. The system is designed to adapt with the user, changing the difficulty of sessions to match their capabilities. Variables such as the force threshold, game score, or endurance can be factors in considering difficulty level. If a user consistently meets the grip threshold and avoids in-game obstacles, the game introduces narrower pipe gaps or slightly increases gravity to maintain challenge. Conversely, if the user fails repeatedly, the threshold is reduced temporarily and the game is made easier. This feedback mechanism ensures that the system remains both motivating and accessible.

3.4 User Interaction Flow

This rehabilitation method consists of two main components that the user is required to use: a VR headset and a sensor-embedded rubber gripper. As this system is designed for stroke patients that have hemiparesis or one-sided weakness, the user can hold the gripper in the functional hand and wear the headset. Upon use, the system will alert the user to squeeze the gripper with maximum effort; then create a threshold based off the maximum value. The main rehabilitation activity begins once calibration is complete, where the user can squeeze the gripper to control a character in a *Flappy Bird* game. Users will be able

to see their current and best score, this implementation can be a source of engagement, as beating a best score can be rewarding. Simultaneously, the user's virtual hands are rendered within the VR display by mirroring gripping actions to simulate bilateral movement. After each session, users can observe their past sessions and progress through a performance report.

4 Simulations and Results

Calibration Phase Action: the user is prompted to squeeze a rubber ball embedded with a Force Sensitive Resistor (FSR) as hard as they can. This is used to capture the maximum grip strength of the user.

User Feedback: a visual indicator (progress bar) fills in real-time, allowing the user to understand their grip intensity. An audio cue confirms the completion of the the calibration.

Outcome: the system stores the peak value and uses it to set a dynamic threshold for jump detection during gameplay, tailored to the user's level of strength.

Game Start Phase Action: upon successful calibration, the Flappy Bird game begins. The user initiates jumps by squeezing the ball with a force greater than the threshold.

User Feedback: the bird responds immediately to user input. Audio feedback includes a jump sound on valid squeezes.

Outcome: the game provides an intuitive and immersive way for users to start therapy sessions. Successful control of the bird indicates motor control and strength accuracy.

Gameplay Monitoring Action: the user continues to squeeze the ball to make the bird fly through the pipe gaps. Each squeeze is detected and translated into a vertical jump in the game.

User Feedback: a running score shows successful passes. Missing a pipe or collision triggers visual and audio failure signals. Sensor readings are tracked live in the background.

Outcome: the user's motor endurance, timing, and strength control are indirectly measured through game performance and recorded sensor data.

Game End and Feedback Phase Action: the game ends when the user hits an obstacle or reaches a predefined score goal. This automatically ends the session.

User Feedback: a summary screen shows the total score, jump count, and average grip force. A message like 'Well done!' or 'Try again tomorrow' is shown based on performance.

Outcome: the user receives immediate, easy-to-understand feedback on their performance and progress. Therapists can review data trends to evaluate rehabilitation effectiveness.



Fig. 5. Interface showing session records, including duration, score, average grip force, and jump count per session.

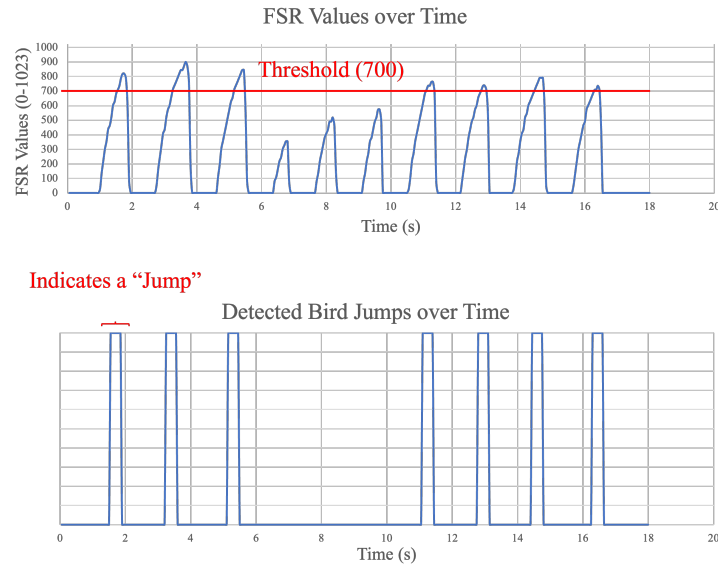


Fig. 6. Time plots of sensor reading and corresponding jumps in the *Flappy Bird* game.

Data Logging Action: throughout the session, all key events and values (e.g., grip force, jump times, score changes) are logged in the background.

User Feedback: no direct user feedback is provided here, but therapists can access session logs via a secure dashboard which can be seen in Figure 5.

Outcome: provides a detailed dataset for long-term tracking of motor improvement and therapy adjustment. Enables evidence-based rehabilitation decisions.

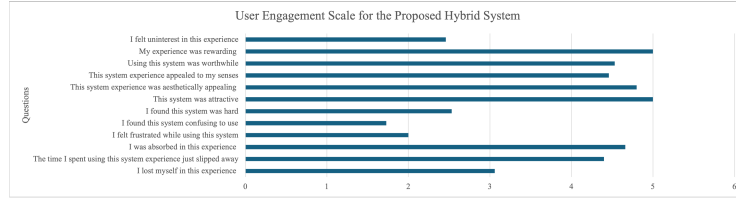


Fig. 7. User Engagement Scale on question rating their experiences on a scale of one to five.

Time plots of sensor reading and corresponding jumps in the *Flappy Bird* game are shown in Figure 6.

To evaluate the effectiveness and usability of the system, a simulated rehabilitation session was conducted involving 15 volunteer participants. All participants were adults aged between 25 and 40 years, consisting of 7 males and 8 females. These individuals were selected based on their self-reported experience with hand-related symptoms, primarily due to office syndrome or mild stroke, including wrist strain, muscle stiffness, and reduced grip strength. Each volunteer provided their informed consent prior to participation. During the simulation, users were guided through the system’s calibration process using a force-sensitive gripper, followed by gameplay-based rehabilitation tasks. Feedback and performance metrics collected from these sessions were used to assess system functionality and user adaptability. In particular, the User Engagement Scale (UES) was used [5]. The UES results are shown in Figure 7. Results show that the system received particularly high ratings for being rewarding, attractive, and aesthetically appealing. Users also reported strong engagement, as indicated by high scores on absorption and time distortion. Conversely, lower scores on confusion, frustration, and perceived difficulty suggest the system was generally easy to use and well-received.

5 Conclusions

In this paper, we have presented a novel hybrid rehabilitation system designed to address the challenges faced by stroke patients undergoing rehabilitation, particularly those with hand weakness. By combining the visual-motor coupling inherent in Mirror Therapy (MT) with the engaging and motivating features of gamification, our system offers an innovative solution for stroke rehabilitation. The integration of a force-sensitive resistor (FSR) into a rubber gripper provides real-time feedback, while the *Flappy Bird*-inspired game transforms repetitive exercises into interactive, enjoyable sessions.

Our initial simulations suggest that the system is both effective and engaging, providing valuable insights into the rehabilitation process. By offering a scalable, low-cost, and portable solution, we believe that our approach holds significant promise for improving patient adherence, enhancing neuroplasticity.

Future work will focus on optimising user experience by refining feedback mechanisms, conducting longitudinal studies to assess long-term efficacy, and integrating additional sensors for personalised therapy. Clinical trials will be necessary to validate the system across diverse stroke patients, and the potential for expanding the system to other rehabilitation domains will also be explored. By addressing these areas, we aim to enhance the system’s accessibility and impact in both clinical and home settings, ultimately improving stroke recovery and patient outcomes.

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