Educational Administration: Theory and Practice
2024, 30(4), 10392 - 10400
ISSN: 2148-2403
https://kuey.net/

Research Article

Skyboard – Telerehabilitation For Parkinson's Victims

Sridhar Iyer[1*], Jharana Solanki[2], Deshna Gandhi[3], Devraj Mishra[4]

[1*]Department of Computer Engineering, DJSCE Mumbai, India sridhar.iyer@djsce.ac.in
[2]Department of Computer Engineering, DJSCE Mumbai, India jharanasolanki@gmail.com
[3]Department of Computer Engineering, DJSCE Mumbai, India deshnagandhi2002@gmail.com
[4]Department of Computer Engineering, DJSCE Mumbai, India m.devraj214@gmail.com

Citation: Sridhar Iyer et.al (2024), Skyboard – Telerehabilitation For Parkinson's Victims *Educational Administration: Theory and Practice*, *30*(4), 10392 - 10400
Doi: 10.53555/kuey.v30i4.7009

ARTICLE INFO

ABSTRACT

Parkinson's disease and stroke cause debilitating motor deficits that affect millions of individuals globally. Traditional rehabilitation approaches often lack accessibility and engagement. And when they do try to adjust, it hinders patient compliance and progress. To address these problems, we developed SkyBoard, a telerehabilitation system designed to revolutionize motor function tele-physiotherapy for patients suffering from Parkinson's and stroke.

With the use of computer vision technologies like Mediapipe and OpenCV, SkyBoard provides an engaging and easy-to-use platform for remote exercises. Using a gamified interface that accurately captures their finger actions, patients do a series of aerial tracing exercises. The technology makes use of machine learning algorithms that have been trained on several datasets in order to accurately evaluate motor function levels.

The two primary SkyBoard modules, Exercises and Detection, provide a seamless development tailored to the individual needs of every patient. The Detection module has included a Spiral Wave detection technique that makes it easier for patients to draw patterns in the air. This approach to assessing motor skills improves participation and is less physically demanding.

The Exercises module was developed in collaboration with physiotherapists and provides patients with a progression of tracing exercises that become harder and harder with time. Every exercise aims to gradually increase motor skills, from basic lines to intricate and complex shapes. Moreover, SkyBoard's dual account features and advanced reporting system allow for continuous patient and healthcare provider monitoring and customized care.

SkyBoard bridges the gap between traditional rehabilitation methods and modern technology to provide a complete and holistic solution that promotes patient engagement, accessibility, and improvement in motor function rehabilitation. As engineering students, we created our idea with the goal of improving the lives of Parkinson's and stroke patients worldwide by advancing healthcare via technology.

Keywords—*telerehabilitation, Parkinson's, healthcare, OpenCV, gamification*

I. INTRODUCTION

Parkinson's disease is a neurological disorder that primarily affects the neurons in the brain that produce dopamine. One of the most common symptoms of Parkinson's disease is tremors in the fingers, which may make everyday tasks like writing, eating, and dressing extremely challenging. The bradykinesia (slowness of movement) and stiffness that often accompany these tremors further hamper in motor function.

Patients with Parkinson's disease have a challenging and ongoing rehabilitation process, particularly with regard to hand motor skills. Typically, treatment involves regular visits to physical therapy centers where patients engage in a variety of physiotherapy exercises designed to improve motor skills and decrease tremor intensity. However, this approach has several shortcomings. First of all, a lot of patients feel that having to go back for follow-up appointments is physically and financially exhausting. Second, since these facilities aren't always easily accessible, people who reside in remote areas could find it difficult to locate and visit specialized physiotherapy clinics.

Furthermore, because typical rehabilitation treatments may need specific equipment and professional supervision, patients may find it challenging to do exercises at home. Lack of options for remote rehabilitation breaks treatment continuity and makes recovery more difficult for patients. This problem is made worse by the fact that access to medical services is much more restricted during pandemics or other health crises.
Thus we introduce SkyBoard, a telerehabilitation platform designed to address these problems. Modern computer vision technology is used by SkyBoard to provide patients with a fun and gamified platform for remote physiotherapy exercise. It uses the well-known and proven Spiral Wave detection test, where patients may now draw specific patterns in the air that are then captured and analyzed by a machine learning model. This raises the engagement of the exercises and provides a more accurate assessment of motor skills. Developed in collaboration with physiotherapists, the exercises progressively increased in difficulty to support the gradual improvement of hand motor skills. With its dual account feature and extensive reporting system, SkyBoard helps patients and medical professionals in motor function rehabilitation by offering tailored treatment and continuous monitoring.

II. LITERATURE SURVEY

Telerehabilitation has advanced significantly in recent years, particularly in the field of motor function rehabilitation for those suffering from Parkinson's disease and stroke. Numerous studies have been done to study the use of technology to facilitate remote rehabilitation, with the objective of reducing the issues encountered by various patient groups. Researchers have worked to increase the accessibility, participation, and effectiveness of rehabilitation programs by using novel approaches and technological advancements. This literature review aims to bring together current research on telerehabilitation for Parkinson's disease and stroke patients, evaluating the methodology, outcomes, and implications of various technological approaches. By critically assessing the current state of knowledge, this research seeks to identify gaps, trends, and opportunities for future progress in telerehabilitation techniques tailored to the unique needs of various patient populations.
A research titled "Telerehabilitation of upper extremities with target-based games for persons with Parkinson's disease"[1] describes a novel technique to telerehabilitation that is particularly developed for Parkinson's disease patients. The research focuses on the rehabilitation of upper extremities, which are often significantly impaired in Parkinson's patients, resulting in problems completing everyday tasks.
The system created in this research takes use of the notion of gamification, which is the use of game-design aspects in non-game situations. Gamification has been found to improve motivation and participation in a variety of settings, including rehabilitation.
This system tracks patient movements using a Kinect™ sensor. Microsoft created the Kinect™, a motion-sensing input device for the Xbox 360 platform. It allows users to operate and interact with the system without the need of a typical handheld controller, instead employing a natural user interface based on gestures and spoken directions.
The study "An Exploration of Motion Tracking and Gamification in Telerehabilitation for Stroke Survivors"[2] looks at the possibility of motion tracking and gamification in telerehabilitation. The authors see the main concern with any virtual system as the possibility for patients to get demotivated, especially in a home-based system with little human interaction.
The research investigates presently existing telerehabilitation systems and finds common concerns, such as restrictions in patient-therapist communication and the use of gamification to inspire stroke patients. The authors suggest a cloud-based approach that would enable therapists and patients to communicate and observe in real-time.
The study's purpose is to propose the concept of a telerehabilitation system with a communication module and gamification elements. The authors feel that such a method might solve the concerns outlined while also improving stroke patients' recovery.
The paper "Parkinson's Disease Detection from Spiral and Wave Drawings using Convolutional Neural Networks: A Multistage Classifier Approach"[3] describes a revolutionary approach for detecting Parkinson's disease. The technology is intended to assess spiral and wave drawing patterns in Parkinson's disease sufferers and healthy individuals.
The authors use two separate convolutional neural networks (CNNs) to analyze both spiral and wave drawings. CNNs are a kind of deep learning model that has shown exceptional performance in fields such as image identification and classification.
The prediction probabilities are learned using a meta classifier that uses ensemble voting to produce a weighted prediction from both the spiral and wave sketches. Ensemble approaches combine numerous learning algorithms to provide higher prediction performance than any of the individual learning algorithms.
The system was trained on 55 patients' data and obtained an overall accuracy of 93.3%, an average recall of 94%, an average precision of 93.5%, and a mean F1 score of 93.94%. These findings highlight the promise of sophisticated machine learning approaches for the early diagnosis of Parkinson's disease.
The research "A Remote Rehabilitation Training System Using Virtual Reality"[4] describes an innovative way to rehabilitation, especially for those who have sports injuries, mobility and balance difficulties, or are

recuperating from an injury. The authors see the need for a more accessible and cost-effective alternative to existing rehabilitation approaches, which often include patients visiting specialist facilities and using expert gait and balance analysis equipment.
In answer to this demand, the authors suggest a homebased rehabilitation system based on Virtual Reality (VR). The system includes a human-like Virtual Coach, which provides an interactive and engaging platform for patients to complete their workouts. Doctors determine the workouts, offering a tailored approach that addresses each patient's unique requirements and development.
The study "Remote Monitoring of Physical Rehabilitation of Stroke Patients Using IoT and Virtual Reality"[5] describes an innovative technique to stroke rehabilitation. The authors suggest a method for remotely monitoring stroke patients' physical rehabilitation using Internet of Things (IoT) and Virtual Reality (VR) technology.
The approach is intended to increase patient participation during physical therapy while also assessing their progress. It monitors using VR-based serious games and a Wearable Sensor Network. Serious games based on various VR environments enable individuals with motor impairments to undertake exercises in a very engaging and non-intrusive manner.
Wearable gadgets help to motivate patients throughout rehabilitation, making the activities more enjoyable. The system also has elements for creating thorough progress reports, which may assist patients personalize their activities and obtain greater rehabilitation outcomes in less time.

TABLE 1. Summary of existing studies

Sr. No.	Paper	Features	Limitations
1.	Telerehabilitation of upper extremities with target based games for persons with Parkinson's disease.	The paper utilizes a Kinect™ sensor for gamified physiotherapy of upper extremities in Parkinson's patients.	The application is limited to upper extremities and requires a Kinect™ sensor.
2.	An Exploration of Motion Tracking and Gamification in Telerehabilitation for Stroke Survivors	The paper proposes a cloud-based solution for real-time observation and communication between therapists and patients.	The paper lacks implementation details and focuses more on the proposal.
3.	Parkinson's Disease Detection from Spiral and Wave Drawings using Convolutional Neural Networks: A Multistage Classifier Approach	The paper uses two different convolutional neural networks (CNNs) for analyzing spiral and wave sketches.	The system is limited to spiral and wave sketches and requires CNNs.
4.	A remote rehabilitation training system using Virtual Reality	The paper proposes a VRbased system with a humanlike Virtual Coach for home-based rehabilitation.	The system requires VR equipment and is limited to certain types of exercises.
5.	Remote Monitoring of Physical Rehabilitation of Stroke Patients Using IoT and Virtual Reality	The paper combines IoT and VR for remote monitoring of physical rehabilitation of stroke patients.	The system is limited to stroke patients and requires IoT and VR technologies.

III. PROBLEM STATEMENT

Parkinson's disease patients' rehabilitation, especially in terms of hand motor function, is a complicated and continuing process. It usually entails frequent visits to physiotherapy centers, where patients participate in a series of exercises aimed at improving motor skills and reducing the intensity of tremors. However, this method has several drawbacks. For example, repeated visits may be physically and financially taxing for many patients. Second, the availability and accessibility of specialist physiotherapy clinics varies by location, making it difficult for people who live in rural places.
Furthermore, typical rehabilitation procedures generally need particular equipment and expert supervision, making it difficult for patients to conduct exercises at home. The absence of home-based rehabilitation

alternatives disrupts continuity of treatment and impedes patients' recovery. The issue worsens as access to healthcare facilities is more limited.
A survey of the literature suggests that telerehabilitation systems face new obstacles nowadays. Some modern technologies, such as Kinect™ sensors, Virtual Reality (VR), and Internet of Things (IoT), need specialist equipment, restricting their accessibility. Furthermore, many of these systems concentrate on certain kinds of exercises or are restricted to specific patient categories.
Some systems, for example, are solely intended for upper extremity use or are confined to stroke victims. Furthermore, although some systems provide cloud-based solutions for real-time observation and communication between therapists and patients, they often lack implementation information.
These constraints highlight the need for a complete, userfriendly, efficient telerehabilitation system that solves these issues.

IV. PROPOSED SOLUTION

We propose SkyBoard, an innovative telerehabilitation system developed to overcome the obstacles that Parkinson's patients confront throughout their rehabilitation. SkyBoard uses effective computer vision and machine learning to provide a unique and effective platform for home-based rehabilitation. The system is intended for improving hand motor capabilities via a series of gamified exercises, while also allowing for continuous monitoring of patient progression. [Fig. 1] displays the proposed architecture of SkyBoard.

Fig. 1. Proposed Architecture

SkyBoard was designed with a dual login system that supports two separate user roles: patients and doctors. Patients can access the system's detection and exercise modules via their login. This enables users to perform exercises, track their progress, and earn coins, resulting in an interactive and motivating platform that encourages patients to regularly engage in their rehabilitation process.
Doctors can use their specific login to monitor the progress of their patients. They can see detailed reports, assign exercises depending on each patient's necessities and capabilities, and provide customized treatment.
This function enables constant monitoring and allows for good communication between doctors and patients, which provides a holistic rehabilitation process.

A. Patient's Login

1) Detection Module

The first module in the patient's login of SkyBoard is the detection module. This module employs the well-known Spiral Wave test [6] for detecting Parkinson's disease. The Spiral Wave test is a rigorous motor assessment used to detect early Parkinson's symptoms. The patient draws a spiral or a wave, and the characteristics of this drawing, such as speed and precision, could indicate Parkinson's disease.
In SkyBoard, we have made important modifications to the traditional Spiral Wave Test. Patients can trace the spiral and wave in the air rather than sketch on a paper. This is made feasible by using OpenCV, a powerful real-time computer vision library. OpenCV watches the movement of the patient's finger in real time, capturing the pattern as it is drawn in the air.
Once the trace is captured, it is processed by a well-trained machine learning model. This model was developed using a huge dataset of spiral and wave drawings from both healthy and Parkinson's patients. It examines the qualities of the patient's drawing to see whether they match to the patterns often found in Parkinson patients [7].
If the model discovers patterns that suggest Parkinson's disease, it tells the user and urges them to see a doctor for additional testing. This early detection system has the potential to greatly improve the prognosis and treatment of Parkinson's disease by allowing for prompt interventions.

2) Exercise Module

The second module in the patient's login of SkyBoard is the exercises module. This module is intended to assist patients improve their motor control via a series of shape exercises. These exercises are specially allocated to each patient by their doctor, enabling a more customized approach to rehabilitation.

The exercises are designed in collaboration with physiotherapists and include tracing shapes such as a line, rectangle, triangle, and circle. As patients' abilities improve, the exercises might become increasingly challenging, creating an overall challenge that promotes in the steady development of motor control.

SkyBoard's distinguishing feature is the gamification of these exercises. Patients get coins for completing exercises and sustaining regular activity streaks. These coins may be redeemed for real-world coupons and vouchers, providing incentive and reward throughout the recovery process.

During the exercises, the speed and accuracy of tracing will be assessed. The system also verifies that the shape is being traced correctly. These metrics give essential information about the patient's growth and assist in the ongoing evaluation of their motor abilities. Gradual gains in tracing speed and accuracy suggest improved motor control, which is an important goal of the rehabilitation process.

B. Doctor's Login

The doctor's login in SkyBoard is meant to make easier the duties of medical professionals in the rehabilitation process. Doctors can recommend specific exercises for patients depending on their diagnosis and present health. This individualized approach guarantees that each patient gets a rehabilitation plan that is suited to their individual requirements and ability.

Once the exercises are prescribed, physicians may track the patient's progression via the system. SkyBoard offers thorough reports that give information about the patient's performance in the workouts. These reports track crucial parameters such as tracing speed and accuracy, traced shape accuracy, and overall motor control improvement. This data enables doctors to monitor the patient's progress over time and alter the rehabilitation plan as necessary.

Furthermore, SkyBoard's reports can be a useful tool for communicating with doctors and patients. They serve as a foundation for reviewing the patient's development, solving any obstacles or problems, and establishing objectives for future improvement. SkyBoard's constant monitoring and individualized treatment make it a full platform for motor function rehabilitation.

The Data Flow Diagram (DFD) Level 0 [Fig. 2.] gives a high-level overview of the SkyBoard system. It depicts how the system communicates with its two primary external objects: patients and doctors.

Patients connect with SkyBoard in a variety of ways. They can register or log onto the system. They may do exercises and detections after logging in. The data from these actions is sent to SkyBoard for processing. Doctors can register or log on to SkyBoard. They can generate reports using data gathered from the patients' exercises.

SkyBoard is the core system for processing all information. It monitors the correctness of the tracings from the patients' exercises and detection and records it in a database. The database stores all of the data. It gets feedback from SkyBoard on the accuracy of the patients' exercises and detections.

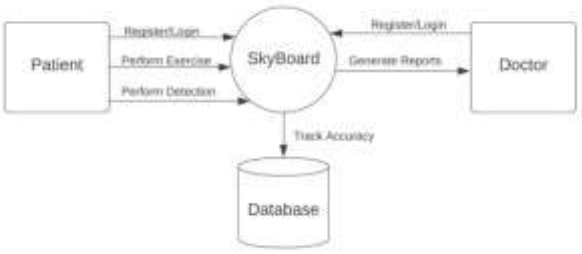

Fig. 2. DFD Level 0

This DFD Model 0 gives a general overview of the SkyBoard system, demonstrating how data flows between it and its surroundings.

The Data Flow Diagram (DFD) Level 1 [Fig. 3.] provides a more thorough picture of the SkyBoard system. It divides the system into its primary processes and displays how data flows between them.

The patient logs into the system using their login information. The login module validates the credentials and provides the patient access to the system.

Once logged in, the patient is allowed to start the exercises. The system captures and stores data from these exercises, such as tracing speed and accuracy, in the database. The patient can also perform detection. The system collects data from various detections, such as spiral tracing, and utilizes OpenCV to analyze them. The processed data is then sent into a machine learning model, which analyzes it and evaluates if it fits the patterns often seen in Parkinson's patients. The findings of it are saved in a database.

The database stores all of the exercise and detection data. It collects information from both the exercises and the detection procedures and saves it for later use.

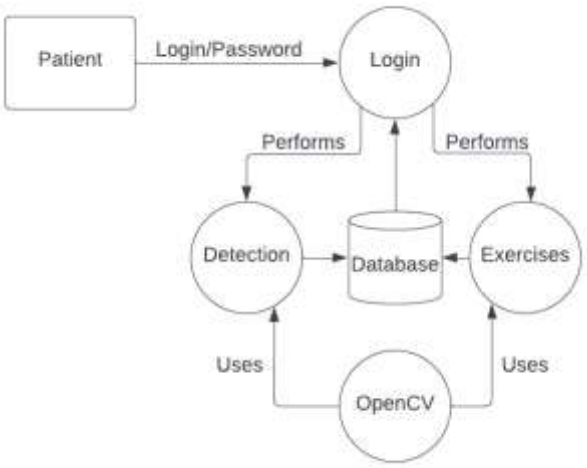

Fig. 3. DFD Level 1

A thorough overview of the SkyBoard system is given by this DFD Model 1, which illustrates the many ways in which data is altered and processed throughout its transition between processes.

V. IMPLEMENTATION

Finally, SkyBoard is developed with the proposed features. These features are an apt solution to tackle the current problems that are predominant in the current healthcare system. We aim to provide a holistic and easy-touse platform that anyone can use from anywhere.

The user interface is made simple and to the point to extract the highest point of efficiency. Such that the patients don't face any trouble in beginning their detection or performing exercises every day. The added gamification features also make it engaging and interactive to use.

Fig. 4. Home Page

The detection page has a singular important card that starts the Spiral-Wave test that helps patients as well as normal users test whether they have the symptoms of Parkinson's. The Spiral Wave Test captures the tracing of the finger when the user begins to draw the spiral and ends when they reach the ending point. The user can also restart or cancel the test while performing it. The tracing is recorded and passed through the ML model to classify and predict. Once symptoms of Parkinson's are found, the doctor can assign exercises [Fig. 5.] to the patients. The doctor can choose which exercises the patient needs and accordingly assign a specific count for each exercise. The doctor can assign the number of days the exercises needs to be performed as well as the number of times it should be performed per day. This determines the level of rigor needed to improve the patients condition.

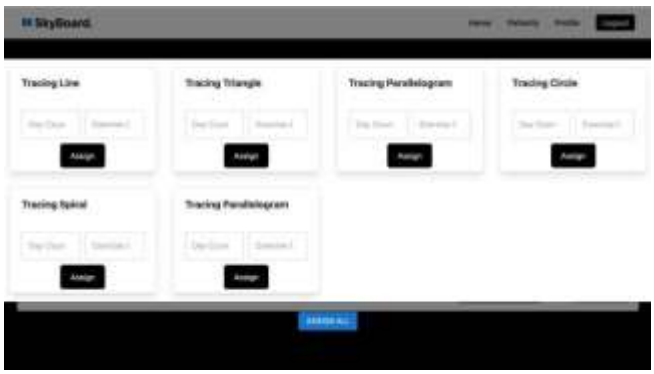

Fig. 5. Assign Exercises

The Exercises page [Fig. 6.] will display the specific exercises assigned by the doctor that the patient has to perform for their rehabilitation. These exercises are assigned only by the specific doctor who will be monitoring the logged in patient. The patient will be able to maintain a streak by performing these exercises. A streak is the count of continuous days on which the patient has performed exercises consistently. This is a gamified way for patients to be motivated. The patient can keep track of their daily exercise progress by looking at the progress bar for each individual exercise.

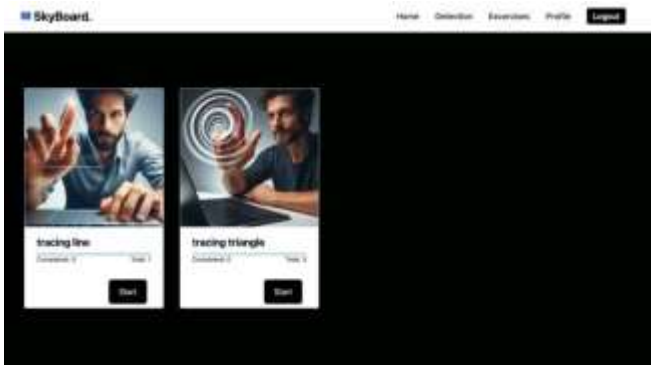

Fig. 6. Exercises Page

When beginning to perform a specific exercise, like the Rectangle Tracing in [Fig. 7.], the system will start detecting the drawing only once the user has begun drawing. It is careful to not start immediate trace recording. The tracing will stop when the patient reaches end point. The system will constantly be checking for the accuracy and speed of the patient and keep monitoring for progress.

Fig. 7. Rectangle Exercise

Lastly, the doctor will be able to look at the detailed progress of their patients in the Reports page [Fig. 8.]. They will be able to see the continuous progress and if the patients are performing well or not in the exercises. The doctor can then understand from the data collected on how to move ahead with their treatment. This will bring technological advancements to a manual and offline process.

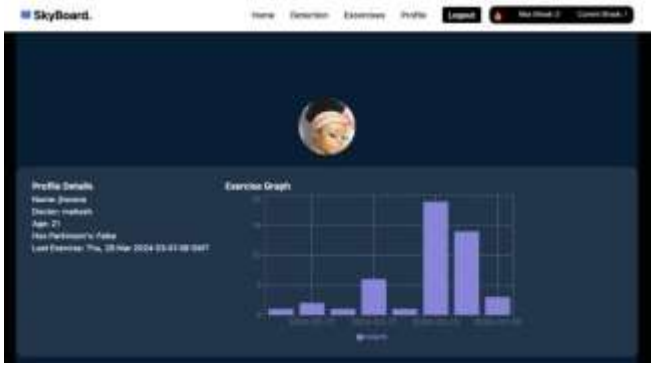

Fig. 8. Reports Page

SkyBoard has been developed to help both the patients and doctors in making the treatment process easier and accessible to everyone.

VI. CONCLUSION

SkyBoard is an innovative approach to hand motor therapy that uses cutting-edge technology to improve patient treatment. It uses OpenCV and MediaPipe, two powerful computer vision to assist tele-rehabilitation. This enables people with motor function deficiencies to do exercises and assessments in the comfort of their own homes, increasing accessibility and convenience.
SkyBoard's design is precise and patient-oriented. It uses powerful machine learning algorithms for symptom detection, allowing the system to personalize exercises to each patient's own rehabilitation route. This individualized approach differs significantly from typical rehabilitation procedures, which are frequently more expansive. Furthermore, SkyBoard gives detailed feedback and progress updates. These insights benefit both patients and physiotherapists, fostering a collaborative and informed therapy experience. The device also offers an interactive atmosphere, encouraging patients to utilize SkyBoard on a daily basisi for therapy. The inclusion of coins and coupons adds a gamification aspect to the training experience, making it more engaging and fun.

SkyBoard is more than a technology innovation; it symbolizes the future of digital health solutions. It demonstrates how technology may be used to enhance healthcare results and patient experiences. SkyBoard contributes to the democratization of healthcare by making rehabilitation more accessible and customizable.
The initiative's patient-centered design and commitment to improving rehabilitation results are expected to reshape the future of rehabilitative care. SkyBoard is creating a new standard for healthcare innovation and patient empowerment by showing how technology can be utilized to provide more effective, customized, and patient-centered care. This is consistent with wider trends in the healthcare industry, which is increasingly using technology to enhance patient outcomes and experiences. SkyBoard is not only transforming the way we approach rehabilitation, but also influencing the future of healthcare.

REFERENCES

[1] Cikajlo et al., "Telerehabilitation of upper extremities with target based games for persons with Parkinson's disease," 2017 International Conference on Virtual Rehabilitation (ICVR), Montreal, QC, Canada, 2017, pp. 1-2, doi: 10.1109/ICVR.2017.8007466.
[2] A. Islam, J. Y. Qi, M. T. K. Tsun and L. B. Theng, "An Exploration of Motion Tracking and Gamification in Telerehabilitation for Stroke Survivors," 2020 IEEE 8th R10 Humanitarian Technology Conference (R10-HTC), Kuching, Malaysia, 2020, pp. 1-6, doi: 10.1109/R10-HTC49770.2020.9356992.
[3] S. Chakraborty, S. Aich, Jong-Seong-Sim, E. Han, J. Park and H. -C. Kim, "Parkinson's Disease Detection from Spiral and Wave Drawings using Convolutional Neural Networks: A Multistage Classifier Approach," 2020 22nd International Conference on Advanced Communication Technology (ICACT), Phoenix Park, Korea (South), 2020, pp. 298-303, doi: 10.23919/ICACT48636.2020.9061497.
[4] C. Georgiadis et al., "A remote rehabilitation training system using Virtual Reality," 2021 6th South-East Europe Design Automation, Computer Engineering, Computer Networks and Social Media Conference (SEEDA-CECNSM), Preveza, Greece, 2021, pp. 1-4, doi: 10.1109/SEEDA-CECNSM53056.2021.9566227.
[5] O. Postolache, D. J. Hemanth, R. Alexandre, D. Gupta, O. Geman and A. Khanna, "Remote Monitoring of Physical Rehabilitation of Stroke Patients Using IoT and Virtual Reality," in IEEE Journal on Selected Areas in Communications, vol. 39, no. 2, pp. 562-573, Feb. 2021, doi: 10.1109/JSAC.2020.3020600.
[6] A. Rosebrock, “Detecting parkinson’s disease with opencv, computer vision, and the Spiral/Wave Test,” PyImageSearch, https://pyimagesearch.com/2019/04/29/detecting-parkinsons-diseasewith-opencv-computer-vision-and-the-spiral-wave-test/ (accessed Feb. 27, 2024).

[7] S. Chakraborty *et al.*, “Parkinson’s disease detection from spiral and wave drawings using convolutional neural networks: A multistage classifier approach,” *2020 22nd International Conference on Advanced Communication Technology (ICACT)*, Feb. 2020. doi:10.23919/icact48636.2020.9061497

[8] M. F. Allebawi et al., “Parkinson’s disease detection from online handwriting based on beta-elliptical approach and fuzzy perceptual detector,” IEEE Access, vol. 12, pp. 56936–56950, 2024. doi:10.1109/access.2024.3387342

[9] J. A. Stamford, P. N. Schmidt and K. E. Friedl, "What Engineering Technology Could Do for Quality of Life in Parkinson's Disease: A Review of Current Needs and Opportunities," in IEEE Journal of Biomedical and Health Informatics, vol. 19, no. 6, pp. 1862-1872, Nov. 2015, doi: 10.1109/JBHI.2015.2464354.

[10] J.M.P. Bank et al., "Optical Hand Tracking: A Novel Technique for the Assessment of Bradykinesia in Parkinson's Disease", Mov. Disord. Clin. Pract., vol. 4, pp. 875-883, 2017.