# Real-Time AI-Powered Platforms for Managing Patient Rehabilitation Programs

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### 1.1. Background and Significance

Patient rehabilitation is essential due to the high rate of injuries, both temporary and chronic, in everyday life. There is a significant market gap related to both disease and therapy management capabilities of existing applications currently used. Therefore, there is a growing trend in the search for technological platforms for rehabilitation from computer science perspectives, using sensors and computing algorithms to manage patient therapies. These platforms should allow the user to define, manage, and monitor multiple rehabilitation sessions, with support and detailed guidance, helping their recovery and improving their lifestyle. Furthermore, the industrial point of view is also of great importance, due to the composition of the current industry being mainly small and medium-sized companies. The use of projects and technological consortiums financed by the government allows companies that do not have specialization in the area to invest in technological development.

On the other hand, from the research perspective, the unit of the human body affected should be considered; that is, to treat the human body as a unique sensor with a specific quantity of degrees of freedom, composed of a finite number of degrees of freedom linked by chains. Therefore, considering a patient in a rehabilitation process, some of the most important parameters to be monitored are those related to kinetic (forces) and kinematic aspects (displacement, velocity, acceleration) of its member movements. Typically, 3D accelerometers, either alone at fixed points of the segments of interest in combination with suitable algorithms for joint angle estimation, or in pairs at a particular joint in combination with suitable algorithms for the estimation of joint forces, are employed for this purpose. Constraint-based force estimation algorithms rely on a number of available acceleration data, usually being limited to available accelerometers. That is, the monitored body must be equipped with a relatively large number of accelerometer nodes, either fixed or mobile.

### 1.2. Purpose of the Study

Although many AI platforms are developed to support rehabilitation programs for various pathologies and with different rehabilitation equipment or robots, none of them has been truly realized and practically proven to be successful. The objective of this study is to develop a practical and real-time AI-powered software platform for managing patient rehabilitation programs within hospital settings. Our design focuses mainly on gait rehabilitation for post-stroke patients, and the platform could also be researched to validate its effectiveness for other patients with gait impairments caused by other diseases. Compared with existing platforms, the development of our platform is more likely to be practical and has economic interests due to the introduction of AI technology related to the gait rehabilitation process for patients recovering from post-stroke therapy. Providing evidence for its practical realization and economic efficiency is part of our further work.

## 2. AI in Healthcare

Healthcare is one of the largest, most complex industries in the worldwide economy. Contemporary health systems demand a high level of expertise for delivering a wide set of interrelated tasks. Initially, for example, the physician diagnoses a new patient using elaborate health data in the form of computerized tomography scans or electrocardiogram images. Next, the same doctor should consult those health records to collect and analyze the patient's history and perform the necessary laboratory tests. After estimating the patient's diagnosis and predicting other diseases, the physician should also consider all relevant patient information, draw up a treatment plan (remoteness and localization of essential disease formations, value of biological tissue, etc.), and adjust that treatment. In short, the doctor needs to interpret extremely diverse forms of knowledge, often from incomplete information. In addition, the doctor must be aware of and react to a possible array of adverse effects that may occur during treatment, interpret elaborate physiological signals, and actively engage with the family, employment, food, and health precautions of the patient in order to reduce or avoid impairments.

While the human body often produces clues such as bruises, blood pressure, respiratory rate, body temperature, and changing physiological data, diagnosis using advanced sensor technologies is one of the areas where recent intelligent systems focused on human health can present valuable and increasingly powerful contributions. Digital data science reveals the drastic possibilities for chronic, pandemic, and acute health administration. Knowledge must be acquired from various sources, including evidence-based knowledge derived from research data, applied knowledge acquired from treatment experience with a particular patient, and singular knowledge understood and recorded from explicit patient narratives via the practitioner. These three knowledge sources differ in terms of evidence diagrams, storage and access, and patient engagement and preferences data. When designing a new treatment plan, patient information aims to encourage the collaboration of medical professionals and to adhere to current practice guidelines. Managing their rehabilitation programs, the main aim of this study is the introduction of an innovative AI-based platform.

### 2.1. Overview of AI Applications in Healthcare

The value of AI in healthcare is now widely recognized. AI has the potential to improve patient outcomes by enhancing the accuracy of diagnosis and treatment and by driving efficiencies in healthcare service delivery. It can also support new research and treatment paradigms and lead to broader market changes in healthcare. Intelligent systems are already demonstrating impressive improvements in diagnosis and treatment through rapid synthesis and interpretation of vast amounts of clinical information.

The device is capable of diagnosing diabetic retinopathy in under 30 seconds and was trained using a large number of retina images. AI has the potential to significantly alter the cost and delivery of healthcare services. Ambulatory monitoring and personalization can grow to unprecedented levels through real-time physiological status tracking and feedback convergence, and ambulatory care will become truly personal. Such personalized approaches can deliver a new level of user experience in several areas. First, a high level of personalization can be provided at minimal marginal cost. Second, the accuracy and stability of the services will increase significantly.

The accuracy of consumer health devices has become more and more precise over time, and these devices have significantly improved in terms of their recognition performance. Although physiological sensing was previously reserved for use in hospital environments with high-quality clinical equipment, the complexity and costs associated with signal processing, machine learning algorithms, and feature extraction have decreased significantly. Among others, some technologies that have greatly democratized signal processing and machine learning approaches are the continuation of advancements in technology, increased ubiquity of biometrics, and increased exposure to AI through the use of related technologies such as cloud computing. Additionally, there is significant democratization of AI technology in diverse healthcare applications.

**2.2. Benefits and Challenges of Implementing AI in Rehabilitation Programs**

The main benefit of a personalized, precision AI-powered platform is the ability to optimize rehabilitation paths for individual patients to ensure maximal recovery to the highest attainable functional state. This can be achieved by enabling the repository of large sets of interaction data among the system components that cover all aspects of the patient's condition. AI models can then learn preferences in terms of the medical state, physical and social surroundings, administrative limitations, as well as subjective mental state goals of the patient, while satisfying established medical constraints. An eventual goal could be designing a therapy that would be perceived by the patient as activity, fun, or engaging, so that they remain motivated to achieve rehabilitation program objectives. This would help in more accurately recovering patient sensory-motor patterns and anticipating the patient's recovery to the maximum attainable state.

To achieve these goals, specialized interventions for each patient could be generated by the AI models that would combine a set of exercise programs by prescribing specialized exercise preparation activities to the patient assistance tools, and adapting those with changing patient rehabilitation dynamics. The control algorithms need to be robust to varied adaptation levels of the patients, as well as to the convergence of optimization objectives, objective disruptions, or new knowledge emerging in real-time, which may be a result of comorbidities, additional tests, or patient preferences and beliefs.

**3. Rehabilitation Programs and Patient Management**

This study provides detailed information about the rehabilitation concepts, patient management, and the patient rehabilitation programs. The model for the intelligent patient rehabilitation management system is an ideal management model. The basis for the patient management model is the rehabilitation program model. The quality of implementation of the rehabilitation programs for brain-damaged and orthopedically impaired patients is determined by the development and implementation of protocols, guidelines, and algorithms. These patient programs or patient treatments usually follow the same steps or processes that result in the same performance or results. These programs have similar and positive track records, ultimately ensuring similar successful treatments and outcomes. In the different rehabilitation programs, the different patient functions are the application of different treatment modalities. These rehabilitation programs usually respond well to task-related physical therapy methods. These programs use functional treatment activities to enhance the ability of the patients to adapt to the deficits and to enhance their life-functioning abilities. The patient rehabilitation programs focus on independent living within the environment, participating in home and community life, productive work, and education as much as possible. The rehabilitation disciplines are available along with the general treatments. The patient's schedule is made according to the schedule of the physicians, availability of staff, and the patient's number. Their treatments must be meaningful, and abilities to achieve successful treatment programs. The offer enables the patient to accomplish their immediate physical and social environments.

### 3.1. Key Components of Rehabilitation Programs

Rehabilitation programs are vital for patients' recovery and are part of the holistic approach to health preservation and improvement. Conditions vary from mobility and functional limitations, pain, weakness, and neurological impairments to patients with different mental illnesses, trauma, or injury to some distinct body parts. The key goal of these programs is not just immediate patient recovery but establishing improved adaptation to chronic health conditions and limitations. Thus, a serious emphasis of such programs is reviving and improving body abilities and functions that contribute to cognition, mobility, and mental health. This approach is also known as compassionate, patient-centered, and outcome-based, and it leads to the seamless integration of medical and other treatments with long-term self-care strategies.

Rehabilitation programs consist of a few features: built-in solid theories and methods, the ability to respond to well-defined patient needs, direct applicability at the clinical bed, and adaptability to the possibilities for effective implementation of assistive technologies. In terms of methods, multi-sensory stimulation stands as a pearl of non-pharmacological intervention. While sensors, wearables, and mobile applications grant active knowledge of the day-to-day patient state, they also provide faster, reliable monitoring and feedback compared to traditional methods. Even machine learning models can predict patient states and suggest optimal interventions, significantly increasing efficiency and ensuring precise dose-response relationships.

### 3.2. Importance of Personalized Therapy Plans

While not all AI-supported rehabilitation systems are personalized, a desired ideal outcome of their use is personalized therapy plans that consider individual patient-related factors. This ought to be highly motivating considering the large variability in patient profiles and available resources. In the context of cardiac patients, the patient's age, gender, comorbidities, and risk factors for developing coronary heart disease are all important. For example, physiotherapy is customized by available equipment, heart rate, patient health, and their tolerance to physical activity. Medical treatment plans, such as drug prescriptions and doses, scheduled examinations, and monitoring frequency need to be personalized.

A system that carefully considers the patient's individual needs and circumstances is required to maximize the potential improvements in that patient's quality of life. Given the lack of skilled physiotherapists and the few hours that each human expert has to spend with patients every day, AI-supported systems are not merely a means of addressing the shortage of skilled individuals in this field. They are a solution that will provide valuable rehabilitation care for all patients from anywhere, regardless of their therapeutic objectives and the resources available, and will do so in a way that best meets their individual needs, while at the same time guiding, automating, and optimizing patient care.

## 4. Utilizing Machine Learning in Rehabilitation Programs

Rehabilitation programs, particularly those aiming at cognitive enhancement, need to provide personalized care. The amount, type, and intensity of therapeutic activities need to be tuned to the individual patient's preferences and capabilities. Considering patient preferences when they are available is of great importance for maintaining engagement in therapeutic activities and motivation—two primary factors known to facilitate a successful rehabilitation process. Quantifying and taking into account such patient preferences in the context of rehabilitation and customizing patient-specific recovery curves requires a large amount of patient recovery data. Such data could then be used to forecast recovery as a whole and to plan and personalize individual patients' therapeutic programs.

Over the last decade, current technology and the rise of the do-it-yourself movement have engaged millions of people in various daily life activities that were not possible or considerably hard to perform on their own. It has improved care and quality of life for patients, involved them in empirical scenario-driven studies of various patient and patient-environment mediators, increased the amount of data, and enriched people's understanding of the phenomena. All of these activities co-shaped yet another revolution in psychiatry and neurorehabilitation—the era of smart assistive technology for patient rehabilitation.

Using machine learning when developing smart rehabilitation situational awareness technologies is a promising approach to extract actionable knowledge from a vast amount of routine home monitoring data. These days, the interest in advanced rehabilitation technologies has been rising as never before. The initial push for their development came from natural disasters, healthcare, and military service stakeholders, aiming to significantly improve care for increasing numbers of TBI survivors. The ensuing popularity and wide acceptance of commercial and DIY unobtrusive wearable biomedical devices have caused the attention devoted to technology-driven patient care to significantly expand: e.g., from hospital-to-home supportive care, rehabilitation on demand and in real life, and technology-enabled resilience, to maintaining the quality of people's lifestyles despite disability.

Each of those stakeholders shares concerns about RMT and neurohabilitation programs, among which are personalization, objective monitoring in both hospital and home settings, early intervention for maximum effect, reinforcing accomplishments out of the comfort zone, maintenance, and individual protection from secondary blows. In this context, we present and discuss several examples demonstrating how artificial intelligence is employed in smart patient rehabilitation platforms to address those concerns.

**4.1. Machine Learning Techniques for Tailoring Therapy Plans**

The developed AI-based system is capable of providing preliminary estimations of hard clinical outcomes for therapy plans that are developed and modified during the early recovery periods. Such a task of building optimal therapy programs for upper limb rehabilitation is formulated and solved by using dimensionality reduction, feature selection, and optimization techniques. The model is trained using rehabilitation therapy plans. A novel framework has been developed to tailor the therapy program for the rehabilitation of the shoulder and elbow of the patients, continuously monitoring the patients' recovery and the capability of generating tailored programs at the clinic during the chatting sessions. The trials conducted on actual subjects have shown that the proposed framework generated efficient therapy plans and also indicated quicker recovery after completion.

### 4.2. Real-Time Monitoring of Recovery Progress

Providing patients with access to information and detailed guidance in real time during their rehabilitation process is crucial, as it not only addresses patients' uncertainty but also boosts their compliance. Furthermore, continuous monitoring of the patient's recovery progress allows the exercise pattern to be tailored and optimized on a regular basis. The obtained rehabilitation program can be improved by monitoring the patient's recovery progress in real time, while taking into account the challenges occurring in the course of daily life, as well as potential changes in the patient's condition. This is important, as the patient's progression, or lack thereof, has implications for the treatment efficacy and the patient's readiness to return to work or other activities, such as specific sports or hobbies. It might also help to reveal specific issues that are not addressed in general exercise programs and could even provide insights that help narrow down a diagnosis if the patient's full clinical history is not known.

If a patient during a training session indicates on a visual analogue scale that they are in severe pain in a specific area of the ankle or leg and seems to have trouble completing or demonstrating an exercise, this information could raise the rehabilitation professional's interest and encourage them to coach the patient or interpret the exercises differently. This information is complementary to patient-reported outcomes, which are typically collected at specific time points, such as at the start or the end of a particular rehabilitation phase. It helps to understand the emotional state of the patient and to optimize their intrinsic motivation, who might, for instance, indicate anxiety at the sight of a particular exercise due to fear of failure or pain. Another benefit is that this biofeedback tool enables the rehabilitation professional to detect and correct incorrect exercise execution.

## 5. Case Studies and Success Stories

As previously discussed, rehabilitation is a crucial part of the treatment plan for illnesses, injuries, and surgeries. Its impact can guarantee a patient's return to full activity, as well as their recovery speed, physical function, and quality of life. Evidently, many healthcare professionals consider rehabilitation a discipline as essential, complex, and interdisciplinary as the area of care that received that patient. Despite its importance, access to personalized, professional, evidence-based rehabilitation is restricted by geographical, financial, and knowledge distribution boundaries, or other barriers in healthcare ecosystems, such as time, fatigue, and transportation. As a result, suboptimal adherence to guidelines, high variability in care, and, as a result, variability in efficacy, effectiveness, safety, and quality of care can compromise patient outcomes.

The use of applications that guide patients in rehabilitation exercises, instead of common video-based practice, can help patients adhere to their rehabilitation exercises, realize their potential outcomes, and in some cases be an option for combining therapy and prevention with rehabilitation, without the need to further burden healthcare systems. When combined with principles of artificial intelligence, games, and other behavior change strategies, the potential and impact of health exercises can grow even more. Established quickly and consolidated during the pandemic, digital platforms began to be used by professionals and patients to maintain follow-up, enabling distant specific orientation, exercise, and self-management. Such platforms have the potential to facilitate decision support, tracking, measurement, information sharing, home telemonitoring, and remote physical therapy interventions. This chapter introduces two such developments and shares the respective preliminary outcomes from interventions.

**5.1. Impact of AI-Powered Platforms on Patient Outcomes**

The most important measure of any treatment or intervention in medicine is the impact on patients. Real-time, AI-powered platforms used to improve outcomes from rehabilitation programs are no different. Strong outcomes correlate with enhanced patient satisfaction, reports of progress, and, importantly, lower-cost health care. For many health care interventions, the cost-effectiveness of the intervention is the dominant feature. New AI-driven technologies and platforms inherently improve both the effectiveness and cost-effectiveness of patient rehabilitation compared to current practice. Automated, real-time, AI-driven technologies create opportunities for precision health care, personalizing a solution to the individual patient at hand to positively impact outcomes and lower costs across civilizations, describing an opportunity for a global solution to patient management challenges. These platforms also allow for near-universal capacity in terms of patients served. Platforms are not distracted by other activities such as non-clinical reviews of analytic data.

Efficient platform interactions typically occur on mobile platforms, producing automated documentation suitable for review and modification by the patient's health care providers, ensuring a continuously accurate ante- and post-operative orientation to the patient's evolving status with an embedded capacity to lead to proactive and reliable care.

**5.2. Lessons Learned and Future Directions**

Over the course of several years, we learned the following: Many patients are not compliant with the exercises and do not follow their program as prescribed. Typically, these patients require more positive feedback and motivation to continue the exercises, as well as different learning techniques to understand them. Some patients appeared confused with the video of the exercises, reverted to suboptimal compensatory movements, or required the physical presence of a human to correct them. After many reminders about the working-from-home modalities, we discovered the patient was not using the technology properly to update his progress. Technology networking issues and system checks required significant attention. The technology for measuring the patient's performance of the exercises worked as described and supported efficient monitoring of the patient's adherence and progress.

There was no clinical staff overload with the program. Critical for patient recidivism, patients were reimbursed for using the technology. Since this technique was relatively costly for the hospitals, it became difficult to locate hospitals to host the patients on the technology. The real-time technology reduced human costs and operated to limit direct in-hospital patient participation to only a few minutes per week. Currently, the learning mode is developed ad hoc by the physical therapist, and the system learns via the cloud. The algorithm to recognize exercises involves first a verification of the correctness of the performed posture with the target posture, then a verification of the correctness of the performed movement, and finally of the coordination between a performed posture and performed movement.

**6. Future Conclusion**

There is a crucial lifetime window of post-neurological injury or neurodegenerative disease that appears to be associated with a period of augmented neural plasticity. An opportunity window for accelerated rehabilitation of about 6 to 8 weeks may contribute to considerably enhancing recovery outcomes and patients' quality of life from severe neurological injuries or neurodegenerative diseases, eventually causing major healthcare cost savings. Real-time AI-powered platforms offer a unique opportunity for implementing patients' brain plasticity-friendly rehabilitation, those that can more closely mimic the dynamic nature of the physical therapists' adjustments. Responsive, adaptive non-invasive neuromodulation therapies targeting different levels of auditory, ocular-motoneural, and visuoparietal non-invasive could boost a critical period of brain plasticity up to a level sufficient to differentiate auditory, speech, and ocular-motoneural systems.

The aggregation of the data collected with the neurodevelopmental and injury-driven responsive and adaptive approaches represents a unique opportunity for the so-far unidentified conditions as well as for acceleration rehabilitation studies. As the technology has been recently cleared, designing such real-time AI-powered platforms that can work as digital healthcare and clinical trial platforms can be envisioned. We strongly believe that this shared vision will accelerate the standardization of real-time AI-powered platforms for reducing the socioeconomic burden caused by neurological diseases.

## 7. Conclusion

In this paper, we have gone through the development process of an AI-powered platform using RNN-LSTM single and multi-modality model to analyze and recognize patient's activities for post-ICU rehabilitation programs. To achieve this research objective, we use different Artificial Intelligence techniques such as RNN-LSTM model, data preprocessing, data augmentation, classifiers, ensembles, random forests, multi-modality fusion modal, selection of most relevant sensing modalities, Bayesian analysis, determination of distribution of time splits, among others, for solving a set of challenging and related sub-problems in AI, where the solution for each subproblem provides information both to guide the development of subsequent subproblems, and to guide better development of the overall project. We propose an RNN-LSTM multi-modality architecture where we used different CNN and LSTMs as a module and designed top-level fusion module architecture so that the performance of the model could be optimized. As a single-modality solution, we utilized the raw sensor data from different sensing devices with variable sampling rates for detecting and recognizing the patient's activity level and provide appropriate feedback based on the detected patient's behaviors.

The strength of the proposed top-level model is that it considered both patient and clinician feedback to allow optimal long-term adherence to clinical protocols without a compromising healthcare quality. With the real-world data, the performance of proposed top-level model was analyzed and verified the efficacy of the proposed top-level model. The performance was also benchmarked against popular ensemble model like random forests and we noticed the proposed model has an ability to develop inherently combined efficient and optimized single multimodal structure to be able to address patient specific rehabilitation programs tasks. At last, we conclude that the combination with top-level fusion of multimodality improves safety and ensures the best possible solutions, overcoming some of the intrinsic limitations associated with each different modality. Therefore, should ideal solutions be implemented, multimodal fusion became increasingly relevant as these merged simultaneous processing and communication of data benefited from each other.

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