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USING MOVEMENT CAPTURE SYSTEMS IN HOME REHABILITATION – ADVANTAGES AND LIMITATIONS

Abstract. The research focuses on the utilization of gamification and Kinect technology in rehabilitating the musculoskeletal system. It elucidates the potential of gamification in enhancing patient motivation, adherence to exercise regimes, and overall health perception. The use of Kinect technology enhances the efficiency of the rehabilitation process, making it more accessible and safer both in clinical and home environments. The advantages and limitations of Kinect usage in rehabilitation are highlighted, alongside the necessity for further refinement of compensation algorithms and accounting for variability in motion assessment during early stages of treatment. The study indicates the promising role of gamification in healthcare and the utilization of Kinect technology as an effective tool for improving rehabilitation outcomes for patients with musculoskeletal impairments.

Keywords: rehabilitation, joint mobility, home rehabilitation, muscle strength, musculoskeletal system, injuries, joint diseases, stroke, neurological disorders, physical therapy.

Relevance of the research

The development of effective rehabilitation methods, especially in home settings, for patients with injuries, joint diseases, strokes, and other musculoskeletal impairments is critically important for enhancing quality of life and facilitating the rapid recovery of patients.

Objective

Evaluate the effectiveness of motion capture systems in rehabilitation at home, determine their advantages and disadvantages.

Key Research Materials

The utilized research materials encompass scientific articles, journals, conference presentations, books, and other scholarly sources containing data on marker-based and markerless motion capture systems, analysis of rehabilitation methods, and their effectiveness.

Rehabilitation in medical science aims at restoring lost functions, promoting independence during urgent medical care, and beyond, aiming to transition patients from bedridden to active life with the assistance of a multidisciplinary team including physiotherapists, medical professionals, caregivers, and patient’s relatives [1].

Rehabilitation methods such as physical therapy, virtual reality, exergaming, and regenerative methods are employed for musculoskeletal system restoration. Serious gaming facilitates the integration of quantitative motion data into rehabilitation, reducing the need for constant supervision and increasing patient adherence. The main challenge lies in ensuring evidence-based and personalized rehabilitation, as well as improving coordination among healthcare providers.

In recent years, the concept of remote rehabilitation utilizing motion capture systems has significantly evolved. Markerless MoCap systems have emerged, eliminating the need for body markers. Such an approach reduces technical and financial requirements, making it suitable for remote home-based medicine. Telerehabilitation, or remote physiotherapy, has become a common practice, utilizing these systems for body movement assessment from standard video recordings [2].

Healthcare gamification applies gaming principles and mechanics to non-gaming programs to enhance clinical outcomes. It typically includes progress indicators for measuring success, progress sharing with others to create competition, and rewarding with virtual incentives for achievements. Enhanced applications offer gaming exercises for various health conditions. Common themes of gamified healthcare programs include medication adherence, fitness, rehabilitation, emotional health, and pediatric healthcare. Gamification benefits both users and healthcare providers by improving user engagement, involvement, and satisfaction, leading to increased retention and brand loyalty [3].

Healthcare app gamification benefits both providers and patients. For providers, it increases patient data collection, app utilization, and facilitates education. Patients benefit from better engagement, education, and motivation towards healthier habits. Three pathways for implementing healthcare gamification include chronic disease management, rehabilitation enhancement, and medical education improvement. Trends in healthcare gamification include mobile apps and wearable devices, integration of virtual reality and augmented reality, social connections, focus on cognitive and emotional health, telemedicine integration, and serious gaming for learning and training [3].

Study [4] demonstrated that gamification in musculoskeletal rehabilitation can yield results comparable to or even better than traditional physiotherapy or home exercises. Patients participating in gamified rehabilitation programs reported improvements in motivation, adherence to exercise regimens, quality of life, and perceived health status. Additionally, the economic efficiency and safety of using exergaming in musculoskeletal rehabilitation were highlighted as advantages of this approach [4].

The process in rehabilitation centers is often costly, hence utilizing feedback and visual aids such as Kinect for effective treatment makes the process more accessible. Physiotherapists develop individual exercise programs, monitoring posture and range of motion. The Kinect system in a home environment fosters engagement and motivation, providing accurate feedback and continuous progress monitoring. Advantages include detailed session tracking, convenience for both patients and therapists, with no need for special equipment during rehabilitation. Moreover, due to its economic efficiency, flexibility, and remote rehabilitation function, Kinect-based rehabilitation proves to be a safe and effective method for providing standard rehabilitation at home [1, 4, 5].

Study [5] confirms that the use of Kinect-based rehabilitation games improves upper and lower limb motor functions, balance, and cognitive functions in stroke patients. To promote motor recovery, attention should be paid to developing rehabilitation programs adapted to the abilities of stroke survivors [5].

Study [4] showed that Kinect camera, positioned at a 45° angle to the walking path, achieved 93.7% accuracy for position and sway classification, whereas positioning it at a 90° angle yielded 93.1% accuracy. Kinect promises gait analysis in medical rehabilitation with suggestions for future research to increase sample sizes and control recording environments. This indicates that Kinect can be a valuable tool for gait analysis in medical rehabilitation programs [4].

Microsoft's Kinect SDK (Software Development Kit) offers a comprehensive solution containing a pre-built algorithm for real-time tracking of up to six full-body user poses. It evaluates the three-dimensional positions of 21 body joints using quaternion-based rotations. The algorithm employs a random forest approach trained on various real and synthetic data [6].

Rehabilitation involving the capture of 21 joints can be beneficial for patients with various conditions requiring movement function restoration and muscle strength improvement. Some conditions where this rehabilitation may be applicable include musculoskeletal injuries (e.g., fractures, muscle strains), joint diseases (such as arthritis or osteoarthritis), post-stroke condition, spinal and brain injuries, as well as other neurological disorders restricting movements [6].

The Kinect rehabilitation process is illustrated in Fig. 1.

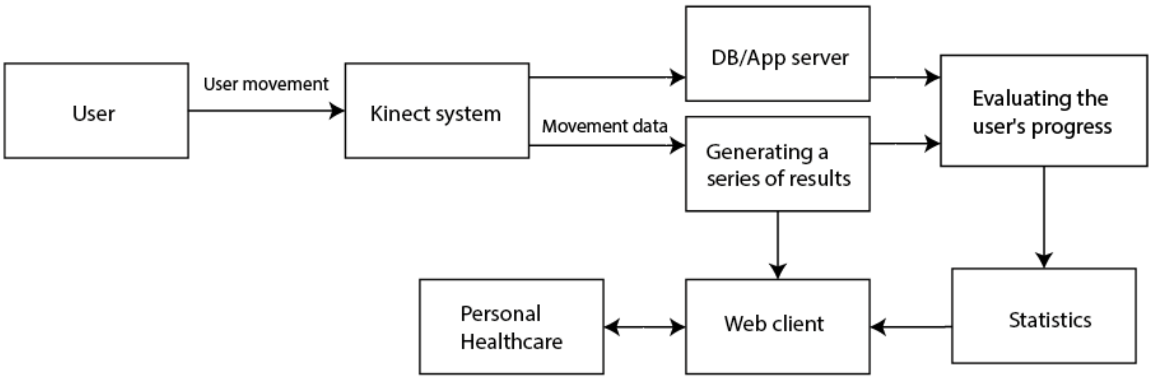

Fig. 1. Process of Kinect rehabilitation

The diagram illustrates the process of generating a series of events based on user motion data obtained through the Kinect system. The user performs movements tracked by the Kinect system. The Kinect system collects user motion data. User motion data is sent to the DB/App server. The DB/App server processes user motion data and generates a series of events. The DB/App server evaluates user progress based on the series of events. Progress assessment can be used to personalize the user experience or provide feedback. The DB/App server generates a series of outcomes based on the user's progress assessment. Outcomes may include statistics, personalized advice, or rewards. The outcomes are sent to the web client. The web client visualizes the outcomes for the user [1].

The structure of the Kinect sensor is depicted in Fig. 2.

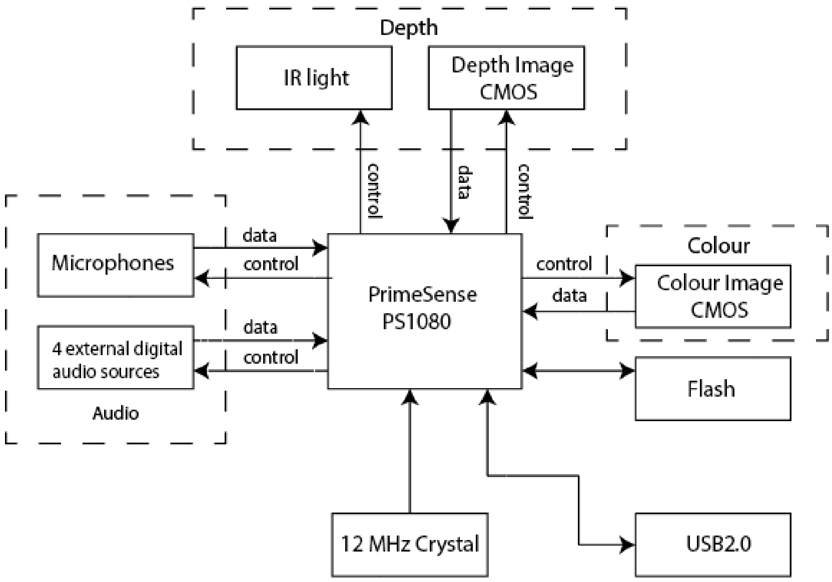

Fig. 2. Schematic structure of Kinect [7]

Kinect consists of two main sensors: a depth sensor, which uses infrared light to create a three-dimensional image of the scene, and a color sensor, which uses a camera to capture a color image of the scene. The image processing subsystem processes data from the Kinect sensors to obtain information about objects and people in the scene, including calibration, noise reduction, segmentation, and feature extraction. The motion tracking subsystem utilizes this information to track the movement of objects over time, including skeleton tracking and gesture recognition. The speech recognition subsystem uses Kinect microphones to recognize human speech, including speech recognition, speaker identification, and intent recognition. The user interface provides means of interaction with the system, such as a visual interface, audio interface, and input interface [7].

The rehabilitation system includes a set of functional tests for assessing physical functionality. Motion data is analyzed by software using methods of reliability and validity assessment. Error analysis includes the Bland-Altman method and Pearson correlation coefficients, as well as visual analysis of Bland-Altman plots [8].

Markerless motion capture (MMC) technology has been developed for tracking and analyzing motion without the need for markers. This allows for experiments in motion capture to be conducted more conveniently, as there is no need to place markers on the body. MMC technology enables the capture of more realistic human movements in a natural environment using portable and more affordable sensors, distinct from multi-camera marker systems [9].

Research [10] identified negative aspects such as motion recognition issues in low light or obstacles in front of the camera. These issues require further work on compensation algorithms. The use of three Kinect cameras improves measurement accuracy by 15.7% compared to using a single camera. However, the error rate in pose recognition may vary for different body segments, with error rates ranging from 0.4% to 36% [10]. The system can reliably assess joint angles and positions of the lower limbs during simple movements, but its reliability decreases with movement complexity. At the early stages of rehabilitation, variability and deviations in joint angle and orientation assessments should be considered [10].

The development of gaming applications offers several advantages, including the use of Kinect technology for innovative rehabilitation methods. Patients with stroke or musculoskeletal problems can undergo therapy at home with a physiotherapist through the integration of gaming with rehabilitation exercises. Kinect cameras and sensors allow patients to interact with devices without physical contact, although continuous therapist supervision ensures safety [9, 10].

The use of Kinect in-home rehabilitation has its advantages and disadvantages. Serious games built on Kinect enable patients to perform exercises in a playful manner, enhancing their motivation and integrating quantitative motion data into the rehabilitation process. This can assist clinicians in monitoring and supporting patients during exercise, reducing the need for constant supervision. However, it is important to note that some aspects of movements, such as elbow and shoulder positions, may be less accurately detected by the Kinect system, especially in seated or lying positions. It is also worth considering that some patients may find it difficult to correctly perform movements in front of the camera, which may necessitate additional adjustment or expert support. All these factors require careful attention and an individualized approach when using Kinect in-home rehabilitation [1, 10].

Results

The study results indicate that the use of motion capture systems, including Kinect, in home rehabilitation has its advantages and limitations. Motion capture systems can be beneficial for monitoring and improving the musculoskeletal condition of patients, particularly aiding in the execution of rehabilitation exercises, reducing the need for constant supervision, and increasing patient compliance. However, it is important to consider that these systems have limited accuracy and reliability, especially when performing certain movements or in different postures. It is also important to consider the individual needs of patients and coordination among various healthcare providers to ensure the quality and continuity of the rehabilitation process.

Conclusions

The research confirms that gamification in rehabilitation can lead to outcomes surpassing traditional methods, providing patients with improved motivation, adherence to exercise routines, quality of life, and overall health perception. Additionally, the use of Kinect-based technologies makes the rehabilitation process more accessible, efficient, and safe both in clinical settings and at home. However, the study identified some negative aspects, such as motion recognition issues in complex conditions, as well as error rates in measurements that require further work and algorithm refinement for compensation. It is also important to consider variability and deviations in the assessment of joint angles and orientations, especially in the early stages of rehabilitation.

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