

Artificial intelligence in rehabilitation

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Abstract

Artificial intelligence (AI) is used in various fields, including rehabilitation. The main goal of using this technology is to enhance the performance of individuals with different disorders. Additionally, AI is utilized to improve diagnostic procedures and monitor the progress of patients. The main question that arises is how AI impacts the field of rehabilitation and what are the advantages and disadvantages of using this technology in rehabilitation. A search was conducted in databases such as Google Scholar, Web of Science, Scopus, and PubMed using keywords like artificial intelligence combined with prosthetics and orthotics, speech therapy, audiology, occupational therapy, physical therapy, and artificial eyes. It appears that AI significantly enhances rehabilitation outcomes. However, there are drawbacks, such as a lack of real communication between therapists and patients. Furthermore, the accuracy of AI depends on the amount of data used to train the system. Lastly, ensuring access to this new technology for all patients is crucial. It is highly recommended that individuals with disabilities be involved in the design process of AI-based systems.

Keywords: Artificial intelligence, Orthosis and prosthesis, Speech therapy, Audiology, Physical and occupational therapy

Introduction

Artificial intelligence (AI) plays a significant role in our daily lives. It influences all fields of human life which finally make life less challenging and more comfortable. Now it is used in all fields of medicine and rehabilitation. One application of AI is in the field of artificial limbs and assistive devices [1–3]. The question of whether machines can think is at the core of AI. In reality, AI is a combination of sciences, theories, and techniques such as mathematical logic, statistics, computational neurobiology, and computer sciences [4]. Several factors influence the progression of AI, including improvements in computer performance and the impact of the Second World War. However, there has been a significant improvement in AI since 2010 due to the considerable increase in computing power and access to massive amounts of data [2].

Artificial intelligence has been used in various fields such as screening, diagnosis, treatment, and prevention of diseases and injuries. It can be used for decision making. Like other fields, AI has been used significantly in the rehabilitation of the individuals with various disorders [3–5]. This technology is utilized in somatosensation, auditory sensation, speech synthesis, optical prosthesis, upper and lower limb prostheses and various designs of assistive technologies for the individuals with musculoskeletal system disorders [5,6]. Actually, applications of AI can be categorized into application based system, robotic devices that replace function, robotic devices which restore functions, gaming system, and also applications used for wearable sensors to detect the motions. It seems that use of AI in rehabilitation is growing to include all fields of rehabilitation.

The main goal of using various technologies in the rehabilitation of individuals with disabilities is to enhance their performance and reduce their reliance on assistance for daily activities. Artificial intelligence (AI) encompasses a range of approaches aimed at addressing challenges associated with the use of assistive technologies. AI is utilized in the creation of artificial limbs (both upper and lower

limb prostheses), robotic rehabilitation, and exoskeletons for subjects with spinal cord injuries to facilitate standing and walking [4]. AI is applied across various areas of rehabilitation, and this review aims to showcase its use in different rehabilitation fields.

Use of AI in Visual Rehabilitation

One notable application of AI is in the development of bionic eyes. The first successful experiment involving electrical stimulation to restore vision was carried out in 1929 by German scientist Georg Von Bekesy [5,7–9]. However, the first successful retinal implant was created in 1968 by a team of researchers led by William Dobbelle. This implant featured a wire inserted into the retina and connected to an external camera for image capture [5]. The advancement of microelectronics and nanotechnology has significantly impacted the development of bionic eyes. AI-driven approaches have been instrumental in enhancing the performance of bionic eyes through improved image processing, the creation of machine learning algorithms, and the utilization of neural networks [5].

The resolution, color and contrast of images from a bionic eye camera can be improved through the use of AI image processing. Analyzing the data generated by bionic eyes and optimizing neural networks have been utilized to develop sophisticated bionic eyes that can interpret visual information in a more naturalistic way [10,11]. Bionic eyes also known as visual prostheses are implantable devices designed to restore vision to individuals with visual impairments. There are three main types of bionic eyes: retinal implants, optic nerve implants and cortical implants [5].

There is no doubt that bionic eyes have undergone significant advancements due to the use of AI in their design, functioning and commercialization. Machine learning algorithms have been utilized to analyze the electrical signals produced by the bionic eyes and optimize the stimulation parameters to generate clearer and more stable images [5]. The incorporation of AI based approaches has led to significant advancement in the field, with the potential to greatly improve the lives of individuals with visual impairments. It appears that we will continue to see further improvements in the designs and functionality of bionic eyes leading to more effective and widely available treatments for individuals with vision loss.

Use of AI in the Field of Speech Therapy

AI has also been used in the field of speech therapy and audiology. There is no doubt that children with communication disorders suffer from a variety of difficulties which influence their abilities to communicate [12–14]. AI has been used to develop new tools to help overcome these communication challenges. AI is also used in accessibility tools, games, and screening tools to improve the communication of children with speech, hearing and language disorders [14]. The use of AI in speech languages pathologies can be divided into combining crowd sourced data, machine learning algorithms, biofeedback and gamification [14]. Actually, AI is used exclusively in the field of speech therapy. An AI screener is used for the early identification of potential speech and language impairment and disorders. An AI Orchestrator is an artificial teaching assistant that helps students with ability-based interventions [14,15]. The AI screener listens to and observes the performance of children in classrooms, collecting samples of children's speech, facial expressions, gestures and other data, over different time periods. Based on the collected data, it is possible to monitor the speech performance of children and if needed suggest a formal evaluation with a language

pathologist. Another application of AI in this field is the use of this technology to treat speech pathology based on sounds and words pronunciations.

Text-to-speech (TTS) software is another application of AI that converts written text into spoken words. This software is useful for individuals who have difficulties with reading and writing. Speech detection software is another application of AI that converts spoken words into written text. This software is beneficial for individuals who struggle with typing or writing. Through the use of AI, it is possible to identify speech pathologies. Speech can be compared between individuals with normal conditions and those with abnormalities, and adjustments can be made to help the speech fit within normal parameters [16–18].

There are benefits and challenges associated with the use of AI in the field of speech-language pathology treatment. AI can assist speech therapists by providing them with accurate information and feedback to evaluate their patients. Additionally, AI can analyze a person's speech pattern, pronunciation, and fluency in real time. However, one of the main challenges of using AI in speech therapy is limited access to technology. Furthermore, it appears that the impact of human interaction in speech therapy for individuals with speech pathologies cannot be replicated by AI [19].

Use of AI in the Field of Audiology

AI is also used in the field of audiology. Audiologists can make better decisions as they have access to data and insights through the use of AI [20]. The performance of hearing aids is improved due to the use of AI, which ultimately increases satisfaction rates and happiness with the devices [20]. Machine learning creates customized settings based on user specific needs and the amount of hearing impairment. It is possible to analyze the users' listening habits and preferences in order to optimize their hearing aid settings [20,21]. AI and machine learning are also used in the audiology field to enhance diagnostic accuracy. In fact, based on these technologies it is possible to quickly and effectively analyze vast amounts of data providing a more precise and consistent evaluation of hearing abilities [22,23].

Automated screening and monitoring is another advantage of using AI [24]. With this technology collected data can be analyzed immediately and compared with normal data to identify early hearing loss and changes in auditory function [20]. Personalized hearing solutions, enhanced rehabilitation and therapy, tele-audiology and remote care, predictive analytics and public health are other advantages of using AI in the field of audiology [20]. In the rehabilitation and therapy of those with hearing impairment, virtual reality is used with AI to create immersive environments for individuals with hearing loss to practice communication skills and simulate real life listening situations. Identification of trends, risk factors, and prediction of hearing loss are other advantages of using this new technology [20].

Use of AI in the Field of Orthotics and Prosthetics

AI is also used in the design of orthoses and prostheses. According to available literature, amputees face various challenges in performing their daily activities with existing prostheses [25–27]. The main expectations for orthotics and prosthetics devices are user-friendliness, adaptability, robustness, durability, and affordability [26]. The use of AI not only enhances the performance of lower limb prosthetic components but also improves the comfort of the

prostheses by adjusting the volume of the socket to fit the stump [28]. This method, known as negative pressure elevated vacuum or dynamic vacuum, involves vacuuming the air between the liner and socket wall to create a negative pressure across the stump. A study conducted by Youngblood *et al.* demonstrated that a vacuum-assisted socket minimizes pistoning within the socket [28]. The fit of the prosthesis socket is undeniably crucial as it impacts the willingness of subjects to use the prosthesis, their daily functionality, and ultimately their quality of life. One solution to improve the close fit of the socket is the use of a MITS fit socket, which detects the areas of softness and stiffness in the stump [25,28].

Machine learning techniques (MLT) have been used to improve comfort and mobility for individuals using active lower extremity prostheses [25]. For lower limb prostheses, MLT is used to detect events and activate the prosthesis components (mostly ankle and knee joints) in real time conditions. There are various methods of MLT, with the most common ones being random forest (RF), neural network (NN), k-nearest neighbors (KNN), support vector machine (SVM) and decision trees (DT) [25]. In the field of prosthetics, machine learning has been used to identify the appropriate prosthesis, providing training, detect falls, manage the temperature of the intra socket space and control the suspension of the prosthesis.

The input information for the prosthesis is obtained from an accelerometer, gyroscope and EMG signals which may be collected from thigh and shank muscles. Based on the available literature, the use of advanced technology such as motor learning, artificial intelligence, etc., improve performance of the subjects with lower limb amputation. This ultimately increases their functionality, decreases the risk of falling, and improves their quality of life [25,29].

The new technologies mentioned above are also used in the design of upper limb prostheses. The functional prosthesis system for the upper limb is categorized into three blocks including EMG sensing, control system, and feedback systems [30]. It should be emphasized that while the efficiency of lower limb prostheses depends on stability and the performance of the suspension system, for the upper limb the functionality of the prosthesis during daily activities is more important. Targeted muscle reinnervation (TMR) is one approach that uses the signals of muscle to control the prostheses. This can be achieved with two sensors for below elbow prosthesis and more sensors for above elbow prostheses [31–33].

One method used to optimize the performance of modern prosthetic devices is the use of artificial intelligence. Myoplus pattern recognition is a new prosthesis developed by Otto Bock Company. The system automatically recognizes the movement pattern for a specific grip and performs it automatically [34]. The I limb quantum is another well-developed upper limb prosthesis with five independently motorized fingers and powered thumb rotation that facilitate motions. It has 36 different grip options which cover all the needs for daily activities [34].

In the field of orthosis, machine learning is used to control real-time movement in order to predict the required motions [27]. Orthoses are used for various purposes, including stabilizing the body, improving the function of paralyzed limbs, and changing alignment, mostly in the upper, lower limbs, and spine. This technology is also used to stabilize paralyzed joints, often referred to as stance control, and is used for subjects with stroke and spinal cord injuries. Various assistive devices for spinal cord injuries have been developed based

on artificial intelligence (AI). The knee joint of these orthoses, also known as exoskeletons, flex in the swing phase and are locked in the stance phase. AI is used in the development of robotic exoskeletons, which can be used as rehabilitation devices or as a light, portable, and ergonomic system. Depending on the performance of the exoskeleton, various AI methods may be used. In exoskeletons for lower limbs, motors are used to move the legs, although they are mostly controlled by users. In newer exoskeletons, AI computer software processes videos to recognize stairs, doors, and other features of the surrounding environment. Based on this information, the activities of actuators are controlled to climb stairs and overcome obstacles. Generally, exoskeletons or rehabilitation robots use sensors and data to analyze the situation and control the systems. They vary in their degree of autonomy, from fully autonomous (robots make decisions) to fully teleoperated (an operator makes all decisions for the robots) [3].

For the upper limb the AI based exoskeleton can be divided into three groups: fixed robotic exoskeletons, semi mobile devices, and soft light weight devices. It is established that AI should aim at intention detection, offering modulation of the control scheme of a human robot task and providing feedback during training exercises. AI has provided the basis for the development of a more reliable system; however, further research is needed. Future research aims to develop exoskeletons that automatically adapt to the environment or user actively learning from input exercises. The structures of the exoskeleton should also be developed to provide compact and reliable tools that suit neuromotor and musculoskeletal rehabilitation [3,26].

Use of AI to Detect Falls

The fall detection system is an example of utilizing AI with sensors to detect falls. The system's aim is to identify falls and promptly alert medical staff or emergency services if assistance is needed. There is a requirement for the integration of therapists' or rehabilitation specialists' expertise to evaluate and confirm the results of patients' assessments when using robotic rehabilitation systems [35].

Conclusion

Based on this review, AI is exclusively used in various fields of rehabilitation to monitor the performance of subjects, determine their progression, and improve it. There is no doubt that AI will significantly influence the rehabilitation process, but it also has some disadvantages. It is crucial to involve disabled individuals in the design of AI software and technology intended for use by those with disabilities. Therefore, it is recommended that disabled people be included as part of the design team.

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