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Artificial Intelligence in Rehabilitation Evaluation Based Robotic Exoskeletons: A Review

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Abstract: The center and foundation of recovery is evaluation, which will lead to the whole therapy phase. Healthcare professionals or clinicians must evaluate patients' lower/upper-limb activity based on discretionary and objective assessments during recovery. Existing approaches can result in a significant error and high expense. As a result, AI is being used in the area of medical recovery. The implementation of analytical estimation approaches based on AI, such as error of trajectory function, joint angular velocity, and joint angels, and function of sEMG's signal will be summarized in this analysis. Eventually, the study suggests that the size of data and the number of features affect current objective approaches. This study will include guidance for a more extensive application in the area of recovery.

Keywords: Artificial Intelligence (AI), Rehabilitation, Robotics, Wearable actuator

I. INTRODUCTION:

AI, in computer technology, also known as machine intelligence, is intelligence presented by robots instead of actual intelligence illustrated by animals and humans. Top Global textbooks describe AI as an analysis of "intelligent agents," or actuators that perform their world and take measures that enhance their possibilities of obtaining their purposes. Machines that rival "intellectual" tasks that individuals equate with the mind of a human, for example, "problem-solving" and "learning," are applied to AI informally.

Healthcare professionals or clinicians must assess the activity of patients' limbs through rehab preparation, which is the primary method for determining the degree of healing of patients and may direct therapeutic strategy. Subjective and quantitative assessments are the two types of rehabilitation evaluations. The subjective appraisal is a method of evaluating a patient's recovery based on personal knowledge. This approach is simple to use and can generate numerical scores or labels for analytical assessment. These labels can be utilized to qualify the model and assess the features' functionality. On the other hand, individual evaluation is expensive and vulnerable to human control and may be quickly disrupted by other variables such as multiple operators. The term "objective assessment" applies to the use of artificial intelligence systems to assess the recovery of patients. This approach is objective and effective, but it also depends on subjective judgment to generate quantitative scores simplified by artificial intelligence. This paper would summarize objective recovery evaluation approaches widely employed in healthcare settings and artificial learning technology to improve clinical outcomes.

II. ARTIFICIAL INTELLIGENCE (AI) TECHNOLOGY IS USED FOR EVALUATION.

In recent decades, the word "artificial intelligence" has sparked a lot of debate. This is a computer science division whose purpose is to create intelligent machines that can think like humans. Artificial intelligence technology is popularly employed in medical recovery, including rehabilitation evaluation for lower and upper limbs, traditional Chinese medicine (TCM) tongue photo characteristic measurement and analysis, TCM oscillation determination and classification, tumor identification and diagnosis, and so on. The AI algorithms will independently assess a patient's condition and have shown positive outcomes, as well as promising study opportunities. Machine learning and computer vision are two examples of artificial intelligence areas. Machine learning is one of the most powerful methods for achieving "knowledge" amongst them which encompasses multiple fields, considering not just algorithm models, including artificial neural network (ANN) and support vector machine (SVM), but also statistics and probability theory. It has been increasingly relevant in departments such as speech recognition and image recognition in modern times. Machine learning removes "features," which are then used as input to the algorithm to learn and optimize the best model by utilizing the preprocessing of the input signal. Studying deep/abstract functionality is another way to think of machine learning. These four AI-based actual evaluation approaches derive various characteristics for various signals. Moreover, these characteristics perform an essential role in learning and optimizing the accurate evaluation algorithm.

III. SEMG SIGNAL PROPERTIES WERE USED TO MAKE AN ASSESSMENT.

Surface electromyogram signal (sEMG) is widely used in clinical, internal medicine, and other areas in recent years. During limb activity, sEMG is an electrical stimulus followed by muscle contraction; these electrical signals are nonstationary poor signals that are superimposed on the surface of the human skin. The use of sEMG in the field of rehabilitation evaluation for upper limbs is also quite general. According to the report, the sEMG is described as the consolidated impact of electrical nerve activity and superficial muscle on the surface of human skin. The acquisition of signal has the benefits of easy to use in being noninvasive and invasive. Furthermore, sEMG provides a wealth of knowledge about fitness habits and desires and has significant functional importance (see Fig 1). Wang Yuan et al. [1] collected signals' surface electromyogram of the human pectoralis major, trapezius, triceps, and brachioradialis muscles using electromyography acquisition devices in 2020. The signs were combined after wavelet denoising, then extraction of characteristics such as root mean square (RMS) and electromyogram (iEMG), then applying these characteristics to measure the upper limb of the patient exhaustion recovery. Nevertheless, the data used volume in this process is comparatively limited, and the elements are pretty straightforward. In 2013, Xugang et al.[2] utilized sEMG as the initial signal; the surface electrodes were used to generate the EMG signal. The EMG collector registered the muscle's bioelectric behavior. It is the amount of the potentials unit action in various superficial muscle fibers and reflects the operative condition to the whole muscle. Hence, the signal acquisition device for the surface myoelectric is made up of three parts: an instrument amplifier, a pickup electrode, and a secondary signal processing component with amplification, filtering, and A/D performance, as well as a device communication portion. The signal is sent in real-time to the server.

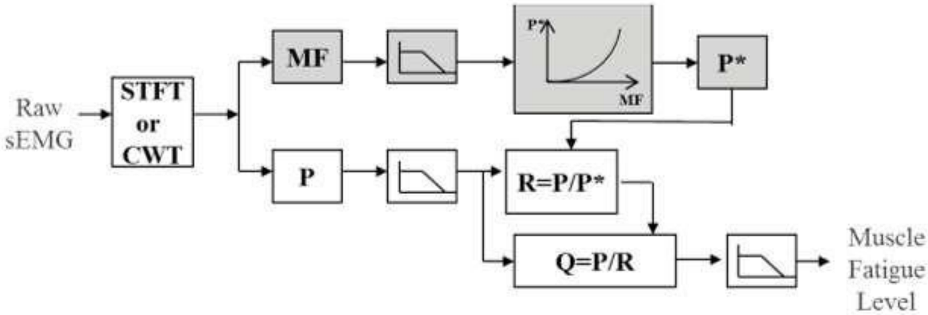

Fig.1 Muscle Fatigue Detection Signal Flow Diagram

The signals of the upper limbs of the patient are obtained according to various activity gestures by using sEMG. Then filter the features extracted from the surface EMG signals, such as wavelet packet capacity root mean square and simple scale entropy. So, the screening methods are as follows: one, pick suitable defining and representative characteristic values for various categories of actions; two, aim for different abilities to execute activities. That is, the chosen feature values must be expressed while performing complete and insufficient actions. Finally, the basic Fugl-Meyer scale scores are utilized as practice labels to refine the best model by training the chosen functions. Nevertheless, the data utilized with this process is insufficient, and the proof is inadequate to draw decisions.

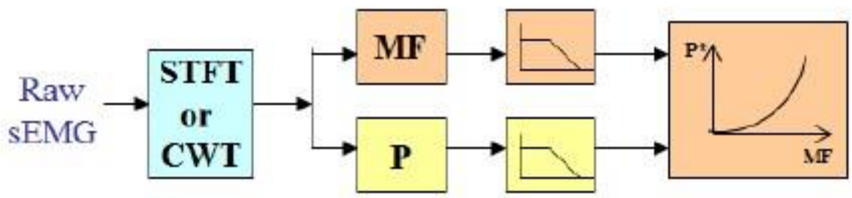

Fig.2 Obtaining the MF and P* relationship using a signal flow diagram

IV. THE EVALUATION IS DEPENDENT ON THE CHARACTERISTICS OF MOTION TRAJECTORY ERROR

For over 30 years, human movement trajectory analysis and modeling technology have been studied in surgical recovery. Upper limb rehabilitation evaluation techniques are now being researched using trajectory monitoring and analysis approaches. Dynamic movement, for example, is a technique for bringing the upper limb of the patient into a more desirable location. The upper limbs are capable of performing various complicated and accurate movements, the bulk of which includes the synchronization of several joints and muscles, then the actual trajectory will diverge from the optimal trajectory if any partnership ends. Costin et al.[3] utilized image processing techniques to predict the correct path for the limbs of the patient in 2014, and compare the uniform root mean square error, arc length ratio, and percentage error of the ideal and actual trajectory. Eventually, train the upper limb regeneration assessment model using the three values collected as characteristics. On the other hand, the image analysis effect affects this computer, and the number of features is comparatively tiny.

V. JOINT MOTION ANGLE CHARACTERISTICS ARE USED TO MAKE AN ASSESSMENT.

Human movement criteria have recently been found to be extremely important for recovery evaluation in recent research. In the analysis of recovery evaluation algorithms, the motion range of the upper limb (maximum angle of motion) is utilized. The overall rotation angle of human joints varies across a narrow range of usual circumstances. The maximal angle of rotation of the joint can shift significantly if upper limb control is lost. Kusaka et al. [4] utilized Kinect to capture human movement photographs and measure real-time upper limb joint angle variables in 2014. The average error within the real observed angle parameter and the estimated angle parameter is less than 10° after verification. The subject is required to conduct specific acts as well as to measure angle parameters. Estimate the angle dimensions of upper extremity operation before and during rehabilitation therapy as the patient makes complex gestures. According to the data, the range of the patient's joint mobility (maximum angle of motion) receiving rehabilitation therapy improved dramatically, demonstrating that the range of joint movement can be used as a feature to illustrate the degree of upper-limb recovery, which is critical in quantitative assessment. However, the image processing impact would influence this approach and the fact that the volume of data is too limited and the functionality is too simple.

VI. BASED ON THE ANGULAR VELOCITY PROPERTIES OF THE JOINTS, AN ASSESSMENT IS MADE.

The maximal patient's joint angular velocity has recently been thought to represent the degree of upper limb recovery. The study related the maximum joint angular velocity to the same patient's therapeutic (subjective) test score, and the patient's joints median angular velocity slightly improved as the professional assessment score increased. Taniguchi et al. [5] created a limited-degrees-of-freedom upperlimb recovery evaluation robot in 2015. To accomplish the goal of limiting joint freedom, the system should be used to repair the elbow or shoulder joint. The recovery teaching posture is designed to reduce the effect of limb weight on the body. Estimate the measurement of the angular velocity and the joint angle over time during exercising, and eventually apply functional electrical stimulation (FES) as an alternative therapy, which has been used in outpatient treatment as a supplement. FES technology activates dysfunctional limbs with low-frequency pulse currents through acute results it causes and modifying via the specialized nerve center, restoring or fixing the lost functions. Encourage the restoration of functionality. FES may help people with affected limbs by relieving discomfort, bypassing injured nerve impulses, stimulating muscles using preset relaxation procedures, inducing muscle movements, and simulating regular voluntary movements to enhance or restore dysfunction. Standard muscle or muscle group contractions serve a function. Before and during electrical stimulation therapy, the maximum patients' joints angular velocity was calculated; and clinical studies have demonstrated that when the joint's maximal angular velocity rises, so does the patient's ranking. This is a novel approach to upper-limb recovery testing, demonstrating that the maximum joint angular velocity should be utilized as the appraisal function. However, this method's properties are overly simplistic; and in this analysis, four commonly used upper limb rehabilitation evaluation algorithms are addressed. The use of joint angular velocity, trajectory description, joint angle, EMG signal, and other data in recovery evaluation algorithms has been shown to be successful. However, these methods are not without flaws. Image processing, for example, impacts the efficiency of such algorithms, assessment characteristics are overly simplistic, and the amount of data required by recovery appraisal algorithms needs to be increased.

VII. THE SOCIAL ROBOT AS AN EVOLUTION OF THE COLLABORATIVE ROBOT

VII.1 Defination of Collaborative Robots:

The word "co-robot" comes from combining terms "collaborative" and "robot" [6]. It was applied to inventions that had been in use since 1996 due to the creativity of two Northwestern University academics, Michael Peshkin and J. Edward Colgate [7]. Cobots are built to communicate with workspace - humanin a complex task setting. This field is now one of the most critical innovations in the robotics industry.The International Federation of Robotics, a technical, nonprofit organization, recognizes industrial robots used in collaborative and automation robots that can be used for commercial and home use. [8]. Collaborative robots are divided into four categories in the field of:

1. Reactive collaboration robot: responds in real time to the worker's movements;
2. Cooperation: both the person and the computer continue to move and operate at the same time.
3. Coexistence: While there is no shared workspace, humans and robots collaborate.
4. Sequential collaboration: a person and a robot share a workspace but do not work at the same time.

VII.2 Defination of Social Robots:

Collaborative robots can communicate and collaborate with humans. However, we are dealing with a socially interactive robot, also known as a social robot, if this contact and job operation is more defined by social interaction before it becomes the primary function[9].To put it another way, social robots are interactive robots developed in social interaction to communicate with people.We must recognize that robots are and will continue to become our essential part.Artificial intelligence interaction will become more common in offices, restaurants, healthcare centers, and various other gathering areas. In their collaborative interactions, social robots (SRs) can:

- Developing and establishing social relationships;
- Using "normal" cues like movements and gaze;
- Learning social skills and role models;
- Being able to express and interpret emotions;
- Using highlevel dialogue to communicate;
- Having one's unique character and personalityexpressed.

SRs can be utilized for a range of things, including instructional and clinical uses. There are some models of SRs created for usage by older adults [10-13] in hospitals or nursing homes, for example, to (a) support such motor movements; (b) maintain the older adults through feeding; (c) assist them in medication treatment; (d) support them cognitively; for example, by inciting them with games then encouraging them from a cognitive standpoint; (e) Or, in a broader sense, double as hospital support.As a result, SRs are regarded as one of the essential gerontechnology of the future. Regarding the required social distancing supervening duty to fight the pandemic during the COVID-19 period, there is a rise in the usage of SRs in beneficial practices [14]. The use of Pepper in this area in the UK during the COVID-19 pandemic [15] is one non-exhaustive example [16-17]. Social robotics may be used for various purposes, including: (f) help in the rehabilitation treatment of children with contact disorders, for example, autism or others, in which the robot can be a helpful instrument stimulation [18-26].

Nevertheless, robotics may be utilized in the home setting in conjunction with automation systems to assist the elderly in making the tasks mentioned above. For example, Wakamaru [27] can be implemented into domotics with a variety of help options. Besides, home-telepresence robots serve as home management negotiators, enabling contact with others through appropriate devices (speakers, cameras, microphones, etc.) while also enhancing the subject's protection; for example, JIBO [28] and Kuri [29] are telepresence robots families.

VIII. SOCIAL ROBOTICS RESEARCH DIRECTIONS

VIII.1 Possible Classification*:* The research direction for SRs is classified by Sheridan [30] recently as follows:

- *Adaptation, Personality and Affect:* The study in this direction [30-36] focuses on using SRs knowledge to tailor to the user's particular needs and success aims, thus increasing recognition; hence, some researches concentrate, i.e., on how robot mimics and convey emotions of human such as rage, hatred, terror, pleasure, disappointment, and wonder.

- *Actionable Sensing and Control:* This segment looks at the science concentrates on the physical interface between SRs and humans, together with bioengineering solutions in mind [37-44]. While protection is necessary for robot-human cooperation for industrial operation and particularly preventing accidents, in SRs, the protector is diverse; for example, some social tasks like makeup for human's face to the human face are given special consideration. The issue of motion preparation has received more recognition, not only for contact avoidance (safety endures primary care) and human likeness. In certain situations, the pressure of a robot, for example, elicits a favorable reaction in a person, so this factor must be accurately weighed.
- *Support to the Aged and Disabled:* This is a popular social robot app. Families dealing with an autistic relative, for example, often have difficulty communicating socially and emotionally [45-51]. Sheridan [30] has recognized and established several limitations in the study on the usage of robots for autistic children, including variety in focus, bias in the study via impairments individual behavior, the efficacy of the interaction between robot-human after disability, and the utilize of the robot which is based motor therapy in autism.
- *Toys and the Social Robot Market in General:*Sheridan [30] presents the critical point related to human factors and social-psychological, which should be applied to SRs for consumer acceptance, sales appeal, and regulatory acceptance of the government. Since children are the most defenseless of the different user groups, this is particularly true for children's toys, and it should be noted that, as can be seen on the internet, the majority of social robot sales are for children's toys.

VIII.2 **Personal Issues to Consider:** Sheridan's categorization [30] can be used as a benchmark for assessing potential developments in social robots, especially in the areas of assistance and rehabilitation. Without adding new categorizations or concentrating on the recovery market, two recent additional factors are worth mentioning: the first is the creation of animal-like robots that serve as a form of robotbased pet therapy; the second is the effect of science and clinical applications on SRs, which was foreshadowed due to the COVID-19 pandemic. In terms of the four categories mentioned above, both subjects are translational.The COVID-19 pandemic has brought the issue of elderly frailty to the forefront in a dramatic way. To prevent contagion, the elderly were often placed in forced isolation. As a result, there have been challenges in health care (including psychological) as well as the emergence of troubling factors like fear, anxiety, and other psychological disorders. During this time, their functional capabilities have deteriorated. To mitigate the issue, several nursing homes have begun using robots to care for the elderly to reduce their isolation while still improving their mental health. Pepper [14] in the United Kingdom is an example of this. SRs have fueled study and clinical application during the COVID-19 pandemic, including the previously mentioned Robear [52]. It would be possible to comprehensively analyze this and make a map point at the end of the pandemic.

IX. Conclusions and Discussions

The potential to play the part of an engaging social communicator and, as a result, to be a social robot[53] is the most recent development of collaborative robots (historically proposed for collaboration with human subjects) [6]. This new position has a lot of potential in rehabilitation and assistance for people with disabilities, especially the elderly and handicapped. SRs have shown to be especially useful in treating the elderly and children with communication disorders such as autism [54]. The COVID-19 pandemic has recently resulted in increased activity in both scientific and clinical applications of SRs. In reality, SRs provide a way to preserve the continuity of treatment, contact, and psychological support in circumstances where there are rules/initiatives to maintain social distancing to prevent infection; in other words, they serve as a lifebuoy [13,14]. In the field of SRs, a specific research path has been identified.

Sheridan [30] recently classified the research directions in the field of SRs as follows: (1) Affect, Personality, and Adaptation; (2) Sensing and Control for Action; (3) Assistance to the Elderly and Handicapped; and (4) Toys and Markets. The effects of the COVID-19 pandemic on research activity [13,14] as transversal fields of this research route. The latter sparked a lot of debate about the use of SRs in recovery and assistance, in addition to the economic and ethical considerations.The central question of whether SRs can provide true selflessness, kindness, and comfort, which should be at the heart of any assistance scheme, has sparked an ethical debate. Epistemologists are concerned that as SRs become more widely used, they will increase long-term isolation by reducing direct human interaction and raising a sense of disconnection. This is not when SRs are used as facilitators or mediators between humans, as they are in most domotics applications and some autism-related applications, such as the robot Kaspar [55,56].

It is precisely because of this position that we consider the additional opportunities for SRs in telerehabilitation applications, which can occur in three key areas:

- Facilitators/mediators link vulnerable and/or disadvantaged people with the health care system and/or family members for more comprehensive recovery supervision.
- By adjusting SRs to the patient's telerehabilitation needs, they will help tailor patient-centered therapy.
- The new robotic rehabilitation technologies of the upper and lower limbs are incorporated into the telerehabilitation mechanisms and processes in the domiciliation of treatment and the basis of the previous stage.

When we consider SRs, and if we are concerned about the issues mentioned above (increasing isolation, reducing communications, and so on), we must also consider the other side of the coin; that is to say, in this pandemic season, a robot of this kind might provide solutions to many of the problems that nursing homes and hospitals face, such as a shortage of staff. During periods of lockout, many elderly and disabled people are left entirely isolated in their homes, with little access to medical care. Furthermore, even without the COVID-19 pandemic, there was already an issue of assistance for the aged, weak, disabled, ill, lonely, and non-self-sufficient (worldwide and at all times). In general, robotic caregivers, in my opinion, should be regarded not only with skepticism but also as a potential source of assistance. There is no question that robotics will play a significant role in future health and treatment. The robots can assist in surgical procedures (both in-person and remotely), recovery, home automation, hospital hygiene, dispense lunch and medications, and provide general assistance. True, robots cannot currently communicate human emotions; however, they can perform tasks precisely and effectively. Therefore, they may be of great assistance in coping with disability and a variety of healthcare issues.

From an economic standpoint, it is essential for insurance firms in various ways, including the possibility of creating new insurance formulas based on the use of care-robots and the implementation of new plans that cover the risks associated with their service. As with other artificial intelligence applications, the opinion and approval of all concerned actors, ranging from doctors, nurses, and caregivers to patients and their families, would be a key factor in the spread of SRs. As a result, dedicated studies focused on dedicated broad surveys [57,58] will be needed to face the final yard, in which artificial intelligence will undoubtedly play a key role [59], given that artificial intelligence will be crucial for specifying the extent and characteristics of social robot empathy shortly. All of this is critical because, according to studies focusing on bibliometric indicators, the sector is experiencing substantial growth. For example, according to a study published in [60], the field began to expand in the mid-1990s, and after 2006 [60], we can see a greater number of publications. The authors [60] gathered data from scholarly papers in the robotics and social robotics fields, highlighting the significant increase in the number of publications on SRs (a) in terms of several articles and (b) in proportion to all-robotics science.Furthermore, official studies show that the demand for social robots is expected to expand at a compound annual growth rate of around 14% from 2021 to 2026, owing to advances in artificial intelligence (AI), natural language processing (NLP), and the advancement of platforms such as the robotic operating system, which have facilitated the rise of social robots.

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