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Control Strategies for Robot Therapy

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Abstract: The patients hit by stroke have primary concerns of upper and lower limb weakness. To recover from these disorders patients, undergo a process known as rehabilitation. Robotic devices have the potential to address this area as noted by the previous studies. The purpose of this technology is build such devices which serves individuals motor impairments to practice the movement without the supervision of therapist. Formerly several devices were developed but such resources are limited. Studying and improving the devices used in therapy maximises the potential of restoration and provides greater means of access to cost effective healthcare devices. Control strategies play a substantial role in the success of these type of robotic devices. The purpose of this study is to document a review of control strategies which have been implemented previously on the rehabilitation robotic devices assisting either upper or lower limb in order to facilitate the development of new and improved strategies.

1. INTRODUCTION

Neurological disorders due to stroke and spinal cord injuries cause functional disorders to the neural system and motor functioning, which in general results in motion infirmities and impairment of upper/lower limb. These disorders significantly reduce the quality of life and limits the independence. Fortunately, various approaches exist for the restoration of these extremities, e.g. orthoses, functional electrical stimulation and physical therapy. The most common is the physical rehabilitation which has shown positive outcomes. The therapy depends on duration, repetition, intensity and task specific orientation of the training (Platz 2003), (Feys *et al*. ,2004) patient's health condition, attention and effort to do the exercise. In this case robotic rehabilitation devices may be a good option to opt in motivating the patients for the therapy for quick recovery. The enthusiasm of using rehabilitation robotic devices is the computers graphical environment, which encourages the therapeutic activities of the impaired limb with implementing an effective control algorithm to escalate recovery. Statistically rehabilitation robots have significant benefits, with improved kinematic parameters, path following and smoothness in movement. Control techniques for rehabilitation devices developed previously are specific to concepts of rehabilitation process, neurosciences and motor learning. In this review paper these concepts are briefly defined and emphasises on how the control strategies achieve these concepts. The strategies implemented by the researchers with their devices are provided in **(Table. 1)** and the techniques are elucidated in the next section of this paper.

2. CONTROL TECHNIQUES

This section of the article focuses on the control techniques which have been implemented on robotic rehabilitation devices for upper and lower limb. The movements of the robotic device are handled by the control section, which ensures that the movements are either assisted, semi assisted, passive or perceptual that is haptic. Active devices provide motion assistance using actuators, thus they possess capability of moving the muscles while passive devices do not assist in moving limbs but resist the effort when motion is exerted in wrong direction.

Haptic devices interact with patients by sense of touch. They may be classified as active or passive which depends on their type of actuators. They are commonly utilized in rehabilitation with virtual environment interfaces.

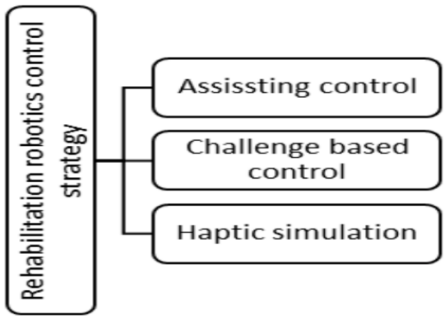


Fig. 1: Robotic control strategies

Assistive Controllers

Assisted exercises uses external, physical assistance such as exoskeletons to aid the patients in accomplishing intended movement. This type of assistance is required when the patient is excessively feeble to perform specific exercises. The patient is inactive during the exercise while the device moves the muscles in a specified path. However, by using the active devices, the exercises are considered to be passive because patient's effort is not required. Physically assisting the movements may benefit the patients to perform more activities in a shorter amount of time, potentially allowing more intense practice

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(Harkema, 2001) Another class of assistance is the passive assistance which is impedance based assistance. In this type of control technique patients move along a specific trajectory in which robot does not intervene in this process. However, when the patient deviated from the path, robot creates restoring force to get the movement on the specified path. This type of controlled robots provide assistance when required. If the patient could not complete the task, in that case robot assists the patient to finish the task. The counterbalancing assistance is another strategy used in rehabilitation clinics to balance the limbs. The assistance may be used to keep balance while walking and gait training. The assistance is controlled through a software which determines weight required for performing any movement per individual needs. There are few devices which use electromyography signals i.e. EMG assistance to drive the movement of the robot. The EMG signals are tracked from specific muscles such as triceps and biceps, which can be used as a trigger or an indication of a generated effort after some signal processing, which is then used for assisting the motion if signal cuts off the threshold. Another type of assistance which uses adaptation according to individual needs is the adaptive assistance. In this type control technique, the control parameters adjust itself, so the assistance can be tuned automatically to the changing needs of the patient. This adjustment may occur during the exercise or over the course of rehabilitation. It is a key part of patient cooperative training strategies developed in which adaptively takes the patient's intention into account rather than imposing a fixed control strategy.

Challenge based Controllers

The challenge based controllers in some ways make task more difficult or tough. It is opposite to assistive controllers which makes the task easy. In this strategy, difference between the actual and desired trajectories increase and it promotes exertion of effort. This type of strategy includes providing resistance to the patient's movement promoting increased effort. Furthermore, error augmenting control algorithms have been described to influence motor adaptation and improve motor function in adults suffering from stroke.

Table 1: Control strategies for robotic therapy

Device name	Year	Attachment location	DOF	Type of assistance
REHAROB	2005	shoulder, elbow and forearm	6	Assistive control
Act 3D]	2005	shoulder and elbow	3	Haptic and admittance control
PneuWrex	2006	shoulder and elbow	4	Impedance Control
Lewis	2009	upper arm, elbow and forearm	3	Haptic Master slave, bilaterally using EMG based admittance control.
ARAMIS	2010	elbow, forearm and wrist	6	VR visual feedback and adaptive control
L-Exos	2012	wrist rehabilitation and can perform grasping, reaching	5	Haptic control
ULERD	2013	elbow, forearm and wrist	3	Assistive control, tele rehabilitation, remotely controlled
Physiotherabot/WF[	2014	Upper limb	3	Hybrid Impedance Control (HIC)
O4CHS, Odstock	2015	Multijoint upper limb	5	functional electrical stimulation (FES)
T-WREX]	2006	Shoulder, elbow, wrist, grip	5	counterbalances the weight of the arm using elastic bands
3RPS-R	2011	forearm and wrist	4	Assistance as needed impedance control,
UEKI	2012	Thumb,finger and wrist. Flexion/extension and abduction/adduction finger, thumb opposability, and hand–wrist coordinated motions.	18	Counter balanced, VR based symmetrical master–slave motion assistance "Self-motion control"
Hip orthosis exoskeleton	2004	hip joint (flexion)	1	myoelectric signal Assistive control
Powered lower-limb orthosis	2006	hip joint (flexion, extension, abduction and adduction), knee joint (flexion and extension) and ankle joint (dorsiflexion and plantar-flexion)	5	Powered/active assistive control
Robotic gait trainer in water(RGTW)	2008	hip joint (flexion and extension), knee joint (flexion and extension)	5	Powered Assistive control
Powered ankle-foot exoskeleton	2009	Ankle joint (dorsiflexion and plantar-flexion)	2	Resistive/assistive/controlled Control conditions
Robotic orthosis for gait rehabilitation	2013	hip joint (flexion and extension) and kneejoint (flexion and extension)	6	Adaptive control
Robotic Gait Training Orthosis	2016	Lower limb	6	Robust Adaptive seamless assist-as-needed (AAN) control
L. Emken	2005	Ankle joint	2	Error amplification adaptive control.
ARBOT	2013	ankle rehabilitation	2	admittance-based assistive control
Robotic gait training orthosis	2013	hip and knee flexion/extension All other DOFs were kept free	2ACTIVE 4PASSIVE	adaptive impedance control,AAN

One of the challenge based devices are the resistive robotic devices which apply constant resistance to the movement. This type of therapy is usually applied on the patients with low level of impairment. These devices have been used for grasping and walking practice. This technique has positive rehabilitation effects for patients with neuromuscular and orthopaedic conditions (Dong, *et al.*,2005). This is a robotic therapy in which the usage of unaffected limbs is constrained to some level in order to encourage the patient to use the weak limb. The idea of this strategy is to forcefully practice with the impaired limb.

Furthermore, other devices use constraint induced strategy to initiate some constraints in the exercise so patient could reduce using unaffected limb and motivates to use affected one. The difficulty in challenging exercise increases in every session and the process is known as shaping.

Another type challenging strategy is Error amplification strategy in which movement errors are amplified in order to get to the desired spot. The error augmentation can improve the rate and extent of motor learning and it may facilitate neurorehabilitation.

Haptic Controllers

Haptic devices may be used for rehabilitation in a way that they may interfaced with virtual environments to create interactive simulation with variety of real life solutions. These types of environment can create many simulations of real life situations giving an appropriate context to the movements being practiced and automatically grade the level of difficulty. They may be used as active or passive depending on type of actuation. A haptic system may provide patients recovering from neurological motor deficits by combination of robotics and interactive virtual reality.

3. CONCLUSION

Several types of robot therapy with several control strategies have been introduced in recent years. However, there is still a significant requirement to address this area. The controllers are categorized into three categories, which are assistive, challenge based and haptic controllers. In this article we made an effort to document a review of the existing control strategies which have been implemented on rehabilitation devices. Assistive controllers may be used when patients require too much of physical assistance to move their impaired muscles. Challenged based controllers are the counterpart of assistive controllers which may be used to force the patients to move their impaired limbs. These sort of strategies may not help with patients who have completely impaired limbs but it can be implemented on the patients who can partially move their impaired limbs. The other type of setups which use haptic technology may help in rehabilitation by turning the exercises into computerized games which encourages the patients to complete their exercises and keep precise records of their performance. The purpose of this article is to provide a reference about existing strategies in order to assist the future studies in this area.

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