An assisting robotic system for rehabilitation and training of elderly people

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Keywords: Service robots, assisting devices for elderly people, rehabilitation, design.

Abstract

In this paper problems and characteristics are discussed for designing and operating a new system that can be used to assist elderly people in rehabilitation and training of limbs both at hospital frames and home environments. The proposed system, that is based on a portable parallel manipulator architecture with multidisciplinary equipment (as with heterogeneous sensorial and communication equipment) in multimodal human-machine interfaces and operation regulations, is outlined through considerations that are used in the project proposal for funding with the aim to stress problems in the formulation of a project funding plan with acceptance also from medical operators. The results of the project should be of benefit for elderly people users as well for medical operators.

1. Introduction

The project proposal is aimed to develop activities for design, construction, and testing of an innovative system that can perform the assisting activities of rehabilitation and training of limbs of elderly people into one unique device. One of the most challenging research topics in the framework of the European Union refers to the development of assistive devices for aging population to preserve both the quality of life and their independent living. Some motion distortions can appear in a large segment of the population as related to the age and/or age-related diseases or incapability that can be mitigated by proper rehabilitation and exercising. In this framework the authors propose an innovative device that is based on the particular properties of parallel structures, capable of providing home assistance for training and rehabilitation tasks for elderly people. The system structure is summarized from conceptual viewpoint in Figs.1 and 2 in which main different activities and aspects are outlined as pertaining to the main units: a portable system that is based on a cable parallel manipulator architecture, sensored mechanical interface supported by telesupervised visual reality software, control equipment for intelligent controlled operation, medical-based strategies. The units are the components of a transportable system than can be fairly used directly by elderly people users in home environments and hospital frames with tele-supervision of medical operators and with intelligent controlled operation in medical-based procedures. The idea is to have a portable system than can be fairly easily accommodated in house environments as well in hospital frames as a personal service system that can be handled by elderly people with autonomy but supervision of medical staff with telepresence.
In the paper medical requirements will be outlined as referring to technical needs for developing design and operation of the system as in the structure of Fig.1 by discussing solutions for mechanical interfaces, sensing interfaces that are connected to the mechanical interface and for intelligent supervision of the operation, and operation planning for exercising and rehabilitating the motion of limbs of elderly people.

Fig1 A conceptual scheme of a cable-based parallel manipulator system for rehabilitation/exercising of elderly people limbs

Fig2 A conceptual scheme for the multi-disciplinary aspects in developing a rehabilitation/exercising system for elderly people.
The project is aimed to develop suitable designs and operations of robotic systems for rehabilitation and physiotherapy applications that can be operated both in hospital environment and patient house, as particularly developed for elderly people. An important issue will be the development of the easy user-oriented operation of designed new robotic systems, (Ceccarelli 2011).

In addition, the project will have the goals of defining an engineering frame for a specific contest for using parallel manipulator architectures in medical applications and of establishing a frame for formation and training of engineers, doctors, and nurses in design and use of the designed new robotic systems for rehabilitation and training of limbs of elderly people. Specific attention will be addressed to the design of suitable interfaces as well the overall design in terms of shape and size with the aim to make the system attractive and indeed acceptable to elderly with disability or injuries that limit their limb capabilities.

In particular, the project is aimed to introduce robotics technology in the specific activity for physiotherapy, but with suitable characters to enhance the acceptance and efficiency of medical treatments for elderly people. This main objective will require strong interactions and mutual understanding among project partners with different background, as coming from engineering areas, medical frames, and market enterprises.

By social viewpoints the project objectives can be recognized in aspect that make possible to have elderly people autonomous in the activities for their exercising and/or rehabilitation both in home environments and hospital frames although they are not left alone thanks a monitoring and supervision of nurses and doctors through suitable equipment of tele supervision and telecommunication. In addition, the possibility of operating the assisting system by themselves will give the elderly people the psychological feeling and capability of being fully capable to arrange the system for their needs as function of their conditions at the moment. The technical aspects are focused in the development of suitable systems with advanced functionalities with respect to the existing assisting medical devices by using robotic solutions with proper constraints from the physiotherapy environments. The robotic solutions will be investigated and designed to achieve proper levels of robustness, adaptability, autonomy with a strong care for safety in human-robot interaction (human-machine interaction). The robustness is intended both in term of design structure and operation reliability. Adaptability is aimed to achieve solutions that can be properly adjusted as function of patient-user characteristics as well as training physiotherapy needs. Adaptability will include also transportability in order to easily install and uninstall the system that can easily follow the patients from hospital frames to house environment and vice versa.

Autonomy will be ensured with intelligent functioning which nevertheless will be constrained and/or supervised by medical operators in order to ensure the proper level of actions of the system. In the project activity a specific attention will be deserved to the safety aspects as related to the strict interaction between the patient-user and robotic system, by also considering that the psychology of those patient-users can be much more sensitive than usual to new devices and/or unconventional therapies.

An objective refers to clinical requirements and protocols as focused in achieving the definitions of conditions that can be worked out with a robotic system and consequently medical protocols will be adjusted or designed for a proper operation of a robotic system with specific medical frames. Training and rehabilitation of limbs require specific strategies for each application that are identified also by biomechanics aspects of motions as function of disabilities and injuries of limbs. In addition, the age of patients is also an important factor in outlining the range of exercising/rehabilitating motions so that elderly people must be treated with specific attentions, even for the variety of their structures and conditions. Therefore medical protocols are required to be adjusted as function of patient characteristics but even of the assisting device in the exercising/rehabilitating actions, both from medical and technological viewpoints.
Objectives on strategies for automatic/guided training of elderly people patients are directed to a development of suitable strategies for the exercising/rehabilitation therapies of elderly people with adaptive automatic and robotic features but by fulfilling clinic requirements and acceptance but satisfaction of the elderly people even with aspects of hobby time exercising. An adaptive functioning of the system is aimed at adapting to the exercise levels a elderly person can perform and can switch automatically to another level (e.g. a elderly person is helped to do hand stretches to improve muscle force with a resistance of 10 N, and when the systems sees that the elderly person can do 20 times the exercise without effort, it can automatically or adaptively change the force to 15 N or in the opposing situation the system decreases it to 5 N).

A final target is consists in reducing the therapy costs and increasing patient comfort on the specific field of medical assisting devices for rehabilitation and exercise with elderly patient.

The project proposal aims to develop a system for health assistance of elderly people to facilitate their exercising and physiotherapy in home environments in ensuring their good quality of life in terms of independence and healthy conditions with reductions of costs and actions form medical care organizations. The proposed robotic platform is structured with ICT solutions to ensure intelligent operation, user-guided use, and tele-supervision by medical staff to make safe and comfortable the operation of the system by elderly person by their own. The activities for design, operation performance, and construction of a demonstrator prototype are planned to include problem considerations and solution proposals from several aspects for a multidisciplinary approach that the nature of a acceptable implementation requires for elderly people. Relevant disciplines that can be involved in the proposed work program can be identified mainly, but not only, in Service Robotics, Physiotherapy, Medical Care, Control Systems, Mechanism Design, Virtual Reality, Human-Machine Interfaces, Sensors, by looking at hardware designs and software solutions linked to medical strategies with features for a feasible implementation at proper levels of safety, conform, and flexibility. Innovative are the outcomes as oriented to the end-users who can be identified primarily to elderly people. Special attention is devoted to developments for modularity of solutions that can ensure a wide flexibility for a fairly simple adaptation to the wide range of situations and conditions in the system applications as medical or training devoice for elderly people.

Medical care will be worked out by continuously considering both the therapy / exercise goals and medical frames. Therapy goals are identified in exercising and/or rehabilitating limbs of elderly patients whose capabilities need to be restored or enhanced as due to injuries or disabled conditions just because of the age. The peculiarity of the project goal is also in defining solutions that can be used at the hospital frames for the initial therapy but then they can be transported and used in home environments in which elderly patient can feel more comfortable with the family presence and support, but still with a remote supervision by medical staff. In addition, medical constraints will be considered in terms of clinical procedures as well as medical monitoring that are thought both with physicians or nurses interventions as well as with intelligent monitoring for remote supervision and/or recording. Aspects of medical cares will be also very influential in proper development of interfaces that will permit a comfortable safe use of the robotic system but also that will give a proper level of intelligent monitoring of the interaction of patient limb with the robotic operation. Aspects of specific shape design will be considered for the interfaces as well for the whole design of the systems. Other aspects of medical cares will be considered as from physician viewpoints for the clinic procedures and standards, even for definition of new protocols or adaptation of existing protocols to be properly calibrated to the operation of the system. Thus, one of the most important aspects is considered the feature of low-cost solution both for the design structure and programmable operation. In general, an accurate objective mobility assessment can be required for decision-making and therapy planning in rehabilitation medicine. Those assessments can be useful to determine mobility features for applications both in home environments and hospital frames, to facilitate and improve clinical decision-making for rehabilitation programs as function of the many influential aspects like assistive devices, exercise types, treatment, and so on, and to evaluate results and progress during and after rehabilitation therapy. Currently, many types of mobility assessments are performed in a clinical frame and are supervised by the rehabilitation physician. These assessments include anamnesis of previous
patient conditions, clinical tests, quantitative and qualitative measures, and subjective feedbacks from a patient. All these are even more difficult activities with elderly patients. Although clinical mobility tests have value from medical viewpoints, assessment tools may not be appropriate for determining significant factors for an independent walking rehabilitation and for the impact of the environment on individual mobility capabilities. Therefore a monitoring of the motion capabilities outside of clinical frames can be important for a full understanding of the results or progress of a rehabilitation since moving in real world is different from moving within a frame for measurements within clinic frames. Portable mobility monitoring systems are designed to be worn as suite and allow mobility monitoring in home environments and any other frames. Several portable mobility monitoring system can measure biomechanical and/or location parameters, but most of them lack on acquiring environmental or contextual information. Contextual information is related to data on where, what, and how a person moves. A camera can provide contextual information of a surrounding environment. But portable systems with contextual information, such as context-aware systems and life logs, are not suitable for people with physical disabilities in external general environments. Other context-aware portable systems use context information to better recognize activities, but environmental characteristics are not considered with their impact on mobility performance of the monitored person.

State-of-the-Art

The paper will focus of new development that represents an extension of the state-of-the art in this field (e.g. devices presented in Fig. 3). The novelties of the solution to be proposed in this paper will include more user-oriented architecture, intelligent human-machine interface and full mobility of the system as depicted in Fig. 2.

Main References

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