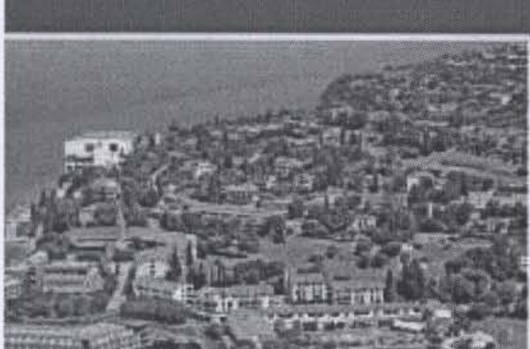
Proceedings of the

7th Mediterranean Congress of Physical and Rehabilitation Medicine

Portorož - Portorose, Slovenia
September 18-21, 2008



EDIZIONI MINERVA MEDICA

Contents

Robotics in rehabilitation

M. Munih, T. Bajd

Faculty of Electrical Engineering, University of Ljubljana, Ljubljana, Slovenia

Acknowledgements. — The described original research work was supported by the Slovenian Research Agency, and Gentle/S, I-Match, Alladin and MIMICS projects from EU.

The paper presents background, main achievements and components of rehabilitation robotics in a simple way, using non-technical terms. The introductory part provides a look on the development of robotic approaches in rehabilitation of neurological patients. In a sequence are covered topics of virtual reality in rehabilitation, hapticity and interaction between robot and human. This is followed by illustrating importance of passive exercise and active tasks. Mentioned is a number of upper and lower extremity rehabilitation robotics devices. The closing part stresses also the advantage of quantitative measurements.

The application of robotic approaches in neurological patient rehabilitation has been introduced almost two decades ago. Conventional therapeutic techniques and robot assisted techniques should be perceived as two complementary approaches. The activities of a therapist unavoidably include subjective elements, attention is most frequently directed to the problem solving, on predefining some intermediate goals and then adjusting the theraphy in gradual steps to finally learn complete movement. Robotic therapy will in the future probably complement the existing clinical practice: by reducing a therapist's workload, providing less costlier and more extensive therapeutic programmes; by new quantitative indicators about a function or injury and last but not least by new insights into the treatment process. Two very positive aspects of robotic therapy are primarily high repeatability and automatic measurement during exercise. One of the natural common points of conventional and robotic therapy is related to the way of haptic interaction between a patient and a therapist in which the force is a media and mechanical energy perceptibly flows in both directions. The robotic therapist devices differ in a number of ways from today mostly spread industrial robotic manipulators. These are traditionally moved between two known points along the trajectory of positions in the space. Maintaining known and highly accurate position is important task of an industrial controller. On the contrary, the programmable compliance, or adjustable stiffness of mechanisms is the property expected at first from the robotic therapist. Most of us is familiar with VR technology from various spheres of life.[1] It is widely used for entertainment (*e.g.* games) and military simulations. Lately, its use has expanded to other areas, for instance computer-aided design (CAD), architecture, general virtual presentation of data and to medical applications. In rehabilitation, the virtual reality is usually understood as a three-dimensional computer model which primarily defines the geometrical model (kinematic or dynamic model) of different virtual objects and their environment. It is possible to define not only the image of objects, but also their inherent physical characteristics. Such virtual world can change in time – not only the position and orientation of particular item, but also dynamic characteristics of the surroundings, such as friction and gravity or mass, moment of inertia, forces, torques, and torques and forces resulting from interaction of objects and, for instance, compliance (stiffness) of objects, roughness and smoothness of objects that cannot be visually detected or presented. These require the sense of touch ability with the object (robot), namely the force has to be provided to the user with the value being dependent on the parameters,and the model of a virtual environment. The verb 'απτω' - hapto is originating from Greek for reaching, holding and touching. If a person exerts force $\boldsymbol{F}$ onto mass m, which is integrated in the environment via the damper b and the spring k, the move x is determined by the differential equation: $F = m\ddot{x} + b\dot{x} + kx$. If the coefficients for mass m, dumping b and stiffness k are constant, the force depends on the position (distance to origin), velocity and acceleration. The values of m, b and k also change locally in the virtual environment or belong to an object, actually, each of the three parameters, e.g. k, has six values at the same point (or position) in space: *e.g.* k_x, k_y and k_z along individual axes of space, and k_{Rx}, k_{Ry} and k_{Rz} rotationally around individual axes of space or object. The same applies to the other two coeficients b and m. An empty space has nil or small values of all six k. A flat wall in a virtual environment is represented as a high k horizontally. In rehabilitation is often used haptic rendering to denote a virtual tunnel that connects two extreme points of movement, the starting and the final one. The trajectory between them can run over a straight line or a curve having a different shape. All elements m, b and k along the direction of movement equal zero, whereas perpendicularly to the direction of movement the stiffness coefficient k increases by selected function. This is reflecting in the virtual pipe or tunnel that is forcing the user to the central curve line, where this force component does not exist. Further to vision and haptic modalities, some information can be supplied to the user via sound or other modalities, as in MIMICS (EU FP7) project. In particular cases would be sound produced during movement along rough or smooth surface, along the ladder with crossbar, or when typing on various types of virtual keyboards. Robotic devices in positional trajectory mode are enforcing passive movements, namely for simple positional control of extremities, which, however, does not involve active participation of a patient on neuromuscular and sensory level. CPM (Continuous Passive Motion) devices have been used in postoperative rehabilitation of joints since approximately 1960. The CPM devices are very efficient in preserving the range of movement, they reduce stiffness in joint, decrease the need for drug administration and in general shorten the inpatient length of hospitalization. Comparison of CPM and physiotherapy reveals in majority of cases a weaker muscles, delays in activation of extensors and stiffness of flexors. It would be difficult to expect anything else, since the CPM devices only move a person's extremities without activating the muscles. In active assissted exercises the robot moves the extremity along a predetermined trajectory, while in active constrained and resistance exercises the robot provides higher opponent forces. The findings of the Fasoli trial disclose that the active resistive exercises are more useful than active constrained exercises as regards the upper extremities. In adaptive exercises the robot is providing an previously unknown dynamic environment to which the subjects have to react. One of the methods that has not yet been mentioned is gravity compensation of the upper extremity. The evolution of gravity compensation devices has been going on for decades. For instance, Beer *et al.*[2] specifically investigated the implementation and reach of gravity compensation for the upper extremity. Recently, three arm gravity compensators were put on the market: Armon,[3] Dynamics Arm Support [4] (DAS) and Armeo [5].

A number of research or commercial platforms exist today that are designed specifically for the tasks of rehabilitation robotics, while in some other platforms the primary designing goal has been aimed at something else, but the properties of resulting device also suits needs of rehabilitation. Regardless of the origin of devices can these be of two types, including exoskeleton or the end effector type, some examples are mentioned in sequence.

Perry *et al.*[6] is using an exoskeleton robot with seven degrees of freedom in the most important joints of human arm. L-Exos is a tendon driven wearable haptic interface with 5 DoF. Neural control of an upper limb Powered exoskeleton system has 8 DoF. ARMin represents an interesting later design that at the moment enables movements in 6 DoF.[6] Examples of end effector upper extremity devices include MIT Manus,[7] Assisted Rehabilitation and Measurement (ARM) Guide,[8] Mirror Image Motion Enabler (MIME), Bi-Manu-Track,[9] GENTLE/S,[10] Neurorehabiltation (NeReBot), REHAROB, Arm Coordinating Training 3-D (ACT^{3D}), Braccio di Ferro,[11] and NEDO project device. There are also devices available for the lower extremities, Gait Trainer GT I, end effector type and HapticWalker(exoskeleton type) most frequently in combination with treadmill, and of mostly used Lokomat by Hocoma.[5] Research devices are also available for exercising some other joints of the body, like ankle, wrist, individual fingers [12, 13] or several fingers simultaneously.

In neurology, standard rating scales are used for measurements, mainly for the purpose of early systemisation. The haptic, robotic technology is providing abilities for the next stage in rehabilitation, *i.e.* objective measurement during exercise. Often can be measured directly or derived the quantities that vary with time (position and orientation, velocities, accelerations, forces, torques). The presentation of these quantities for individual relevant points of the body alone offers objective basis for evaluation, similar as in kinesiology. Checking of these quantities could be valuable for an expert. Observation of measured data in a frequency domain can result in new views, for instance, in the case of the Parkinson's disease, the amplitude and frequency of shaking are determined depending vs. place and time. The measured quantities can be used as entries into various physical or physiological models and through them new significant parameters may be acquired, e.g. active torques of the muscles of individual joints, passive torques in joints or even mass and evaluation of moment of inertia of some body segments.

The general development of technology in the recent period made possible realisation of many visions. However, most of hi-tec systems are only being introduced into our lives in the fields of computing, virtual reality visualisation, medicine in general, and a narrow field of rehabilitation. Previously most simple devices in rehabilitation, accessories and physiotherapist's hands will in the future be in part complemented by perfected computerized and partially robot distinction devices. These offer the previously known and also some new aspects of rehabilitation.

References

1. Burdea C, Coiffet P. Virtual reality technology. Wiley-Interscience; 1994.
2. Beer RF, Dewald JP, Dawson ML, Rymer WZ. Targetdependent differences between free and constrained arm movements in chronic hemiparesis. Exp Brain Res 2004;156:458-70.
3. www.mginside.info
4. www.exactdynamics.com
5. www.hocoma.ch
6. Perry JC, Rosen J. Design of a 7-Degree-of-freedom upper limb powered exoskeleton, BioRob 2006, The IEEE/RAS-EMBS International Conference on Biomedical Robotics and Biomechatronics, Pisa 2006. p. 805-10.

7. Nef T, Mihelj M, Riener R, Min AR. A Robot for Patient-Cooperative Arm Therapy, Medical and Biological Engineering and Computing 2007;45:887-900.
8. Krebs HI, Hogan N, Volpe BT, Aisen ML, Edelstein L, Diels C. Overview of clinical trials with MIT-MANUS: a robot-aided neuro-rehabilitation facility. Technol Health Care 1999;7:419-23.
9. Reinkensmeyer DJ, Kahn LE, Averbuch M, McKenna-Cole A, Schmit BD, Rymer WZ. Understanding and treating arm movement impairment after chronic brain injury: progress with the ARM guide. J Rehabil Res Dev 2000;37:653-62.
10. Hesse S, Schulte-Tigges G, Konrad M, Bardeleben A, Werner C. Robot-assisted arm trainer for the passive and active practice of bilateral forearm and wrist movements in hemiparetic subjects. Arch Phys Med Rehabil 2003;84:915-20.
11. Coote S, Stokes E, Murphy B, Harwin W. The effect of GENTLE/s robot-mediated therapy on upper extremity dysfunction post stroke. In: Proceedings of the 8th International Conference on Rehabilitation Robotics; 2003 Apr 23-25; Daejeon, Korea. Daejeon (Korea): Human-Friendly Welfare Robot System Engineering Research Center 2003; p. 59-61.
12. Casadio M, Sanguineti V, Morasso PG, Arrichiello V, Braccio di Ferro. A new haptic workstation for neuromotor rehabilitation. Technology and Health Care 2006;14:123-42.
13. Mali U, Munih M, HIFE-haptic interface for finger exercise, IEEE/ASME Transactions on Mechatronics 2006;11:93-102.

Structuring rehabilitation project and program through the ICF-CY conceptual framework in a neuropediatric rehabilitation hospital

A. Salghetti, S. Betto, F. Da Ros, M. Battaglia, A. Martinuzzi

"E. Medea" Scientific Institute, Conegliano Research Centre, Conegliano, Treviso, Italy

Aim

Rehabilitation is a complex process by which a person is guided to reach the maximal level of functioning possible for a given health condition and in a given context. Rehabilitation as such thus needs a long term goal, reflected in the rehabilitation project, in which the expected level of functioning the person might achieve is projected, and a program, containing the detailed description of the methodology (in term of interventions, tools, timing) by which the team aims at the various intermediate targets. By its nature rehabilitation work is an equipe work characterized by multiprofessionality. When dealing with children with disability the (re)habilitation work, appears if possible even more complex and multidisciplinary, since the health condition affecting the child impacts not only on the present functioning, but projects its consequences on the developmental trajectory of the growing person, involving actors not usually present such as the teachers and the school. The first and most important goal when approaching the rehabilitative work is a clear and shared description of the patient's functional status (with its problems and points of strength), and a concordance upon short and long term targets by all involved actors, including the family and the patient himself. This need for a commonly viewed perspective is however not easily achieved when professionals with different background and non-professional stakeholders are put together. Language differences are not the only problem, in fact the way in which the functional/dysfunctional status of the person and the adaptive/disadaptive environmental response are described is very easily influenced by divergent conceptual views, may thus result in conflicting representations and, eventually, in non harmonized and even contradictory strategies. Diverging conceptual references and linguistic misunderstanding may translate in disarticulated and incoherent programs, severely undermining the rehabilitation project and the final outcome. In 2001 the World Health Assembly approved and recommended to all member states the International Classification of Functioning, Disability and Health (ICF) as universal descriptor of human functioning in the context of any health condition.[1] ICF was intended to be used in various settings and for all age groups, however the need for a specific adaptation for children and youth was indicated by the WHO itself. A work by our group showed that ICF use in the context of a rehabilitation hospital for children with complex disabilities posed some problems.[2] An ad-hoc work group set by WHO developed the adapted version of ICF for children and youth (ICF-CY), which was approved on October 2006, and presented to the international public on October 2007.[3] ICF-CY provides the conceptual framework to which both the description of the functional status of children and adolescents with disabilites should refer, and the common language in which all the professions working in the rehabilitation equipe as well as the family may recognize themselves. The specific and coherent way in which ICF-CY is able to represent in a single unified picture the functioning of the developing person candidates this tool as the logical roadmap guiding the design and the follow-up of the rehabilitation intervention. With these premises, we experimented the introduction of ICF-CY in the process of project and program definition in a tertiary care referral rehabilitation hospital for children with complex and severe disabilities, and we assessed after one year of testing, the impact of such action on the team.

Methods

An ad-hoc work group was constituted within the rehabilitation team of a tertiary care referral hospital for paediatric neuro-rehabilitation in the Veneto Region (Italy). The work group, starting from the analysis of the process, defined the steps in which ICF-CY structure or formal coding could be introduced and linked to specific steps in the rehabilitation work, and eventually elaborated a structured format in which the rehabilitation project and the