Rehabilitation Robotics – From Head to Toe

Peter P. Pott, Institut EMK, TU Darmstadt
p.pott@emk.tu-darmstadt.de
Helmut F. Schlaak

Introduction
Robots can be used as versatile and intelligent exercise devices for rehabilitation purposes after stroke, injury, or surgery. In the following, an overview about this interesting field of technology between classical engineering and modern medical methods will be provided. In the final presentation, selected systems and promising technical approaches will be presented and discussed.

Methods
The overview is based on a thorough literature research and the internet-database MERODA (www.meroda.uni-hd.de). This database provides basic information about more than 500 medical robotic systems used in different surgical disciplines like orthopaedics, trauma, rehabilitation, and imaging. In the following, project names and –codes will be used according to MERODA’s nomenclature.

Results
The literature research identified more than 60 different systems, systematic approaches, and therapy concepts, covering the whole human body from head (TAURUS [1], USA43 [2]) to toe (NZ01 [3]). In most cases, upper limbs (arm and/or wrist) and even fingers (CHINA06 [4], HANDEXOS [5], DEU30 [6], UK09 [7]) or lower limbs are supported. For the lower limbs, two different therapy strategies can be described. Some systems support the feet (e.g. HAPTIC WALKER [8]) and—in some cases—the knee (e.g. LOKOMAT [9]) and perform gait patterns to re-establish walking during stroke rehabilitation or to teach gait patterns to paraplegic patients. The systems support the patient’s weight during walking on a treadmill or comparable devices and provide mechatronic systems attached to the ankle-, knee-, and hip-joints to induce forces and torques.

In all systems, assistive and resistive forces can be applied. Assistive forces support the patient and the limb during training and thus allow complete movements even when muscle forces are (still) too weak. Gait pattern trajectories are defined individually. During on-going therapy the amount of assistance is decreased as muscle forces are restored. Using resistive forces, the muscles are trained further up to a healthy level. By these approaches the patient’s weight and the forces applied by the system act together on the patient.

Another aspect of rehabilitation covered by robotic systems is massage. Here, mobility is restored by constantly applying forces over certain parts of the body (e.g. WAO-1 (maxilla [10]), RUS01 (limbs [11])).

Conclusions
The review shows a wide variety of technology and approaches to use robotics in the field of rehabilitation and physiotherapy. Classical robots, defined as re-programmable manipulators for universal deployment, are used in some cases but mostly purpose-designed systems were identified.

Most of these systems are not commercially available, so only little comparison is possible and prospective studies for these systems are few. For commercial systems, some study results are available proving certain hypotheses while other systems are already widely used in the clinical environment. In all cases, the robots do not replace classical physiotherapy but enhance its outcome as training units can be repeated more often with more precision and less manpower requirements. However, training units have to be designed carefully and their correct accomplishment has to be well monitored to avoid training of wrong limb trajectories and evasive movements of the patients.