MOPASS – Mobile Robotic System for Individualized Gait Rehabilitation

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Abstract

This paper presents the current progress behind the development of the mobile robot based gait rehabilitation system MOPASS. Combining an actuated orthosis with a mobile platform, the developed system provides required mobility of the patient and enables the gait training under realistic conditions. Besides mobility, the system offers doctors and therapists an efficient specification of therapy parameters, e.g. patient adjusted desired joint trajectories and maximum allowed support rate, enabling individualized rehabilitation. The proposed control concept realizes adaptive system behaviour dependent on the individually defined (intermediate) therapy goals and current status and performance of the patient.

1 Introduction

Several exoskeleton based systems are currently available on the market and in research worldwide. This type of robotic systems has been developed to support humans during physically straining work or to restore lost functionality of the limbs [1]-[4]. Over the last decade such devices also find an application in medical therapy, e.g. gait rehabilitation, with the goal to speed up and optimize gait rehabilitation by making use of the accuracy and repeatability provided by robotic devices and to ease the job of the therapists. Even though various devices are available, most of them do not meet the main requirements of the medical personnel: such systems should be mobile, easy to use and both easy to adjust to the patient and to the individual goals of the therapy.

2 MOPASS concept

2.1 System requirements

The main goal of the project MOPASS is to design a rehabilitation system that suits the therapy of two user groups: young and geriatric patients. Due to the natural differences of these user groups, the requirements for the system setup and especially for the operation of the system may vary a lot. Therefore, accurate collection of the group specific needs is a basic condition for designing a useful system. In order to meet the requirements of both groups, an extensive requirements analysis was performed by the clinical partners of the project [5], [6]. The results were prioritized accordant to [7] with MoSCoW (M – must, S – should, C – could, W – won't) method and can be summarized as follows:

- functional requirements on the orthosis, mobile platform and control
  - Individual adjustment of the overall construction to the patient
  - active support of knee and hip joints
  - support of pelvis movement: rotation (active), translation (passive)
  - mobility (individual adjustment of the system velocity)
  - stability and support of the patient during therapy session
  - individual control of hip, knee and pelvis
  - separate control of the left and right orthosis
- requirements on the user interface
  - Therapist interface:
    - definition and adjustment of the individual (intermediate) therapy goals, e.g. desired joint trajectories
    - definition of allowed individual support rate
    - adjustment of the therapy parameters: offline – for session preparation, online – for adjustment of the therapy session on current state and performance of the patient
    - online visualisation of (selected) gait parameters during therapy session
    - adjustable complexity of the data representation
    - summary of the training session
    - (comparative) analysis of the therapy progress and changes between certain therapy sessions
  - separate graphical user interface for the patient

- start / stop of the training session
- reduced graphical representation of the session relevant data
- online adjustment of certain parameter set (e.g. speed, step length) within predefined range

- others
  - recording of the complete data collected during a therapy session
  - obstacle detection during movement
  - additional sensors for detection of the user pose with respect to mobile platform
  - additional bio sensors for collection and analysis of the patient state

Based on the resulting requirements catalogue, the MOPASS system presented in the next sections was developed.

2.2 Hardware setup

The MOPASS system is a fully mobile robotic device mainly consisting of a mobile base and an actuated orthosis. The orthosis provides controlled actuation of hip and knee joints and enables pelvis motion, which is required for a physiological gait pattern. In order to enable individual adaptation of the mechanical configuration to the patient, the system is equipped with motorized mechanisms for height and width adjustment. The adjustment of the orthosis to the individual patient size is performed manually with the help of integrated shift mechanisms in the joint connection elements. In the Figure 1 the hardware setup of the MOPASS system is presented.

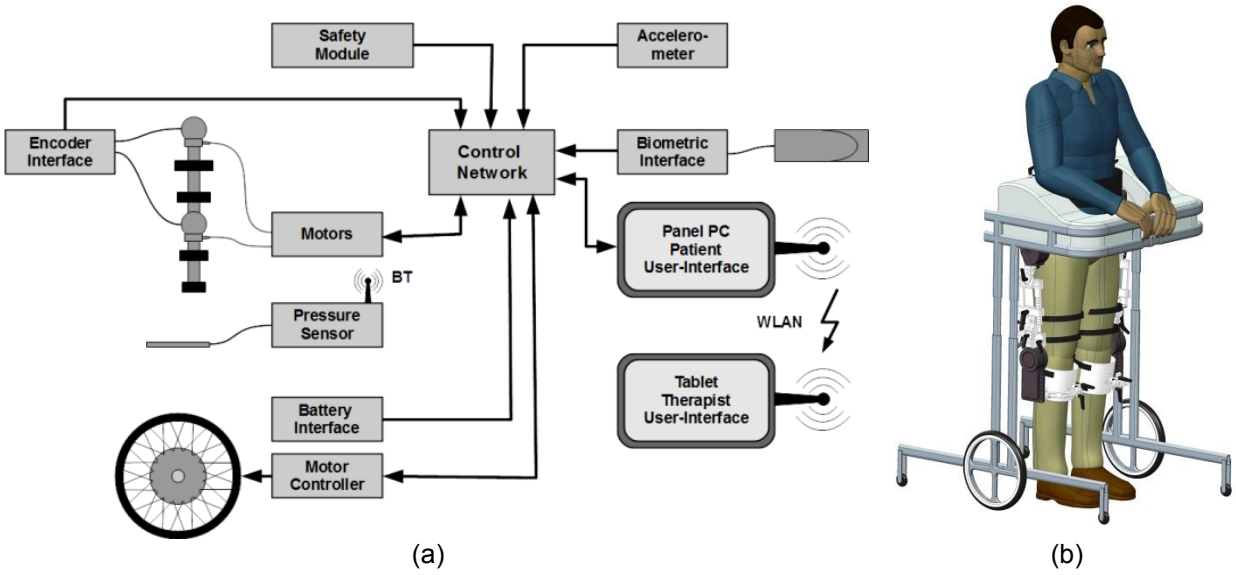


Figure 1 Hardware setup of the MOPASS – system: (a) system components, (b) current system design

According to the requirements described above, the rehabilitation platform MOPASS is equipped with a sensor network integrating both, internal sensors of the orthosis actuators and several sensors to provide patient state information, relative position of the patient within the system, foot pressure and also safety related data. The control network connects the computers of the system. The low-level control PC (on-board) is responsible for the control of orthosis and mobile platform as well as for the data collection from the internal device sensors. The second on-board computer collects data from additional sensors and is also responsible for data exchange and the patient interface. The therapist interface is implemented on a separate tablet PC (off-board) which is wirelessly connected to the network on-board.

2.3 Control strategy

The innovative control system offers different operation modes which allow the development of different training scenarios and an adaptive adjustment of the degree of support according to the individual progress of the therapy. In the FollowUp mode the device exerts no supportive or resistive force/torque to the patient, it just follows the patient's movements and records measurement data. The trajectories recorded in the FollowUp mode are considered as current patient performance and are provided to the therapist interface for modification towards a more desirable trajectory. During an actual training session, an Assisted-as-Needed strategy provides a variable support rate, dependent on the current performance of the

patient. In this operation mode, the control system measures the forces exerted by the patient and provides support forces towards the desired joint trajectories specified by the therapist. An overview of the control strategy is represented in the Figure 2.

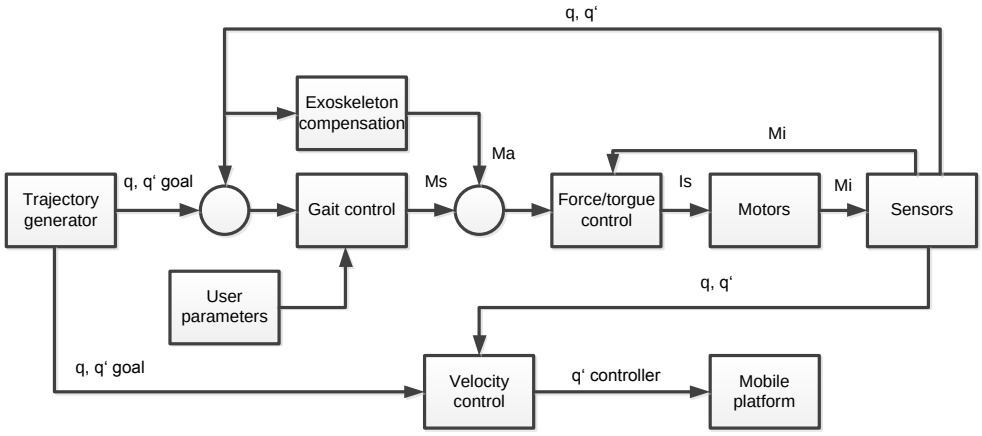
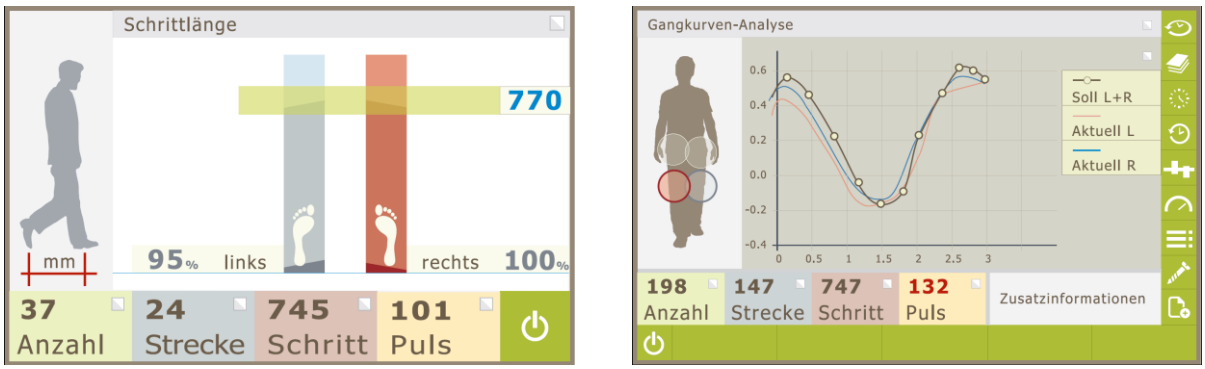


Figure 2 MOPASS control loop

Additionally, the system offers a gait-pattern or trajectory generator that can generate hip and knee angle trajectories depending on the individual patient's capabilities and desired gait characteristics.

2.4 User Interface

The user interface (UI) of the MOPASS system consists of two separate units: therapist UI and patient UI. While the patient UI enables only basic parameter tuning within pre-defined range, e.g. adjustment of the platform speed, start / stop of the training and simplified data visualisation (see Figure 3 (a) for example), the therapist interface enables full control of the therapy and detailed online visualisation as well as offline analysis of the patient performance (see Figure 3 (b) for example).



(a) (b)

Figure 3 MOPASS user interface (design concept evado): (a) online data representation for a patient, (b) gait pattern analysis (therapist display)

The key feature of the MOPASS system is the trajectory generator providing the required functionality for the individualized setup of the therapy and generation of patient specific (intermediate) therapy goals. The current patient trajectory of hip and knee joints is available from the measurements performed during the FollowUp mode. The 'natural gait trajectory' is offered depending on the physical characteristics of the patient (e.g. height) and gait parameters (e.g. cadence). Both gait patterns, i.e. current and 'natural', are shown simultaneously. The therapist can define the desired gait characteristics by shifting the measured current gait pattern towards a healthy gait pattern. This way, the therapist/doctor is able to graphically set up the 'goal' trajectory for each patient. The current training trajectory ((re-)measured in the FollowUp mode) will change automatically to approach the goal trajectory when the patient has performed well with the current one. Alternatively, the therapist/doctor can change the gait parameters (e.g. speed, cadence, step length) manually. In this case, the trajectories will be automatically recalculated to fit the new parameters.

Besides easy modification of the settings for the therapy session, the graphical user interface provides online monitoring of the patient status and performance and enables offline analysis of the rehabilitation

progress. Since the overall sensor data is recorded during training sessions, the data of the therapy sessions to be compared can be easily recalled from the data base and displayed in a combined window for analysis.

3 Results and conclusion

The MOPASS system is now in the final implementation and integration state. Regular discussions with the therapists involved in the project promise high acceptance by the personnel. The evaluation of the final system is planned for May - June 2015 and will be done with both young and geriatric patients. The evaluation of the system with young subjects will be done at the facilities of the NRZ (Neurological Rehabilitation Centre Friedehorst, Bremen) while the Geriatrics Research Group of the Charité, Berlin, will test the system with geriatric persons.
Due to the results of the clinical studies performed in the requirement analysis stage and the great effort to make the system intelligent and convenient to use for both the therapist and the patient, a good acceptance and an adequate progress in the therapy provided by the MOPASS system can be expected.

Acknowledgments

This work is funded by German Federal Ministry of Education and Research (BMBF) within research project MOPASS (grants 13EZ1123A–E).

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