Design and implementation of new robotic walker devices

Lessons learned and industrial perspectives

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***Abstract*—This talk addresses the essential methodological aspects of a collaborative development a robotic walker. Being a classical mechatronic system, created within a framework of a mixed research / engineering project, this device poses typical challenges on the developers, that need to tackled in a systematic way. Based on the lessons learned from similar projects, the author proposes an approach that might be generalisable.**

***Keywords*—mechatronic design, v-cycle, sit to stand**

I. Introduction

The MOBOT Project aims at developing intelligent walking assistant for people experiencing certain mobility problems. The two main target groups are i) users that have sufficient own gripping force in their hands ii) the users that do not have this force. Therefore it is necessary to develop two types of walking assistants; correspondingly the 'rollator type' and the 'nurse type' devices. The project is realized by a interdisciplinary consortium constituted by a number research partners, end users and an engineering company and aims at developing a technology demonstrator covering the early prototype phases: Concept Development, Technical Development, Beta Testing.

II. Methodology

A solid methodology is necessary due to an ambitious goal of evaluating the functional prototype in a real world environment, so the prototype must achieve the required maturity level within the project lifetime. Moreover, the MOBOT project is based on a user-centred design approach (see Figure 3), where the users' needs are concerned from the beginning of the project until the end by means of on-going user involvement into the development and evaluation of each component and of the whole system in real world tests. The major difference from other design philosophies is that the technology is designed according to how users can, want, or need to use it, rather than forcing the users to change their behaviour to accommodate to the technology.

The overall concept of the work on project is based on the V-cycle paradigm, based on "methodology of development of mechatronic systems" as of VDI2206 combined with the ISO 13407 "Human-centred design processes for interactive

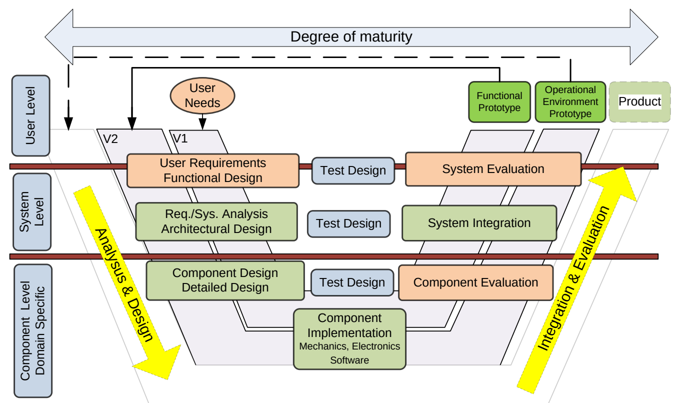

Fig.1. MOBOT development methodology blending ISO-13407 with VDI2206

systems", adapted to an innovative project enabling feasibility studies, early evaluation of prototypes and possibility of revising the technical specifications. Continuous involvement of users requires that the development methodology is flexible enough to adapt to changing requirements. The development stages (User Requirements, Functional Design, Architectural Design, Component Design and Evaluation, System Integration and Evaluation) are organized in cycle resembling the letter V, see Fig. 1. The left hand side of the V is devoted to analysis and design of the system, the right hand side to the system integration and evaluation. One can also distinguish the User, System and Component Levels giving additional perspectives of top (user) and down (implementation) viewpoints. As the system maturity increases with each cycle, so deeper grows the understanding of the user needs, technological possibilities and constraints.

Correspondingly, each development cycle begins with formulating the user requirement and ends up with the evaluation of the system by the user. As the system maturity increases with each cycle, so deeper grows the understanding of the user needs, technological possibilities and constraints. For the rollator type device, it is envisioned to perform two full cycles within the project: V1 ending with a functional prototype, and V2 ending with a prototype tested in the operational environment. For the nurse type device, only the V1 cycle is planned, timely realized in parallel to the V2 cycle for the rollator type.

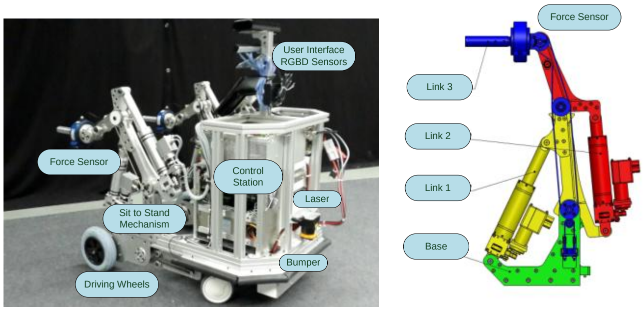

Fig. 2. V1 version of the rollator type device

III. IMPLEMENTATION

A. System Design

The user groups and their specific needs are captured by the clinical partners and comprise the specification of use cases, performance metrics/assessment strategies, and user evaluation studies relying on the expertise in gerontology and rehabilitation. Several design constraints were identified based on the working area (e.g. narrow spaces in bathroom, steps and slopes), anthropometrics (e.g step size, walking speeds), and user needs. Environmental conditions have been studied by the technical partners using a CAD model including walls, doors, furniture, slopes in order to study the maneuverability in the nominal (e.g. way from the patient room to cafeteria) and narrow (e.g. toilet) spaces.

The two main functionalities of the assistive walker are i) to offer active support during walking and ii) to support the user while standing up or sitting, the so called sit-to-stand (STS) transfer. In order to perform the necessary mechanical design, the geometry and the mass properties of the target user group were modeled based on human data and served as input to the biomechanical optimizations of the STS and walking [2]. The output of these computations are the optimal force/motion trajectories being used as input for the electro-mechanical design of the mechanisms.

B. Mechanical Design

The first version of the rollator was developed based on the measurements of the desired workspace and forces profiles performed with real patients, using a steel bar with dummy handles. The forces were measured using force sensors attached to the handles and the workspace and the kinematics of the patient was recorded using vision sensors. The resulting workspace has the size of approx. 30x30cm and the required lifting force is in the range of 224 N. The device developed accordingly is shown in Fig. 2. The main components are the mobile platform, the STS mechanism and the perception and computing workstations. The mobile platform is driven by two active wheels further supported by two castor wheels. The STS mechanism contains two separately driven handles for independent control of the left and right arms. Each arm has two active degrees of freedom and 1 passive degree kept parallel to the ground by means of tendons. The arms are driven by custom made linear actuators with DC motors, ball screws and brakes. In terms of sensing, the motion of the motors is sensed by high resolution encoders; additionally the motor currents are sensed and the interaction forces are measured by force sensors in the handles. The device undergoes the evaluation studies with the clinical partners in the real world environment.

The V2 version of the rollator is developed according to the force/motion profiles resulting from [2]. It turns out the initially chosen motorization cannot handle the required performance and it is necessary to develop drive units of a different characteristics. Currently high power density drive module consisting of a torque motor, harmonic gearbox, brake and position encoder are developed by ACCREA Engineering.

The main concept behind the nurse type device is to mimic the actions of a human nurse helping a person to stand up, as shown in Fig. 3. The human supporter is exerting forces onto the patient's knees and mid-trunk, at the same time offering support for the patient's arms. The mechanism of the nurse type device shall work according to the same principle. As in the case of the rollator, the biomechanical optimization was performed in order to obtain the force/motion profiles of all the actuators. These computations resulted in desired support forces and the trajectories of their application points.

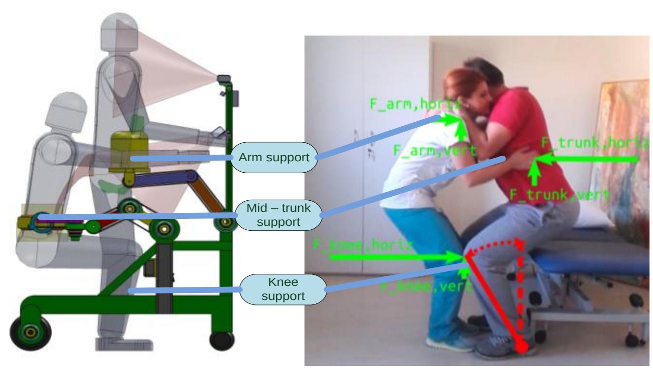

Fig. 3. Conceptual design of the nurse type device

C. Safety Design

The main goal of the safe design is to design robots so they are intrinsically/mechanically safe, i.e. avoiding hazards instead of controlling them. Therefore low power drives limiting external forces / speeds, back drivable mechanisms are chosen. However, assuring intrinsic safety is not always possible and the full safety and risk analysis must be performed. This is planned to be accomplished according to the ISO standards ISO 13849, ISO 13482 and ISO 12100.

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