

User Centered HRI Design for an Intelligent Robotic Rollator

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Abstract—A common problem for the elderly population with mobility impairment is the difficulties in performing Activities of Daily Living (ADLs), that consequently leads to restrictions and the degradation of the living standards of the elders. When designing a user-centered assistive device for mobility constrained people, the variable spectrum of disabilities is a factor that should affect the design process, since people with different impairments have different needs to be covered by the device, thus an adaptive behavior of those systems to real user needs is necessary. In this paper, we present the methodological principles and technologies, for the designing of the robotic rollator platform Human Robot Interaction (HRI) environment. The reported work builds upon experience gained from previous engagement with development of the multimodal HRI communication model of an assistive robotic rollator and its end-user evaluation, leading to our enhanced methodology for identifying and prioritizing user needs as applied in our current HRI design approach. Emphasis is placed on adopting multimodal communication patterns from actual human-human interaction in the context of mobility rehabilitation, which may enrich human-robot communication by increasing the naturalness in interaction from the side of the robotic device by adding more “human” characteristics both in respect to understanding and reaction capabilities of the robot.

I. INTRODUCTION

One of the major challenges that the modern developed societies are facing, is the rapid change in demographic data associated with the aging of their populations. A direct consequence is the increase of the population percentage that faces different degrees of mobility and cognitive problems apart from those caused by chronic related diseases and/or accidents. The need to improve the quality of daily living by supporting mobility and vitality, as well as enhance independent living of elderly individuals with motor limitations [1] has inspired technological solutions towards developing intelligent active mobility assistance robots for indoor

environments, providing user-centered, context-adaptive and natural support [2]–[5].

A novel intelligent robotic rollator is proposed for developing and testing a new pioneering robotic system that will provide a range of mobility and cognitive support functions for people belonging to the aforementioned population groups. The goal is to develop a flexible platform of robotic technologies adapted on a rollator walker aiming to provide active assistance and with the ability to acquire knowledge and adapt to the environment, personalized to each individual user, in order to support mobility and enhance health and vitality. Towards this goal, a number of methodologies are currently been developed, which are foreseen to be synergistically utilized. These include:

- Multi-sensory and physiological signals processing and identification of actions in order to monitor, analyze and predict human gait and other user’s actions.
- Behavioral and user-adaptive robot control and autonomous robot navigation for the dynamic approach of the user and the interactive co-occurrence combined also with voice guidance.
- Human-robot interaction and communication, including speech synthesis and recognition technologies and a virtual assistant (avatar) to enhance the naturalness of communication.

During this research the enhancement of these technologies and their application to meet major social needs are studied. One major characteristic is the synergy of the technological achievements with medical services that concern rehabilitation, aiming at interacting with target populations (patients) in order to design and integrate systems based on the needs of potential users.

Our goal to support elderly people and patients with mobility and/or cognitive inabilities, by achieving:

- Effective patient mobilization in the clinical environment of a rehabilitation center, reducing the burden on clinical staff and increasing the efficiency of rehabilitation programs.

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Fig. 1: The assistive robotic platform concept.

- Continuous support at home through technologies monitoring patients' progress, but also their mobilization through interfaces of cognitive and other support, increasing their degree of independence and improving their quality of life.

II. THE HRI COMPONENTS

The experimental robotic platform, consists of a sensorised passive rollator prototype, equipped with the necessary HRI components, as depicted in Fig. 1. The platform design incorporates HRI equipments in a portable and non-intrusive way. The system incorporates multimodal information from a camera and a microphone in order to capture the area of the torso, waist, hips and the upper part of the limbs, as well to communicate verbally with the user. The main goal is to interact and advice the user during the walking actions and during the execution of various rehabilitation exercises arranged in sessions. The main issue is to capture the upper body motion information and therefore to analyze the stability of the users' motion and assist them accordingly. In addition, through audio communication and avatar performance, the i-Walk system "naturally" interacts with the user at each phase of executed actions, by using simple instructions in order to guide and control the procedure and at the same time to provide reinforcement feedback in order to encourage and help the patient accomplish the executed task.

Furthermore, the platform incorporates visible and easy to use touchable buttons appropriate for the elderly people. Such buttons are very useful not only for emergencies, but also for platform mode selection, while making communication with the system highly accessible for the aged user. Finally, a screen is attached to the platform to provide visible instructions to the user by means of appropriately designed avatars.

In addition, the platform is equipped with biosensors,

attached at the handles, in order to capture basic but comprehensive bio signals like heart signals, pulses, etc. This information is important to continuously monitor the users' status and to relax and protect them from fatigue and stress during execution of the foreseen rehabilitation activities.

III. ROLLATOR USER EVALUATION

As a part of this research, we envision cognitive robotic assistants that act proactively by realizing an autonomous and context-specific monitoring of human activities and by subsequently reasoning on meaningful user behavioral patterns, as well as adaptively and interactively, by analyzing multi-sensory and physiological signals related to gait and postural stability. To address these targets, a multimodal action recognition system has been developed in order to monitor, analyze and predict user actions with a high level of accuracy and detail [6]. Also, one major issue is to enhance computer vision techniques with modalities such as range sensor images, haptic information and command-level speech and gesture recognition, data-driven multimodal human behavior analysis has been conducted, in order to extract behavioral patterns of elderly people. The aim was to import the basic elements of these behavioral patterns into a multimodal human-robot communication system [7], involving both verbal and nonverbal communication conceptually and systemically synthesized into mobility assistance models after taking into consideration safety critical requirements.

The evaluation phases of the rollator-type mobility assistant was conducted at the BETHANIEN-Hospital/Geriatric Centre at the University of Heidelberg, Germany (Fig. 2) and at the DIAPLASIS rehabilitation center in Kalamata, Greece (Fig. 3). These evaluation phases included a relatively extensive number of end users towards an overall benchmark verification of the developed intelligent mobility assistants [8]. Technical functionalities were assessed with respect

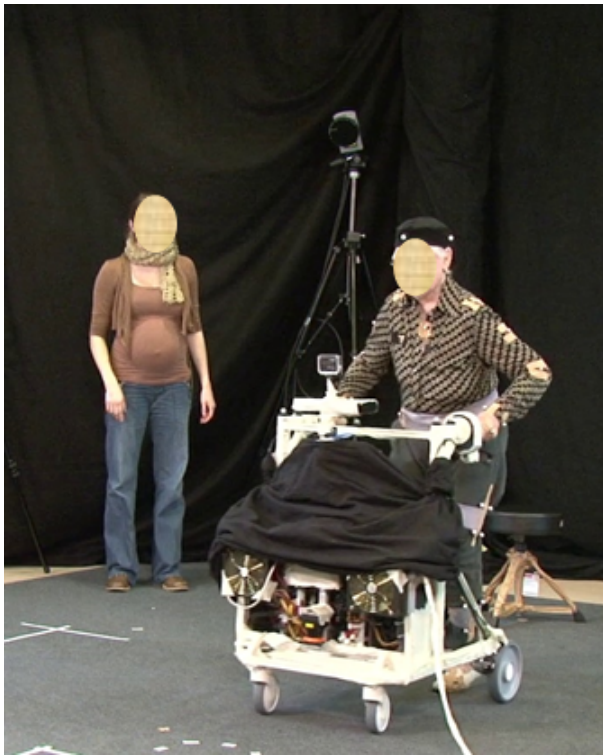


Fig. 2: End-user evaluation of the robotic rollator at the BETHANIEN-Hospital/Geriatric Centre at the University of Heidelberg, Germany.

to accuracy, validity and reliability of technical function. Clinical evaluation targeted at the interaction between a human and the device [9].

The scenarios implemented in validation studies aimed at assessing the performance of an aural cognitive assistance mode of operation and a set of audio-gestural human-robot interactions, aiming to evaluate the mechanisms implemented in order to build a close to natural human-machine communication. Also, the gait analysis tools were tested in order to extract basic human walking characteristics in order to assess, monitor and help the user's appropriately and to prevent fall situations [10]–[14].

Though all trials have been positively assessed in terms of feasibility and adequacy to the user needs, especially regarding the basic walking assistance, and the subjective user perception of the robotic device and its assistance systems [15], the “human” like characteristics of interaction have been the features which have received the highest scores in respect to user trust and user satisfaction. Such results are revealing regarding user expectations from devices, which are designed to be intensively used in a variety of home and clinical/rehabilitation contexts and demand a long-term user engagement [16]. These findings have driven the design of the human-robot interaction model in our current study. Thus, the communication ecosystem incorporates a set of multimodal interaction options which intent to raise user trust and engagement on the basis of knowledge gained from end user evaluation results of the assistive device, but also



Fig. 3: End-user evaluation of the robotic rollator at the DIAPLASIS rehabilitation center in Kalamata, Greece.

through a thorough study of the target group needs and interaction parameters.

IV. USER-CENTERED DESIGN

In order to succeed in applying user-centered design, most system developers put emphasis in gathering user specifications by means of interviews, questionnaires or mocap demonstration to groups of intended users. Following this kind of methodology may prove successful in what concerns assembling the necessary functionalities for a system to address its goals. However, designing the human-machine communication model and interaction environment of an assistive device is crucially related to the degree to which the latter incorporates features of natural human interaction in similar situations, along with an in depth study of technologies selected to provide user access to device functionalities and system information to users.

Therefore, it is crucial to concentrate on human communication situations, which include the use of embodied signals and language, taking into account the whole spectrum of options engaged to express a single linguistic message. This means that in the ideal case, the device's artificial intelligence capacity should be extended significantly, in order to become able to successfully handle communication situations not easy to predict, based on a rather robust underlying dialogue management system. Furthermore, incorporation of various features such as i.e. the use of touch screen, avatars or multimodal means of communication should serve specific needs towards better end-users support and understanding.

In designing the assistive robotic rollator HRI system, the following parameters have been studied in detail:

- 1) The targeted user group(s) as regards rehabilitation needs to be supported by the platform.
- 2) The symptoms which are expected to be supported as defined by a group of experts, including physicians, physiotherapists, ergo-therapists and psychologists.
- 3) The combination of available and missing physical/mental functionalities of the patient target groups.
- 4) The rehabilitation procedures followed in each case.
- 5) The communication patterns used during rehabilitation process, including linguistic and embodied signal exchange between patient and therapist.

Thus, the communication model can be characterized as user-centered because it is built considering all the above parameters. Furthermore, the built in language communication model that is incorporated in the dialogue management system of the platform, makes use of intuitive human language characteristics and the variation met in real human-human communication to provide for a more natural and easier to adopt human-machine interaction, where the goal is increased user trust and acceptance targeting engagement with the platform for a longer period.

V. CONCLUSIONS AND FUTURE WORK

Cognitive and robotic architectures may be able to provide advanced interactive capabilities with humans and influence the usability and functionality of a resulting system, thus, contributing to its quality of services. Such systems may not only integrate multiple advanced cognitive abilities, but also employ methods that are extendible to various other robotic and non-robotic applications required in assisting humans with mobility disabilities [17]. Since, systems failing to address the requirement of high user trust [18] and acceptance seem to fail in respect to user engagement, user-centered system design incorporating “natural” “intelligent” ways of human-machine communication is becoming obligatory.

The assistive robotic rollator end user evaluation process has highlighted the importance of the “human” like system characteristics for user acceptance and engagement. Furthermore, it has also pointed out the weaknesses of the initial design choices, especially focusing on the preset options of the multimodal interaction component of the evaluated prototype as regards the system’s HRI options.

The current goal is to bring HRI modeling further by: (i) fully exploiting information derived from patients’ everyday routines both as regards the range of their available physical and mental functionalities and tasks to be accomplished, and (ii) augmenting the device’s communication capabilities by building an intelligent dialogue management system that entails lexically and semantically extended knowledge based on the actual linguistic and embodied interaction patterns used by the targeted user group in real use environments while interacting with other humans including their therapists.

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