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IFAC-PapersOnLine 49-21 (2016) 656–661

Development of a human-friendly walking assisting robot vehicle designed to provide physical support to the elderly

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Abstract: Up to now, the embodiment of bodily-kinaesthetic, perceptual and cognitive capabilities for assistive robots has been scarcely studied. The author has introduced the development of a human-friendly walking assist robot vehicle designed to provide physical support to the elderly. The proposed system is composed by two-wheeled inverted pendulum mobile robot, a 3-DOFs desktop haptic interface, a mobile computer and a wireless module for communication purposes. In this paper, the authors present further detailed experiments for verifying the stability of the whole system under static conditions. An improvement of the velocity control is introduced with a feedforward approach based on an optimal controller. Pilot experiments with seven healthy volunteers were carried out to validate the feasibility for physical support while walking on a dynamic scenario (e.g. a bump). From the experimental results, the proposed system was stabilized in about 30 seconds under a surface with low friction coefficient. On the other, we could validate the feasibility to provide physical support with the healthy volunteers in the simulated dynamic scenario. Finally, the error in the velocity was less when the two batteries were connected with the proposed velocity control method.

Keywords: Assistive Robotics, Force feedback, Haptic Interfaces

1. INTRODUCTION

In industrialized countries, regional disparities in healthcare and welfare services, increased medical expense caused by aging societies and shortages of medical staff have become serious problems. In Sweden, it is expected that about 25% of Swedes population will be older than 65 years old by 2060 (Wilén and Ljungberg, 2009). For this purpose, robot technology (RT) is expected to be an important key to find solutions to these problems. In particular, roboticists have been developing assistive robots for health care and welfare applications to improve the security, independence and quality of the elderly so they can stay in their homes longer (Bertmar, 2012; Solis and Takanishi, 2011). As a consequence, this opens the opportunity to free up time so that medical staff can provide care for the patients who really may need a human support (Ishii et al., 2009; Yohan et al., 2011).

Even though the market size is still small at this moment, applied fields of human-friendly robots (e.g. assistive robots) are gradually spreading from the manufacturing industry to the third industry. Several companies have introduced assistive robots into the market. Some examples are the GiraffPlus telecare platform designed to help the elderly to stay in touch with care givers, relatives and friends (Giraff Technologies AB), the robotic eating device Bestic designed for persons with reduced or no capability in their arms or hands (Bestic AB), etc.

On the other hand, most of the research has been mainly focused in developing assistive robots for the elderly in terms of telepresence robotic platforms designed for maintaining the elderly social contacts (Kristoffersson et al., 2007; Cosgun et al., 2013), wheeled walker platforms designed for turning away from obstacles and prevent elderly from accidents (Hellström, 2012; Palopoli et al., 2015; Scheggi et al., 2014), pet-like robots designed for raising the quality of life among people with dementia in the later stage of their illness (Asplund and Gustafsson, 2013).

In particular, different walking-aid robots have been proposed during the last decades (Fukuda et al., 2015; Yu et al., 2003; Dubowsky et al., 2000; Hirata et al., 2003; Rentschler et al., 2003; Hirata et al., 2004). In particular, the walking-aid robots can be classified in two main groups according to the mobility factor (Fukuda et al., 2015): active-type walkers driven by a servo motor (Dubowsky et al., 2000; Hirata et al., 2003) and passive-type walkers driven by a servo brake (Rentschler et al., 2003; Hirata et al., 2004). Yu et al. (2003) proposed the PAMM system together with a smart cane robot with a relative small size but the manoeuvrability is compromised by the cost. Fukuda et al. (2015) introduced an intelligent cane robot consisting of a stick, a group of sensors for recognizing the user's intentions and an omnidirectional mobile platform. However, the physical support is provided by means of a fixed length and stiffness aluminium stick and cannot be customized depending on the needs of the specific user (required level of physical support depending on the undergoing daily activity) and environmental conditions (indoor or outdoor). From

Peer review under responsibility of International Federation of Automatic Control.
10.1016/j.ifacol.2016.10.675

those researches; a special focus has been done in terms to increase the level of multimodal interaction, sensing and control to facilitate the perception of the environment for a better guidance and provide a static physical support to avoid falling down. However, dynamic physical support (e.g. by means of a variable stiffness mechanism), the adaptability to the user/task needs (e.g. human-in-the-loop control), and the multipurpose design concept (e.g. provide support to the elderly and/or care gives) have been scarcely studied.

For this purpose, at Karlstad University, Solis et al. (2015) has proposed to incorporate and develop the concept of robotic human science introduced by Takanishi (1995) and to enable its application in a multipurpose human-friendly robot for assisting elderly persons (e.g. walking-support) as well as assisting care givers (e.g. carrying-medical tools). On the one hand, models of human motor control and learning, as well as cognition should allow creating truly interactive human-friendly robots; on the other hand, modelling human-friendly robots allows the development for reverse engineering and scientific understanding of human motion, perception and cognition. The focus of the research is embodying perceptual (sensing the incoming stimuli), cognitive (processing the incoming stimuli) and bodily-kinaesthetic (response to the incoming stimuli as a result of combining perceptual and motor skills) capabilities.

Due to the complexity of the proposed research, two assistive robots vehicles are under development at Karlstad University: an intelligent carrying-medical tools robot vehicle (Solis and Teshome, 2014) and a human-friendly assistive robot vehicle for supporting physically elderly (Solis et al., 2015). The development of a human-friendly robot vehicle for carrying-medical tools (*iCAR*) was presented by Solis and Teshome (2014). *iCAR* is composed by a mobile robot vehicle with on board sensors, and two-actuated and four-passive wheels. A simplified fuzzy logic controller has been implemented for the navigation control. The iCAR was able to correct its posture in order to follow the subject after a transitional period of time (about 4 seconds). After the transitional period of time, the robot was able to smoothly follow the user while walking straight (Solis et al., 2015). On the other hand, a time-delay neural network (TDNN) was designed and implemented for the 3D gesture recognition (8 gestures were defined). A successful gesture recognition percentage of 91% was obtained (Solis and Teshome, 2014).

The development of a human-friendly walking assistive robot vehicle (*hWALK*) was presented by Solis et al. (2015). The *hWALK* is composed by a two-wheeled inverted pendulum mobile robot, a 3-DOFs desktop haptic interface, a mobile computer and a wireless module for communication purposes. A PID controller has been implemented for the stability control and preliminary experiments were presented to verify the stability of the two-wheeled inverted pendulum. As a result, under static condition the *hWALK* was stabilized in about 16 seconds on a surface with carpet padding and 30 seconds on a surface with parquet. Under dynamic conditions on a surface with carpet padding, the system smoothly followed the desired walking motion of the user without instabilities (Solis et. al, 2015).

In this paper the authors present further detailed experiments for verifying the stability of the whole system under static and dynamic conditions. Pilot experiments are proposed in order to validate the feasibility for physical support while walking on a dynamic scenario, e.g. a bump in the street. This paper is organized as follows: at first, a brief overview of the human-friendly walking assisting robot vehicle is described. Then, the details of the calculation of the force feedback to provide physical support to the user are provided. An improvement for the velocity control is introduced. Finally, the proposed experiments to verify the stability of the system, to validate the feasibility to provide physical support to healthy volunteers as well as the performance of the proposed velocity control method are detailed and discussed.

Fig. 1. Human-friendly walking assisting robot vehicle (hWALK) developed at Karlstad University.

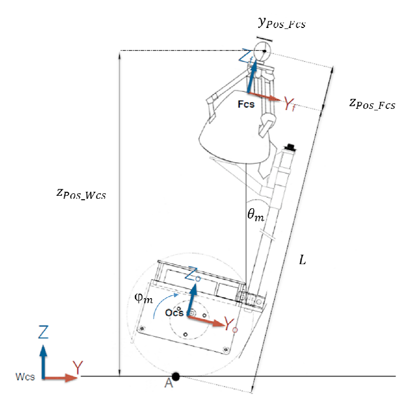

Fig. 2. Model reference defined for the *hWALK*.

2. HUMAN-FRIENDLY WALKING ASSISTING ROBOT VEHICLE

The human-friendly WALKing assist robot vehicle (*hWALK*) has been designed to provide physical support to the elderly while walking. The *hWALK* is composed by (Fig. 1): a mobile platform with on board controller and two actuated wheels (modified version from the one developed at Waseda University (Solis et al., 2011) and now commercially available as MiniWay® (Japan Robotech Ltd.), a commercial available 3-DOFs desktop haptic interface (Novint), a mobile computer used for computing the force feedback processing