Title	高齢者の歩容改善のための骨盤運動を考慮した歩行支援機の開発
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Citation	
Issue Date	2016-09
Type	Thesis or Dissertation
Text version	ETD
URL	http://hdl.handle.net/10119/13830
Rights	
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ABSTRACT

The elderly population is growing fast all over the world. Japan is the most rapidly aging country, and its population aged 65 or above rose to more than 25 percent of the whole population in 2014. Japan is projected to become a super-aged society where those aged 65 or above account for about 36 percent by 2025. Population aging has caused significant challenges of caregiving. Recent advances in robotic technologies have allowed increasing attention to be paid to welfare or rehabilitation services in these rapidly aging societies. Such technological advances have made it possible to design and develop a wide variety of human-friendly assistive robotic systems. Among them, personal assistive mobility devices such as walker, cane, and wheelchair are strongly desired to keep the elderly independent.

A walker is a device for the elderly who need additional support to maintain balance and stability while walking. Basic traditional walkers mainly consist of a frame surrounded by four legs on the front and sides. And, body support is provided by the user holding onto the top of the sides. Robotic walkers with similar mechanical structures to the traditional walkers have emerged, but the installation of mechanical and/or electronic components is often required to promote safer ambulatory assistance. Recent technological advances have allowed the incorporation of a range of features into robotic walkers. Moreover, users utilize their own remaining ambulatory capability when walking with such devices, which plays an important role in helping users exercise. Therefore, the walker needs to be comfortable and easy to use.

Generally, elderly people tend to be in slow motion and suffer from delayed reaction time. Moreover, few are familiar with mechanical or electronic controls. When designing and developing robotic walkers for the elderly, an easy-to-learn and simple-to-use interface system capable of responding to complex and diverse environments is of particular importance. Similarly, the interface should be able to accommodate various individual levels of physical capability. Based on an interface which takes into consideration each of the above factors, the robotic walker prototype, the JAIST Active Robotic Walker (JARoW), was developed.

The mechanical design of JARoW is compact, and its footprint circular, which reduces the potential for collisions with obstacles or walls. JARoW has three main structural parts: a base frame, an upper frame, and connecting rods. The base frame supports the superstructure, and is directly connected to the drive-train and equipped with two Hokuyo URG-04LX laser range finders (LRFs) as the interface system. The length of the connecting rod can be adjusted according to the height of users. Users are able to lean their upper body forward and place their forearms onto the upper frame.

As one type of personal assistive mobility devices, JARoW encourages elderly people to lead more active lives, with reduced need for assistance. Specifically, JARoW does not require specific manual controls or additional equipment. Toward the practical use of JARoW, a walking intent-based movement control was proposed, allowing it to accurately generate the direction and location of its movement in a way that corresponds to the user’s walking behaviors.

In general, the gait parameters of individuals are not always steady during walking. Furthermore, JARoW should be able to accommodate various individual levels of physical capability. For the purpose, a challenge aims at analyzing the different gait parameters of users and applying the analysis into the JARoW's control. As one contribution, a two-layered Kalman filtering scheme and a particle filter-based tracking scheme was developed to estimate and predict the locations of the user's lower limbs, respectively. Based on these proposed schemes, the filtering function was implemented as a main function in the main controller. After the realization of the filtering function, JARoW could autonomously control its smooth motions adapting to the user's walking patterns. Furthermore, the success of the proposed controls for JARoW could be confirmed through extensive experiments where elderly subjects currently using traditional walkers participated.

Meanwhile, the human gait is generally nonlinear, and the center of gravity of the human body can be modeled as a motion represented in 3-D space during walking. The walking behaviors of elderly people with insufficient ambulatory capability can be distinct from several points. Since the elderly sway their body by the movements of upper and lower limbs, there include the following features: shorter stride lengths, longer step interval, and slower walking speed (strides per minute). Moreover, three features result in longer stance phase. The behavioral symptoms of their ambulatory capability are caused by physical deterioration at both cognitive and sensory levels, sequelae by injury, and an increased body sway due to a disability. From medical knowledge and these considerations, simulations and preliminary experiments were performed for changes in stride by the rotations of the pelvis. These results indicated that, by an appropriate force is applied to the pelvis, the force helps an elderly person increase their stride length.

With these results, a more innovative and practical design of the second generation assistive robotic walker (JARoW-II) was designed and fabricated. JARoW-II aims at helping elderly users in need of walking assistance maintain and enhance ambulatory capabilities healthily and independently. In addition to the basic functions of the previous prototype, JARoW-II has advanced features that facilitate pelvic rotation. The control concept of JARoW-II based on the interactive control scheme of JARoW was designed, allowing the elderly to synchronize their walking patterns and the assisted pelvic rotation, resulting in walking assistance and rehabilitation.

Like JARoW, three omni-directional wheels enables JARoW-II under the maneuverability autonomously to move forward and backward, slide sideways, and rotate at the same spot. Such omni-directionality provides a very efficient means of direction control in highly cluttered environments, even in a narrow hallway or in an elevator. Toward easy yet reliable maneuverability, JARoW-II can be employed without the use of any additional equipment or manual controls. Moreover, a novel pelvis-driving unit was developed and integrated into JARoW-II, helping pelvis rotations by applying a desired force to the buttocks of the user in the roll and the yaw directions. The design of the JARoW-II and its control mechanism are explained in detail. Finally, the validity and effectiveness of the proposed control for JARoW-II are verified through extensive experiments in everyday environments, and the results analyzed and compared to previous findings. Specifically, to verify the feasibility of JARoW-II, five persons over the age of 70 participated in outdoor experiments. From these results, it can be confirmed that JARoW-II could provide its potential users with easy, reliable assistance and enhance ambulatory capabilities.

Keyword: robotic walker, human-robot interaction, Easy maneuverability, walking intent, welfare robotics, reflecting pelvic movements