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# The Development of Walking Assistant Robot for The Elderly

Lei Zhang[1, a], Qixin CAO[2,b] Chuntao Leng[3,c], Aolin Tang[3,d], Fei Shi[5,e]

[1] State Key Lab of Mechanical Systems and Vibration, Research Institute of Robotics, Shanghai Jiao Tong University, Shanghai, China

[2,3,4,5] Research Institute of Robotics, Shanghai Jiao Tong University, Shanghai, China

[a]zhanglei@sjtu.edu.cn, [b]qxcao@sjtu.edu.cn, [c]ctleng@sjtu.edu.cn,
[d]tangaolindavid@163.com, [e]disk_shi@sjtu.edu.cn

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**Abstract.** The Walking Assistant Robots(WARs) developed by our institute are introduced in this paper. First, three prototypes with different mechanical and control structures are introduced and compared. Then as for the prototypes Ⅲ, its main framework and three important function modules including force sensor based human-machine interaction, Omni-directional vision based tracking and guiding system, and web-based monitoring system are described in detail. The WAR can recognize the user's intents and execute different assistant functions, such as seating or standing-up assistant, walking assistant, human tracking, location, obstacle detection and avoidance. The application in an elderly care center shows WAR has a perfect and stable performance.

## Introduction

With the aging problem of the global population, the development of the service robot for the elderly or disabled is paid more and more attentions. This kind of robots consists the robots that take care of elderly people[1], the accompany robots that supply emotional support [2], the assist robot that help to finish some operations such as intelligent chairs[3]. In this paper, the robots that assist walking is focused. Morris et al.[4] developed a robotic walker based on XR4000 platform with force sensor handlebars and LCD display. The Walking Helper[5] system consists of an Omni-directional mobile base, a body force sensor, a support frame and a cover around the mobile force. The user's walking intention can be acquired by the body force sensor. The RT Walker[6] is a passive intelligent walker without driving actuators that use servo brakes. The RT Walker has passive dynamics that change with respect to applied force/moment, which is intrinsically safe for the elderly. The iWalker[7] is also a passive and intelligent walker with RFID readers, which is assumed to work on a smart world. The Pearl robotic walkers[8] has an intuitive haptic interface. The software control system enabled data from the force-sensing resistors to actuators directly to drive them move in the user's intended direction.

In this paper, the Walking Assistant Robot(WAR) developed by our institute will be introduced. Different from the robotic walkers above-mentioned, WAR has a novel force sensor interface. Moreover, three generation prototypes with different mechanical and control structures have been developed and compared each other. Many function modules are integrated into WAR to perform different functions.

## The Prototype Design of the Walking Assistant Robot

There different conceptual prototypes of WAR have been developed. The prototype Ⅰ is shown in the Fig.1. Its shape is like a seeing eye dog, the main parts include

- The body made of aluminum alloy plate

- The walking system, which includes a pair of casters as front wheels and a pair of rear wheels driven by DC servo motors.
- The lifting system, which includes two parts, the lifting of legs and hand levers.
- The controlling system consists of upper computer and lower computer. The upper computer is an Embedded Industrial Computer (EIC), which receive and process sensor data, such as vision, pulse and GPS. The lower computer is motion control board designed by ourselves based on STM32 MCU. The controller can drive 2 DC motors and connect to EIC through USB port.
- Force sensor interacting system: Two Force Sensor Resistors(FSRs) are equipped with the handlebars(shown in the Fig.1) . They detect both pull and push pressure, then the pressure signals are transformed into EIC to motion control
- The operating interface includes the touch panel and the force sensors in the handlebars.

As shown in the Fig.2, the mechanical design prototype makes it is feasible to stand up or fall like a dog. When it falls flat in the land, the user can sit on it to have a rest. the prototype Ⅰ can achieve the basic functions in walking assistant, but it is not optimized in the mechanical components, material weight and convenience. For example, because the lifting system of legs applies worm reducers and gear transmission, the moment is very large when the legs are lifting. The driving motor with a big power has to be selected, then, the volume and the weight of the robot beyond the respected values.


Fig.1 The prototype Ⅰ

Fig.2 Two states of the prototype Ⅰ

The prototype Ⅱ is shown in the Fig.3. Compared with the prototype Ⅰ, the prototype Ⅱ focused on the concise design and ease for use. The mechanical structure has been improved and simplified. The lifting system applies the spherical guide and ball screw. The complex controlling system composed by the upper computer is eliminated. The robot can move ahead, move back, and turn by the operating handlebars equipped with the force sensors. The robot will work when the control switch is turned on. The simple operation is convenient for the elderly. Moreover, the diameter ratio of the front and rear wheels is adjusted to create better motion performance. The main characters are

- The main body is composed by some section bars. The bars are strong enough while their weight is very low. They are wrapped by a crust made with vinylite.
- The touch screen is replaced by a board with control buttons and lights. One button is the power switch, the other is the switch controlling the lift of the handle levers. The lights on the board can show the state of the robot and the quantity of the battery.
- The controlling system uses the single chip.
- Infrared sensor is used for obstacles avoidance and an audio guide is added.

Fig3. The prototype II

The prototype Ⅲ integrated the advantages of the two prototypes above mentioned. The mechanical structure is improved based on the prototype II. The controlling system is composed by the upper computer and lower computer. Because the main purpose of the prototype Ⅲ is integrating all different function modules and test their performance, some candidate modules developed for different users:

- A Leadtek GPS module and Omni-directional vision for human tracking and location
- A Sick laser sensor for obstacles detection and avoidance
- A Proface touch panel for human-computer interaction.
- A 2D obliquity sensor for the warning of the falling down of the robot.
- A simple pulse sensor used for the health monitoring of the user
- a CPC V818 GPRS module for communicate with the Web Server in internet
- a microphone for voice instruction

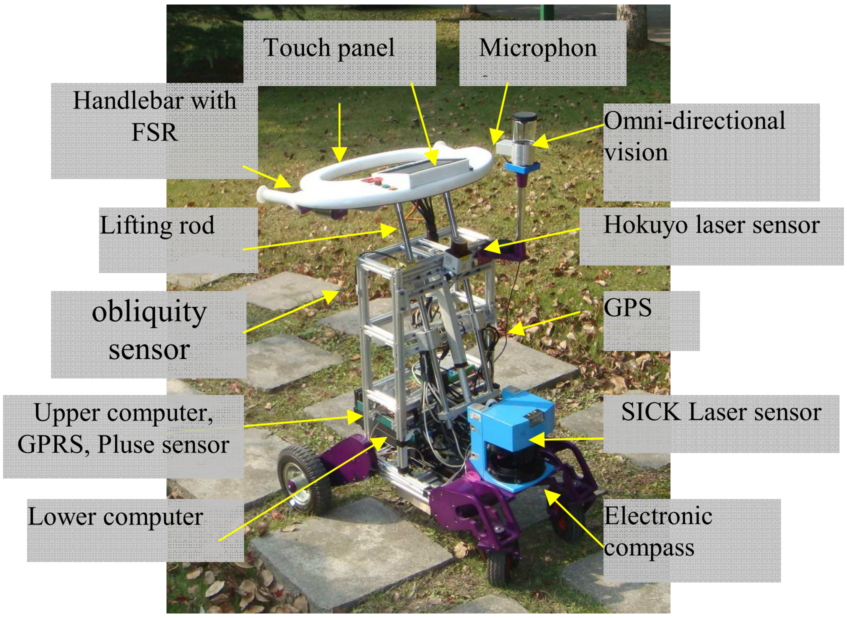


Fig.4 The prototype III

### The Main Control Frame of thePrototype Ⅲ

In the following sections, the prototype Ⅲ will will be introduced in detail as the sample of WAR. The main frame of the prototype Ⅲ is shown in the Fig.5. The upper computer is an EIC It is the brain which control and cooperate all parts of the robot. All sensor data except the infrared data are collected and processed by EIC. It also reads the commands from the touch panel and outputs the state data of the robot to be shown in the panel. EIC also communicated with the web server by GPRS to exchange some data. The lower computer receives the commands from EIC. It processes the signals from FSRs embedded in the handlebars to control the movement of WAR. The feedback signals from the encoders can realize the closed-loop control of actuator mechanism.

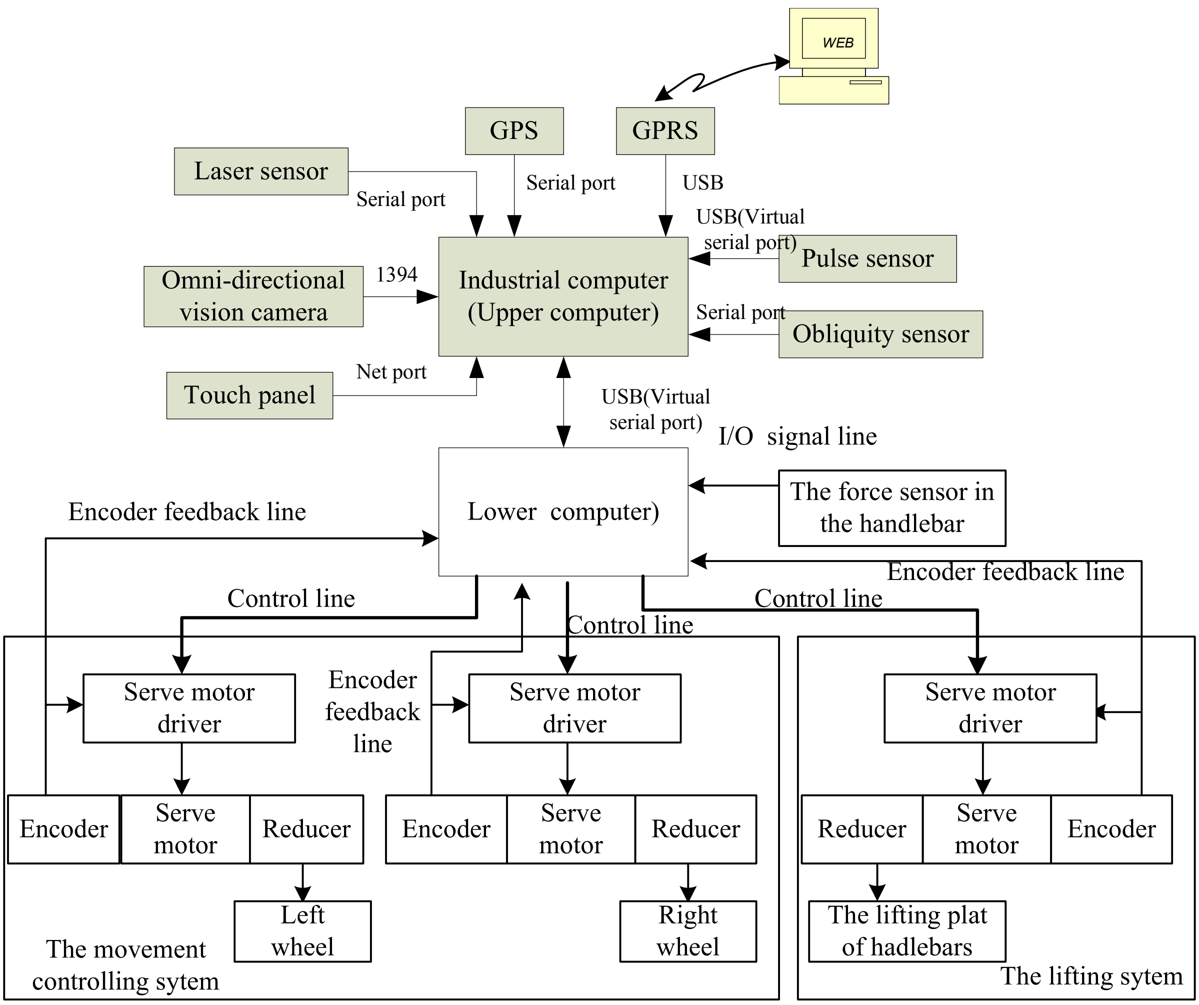


Fig.5 The control frame of the prototype III

There are three main programs in EIC, the main control program, the vision program for object recognition, and laser program for obstacle avoidance. As the core of the controlling system, the main control software

- receives and processes data from all kinds of sensors, such as GPS, pulse sensor and obliquity sensor.
- cooperates all other different software blocks. It decides when one subprogram is started or stopped.
- Communicates with the Web Server by Socket and sends the data about the latitude, longitude and pulse to the Server

The vision program and laser program are both run in the EIC. These two programs transport the needed data to the main control program by Socket communication. The main control program includes two threads, one is main and the other is assistant. The main thread responds to the events of timer, such as sending commands to lower computer and receiving sensor data. The assistance thread deals with the communications with the vision program, laser program and Web Server.

**Force Sensor based Human-machine Interaction of the Prototype III**. As described in Seciton 2, there are two FSRs embedded in handlebars. Its structure is shown in the Fig.6. The FSR is fixed with the handgrip directly so it can detect both pull and push pressure of the handlebar. The pressure signals are transformed in to EIC to calculate the output to the motor control board.

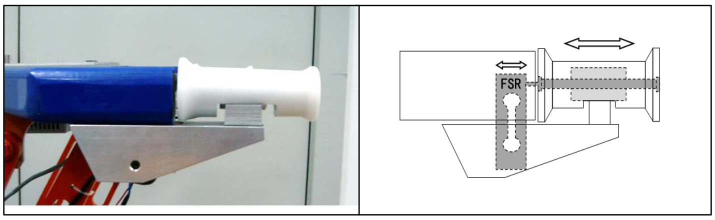

Fig. 6 The structure of FSR in handlebar

Compared with other force sensor devices, the handlebar style is better in the application because it is familiar to the elderly. More importantly, it offers a nature negative feedback loop of the motion control. When the user wants to keep a steady rate, the handlebar will be pulled to decelerate the walker if the walker is faster than the user. On the contrary, the handlebar will be pushed to accelerate the walker. By detecting the user's intentions through physical interaction. The force sensor interface realizes a stable motion control.There are two modes of motion control.

- Force-velocity mode

The velocity of the robot is proportional to the force applied to the force sensor interface, which means the robot will run or stop instantly when the user's hands on or leave the handlebars.

- Force-acceleration mode

In this mode, the acceleration of the robot is set proportional to the force applied to the force sensor interface. Based on the input force signal, the system simplifies the signal and outputs the desired acceleration of each wheel. Fore more experimental analysis of the control effects of two modes can refer [9]. Compared with the force-velocity mode, the force acceleration mode has better stability and maneuverability, but the force-velocity mode has faster response.

**Omni-directional Vision based Tracking and Guiding System of the Prototype III.** The outdoor location of WAR is realized by GPS while the indoor location needs the integration of encoder and panoramic vision. The advantage of Omni-Directional Vision System(ODVS) is its view field is 360° in horizontal direction, so rich information of the images can be acquired. The system consists with a hyperboloidal mirror, cover class, anti-reflect needle and CCD camera. The imaging principle of ODVS will not be described here.

The vision program is mainly used for user tracking. When the user doesn't need walk with the help of WAR, the WAR should recognize the location of the user and automatically follow with him(her). The mean-kernel tracking algorithm is used in which the moving object is characterized by its color-histogram.

In the experiments, the user dresses yellow cloth or tie a yellow block in the leg. Then yellow color is the sign color of the object that WAR will track. Blog extraction method is used for extracting the color block. Then the vision program compute the location of the user and send it to EIC. EIC analyzes the relative position of the user to the robot, then uses the method of Artificial Potential Field to decide the moving direction and speed of WAR. Finally, the decision of EIC will be send to the lower computer as some commands to drive the motor.

**Web-based Monitoring System of the Prototype III**. The monitoring system provides a plat for managers and users for information recording and browsing. It can also be used for emergency help. The system includes two parts, one is the monitoring of the health data of the user(pulse data), the other is position monitoring of WAR. WAR sends these data to the Server by GPRS module.

The system is composed by GPS module (in WAR), GPRS wireless module (in WAR), Web server, SQL database server, WebGIS Server(provided by Google company). The main program is developed by Visual Studio 2005. The database program is developed by SQL Server 2005, and the web map is applied by Google map API functions.

The pulse data of the user received from the WAR can be shown real-time. When the pulse data is out of normal range, for example, the value is larger than 120, the warning will be given in the monitoring window. Moreover, the history data can be inquired by setting the time range through calendar. The pulse can also be shown in curve line style so the changing trend can be recognized clearly. The interfaces of pulse data inquiry will not be shown because of the limit of page.

The GPS in WAR can get the position information of WAR, but this position is expressed by latitude and longitude values. In most cases, these values has no use for the elderly because it can't be understood. It is expected to be transformed into the direct position such as "shanghai, Nanjing road 1180#". Web Server finishes this work.The global position of WAR cab be shown in the map . At the same time, it sends transformed position to WAR. The position is shown in the touch panel, so the user can easily know his(her) position.

## Conclusion

Three prototypes of WAR developed by our research group is introduced. Especially for the prototype Ⅲ , its basic control framework, the force sensor based human-machine interaction, the Omni-directional vision based tracking and guiding, and web-based monitoring system are described in detail. By the integration of all different function modules, the prototype Ⅲ has a good performance. It's support force is not smaller than 80kg while the pull force is not smaller than 3kg in horizontal direction; It's speed is in the range of 0-0.5m/s; It's weight is not larger than 30kg; It's continuous working time is 3 hours; It is adaptable to indoor environment and outdoor plat surface.

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