Preliminary design of ANG, a low-cost automated walker for elderly

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Abstract. We present the overall design of ANG, a new walking aid for the elderly. The objectives of this walking aid is to provide a low-cost and low-intrusivity aid for the elderly. ANG is based on a classical 4-wheel Rollator, the two rear wheels being fixed while the two front are caster wheels. The rear wheels have been motorized, a bistable clutching mechanism allowing to clutch and unclutch the motors at will. ANG will provide fall prevention, navigation assistance, walking aid and may also be used as a rehabilitation tool. We present in this paper the mechanical design of ANG and some of the modes in which it may be used.

Key words: walker, elderly aid, assistance robotics

1 Introduction

The ability to walk is one of the most important and fundamental function for humans. A consequence of aging societies is that the number of elderly is rapidly increasing in many countries. Such people may suffer from locomotion handicap because of the decline of physical and muscular strength. A related problem is the fall: in France in 1997 there has been 2.5 millions elderly falls with over 40% of people over 60 years old concerned by this problem, which may lead to dramatic consequences. This paper focuses on the design of a walker-type support system with the following motivations:

- *low cost*: although assistance robotics addresses helping elderly, the cost of system such as humanoid robots is by far too high to be afforded by a vast majority of elderly. Our purpose is to design a low-cost system that is however offering a large panel of functionalities, that will be presented later on
- *low intrusivity*: social acceptance is a key issue for assistance robotics. Our goal is to design an assisting system that look familiar
- *interface*: elderly have various physical and cognitive abilities and consequently various interfaces to control the system must be available

Various passive and active walker have been proposed in the past: the passive walker of MARC at Virginia University [1],the active PAM-AID and its extension GUIDO [10], PAMAID [14], NURSEBOT [4], the sit to stand devices MONIMAD of LRP [12] and of Chugo [2], IWalker [9], RT-Walker [8], the sophisticated CARE-o-BOT [5] and the omnidirectional walker of Chuy [3].

2 Design

ANG (Assisted Navigation Guide) is based on a commercially available 4-wheels Rollator walker, the two rear wheels being fixed while the two front are caster wheels (figure 1) and hence is similar in principle to the NURSEBOT and iWalker. A first modification was to motorize the two rear wheels with 12V cc 157W DC motors whose velocity is reduced by two levels of belted drives (with reduction 1:2.1 and 1:2) and a planetary gear (with reduction 1:15). The high reduction ratio leads to a system that is mechanically irreversible. Encoders with 2048 impulses per turn have been added directly on the rear wheels and we consider having also encoders to indicate the direction of the front wheels. There is a braking system on the handles and the elderly may seat on the walker. The originality of the motor system of

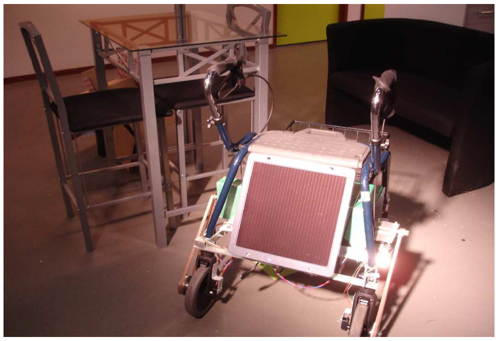

Fig. 1 The ANG walker in a typical elderly flat. The two motors are located behind the solar panel while the electronic is located below the motors

ANG is that it uses a clutch system based on a computer-controlled bistable spring electro-magnet that allow to clutch and unclutch the motors through a Oldham coupling. The interest of such clutch is that it uses energy only during the transient phase (figure 2). The motors rest on a plate that is located about 45 cm from the ground while the electronic part and batteries are located below the plate. A direct consequence is that the center of gravity (CoG) of ANG is about 20 cm below the CoG of the original walker, thus ensuring a better stability.

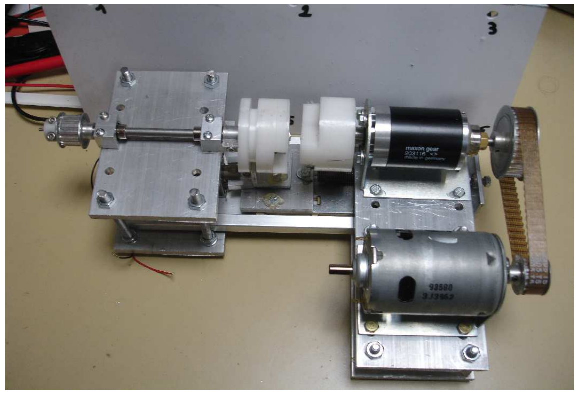

Fig. 2 The clutch system for the motor of ANG. The electro-magnet is located below the belt pulley on the left side.

The wheel diameter is 0.2m and the reduction ratio is 1:63, while the motor maximal speed is 8300 rpm, leading to a maximal velocity of about 1.38 m/s (roughly 5 km/h) which is quite higher than the average velocity of elderly.

The weight of ANG is about 20kg, to be compared to the 180 kg of Care-O-bot 3, and it is planned to be used both indoor and outdoor. Further planned equipments are:

- front and lateral ultra-sound sensors, rear infra-red distance sensors located all along the handles of the walker and ultra-sound sensors looking backward and close to the ground
- a GPS locator, compass, accelerometers, RFID receiver and a webcam
- force sensors in the handle of the Rollator
- a 5W solar panel at the rear of the Rollator
- tactile and joystick interfaces

The control part is based on low-cost USB building blocks Phidgets[1] that allows one to manage various sensors and provides sophisticated motor control. An on-board computer (currently a micro-laptop with a wifi connection) manages the various modes of ANG.

3 Functionalities

Two basic modes are available for ANG: the *free mode* in which the motors are unlatched and the system basically behave like the initial Rollator, although the wheels rotations are measured and the *motor mode* in which the motors are clutched and

[1] www.phidgets.com/

provide either braking power or motion help. In a normal walking mode we believe that the free-mode should be preferred as much as possible for various reasons:

- to maintain the cognitive/physical activities of the elderly
- in the motor mode it will always be difficult to determine the intent of the elderly and even with the best control approach the user will always feel a slight delay in the answer of the walker, that will be negatively resented
- active walker present usually a larger task completion time than passive walker [14]

However the motor mode is necessary as will be illustrated in the following sections.

3.1 Fall detection and prevention

As mentioned in the introduction fall is a major problem for elderly. This issue has been addressed by Hirata with the passive *RT-walker* that provides only braking power to the rear wheel. Using distance measurements of several laser rangefinders and a simplified 2D human kinematics model with seven links a stability region is determined for the human center of gravity (CoG). If the CoG is outside the stability region fall is assumed and a fall preventive algorithm based on the braking of the rear wheels is applied [8].

We plan to use a similar method but with several improvements. The 2D kinematic model used by Hirata may allow one to detect vertical and horizontal fall but not lateral one. Furthermore if a fall occurs in spite of the walker behavior the passive RT Walker cannot provide a support to the elderly. In our *free/fall-detection mode* the distance sensors, the force sensors in the handles, the acceleration of the walker and the velocities of the wheels will be used to detect a possible fall, while the motors are unlatched. Our first experiments have shown that a horizontal fall can simply detected by monitoring the wheels velocity. To manage the lateral and vertical fall we will rely on an array of distance sensors located all along the handles of the walker, ultra-sound sensors to locate the foot position. The sensors will be used to locate specific points of the joints and links of 3D human model. An initial calibration procedure will allow one to place the sensors in the optimal position and to identify the main geometrical parameters of the 3D model for the current user. Being given the usually slow velocity of the walking of elderly we believe that the sensors measurements will allow us to locate his CoG and to detect all types of possible fall.

If a fall is detected the walker moves in the *fall prevention* mode and the motors are clutched to try to prevent the fall. For a vertical or lateral fall the best strategy will be that the velocity of the walker become 0, providing a strong support to the elderly. This may not be the best strategy for a horizontal fall as the weight of the elderly may cause a sliding of the walker even if the wheels are blocked by the motors. It may be better to adopt an anti-skid approach in which the walker moves along the fall direction, progressively braking but avoiding the skidding of the wheels.

In spite of the prevention scheme falls may still occur: the location of the elderly with respect to ANG will be determined by using the distance sensors and the walker will come close to the elderly to provide a support. Here again the walker sensors may be used to determine the pose of the elderly on the ground in order to present the walker in the best support position. If the elderly still cannot get up we will use a *smart object* (namely a Nabaztag) that can call for help using voice synthesis or even make a call phone to a rescue center. The rescuer may then even move the walker around using a web based navigator tool (see the motion section) to assert the gravity of the fall and to reassure the elderly.

3.2 Trajectory, Motion planning and Navigation assistance

The purpose of motion planning for a walker is to provide a navigation help that may be local (e.g. follow a wall using distance sensors) or global (e.g. determine the trajectory to reach a given location, using, for example, a GPS). Trajectory planning addresses the safety of the walker motion (e.g. braking when the walker moves downhill, avoiding obstacles, ...). Several trajectory algorithms and motion planning methods, directly derived from the motion planning and mobile robotics community, have been proposed in the past either for active or passive walkers [4, 6, 7, 9] but the utility of such tool has yet to be demonstrated as clinical evaluations have shown a negative opinion of the elderly [15].

Trajectory and motion planning algorithms will also be available for ANG but we plan to add several motion functionalities. In the *slave* mode the motors are clutched and ANG will follow or be in front of the elderly, being at a constant distance from him. This will allow the user to move temporarily away from the walker (for example to fetch a piece of grocery). Such mode will use the distance sensors to determine the location of the elderly but will require sophisticated control algorithm as soon as the elderly will turn.

The *distance-constraint* mode is a variant of the slave mode with the user having his hands on the handles and the distance threshold being fixed to the average value of the distance to the hip when the elderly is using the walker in the free mode. This will allow to adapt the velocity of the walker to the velocity of the user. If the distance threshold is decreased below the average distance value the walker moves in the *assisted* mode which allow to provide a motion help, drawing the elderly when moving uphill or braking when going downhill.

We plan to implement also a *teleoperated* mode in which a tactile interface and a simple joystick will allow the elderly to control the walker motion within a limited distance.

ANG will also be able to work in an *autonomous* mode by using the ultra-sound and IR sensors for local navigation. This may be completed outdoor by a *navigation* mode using GPS information, that will allow the walker to guide the elderly to reach a specific location.

An important aspect of ANG will be *situation monitoring*: the walker will be used on a regular basis for specific trajectories (e.g. moving from the bed to the kitchen) and its motion may be recorded. As the physical abilities of elderly change slowly with respect to time monitoring these trajectories may help to anticipate difficulties for the elderly.

3.3 Rehabilitation

Walking rehabilitation and training is another use of walkers [11, 13]. In the *rehabilitation mode* the elderly will have to complete specific trajectories as determined by a doctor while ANG may exert a resistive force or introduce some planned disturbances. The originality of ANG will be to store all sensor data during a rehabilitation session for analysis by a doctor. Data will be downloaded through the wifi connection and the doctor will be able to modify on-line the training exercises during a session.

3.4 Energy management

Energy management is a crucial issue for assistant robots, although energy performances is most of the time neglected. Walkers have an extensive use and it cannot be accepted that the batteries fail in the middle of this use. It is quite difficult to find the energy consumption of other walkers but we believe that the six 12V 1.2Ah lead-acid batteries of ANG will lead to at least the same motion range (10.9km) than PAMAID [14] although the battery power is much less than the Care-O-bot 3 (60Ah at 50V). As walkers are often used outdoor the 5W solar panel may extend this range. We plan however to implement a battery management system (BMS) that will use the motor energy when walking downhill to charge the batteries, prevent the user to use the walker with a low battery state, allow for a *solar follower* charging mode (the walker will rotate according to the sun motion using the compass and the charging current of the solar panel) and an *automated docking* mode in which the walker at home will autonomously dock to charge its batteries.

3.5 Interfaces

ANG is planned to be used by elderly that may have various level of physical abilities and may be reticent to use a hi-tech device. Furthermore the abilities of this type of user may change on the long time. Hence interfaces is a major issue for acceptance and effective use by elderly. Sensors such as the force sensors in the handle, distance sensors may be used to detect the user's intents, manage local navigation (e.g avoiding obstacles or following a wall) but one should take care of ambiguous or even erroneous user/sensors inputs. Furthermore a fully automated walker may not solicit the elderly physical/cognitive abilities, while managing on his own the walker may be a good training exercise. Hence we plan to provide several simple interfaces allowing the user to manage the mode and motion of the walker. The use of these interfaces will be monitored, especially during specific trajectories of the walker that are performed every day, to detect a loss of ability to use the current interface (and possible propose a new one) and possible motion problems.

4 Conclusions

We have presented the preliminary design of an assistant walking aid that combines the advantages of passive and active walker. The main ideas of this design is to propose a low-cost, low-intrusivity walker solution. Using an already accepted mechanical design is a key solution for social acceptance. We also believe that a key issue for a walker is to use an appropriate 3D human kinematic model that may be used for fall detection/prevention and determining the user intents. This model however has to be adapted to the elderly morphology and physical abilities, that may change over time. The proposed walker is also intended to be used as a calibration tool that will allow to determine the physical parameters of this human model.

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