Research and Design of Mobility Aids

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Abstract: This paper designs a multifunctional mobility aid based on the STM32 microcontroller, which mainly provides security for the daily life of the elderly. The paper analyzes the basic working principle of the mobility aid, and designs the mechanized structure; thereby realizing the mechanization, intelligence and multi-functional technical characteristics of the mobility aid, which can effectively avoid the troubles caused by leg failure in function of the elderly, and provide convenience for the elderly to go out.

1. Introduction

China has become one of the fastest growing aging countries in the world, which means that the design of products for the elderly and the expansion of their market have entered a very important period. Aging gradually degenerates the physical function of the elderly, especially muscle atrophy and osteoporosis, which makes them difficult to walk. Therefore, mobility tools are needed to assist walking. Although there are many kinds of mobility aids in the market, their design do not take into account most of the characteristics of the elderly, and there are many defects, which not only fail to bring a good product experience, but also make the elderly feel resistant. Accordingly, designing a mobility aid needs to consider the special needs of the elderly to ensure the safety, convenience and comfort is of great significance to the elderly. This kind of instrument can help the elderly to walk as well as the functions of falling prevention, auxiliary standing up, carrying up and down stairs and emergency call for help. Compared with the existing walking aids, the proposed design in this paper provides more security for the elderly to go out, and more flexible than other mobility aid products. The elderly carrying this kind of mobility aid can basically solve the troubles caused by the inconvenience of daily go-out of the elderly, and provide better facility systems for them. This paper mainly analyzes and discusses the hardware control, working principle, mechanical structure and related design of the mobility aid as the following paragraphs.

2. System hardware configuration

The proposed multi-functional mobility aid is working in the control of the driving circuit which is shown in figure 1. The system consists of three parts: power circuit, control circuit and other functional circuits. Power circuit is a DC-DC converter which reduces 24V DC of lithium battery to 5V and 3.3V output. It provides the power supplies for different blocks in the system. Control module uses STM32 series microcontroller supplied by 3.3V DC power. Since the characteristics of high speed, low power
consumption, low voltage, it can responsible for signal communication and system control. Other circuits include: switches, crawler, encoding motor, motion motor driver, screw motor diver, communication module, GPS module and obliquity sensor interface. Switches, which can be divided into five categories according to their functions. The main switch of the device is responsible for the power on and power off of the whole device. After touching the switch for going upstairs and downstairs, the crawler device is activated through the control circuit to realize the function of going up and down stairs. Auxiliary standing switch can assist the elderly to stand up. Automatic alarm SOS switch is used to call family members for emergency rescue by pressing this switch when the elderly fall down unfortunately. Speed button is used for speed adjustment. Crawler is used for providing power source for going up and down stairs. It has a stable function of going up and down stairs, and realizes going upstairs and downstairs respectively with the positive and reverse track.

Encoding motor calculates the acceleration by measuring the motor speed. When the old man is about to fall down, the device will generate enough acceleration, exceeding the set value. Therefore, the motion motor is reversed by the controller to prevent falling. At the same time, it also has the function of wheel locking, which is a prerequisite for assisting the elderly to stand up and prevent the elderly from falling down due to the wheel uncertainty. Motion motor driver has two coding motion motor, which drives to control the running direction and speed of the two coding motion motors. Screw motor driver has two-way stepping motor drive to control the movement of two-way stepping motor. Communication module is used for the interconnection of devices and mobile phones to realize the Internet of things. GPS module is used to locate the elderly in case of emergency. Obliquity sensor interface is based on the horizontal plane and has different inclinations under different road conditions to achieve different power provided by the motor and provide more comprehensive aid walking performance for the elderly.

Figure 1. Hardware composition of the mobility aid system

3. Working principles
The mobility aid concludes five main functions. Working principle and control methods of the mobility aid are shown as follows.

For mobility assistance function, it is understood that most of the elderly will experience degradation of leg function and fatigue of walking. This mobility assistance function mainly helps the elderly solve the problem of leg degeneration. The specific performance is that when the elderly walk outside, carrying this device, the mobility aid can not only be an upholder for the elderly, but also provide a certain amount of power to drive the elderly to walk. To satisfy their own needs, the elderly can adjust the speed of the mobility aid by a speed adjustment button according to their average walking pace. Considering the different road conditions, we will use the oblique angle sensor, and use horizontal road as a benchmark to take three situations of driving uphill, driving on horizontal roads,
and driving downhill into consideration. The working principle is as follows: Assuming that the elderly are walking on a horizontal road at a speed of 0.8m/s, and the mobility aid will provide a speed of 0.8 - 0.9m/s to drive them to walk forward. When the next motion state turns to be an uphill situation, the oblique angle sensor will gradually deviate from horizontal direction at the moment of the elderly walking uphill. Changing with the change of motion state, the oblique angle sensor will deflect to some extent, and then send the deflection signal to the single-chip microcomputer in order that the single-chip microcomputer will control the motion motor to increase the output power of the motion motor within a certain range. Therefore, the elderly can walk uphill without too much difficulties with the help of this device. When the elderly are walking downhill, the working principle is basically the same as that of uphill, however, the difference will appear when the oblique angle sensor deflect in the opposite direction. Accordingly, the output power of the motion motor will be reduced, and then deceleration will be realized to make sure of safety of the elderly.

For the fall prevention function, the specific performance is that when the elderly are about to fall forward due to the uneven road conditions, which will immediately provide the device a forward force to increase the speed of the device, and the change of speed will be detected by the motor encoder. According to the acceleration formula, that is (1).

\[ a = \frac{v - v_0}{t} \]  

The calculated acceleration “a” will be extremely greater when numerator difference value “v_0” is certain and time “t” is very short because of instantaneous high-velocity “v”. When acceleration “a” exceeds the predetermined value, the single-chip microcomputer will send signals to control the motion motor to work reversely for a period of time so as to make the elderly stand upright instead of being leaning and about to fall. As a result, it will prevent the elderly from falling down and then the fall prevention function can be realized. For stand-up assistance function, the elderly can press the auxiliary stand-up switch when they want to change a sitting posture to a standing posture. In the meantime, the controller will receive the signal and activate the locking device of motion motor to keep wheels immobile, and make the handles slide down to 2/3 of the screw slide. Then the elderly can hold tightly the handles to stand up gradually.

For SOS function, the elderly can press emergency switch placed under this device for help if they encounter any emergencies or fall down but cannot help themselves. The controller will receive the signal, and the emergency information can be sent to family members by control module, and then family members can observe the specific location of the elderly so as to rescue them, because this device installs the GPS system. For upstairs and downstairs assistance function which is designed for the elderly who cannot go upstairs and downstairs independently, it mainly assists the elderly to go upstairs and downstairs through crawlers. The upstairs and downstairs switches are designed separately. When the elderly go upstairs, they can press the upstairs switch and stretch out the seat and sit on it. Meanwhile, family members can pull the hand on the top of the device to start the crawler carrying the elderly to go upstairs. The principle of the device going downstairs is the same as going upstairs, what they need to do is just turning on the switch.

4. Mechanical structure
As Figure 2, Figure 3, Figure 4, Figure 5, Figure 6, Figure 7 and Figure 8 show, the mobility aid is divided into two parts, with the seat inbetween.

The upper half of the device has the driving mechanism a) to assist walking which could aid the seniors to walk up and down stairs under family member’s help. In the center of the device, the seat b) and backrest are set up to hold the seniors to up and down or halt to rest. The seat opening and closure is controlled by the universal joint. one seat belt is attached to seat for safety. Moreover, the two armrests have functions buttons respectively, on the right armrest there is main on/off switch and actuating switch to climb up-or-down; on the left armrest, there are two variable-speed switch to adjust the velocity.

The lower half of the device is set up with battery and circuit configuration. On the right side there
is switch to assist the seniors to stand up and SOS button for emergency. There are four wheels at the bottom- the two at the tail are equipped with programmed motion motor c) to provide mobility, and the two at the front are universal wheels to control direction. To assist the seniors to stand up, the front of the device is arranged with the screw rod slid table. Also, the crawler track is set on the back side, its active motor could carry the seniors up and down the stairs; inside the track there is one follow engaged wheel in the middle to support the crawler component. Also there is universal joint to control the crawler device’s opening and close. Finally, the tilt angle sensor is arranged at the bottom side to drive complete device.

Figure 2. Crawler attachment
Figure 3. Crawler-capstan motor

Figure 4. Universal wheel
Figure 5. Engaged wheel

Figure 6. Screw slid table

Figure 7. Universal joint
Figure 8. Getting drawing

5. Conclusion
There is no doubt that the products for the elderly are hotly needed in our society. This paper proposed a multi-functional mobility aid based on STM32 microcontroller, switches, crawler, encoding motor, motion motor driver, screw motor diver, communication module, GPS module and obliquity sensor
interface. It provides convenience as well as reduces the possible danger and protects the elderly as much as possible. It is in a very simple structure which is easily implemented. Through the analysis and design of the walker, we hope that there are more effective products are brought into the market to improve the quality of the old’s life and contribute to a better global society.

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