Development of Intelligent Walker with Dynamic Support


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Abstract: Walking as a basic ability of human beings enables independent activity. For people with a walking disability, however, walking can be very difficult and often requires a walker. Most mechanical or mechanical-electrical walkers available today come with various defects and fail to offer satisfactory movement support. The strategy to maintain a constant distance between the user and walker, as proposed by Goro, has good potential for implementing an ideal walker, but it still has some problems in terms of reference points to the human body and its framework design. Thus, the purpose of this research is to solve these problems by developing a walker with dynamic support and verify its clinical feasibility. In this study, a specific relationship between the person’s ankle and the walker position was identified. Consequently, the distance between the ankle and walker was detected and then used to control walker movement. In addition, a powered transmission device and omni-directional wheels were utilized to ensure sturdy support and good turning functionality. The results of the experiments in this study indicated the maximal force of pushing forward of this new walker was 58.3N, or 5-8 times as high as a 4-wheeled walker, and its lateral pushing force was up to 84N. In terms of turning functionality, the new walker had a radial range of 12-13.1 cm, which was the same as that of the 4-wheeled walker, and there was an improvement in terms of functionality compared to Goro’s walker.

Index Terms--- walker, dynamic support, walking aid, ultrasonic range finding

1. INTRODUCTION

Mobility plays an important role in living standards, physical and psychological health, working and learning, and interpersonal relationships. However, some people need to use walking aids to ambulate independently. Walking aids are used to reduce the weight borne for those users with lower extremity disability (Bateni and Maki 2005). Besides, walking aids can increase users’ base of support (BOS), which is the area surrounded by the feet and walker, to improve balance (Fast, Wang et al. 1995). These are the basic concepts of walking aids. An investigation in the United States showed the people using walking aids had increased by 96% from 1980 to 1990, and the number of injuries had increased by 98% from 1987 to 1992. This suggests the incidence of injuries had increased by more than the increase in the number of users. In other words, the more often a walker is used, the more accidents occur (Charron, Kirby et al. 1995). This provokes the question whether walkers are really safe for use. Therefore, we researched walkers to increase their safety. As mentioned above, it was believed walkers could provide two major functions: (1) reducing the weight borne (Bateni and Maki 2005), and (2) increasing the base of support (Fast, Wang et al. 1995). We doubted whether the walkers on the market met the requirements during entire gait cycle. Therefore, we examined traditional walkers, including the standard walker, four-wheeled walker, and front wheeled walker. Generally, standard walkers had high stability, but users need to pick it up for progressing, which would lead to higher falling risk and slower moving speed.

Four-wheeled walkers seemed to provide a large base of support and less energy consumption for progressing, but they are unable to withstand the thrust force from the user. As for front-wheeled walkers, the users need to lift the walker slightly to move forward and provide downward force for stable support. This kind of maneuver seems to require a high level of manual control. In addition, it had been reported they are difficult to use on carpet (Mahoney, Euhardy et al. 1992; Mann, Hurren et al. 1995; Van Hook, Demonbreun et al. 2003).

In addition to the observed problems, we further analyzed the kinetic interaction between a walker and its user. Standard walkers can withstand anterior-posterior and lateral horizontal force to some extent, and large vertical force when on the ground. However, when a standard walker is lifted off the ground, it cannot withstand any force at all and becomes an extra load for the lower extremities. Four-wheeled walkers easily move forwards, but provide very little anterior-posterior support. In other words, they are unable to prevent the user from falling. As for the front-wheeled walker, the user must reduce the vertical download force and increase the horizontal force to overcome the ground friction force to move it forward. In this sense, the user consumes extra energy when progressing.

Because the pure mechanical walkers mentioned above have many limitations, some researchers applied mechatronic technologies to try and reduce those limitations. The walker designed by Goro (Miyawaki, Iwami et al. 2000) is equipped with a sensor that detects the distance between the walker and
the user’s abdomen, and the walker is driven by a motor to maintain a preset distance. This control strategy might withstand the user’s horizontal thrust when stationary or moving. However, due to their physical construction, the walker cannot provide lateral support. Another walker was developed by Angelo’s team (Sabatini, Genovese et al. 2002). They applied a control strategy similar to Goro’s. Unlike Goro’s walker whose direction is changed by the user’s manual force, Angelo’s walker will change direction automatically according to the user’s lateral movement. This method is unnatural for the user; and even worse, it cannot provide lateral support if the user falls to the side.

Goro and Angelo’s strategy of maintaining the distance between the walker and user has good properties from the viewpoint of providing dynamic support, but the physical construction of their walkers has some limitations, such as the heavy weight, unnatural maneuvering to turn the walker in different directions, lack of lateral horizontal support. Further, as the distance is referred to the user’s abdomen, it might cause some problems. For instance, if the user leaned forward and did not move his or her feet, the walker would still move forward and not provide support to the user.

The walker designed by Oscar (Chuy Jr, Hirata et al. 2005) utilized another control approach. They detected exertion force from the user’s hands and then changed the walker’s movement accordingly. In other words, the walker will move away when the user required horizontal force support unless the user exerted download force beforehand to lock the walker from moving. Therefore, this walker only bears pushing forces when it is stationary, but cannot provide any support to the user when moving. The walker designed by Yang (Yang 2004) was equipped with dampers and an electromagnetic brake in the rear-wheel. When the velocity or acceleration of the walker exceeded a preset value, the braking system would activate to prevent it from running away. As to the damper whose friction is adjustable, however, it would continuously produce horizontal resistance. The user must expend extra effort to overcome the friction force from the damping when moving forwards.

We believed, in terms of user’s needs, an ideal walker should provide immediate support whenever required, and it should be an easy-to-use device. We envisioned an ideal walker with the following features: (1) Provide dynamic support: whenever the user is walking or standing, a walker should provide a relatively stable support for the user to recover from losing balance or when his or her lower limbs become unstable. (2) Little or no effort to use: users do not need to make extra effort to move and change direction. (3) User-friendly: the movement speed and direction can be controlled by the user subconsciously, so he or she does not need special training or change their original gait.

2. METHODOLOGY

2.1 Principle of system operation

Our system concept follows Goro’s idea, but we used the midpoint between both feet as the control parameter to move the wheeled walker. The following requirements could be met using this approach. The user could move the wheeled walker without applying any force. The walker would keep the same distance from the user, even when handle force was applied. In case the user leans forward or backward, as his feet are stationary, the walker would not move and would support the user. Further, since the walker was equipped with power, it did not require the user to expend extra effort to operate uphill and downhill.

2.2 System framework

Our wheeled walker can be divided into five major subsystems in the system framework, as shown in figure 1.

1. Sensor system: Ultrasonic range finders were used in...
detecting the distance between the user and walker. Two ultrasound transmitters were tied to both of the user’s feet, and two ultrasonic receivers were separately equipped on the walker. The time difference between the transmitters and the receivers was used to calculate the distance between the user and walker.

2. Motor and transmission system: A stepper motor and motor driver were included in the motor system. The transmission system was composed of a reduction gear train and an omnidirectional wheel.

3. Support frame system: The support frame was a commercial four-wheeled walker from the market. It could provide users with hand support when needed.

4. Control system: PSoC microcontroller from Cypress was used to process the acquired distance data, and produce the motor control signal.

5. Power system: The power system was equipped to provide stable power for other systems.

2.3 Distance control strategy

The control strategy clearly influenced this new type of wheeled walker’s performance. The system was designed to move with the user’s feet in real time. Figure 3 shows the speed control process. The walker would stay within the range of the dead band, which was 33cm to 35cm between the walker and the user. When the user stepped forward or backward, the distance would be out of the dead band range. Thus, the speed of the walker would change as the simple P control until the speed limit was reached. The purpose of the speed limiter was to prevent the stepper motor from losing step. This control strategy was compiled in the microcontroller.

3. RESULT AND DISCUSSION

3.1 Support force

The six-axis force transducer was used to measure the force that we thrust at the walker and increased the effort slowly until the walker was pushed away. The test result is shown in figure 4. A traditional wheeled walker can only withstand a horizontal thrust of 7.9N, even with downward pressure. This new type of wheeled walker could withstand horizontal thrust of up to 75N. In other words, the new type of wheeled walker could withstand 10 times more pushing force than the traditional wheeled walker could. The test result showed this new type of wheeled walker withstood more horizontal force than the traditional one. Figure 4 also showed ideal stable support in the blue line. The stable support must provide at least 100N support force to maintain the user’s balance.
Therefore, this new type of wheeled walker still requires further improvement to achieve better protection and stabilization. To improve the ideal operational condition, we will increase the motor torque to 100N in future research.

3.2 Automatically follow

We observed the relative distance between the user and the new type of wheeled walker, as shown in Figure 5. During normal walking, the walker can remain in the setting distance (35-40cm). However, the motor equipped on the walker could not provide enough torque. The walker would be pushed away, but still return to the setting distance (40cm) after the removal of the pushing force, and continue to automatically follow. In the automatically following test, the new system could remain at a constant distance between the user and the walker. Even if the stepper motor goes out of step because of the larger pushing force, the system would return to the setting distance after the pushing force was withdrawn.

3.3 Uphill and downhill

We built a woodblock ramp in our laboratory (according to the handicap ramp regulations in Taiwan, the ramp ratio is 1:12) for testing. The results showed although the system can automatically follow on the ramp, the omnidirectional wheel slid along the ramp but did not revolve while were applying a pushing force. For the reason, we thought the friction between the omnidirectional wheels and woodblock ramp was too small to withstand the pushing force. In future study, we will equip the wheels with appropriate friction force. Therefore, the system will operate stably on the ramp.

3.4 Change direction

To test the turning mobility of the new type of walker, this study tested turning 90 degrees to compare the new type of walker with a four-wheel walker. The results are shown in figure 6 and 7. The markers moving path setting on the user’s abdomen was represented by the blue line and the walker’s anterior feet were represented by the red and green line. The dashed circle diameter indicates the minimum of the turning range. The minimum circle diameter of the new type walker was about 13.1 cm and the wheeled walker was about 12.4 cm. The turning mobility of the new type walker was the same as the wheeled walker.

4. CONCLUSIONS

In this research, we designed a mechtronic walker using a different control strategy that maintained the distance between the user’s feet and the walker. This walker provided horizontal support force of about 75N, but it required 100N horizontal force to prevent it from falling. Although the torque of the stepper motor was not enough, it still provided ten times greater force than the four-wheeled walker provided.

In the automatically following test, this walker could keep at a constant distance between the user and walker. Even if the stepper motor was out of step because of the larger pushing force, the system would return to the setting distance after the pushing force was withdrawn.

In the ramp test, the wheels of the system slid down because the ground friction force was insufficient.

REFERENCES


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