An Ambulatory Assistant Wheelchair for Individuals with Lower Limb Weakness

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***Abstract*—A low cost prototype of an ambulatory assistant wheelchair designed for patients with lower limb weakness is proposed. The device has similar functions as a motorized wheelchair powered by battery. However, passive leg exercise function is available to assist lower limb therapy. The walking aid is integrated with an auto-brake mode, similar to a roller walker. The feature Android Remote Controller Add-ons is an application of Android platform device which assists patients to drive and park the wheelchair beside their stationary chair, bed, or make other indoor transport. Besides that, motility with Kinect is also another add-on system, which assists physicians to monitor the progress of patients in his rehabilitation program.**

***Index Terms*—Android, kinect, patient rehabilitation, wheelchair, lower limb assist.**

I. Introduction

The undesirable abnormal gait can be caused by various problems to the lower limbs, such as medical conditions, accidental injuries, and natural aging process. People with lower limb weakness rely solely on their upper body to lead a normal daily life. Wheelchairs are the most effective equipment used to regain their mobility. For rehabilitation, physiotherapy is often needed to regain control of the body in balancing, coordination, walking, and general mobility.

Varieties equipment exists in the market to assist the disabled and elderly individual. Wheelchairs are widely used by patients with a lower limb problem to regain their mobility, because they are generally cheaper and lighter than power wheelchair. A hybrid wheelchair is developed by Rahulanker and Ramanarayanan, named battery assisted wheelchair, which can be used to switch between manual and electric wheelchair [1]. Some studies show that the integration of speech system to the motorized wheelchair will assist the handicapped users [2], [3]. However, patients are still required to undergo therapy and exercise. Patients with lower limb problems have difficulty in walking and not every patient can afford to have an exercise equipment at home. Thus, these patients need to go to a rehab or therapy center to do their exercises.

A new type of wheelchair has been developed, which is known as cycling wheelchair, and it has a pedal-driven system similar to a bicycle [4], [5]. Functional electrical simulator (FES) is developed by Takazawa *et al.* [4] to achieve motion control on the cycling wheelchair. Hirata *et al.* [5] introduced a new type of cycling wheelchair which uses leg pedal force to move the wheelchair and do not require FES [5]. Hwang *et al.* [6] developed a wheelchair integrated with lower limb exercise to assist the disabled.

On the other hand, Chang *et al.* [7] developed an indoor system named kinect-based powered wheelchair control system, so that the patients can command the motorized wheelchair to move towards their position when needed. The wheelchair will move back to the parking location when not needed. Thus, a good system will help to improve the quality of life of the handicapped or elderly. Sim *et al.* [8] developed a prototype of a walking assist device that reduces the force subjected to the knee.

This study introduces a low cost prototype of a wheelchair named ambulatory assistant wheelchair as shown in Fig. 1. This device is integrated with the functions of motorized wheelchair, passive motion leg exerciser and walking aids with auto-braking. There is also an android apps remote control integrated to the device that improves the device and better serve the patients with lower limb weakness.

Fig. 1. Prototype of wheelchair type ambulatory assistive device.

II. Ambulatory Assistant Wheelchair

Fig. 2. Walking aids with auto-braking mode.

The ambulatory assistant wheelchair has four modes which controlled by microcontroller, as shown in Table I. The device has two controllers; one is located beside the armrest, and one is located behind the back support of the seat. Assist mode in the table enables the medical personnel to control the wheelchair from the rear. This mode is useful for medical personnel in assisting the patient if the patient has difficulty to control the device himself or herself. This mode is almost

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similar to the roller walker as shown in Fig. 2. However, users do not need to push the device; a press on the switch will enable travelling a certain distance followed by a halt (auto-braking). The travel distance can be set at the controller. The process can be repeated whereby walking is performed.

TABLE I: FUNCTIONS OF AMBULATORY ASSISTANT DEVICE

Mode	Functions	User Control	Assist Mode
Motorized wheelchair	Same function as standard motorized wheelchair.	√	√
Passive motion leg exerciser	Passive motion cycling exercise device.	√	√
Combination mode	Motorized wheelchair + Passive motion leg exerciser.	√	√
Walking aids with auto-braking	Same function as roller walker.	√	X

III. ANDROID REMOTE CONTROLLER ADD-ONS

A software-based remote controller is developed, which is able to be installed on a smart phone device. An off-the-shelf PIC-based component is used to interface with the main circuitry via Universal Asynchronous Receiver/Transmitter (UART) and parallel bus. The component allows interfacing with external hardware in the same way as high-end microcontrollers do, allowing the hosting of a mobile device via Bluetooth or USB, providing the software development kit (SDK) to interface mobile application software with hardware using preprogrammed microcontroller in it. This enables the application software to send commands to the main circuitry.

The user is required to install an application that allows the establishment of Bluetooth connection between the mobile device and the component, in order to configure the system for first time use. Once the system is configured then the application software is ready to communicate remotely with the hardware. The application software facilitates the user to set the desired mode, adjust the seat, drive the wheelchair remotely and customize power profile to conserve the battery energy. The block diagram for android remote controller add-ons is shown in Fig. 3.

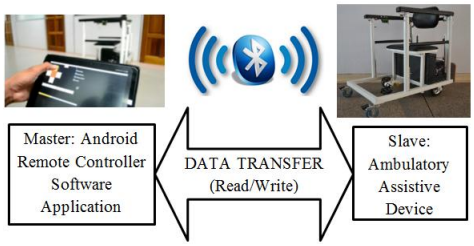

Fig. 3. Block diagram for android remote controller add-ons.

IV. MOTILITY WITH KINECT ADD-ONS

Motility with Kinect is an add-ons software application for ambulatory assistive device, which it observes and monitors the progress of rehabilitation of patient through passive motion cycling exercise of ambulatory assistive device. The benefit of using this system is that, the medical personals are able to monitor the patients without physically present via Cloud system. Hence, patients are able to do exercise at home. All the patients' data will be stored and send to the medical personals via Cloud System.

The setup of this system is as shown in Fig. 4. It requires a display screen, a pc with motility with Kinect software application, a Kinect for Windows hardware with stand, an ambulatory assistive device, and a patient sitting on the device. It is recommended to maintain the distance between patient and Kinect for Windows about 1 to 2 meters.

Fig. 4. Setup of motility with kinect system.

Based on Fig. 5, it shows that the application works as optional add-on by using a 3-D depth sensor, which is independent of the wheelchair. It captures the circular motion of passive exercise to determine the number of cycles and average cycles per minute. The skeleton data is utilized to calculate the motion data, the algorithm is executed every 200ms by the main program. The algorithm is based on a simple idea that when the patient exercises, the feet move in circular motion, while knees move in a vertical position (up and down). So by capturing the movement of knees, it can determine the cycle.

The raw video and skeleton motion video is captured throughout the exercise. Once the exercise is completed, the captured and calculated data are then uploaded to cloud for doctors to review and analyze the patient's performance. The information are extracted from the raw data and it's displayed in form of graphs such as average cycles over the time, variation in exercise duration over the time, variation in average cycles over the time and respective skeleton motion video. It helps doctors to identify the problems and give suggestions for improvements.

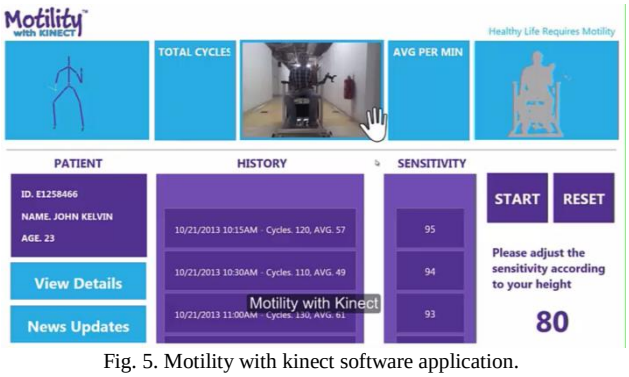

Fig. 5. Motility with kinect software application.

The application software is designed using multiple architectural styles. The Software Based Remote Controller and Patient Monitoring System communicates with each other by using Message Bus Architecture where AllJoyn Framework is used to establish a unique communication bus where both peers can communicate via message passing using remote procedure call (RPC). This communication between the two enables the patient to start and stop the

wheelchair exercise device with hand gestures. While the system's main architecture style is Model View Controller (MVC) and secondary is Service Oriented Architecture (SOA). The data is sent and received over the network in JavaScript Object Notation (JSON).

V. Results and Discussions

A. Survey of User Rating

The statistical data and user ratings are collected through a survey; a form was created and passed to the users asking them to rate the different aspects of the device from the lowest rating points 1 to the highest 5. In the survey users' age data is collected, while the data about aspects of the device are stability, safety, comfort ability, user friendliness and appearance of the device. The results of the survey are shown in Table II.

TABLE II: Results of Survey

	Average Score of Survey for Every Groups (1 Group = 10 Users)									
Group	1	2	3	4	5	6	7	8	9	10
Safety and Stability	4	5	5	4	5	4	5	5	5	4
Comfortable	4	3	4	5	3	5	3	5	4	5
User Friendly	4	4	3	4	5	4	4	4	4	4
Useful Functions	5	5	5	4	4	5	5	4	5	5
Appearance of Device	3	4	4	3	4	3	4	4	4	3
Total Score	20	21	21	20	21	21	21	22	22	21
Average Score	21/25									

The sample size of the data is 100 that include patients, individuals and elderly personal with lower limb weakness. Table II shows that the patients are satisfied enough with the features related to safety and stability. As the seat is redesigned in this work users are feeling more comfortable, therefore survey shows good ratings in this regards. The survey also determines some of them need a bit of quick training in order to get used to of device features. The device functions are serving their purpose of design. As this is the prototype not a final furnished product so customers are fairly satisfied with appearance, but the design of overall device is up to user expectations.

B. Comparisons with Existing Products

The comparison is made between different variants of wheelchairs rather than individual products, as shown in Table III. Our new variant of wheelchair offers more functions as compared to earlier variants. At the same time, it provides tools such as patient monitoring system with data collection capabilities and cloud services, useful for rehabilitation centers at hospitals. It also offers software-based remote controller for the patient. The new variant is using new technologies as compare to the older motorized wheelchairs available in the market. It is a novel solution that offers more features in one product, and takes care of supporting tools and services for the medical staff. The cost of the device with all the functionalities and services may be comparable to existing motorized wheelchairs. The existing motorized wheelchairs are expensive and their cost goes beyond RM 5000. It is believed that the new design has good commercial potential and can fulfill the changing market needs.

TABLE III: Comparison of Prototype with Existing Device Available in the Market

Product/Features	Manual Wheelchair	Motorized Wheelchair	Ambulatory Assistant wheelchair
Mobility	Arm force	Battery power	Battery power
Arm Rest	Fixed	Lift up	Side Way Adjustable & Open able
Adjustable Seat	No	Depends on model	Yes
Adjustable Back Support	No	Depends on model	Yes
Lower Limb Exercise	No	No	Passive motion
Transportation Purpose	Foldable /Detachable *(Depend on model)*	Foldable	Detachable arm rest & back support
Direction Control	Arm force	Joystick	Low pressure press switches
Stopping Mechanism	Arm force	Electronics	Electronics
Mode Changes	No	No	Motorized wheelchair, Leg exerciser mode, walking aid mode
Remote Control	No	Maybe	Android remote controller add-ons
Rehabilitation Monitoring System	No	No	Motility with Kinect
Price in Ringgit Malaysia (RM)	More than RM300	More than RM6000	Around RM6000

VI. Conclusion

The ambulatory assistant wheelchair has different modes as shown in Table I and Table III, which may assist individuals with lower limb weakness in difference ways. Besides that, Integration of Android Remote Controller Add-ons makes the device unique.

The motility system is based on the concept of interactive smart system via cloud technologies which promote user friendliness and assists the patient in rehabilitation program in smart way. The interaction design is done based on the concept of natural user interface, which enables the system to sense motions and gestures of users. Meanwhile, doctor, patients and exercise system remain updated and interconnected via cloud technologies.

Thus, we strongly believe that these applications will serve the medical personals and individuals with lower limb weakness better.

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