

Design considerations of ASBGo++ (Plus Plus) Smart Walker

Abstract – The development of a gait disorder leads to the loss of the ability to walk and may cause dependence of others in daily life, which is a major determinant in life quality. Thus, devices that provide mobility assistance and ambulatory daily exercises are essential for the health and life quality of such individuals. The ASBGo Smart Walker is an academic project aimed to create a medical solution for rehabilitation of patients with gait disorders. Based on the acquired know-how, the physicians, physiotherapist and patients' feedback, a new prototype, named ASBGo++ (*Plus Plus*) was developed, mechanically and electronically improved. This paper will focus on the proposed mechanical, design and ergonomic considerations, enhancing the positive aspects of this smart walker and emphasizing the features that are most highlighted in its design, structure, and functionality.

Keywords: Smart Walkers, gait disorders, mechanical design.

I. INTRODUCTION

Bipedal locomotion is one of the most important function of the human body, as it enables the mobility of the body through space, changing, therefore, the position of the person [1]. As part of human locomotion, the human gait affects not only the individual's locomotion capacity but also the physical and psychological health, and the ability to perform personal tasks. Nonetheless it has the tendency to decrease, gradually, with age as a consequence of neurological, muscular and/or osteoarticular deterioration [2].

Different conditions such as poliomyelitis, spinal cord injuries, stroke, Parkinson, cerebral palsy and multiple sclerosis may lead to gait disorders such as ataxia, waddling, disequilibrium and antalgic, causing a loss of locomotion capacities [3]. Therefore, as daily exercise and rehabilitation may lead to fall prevention and postural stability, the

demand for augmentative devices that extend independent living and promote improved health is growing [4]. These devices, help to stable the gait, support the body weight and prevent falling accidents enabling at the same time an adequate progress in the rehabilitation [5].

In the field of robotic technologies for gait assistance, a well-known augmentative device is the smart walker (SW). Such device empowers the user's natural mean of locomotion with the help of mechanical structures, electronics, control systems, and sensors. Also, it presents a similar mechanical structure to the four-wheeled walker with a controlled guidance maneuverability.

These devices include functionalities like physical support; navigation and localization (i.e. cognitive and sensorial) assistance, and integrates an interface able to read and interpret the user's command intentions to drive the device accordingly [4]. Nevertheless, some of the existing robotic walkers do not incorporate all these required features for the rehabilitation adapted and focused on gait disabled people. In other words, walkers that provide sensorial and cognitive assistance, often, do not present an appropriate physical support or an advanced human-machine interface, and vice versa.

This paper introduces the latest prototype developed by the working group with the same acronym, after six years of research and clinical trials: the ASBGo++ *Plus Plus* (Smart Walker for Mobility Assistance and monitoring System Aid). This device was subjected to improvements in the mechanical and ergonomic design to contribute towards better and efficient rehabilitation purposes.

In the following sections, a brief state-of-the-art of Smart walkers will be presented. Section III describes the ASBGo++ walker in detail, in terms of the project evolution. Thus, in this section are described the mechanical and ergonomics considerations and the proposed

modifications of the prototype to achieve a better and improved walker. Section IV presents and discusses the results obtained. Finally, section V presents conclusions and future work.

II. STATE-OF-THE-ART

There are many smart walkers that fulfill the functionalities previously mentioned. The physical support functionality focuses on structural enhancements to the standard four-wheel walker device, improving stability during gait. The totality of the SW (Figure 1) has physical support, and what distinguishes from each other is the type of enhancements. For example, Simbiosis [5] and JARoW (JAIST Active Robotic Walker) [6] provide a forearm support to offer more assistance during gait, through the upper extremities, thus reducing the weight bearing on the lower extremity joints. The shape of the SW also differs. Examples are the U-Shape frame of the i-go walker [7], that also has a regulatory rod for adjusting the handle's height for the user and the circular shape of the JARoW, which reduces the potential of collisions with obstacles.

The SW may also provide navigation and localization assistance. The walking aid robot of Ye et.al has ultrasonic sensors placed around it to detect the surrounding range, leading the rods to contract when passing through the door, even in narrow spaces [8]. On the other hand, RT Walker, by using laser range finder sensors, could detect an obstacle and therefore realize a collision avoidance and compensation function [9]. The i-walker has also navigation and obstacle avoidance assistance, for instance it incorporates inclinometers on its system that can detect if the surface is inclined or not [10].

The interfaces appear as elements that establish a bridge of interaction between human and machine. These interfaces may be direct or indirect, depending on whether the user





Figure 1. Smart walkers. (a) JARoW [6]; (b) Simbiosis [5]; (c) i-go [7]; (d) Ye et al. [8]; (e) RT walker [9]; (f) i-walker [10]; (g) GUIDO [11]the Assistive Mobility Device (AMD); (h) UFES [12].

commands the device, manually or not. The objective is to read and interpret the user's intentions, with the help of sensors, and command the device accordingly. The GUIDO and i-Go walkers are examples with a handlebar with force sensors do determine the intended direction of travel [7], [11]. Regarding the UFES robotic walker, its control system relies on a human machine interface (HMI) responsible for the acquisition and interpretation of user's upper and lower limbs postures and gestures during gait combined in order to command the device's motion [12]. The same approach is implemented on the JARoW device.

III. ASBGO SMART WALKER PROJECT

The development of an ASBGo 4-wheeled motorized walker aims to provide safety, a natural maneuverability and a certain degree of intelligence in assisting with the use of multiple sensors. This device was specially design to take into consideration a rehabilitation treatment for patients with ataxia. The walker provides information about the user gait pattern, identify the movement intentions by evaluating the direction and speed, and ensure security conditions by detecting possible falls.

It includes functionalities like physical support, cognitive and sensorial assistance, biomechanical monitoring, safety and human-machine interface. This way, ASBGo has four operating modes: autonomous mode, manual mode, safety mode and remote control mode. These

four operating modes make possible the adaptation of the ASBGo's operation depending on the difficulties of the patient and provide safer, comfortable and efficient rehabilitation. With all these features the walker is able to provide important insight on the user's state for further clinical evaluation by the physiotherapist [13]. The evolution of the project is show in Figure 2 in terms of different prototypes that were designed by the working group.

After one year of clinical trials, treating six patients with cerebellar ataxia, in Hospital of Braga, Portugal, the third prototype was evaluated and eventual issues were discussed between the research team. Relying on the physicians, physiotherapists and patient's feedback together with the point of view of the engineer involved in every experiment, the team pointed some problems and proposed the respective solutions to improve and upgrade the walker. In this section a brief evolution of the project that culminated on the fourth prototype, the ASBGo++, is presented. Before this, it is important to describe the third prototype in terms of mechanical and design features. Hence, the specifications design and functionalities are presented in Table 1.

Table 1. Specifications and features list.

Parameter	Specifications and features
Length x Width	1 m x 1 m (maximum)
Height Regulation	1.50 m – 1.75 m (mechanical lifting system)
Mass	50 kg
Gait's area	0.50 m x 0.50 m
Material	Base – Steel; Top – Aluminum
Base structure	10° angled for each side
Steering	Motorized rear wheels. Each rear wheel is installed with an encoder.
Wheels	Four pneumatic wheels with 200 mm of diameter.
Adjustments	Handlebar Length – linear guideways Height – Mechanical lifting system (height regulation) Forearms Width – Velcro
Physical Interaction	Potentiometers
Electronics' storage	Box to storage the electronics parts, batteries and sensors.
Communication and programming	Arduino platform and portable computer
Others	Abdominal surface area with a curvature in the contact area. Handlebars to assist the transition of sit-to-stand.

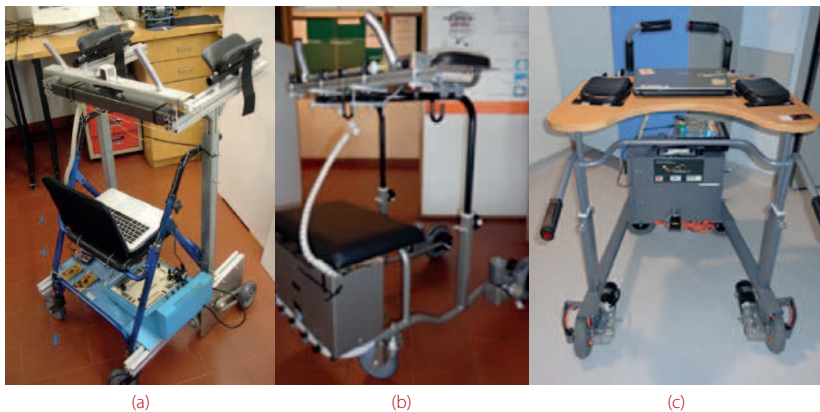


Figure 2. ASBGo prototypes: (a) first; (b) second and (c) third.

The interface between the user and motor controller of the wheels, the handlebar, is based on low-cost electronics composed by potentiometers to detect forward and turning directions: a linear potentiometer to detect directional changes in speed and a rotatory potentiometer to detect forward changes in speed. The walker is also equipped with other sensors such as force sensors resistors, infra-red sensor, laser range finder, active depth sensor and sonar sensor, all acting as indirect interaction [13]. It is important to note an existing abdominal surface area with a curvature in the contact area with the user to center him and correct his back posture with normal flexion of the back, independently of his anatomy.

As mentioned, after clinical trials some considerations regarding the third prototype were discussed and mechanical modifications were implemented, following five steps: 1) definition of the user's central point to define the base position of the handlebar – ideal user's position; 2) definition of the structure's base – Interference in gait; 3) selection of the lifting system; 4) restructuring of the surface's area; 5) reformulation of handlebar's structure. Detailed considerations, modifications, and the implementation's process can be consulted in previous work [14].

The design CAD and the physical model are represented in Figure 3. Currently, the production of the mechanical features of the fourth prototype is made by the Orthos XXI Company, a Portuguese manufacturer company of orthopedic devices.

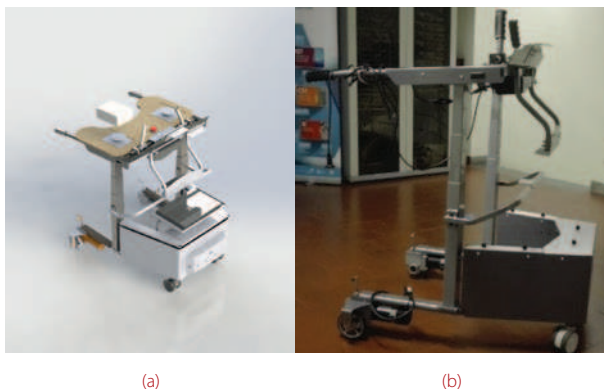


Figure 3. ASBGo++ Smart Walker: (a) CAD and (b) physical model.

The physical structure of the smart walker is made of aluminum alloy, has two front caster wheels, and two rear wheels coupled to the motors (direct connection). In the fourth prototype, wheels with smaller diameter were installed for a better device's driving. The gait's area is 58cm of width and 69cm of length, giving the necessary space for the mid stance phase gait of patients with ataxia and cerebellum lesions, as they have a wider gait base of support [13]. An improvement implemented on the new prototype when comparing to the previous one.

One of the major goals of this project is to make the device adaptable to users with different degrees of disability and different body structures.

Therefore, the walker allows an adjustment in height of 65cm, through electric lifting columns, and a lateral adjustment of the handles according the patient's shoulder width. There are two types of physical support: forearm support and two handles on the back of the walker. The forearm supports are placed on the abdominal surface area, made of wood.

The box compartment for the electronics was placed on the front of the walker in a lower level to improve the general stability of the walker. The handlebar is the main interface of the device, providing a direct interaction between the smart walker and the user. It is used as Human Machine Interface, during manual mode that is characterized by the movement of the device under the guidance of commands defined on the interface by the user: start to walk, accelerate, slow down and turn left or right. Concerning the reformulation of handlebar's structure, the material previously used (aluminum 6063-T6) was not very resistant, and with excessive friction and the tensions caused on the device lead to a buckling of the handlebar's tubes. Therefore, the change to a more resistant material such as steel plate S235JR (EN 10025-2) and Chrome Steel for the tubes was taken into consideration in the fourth prototype. Thus, the mechanical components were rearranged. For instance, the compression spring for the translation movement was moved from the edges to the center of the device. The modifications on the handlebar's prototype are seen in Figure 4.

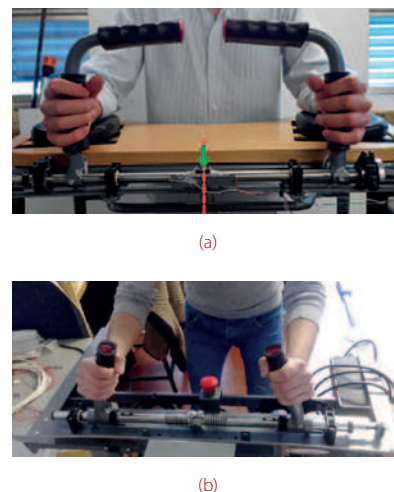


Figure 4. Handlebar: (a) third and (b) fourth versions.

Be noteworthy of the existence of an emergency button, near the handlebar (red button in Figure 4) and thus accessible to the user. This component is extremely important for any electronic medical device to guarantee safety for disabled users.

It must be pointed that, regarding functionalities it was included a biofeedback approach using body tracking through visual support [15]. The proposed functionality identifies user's central points (shoulder, hips and upper body), the velocity of the upper body's center and the patient's hands position. With this data, the interface will expose the coronal, axial and sagittal views of the patient, giving important information regarding posture. This way, it is possible to determine if the patient is correctly holding on to the handle grips and if he/she is balanced, preventing, thus, the risk of fall.

The electronics' implementation on the new prototype is being done by the ASBGo working group. This implementation will have a robust, flexible and modular software architecture using, as core of the system, a robotics middleware called Robot Operating System (ROS) [16]. The new ASBGo++'s system architecture is considered more reliable than the one used in previous prototypes, resulting thus in an improved ready-to-use and user-friendly device. In this way, this new model will substitute the third prototype on the clinical trials, at a Hospital in Braga.

IV. CONCLUSIONS AND FUTURE WORK

This study proposed improvements and upgrades from a mechanical design perspective on a third prototype of a Smart walker. Five steps were assigned by the team regarding the mechanical and ergonomic design considerations. As the development proceeded, the progress of both mechanical and electrical improvements design solutions lead to the ASBGo++ prototype. This model has more ergonomics and higher comfort, wider gait's area, better materials' strength and design, and more secure than the previous prototypes. At the end, the modifications implemented so far appear to be effective, since comparing to the third prototype all the

issues were fixed and other improvements were implemented

Moreover, this paper presented the positive aspects of the ASBGo++ device emphasizing the features that are most present in its design, structure and functionality. Some of the features are the human-machine adaptability, diverse rehabilitation oriented modes, safety measure and a robust reliable stable structure. It is worth recalling the fact that ASBGo previous prototypes undertook clinical trials and the new version will soon be used for further analysis of its performance. In conclusion, the ASBGo++ model is one of the most prepared and efficient SW, able to incorporate all the required mentioned features for the rehabilitation adapted and focused on gait disabled people.

For future work, a study regarding the equilibrium stability while falling is being undertaken. Finally implementing all the electronics in the new prototype, especially the sensors, are the main concerns to start the new clinical trials in Hospital of Braga. All the results obtained are intended to be used towards a commercial product, with an affordable cost but high reliability and safety.

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