

# A Navigation Aid for Blind People with Walking Disabilities

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**Abstract**—Many blind people require travel aids to navigate in unknown environments. However, the majority of the corresponding devices are not designed for people with walking disabilities. In this paper, we present a smart walker that does not only provide walking assistance but also enables blind users with mobility impairment to avoid obstacles. By leveraging existing robotics technologies, our system detects both positive and negative obstacles such as curbs, staircases and holes in the ground and transmits obstacle proximity information through haptic feedback. Initial experiments show that our smart walker enables human users to navigate safely in indoor and outdoor environments.

## I. INTRODUCTION

According to a recent report of the World Health Organization [1], 81.7% of all 39 million blind people worldwide are 50 years and older. These people have an inherent risk towards walking disabilities. However, established navigation aids for the blind such as white canes or guide dogs provide limited assistance. A conventional technique for blind people who depend on a walker is to regularly stop and monitor the environment with a cane stick. This is tediously slow and it comes with the inherent risk of missing objects that do not touch the ground, such as tabletops. Existing electronic aids for the blind solve this problem to some extent, but most of these devices are not designed for blind people with walking impairments. Furthermore, in most cases, these devices are able to detect positive obstacles but fail to recognize dangerous negative obstacles, such as downward staircases or road curbs.

In this work, we present a smart walker that provides navigation assistance to blind people with walking disabilities. Our system robustly detects and warns users about positive and negative obstacles, leveraging recent advances in the field of robotic perception. It is based on the ROS framework [2], which simplifies the use of existing, publicly available modules and increases its flexibility.

## II. SMART WALKER OVERVIEW

Our system consists of a standard off-the-shelf walker, retrofitted with sensors and data-processing capabilities. The sensing and processing unit is built in a modular fashion, such that it can be easily mounted on different walker brands. The system additionally includes a vibration belt comprising five vibrating motors, which provide haptic feedback to the user. An image of the smart walker is shown in Figure 1, while Figure 2 depicts the vibration belt.



Fig. 1. The smart walker, a modular system composed of a standalone processing unit and an off-the-shelf walker. The processing unit includes two laser scanners and the required computing capabilities. The lower laser scanner is fixed and used for egomotion estimation. A servo motor tilts the upper scanner continuously up and down to acquire a three-dimensional representation of the environment.

We use two planar laser range finders for perception and estimation of the egomotion. The first laser scanner is fixed with respect to the walker and it is used to calculate the egomotion by laser scan matching [3]. The second laser scanner is continuously tilted by a servo motor to sense the three-dimensional environment. We fuse the egomotion estimation with the measurements of the second scanner and the servo motor to obtain a dense three-dimensional point cloud.

Our approach leverages terrain classifiers from robotics to detect hazardous positive and negative obstacles from point clouds. Specifically, we modified the “height-length-density” (HLD) classifier, which is designed to determine safe and traversable cells in a planar grid map [4]. Our modification improves its suitability to human motion with a walker in tight narrow indoor spaces.

We compute the distances to nearby obstacles by fusing traversability information from the classifier and data from the fixed laser. This information is then relayed to the vibration belt via bluetooth. Obstacle distances are encoded with pulse-frequency modulation such that closer obstacles result in the respective motor vibrating with a higher repetition rate. If the obstacle proximity is below a provided threshold, the corresponding motor is turned on constantly. This is similar to the *Parking Distance Control* system used in cars. Figure 3 provides an overview of our system.

## III. EXPERIMENTS

In an exploratory evaluation, we presented an early prototype of our smart walker at SightCity 2014, Germany’s biggest exhibition about aids for the blind [5]. Visually impaired vis-

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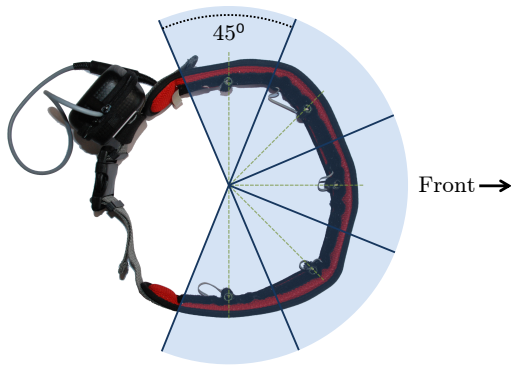


Fig. 2. Vibration belt with bluetooth receiver and power supply. Five vibration motors are mounted around the user's waist. The vibration pattern of each motor encodes the distance to the closest obstacle within the marked angular range.

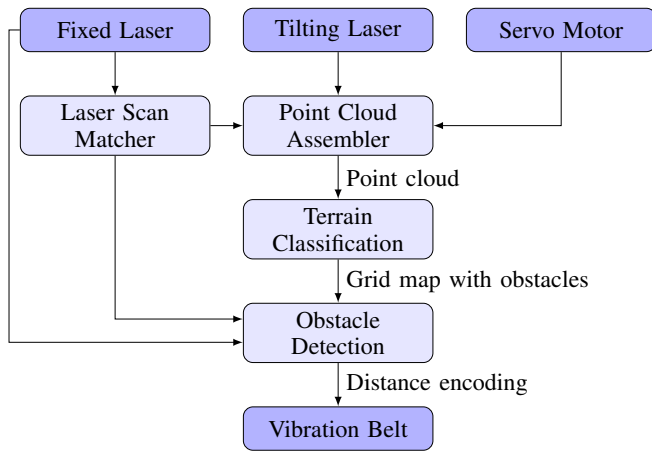


Fig. 3. Hardware (dark) and software (light) architecture of the smart walker.

itors and mobility teachers tested our system and participated in a qualitative evaluation. Results from our questionnaire indicate that our walker enabled them to successfully avoid the obstacles in their environment. Most of the users stated, that they were able to sense the haptic signals clearly and felt safe while using our system. They also expressed that our smart walker was easy to adapt to, requiring only a few instructions. Suggestions included the introduction of semantic obstacle feedback, allowing the distinction between positive and negative obstacles. Additionally, we received positive feedback given our capability to robustly identify negative obstacles as available electronic blind assistances are limited in this regard. We are currently in the process of preparing a large scale quantitative evaluation of our system based on the qualitative results and feedback obtained at SightCity 2014.

#### IV. RELATED WORK

There has been a significant amount of research covering the development of *Electronic Travel Aids* for visually impaired [6]. Existing systems can be categorized by their level of autonomy. High-level systems execute global path planning and guide the user along a specific route [7], [8], [9]. Systems with a medium level of autonomy propose a direction to avoid close obstacles [10], [11]. Low-level approaches detect obstacles in the vicinity of the users and inform them about their positions [12], [13]. Shoval et al. compare different levels

of autonomy and conclude that users traveling in unknown environments prefer low-level approaches [14].

Though the smart walker realizes the low-level autonomy paradigm, our system architecture and sensors are flexible enough to allow an increased level of autonomy by incorporating additional data processing modules.

#### V. CONCLUSION

We presented a smart walker for blind people with walking disabilities. Our walker detects obstacles and transmits a haptic feedback of the obstacle locations to the user. Contrary to existing solutions, our system is able to detect negative obstacles such as curbs, staircases and holes in the ground. It is easy to adapt to and designed to operate in unknown indoor and outdoor environments. Further work will focus on the miniaturization of the system with more affordable sensors. We will incorporate vibration feedback with different encodings so that users can distinguish between positive and negative obstacles. Furthermore we are currently investigating the use of vibration motors in the handles to realize path planning and guided navigation.

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