Optical Flow based Obstacle Avoidance for the Visually Impaired

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***Abstract*—Vision is a vital cue for human navigation. Thus, visually impaired people encounter many challenges in day-to-day travelling. Identifying and avoiding obstacles in the environment is the most crucial among them. To empower blind navigation, numerous electronic travel aids were created in the past few decades, by using various obstacle sensing technologies such as sonar, infrared, and stereo vision. However, optical flow estimations based navigation, which is heavily used by insects and experimented in the field of robotics, has not been used in them. This project aimed to evaluate the potential optical flow estimation based techniques has in guiding a visually impaired person to avoid obstacles using auditory and tactile feedback. To demonstrate the researched core concepts, a prototype consisting of a virtual reality world was designed and developed. It also employs an existing optical flow algorithm for motion estimation, other image processing techniques, speech synthesis for auditory feedback and embedded programming for tactile feedback. The modular design of the prototype enables it to be used either in simulation mode, or as a standalone application in a real world environment. This work demonstrates the attractive possibilities of using optical flow estimations for visually impaired navigation.**

Keywords-blind navigation; obstacle detection; optical flow; time-to-contact; auditory feedback, tactile feedback

I. INTRODUCTION

Vision is the main cue used by humans in obstacle avoidance, which can be seen as a trivial task to the visually-able navigator; a process done automatically by using eyes and with minimum cognitive effort. In contrast, for a visually impaired person, vision must be substituted by auditory, tactile and olfaction senses and it is a stressful and cumbersome process which is cognitively demanding and often requires problem solving in every step he/she takes [5].

According to their motion properties, obstacles are categorized as static and dynamic. To avoid them and aid mobility, several traditional travel aids and electronic travel aids (ETA) were introduced [6]. The traditional white cane (or walking cane) and the guide dogs are the most popular obstacle detection aids used by the blind community [3]. For the ETAs, various sensor technologies such as sonar, infrared, vision and several feedback technologies like auditory, vibro-tactile and electro-tactile have been used. [4] provides an extensive survey on these ETAs. Out of the sensor technologies, computer vision provides following advantages over more traditional modalities such as sonar, active infrared and structured light. 1) Given the proper optics, vision essentially has no distance limitation, possibly making use of wide angle lenses at one extreme to telephoto lenses at the other. 2) The information available in an image is both spatially dense and potentially of very high resolution. 3) It is a totally passive sensor, and need not be excluded from the sensitive environments where the emission of sonic or infrared pulses might be intrusive [2].

Several vision based ETAs are vOICe [13], Tactile Visual Substitution System (TVS) [7] and Electron-Neural Vision System (ENVS) [12]. vOICe consists of a digital camera attached to conventional eyeglasses, headphones, and a portable computer with the necessary software. The camera captures images and the computer uses a direct, unfiltered, one-to-one image-to-sound mapping. The sound is then sent to the headphones. The main argument behind vOICe is that human brain is powerful enough to process complex sound information. TVS is a wearable device that converts visual information into a tactile signal. It consists of a tactor belt with 14 vibrator motors spaced laterally, a camera belt with two web cameras attached and a portable computer carried in a backpack. A 2D depth map is created using the images from the two cameras. Then it is sliced in 14 vertical regions. Each vibrator motor is assigned one region and the value of the closest object in each region is transformed to vibration. Vibration frequency and distance of object are nonlinear (increases dramatically for closer objects) and very far or very close objects are ignored. Information given by the tactor belt is applied on the skin of the abdomen. ENVS contains visual sensors, GPS, and electro-tactile simulation. The prototype is consisted of a headset with two stereo cameras and digital compass, a portable computer with GPS capabilities and database of landmarks, the transcutaneous electrical nerve stimulation (TENS) unit, and the TENS gloves. Stereo cameras, using stereoscopic vision, create a depth map of the environment and using the portable computer, information regarding the obstacles (from the depth map) or landmarks (from GPS) is transformed via TENS to electrical pulses that stimulate the nerves in the skin via electrodes located in the TENS data gloves. The amount of stimulation is directly proportional to the distance of the objects.

Existing devices do not use or attempt to make use of Optical flow in any way. This is an interesting observation given that the same technique is used predominantly in the insect world for navigation [19-21] and is also so frequently prototyped for robots [15][17][18].

The use of optical flow is viewed by many researchers to be an adept technique for the purpose of automated vision based navigation. Thus [10] states that the estimation of motion in images is a basic task in computer vision with many interesting applications such as segmentation, structure from motion and