Anajaa-Visual Substitution System: A Navigation Assistive Device for the Visually Impaired

Authors : Juan Pablo Botero Torres, Alba Avila, Luis Felipe Giraldo

Abstract : Independent navigation and mobility through unknown spaces pose a challenge for the autonomy of visually impaired people (VIP), who have relied on the use of traditional assistive tools like the white cane and trained dogs. However, emerging visually assistive technologies (VAT) have proposed several human-machine interfaces (HMIs) that could improve VIP's ability for self-guidance. Hereby, we introduce the design and implementation of a visually assistive device, Anajaa – Visual Substitution System (AVSS). This system integrates ultrasonic sensors with custom electronics, and computer vision models (convolutional neural networks), in order to achieve a robust system that acquires information of the surrounding space and transmits it to the user in an intuitive and efficient manner. AVSS consists of two modules: the sensing and the actuation module, which are fitted to a chest mount and belt that communicate via Bluetooth. The sensing module was designed for the acquisition and processing of proximity signals provided by an array of ultrasonic sensors. The distribution of these within the chest mount allows an accurate representation of the surrounding space, discretized in three different levels of proximity, ranging from 0 to 6 meters. Additionally, this module is fitted with an RGB-D camera used to detect potentially threatening obstacles, like staircases, using a convolutional neural network specifically trained for this purpose. Posteriorly, the depth data is used to estimate the distance between the stairs and the user. The information gathered from this module is then sent to the actuation module that creates an HMI, by the means of a 3x2 array of vibration motors that make up the tactile display and allow the system to deliver haptic feedback. The actuation module uses vibrational messages (tactones); changing both in amplitude and frequency to deliver different awareness levels according to the proximity of the obstacle. This enables the system to deliver an intuitive interface. Both modules were tested under lab conditions, and the HMI was additionally tested with a focal group of VIP. The lab testing was conducted in order to establish the processing speed of the computer vision algorithms. This experimentation determined that the model can process 0.59 frames per second (FPS); this is considered as an adequate processing speed taking into account that the walking speed of VIP is 1.439 m/s. In order to test the HMI, we conducted a focal group composed of two females and two males between the ages of 35-65 years. The subject selection was aided by the Colombian Cooperative of Work and Services for the Sightless (COOTRASIN). We analyzed the learning process of the haptic messages throughout five experimentation sessions using two metrics: message discrimination and localization success. These correspond to the ability of the subjects to recognize different tactones and locate them within the tactile display. Both were calculated as the mean across all subjects. Results show that the focal group achieved message discrimination of 70% and a localization success of 80%, demonstrating how the proposed HMI leads to the appropriation and understanding of the feedback messages, enabling the user's awareness of its surrounding space.

Keywords : computer vision on embedded systems, electronic trave aids, human-machine interface, haptic feedback, visual assistive technologies, vision substitution systems
Conference Title : ICHMID 2021 : International Conference on Human Machine Interface Design
Conference Location : London, United Kingdom
Conference Dates : October 21-22, 2021