Computer Vision-based System for Impaired Human Vision Compensation

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Abstract—**In this short article we describe and discuss architecture of computer vision-based system for partial compensation of lost or impaired human vision.**

Keywords–Computer vision; Mobile application; Aid for blind and visually impaired; Tactile feedback; Impaired human vision compensation.

I. Introduction

More than 250 million people worldwide have moderate to severe vision impairment, while ($\approx$ 36 million are blind) [2]. During the past decades significant effort was devoted to develop computer vision and other sensor based aids (e.g. [3], [4], [15], [6]) for helping the blind and visually impaired users to perceive the surrounding world. However, computer vision is rapidly evolving field, and systems based on the aforementioned approaches often lack accuracy and reliability in real-world conditions. In this article we describe a system, which employs modern computer vision techniques for compensation of lost or impaired vision function in humans. Many of the previously proposed electronic aids for the blind count on highly specialized hardware, for instance smart glasses [6], Microsoft Kinnect sensors [13], helmet-mounted photo sensors and cameras [14]. Such advanced and costly technology brings additional complexity into daily tasks, which visually impaired people currently manage by the help of a white cane. This project puts major emphasis on developing a tool, which seamlessly integrates with the hardware visually impaired person already has on-hand and is used to (smartphone). This paper describes a high level architecture of the proposed technology aid for visually impaired people.

II. Method

Following the principles of participatory design [11], [12] we included the final users into the design process of the system. Two visually impaired persons participated in discussion and focus group meetings together with the project team to identify the key properties of the solution. During the six discussion sessions major attention was paid to:

1) Functionality and key features of the solution addressing real-life scenarios of visually impaired persons;
2) Technical feasibility, connecting user needs to the latest development in computer vision and assisted technologies;
3) Interface between the visually impaired person and the assisted technology;
4) Appearance, usability and potential costs of the final product.

Design process involved testing of the existing mobile phone app (Seeing AI) for assisting visually impaired persons. Semi-structured tests were performed by the visually impaired participants accompanied by a researcher from a project group. Strengths and weaknesses of the existing solutions are reflected in the design of the proposed system.

III. Results

User-centered design sessions with visually impaired persons provided substantial input for the design of the proposed system (Fig. 1). The process made it clear that understanding of the user needs was limited in the project group. Based on the results of the user-centered design process, we present the outline of the system for impaired human vision compensation.

The key part of the proposed system is a smartphone device, connecting user interface and data processing components into a well-functioning ecosystem. Smartphone was selected due to its high availability and capability to perform required computations or forward visual information for processing to the external server via the Internet connection.

The cornerstones of the proposed solution are its inferface and external server, capable running computationally demanding vision processing algorithms.

The interface consists of a wearable forehead belt, integrating RGB and depth cameras, tactile feedback device and bone conductive headphones. Altough more expensive than standard ones, bone conductive headphones allow the user to perceive audio information from the surrounding environment, which is essential for the visually impaired people.

External server processes received visual data according to user request with computer vision algorithms: faster RCNN object detector [10], trained to detect important objects, CNN-RNN-based scene description [7], place recognition [9], face recognition [1], obstacle detection [8], and other algorithms, and transmits feedback signal back to the smartphone device for presenting to the user via the above described interface.

Discussions on functionality and key features of the solution revealed a gap between the aims of the existing tools, which are often focused on advanced navigation and scene description features, and actual user needs. The end users highlighted that a simplistic solution for navigating is lacking. Major focus was put on a easy to use and minimalistic tool, which can be trusted. Object detection, and direction and approximate distance to obstacle were highlighted as major requirements. To our surprise, only 5-8 distinctive object classes (for instance, buss stop, pedestrian crossing, doors, stairs,

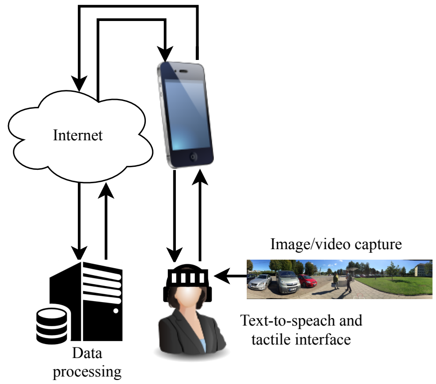

Figure 1. Schematics of vision compensation device.

etc) were of major importance while navigating. Additional information, such as type of a passing car, blossoming flowers in the park or person passing riding a bicycle was considered as overwhelming and distractive. Another important functionality required by end users was navigation aid.

Computer vision technology is under rapid development and during last years made major breakthrough in performance and efficiency. Deep learning neural networks, which are de facto standard in modern image/video processing, are now well supported by software libraries and dedicated hardware built-in even in relatively low-power computational devices, such as smartphones. These devices are also equipped with 4G Internet connectivity and sufficient computational power to perform initial data processing locally. The maturity of the aforementioned technologies suggest that our proposed computational aid for visually impaired persons may be highly feasible.

The cornerstone of this project is the interface between the visually impaired person and the assistive technology. We are proposing a combination of audio and tactile feedback, which may improve the interaction between the assitive technology and the user. Similar interfaces were suggested by research communities earlier [6], [15], however, current knowledge on user preferences and evaluation of various options of tactile feedback (placement on the body, frequencies, strength, etc.) is limited.

Appearance, usability and cost of the final solution is of major importance to the users. The proposed assistive technology should supplement the tool that visually impaired persons used for decades - the white cane. Using a white cane requires little to none training, has very low costs and is relatively reliable. It provides information on the surrounding objects 1-2 meters in front of the user. While the cane can used to detect a nearby obstacle, electronic travel aid could be beneficial for longer range (10-20m) route planning and object recognition. However, it should integrate seamlessly into the existing navigation practices of visually impaired people.

IV. Discussion

In this article we outlined an idea of complex computer vision-based sensor architecture, which can help to partially compensate impaired or lost human sight. Main advantages of therein suggested system are: ability to use efficient (but still computationally intensive) modern computer vision algorithms via Internet connection, present the signal to the user by combined bone conductive headphone-tactile actuator, low cost and consequently increased potential availability of the device. The suggested system integrates well with the main blind person's aid - the white cane. The hardware architecture can be used as the basis for various computer vision-based software modules, allowing to help visually impaired users in everyday routines (e.g. outdoor/indoor navigation, object/face recognition, obstacle detection, navigation). On the other side, due to remotelly carried visual analysis, in some cases the suggested system may suffer from too large latency, its reliability depends on stability and quality of Internet connection.

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