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Image Processing and Tactile Methodologies of a Navigation System for Visually Impaired People

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Abstract

The development of a navigation system to provide information of the environment is a significant progress in the daily living of blind and visually impaired people. This document introduces a project whose objective is to provide the distances up to the objects that are present in a scenario, combining the information captured by two stereo cameras and using a tactile sensor array to represent the image by means of the surface that will be touched by the visually impaired person. So, on the one hand, the device integrates the image processing algorithms capable of obtaining the depth maps from which we extract the distances up to the objects of the scene. On the other hand, the information extracted by the image processing algorithms is shown to the blind user by means of a "tactel" (an array of tactile elements in which each one is equivalent to a pixel of the image scenario), so different depths will be detected and represented. In addition, the stereo cameras will be integrated over a pair of sun glasses, in order to facilitate the way that the visually impaired person can wear them.

1 Introduction

The human eye provides a rich and complex set of information about the surrounding environment such as the position, volume and other properties of the objects [1]. Without visual information people suffer many inconveniences in their daily and social life, mainly when they try to find their way in the environment.

Nowadays, white cane and seeing-eye dogs are widely used as walking support for blind people [2]. Usual routes for a certain user can be reached with the traditional white canes and guide dogs [3]. Nevertheless, for new unknown destinations the limitations of these aids become clear [4]. The traditional white cane is the simplest example of a visual sensory substitution device, which gives the information about near objects to a blind person. However, the range of obstacle detection with a white cane is very limited in comparison with the vision. The information obtained is very poor in temporal and spatial resolution. The error is extremely high. Therefore, the necessity to detect possible obstacles with a high precision, in near and far area, for total and partially sighted people, becomes crucial.

The development of fast and economic digital electronic and sensory devices has opened new pathways to implement new and sophisticated equipments, in order to help the humans in their everyday life [5].

Remarkable work and advances have been made in the development and technical optimization of assistant systems for the visually impaired. Various successful results have been achieved with electronic eyes implants. Nevertheless, many problems remain when representing the real-time information that is changing around the user.

A variety of electronic travel aid systems, offering different levels of environmental information, using different types of sensors (such as video data acquisition), and focused on sound and/or tactile representation have been developed [6, 7]. Moreover, technologies such as Global Positioning System (GPS) [8] and Geographical Information Systems (GIS) are being researched for macro-navigation [9]. Moreover, systems under research that are based on the use of ultrasonic waves, as Sonic Vision and Laser Cane [10], display images by differences in frequency pitch and volume, using speaker array and/or using stereophonic effects [11].

In this sense, it must be remarked that to elaborate a good infrastructure enabling impaired users to easily understand the circumstances in their surroundings, a device which will not interfere with the sounds coming from the environment such as traffic signals bumps, etc. is required [12].

In this context, we present a project whose objective is to provide blind and visually impaired users a tactile representation of the scene that is in front of them. Thus, we propose to provide distances up to the objects by means of a "tactel" (an array of tactile elements) that will be automatically pressed or not depending on the current distance to objects. This way, the blind user will touch the tactile screen, obtaining information of the shape and the distance up to the objects that are present in from of him. Information about distance to objects will be obtained by processing two stereo images by means of algorithms to calculate depth maps (i.e. we will reconstruct three-dimensional information from two images –that each one provides two-dimensional information).

Moreover, in order to facilitate the way that the visually impaired person will transport the prototype of this project, all the devices will be as small and light as possible.

This paper is organized as follows. Section 2 will describe the tactile elements that will be used to provide the depth information of the scene to the blind user. Section 3 will introduce the stereo cameras and the image processing algorithms that will be used in order to obtain a representation of the different depths of the objects of the scenario. Section 4 will describe the communication processes between the stereo cameras and the tactile elements. It will also describe the interface used to communicate with the final user. Finally, Section 5 will draw the conclusions of the work presented.

2 Tactile array elements

2.1 What is a Tactel?

To be easily and intuitively explained, we could say that a *Tactel* is, to the sense of touch, what a pixel of an image is to the sense of vision.

A computer or laptop screen is composed by an array of N rows and M columns. Its resolution increases as long as the number of pixels of the rows and columns becomes higher (it is common to use arrays of 3x3 pixels for each millimetre of the screen).

A *Tactel screen* will also be an array of N rows and M columns of *tactels*. However, we have to take into account that we cannot detect 3x3 *tactels* for each millimetre (as in the usual screens), since each *tactel* needs a space to work properly. For example, to represent Braille characters using tactels we have to keep a distance of around 2 millimetres between *tactels* to facilitate the way that they mechanically work.

2.2 All/nothing actuators and lineal actuators

To move each *tactel* of the screen that the blind user will touch, it is necessary the work of an actuator. An actuator is a piece that rises up or puts down each tactel element.

In the case of the existing *tactel* screens used to represent Braille characters, the actuators used to move them are called all/nothing actuators. This means that the *tactel* element has only two possible positions, up or down, with no possibility to situate it in an intermediate height.

All/nothing actuators are typically made of a small electromagnet with a spring. When the electromagnet is activated, the spring moves the *tactel* element to the maximum height (up). When the electromagnet goes off, the *tactel* element is put down to the initial position (down).

Another type of actuators are those ones called lineal actuators. In this case, its working mechanism is much more complex, since its control is not mechanical but electrical.

Lineal actuators typically employ an engine that can turn a screw, creating a lineal displacement. Moreover, lineal actuators can stop at any position of their length, making possible to provide different elevations to the *tactel* element (not only up or down positions). Figure 1 shows a picture of an electrical microengine that can be used to move a *tactel* element.

Fig. 1 Electrical microengine.

2.3 Actuators chosen for this project

All/nothing and lineal actuators both present advantages and disadvantages in the integration of a project as the one that is described in this paper.

All/nothing actuators are very popular, since their control is mechanical (not electrical) and their cost is very low. However, they can only provide two positions to the *tactel* element (up or down), so this hampers we can use them in this project (since we need the possibility to indicate different depths of objects by using different heights of the *tactel* elements).

Lineal actuators can provide larger displacements and the possibility of situating the *tactel* element at different heights, making them the most suitable option for the prototype we want to develop. Thus, if we use a matrix a *tactel* elements that work by means of lineal actuators, we could represent a relief of the scene that is in front of the user by situating at lower heights more distant objects and at the maximum height the nearest objects. Nevertheless, using lineal actuators presents the disadvantage of needing a more complex control, which results in a higher cost.

3 Stereo vision system

In order to obtain the information of the scenario where the visually impaired user is moving along, two small stereo cameras will be part of our project.

As one of the objectives of the project is to integrate all the devices in a prototype as small as possible, we will use two micro-cameras that will be situated over a pair of sunglasses. This way, the device could be easily worn by the blind user.

The image processing block will consist of the capture of two stereo images, in order to reconstruct the depth information of the objects that are present in the scene by means of processing the disparity between the left and the right stereo images.

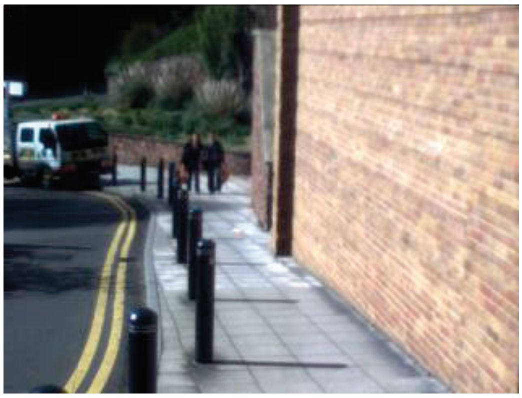
Disparity can be defined as the difference between the pixels location in left and right images. As it occurs for our human vision system, we appreciate more differences between what our left and right eyes perceive in location for objects that are near to us than for objects that are farther. So, similarly to this, disparity in stereo images increases as long as objects are nearer to the cameras, and decreases when objects are situated at higher distances.

There is a lineal relation between disparity and depth. High disparities imply short distances and smaller disparities refer to larger distances (larger depths in depth maps).

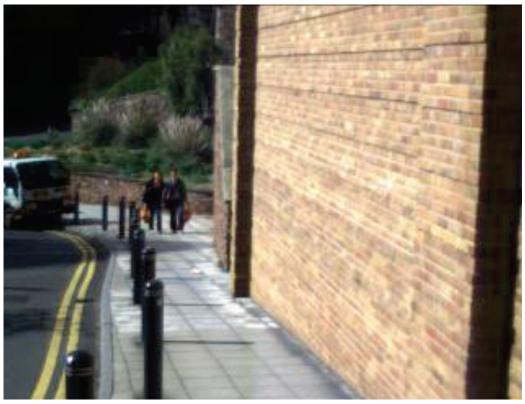
There are several algorithms to estimate depth maps in the state-of-the-art. We will need an algorithm that provides depth maps with accurate information of the shape of the objects and the depth at which they are located. We also need that it can be processed in real-time, with the lowest computational cost possible. So, we will choose the most appropriate algorithm according to the requirements of the system.

In Figure 2 we show an example of left and right images captured by the two stereo cameras and a depth map obtained by processing the disparity information.

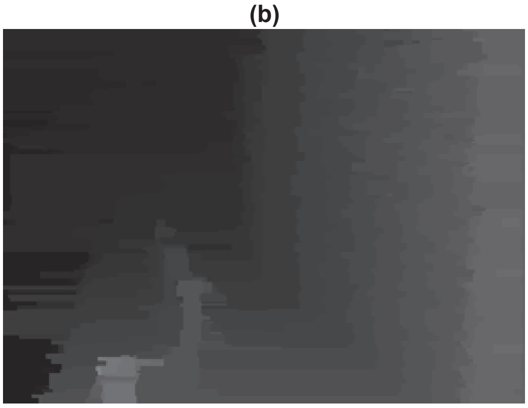
We can observe that in the depth map the distance information is provided by using different grey levels. So, all the pixels corresponding to an object have the same grey level, which is associated to a certain depth.



(a)



(b)



(c)

Fig. 2 (a) Example of image captured by the left stereo camera. (b) Example of image captured by the right stereo camera. (c) Depth map obtained by processing the two stereo images.

4 Communication between stereo cameras and Tactel *elements*

In Figure 3 we show the communication processes between all the devices involved in this project.

The aid navigation process will start when the stereo cameras capture two images of the scenario that is in front of the blind user that is wearing the project prototype.

Then, stereo images are the input information of an algorithm that estimates the disparity between the two images and associate each different disparity to a determined depth.

Once we have the depth information of all the pixels of the scene, it is sent to the array of *tactel* elements. This way, each one of the linear actuators rises up a different displacement, which makes that each *tactel* element associated with each one of them is situated at a different height.

We will send the information of groups of pixels with the same depth to each *tactel* element. Thus, we will save in the number of *tactels* and actuators that will be necessary in our system. This is very important in order to facilitate the size of the array of *tactels*, its portability and the duration of the batteries that will provide energy to all the components of the system.

Finally, we will have a tactile relieve image where each object of the scene will be represented by means of different *tactel* elements at the same height, recreating a special 3D image (what is the final user interface). This 3D image is the output of the presented system (the interface that will interact with the blind or partially sighted user).

The visually impaired user will touch it and will get information about the shape of the objects of the scene, their height, their relative position in the space, and the distance at what they are located.

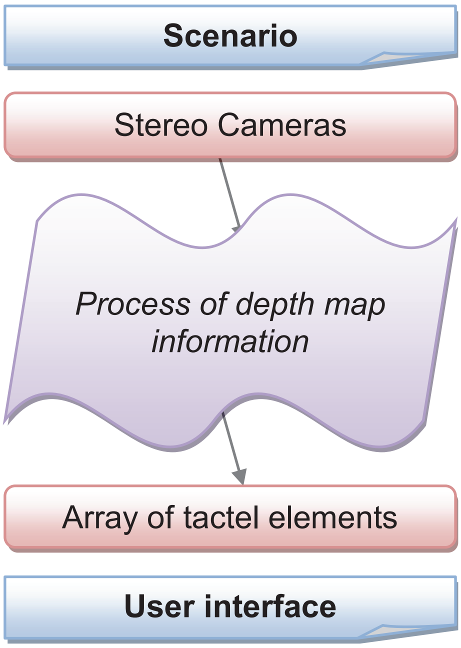


Fig. 3 Communication between modules in the project.

5 Conclusions

In this paper we have presented a project whose objective is to create a navigation system to aid visually impaired people to get information of their environment.

The project consists of the combination of the information obtained by a pair of stereo cameras, which is processed in order to obtain a two-dimensional image with information of the distances to the objects of the scene (what is called depth map).

The depth map information is sent to a tactile array, composed by *tactel* elements. This way, each tactile element will present a different height, according to the real distance at what the object that it represents is located.

All the processes involved must run in real-time to provide information of the current objects present in the scene. Moreover, another challenge of the project is to implement all devices in hardware elements that must be as small, light and portable as possible, in order to disturb as less as we could the daily live of the visually impaired person.

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