Automatic Detection of Tactile Paving Surfaces in Indoor Environments

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***Abstract*—There are around 285 million people in the world with some kind of visual impairments. In Brazil, there are 35.7 million people with visual impairments, of these 6.5 million are totally blind or have great difficulty to see. Individuals with visual impairments have many challenges in autonomous locomotion, even in indoor environments. Many places, as banks, airports, malls, public buildings, etc., have tactile paving to aid these individuals, however, sometimes it is a difficult task locate and follow this type of paving. Thus, the main goal of this work is to present a model that, based on computer vision techniques, helps the individuals with visually impaired to locate, identify, and be guided by tactile paving surface in indoors environments. Our initial results on detecting tactile paving show promising results.**

***Keywords*-Computer Vision; Image Processing; Accessibility; Visually Impaired; Tactile Paving Surfaces.**

I. Introduction

According to data from the World Health Organization[1] (2014), it is estimated that 285 million people in the world have some kind of visual impairment. Among these, 39 million are totally blind. In Brazil, as reported by the Demographic Census of the Instituto Brasileiro de Geografia e Estatstica (IBGE)[2], there are 35.7 million people with visual impairments, of these 6.5 million are totally blind or have low vision.

The most common resources to visually impaired people for navigation are the white cane and guide dog. The guide dog is a difficult solution in Brazil, because of the lack of training schools and the difficulty of acquisition and maintenance of the dog. The white cane is cheaper and simpler, but does not provides all the information about the environment for a safe navigation [1], especially in unknown places, where these people have great difficulty for getting around [2].

With the constant evolution of mobile devices, there are lots of possibilities for the development of assistive technologies for visually impaired people. This is because smartphones can provide several input information for these technologies, such as camera image and GPS information.

Individuals with visual impairments have many challenges in autonomous locomotion, even in indoor environments. Many places, as banks, airports, malls, public buildings, etc., have tactile paving to aid these individuals, however, sometimes it is a difficult task locate and follow this type of paving.

Considering this context, the main goal of this work consist in present a model, based on computer vision techniques, for helping people with some kind of visual impairment to locate, identify, and be guided by tactile paving surface in indoors environments. This model uses images from a smartphone camera to detect and identify a pattern of tactile paving surface. This is an ongoing work, and we are presenting its initial results on detecting tactile paving.

This paper is structured as follows: In Section II we provide an overview of some related approaches. The proposed model and its implementation are detailed in Section III. In Section IV we present some initial results and finally, our conclusions and suggestions for future work are presented in Section V.

II. Related work

We can find several works in the literature aimed to assist visually impaired people for getting around [3], [2], [4], [5], and some of them uses computer vision techniques.

Many of these studies offer guidance on walking in indoor environments, as Navatar [3], which aid visually impaired people to navigate indoor through the physical characteristics of the environment. Another approach of this problem is concerned with the detection of objects and obstacles [6], [4]. However, these solutions assume that the blind person is navigating through a residence or a place with reference points and objects, not in a public place as a mall, airport or bank.

The automatic identification and detection of tactile paving surfaces is one way to assist in the displacement of these persons. However, the majority of these works detects outdoor tactile paving surfaces [7], [8]. Since it was hard to find a work that uses computing vision on indoor public environments for detecting tactile paving surfaces, we concluded that this is an open problem.

Continuing the research of our group in this area [9], [10], [11], in this work we describe the changes made to the algorithm that detects outdoor tactile paving surface to detect another pattern of tactile paving surface used in indoors environments in Brazil.

[1] http://www.who.int/mediacentre/factsheets/fs282/en/
[2] http://www.ibge.gov.br/home/

III. Model Description

There are different patterns of tactile paving surfaces for sidewalks and indoor environments. We already developed an algorithm for the detection of tactile paving surfaces for sidewalks [10], but here our focus is the detection of tactile paving surfaces for indoor environments. Because of the differences between the internal and external tactile paving surfaces (see Fig. 2), the previous work [10] wasn't able to properly detect the internal ones, but we can use a similar methodology. Through frames captured by a camera, the algorithm analyzes the images looking for an area of possible tactile paving surface. If this area is identified, the algorithm analyzes its texture and decide if there is, in fact, a tactile paving surface. In positive case, we use a Grey Level Co-Occurrence Matrix (GLCM) and a supervised learning model called Support Vector Machine (SVM) to detect the texture and differentiate between warning and directional tactile paving surfaces. Then, a user feedback is given in audio format. This process can be seen in Fig. 1 and the details of each part are presented in the following subsections.

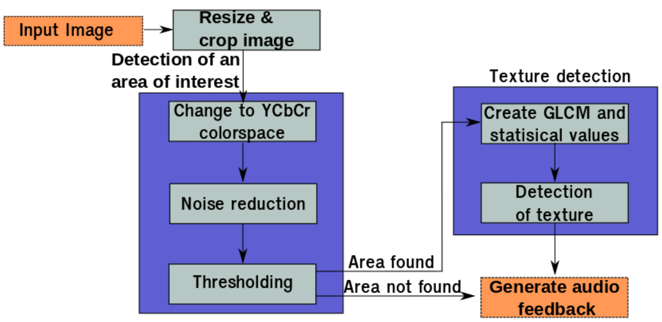


Fig. 1. Main model.

A. Tactile paving surface

A tactile paving surface is a textured ground surface that is located in several places, to guide a visually impaired person in a safest way. These surfaces can be located in external places, as sidewalks, or in indoor environments, as malls and banks. Although they have the same purpose, there are different patterns for these surfaces. The external ones correspond to a squared block, and the internal ones look like stickers that are glued on the floor, as is shown in Fig. 2. This difference makes different the detection based in computer vision for each pattern.

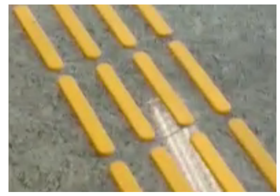
There are two types of tactile paving surfaces: directional and warning. The directional surface (Fig. 2(c)) indicates a way for safe passage, while the warning surface (Fig. 2(d)) indicates that there is an obstacle or a change of direction on the path. In Brazil, the internal tactile paving surfaces appear usually in black and yellow.

B. Detecting an Area of Interest

In the first part of the algorithm, we decrease the frame resolution to 320x240 pixels in order to increase the performance. After that, the frame is converted to YCbCr color

(a) External Directional

(b) External Warning



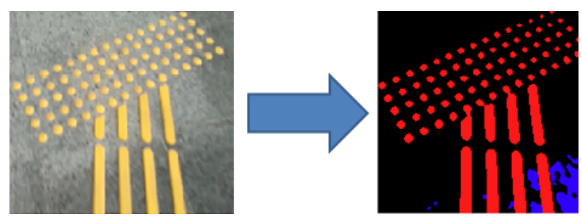
(c) Internal Directional

(d) Internal Warning

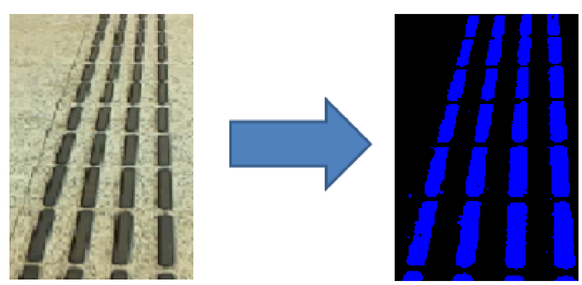
Fig. 2. Tactile paving surfaces.

space, followed by an application of a blur filter (Median Blur) to reduce the noise.

Then, we apply a threshold to do a segmentation, separating the tactile paving surface from the rest. Since there are different colors of tactile paving surfaces, we define two configurations to represent them: Type A and Type B, for yellow and black surfaces, respectively. Applying a threshold on the image, a filtered image of the pattern is generated, as illustrated in Fig. 3.



(a) Type A



(b) Type B

Fig. 3. Thresholding the filtered images

The yellow surface is filtered through the threshold, generating a red surface with blue marks representing the shadows. However, the black surface is also converted to blue, in similar tone as the shadows. Although this proves that a color-based analysis is not enough to determine if there is a tactile paving surface on the floor, it is a good way to determine if there is a possibility of its existence. Through the color of the surfaces, we can detect its area and extract and analyze its texture. The whole process described in this subsection can be seen in Fig. 4, containing the change of color space and blur (Fig. 4(b)), the threshold process (Fig. 4(c)) and a visual representation of the area of a possible tactile surface (Fig. 4(d)). For the recognition of tactile paving surfaces with different colors, the only change in the model would be adding a new Type (Type C, for example), with another filter thresholds.

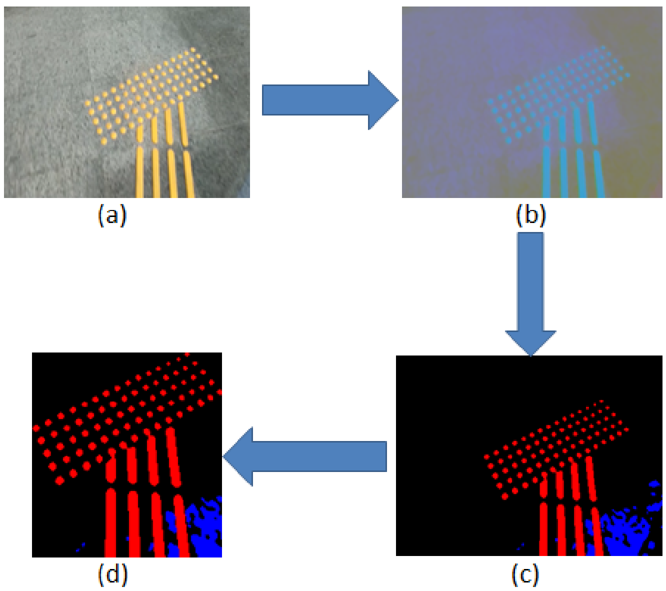


Fig. 4. Process to detect an area of interest:(a) Original image; (b) After changing to YCbCr color space and blur; (c) After threshold; (d) Area of a possible tactile surface.

C. Extracting and Analysing the Texture

To extract characteristics of a texture of images, we used a Grey Level Co-Ocurrence Matrix (GLCM), which is a statistical method that considers the spatial relationship of pixels. The information about the texture is extracted by four statistics: entropy, contrast, homogeneity and uniformity (or energy)[3]. Along with the GLCM, we use a supervised learning model called Support Vector Machine (SVM) [12] to classify the data generated by the GLCM on training images.

These images consist in 124 samples with a resolution of 30x30 pixels each, which 62 of them are fragments of directional tactile paving surfaces (Fig. 5(b)), called Class 1 training samples, and the other 62 are images of paving without the tactile paving surface (Fig. 5(a)), called Class 0 training samples. Separating the samples in these two classes, the SVM will learn the characteristics of each class and will be able to differentiate images with or without tactile paving surfaces.

[3] www.mathworks.com/help/images/gray-level-co-occurrence-matrix-glcm.html

(a) Class 0 training samples (not directional pattern)

(b) Class 1 training samples (directional pattern)

Fig. 5. Examples of training samples.

After training the machine, we have the SVM prediction function that can predict if an area is a tactile paving surface or not. We iterate through the area of a possible paving surface previously discovered, testing if there is a directional tactile paving surface. Each iteration consists on jumps of 5 pixels through the whole area, analyzing blocks of 20x20 pixels. If the algorithm detects a Class 1 surface, it draws a square to indicate the detection, in order to facilitate the validation of the program.

IV. Experimental Results

All experiments were performed using a Intel Core i7 processor, 2.4GHz and 8GB of memory. For implementation, we used C++ programming language and OpenCV version 3.0. The initial results were obtained using images of directional and warning tactile paving surfaces that appears in indoor environments. We tested 20 images containing both types of tactile paving surfaces to identify the directional surface, and we can see some results in Fig. 6.

As Fig. 6 shows, images containing vertical and inclined directional paving surfaces are easily detectable, (Fig. 6 (a) and Fig. 6 (b)), stamping each iteration with positive feedback with a red square. However, horizontal directional paving surfaces are not being detected yet. The Fig. 6 (c) shows this false negative.

Warning tactile paving surfaces in some images are correctly not being detected, as shown in Fig. 6 (c), but in some cases they are detected. This false positives are indicated by a green square in Fig. 6(d). In other cases, there are some false positives in areas which the ceiling lamps are reflected by the floor, as can been seen in Fig. 6(c) and Fig. 6(a), indicated by a black square.

V. Conclusion

In this work we propose a new model to support navigation in indoor environments for the visually impaired persons. It is still in development, but the initial results are promising. It already provides a good detection of vertical and inclined tactile paving surfaces of the two types of patterns, with low cost and minor user intervention, keeping his hands free. In this work, computer vision algorithms are combined with machine learning techniques to provide information to the user. The images used for processing can be acquired through a smartphone, attached to the body of the user.

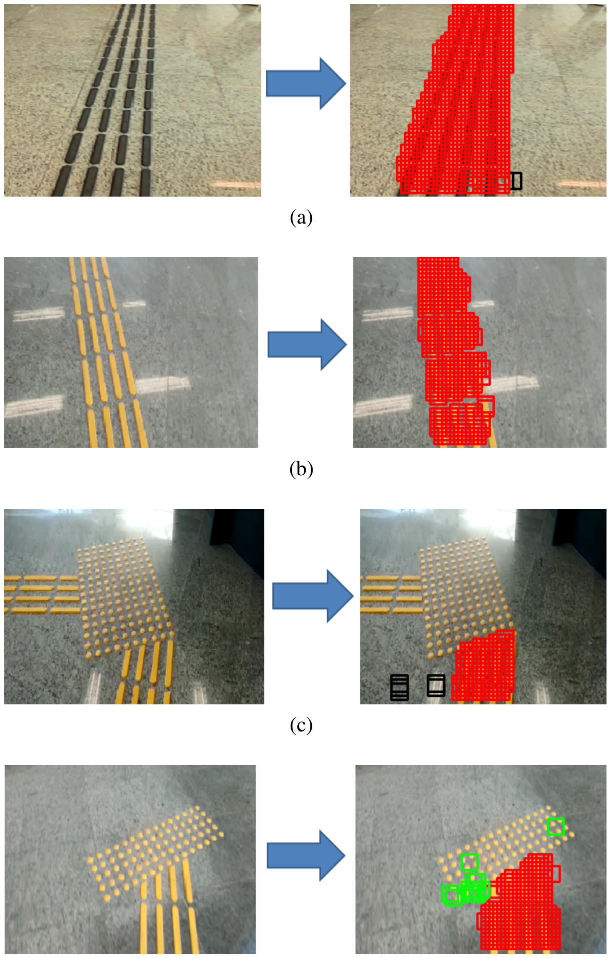


Fig. 6. Initial results.

Our Ground Truth still has a few samples, and we still need to add more samples to improve the results, eliminating some false positives and negatives, adding more horizontal tactile paving surfaces, and adding another SVM to train the algorithm to recognize warning tactile surfaces. For future work we intend to add these features, study techniques to increase the performance of the algorithms (if needed), integrate this work with the already developed model from Ghilardi master thesis[9] and, finally, explore ways to adapt the algorithms to run on smartphones[4].

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