A DEEP LEARNING AUTOMATIC TACTILE PAVEMENT DETECTION SYSTEM FOR THE VISUALLY-IMPAIRED

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1. Introduction

In 2020, it was estimated by the World Health Organization(WHO) that approximately one billion suffer from near or distance vision impairment[1]. This vision impairment and blindness are mainly caused by uncorrected refractive errors and cataracts.

These visually impaired individuals struggle to navigate their environments. Therefore, they find themselves at the mercy of family, friends, or strangers. The advent of the guide canes offered some relief to these individuals as they at least could find their way around familiar environments with very little assistance.

In metropolitan cities such as Istanbul, London, etc, tactile pavements can easily be found in places such as metro stations, bus stations, parks, and highly visited places. These pavements serve as a warning and directional tool to help visually impaired individuals avoid obstructions or hazardous situations. This advancement made it easier for visually impaired individuals to maneuver their way around the city with less effort using guide canes.

However, despite all these efforts, these individuals still find it extremely difficult to walk with freedom and explore the world without assistance from people. One of the biggest problems that these individuals face is to locate tactile pavements around them.

It is impossible for them to tell if a tactile pavement is present or not in their immediate surrounding. In addition, they can't tell what type of tactile pavement it is. They have no clue in what parts of the cities they can find these pavements.

The objective of this project is to design an intelligent system that addressing these problems by harnessing the power of sophisticated state-of-the-art image processing and artificial intelligence algorithms, coupled with advanced digital smartphone technology. This system will be able to detect and classify tactile pavements. Provide navigation information through voice commands to direct the user to the detected tactile pavement. This will potentially give visually impaired individuals the ultimate independence and freedom of movement.

2. Literature Review of Current State of Technology.

The problem of visual impairment has been around for a long time and a series of research has been conducted to develop assistive tools that can help these individuals find their way around in both indoor and outdoor environments. Wise E et al [2] developed an Infrared Data Association (IrDa) technology that functions as a detector to guide visually impaired individuals in indoor environments.

Xu Jie et al [3] developed a portable Electronic Travel Aid(ETA) technology that uses image segmentation, image edge detection, and blind sidewalk edge searching to divide the blind sidewalk from the pavement and feed the information of the blind sidewalk orientation to the user in real-time. In [4], Daniel C et al applied image processing techniques such as filtering and texture extraction to segment and identify tactile pavements.

Ito Yuki et al[5] build a system that detects Tactile pavements in images by converting these images from RGB color space to HSV. Marcelo C et al[6] proposed an approach that uses computer vision algorithms combined with decision tree algorithms to automatically detect tactile pavings. Anur Bin et al[7] developed a tactile pavement detection system that used MATLAB including the Arduino platform and speaker as guidance tools for easy navigation and guidance of visually impaired persons.

Other related work directed towards developing navigation assistive tools for the visually impaired can be found in the literature at [8][9][10][11].

3. Novelty of Tactile Pavement Detection System

Based on the research carried out in the literature, researchers have diligently worked on developing indoor and outdoor navigation assistive tools for the visually impaired. Given that the problem domain of this work focuses on designing an outdoor navigation system, I shifted my attention to analyze only the existing outdoor research done by previous researchers.

Some researchers relied on incorporating GPS technology into their systems. However, GPS suffers from the problem of accuracy. The accuracy of GPS is even made dire when used near tall buildings. This is because the error in measurement can be catastrophic as it can drive a user to the middle of the road.

Other outdoor systems that have implemented image processing algorithms acquired reasonable results. However, traditional image processing techniques such as lighting conditions, partial occlusions, etc. Some previous researchers designed navigation systems that used machine learning algorithms to detect tactile pavement. Unfortunately, these algorithms rely deeply on hand-engineered features. These features are time-consuming, brittle, and not scalable in practice.

In this research project, we design a detection system that harnesses the power of automatic extraction of low, mid, and high-level features using deep convolutional neural network algorithms to accurately detect tactile pavements on the surrounding environments of visually impaired individuals.

With the advent of state-of-the-art deep learning algorithms that is fueled by the availability of computationally powerful CPUs and GPUs, we are capable of designing highly efficient cutting edge detection and navigation system that uses very minimal resources but yet achieves remarkable results.

By comparing several deep convolutional neural network models, we will deploy the best model into the smartphones of the visually impaired individuals that can then be used for real-time automatic detection of tactile pavements in their immediate environmental surroundings.

This project has the advantage of not requiring external independent systems for its implementation but rather leverages the already existing mobile technology.

Based on the high detection accuracy of state-of-the-art deep learning detection algorithms that are invariant to changes such as rotation, lightning, etc, there's a high probability of obtaining prediction accuracies higher than those in the literature. The project is highly scalable as it involves using only the mobile phone as the main device.

We don't aim to eliminate the use of guided canes, rather our objective is to provide a tool that can help visually impaired individuals locate any tactile pavements in their environment for which they can then find their way to their destination using their guided canes.

4. Implementation of Idea.

In order to implement the novel detection navigation system to aid the visually impaired, we partition it into 3 main phases.

4.1. Dataset Acquisition and Preprocessing.

To train the models for the detection system we need to collect hundreds of training images of the tactile pavements. Figure 1 shows the different types of blister and directional pavements.

The next step is to preprocess the images using Image preprocessing techniques such as cropping, grayscaling, and filtering. This will increase the computational efficiency of the model.

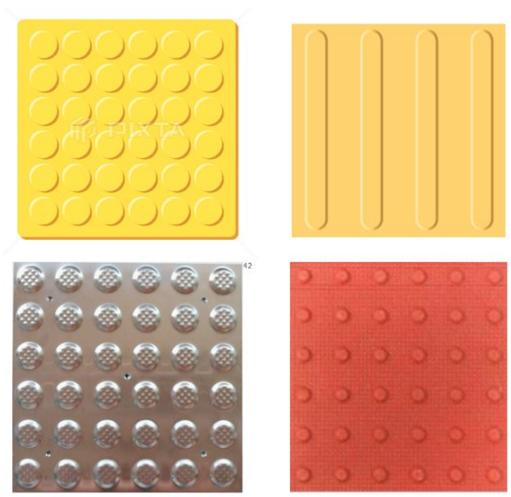

Figure: Sample of different types of tactile pavements necessary for model training.

4.2. Model Training and Tactile Pavement Detection

After preprocessing we will train the models using different state-of-the-art deep learning model architectures. Some of the model architectures to be trained include VGG-19[12], Resnet50[13], DenseNet[14], Alexnet[15], and MobileNet-V2[16].

Our choice of the best model will be based on detection accuracy and also computational efficiency. This is because the model will be deployed on mobile devices with low computational power.

Based on preliminary research I’ve conducted, mobileNetV2 seems to be the best candidate model to consider due to its small model size and high accuracy.

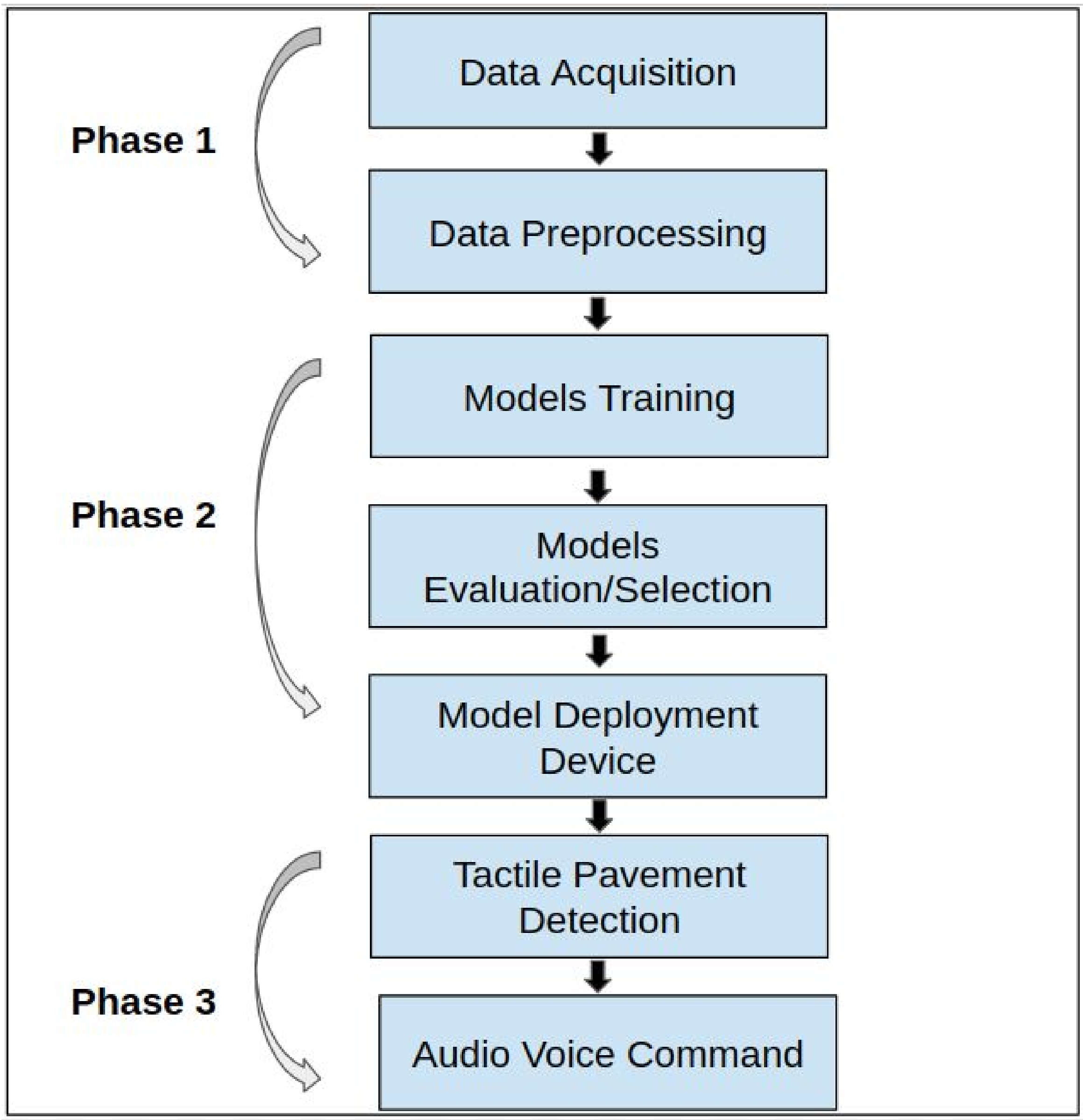

Figure 2: Flow Chart Design of the Deep Learning Automatic Tactile Pavement Detection System.

4.3. Direction and Voice command.

This module of the detection system will play a vital in the functioning of the detection system. When a tactile pavement is detected we need a technique to communicate this information back to the user, The information communicated to the user includes the type of tactile pavement detected, the distance between the user, and the tactile pavement. Finally, by leveraging the GPS guiding system of the mobile phone, we can guide the visually impaired individual towards the detected pavement with high precision. This will be accomplished by developing an independent mobile application that runs the model and also converts the detections to voice commands that can then be used to direct the individual.

The system design is shown in Figure 2 above.

5. Expected Impact on Society.

The one billion people in the world that suffer from vision impairment according to WHO, paints a clear picture of the earth-shattering impact this simple yet sophisticated deep learning-based tactile pavement detection system technology can have on the lives of these individuals.

This system will permit visually impaired individuals especially in the big metropolitan cities where tactile pavements are present to easily detect tactile pavements around them. Therefore, they'll be able to walk with more freedom and confidence.

This system will uplift the burden that these individuals have on their families and on society as a whole. They will not require assistance from anyone to find tactile pavements in their immediate surroundings.

The core of the system is mobile devices that are widely available, hence, the model can be easily deployed to serve millions of people around the world. It is highly scalable.

Its simplicity will mean that it will require very little training time for visually impaired individuals to learn and start using the system. This is contrary to other existing assistive tools such as Braille that requires a long training time for new visually impaired individuals to get familiar with.

This system is versatile and highly adaptable. It can be modified easily for use in indoor scenarios to help these individuals locate other items in their homes using only their mobile phones.

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