ECE4871 – Culminating Design Project

Evaluation Form – Technical Background Review

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_______ / 30 Technical Content

- Current state-of-the-art and commercial products
- Underlying technology
- Implementation of the technology
- Overall quality of the technical summary

_______ / 30 Use of Technical Reference Sources

- Appropriate number of sources (at least six)
- Sufficient number of source types (at least four)
- Quality of the sources
- Appropriate citations in body of text
- Reference list in proper format

_______ / 40 Effectiveness of Writing, Organization, and Development of Content

- Introductory paragraph
- Clear flow of information
- Organization
- Grammar, spelling, punctuation
- Style, readability, audience appropriateness, conformance to standards

_______ / 100 Total - Technical Review Paper

Technologies for Live People Counting Systems

Introduction

COVID-19 has tremendously altered the state of public transportation: regulations regarding the population density in confined spaces such as buses are placed globally. With now decreased vehicle capacity and fluctuating demand, it is crucial for transportation authorities to wisely plan the deployment of vehicles for better profitability, efficiency, and service. With the aid of a people counting system that illustrates changes to the number of passengers throughout bus routes, transportation authorities can make their decisions on a quantitative basis. This paper reviews the state-of-the-art technologies and commercially available products for people counting systems.

Technologies of People Counting Systems

Our project requires a people counting system that is low-cost, widely applicable, and needs minimal modifications to existing hardware. Therefore, only a portion of commercially available people counting systems are suitable for our project. For instance, a ticket-based counting system cannot track people getting off the bus if the fare is unified regardless of distance traveled. In summary, there are two types of technologies that suit our project: motion sensors and video-based pattern recognition [1].

Passive Infrared (PIR) sensor is a low-cost member of the motion sensor family. It utilizes the fact that humans emit heat in form of infrared radiation. Therefore, the movement of a human body can be translated to an above ambient infrared source. A PIR sensor consists of a pyroelectric sensor, usually in the shape of a rectangle, and a lens. A pyroelectric is a device that, when introduced to infrared radiation, accumulates charges on its surface [1]. The change in surface charges is amplified through an amplifier such as an operational amplifier (OpAmp) and a Field Effect Transistor (FET) to notable voltages differences. To avoid false positives caused by light sources, temperature changes, etc., a sensor is divided into two sensing elements. They are arranged in a special way such that, as a human body passes by the pyroelectric sensor, the output analog signal will appear as a positive pulse followed by a negative pulse [2]. Signal processing circuitry will detect this pattern and output a logical high through the output pin. The lens focuses the incoming IR signals onto the sensor to widen the detection range.

Video-based pattern recognition is an application of artificial intelligence. A successful design of video-based people counting systems usually includes two models: one for identifying moving objects from a stationary background, and another for confirming that the moving objects are indeed humans [4]. The latter is required to prevent false positives, for example, passengers' accessories. There are two methods of data processing associated with video-based human recognition. About data processing, the video can either be processed locally on buses using specialized hardware and only a live people count will be sent to the cloud, or the raw video can be sent to a data processing center where computation power is more abundant. These two methods differ in the resource allocated between buses and the data center. This technology is most effective for buses with security cameras already installed, as the data processing requires minimal changes to existing hardware. But such video-based technology may raise privacy concerns among the public, which will impede deployments.

Commercial Products of People Counting Systems

A popular commercial PIR sensor, HC-SR501, is a highly-integrated module at $2 per unit. It accepts DC voltage input from 5V to 20V and can detect motions inside a 120-degree cone within seven meters [5]. The accuracy of PIR sensors will vary depending on the placements of sensors and post-data processing.

For video-based people counting systems, Beijing Transport offers a mature solution that ultimately visualizes the crowdedness of buses on their mobile app. They take advantage of existing installations of surveillance cameras on ceilings of subway stations and buses. Using a model written in a open-source computer vision library, OpenCV, Beijing Transport's solution has an average accuracy of 86% and can process videos at 16 fps at a 1280x720 resolution on a 3.2 GHz CPU with 8GB of RAM [6]. However, it is hard to estimate the cost of such systems because it depends on the difficulty of integration with existing hardware.

Implementation of a PIR-based People Counting System into Our Project

For our project, we believe using PIR sensors is the most effective choice among the technologies discussed above. Its low per-unit cost makes mass deployments across the entire bus fleet viable and it does not raise privacy concerns among passengers.

The integration of the PIR sensor onto buses must carefully consider the arrangement of sensors. We propose the PIR sensors to be installed on the bus door, approximately at the height of adults' chests when first stepping on the bus. With this arrangement, the sensor will approximately face passing by people's shoulder when the doors are open and should not be confused with the overlap of body parts, such as legs. If pursuing higher accuracy, we can install more sensors on the opposing door or surface and increase or decrease people count when all sensors yield matching results. Moreover, with the placement of two or more PIR sensors in an array, we can use the time difference between sensors to identify the direction of people's movements, making this design applicable to buses whose doors are used for both getting on and off.

References

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