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Path Guardian

Adaptive Pedestrian Monitoring and Traffic Signal Control in Noisy Environments Using Collaborative Human-Automation Tracking

Abstract

This paper presents a new traffic management system that actively monitors pedestrian crossings and regulates traffic signals using a system employing automated detection and occasional human oversight. This system integrates methods of two key patents: (1) *Collaborative human-automation tracking of targets in live video*, and (2) *Fixed and moving object detection and tracking for noisy environments*. By combining object tracking and noise filtering, this proposed framework enables additional applications, allowing for real-time pedestrian counting and integration with existing traffic cameras for use in collisions (pedestrian-vehicle or vehicle-vehicle). This system can enhance the safety, accuracy and adaptability of traditional pedestrian crossings in urban, suburban, and rural environments.

1. Introduction

When taking into consideration safety on public roads, safety is of utmost importance. However, pedestrian solutions are often half-baked, lacking features that could make crossings safer and incentivise walkers to cross at designated locations. As traffic increases and roads widen, the importance of prioritizing people on the streets only becomes more important. Indeed, accidents involving pedestrians are on the rise. According to The Governors Highway Safety Association, traffic fatalities involving pedestrians have increased

4.6 percentage points from 2010 to 2021 (1) . Ensuring safety and efficiency requires a smarter system than fixed-timer traffic lights and traditional motion sensors. To this end, we introduce a comprehensive vision-based platform capable of:

- Adaptive traffic signal regulation
- Accurate pedestrian tracking and counting
- Early detection of potential pedestrian-vehicle collisions

2. Background and Related Work

2.1 Collaborative Human-Automation Tracking

The United States Navy patent *US 11,356,599, B2* allows for real-time object tracking, fusing spatial, motion and trajectory information while presenting confidence scores to human testers. This allows operators to seamlessly assume control when the system is unsure about a specific object's identity.

2.2 Detection and Tracking in Noisy Environments

US 11,138,442 B2 from Motorola Systems provides a method for tracking moving and fixed objects in high-noise scenarios with dynamic background modeling, contour-based segmentation and adaptive thresholding. These features allow this patent to be easily adapted to a complex pedestrianized environment and various harsh weather conditions.

3. System Architecture

3.1 Sensor Configuration

High resolution night-vision cameras will be placed on poles at opposite corners of an intersection with proper visual sight over the entire intersection

3.2 Object Detection and Noise Filtering

- Background modeling using per-pixel Gaussian mixtures
- Motion detection via high-pass filtering and frame differencing
- Contour extraction and supervised classification to label pedestrians, vehicles, or background noise

3.3 Multi-Modal Object Tracking and Confidence

Each object is tracked using:

- Spatial appearance features
- Motion vectors and acceleration
- Trajectory prediction

Confidence scores will be calculated through the system based on how similar an object looks to one of the pre-programmed items.

4. Core Applications

4.1 Adaptive Traffic Signal Control

When the system believes that there are people present at the intersection waiting to cross, it will send a signal to the traffic control system to allow for pedestrians to cross the intersection. The number of pedestrians required to trigger the system will be set to match each intersection's car and human traffic levels. If needed, a human operator can manually trigger the system. Functional Demo Here.

4.2 Pedestrian and Vehicle Counting

The system will count the quantity of human and vehicle traffic while providing the service specified in

section 4.1. These counts can then be utilized to determine areas of improvement, predict future traffic or analyze historic trends. Functional Demo Here.

This counting system will be aided by the technology mentioned in the patent from section 2.1. This patent's feature matching technology will allow each individual person to be tracked, regardless of obstructions, while also preventing double counting.

4.3 Pedestrian-Vehicle Collision Detection and Prevention

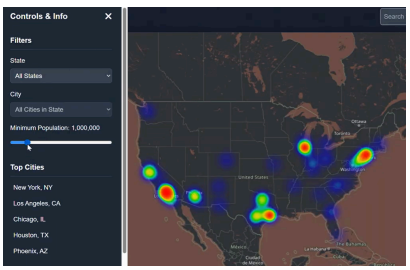
This model will constantly track the trajectory and identity of every object within its viewpoints and therefore can determine when and where a crash may occur and send an alert to emergency responders. This will make participating intersections safer by allowing victims to receive care far quicker than if the accident occurred in an unmonitored location. If it is determined that a collision did occur, the video feed from the collision will be stored in a database for use by law enforcement.

5. Revenue Streams

5.1 Traffic Control Systems

This aspect of Path Guardian is the main purpose of the system. Included in the direct purchase are two high-definition and night-vision capable cameras, two weatherproof control modules, and the installation fee. The cloud based service will be provided for a separate monthly fee.

5.2 Pedestrian Statistics



This function enables city planners or other professionals to access the statistics database through a "heat map" representing pedestrian traffic over a set time period for a

monthly fee. Those interested can also purchase the raw data of pedestrian, vehicle, and collision counts for a set rate. Functional Demo Here.

5.3 Licensing Software

The detection software, which is tuned to detect humans, vehicles, and collisions in traffic conditions, can be sold or licensed to third parties for personal or commercial use.

6. Cost Breakdown

6.1 Traffic Control Systems

The cost for this aspect of the system consists of: $500 for two weatherproofed and reinforced computer modules, $100 for two night-vision cameras, $500 for installation, $1200/year service costs. The total cost is estimated to be $1100 with $1200/year service fees.

6.2 Pedestrian Statistics

The subscription to the heatmap system will cost $30/month while the individual intersection statistics will cost $10/intersection/week.

6.3 Licensing Software

The cost of the human detection software utilized by Path Guardian will be determined once a stable release of the system is produced and design costs can be totaled.

7. Privacy and Safety Concerns

This cloud-based system with cameras placed throughout cities causes several safety concerns including hacked systems, computer errors, and stalking.

7.1 Hacking

This system will be well secured and encrypted with keys generated using the traffic patterns monitored. Simultaneously, we will employ strong user certification while closely monitoring all logins. Next we will release regular updates and security patches to prevent any nefarious actions against our systems and the people we protect. Lastly, we will reinforce the shell of our onsite computer module, preventing any physical interception or tampering of signals.

7.2 Computer Errors

This is a valid concern and will be addressed with the seriousness it deserves. Firstly, we will employ strong testing procedures along our product line and throughout the software design process. Next, we will employ a zero tolerance policy for cost and corner cutting. Finally we will regularly inspect the work of our installation technicians while heavily training new technicians.

7.3 Stalking and Camera Misuse

While our system will be well secured and free from almost all weak points, there is still the chance that an employee of the company will misuse the live camera feeds to monitor or stalk a person. We will prevent this by only allowing specific, certified workers to access live feeds. If requested, cities can request access to their traffic camera feeds for public use.

8. Extended Applications

8.1 Search and Rescue

Path Guardian object detection extends far beyond intersections. In the event of a missing person situation this model can help detect where the person is. Through the use of human tracking, the model can find a missing person in roads, forests, or even fallen rubble. This model can save rescuer’s resources by helping search and rescue teams pinpoint the exact location of a person from a small area. This system can help first responders in areas

inaccessible to humans. Despite this model being designed for only urban environments, it can still be of some use in other areas once properly adapted and trained.

8.2 Addition to Existing Mapping Systems

Inclusion of Path Guardians to public mapping systems can help present detailed information on pedestrian and vehicle movements to users. The data Path Guardian already stores can be sent to third-party mapping services. By using the existing mapping API keys, the model can help delivery services and public transportation by reducing time stuck in traffic for both people and cars. Based on the current plan for Path Guardian, integration into an existing mapping system will be difficult and will require significant effort and time.

9. Conclusion

By including *US 11,138,442 B2 and US 11,356,599, B2,* Path Guardian has the ability to prevent unnecessary pedestrian casualties in an ever worsening traffic safety situation where thousands of pedestrians lose their lives each year to drivers on the road and tens of thousands are injured. By implementing object tracking into pedestrian crossings, it is possible to reduce these unnecessary injuries and fatalities significantly. By using cameras instead of traditional push-to-cross systems, human error can be reduced. Furthermore, since the cameras can capture many different aspects of traffic, it can be programmed to act in response to accidents where emergency services are necessary. Reaching beyond this application, this technology can be used for a variety of purposes including search and rescue and data collection for the improvement of navigation technologies. Addressing privacy and safety concerns is up to clients to determine at their discretion, but all feeds and data will be encrypted as it is transferred across the web.

Overall, Path Guardian is a system that will be able to better address the growing pedestrian safety issue while maintaining a high standard of quality and safety.

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