Automated Traffic Regulation using Radio Frequency Identification and Geo-Fencing

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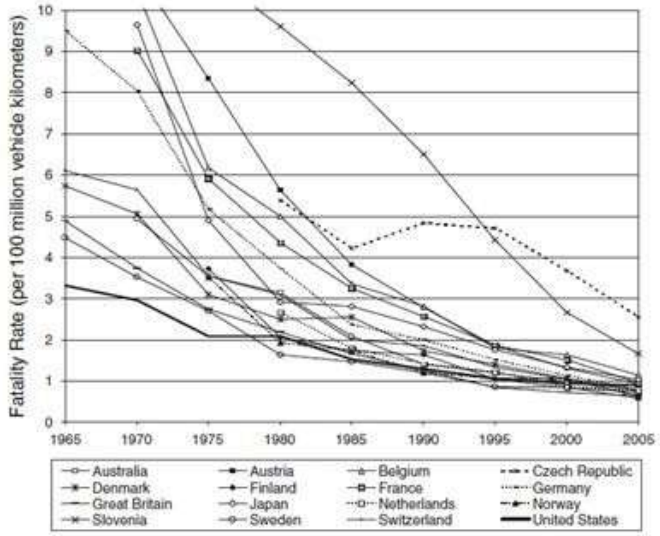
Abstract - *Rampant road accidents are among the most precarious problems in the world that demand a prompt resolution. They have not only ended up taking millions of lives each year, but have also cost governments a significant portion of their GDP. Elimination of elements that lead to this menace is a process that is highly critical. The purpose of this study was to peruse and scrutinize the current situation and traffic signal regulation mechanisms by taking up multiple case studies across the globe. To prevent such unfathomable consequences, this paper aims to propose a signal violation detection system which can appreciably alleviate the magnitude of such cases. It does so by making use of relatively newer technology models, primarily Radio Frequency Identification (RFID) and geo-fencing mechanisms.*

Key Words: Road Safety, Traffic Signal Violations, Traffic Regulation Mechanisms, Automated Enforcement, Radio Frequency Identification (RFID), Geo-fencing,

1. INTRODUCTION

Worldwide, road traffic injuries claim more than 1.2 million lives each year and is amidst the leading causes of death among young people. It is estimated that road traffic injuries cost governments approximately 3% of their GDP, and up to 5% in low and middle income countries. Without action, annual road traffic deaths are predicted to increase to around 1.9 million by 2030 and become the seventh leading cause of death.

To solve the alarming problem and prevent such unfathomable consequences, signal violation detection systems are needed. The requirement is a system that enforces traffic laws at all times, and apprehends those who do not comply. Such a signal violation detection system must be realized in real-time (since authorities track roads at all times). Hence, traffic enforcers will be better equipped to implement road safety laws, since the automated system detects violations faster and more efficiently than humans.



Fatality rates per vehicle kilometer, selected high-income countries, 1965–2005. (Source: OECD n.d.; OECD and International Transport Forum 2010.)

2. PROVISIONING

The experience of benchmark nations indicates that the successful national programs function effectively at two levels of activity:

> Management and planning: Transportation, public safety, and public health administrators systematically measure progress toward quantitative objectives, direct resources to the most cost-effective uses, and communicate with the public and elected officials to maintain support.

> Technical implementation of specific countermeasures: A multitudinous array of measures is engaged for regulating driver behavior, cultivating effective emergency response, and securing safe design and maintenance of roads. The techniques are generally of proven high effectiveness and are comprehensively applied. Regular analysis and monitoring to identify problems, and measuring progress toward goals can be made use of to determine the effectiveness of the implemented operations. Monitoring allows feedback that can be used to reinforce the accountability of program managers.

3. CURRENT NATIONAL STRATEGIES AND DRAWBACKS

Countries like the United Kingdom, Sweden, France, United States and India have progressively strengthened their laws in the past few years and have established policies to reduce fatalities by intensified law enforcement relying especially on automated speed administration coordinated with public communication and marketing campaigns. In the United Kingdom, NGOs were instrumental in initiating the New Car Assessment Program (NCAP) and the Road Assessment Program (RAP) in the 1990s. These programs rate vehicles and roadway segments for safety and publicize the ratings. The initiatives are generally centrally planned and administered; a central facility monitors the nationwide network of automatic speed cameras, issues citations, and collects fines. It is supplemented by central data collection and analysis to guide management and measure results. However, there are multiple drawbacks associated with the same:

A. Traffic cameras violate privacy and a citizen’s right to face his/her accuser. Traffic cameras photograph people without their knowledge and are a clear violation, for instance, of Article 21 in Maryland’s Declaration of Rights because they violate your right to face your accuser. Furthermore, according to the ACLU, traffic cameras violate privacy rights and can be abused. They believe that any implementation of “a system that leads to widespread installation of cameras throughout [a] state cannot be ignored or minimized. Further desensitization of privacy rights is inevitable, and the data collected by these cameras will [eventually] be used for purposes other than tracking reckless drivers.”

B. Traffic cameras often do not work correctly. The camera and recording system may not be maintained properly. For instance, laws of most countries require cameras to be checked daily but they are often not.

C. The person driving the car may not be the owner of the car. The driver is not positively identified by the camera, so the default is to charge the vehicle's registered owner with the violation. The owner, who may not have been the driver, is presumed guilty. A bedrock principle of justice systems all over the world—a defendant is innocent until proven guilty—is unceremoniously discredited.

D. According to the US Federal Highway Administration, the data on automated enforcement systems has not proven that cameras are effective. An investigative report by the Washington Post has shown accident rates increasing by double-digit percentages after the introduction of cameras. According to a US News report, governments are implementing traffic cameras to generate revenue, not to protect drivers. Red-light cameras are a money-making enterprise for the cities that deploy them and for the camera vendors that build their business profitability around the ticketing machines.

4. TECHNOLOGY

4.1 Radio Frequency Identification

Radio-frequency identification (RFID) refers to the wireless non-contact use of radio-frequency electromagnetic fields to transfer data, for the purposes of automatically identifying and tracking tags attached to objects.

The Ultra-High Frequency (UHF) RFID technology encodes a digital signature on a small microchip attached to a copper foil antenna. This tag receives energy from UHF radio waves transmitted by an RFID reader; harvests this incoming radiofrequency energy to transmit its encoded digital signature back to the reader. These RFID tags, although small, can be read several yards away from the reader's antenna.

The RFID reader is a device responsible for communicating with tags. Generating and receiving waves is possible due to the integrated antennas that detect tags in their range, decode them and write to them. The idea of the object identification process is to send a radio wave via the reader’s antenna and await a response from the encountered tags. The antenna then generates a varying electromagnetic (EM) wave which induces voltage powering tags’ circuits. The transponder responds by modulating the EM field induced by its coil, sending out the data it contains, which is picked up by the same antenna.

4.2 Geo-fencing

Geo-fencing is a feature in a software program that is used to define geographical boundaries. A geo-fence is a virtual barrier, whose tools monitor when mobile devices or other physical objects enter or exit an established geo-fenced area and provide administrators with notifications every time there is a change in status for a device.

Geo-fencing combines awareness of the user's current location with that of the user's proximity to locations of interest. To mark a precise location and adjust the proximity for the location, the latitude and longitude define a geo-fence at the location of interest.

The Geo-contextual trigger is a function of:

Location Accuracy – The device location must be correctly determined relative to a geo-fence.

Tracking Rate – The cadence by which the device provides a location update to the server, a location is calculated, where the device is evaluated against eligible events (with associated actions).

Device Speed – The speed of a device determines the time period within which the device must provide a location update to be evaluated against eligible events (with associated actions).

Device Route – The path a device takes across a geo-fenced area which affects the time period within which location update must occur.

Geo-fence Size – A larger geo-fence provides a longer period for a location update, unless the device track skirts the edge of the geo-fence.

5. PROTOTYPE SPECIFICATIONS

The prototype we modeled and employed an Arduino ATmega328P microcontroller, which is a high performance, low power controller from Microchip. It is an 8-bit microcontroller based on AVR RISC architecture. We also make use of a RC522 Passive UHF RFID Reader with a range of 10cm which logs the data from the tags in a database. Apart from being real time, this system also makes use of a user-friendly graphical interface associated with the system to make it simple for the user to operate the system, monitor traffic and take action against the traffic law violation.

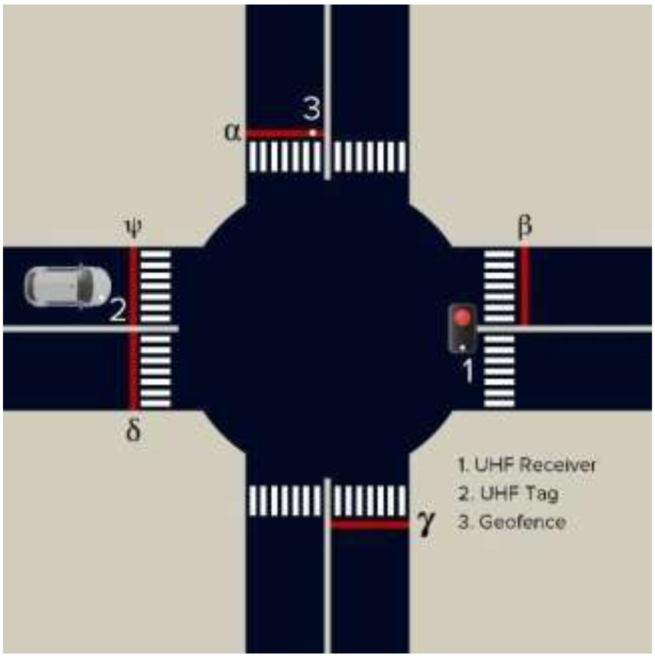
6. PROOF OF CONCEPT

In this study, we deploy a conventional active UHF RFID system - which provides us with a frequency from 300MHz to 3 GHz and a large read range - up to 100 meters.

The RFID tag will act as a beacon, transmitting its location every two seconds when it is in the range of the RFID reader. The UHF RFID tags will be embedded in the license plate of the vehicle and will contain all information about the vehicle and its owner. The antenna is installed onto the traffic signal and a two-dimensional mapping of vehicles near the intersection gets automatically set up.

A separate program to filter out the data from the database for each configuration of the traffic signals at the intersection will be set up. Upon the violation of the geo-fences, the antenna automatically appends all details stored in the tag into a federal database, which can be constantly monitored and regulated by a traffic police agent. A single antenna will have the capacity to handle information from multiple vehicles that are within its range.

Through the due course of this study, let us presume that the vehicle is present at any location at a given crossing. From here, there are four possibilities in which the car can move: turning left, moving straight, turning right, or making a U-turn. As part of our system, a geo-fence gets activated on all paths in the crossing automatically.

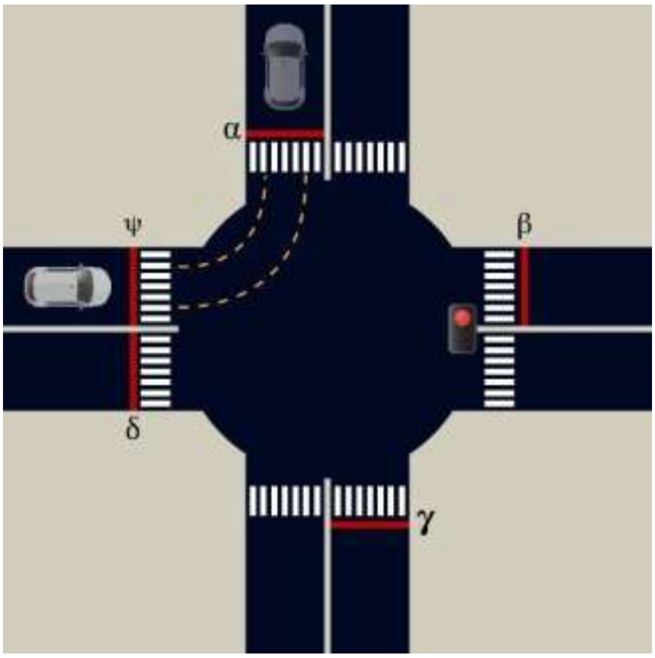


To move in any of these four directions, the car must first cross the geo-fence to leave the segment of the road that it is present in. We call this the primary geo-fence and label it as an arbitrary variable $\boldsymbol{\psi}$.

Let us further assume that the other geo-fences that are part of the crossing for turning left, moving straight, turning right and making a U-turn are assigned variables $\boldsymbol{\alpha}, \boldsymbol{\beta}, \boldsymbol{\gamma}, \boldsymbol{\delta}$ respectively.

We shall now study all the four cases in detail.

Case 1: Left Turn

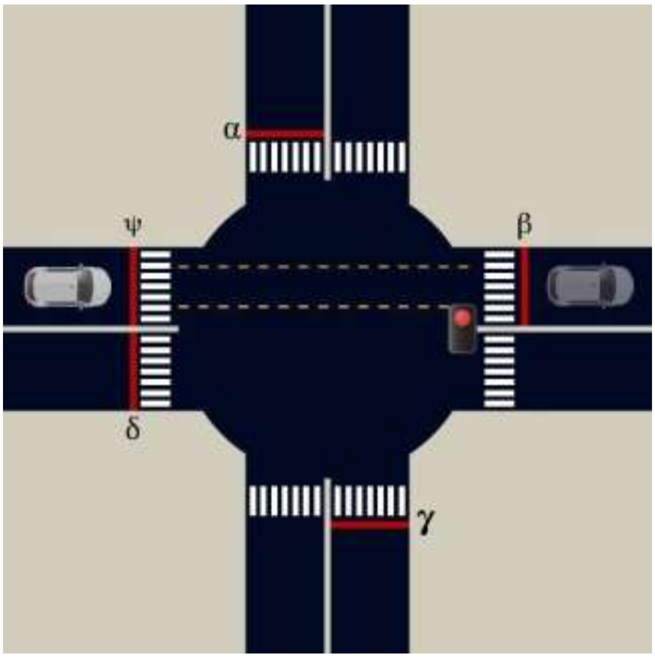


While taking a left turn, the vehicle crosses the primary geo-fence (ψ), followed by the left geo-fence (α). In such a scenario, the vehicle tag gets assigned a value $\psi\alpha$.

Now, the tag is charged depending on the status of the pedestrian traffic signal at the time of violation.

If the pedestrian traffic signal is green, then any tag with value $\psi\alpha$ gets added to the federal database instantaneously. However, if the pedestrian signal is red (ergo a free left turn scenario), then the record gets discredited from the database.

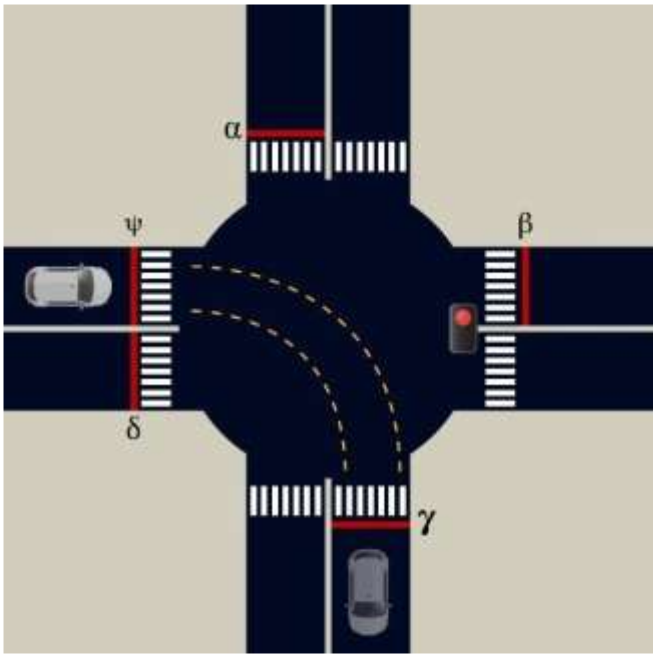
Case 2: Moving Straight



While going straight, the car crosses the primary geo-fence (ψ) and the straight geo-fence (β). In this scenario, it automatically gets assigned the value $\psi\beta$. If the vehicle registers a $\psi\beta$ when the light is red, it gets added to the federal database, from where an officer can consistently keep an eye on the system.

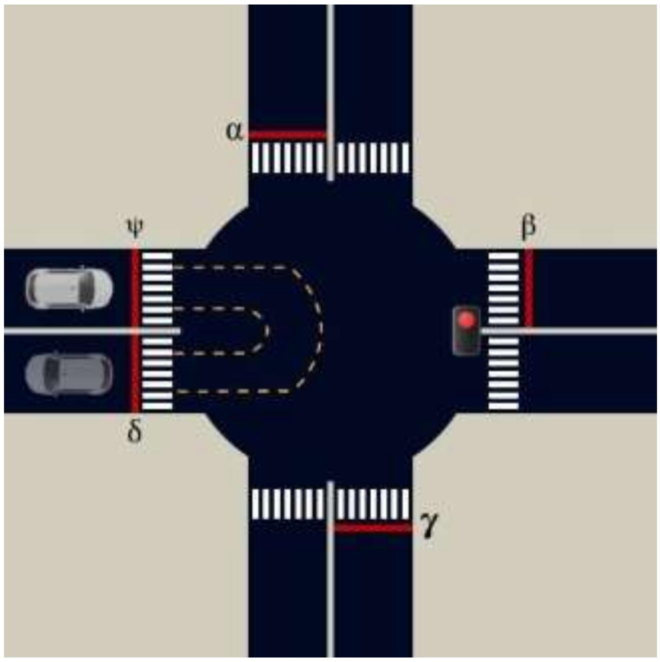
Case 3: Right Turn

While taking a right turn, the car crosses the primary geo-fence (ψ) and the right geo-fence (γ). In this scenario, it automatically gets assigned the value $\psi\gamma$. Similar to Case 2, if the vehicle crosses the intersection when the light is red, the tag ID gets added to the database. If the light is green, the entire record gets neglected.



Case 4: U-Turn

While taking a U-turn, the primary difference is that the tag is interlinked to both the pedestrian crossing and the traffic signal. The car crosses the primary geo-fence (ψ) and the U-turn geo-fence (δ). In this scenario, it automatically gets assigned the value $\psi\delta$. If the vehicle crosses either or both of the geo-fences when the light is red, the tag ID gets added to the federal database.



7. FEATURES OF INTEREST

The proposed solution can also be integrated with current Closed-circuit television (CCTV) implementations to filter out data from the footage which can be put to use if the violator wishes to dispute the ticket.

Emergency vehicles. including ambulances, police vehicles and fire trucks will have special tags and will be added to an alternative database which can be regulated if the vehicles' special status are being misused.

Depending on the length and density of traffic in the intersection, the tag will reset periodically to reduce the load on the system and the vehicle can be ticketed for obstruction of traffic if only a single variable is registered (?), based on the speed limits in the given locality.

A similar traffic management mechanism can be adopted for countries where vehicles are driven on the right side of the road.

8. SCALABILITY

This mechanism is easily scalable since the geo-fencing values can be adjusted, factoring in the size of the intersection. Apart from the current CCTV integration in case of ticket disputes, the proposed solution can also be integrated with Light Detection and Ranging (LiDAR) technology to detect speed violations and can be used to send the footage of the violation directly to the owner of the vehicle via a 5G network. Furthermore, this system calls for negligible maintenance, which is not the case when we take into account the current road safety measures like CCTV cameras.

9. CONCLUSION

Through the means of this paper, we have accomplished the thorough scrutiny and comprehension of the current traffic signal management mechanisms that are being implemented. The disadvantages and advantages of the current and proposed systems have been underscored and the convoluted functioning of the active UHF RFID and geo-fencing techniques has been exemplified. The paper further went on to put forth an alternative system to automate the regulation of traffic signal violations by reducing human error, which is broken down into case studies in order to shed light on the intricacies and benefits of the proposal.

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