GPS Projectile Vehicle Tracking System

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Abstract—**This project aims to create an effective and cost-efficient Projectile Vehicle Tracking System, to be used by police to track suspect vehicles. It can transmit accurate real-time location information and can be thrown onto the suspect vehicle. Android applications were programmed and GPS location information was transmitted via SMS. A suitable casing was designed to enable being thrown on the suspect vehicle. Rare Earth Magnets were used to attach the Tracking Device onto the car so that they do not interfere with GPS signals. The casing with magnet design has an average success rate of 90% on various surfaces. The location coordinates sent by the Tracking Device are accurate and their corresponding multiple pins are successfully reflected on Google Maps at the Control Device held by the user. The system starting overhead is approximately 1 minute 34 seconds to show the efficiency of our designed Android applications. The optimum interval between SMSs is tested and can be set as 10 seconds as a recommended interval.**

Keywords-Projectile Function; Vehicle Tracking System, GPS

I. INTRODUCTION

In the recent years, there has been a rise in the number of traffic violations and illegal entrants speeding through roadblocks. In 2002, there were 700 car chases within Los Angeles, yet not all were apprehended [1]. In Singapore, there was a rise of 15,085 speeding violations from 2012 to 2013 [2]. In 2014, two vehicles drove through security barriers at Woodlands Checkpoint, with one vehicle staying undetected for three days. An officer was injured in the incident too [3]. Hence, this project aims to propose an effective and cost-efficient method to track these vehicles and reduce the number of speeding violators, through the creation of a Projectile Vehicle Tracking System.

II. ENGINEERING GOALS OF RESEARCH

The engineering goal is to create an effective and cost-efficient GPS Projectile Vehicle Tracking System that can be used by police to track suspect vehicles and speeding violators. This system is expected to transmit accurate, real-time information regarding the target's location to the police. Also, it will come with a projectile function, enabling the police to manually throw the device onto a vehicle, should it be too fast for them to identify it. Upon completion of this project, it is hoped that the system is able to improve police efficiency and catch more speeding and suspect vehicles. This will tighten security at immigration checkpoints and act as a deterrent to offenders too.

III. SYSTEM PROGRAM DESIGN

A. Android Apllication

The Android Application was used as it can support many types of systems and programs. The Android Accessory Development Kit, Eclipse was used to develop and build a personalized mobile phone application. An Android phone and an Android tablet were used for the Tracking Device and the Control Device respectively.

B. Android Program for the Tracking Device

The Tracking Device, primarily used to obtain location coordinates of the vehicle and message them to the Control Device, is attached to the suspect vehicle. There are four modules involved in the Tracking Device system, namely the GPS Module, the Data Processing Module, the Setting Module and the GSM Module. The GPS Module first gets GPS information from satellites. The Data Processing Module converts this data into coordinates in the form of "longitude" and "latitude". Next, the Setting Module sets the four parameters required in this program: the Control Device's number; the Tracking Device's number; the time interval between each SMS, and Autotext. Lastly, the GSM Module sends and receives messages from the Tracking Device to the Control Device. After coding for the Tracking Device, the designed Android App was exported into the Android phone for use.

C. Android Program for the Control Device

The Control Device is the device (the Android tablet) held by the police. It is the device that starts the entire application, by sending a "Start" message to the Tracking Device. Once the application starts, the Tracking Device will begin sending coordinates to the Control Device. Once the message is received, the Google Maps Module at the Control Device will convert the coordinates received into a pin on Google Maps. After coding for the Control Device, the designed Android App was exported into the Control Device for use.

IV. EXTERIOR DESIGN OF TRACKING DEVICE

The exterior design of the Tracking Device is crucial for its projectile function to work. Hence, a series of experiments were conducted to create the most viable design.

A. Use of Magnets

Magnets were chosen to attach the Tracking Device to the vehicle, since the car exterior is made of ferromagnetic material. The magnets chosen for this project are Rare Earth Magnets (Neodymium Iron Boron), since they are inexpensive and have great magnetic strength.

B. Magnetic Interference with GPS Signals

Magnets were placed in three different positions (S1, S2, and S3) on the phone (Fig. 1) to test if the position of the magnets had an effect on GPS signals. A test was conducted for each position. The message interval was set to 1 minute. The Tracking Device was attached to the car before starting the application. The car drove along a route, and the interval between each coordinate received was recorded. After the test, it was observed that S3 had the most consistent message intervals, indicating that it resulted in the least GPS signal interference, due to the magnets being the furthest away from where GPS signals are received on the phone. Hence, in the subsequent designing of the exterior, the distance between the magnets and the GPS signal receiver was taken into consideration.

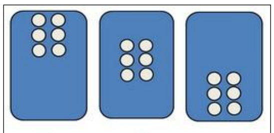


Figure 1. Positions of Magnets on the back of an Upright Device (the blue area represents the phone; the silver area represents the magnets)

C. External Properties of Tracking Device

For the Tracking Device to be easily thrown and attached to the car, it has to be able to withstand a large impact, adhere to curved and flat surfaces, and be light and easy to throw.

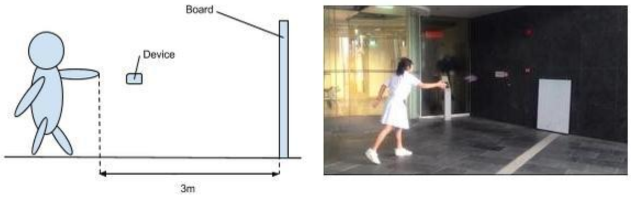
(a) A Styrofoam Sheet (b) Foam Pouch (Side view) (c) Foam Pouch with Magnets Placed in Balloon Attached

Figure 2. External Design for the Tracking Device

As the Tracking Device needs to withstand large impacts, the design in Fig. 2 was used. The phone was wrapped in Styrofoam and placed in a foam pouch for extra protection, as foam absorbs shock well, and is lightweight and waterproof. A balloon, filled with 6 Rare Earth Magnets, was attached to the pouch to enable the device to adhere to the car.

D. Testing of External Design

A test was conducted to ensure that the design works on various surfaces. Three surfaces were used. To ensure that the material is the same as the car exterior, a ferromagnetic whiteboard was used as the straight and slanted surface. The thrower is positioned 3m away from the surface and throws the Tracking Device ten times onto each surface. The number of successful throws is recorded. Fig. 3 illustrates the set up of the experiment. The experiment was also conducted by Singapore Police Force with a car door.



(a) Side View of Experiment (b) Actual Image of Experiment

Figure 3. Testing External Design

The test results are shown in Fig. 4. From Fig4, it is concluded that the design has an average success rate of 90%. Hence, this design was used for the rest of the project.

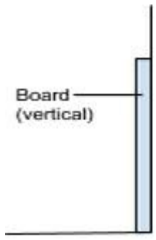
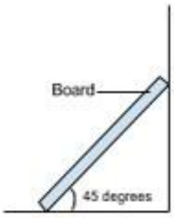
Successful throws on a vertical magnetic board: 9 out of 10 	Successful throws on a magnetic board inclined at 45 degrees: 10 out of 10 	Successful throws on a car door: 8 out of 10 

Figure 4. Results of Throwing Test

V. TRACKING SYSTEM TESTS

A. Location Accuracy Test

In order to investigate the location accuracy of coordinates sent from the Tracking Device, a vehicle was driven along a route with the Tracking Device attached to it. The message interval was set to less than 30 seconds, so as to collect more observations within a short duration. When a new pin appears on Google Maps, it was tallied with the car’s location, to see if the pin displayed is accurate. This was checked multiple times for reliable results. This test is repeated along different routes to ensure the accuracy of the device. Table I shows the results of a successful experiment which was done in a moving car, above ground, with 20 seconds message interval. Fig. 5 shows the pins on the Google Map for the test.

TABLE I. RESULTS OF FIELD TEST

No.	Time	Place	Above/ Below Ground Surface	Train Moving/ Stationary	Location Reflected On Receiver Accurate (Yes/ No)	Longitude	Latitude
Start	14 56	Star Vista	Above	Moving	NIL	NIL	NIL
1	14 58	North Buona Vista Road	Above	Moving	Yes	103.7863678	1.3007858
2	14 59	North Buona Vista Road	Above	Moving	Yes	103.7863064	1.2954347
3	15 00	Near AYE/ Portsdown Fly-over	Above	Moving	Yes	103.7938185	1.2886429
4	15 01	Near AYE	Above	Moving	Yes	103.7960024	1.2872937
5	15 02	Alexandra Fire Station	Above	Moving	Yes	103.8036073	1.2883222
6	15 03	Queen's Cl	Above	Moving	Yes	103.7999045	1.2919725
7	15 04	Blessed Sacarment Church	Above	Moving	Yes	103.7991532	1.2948494
8	15 06	Commonwealth Avenue	Above	Moving	Yes	103.7953191	1.3051548
9	15 06	Commonwealth Avenue	Above	Moving	Yes	103.7945493	1.3058197
10	15 07	North Buona Vista Road	Above	Moving	Yes	103.7902568	1.3055387
11	15 08	North Buona Vista Road	Above	Moving	Yes	103.7873966	1.3033051
12	15 09	Buona Vista Fly-over	Above	Moving	Yes	103.7859532	1.2064047
13	15 10	Portsdown Fly-over	Above	Moving	Yes	103.7917815	1.2902361
14	15 11	Portsdown Fly-over	Above	Moving	Yes	103.7942299	1.2883314
15	15 13	Queen's Cl	Above	Moving	Yes	103.8040525	1.2876733
16	15 13	Queen's Cl	Above	Moving	Yes	103.8034652	1.2883475
17	15 14	Back in the Lab	NIL	NIL	No	103.8034652	1.2883475
18	15 24	Back in the Lab	NIL	NIL	No	103.8034652	1.2883475
19	15 24	Back in the Lab	NIL	NIL	No	103.8034652	1.2883475
20	15 27	Back in the Lab	NIL	NIL	No	103.8034652	1.2883475
21	15 47	Back in the Lab	NIL	NIL	No	103.8034652	1.2883475

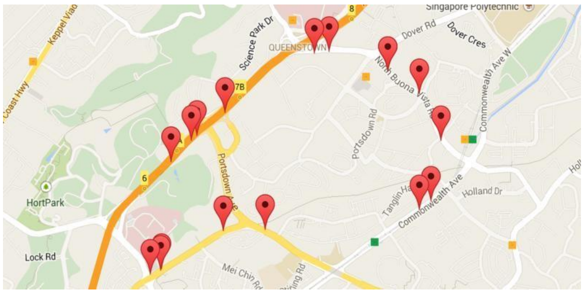


Figure 5. Received Vehicle Locations Shown in the Map

As shown in Fig. 5, all pins on Google Maps tally with the location observed from the car. Hence, the coordinates sent by the Tracking Device are accurate and precise. The coordinates on the Tracking Device changed consistently when the location of the Tracking Device changes. There are multiple pins reflected on Google Maps when the Control Device receives messages with different coordinates. So the Tracker Device works well when used above the ground surface, due to stronger GPs and mobile signal.

The field test was also conducted under ground. The coordinates on the Tracking Device did not change, despite physical change in the Tracking Device's location. Also, the Control Device did not receive any messages from the Tracking Device, despite having sent the "Start" message from the Control Device to the Tracking Device to start the application. This proves that there is no GPS signal underground, and that the Tracking Device does not work well underground.

B. System Starting Overhead Test

The system starting overhead refers to the time from the time when the Control Device sends a "Start" message to the time when the Control Device receives the first set of coordinates from the Tracking Device (Fig. 6).

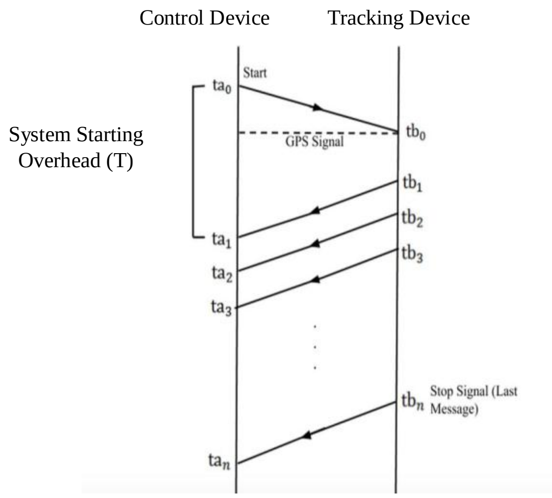


Figure 6. System Starting Overhead Diagram

The system starting overhead indicates the efficiency of our designed Android applications and the SMS communication delay, which depends on mobile network from Telco service provider. When the "Start" message is sent to the Tracking Device, the stopwatch starts timing. Once the first set of coordinates has been received by the Control Device from the Tracking Device, the stopwatch is stopped. This test was repeated four more times in four different locations to ensure that the system starting overhead remains consistent regardless of the location. Table II shows the results, with the average system starting overhead being 1 minute 34 seconds. This overhead however, can be shortened by using much quicker mobile networks 4G or 5G instead of 3G.

TABLE II. SYSTEM STARTING OVERHEAD RECORDED FROM FIELD TESTS

No.	Location	System Starting Overhead
1	Fusionopolis	1 minute 33 seconds
2	Buona Vista MRT	1 minute 34 seconds
3	Star Vista	1 minute 49 seconds
4	Olds Motor Mart	1 minute 20 seconds

C. Optium Interval Test

Although the interval can be adjusted to the user's preference, not all intervals will function properly. Intervals that are too short will result in a blank message being received, as the Tracking Device is unable to process the GPS signal from satellites at such a short span of time. Intervals too long will decrease the efficiency of the tracking. Thus, the optimum interval for the Tracking Device was investigated, to exist as a recommendation when the police use the device.

In one test of a pre-set interval of 2 seconds, the results indicates that the surge of messages show the same location coordinates, despite a physical change in location. The possible reason may be the 2-second small time interval could cause the Tracking Device does not have enough time to process the new GPS signal and could have also results in a lag in the messages received. So to test for the optimum interval, four intervals were investigated, i.e., 5 seconds, 10 seconds, 15 seconds, and 20 seconds. The vehicle drove along a fixed route with the Tracking device attached to it. A stopwatch was used to measure the duration between the coordinates received. The field tests were done for four different intervals, as shown in Table III.

TABLE III. INTERVALS BETWEEN EACH MESSAGE RECIVED BY THE CONTROL DEVICE FOR THE DIFFERENT INTERVALS SET

Interval Pre-set between each Message			
5 seconds	**10 seconds**	**15 seconds**	**20 seconds**
00:12.35	01:01.05	01:27.43	01:01.56
00:46.61	00:02.26	00:10.06	01:12.33
00:52.33	00:35.40	00:31.95	00:22.01
00:48.55	00:50.98	01:07.69	01:45.04
00:25.46	00:12.71	00:10.64	00:40.58
00:24.76	00:41.66	01:14.08	00:32.33
00:24.88	00:44.48	00:14.11	01:56.21
00:24.86	00:08.89	00:55.73	00:11.01

In Table III, the intervals between messages are inconsistent, due to the inconsistent 3G SMS communication delay. However, the time interval between the messages increases as the pre-set interval between messages increases. . In the field test for a pre-set interval of 5 seconds, occasional blank messages were observed in between the messages received, like in Table IV, "No.1". This may be because the Tracking Device was unable to process the GPS signal from satellites in time.

The recommended optimum interval was 10 seconds, as it does not result in the spamming of messages, and it provides frequent updates of the Tracking Device's coordinates, for effective tracking of vehicle location.

TABLE IV. BLANK DATA FROM FIELD TEST

No	Time	Place	Above/ Below Ground Surface	Train Stationary/ Moving	Location reflected on Receiver Accurate (Yes/No)	Longitude	Latitude
Start	1434	Buona Vista MRT	Above	Moving	NIL	NIL	NIL
1	1435	Buona Vista MRT	Above	Moving	NIL	NIL	NIL

VI. CONCLUSIONS

The Projectile Tracking System has shown success in accurately sending real-time information of a vehicle's location to the Control Device. The projectile function has a high success rate too. The system starting overhead shows the efficiency of our designed Android applications. The optimum message interval is tested as a recommended interval. Hence, this project has managed to create a system capable of efficiently tracking suspect vehicles, thus benefitting the police. An extension for this project would be to incorporate a predictive algorithm that predicts a vehicle's path should the GPS signal be lost, into the programme of the Tracking Device, taking into account the vehicle's speed, direction and location so that the vehicle can still be tracked when GPS signals are lost. Mobile cellular techniques may also provide the estimated location of vehicle.

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