GPS Tracking Simulation by Path Replaying

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***Abstract*—GPS (Global Positioning System) has a variety of applications among which real-time tracking finds significance in day-to-day life. GPS tracking is defined as the measurement of object position and orientation in a given coordinate system using GPS data at different points of time. GPS data are collected from GPS receivers attached to the moving objects and these data are used for tracking objects in real-time. Researchers who work in GPS tracking need GPS databases which contain huge volume of GPS data generated by hundreds of GPS receivers. But the presently available GPS databases are owned by private players and are not available for use by the researchers. This work is an attempt to generate a database of GPS data which can be used by the researchers to develop and test GPS applications. The approach consists of three successive steps: Collecting floating car data (FCD) of each path once in a log file; refining the log file; and replaying multiple instances of several log files simultaneously after replacing some old values with new values to simulate GPS tracking. Thus a single path tracked previously can be used to produce a tracking simulation of a number of moving objects by path replaying and each and every execution of the simulation generates a set of new GPS tracking data of several moving objects. These data are stored in a database and can be used as sample data for developing and testing GPS applications.**

Keywords: GPS receiver, GPS simulation, GPS data, Real time tracking.

I. INTRODUCTION

The applications of GPS tracking in real time have found its place in almost all walks of life, for instance, navigation, map making, land surveying, fishing and trekking. GPS has many technical and economical benefits to almost all industries and nowadays many companies are developing GPS [1] enabled applications and systems. More research is being carried out in this domain as GPS has the unique capability of locating any moving object over the earth in terms of latitude, longitude and altitude with high accuracy.

Private and Government owned transport, shipping and cargo companies have started using GPS to track their vehicles. They maintain a tracking database of their own vehicles and they do not want to share this database with anybody else because of the fear that these data may be used by their competitors. But researchers need GPS databases generated by hundreds of GPS receivers. This introduces a new problem domain of non-availability of sample data to develop and test GPS applications. Hence the need for a GPS tracking simulator is vital to generate GPS databases. Such a simulator will greatly reduce the expenses in research area and enable us to have more researches carried out in the allocated budgets.

This paper presents a GPS tracking simulation process which produces a database of GPS tracking data. GPS simulation has already been carried out by some of the researchers, but with limitations like hardware dependency, involvement of certain cost, complexity, lack of provision for GPS database creation and lack of provision for integration of digital maps. These limitations have been addressed in this work. The remainder of this paper is organised as follows. Section 2 of this paper describes the tracking of moving objects using GPS. Previous work in this area is discussed in Section 3. In Section 4, the simulation scenario is introduced. The results of the simulation along with a comparison of output data items with real-time data are dealt in Section 5. The work is concluded and the possible improvements are discussed in Section 6. The path replaying simulator has been designed using Matlab 7.6.

II. TRACKING USING GPS

A. A. Global Positioning System

There are many thousands of civil users of GPS system world-wide. GPS is a Satellite Navigation System funded, controlled and operated by the U. S. Department of Defense [2, 3]. The GPS system consists of three segments viz., satellites that transmit the position information, the ground stations that are used to control the satellites, and finally there is the receiver that computes its location anywhere in the world based on information it gets from the satellites [4].

The satellite segment consists of a minimum of 21 satellites and 3 working spares. The GPS satellites broadcasts two signals, PPS (Precise Positioning Service) which is available for use by military and government and SPS (Standard Positioning Service) which is available for use by public [5]. The Control Segment consists of a system of control stations located around the world. The Master Control facility is located in Colorado. These stations measure signals from the satellites which are incorporated into orbital models which in turn compute precise orbital data and satellites clock corrections for each and every satellite. The Master Control station uploads ephemeris and clock data to the satellites. The satellites then send subsets of the orbital ephemeris data to GPS receivers over radio signals. The Receiver Segment consists of GPS receivers which are used for navigation, positioning, time dissemination and other applications. A GPS receiver receives signals from more satellites than are actually needed for a position fix. The reason for this is that if one satellite becomes unavailable, the receiver knows exactly where to find the best possible replacement. Three satellites are required for two dimensional positioning and four satellites are required for three dimensional positioning. Two dimensional positioning reports position only in terms of latitude and longitude whereas three dimensional positioning reports position in terms of altitude as well. In general, a GPS receiver can provide position information with an error of less than 10 meters, and velocity information with an error of less than 5 meters per second.

Fig. 1 GPS tracking with the help of a GPS receiver fixed in a moving object.

Many of the tracking systems combine GPS, GSM technologies. In less than ten years since the first GSM network was commercially launched, it became the world's leading and fastest growing mobile standard, spanning over 200 countries. There is at least one cell tower in every 900m-1000m radius in the high traffic regions (city limits) and in the low traffic regions (high ways) a single cell tower can cover a radius up to 10 km. The operation of GPS tracking is explained in Fig. 1. The GPS receiver captures position data from the satellites, computes the position of the object, say, a vehicle, and sends this information to a central base station, using SMS (Short Message Service) or GPRS(General Packet Radio Service). If the optional storage module is installed, location data can even be stored when the vehicle is out of range of the cellular operator and retrieved later. GSM technology is used to transmit this information which in turn is collected by the server at the base station. The geographical position of the object can be displayed at the base station using a suitable application.

B. B. NMEA Specification

The NMEA (National Marine Electronics Association) has developed a specification that defines the interface between various pieces of marine electronic equipments. The NMEA standard permits marine electronics to send information to computers and to other marine equipments [6] in predefined formats. GPS receiver communication is defined with NMEA specification. Most computer programs that provide real time position information recognize data that are in NMEA format which includes the latitude, longitude, velocity and time computed by the GPS receiver. In NMEA specification system, data is sent as a line of text, called a sentence which is totally self contained and independent from other sentences. The data is contained within this single line and the data items are separated by commas. The commas act as terminators for the sentences and the programs that read the data should only use the commas to determine the end of a data item.

The GPS receivers produce GPS data in the form of standard NMEA sentences. The most important NMEA sentences include the $GPGGA which provides the current fix data, the $GPRMC which provides the minimum GPS sentences information, and the $GPGSA which provides the Satellite status data. The $GPRMC sentence is used for the tracking of moving objects.

III. PREVIOUS WORK

GPS simulators help the researchers to carry out their research work with minimal cost and with accurate data which they need. Though some work has been done in this area, more GPS simulators are being developed to suit the custom needs of the hour.

A GPS device emulator [6] namely, the GPS Generator PRO, has been designed for providing assistance in developing, testing and debugging programs and equipment working with the NMEA-0183 protocol. This emulator generates NMEA messages from different data inputs. It can operate in 2 modes: 1)User select map, start point, heading, speed; 2)User select NMEA log file. The user can change speed and heading during simulation. The generated NMEA sentences can be used by other mapping software. But buying this software involves cost.

A device for generating NMEA sequences for testing embedded GPS reception firmware and hardware is described by Sinivee V [7]. This work describes a prototype GPS data simulator designed and built in Department of Physics of Tallinn University of Technology, Estonia. Device can work in standalone mode and also in conjunction with control software. Configuration program can be used to generate test strings without tester hardware as well. First version of the device was limited to generating only one NMEA message and enabled simulation of communication errors. Later versions were developed to a more universal device with control via a GUI running on an ordinary PC. But there is no option provided in this software to create a database of NMEA sentences. Hardware dependent GPS simulators [1, 8] are also available and they operate by generating pseudo GPS signals.

A keyboard or mouse controlled NMEA sentence generator, Virace GPS Simulator [9] V0.01, can produce 3 COM port outputs. This simulator supports NMEA sentences like $GPRMC, $GPGGA, $GPGSA and $GPGSV. A lot of defined keys for steering and speed are available in this simulator. It supports three display and input formats of latitude and longitude. The disadvantage of using this is that it does not support GPS track replaying.

A work in this area has recently been done by the authors [10] to generate a sequence of NMEA sentences which in turn are used to simulate a GPS tracking environment. The generated data were similar to the data generated in real time by a GPS receiver and this simulator was used to create a database of sample GPS data which can be used by researchers to develop and test GPS applications. This generator can be used not only by software developers, but also by users, who want to learn navigation software before buying GPS receiver. This system generated random directions, but not based on the existing routes available on ground.

Thus a few number of GPS tracking simulators are available but with some limitations. Mostly these simulators involve some cost and hardware dependent. Some simulators suffer from lack of support of customized digital maps. Some of the generators require keyboard or mouse control for path creation. In some generators, there is no provision for database creation. The GPS tracking simulator proposed in this work addresses these problems.

IV. MODELLING DYNAMIC ENVIRONMENT OF MOVING OBJECTS BY PATH REPLAYING

The dynamic environment of moving objects is modelled using the following steps.

C. Collecting Floating Car GPS data in a log file
D. Log File Pre-processing
E. Replaying multiple instances of several log file.

F. A. Collecting Floating Car GPS data in a log file

Nowadays, the main research focus in the community of Intelligent Transport Systems (ITS) is how to acquire real-time and dynamic transportation information. This information can be applied in the transportation area like vehicle tracking, navigation, road guidance and so on. GPS is one such system which is used to provide real time information on moving objects.

Fig. 2 A moving vehicle (Floating car) fixed with a GPS receiver

The Floating Car (Probe Car) technique is one of the key technologies adopted by the ITS to get the traffic information in recent years [11]. Its basic principle is to periodically record the location, direction, date, time and speed information of the traveling vehicle from a moving vehicle with the data of the GPS as shown in Fig 2. The information can be processed by the related computing model and algorithm so that the floating car data can be associated with the city road in real time [12]. This data can also be used as a source of data for creating research and commercial applications on vehicle tracking and road guidance systems.

Mostly, the GPS receivers generate $GPGGA, $GPGSA, $GPRMC, $GPVTG and $GPGSV sentences at a regular time interval. A sample list of NMEA sentences produced by the GPS receiver and stored in a log file when travelled in a road is given in Fig. 3.

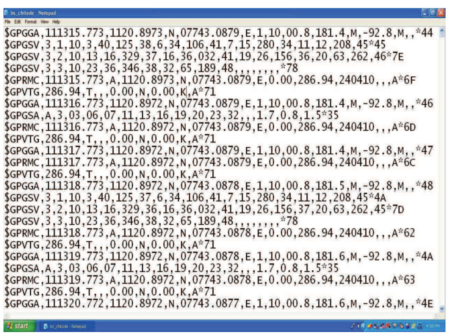


Fig. 3 Log file of floating car GPS data with $GPGGA, $GPGSA, $GPRMC, $GPVTG and $GPGSV sentences

G. B. Log File Pre-processing

The log file contains a number of different types of sentences but the $GPRMC (recommended minimum sentence C) provides the essential GPS PVT (Position, Velocity and Time) data. All GPS receivers output this sentence along with some other sentences. This data is used to locate moving objects in terms of latitude and longitude. The moving object, if attached with a GPS receiver, can be located with the help of this NMEA sentence. The $GPRMC data format [13] is given in Table 1.An example of $GPRMC NMEA sentence is given below:

$GPRMC,120642.206,A,1118.4253,N,07742.4325,E,31.6,317.52,140510,,,A*62

Where

$GPRMC : Recommended Minimum sentence C
120642.206 : Fix taken at 12:06:42.206 UTC
A : Status A=active or V=Void.
1118.4253,N : Latitude 11 deg 18.4253' N
07742.4325,E : Longitude 77 deg 42.4325' E
31.6 : Speed over the ground in knots
317.52 : Course over the ground
140510 : Date – 14th of May 2010
A : Autonomous mode
*62 : The checksum data, always begins with *

TABLE I

$GPRMC DATA FORMAT

Data Item	Format	Description
Message ID	$GPRMC	RMC protocol header.
UTC Time (Coordinated Universal Time)	hhmmss.sss	Fix time to 1ms accuracy.
Status	Char	A Data Valid. V Data invalid.
Latitude	Float	Degrees * 100 + minutes.
N/S Indicator	Char	N=north or S=south.
Longitude	Float	Degrees * 100 + minutes.
E/W Indicator	Char	E=East or W=West.
Speed over Ground	Float	Speed Over Ground in knots
Course over Ground	Float	Course Over Ground in Degrees
Date	ddmmyy	Current Date
Magnetic Variation	Blank	Not Used
E/W Indicator	Blank	Not Used
Mode	Char	A Autonomous
Checksum	*xx	2 Digits
Message Terminator	<CR><LF>	ASCII 13, ASCII 10

Hence the next step in the simulation process is to refine the log file by removing other sentences in such a way that it contains the $GPRMC sentences only as shown in Fig 4. This refined log file now contains the path of the probe car in terms of latitude and longitude at an interval of one second per sentence.

In this context, replaying means picking the $GPRMC sentences one by one from the log file and plotting the latitude and longitude position of the object continuously in a map. During replay, new $GPRMC strings are also generated for the moving object as described below.

For instance, consider the following sentence in refined log file.

$GPRMC,120642.206,A,1118.4253,N,07742.4325,E,31.6,317.52,140510,,,A*62

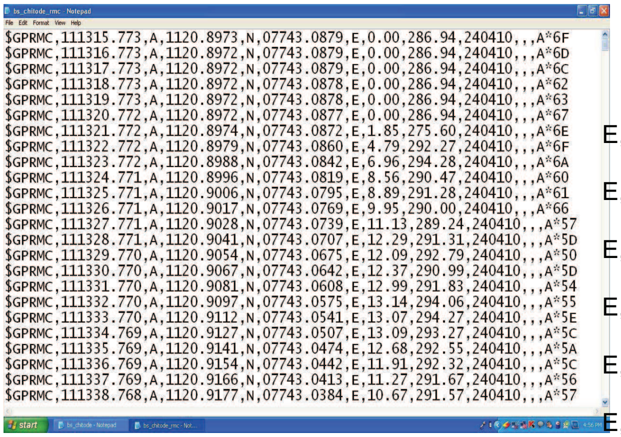

$GPRMC,111315.773,A,1120.8973,N,07743.0879,E,0.00,286.94,240410,,,A*6F
$GPRMC,111316.773,A,1120.8972,N,07743.0879,E,0.00,286.94,240410,,,A*6D
$GPRMC,111317.773,A,1120.8972,N,07743.0879,E,0.00,286.94,240410,,,A*6C
$GPRMC,111318.773,A,1120.8972,N,07743.0878,E,0.00,286.94,240410,,,A*62
$GPRMC,111319.773,A,1120.8972,N,07743.0878,E,0.00,286.94,240410,,,A*63
$GPRMC,111320.772,A,1120.8972,N,07743.0877,E,0.00,286.94,240410,,,A*67
$GPRMC,111321.772,A,1120.8974,N,07743.0872,E,1.85,275.60,240410,,,A*6E
$GPRMC,111322.772,A,1120.8979,N,07743.0860,E,4.79,292.27,240410,,,A*6F
$GPRMC,111323.772,A,1120.8988,N,07743.0842,E,6.96,294.28,240410,,,A*6A
$GPRMC,111324.771,A,1120.8996,N,07743.0819,E,8.56,290.47,240410,,,A*60
$GPRMC,111325.771,A,1120.9006,N,07743.0795,E,8.89,291.28,240410,,,A*61
$GPRMC,111326.771,A,1120.9017,N,07743.0769,E,9.95,290.00,240410,,,A*66
$GPRMC,111327.771,A,1120.9028,N,07743.0739,E,11.13,289.24,240410,,,A*57
$GPRMC,111328.771,A,1120.9041,N,07743.0707,E,12.29,291.31,240410,,,A*5D
$GPRMC,111329.770,A,1120.9054,N,07743.0675,E,12.09,292.79,240410,,,A*50
$GPRMC,111330.770,A,1120.9067,N,07743.0642,E,12.37,290.99,240410,,,A*5D
$GPRMC,111331.770,A,1120.9081,N,07743.0608,E,12.99,291.83,240410,,,A*54
$GPRMC,111332.770,A,1120.9097,N,07743.0575,E,13.14,294.06,240410,,,A*55
$GPRMC,111333.770,A,1120.9112,N,07743.0541,E,13.07,294.27,240410,,,A*5E
$GPRMC,111334.769,A,1120.9127,N,07743.0507,E,13.09,293.27,240410,,,A*5C
$GPRMC,111335.769,A,1120.9141,N,07743.0474,E,12.68,292.55,240410,,,A*5A
$GPRMC,111336.769,A,1120.9154,N,07743.0442,E,11.91,292.32,240410,,,A*5C
$GPRMC,111337.769,A,1120.9166,N,07743.0413,E,11.27,291.67,240410,,,A*56
$GPRMC,111338.768,A,1120.9177,N,07743.0384,E,10.67,291.57,240410,,,A*57

Fig. 4 Refined Log file of $GPRMC sentences

H. *C. Replaying Multiple Instances of Several Log Files*

During simulation, the values in the date and time fields in the above sentence are replaced with system date and time values as shown below. The micro-time in the time field is left unaltered because of its insignificance. The check sum field is also left unaltered as it is insignificant in simulation. The remaining values are treated as current values for simulation. So the newly generated sentence for simulation will be

$GPRMC,151245.206,A,1118.4253,N,07742.4325,E,31.6,317.52,221110,,,A*62

The different fields of the newly generated sentence for the currently moving object can be extracted and stored in the database.

V. GPS TRACKING SIMULATION RESULTS

Wonde-X series GPS receiver (ZX4125) was used in order to produce log files once for each path. The GPS receiver is fixed in a moving car and the NMEA sentence generated by it are stored in the log file in a laptop kept in the moving car. The log-file is then refined and replayed to produce simulation of one moving object. During replay, new $GPRMC sentences are produced out of the sentences present in log file. For instance, the first ten sentences originally available in the log file for a particular path is given below.

$GPRMC,111315.773,A,1120.8973,N,07743.0879,E,0.00,286.94,240410,,,A*6F

$GPRMC,111316.773,A,1120.8972,N,07743.0879,E,0.00,286.94,240410,,,A*6D
GPRMC,111317.773,A,1120.8972,N,07743.0879,E,0.00,286.94,240410,,,A*6C
$GPRMC,111318.773,A,1120.8972,N,07743.0878,E,0.00,286.94,240410,,,A*62
$GPRMC,111319.773,A,1120.8972,N,07743.0878,E,0.00,286.94,240410,,,A*63
$GPRMC,111320.772,A,1120.8972,N,07743.0877,E,0.00,286.94,240410,,,A*67
$GPRMC,111321.772,A,1120.8974,N,07743.0872,E,1.85,275.60,240410,,,A*6E
$GPRMC,111322.772,A,1120.8979,N,07743.0860,E,4.79,292.27,240410,,,A*6F
$GPRMC,111323.772,A,1120.8988,N,07743.0842,E,6.96,294.28,240410,,,A*6A
$GPRMC,111324.771,A,1120.8996,N,07743.0819,E,8.56,290.47,240410,,,A*60

The new $GPRMC sentences produced from the above sentences during simulation are listed below.

$GPRMC,040210.773,A,1120.8973,N,07743.0879,E,0.00,286.94,251110,,,A*6F
$GPRMC,040211.773,A,1120.8972,N,07743.0879,E,0.00,286.94, 251110,,,A*6D
$GPRMC,040212.773,A,1120.8972,N,07743.0879,E,0.00,286.94, 251110,,,A*6C
$GPRMC,040213.773,A,1120.8972,N,07743.0878,E,0.00,286.94, 251110,,,A*62
$GPRMC,040214.773,A,1120.8972,N,07743.0878,E,0.00,286.94, 251110,,,A*63
$GPRMC,040215.772,A,1120.8972,N,07743.0877,E,0.00,286.94, 251110,,,A*67
$GPRMC,040216.772,A,1120.8974,N,07743.0872,E,1.85,275.60, 251110,,,A*6E
$GPRMC,040217.772,A,1120.8979,N,07743.0860,E,4.79,292.27, 251110,,,A*6F
$GPRMC,040218.772,A,1120.8988,N,07743.0842,E,6.96,294.28, 251110,,,A*6A
$GPRMC,040219.771,A,1120.8996,N,07743.0819,E,8.56,290.47, 251110,,,A*60

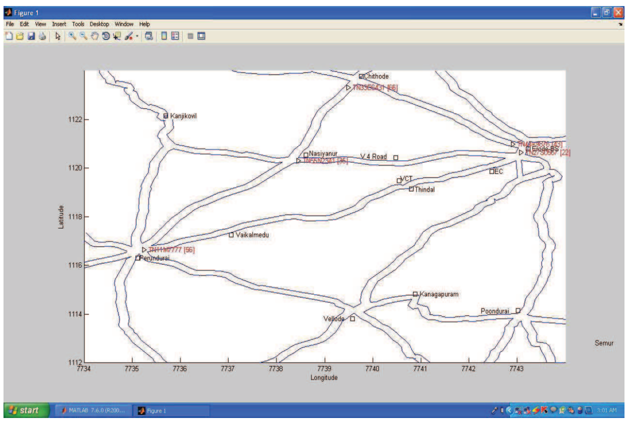


Fig. 5a

Thus each moving object is associated with new $GPRMC sentences generated out of old sentences available in refined log file. The digital map built in the earlier work [14] of authors is used to plot objects in a 2D-plane. Multiple instances of the log-file are replayed in parallel to get simulation of several moving objects as shown in Fig. 5a and 5b. The values of fields in the new strings are stored in the database as shown in Fig. 6. It can be noted that only the significant values in the $GPRMC sentence is stored in the database along with an object identification field, say, vehicle number.

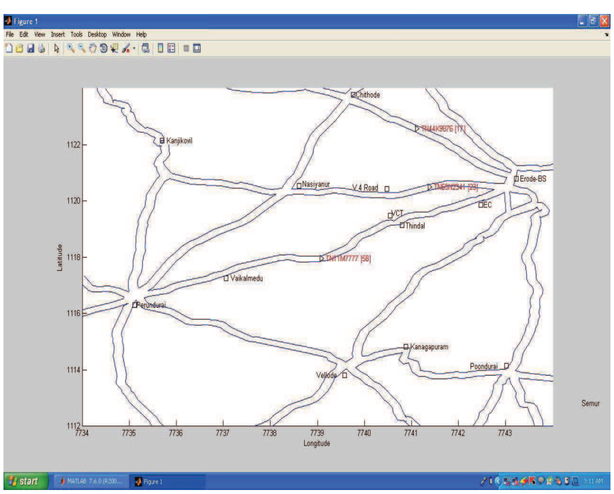
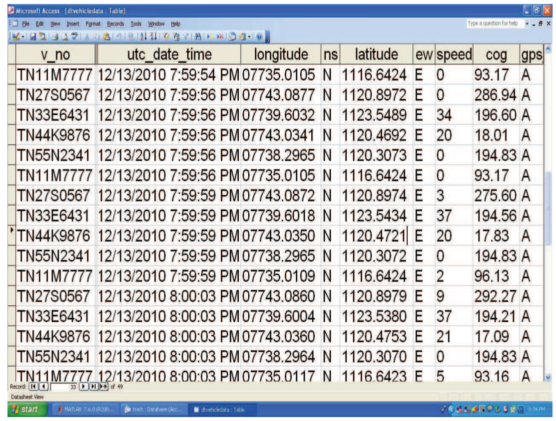


Fig. 5b

Fig. 5a, 5b Moving objects simulated and plotted in the map at different instances of time.



v_no	utc_date_time	longitude	ns	latitude	ew	speed	cog	gps
TN11M7777	12/13/2010 7:59:54 PM	07735.0105	N	1116.6424	E	0	93.17	A
TN27S0567	12/13/2010 7:59:56 PM	07743.0877	N	1120.8972	E	0	286.94	A
TN33E6431	12/13/2010 7:59:56 PM	07739.6032	N	1123.5489	E	34	196.60	A
TN44K9876	12/13/2010 7:59:56 PM	07743.0341	N	1120.4692	E	20	18.01	A
TN55N2341	12/13/2010 7:59:56 PM	07738.2965	N	1120.3073	E	0	194.83	A
TN11M7777	12/13/2010 7:59:56 PM	07735.0105	N	1116.6424	E	0	93.17	A
TN27S0567	12/13/2010 7:59:59 PM	07743.0872	N	1120.8974	E	3	275.60	A
TN33E6431	12/13/2010 7:59:59 PM	07739.6018	N	1123.5434	E	37	194.56	A
TN44K9876	12/13/2010 7:59:59 PM	07743.0350	N	1120.4721	E	20	17.83	A
TN55N2341	12/13/2010 7:59:59 PM	07738.2965	N	1120.3072	E	0	194.83	A
TN11M7777	12/13/2010 7:59:59 PM	07735.0109	N	1116.6424	E	2	96.13	A
TN27S0567	12/13/2010 8:00:03 PM	07743.0860	N	1120.8979	E	9	292.27	A
TN33E6431	12/13/2010 8:00:03 PM	07739.6004	N	1123.5380	E	37	194.21	A
TN44K9876	12/13/2010 8:00:03 PM	07743.0360	N	1120.4753	E	21	17.09	A
TN55N2341	12/13/2010 8:00:03 PM	07738.2964	N	1120.3070	E	0	194.83	A
TN11M7777	12/13/2010 8:00:03 PM	07735.0117	N	1116.6423	E	5	93.16	A

Fig. 6 GPS database extracted from new $GPRMC sentences produced by the simulator

Thus, it is observed that the new $GPRMC sentences generated during simulation resemble with the sentences generated by actual tracking. Besides, a replay of multiple instances of the previously tracked path produces a GPS tracking simulation of moving objects on ground. The significant values are stored in the GPS database.

VI. CONCLUSION AND FUTURE WORK

This paper introduces a GPS tracking simulation process which is used to simulate a number of moving objects by path replaying. It is found that the generated sentences are similar to the data generated in real time by a GPS receiver and they are found to fit within standards. This GPS tracking simulator has eliminated the limitations of the previous work carried out in this area. The data generated by this software are used to create a database of sample GPS data which can be used by researchers to develop and test GPS applications. This generator can also be used by software developers as well as the novice users of GPS to learn navigation software. At present this system simulates a fixed number of vehicles initially set during the execution. In future, this work can be extended to simulate random number of moving vehicles at any point of time.

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