Proceedings of the Sustainable Research and Innovation Conference,
JKUAT Main Campus, Kenya
8- 10 May, 2019

Development of a Real-time Outdoor Positioning System for an Escaping Target

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Abstract—Tracking and pursuit has vast applications such as wildlife monitoring and military applications among others. It requires accurate information in real-time on location of assets. In most of tracking scenarios, Global Positioning System (GPS) is mainly used to provide location coordinates in terms of longitudes, latitudes and altitude. These coordinates are then transmitted through some wireless system to a central server. Usually user relies on third party map providers such as Google maps and MapQuest maps which interpret position data relative to land marks. In this paper, a GPS based system for outdoor positioning of an evading ground target relative to the pursuer is proposed. The system captures the GPS data of the pursuer and the evader and uses the data to compute in real time the bearing and the distance between them. This information can be utilized for pursuit purposes. The development and testing of electronic hardware and software is presented where location information is acquired using GPS module and transmitted using Wi-Fi to a central computer for interpretation. This real-time location system is part of a positioning system for exact location of an escaping ground target in an arena.

Keywords—Outdoor Positioning, Pursuit navigation,Tracking systems,

I. INTRODUCTION

REAL-TIME positioning systems have recently found vast applications in everyday use such as urban traffic navigation, vehicle parking space management, tracking and pursuit among others. Most of these utilize Global Positioning System (GPS) to provide provides continuous location and timing information.

GPS technology was invented in early 70s and became fully operational in 90s, it has found wide applications beyond its initially intended military uses into commercial and research systems [1]–[3]. It was developed by US military as a successor to transit system, a maritime navigation system previously used by us navy. There are other navigations systems such as Global Navigation Satellite System (GLONASS) by the Russian military, Galileo by the Europeans and a Chinese system called Compass [4], these are mainly in the development stage. GPS is way more developed and uses triangulation to compute position from signals sent by satellites with an approximate error of 10m, which may be adequate for many open-air applications [5].

Furthermore, GPS system quickly and accurately provides information regarding time and device velocity [4]. Modern GPS receivers have been miniaturized and their power consumption greatly reduced that they can be easily embedded on small electronic devices such as mobile phones for end user tracking or a remote device for localization. When applied in a remote device the acquired GPS signal is relayed wirelessly to another device for information processing. Multiple wireless technologies have previously been deployed such as UHF band frequencies, CDMA and WiFi.

Recent research has seen development of application specific positioning systems such as one by Shoab [6] where a GPS based location data logger was developed. Their research focused on interpretation of National Marine Electronics Association (NMEA) sentences. Another system was developed by Shashidhar [2], where a GPS data logger was fabricated on a single board. This has been applied in pursuit and evasion scenarios where the pursuer and target are monitored. GPS provides an accurate mechanism of determining the evaders position relative to the pursuer. Where the pursuit is in real-time, the positioning system should then provide real-time information on the location of both the pursuer and the evader.

II. POSITION MEASUREMENT SYSTEMS

The developed system provides realtime information on the location of an evader relative to the pursuer, by computing the Line of Sight (LOS) distance and the angle.

First, a map is developed for the whole area of testing, GPS coordinates of the pursuer and the escaping target are determined,then distance is computed using haversine equation. The developed system relies on GPS for location of field assets and Wi-fi for transmission of data to a ground monitoring station. The station has a computer running a program designed to monitor a randomly moving ground target with an aim of confining it within a defined boundary.

Position measurement involves the reception and transmission of signals between hardware components of the system [7]. A general positioning system has a measuring unit and a signal transmission system. The way the two systems are deployed

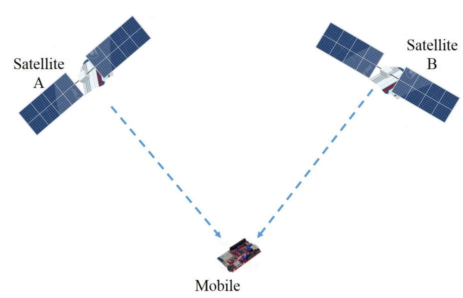

Fig. 1. GPS Signal Receiver Configuration

depends on the positioning topology. In a remote-positioning

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topology, the measuring unit is mobile, it receives the signals of several transmitters in known locations and computes its location based on the measured signals as shown in Figure 1. Triangulation is then used to determine the position of the receiver in latitudes and longitudes. The location information can be relayed through a wireless data link to a master station.
The master station uses the position data to determine the location of assets in the system from longitudes and latitudes. For a flat surface, this is computed using the haversine function (1) [8]. The function provides a means of determining the great circle distance which is the shortest distance between two points, measured along a sphere [9]. In this case the sphere is the earth whose average radius at the equator is R. The equation determines the distance from point P to point Q along the indicated path as shown in Figure 2
The haversine function is then applied to determine the

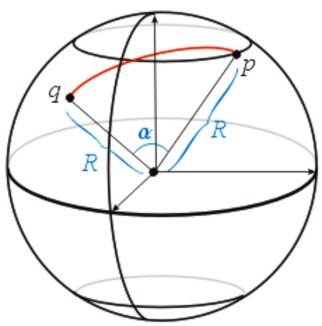

Fig. 2. Great Circle Distance

distance d, while triangle equation determine the angle α.

$$d = 2r\sin^{-1}\left(\sqrt{\sin^2\left(\frac{\phi_2-\phi_1}{2}\right) + \cos(\phi_1)\cos(\phi_2\sin^2\left(\frac{\lambda_2-\lambda_1}{2}\right)}\right)$$

where:-

d is the space between two coordinates.
r is the radius of the sphere

ϕ_1, ϕ_2 Longitude of position p and q.

λ_1, λ_2 Lattitude of position p and q.

The bearing is then computed from triangle geometry equations.

In developing a positioning system, it is important that it meets key performance metrics as explained in the works of [7]. The main benchmarking parameters are:-

- **Accuracy**: Higher accuracy results to better systems
- **Precision**: This is a measure of the robustness a positioning technique. It reveals the variation in its performance over many trials.
- **Computing complexity**: This is mainly indicated by time taken by the system to compute new location.
- **Robustness**: this could be evaluated by ability to determine location using incomplete information.
- **Scalability**: It is a question of how well the positioning system will perform when the scope becomes large.
- **Cost**: This is a measure of money spent in developing the system, space occupied, weight and energy consumption.

The system developed will therefore be evaluated against these parameters.

III. System overview

The development of the positioning system entails assembly of the hardware, development of a functional code and testing.

A. Hardware

The hardware developed consists a ground station, a mobile GPS receiver and wireless communication equipment. These were to function as illustrated in Figure 3 The mobile GPS

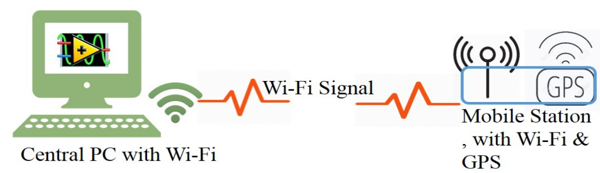

Fig. 3. Hardware Connections

receiver is portable and with ability to endure outdoor environment for long. It should have a mobile power supply unit that could sustain it for a long time before recharging it.
The hardware for the system consist of Pmod GPS receiver, chipKIT WF32 both by Digilent and a rechargeable Li-ion 5V battery. The *PmodGPS* sensor uses UART interface for communication and was connected to WF32 TX (transfer data) and RX (receive data) pins. The chipKIT WF32 is a WiFi enabled Arduino based board with a PIC32 microcontroller (80 MHz). The assembly is as shown in Figure 4,more detailed information of these boards are presented in their reference manuals [10], [11]. The hardware also consists of a long range WiFi access point for connection of the mobile unit to the monitoring PC.

B. Software Architecture

The software platform provides a means of acquisition of location data and interpretation to determine relative location of the remote module. First, GPS data is received by the Pmod receiver module and transmitted to the chipkit board, It is received,coded then transmitted over WiFi to the central computer for interpretation as shown in Figure 5. The WiFi signal is carried through standard networking equipment and can span up to two kilometers under clear line of sight. The position data transmitted over WiFi is in form of National Marine Electronics Association (NMEA) sentences. NMEA is a standard data format for GPS devices [12]. NMEA data is contains multiple data items in a single line separated by commas [13]. Each NMEA sentence begin with $ and can‘t be longer than 80 characters including line terminators [6]. In these sentences the data items are separated by commas The main data items are Satellites in view, Longitude, Latitude, Altitude and Time. The sentences are then interpreted using a code in LabVIEW then distance and bearings are determined.

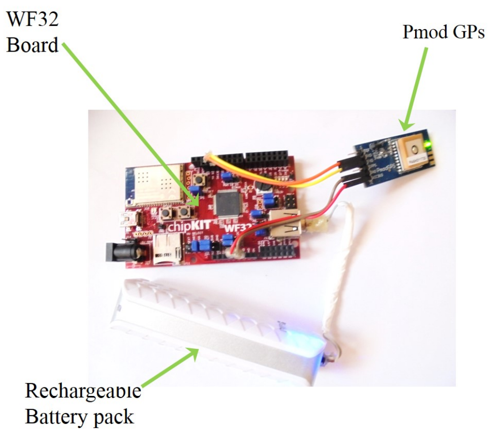

Fig. 4. Portable unit

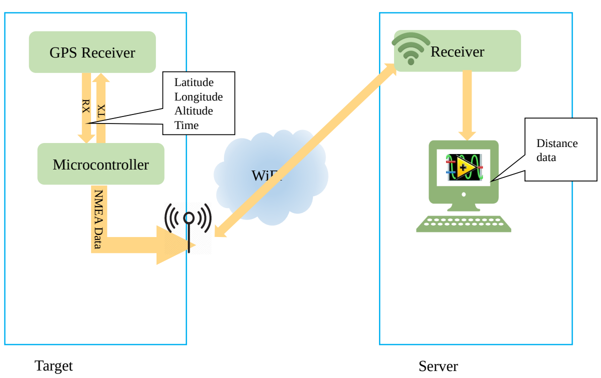

Fig. 5. Software Architecture

IV. Test Setup and Results

The system was deployed for testing, where first the co-ordinates of a stationary pursuer were acquired and distance obtained against a stationary evader. A program was developed in LabVIEW for acquisition of coordinates from microcontroller through WiFi as shown in Fig 6. The program acquires

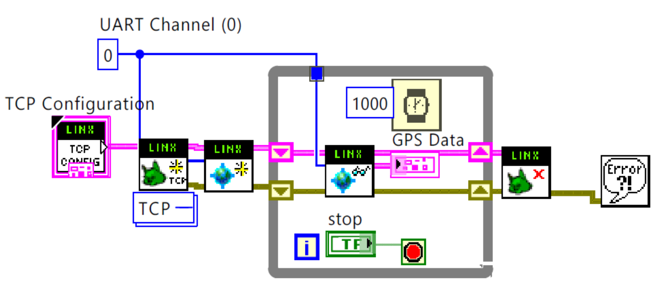

Fig. 6. LabVIEW Screen-shot for Location Acquisition

NMEA sentences from ChipKit WF32 through WiFi from UART channel 1, the sentences are then interpreted to give 11 parameters. A sample was taken from iPIC center for the pursuer as shown in the screen-shot Fig 7. The device name box indicates the identity of the hardware used by the computer for data acquisition, Time provides the 24Hr clock data on the time of the experiment 1:40pm, Date is the date when the data was taken(25th Feb). Fix type (3) means that

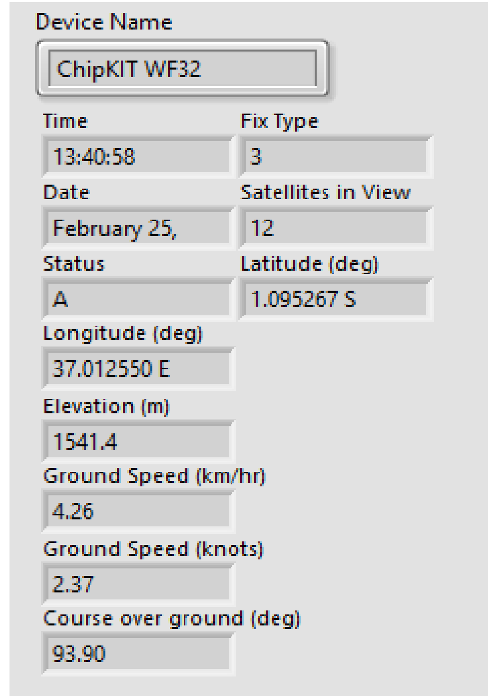

Fig. 7. GPS Parameters of Pursuer

the data obtained is for three dimensional location. The Status provides Navigation receiver warning status where A means OK and V indicates presence of a warning. Satellite in view gives the number of satellites available, the higher the number the better. The Latitude and Longitude data is given in decimal degrees while the altitude is in metres. Of these parameters, only the Latitude, the Longitude and Time are of interest to the research.

The coordinates of the evading target were acquired in a similar manner and the motion pattern plotted as shown in Fig 8 The location data of the moving target was used to compute its relative location with respect to the pursuer. The distance was obtained using haversine equation. The location of the pursuer is indicated as lat1 and lon1 wile of the target as lat2 and lon2. The bearing of the moving target was also computed.

The results of distance and bearing are as shown Fig 9.

The angle is computed counterclockwise from the geographical north in degrees while the distance is in meters.

V. Evaluation

The developed system was evaluated using standard benchmarking parameters and was found to be accurate in providing distance information that is useful for desired applications. In terms of cost, the portable module is light in weight (about 0.2kg) and it can be tagged on a real target. The system is scalable in that it can be expanded to accommodate more targets and the range signal acquisition can be extended by including more WiFi access points.

VI. Conclusion

In this paper, This paper, the development of a Real-time GPS based system for outdoor positioning of an evading

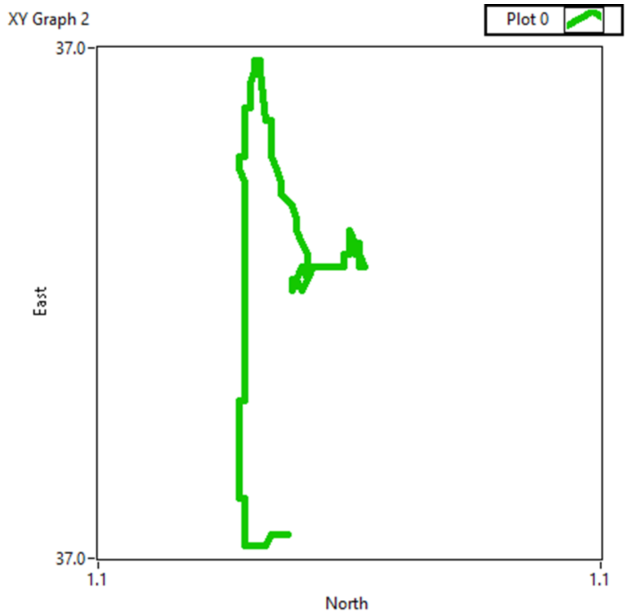

Fig. 8. Sample Ground Motion

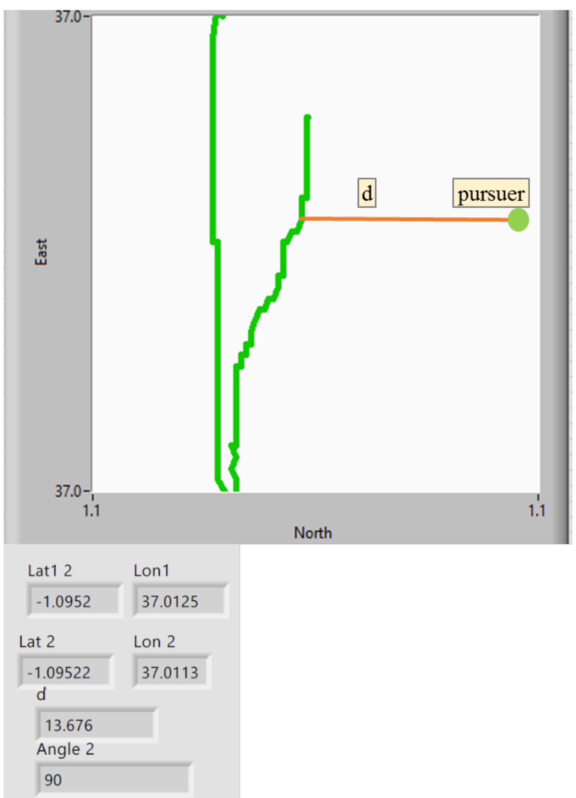

Fig. 9. Distance and Bearing

ground target relative to the pursuer has been presented. The developed system generates results that can be used in real time pursuit purposes scenario.

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