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Low Cost Local Positioning System (LPS) – Design and Development for vehicular tracking

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Abstract: Local positioning System is a well known problem that has been in focus for years. If the position by any means of transport having contact with ground is known, there are many important applications. While GPS has been widely used for outdoor application there is as yet no local positioning system with broad applicability for situations where GPS is unavailable or unreliable. The main objective of this research is to design and develop a Local Positioning System (LPS) that practically identify the exact location of any means of transport which has physical contact with ground. The system successfully implemented for possible information of direction, and speed of vehicle. The communication strategy is telephonic medium which can be changed to microwave. The research suggests low cost, Local Positioning System (LPS) which is designed, developed and tested and successfully implemented in controlled environment, based on 8751 Microcontroller Assembly language and Visual Basic. This system can be setup in different public departments such as Hospitals Ambulance services, Police Monitoring system and freight services etc. to enhance their effectiveness and efficiency.

Keywords: Local Positioning System, LPS, Micro Controllers, GPS

1. INTRODUCTION

Local positioning, also known as indoor localization is a well known problem that has been in the spotlights for the past years. Once the location of an object or person is known there are many interesting applications. Satellites by their inherent nature can keep a watch on large swaths of the planetary surface. A satellite in polar orbit can scan the entire planet. GPS using satellite has been widely used for outdoor application there is as yet no Local Positioning System with broad applicability for situations where GPS is unavailable or unreliable (Junaid, Fazal. and Waheed. 2012 and Mahmood 1997) .

Local positioning systems are positioning systems working with local coordinates in a regionally limited area. For this purpose an infrastructure is established where the positions of one or more moving points can be determined and their local or global positions can be calculated (Jochen Johannes 2008). Position measuring systems can be distinguished according to the different measuring procedures (Aswanikumar, Prasad, 2012). As the technology is advancing, many intellectual ideas and procedures have been discovered for example The Minimal Detectable Bias method of Fault Detection is frequently employed to determine if a position has integrity (Nathan, Jinling 2011), the architecture of a remote low-cost position sensing infrastructure for ubiquitous computing (Changsong and Sidney 2006) and Wireless indoor positioning systems have become very popular in recent years (Liu, and Student Member, 2007).

Local positioning systems (LPS) fall primarily into two categories (Vossiek, Wiebking, and Gulden, 2003):

1. Self Positioning: A mobile device finds its own instantaneous location with respect to a fixed point, e.g., the starting point or a beacon node, and

2. Remote Positioning: A mobile device finds the instantaneous positions of other objects (mobiles) with respect to its own position. In the self positioning LPS, a mobile uses the instantaneous velocity, direction and the elapsed time to calculate its own relative position.

Such systems are functional in any indoor or outdoor environment, and are typically used in conjunction with communication control center(s) to perform tracking, monitoring, command and control. However, these systems may lose their location information permanently, if their functionality is lost even for a very short period of time. Moreover, any small error in the computation of location may propagate and lead to a large position error or even loss of position information. Bluetooth as a technology with low power consumption for short-range wireless data and voice communication and is a potential technology

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to become an alternative for indoor positioning (Syed and Zekavat, 2004 and Ling, Ruizhi, and Chen, 2010).

The diversity tracking system that sends the geological coordinates of the subject to the host/target. For this, the most popular tool is the use of space satellites. These devices virtually follow a track in any dimension. These systems are undoubtedly remarkable in terms of their accuracy and efficiency but offer a few bottlenecks.

2. MATERIAL AND METHODS

The GPS using the satellites are costly and "unreliable", in that it is vulnerable to the bureaucratic diplomacies especially when it comes to the national security. There is no doubt that the design of the LPS is a mere replica rather than a superlative elucidation of the conventional GPS in terms of versatility and accuracy, but most certainly a cost-effective solution to the obstacles described above. Implementing serial communication using embedded Microcontrollers and PCs through Modems with standard cellular/wireless telephones, any vehicle having a physical contact with the surface of the earth, or in a broader sense, having a physical contact with the atmosphere of the earth, can be tracked and located, easily and cost effectively, without much jeopardy to the transmission.

The LPS is affordable even an ordinary person having a cellular phone or a long-range telephone. As a matter of fact, if a suitable frequency is granted in the city-band range, transmitters could be designed to transmit digital data over long range.

The method of tracking in the proposed LPS is simple yet austere. The ideology may begin with the assumption that the four quadrants of geometrical coordinates are superimposed on the North, South, East and West directions on the map, with the first quadrant representing the North-West and the fourth quadrant representing the South-West.

Coordinate Systems and Degree of Turns

The overview of coordinate system (Koichi, and Yuki, 2012, Marsden and Tromba. 2011 and Yousuf, 1995), for geo-referencing provides a brief description of local and global systems for use in precise positioning, navigation, and geographic information systems for the location of points or points in space.

There are many different coordinate systems, based on a variety on geodetic datum, units, projects, and reference systems in use today.

(Fig.1) depicts that, from the Polar Coordinate System, if the value of the degree of turn (ɵ) of any vehicle and the length covered per unit revolution (r) is known, any object (vehicle to be more exact) can be tracked and located on the surface of the earth with reference to an originating x-y plane superimposed on the N-S-E-

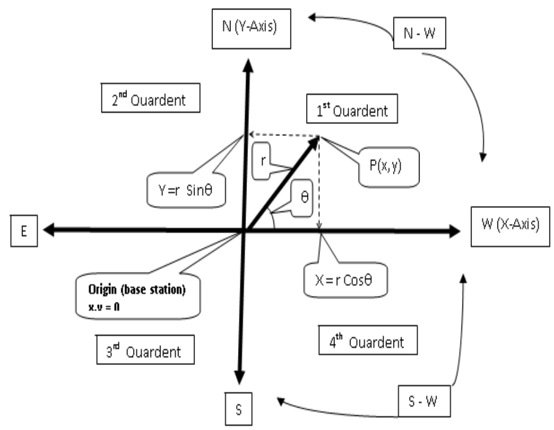

Fig. 1. Degree of Turn

Only for the very first time, when the LPS is installed, the values of x and y are zero (0), every since after that the new values, calculated by the current mileage and theta (θ) is added in the previous one and a database is maintained. Same is the case with theta (θ), which is taken zero for the first time and added in the new value ever after. This is done to maintain a constant reference with the origin. Now only the mileage is constantly increased with a fixed amount as it is taken from the wheel (at least for now) and it takes 156 cm to make a complete revolution (i.e. circumference of the wheel) in our experimental car. So each pulse is received by the system from the wheels, 0.00156 km is added in the mileage count.

Likewise the total displacement is calculated using the following formula:

$Z = (X^2 + y^2)0.5$

This is the distance from the starting position to the final. So, a car with full steering turn may observe the following path shown in (**Fig. 2).**

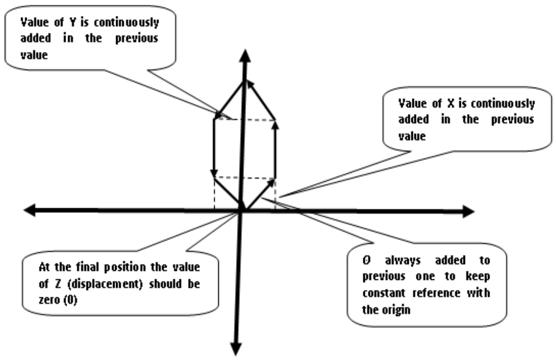

Fig. 2. Position of car with full steering turn

Suppose that the degree of turn is maintained at 30^o and the car is moved. Now the wheel takes 156 cm to make one revolution. In the framework of Cartesian coordinates, it gives us:

$\Theta = 30^o$, and
$r = 156$ cm

At the very first instant, i.e. at the origin, θ, x and y are zero (0). Therefore, the new values of x and y become:

$X = r \cos\theta$
$X = (156) \cos (30)$
$X = 135$ cm
$Y = r \sin\theta$
$Y = (156 \sin (30)$
$Y = 78$ cm
$Z = (x^2 + y^2)0.5$
$Z = [(135)^2 + (78)^2]0.5$
$Z = (24369)0.5$
$Z = r = 156$ cm

This is illustrated in (**Fig. 3).**

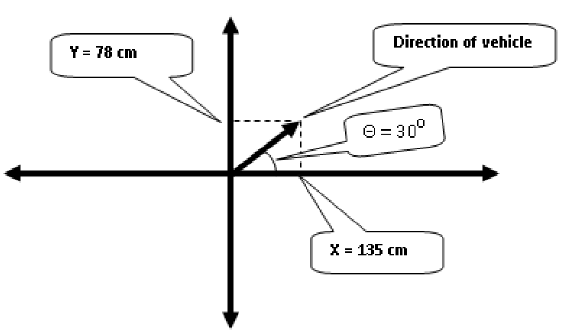

Fig. 3. Position of car with 30 degree of turn

These values of x and y are at taken at the very instant when the wheel makes one complete turn. Now at the next turn, the value of the new θ is added in the previous one and so are the values of x and y. as the steering is kept stationary at 30^o, the new value becomes:

Θ new = (old + new)
Θ new = 30 + 30
Θ new = 60^o
X new = $r \cos\theta$
x new = (156) Cos (60)
x new =78 cm
x = x old + x new
x = 135 + 78
x = 213 cm
y new = $r \sin\theta$
y new = (156) Sin (600)
y new = 135
y = y old + y new
y = 78 + 135
y = 213 cm
$Z = (x^2 + y^2)0.5$
$Z = [(213)^2 + (213)^2]0.5$
$Z = (90738)0.5$
$Z = 301$ cm

Only from now on, the new values will reference the previous ones. This reference is necessary for locating the vehicle's displacement from the origin as shown in (**Fig.4).**

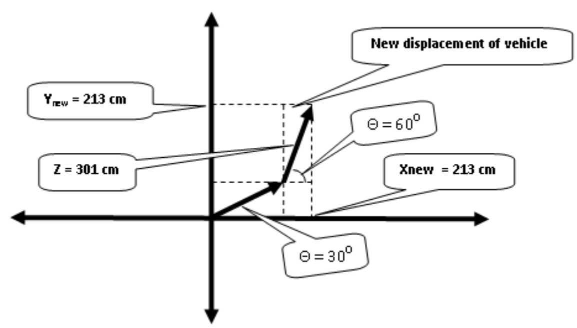

Fig. 4. Displacement from origin

The value of θ is so adjusted that it is 0^o when the steering is straight, assumed to be in the first quadrant (θ =+ve) when turned left and in the fourth quadrant (θ =-ve) when turned right a shown in **(Fig.5).**

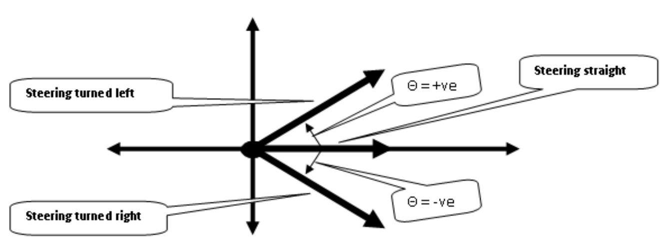

Fig. 5. θ =0 θ =+VE θ =-VE

The value of θ (+ve or –ve) automatically adjusts the x, y coordinates in the appropriate quadrant, hence redirecting the actual location of the tracked vehicle. There may be an implication to the above discussion. What happens if the vehicle is being reversed? The answer to this question is a bit complex referring to an algorithmic approach, called Mirroring, in that, the angle (θ) is converted in the adjacent quadrant.

If the vehicle is in the first quadrant and if reverse gear is deployed, θ is converted to mirror to its next adjacent quadrant. This is shown in **Fig.6** and we see that the vehicle actually points in the direction of P but since it moves in reverse direction, the angle is subtracted from π radians (180^o) to get a mirror image of actual turn of the steering, represented as P'. Since the steering was turned in the left direction θ is positive so according to formula:

$\Theta' = 180 - \theta$
$\Theta' = 180-(+30)$
$\Theta' = 150^o$

Another situation may arise when the steering is turned right. Θ is obviously –ve this times and the value of θ' can be calculated as:

$\Theta' = 180 - (-30)$
$\Theta' = 180 + 30$
$\Theta' = 210^o$

In both the cases, note the position of the arrowhead of P'. The rest of the quadrants shall follow suit.

Suppose θ is $+160^o$ (2nd Quadrant) then:

$\Theta' = 180 - (160)$
$\Theta' = 20^o$ (1st Quadrant)
Also, if θ is 200^o (3rd Quadrant), then:
$\Theta' = 180 - 200$
$\Theta' = 20^o$ (4th Quadrant)

This Mirroring provides a conclusive tool for the practical positioning of any vehicle in a two dimensional plane.

Another question is that how it is possible to follow a circular path if the vehicle is supposed to take a complete 360^o turn? Since r (156 cm as described in the earlier discussion) is a vector quantity, it is not theoretically possible to follow a curved path. The reason will assume this phenomenon is that, since the map coordinates in kilometers and the strength of the vector in centimeters, this value (156 cm) is assumed to be a negligibly small and is viewed as a curve. This is same as determining the area under the curve through integral calculus.

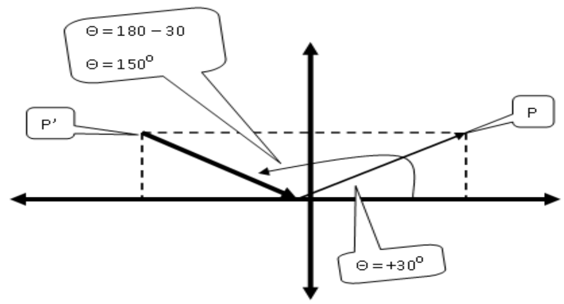

Fig. 6. Position of car with reverse gear

System Requirement And Designing

Using the manual of embedded Microcontroller (Kent Meyer 2012), in the experimental LPS of this research, the values like the mileage, degree of turns of steering, the reverse-forward and the times are acquired by employing an 8051 based circuitry and sending these data to a PC situated inside the vehicle. This PC actually performs the major calculations like the HEX data of the Microcontroller into integers or any other acceptable format, calculating the x-y coordinates, mapping the exact location of the vehicle with respect to the origin, calculating the displacement from the initial to the final position and mileage. Having done that, it becomes quite easy to maintain a database of all the events so that a periodical connection to the base-station via cellular or long-range telephones could be transmit to the station all the necessary parameters regarding the vehicle. This may be done in either of the two ways:

1. The system in the vehicle periodically connects the base-station or
2. The base station periodically connects to the vehicle and extracts required data.

In the light of the preceding discussion, a theoretical model is desired that is cost effective, accurate to a certain extent and most of all, Free from intervention by any foreign fraternity. The GPS relates to a very powerful tool for navigational orientation and is no doubt a distinct solution in this regard but in limits its usage by requiring a huge capital for its setup (Millions of Dollars), it is not perfectly accurate (a standard GPS could send an erroneous signal ranging from 1-100 Kilometers) and it cannot function without the influence of the governing setup.

The LPS is generally intended for heavy-duty vehicles that make a firm contact with the ground. The reasons for that are the systems primary requirements:

1. The degree of the revolution of the steering of the vehicle, **2.** A constant rate of acceleration (Mileage), **3.** The direction (reverse of forward).

As the degree of revolution is necessary and the vehicle should maintain a constant reference and if there is no firm contact with the surface, the vehicle may soon get disoriented. Other requirements may include:, **1.** A constant measure of the rpm of the engine, **2.** The fuel level, **3.** Standard Time, **4.** Vehicle status (Wheels, oil level, Coolant status etc)

In Designing of LPS, criteria adopted for this arrangement is as follows:

As shown in **(Fig. 7)** the system requires a value corresponding to the turns of the steering, an arrangement could be made that includes optical devices and a circular arrangement of 360 slots, Surrounded at the bottom of the steering rod, each slot corresponding to the degree of turn of the steering.

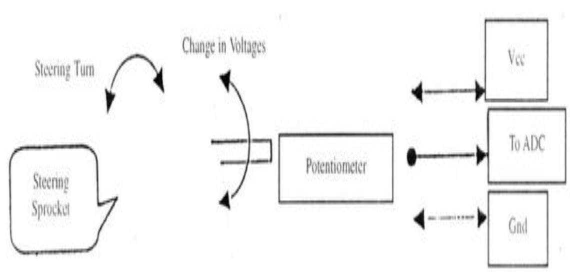

Fig. 7. Measuring steering sprocket

This method is not reliable as if the system shuts down, it will become very difficult to maintain the measure of the last degree of turn (it is an integral part since it disorientate the vehicle if an exact value in not present). Secondly making 360 slots at precise degree levels and then mounting them on the steering would become a hassle. A more reliable solution adopted in this research was to make a voltage reference with a variable resistor, attaching it, with a sprocket to the steering rod converting its output to digital levels with the help of an A/D converter and taking the minimum and maximum extremes of the output levels, assuming that the middle of these extremes is where the steering heads straight and sending these levels to a controller that manipulates it.

For mileage, an arrangement is made using an optoisolator and slot connected to the speedometer cable that intersects the optoisolator, once every revolution of the wheel. Each cut corresponds to the distance traveled, which is equal to the circumference of the wheel. Thirdly, the direction, Whether the vehicle is moving forward or is moving in a reverse direction is indicated by connecting a micro switch to the gear assembly that signals logical low level if the direction is forward, else high otherwise. Optional interfaces like the temperature of the engine its rpm; fuel level, standard time etc can also be included in almost the same fashion.

The following fragments are required by the system to manage the required tasks:

1. An MCS-51 family Microcontroller that manipulates the data transaction on the physical level.

2. A stable voltage source LM309 is recommended because of its characteristic of delivering fixed 5 volts despite of fluctuations ranging between 50 volts.

3. An A/D converter such as ADC0808 which is an 8-bit A/D converter with 8 channels multiplexer.

4. An optoisolator for acquiring the direction of the vehicle 12 or more 7-segment display to display the mileage speed and time other than the computer.

5. A 7414 Schmidt triggers that acts as an oscillator for the A/D converter.

6. The MAX-232 IC may be used for converting the 8751`s serial data into RS-232 compatible protocol, but in the project a more simple approach is employed using an NPN transistor.

7. A potentiometer assembly that sticks with the steering to supply a voltage reference for the A/D converter.

8. An optoisolator assembly, which connects with the speedometer cable of the vehicle to acquire mileage levels.

9. IBM-PC compatible machines with a powerful Microprocessor and enough RAM and data storage media to support hug-programming environment.
10. A fast modem and a cellular/long-range phone.

System specification (Hardware)

The Acquisition section of the LPS consists of 6 segments: **1.** The A/D Conversion, **2.** Speed /Mileage Acquisition, **3.** 2 Digit Seven Segment Display, **4.** RS-232 Compliant Circuitry, **5**. Direction Recognition, **6.** External Oscillator for the 8751 and power resources.

The A/D Converter: It consists of network compromising of 7414 Schmidt-Trigger and the inverter in the IC is connected as an oscillator to produce a 300 KHz clock for the A/D converter. with the V_{REF} of 5V the A/D converter will have 256 steps of 15mV each since the vehicle cuts a full turn of 62° (left to right) the 10KΩ potentiometer delivers out a reference voltage of approximately 1 step of the ADC per 1° degree turn of the vehicles steering. This is later converted into angle of turn (θ) by the software.

Speed/Mileage Acquisition: The Segment mainly consists of an optoisolator that gives out a normally high signal (logic 1) which turns low (logic 0) when the mechanical slit cuts through it. This indicates the complete revolution of the vehicles wheel. That is later converted by the software into Mileage and speed.

12 Digit Seven Segment Interface: The method employed in this scheme deals with the persistence of vision. In the research we display over 12 segments but only one is activated at a time reducing the power consumption of the circuit and the circuitry itself. Using 74159 (4-16 line decoder) which has open collector output and 7447 (BCD to 7 segment decoder/driver) we address the particular display and send the desired digit at an instant, and all the other display are kept with the same digit. Since this is done rapidly that is more than 30 times per second, the human eye can not perceive the sequence of the display. This process runs through interrupts, as the data appears in the registers an interrupt routine is generated that display the required digit. These interrupt are run in the background invisible from the process but so fast (i.e. 1μs) that it feels seamless to the operation.

RS-232 Compliant Circuitry: RS-232 protocol is usually employed for communication between two terminals. This standard requires around-10V for a logical high and 0 through 10 volts for a logical low. In our strategy, we operate on 5V for a low (0) and 0V for a logical high, which inverts any given signal.

Direction Recognition: An optoisolator or a switch was employed for this task. Pin number 7 (P1.6) of the 8751 is used for this purpose. Another optoisolator is connected to the reverse light of the vehicle to indicate that the vehicle is reversing.

External Oscillator for the 8751: The 8751 feature an on-chip oscillator that is driven by a crystal connected to pins 18 and 19, stabilizing capacitors are also employed. The nominal crystal frequency is 12 MHz but in this research, a more accurate frequency of 11.0592 MHz is taken, that can easily provide baud rate of 9600 bps (Nathan L. 2011, Vossiek M. 2003, Ling P. 2010, Koichi H. 2012).

Power Resources: Since the system is supposed to be run within the vehicle (usually 12V), no external supply resources are required. LM309 voltage regulator is used since it outputs rigid 5 volts (the circuits operating voltage) in the output even if the input fluctuates widely (Marsden and Tromba, 2011).

3. RESULTS AND DISCUSSION

Integrating all the components, we come up with the system that successfully manages to impart the value of θ and r, required by the plotting software in the attached computer system. System software developed in Assembly language and visual BASIC. Integration and Evaluation of the system process also come up with some observation summarized in following discussion as primary and secondary with possible solution.

3.1 Primary Observation

3.1.1 Unstable Value of the Received θ: The value of θ is acquired as an integer where as this is not accurate since there lie continues intermittent values between each step received by the Visual Basic routine. Each step is equivalent to 1.22''. This problem may cause θ to be unstable. This problem can be hurled away by attaching to the circuitry a 16-bit A/D converter such as ADC 16071 Delta-Sigma A/D converter. This helps in that since as 8-bit ADC has only 256 possible unique output levels corresponding to the 360° (ideal) steering turn of the vehicle, which somehow limits the actual mapping of the degree –to- signal levels. A more enumerated ADC with 2^{16}=65536 unique steps is an adequate choice.

3.1.2 Imperfect Value of Displacement: This problem is again mainly caused by the integer variables used by the Visual Basic code that round off the fractional part of the acquired value of x and y. This convocation into integer values was implemented for simplicity purpose, and can be improved if floating point variables are assigned in place of the integer variables.

3.1.3 Inaccurate Allocation: This may be the most nature-oriented predicament for the LPS. It can be explained as the physical pressure of the wind causing the wheels to skid in one direction while the steering keeps on transmitting a constant value of θ as shown in **(Fig. 8).**

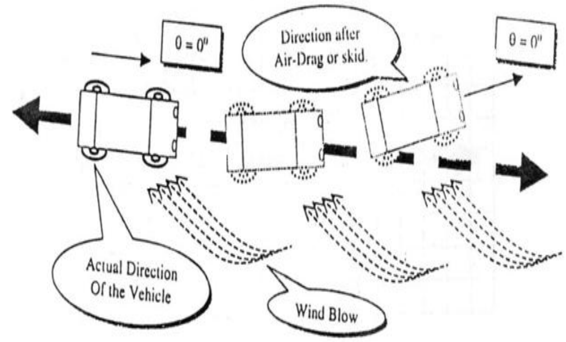

Fig. 8. Inaccurate Allocation

Now this is a major problem, because the value of θ is supposed to change, but it does not because the wheels do not turn. Same is the case when full brakes are applied and the vehicle may skid from a few centimeters to tens of meters, here both θ and r (mileage) may be lost, because wheels are jammed but the momentum displaces the vehicles from the original point.

The answers to these questions require virtuous Research and Development and may imply a few amendments in the design of the experimental LPS. A small turnable wheel can be attached to the chassis of the vehicle, which remains in firm contact with the ground, which may evade this death to a certain extent.

3.2 Secondary Observation

3.2.1 Non-Continuous Transmission: In the LPS, the r and θ parameters of the vehicle are transmitted periodically. This is done to reduce the cost/minute charge of the Cellular/Long-Rang phone. As a continuous transmission would not be feasible, a periodical transmission cannot be reliable. A solution to this could be a package deal with the Telephone Company to charge a fixed amount for round clock usage that particular phone.

3.2.2 No System Backup: As the vehicle shut down its battery power, the system follows suit. This is not desired. As expect for the very first time the LPS is installed in a vehicle, it should keep a record of its mileage and direction need not to maintained as the potentiometric approach always keeps the last value of voltage reference when the vehicle was stopped. The mileage needs a record as it is taken by an optoisolator which only sends pulses and does not keep any reference. For this, a simple database storage routine could be added to the Visual Basic software which always stores the last values of mileage ® and θ. Yet another approach is the use of battery backup. Since the circuitry runs on 5V supply, the battery backup's life is expected to be comfortably sufficient.

4. LPS APPLICATION

As the LPS is intended for tracking purposes of automotive vehicles, so at the current design setup, the LPS is most suitable for the following:

4.1 Hospitals Ambulance services: Certain measures can be taken to allocate residential codes for each registered resident in the vicinity of a hospital, these codes should correspond and map to the geological (x,y) coordinates of the tenant so in cases of emergencies, the code (Geological Coordinates) could lead the ambulance from the Hospital to the patient's main gate. The same way, ambulances could be tracked and location anytime, anywhere and sent to the shortest possible route, as shown in **(Fig. 9).**

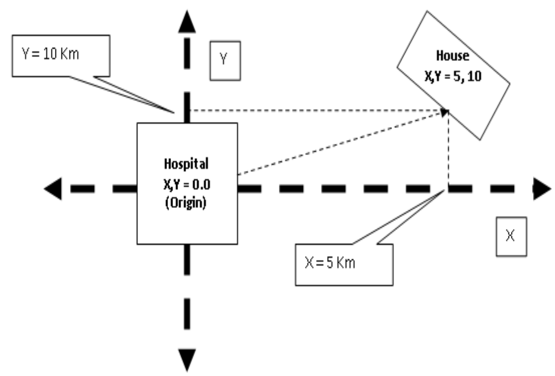

Fig. 9 LPS application for Ambulance service

4.2 Police Monitoring system: Like the ambulance setup, the police mobiles could also be equipped with the LPS and any snatched automobile having the LPS installed could be effectively located. For that both the police mobile and the automotive must have the same origin (The Police Station) as shown in **(Fig.10).**

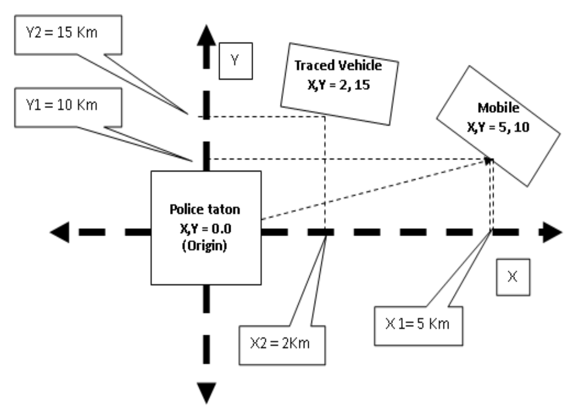

Fig. 10 LPS Application for Police Mobile

5. CONCLUSIONS

While GPS has been widely used for outdoor application there is as yet no local positioning system with broad applicability for situations where GPS is unavailable or unreliable hence the research developed and designed low cost, Local Positioning System (LPS) and tested successfully in controlled environment based on 8751 Microcontroller Assembly language and Visual Basic codes. There are numerous benefits of this research and the designed system can be setup in different public departments such as Hospitals Ambulance services, Police Monitoring system and freight services etc., to enhance their effectiveness and efficiency.

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