

Intelligent Location Identification and Passenger-Alert System in Indian Railways using GPS Receiver

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Abstract—The aim of this work is to develop an intelligent real-time interactive information system which senses the location and calculates the distance of the train to the destination railway station which is taken as input from the passenger. The system also calculates the average speed of the train from the start of the journey and calculates the estimated time remaining to reach the destination based on the remaining distance and the average speed. The proposed system facilitates the passenger to precisely identify the railway schedules which are associated with unexpected delays. The estimated time of arrival can be predicted with high accuracy as time remaining to reach the destination is estimated based on average speed of the train. The system would alert the passenger when the train is within a pre-specified distance to a mentioned destination. An alarm is activated once the distance is within a certain pre-specified limit, thereby functioning as a passenger-alert system. The purpose of this alert system is to make sure that the passenger travelling in the train alights comfortably at the intended destination. A novel embedded system has been designed interfacing a GPS receiver with a host Field Programmable Gate Array (FPGA) board.

Keywords—*Field Programmable Gate Array (FPGA), GPS Receiver, Location Identification, Embedded System.*

I. INTRODUCTION

Unpredictable railway schedules have made it virtually impossible to estimate the time of arrival at the required destination. This may lead to a lot of discomfort in identifying when the destination has been reached, especially during the night hours. Unfamiliarity with a region also makes it uneasy for passengers to alight the train at the required destination. Stations cannot be easily identified by passengers in higher berths and air-conditioned coaches.

GPS tracking was initially developed for military purposes, but it is now widely used for variety of applications like cars, golf carts and even cell phones, because of its versatility [1][2]. There are some types of GPS devices that are extremely miniature in size and hence can be worn on the body or slipped into a pocket. These devices greatly allow people to track others as well as valuables from anywhere else through internet. In fact, with even smaller dimensions and weights coupled with the availability of solar cell power, these GPS tracking systems can be used in number of applications and situations. Location identification using GPS has seen a sharp rise owing to its simplicity and increasing affordability of GPS based devices [3].

Embedded Systems are basically computer systems used for a specific purpose. It has a lot of advantages, which are designed to do meet real time performance constraints. This design strategy also allows the system hardware to be simplified and the streamlined make-up of embedded systems allow their components to be less expensive and so costs are reduced. The hardware is usually in the form of small computerized parts in larger devices which serve a general purpose and the program instructions for embedded systems run with limited computer hardware resources, little memory and small or even non-existent keyboard or screen. These systems do not involve the redundant programming as in other system models.

Field Programmable Gate Arrays (FPGAs) offer significant advantages in high performance and low volume applications. They also offer high flexibility in hardware programming and can be easily reconfigured as per the requirements at a particular point of time without much change in the external circuitry [4]. FPGA's are merely logic multithreading real time processing chips. For example, a microcontroller features certain set of peripherals like UART, SPI, PWM, Timers, and so on, and they are limited to it. Unless microcontrollers, FPGA don't feature built-in peripherals, instead, peripherals can be logically programmed. FPGAs are very powerful in this regard, as they contain raw logic gates, and any hardware can be configured into the gates. For example, it can be programmed to run like being a 1 UART chip, like a 100 channel PWM generators, 20 channel UART controller + 10 ethernet, 40 timers and it can even be reconfigured to emulate a whole microcontroller or several microcontrollers in a single chip, depending on quantity of gates available. In fact FPGA's are often used in PCI bus cards to perform high speed time critical specialized tasks a microcontroller would just couldn't afford due to its architecture. Unless microcontrollers, FPGA don't run on a core, FPGA run multithreaded cores. This is the reason why FPGAs are used for time critical applications like real time multi motor control (period generators) for Computer Numeric Control (CNC), robotic arms, in general terms, any multi-axis (multi-motor) precision application. An emphasis on the importance of using FPGA in the embedded systems using GPS is discussed in [5] - [9]. The real-time performance of the analog signal processing for demodulation unit of GPS receiver is compared with its implementation using FPGA in [5]. Added to it, an all-digital demodulation unit was designed and implemented in FPGA. The implementation of

GPS receiver using FPGA was reported in [6] with an extensive implementation of algorithm for acquisition and tracking of GPS signal. The paper on fast acquisition of GPS signal using extended multiple correlator using FPGA [7] clearly validated the advantages of using FPGA in acquiring GPS signals. Moreover, the FPGA advantages and its future in various fields such as car navigation, transportation, public security etc, were discussed in [8]. A GPS data acquisition and processing system for storage type integrated measurement systems was implemented using FPGA and the results were reported in [9].

Keeping all the above factors quoted in [5] - [9] in mind, a novel embedded system has been designed to resolve this problem using Field Programmable Gate Arrays (FPGA) and a GPS receiver to alert passengers in train when the intended destination is lesser than a pre-specified distance so that they can comfortably alight at the destination.

II. APPROACH AND METHODOLOGY

In this design, a GPS receiver (Baud rate - 9600, Refresh rate - 1Hz) is used to continually track the location of the train. The receiver spots as many satellites as possible and collects positional (x,y,z coordinates) and time data from all the satellites spotted. For example, assuming that four satellites are spotted, the pseudo ranges are calculated as:

$$\begin{aligned} P^1 &= c\tau - c\tau^1 = \sqrt{(x^1 - x)^2 + (y^1 - y)^2 + (z^1 - z)^2} \\ P^2 &= c\tau - c\tau^2 = \sqrt{(x^2 - x)^2 + (y^2 - y)^2 + (z^2 - z)^2} \\ P^3 &= c\tau - c\tau^3 = \sqrt{(x^3 - x)^2 + (y^3 - y)^2 + (z^3 - z)^2} \\ P^4 &= c\tau - c\tau^4 = \sqrt{(x^4 - x)^2 + (y^4 - y)^2 + (z^4 - z)^2} \end{aligned}$$

where,

$$\begin{aligned} P^k &= \text{Pseudo range of } k^{\text{th}} \text{ satellite} \\ x^k, y^k, z^k &= \text{Position of } k^{\text{th}} \text{ satellite} \\ \tau &= \text{Clock bias of receiver} \\ \tau^k &= \text{Clock bias of } k^{\text{th}} \text{ satellite} \\ c &= \text{Speed of light} \end{aligned}$$

The location of the receiver is obtained by solving the above set of simultaneous equations and the position is obtained in terms of the cartesian coordinates and time. The equations can be solved by Bancroft's method, Trilateration, Multidimensional Newton-Raphson calculations or by any algebraic/numerical methods. The coordinates are resolved into latitude, longitude, altitude, speed and course etc. which are parameters of the NMEA protocol. The NMEA supported GPS receiver transfers data as dictated by the protocol. The GPS receiver transfers data to the FPGA host board through the RS232 interface.

III. PROPOSED SYSTEM

A. Algorithm

Fig. 1 is a flowchart of the software code which is employed in the device. Initially, the device displays all railway stations whose positional information (GPS coordinates) are stored, as shown in Fig. 2.

An input is taken from the user by invoking the touch-screen and pointer context Application Programming Interfaces

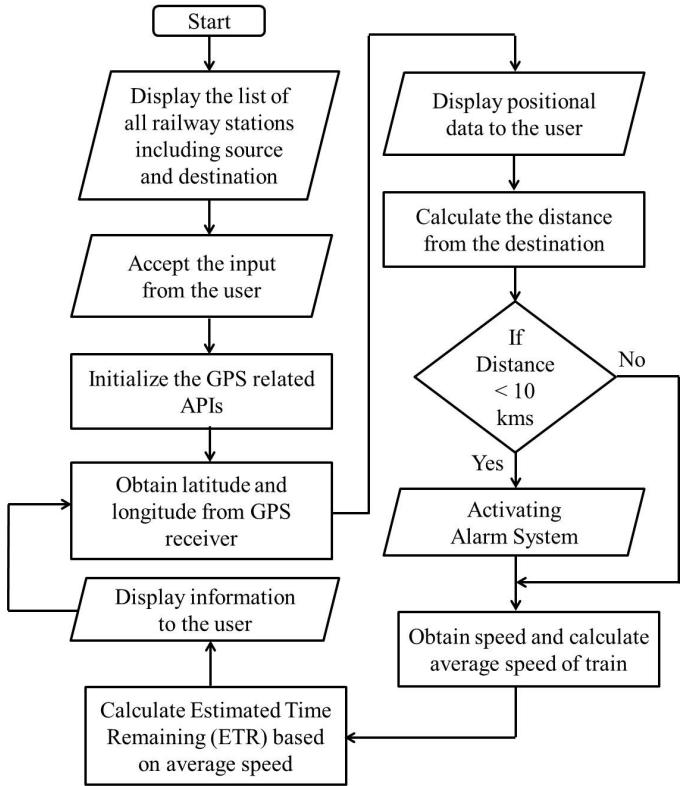


Fig. 1. Flowchart of Algorithm

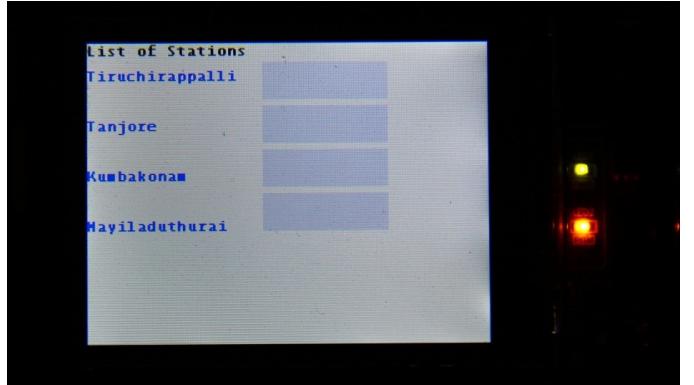


Fig. 2. List of Railway Stations on TFT Display

(APIs). The received input is processed to identify the user's selection. The GPS related APIs are called to initiate the receipt of information from the GPS receiver. The received stream of bytes is decoded and the latitude and longitude component of positional information is retrieved. This data is displayed to the user and the distance (in kilometres) between the train and the destination railway station is calculated using the Haversine formula. The Haversine formula is used to calculate the distance between two points on a sphere from their latitudes and longitudes, having advantages of being well-conditioned for numerical computation even at small distances. The expressions are as follows:

$$\begin{aligned} \alpha &= (a_1 - a_2) * \pi / 180 \\ \beta &= (b_1 - b_2) * \pi / 180 \end{aligned}$$

$$\begin{aligned}
\gamma &= \sin^2 \alpha + (\cos a_1 * \cos a_2 * \sin^2 \beta) \\
\delta &= \arctan(\sqrt{\gamma}, \sqrt{1 - \gamma}) \\
d &= r * \delta
\end{aligned}$$

where,

- a_1 = Latitude at current location of the train
- a_2 = Latitude of intended station
- b_1 = Longitude at current location of the train
- b_2 = Longitude of station
- r = Radius of the earth
- d = Distance between the train and the station

If the distance is lesser than 10 kilometres, the alarm system is activated. The position and speed related information is continually updated, displayed and distance is recalculated at the refresh rate supported by the GPS receiver.

B. Implementation using FPGA

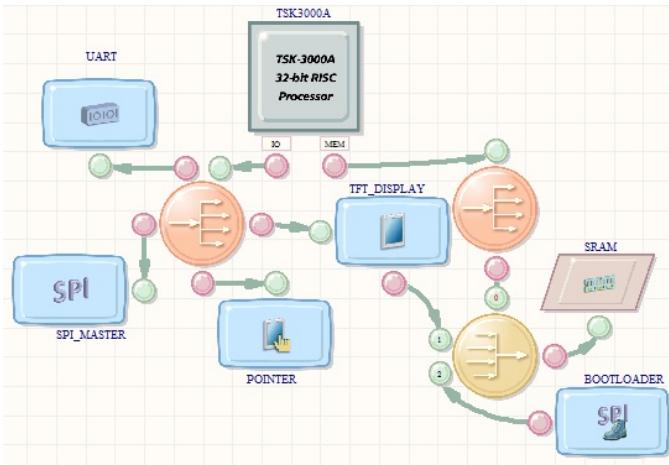


Fig. 3. Schematic of Hardware Implementation in FPGA

The embedded system designed and implemented on the FPGA hosted in Altium Nanoboard NB3000 employs a TSK3000A processor. Fig. 3 is a schematic that describes the major hardware blocks used in the FPGA. The TSK3000A processor is a 32-bit, soft-core, RISC processor and is compatible with the Wishbone bus system. The processor is employed with the other hardware viz. UART, SPI master controller, touchscreen pointer context, Thin Film Transistor (TFT) display, SRAM and bootloader. The UART block is a serial communications port (Wishbone-compliant), providing serial communication with hardware handshake and FIFO buffers. The SPI master controller enables communication with multiple slave SPI peripherals. The pointer component detects the status of stylus (for touchscreen input) and feeds it to the processor. The TFT display controller provides a 32-bit interface between the processor and the LCD display, supporting resolutions of 240x320 and 320x240. This controller also has a timing unit which is capable of generating all required control and timing signals. The SRAM controller provides a

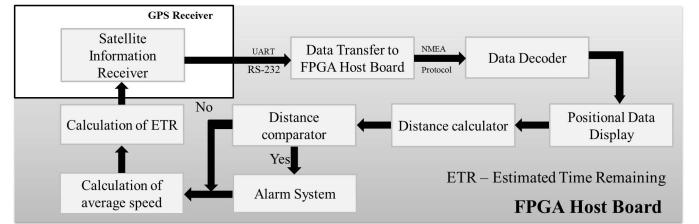


Fig. 4. Block Diagram of the Overall System

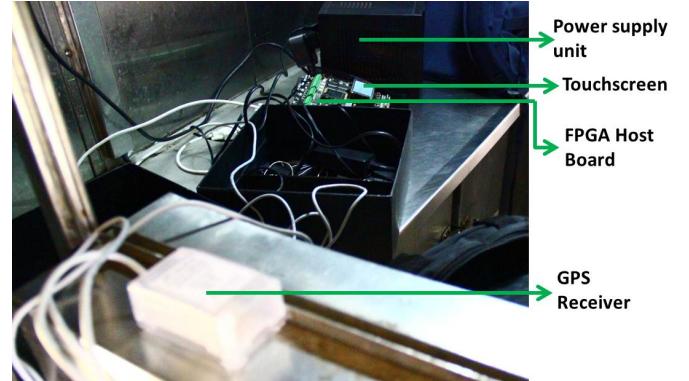


Fig. 5. Photograph of the Entire Test Setup in the Train

simple interface between asynchronous static RAM and a 32-bit processor. The entire design is flashed into the bootloader for standalone operation.

Fig. 4 describes the block diagram of the proposed system. A UART driver is instantiated in the software module of the embedded system to receive the raw data in the NMEA protocol. Sufficient software wrappers programmed over the basic UART driver help in directly rendering the positional data i.e. latitude, longitude and speed of the receiver (which is placed in the train). The required destination is selected by the user by means of an on-board touchscreen interface as mentioned above. An algorithm to calculate the distance between the GPS receiver and the destination, and the average speed of the train is one of the software components of the design. The algorithm continuously calculates the distance and speed as the positional data is periodically refreshed. Once the distance is sensed to be below ten kilometres, an alarm notice is raised on the TFT display.

IV. HARDWARE IMPLEMENTATION AND FIELD TEST

The entire hardware included the FPGA host board interfaced with the GPS receiver by the RS-232 interface powered by an Uninterrupted Power Supply (UPS) unit as shown in Fig. 5. The device was tested between Tiruchirappalli and Mayiladuthurai in Tamil Nadu, INDIA, as shown in Fig. 6. The train was bound to Mayiladuthurai from Tiruchirappalli. The intermediate stations at which the train stops are Tanjore and Kumbakonam. All these railway stations are based in the state of Tamil Nadu, INDIA. The GPS coordinates of the above mentioned railway stations are given in Table I.

The first level of testing was carried out in four phases. Initially, the device was tested at the departing station, Tiruchirappalli for successful alarm activation. The final destination is



Fig. 6. Map of Train Route between Tiruchirappalli and Mayiladuthurai

TABLE I. GPS COORDINATES OF RAILWAY STATIONS

S. No	Station	Latitude	Longitude
1	Tiruchirappalli	10.795318	78.684045
2	Tanjore	10.778036	79.138096
3	Kumbakonam	10.961695	79.388113
4	Mayiladuthurai	11.095272	79.629057

Mayiladuthurai but the device was tested at every intermediate station i.e. Tanjore and Kumbakonam. Hence, the second and third phases include successful alarm activation when the train neared Tanjore and Kumbakonam respectively and the final phase was carried out between Kumbakonam and Mayiladuthurai.

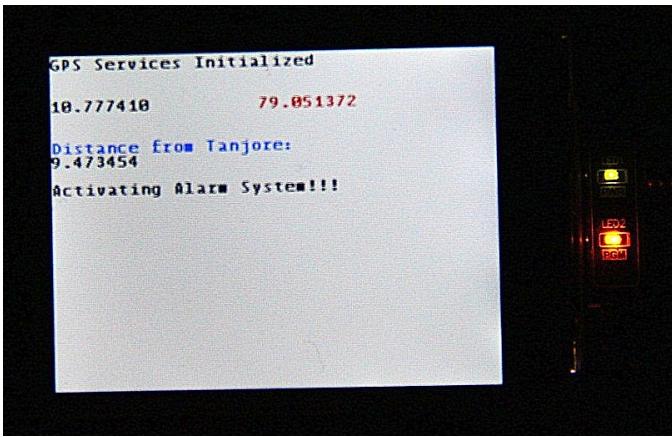


Fig. 7. Activation of Alarm when the Train is less than 10 km from Tanjore

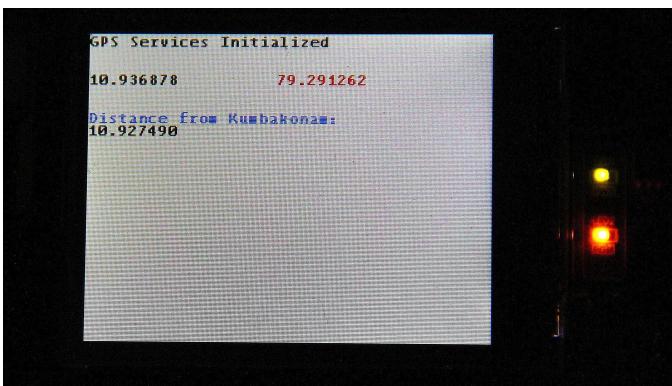


Fig. 8. TFT Display when the train is approaching Kumbakonam

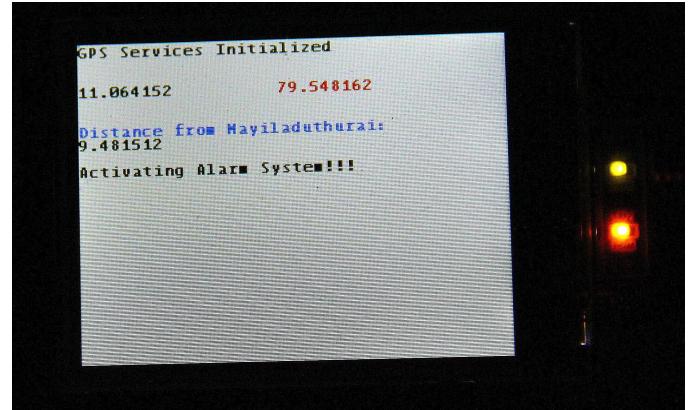


Fig. 9. TFT Display when the train is approaching Mayiladuthurai

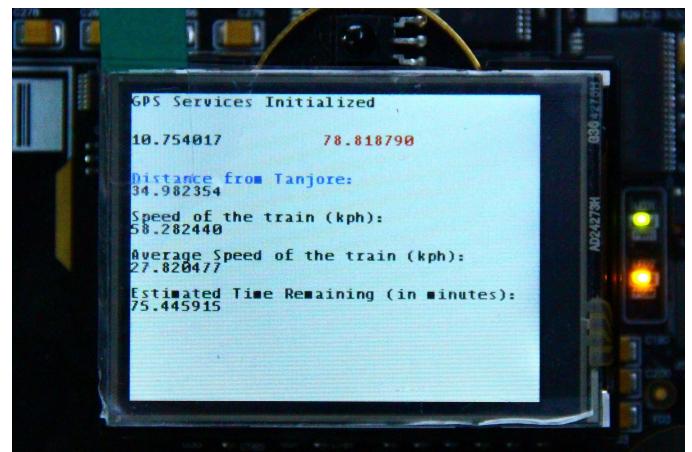


Fig. 10. Information on TFT Display when the Train is between Tiruchirappalli and Tanjore

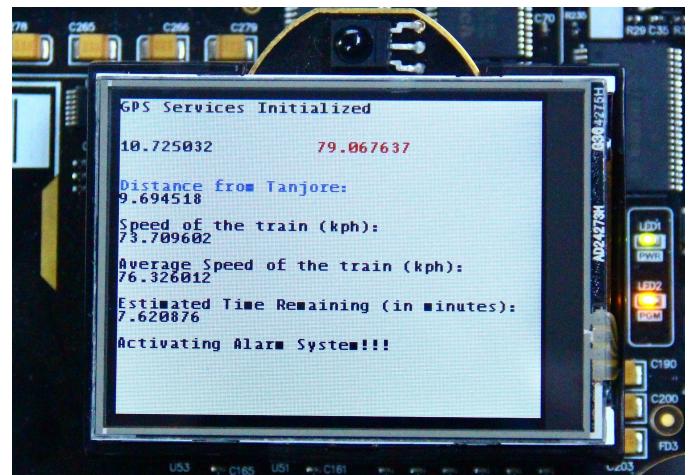


Fig. 11. Activation of Alarm when the Train is less than 10 km from Tanjore

Fig. 7 shows the TFT display during the initial phase of first level testing, when the distance of the train from Tanjore is less than 10 km, indicating alarm activation. After the train reached Tanjore, the destination was reset to Kumbakonam for the test of the next phase. Fig. 8 indicates that the train is at a distance farther than the pre-specified distance from the destination and

Fig. 9 indicates the successful activation of the alarm when the train is approaching the destination railway station of the last phase, Mayiladuthurai.

The second level of testing after including the features of average speed of the train and estimated time remaining to reach the destination was carried out between Tiruchirappalli and Tanjore. Fig. 10 is a screenshot of the TFT display, in the first phase, when the train is between Tiruchirappalli and Tanjore, indicating distance remaining to the destination, average speed of the train and estimated time remaining. Fig. 11 indicates that the distance of the train from Tanjore is less than ten kilometres, indicating alarm activation.

V. DESIGN SUMMARY

The design was synthesized using Altium Designer and the generated device summary is shown in Fig. 12. It indicates that only a fraction of percentage of FPGA resources have been utilized for the design thereby illustrating the simplicity and efficiency of the design in terms of hardware.

Device Resources - Usage Summary			
4-Input LUTs - Logic	4,959 / 22,528	22%	
Average Fan/Non-Clock Nets	3.69		
BUFGMUXs	1 / 24	4%	
IO Pins	118 / 502	23%	
over-mapped for a non-slice resource or if Placed			
RAMB16BWEs	4 / 32	12%	
Slice Flip Flops	2,367 / 22,528	10%	
Slices with only related logic	3,237 / 3,237	100%	
Slices with unrelated logic	0 / 3,237	0%	
Slices	3,237 / 11,264	28%	
Total 4-Input LUTs - Logic	5,187 / 22,528	23%	
Design Statistics - Timing Summary			
No timing constraints.			

Fig. 12. Device Summary Generated upon Synthesis

VI. CONCLUSION

The practical implementation and commercialization of this work could possibly help millions of passengers travelling during situations of late hours and unfamiliarity of the region of destination. This system design provides a superior and user friendly interface (TFT display and touchscreen) and all the required data is periodically updated on the display. An alarm is raised thus enabling the passenger to have a stress-free, comfortable travel without having to worry about the time of reach of the destination, during the journey. This device may be developed as a hand-held device or one that can be deployed in each berth of a train. Such a device will highly benefit the passengers travelling in trains. The future scope of this work is that the coordinates of the stations, instead of being preloaded can be reconfigured to contact a central server for data acquisition.

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