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ABSTRACT

The Global Positioning System GPS, while originally a military project, has significant applications for the civilian industry. Civilian applications benefit from GPS signals by utilizing one or more of three basic components of the GPS location, relative movement, and time.

Muslims around the world perform five prayers a day. The five prayers are based on astronomical position of the sun. Many systems have been developed to serve as prayer time providers but none of these systems provide the time for users that are traveling onboard an aircraft from one country to another, where (depending on the speed and directions of the aircraft) prayer time can change significantly.

INTRODUCTION

Muslims around the world share the same fundamental practice of performing five prayers a day. The five prayers (fajr, zuhur, asar, maghrib, and isha) are speard around the 24 hours based on astronomical position of the sun. Prayers' times are determined using length of the shadow and start and end of twilight (light from sky when sun is below horizon especially in the evening) (Cooper, 1969) . Therefore, prayer times are not the same from one place to another depending on observers' longitude and latitude. Prayers are usually headed by call for prayer known as "Athan". This study will employ GPS to help determine accurate prayer time while traveling across the world.

Large number of civilian applications benefits from GPS signals. The ability to determine the receiver's location allows GPS receivers to perform as an aid to navigation. This study will add one more GPS civilian application that will help determining prayer time for Muslim travelers while onboard an airplane. The GPS receiver will be used to periodically determine the latitude, longitude and elevation of the location of the aircraft. It will communicate with the GPS and based on the time and location, it will update and display the upcoming prayer time.

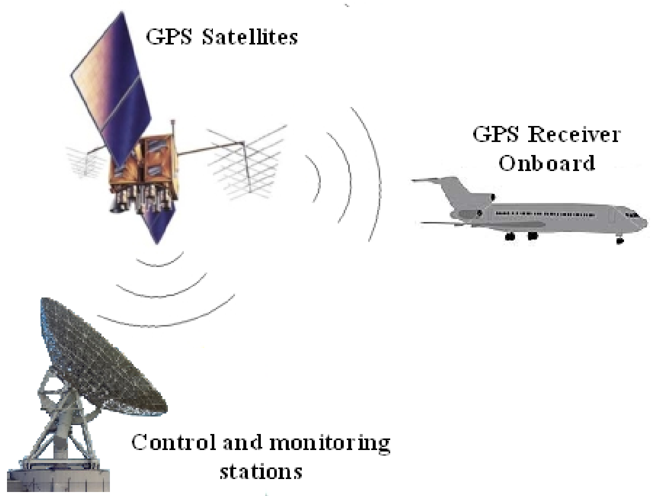
PURPOSE OF THE STUDY

Large number of airplanes travels the world carrying Muslim onboard every day. Plains owned by Muslim countries provide direction for the "Kaabah" in Mecca, where Muslims should face while making their prayers. However, none of which tells their travelers when it is time to say their prayers while traveling around the globe. Traveling Muslims usually estimate prayer times while onboard of an airplane based "their best judgment". Computing appliances have been developed for businesses, students, games for all ages, and for the disabled (McMurtrey, McGaughey, & Downey, 2008). The same computing power can be used to design and develop applications can benefits from GPS signals, to provide a fully automated and accurate prayer time while in motion. Millions of traveling Muslims will benefit from this service.

GLOBAL POSITIONING SYSTEM AND CIVILIAN APPLICATIONS

The Global Positioning System GPS, while originally a military project has significant applications for both the military and the civilian industry. Concerning military applications, GPS allows accurate targeting of various military weapons such as precision-guided missiles. It is also used to navigate and coordinate the movement of troops and supplies.

Figure 1: The Three Parts of GPS.



GPS OVERVIEW

The Global Positioning System (GPS) is a U.S. space-based radio navigation system based on a constellation of about 28 satellites (Diggelen & Abraham, 2001) orbiting the earth at altitudes of approximately 12,000 miles (McNamara, 2004). GPS was developed by the United States Department of Defense (DOD), for its tremendous application as a military locating utility. The system provides location and time information in all weather, day and night, anywhere in the world.

GPS is made up of three parts: satellites orbiting the Earth; control and monitoring stations on Earth; and the GPS receivers owned by users (see figure 1). A satellite has three key pieces of hardware: 1) Computer that controls its flight among other functions; 2) A clock that keeps accurate time within three nanoseconds; and 3) A radio transmitter that sends signals to Earth. The signals broadcasted by the GPS satellites are picked up and identified by GPS receivers. Each GPS receiver then provides three-dimensional location (latitude, longitude, and altitude) plus the time.

GPS has become a widely used aid to navigation worldwide, and a useful tool for map-making, land surveying, commerce, and scientific uses. GPS also provides a precise time reference which makes it perfect reference for prayer time. Many GPS receivers can relay position data to a PC or other device using the NMEA 0183 protocol (Mihai, 2004). defined by the National Marine Electronics Association. The NMEA 0183 standard uses a simple ASCII, serial communications protocol and specific sentence formats for a 4800-baud serial data bus (which can be sent over RS232 serial links). It also defines how data is transmitted in a "sentence" from one "talker" to one or more "listeners". The standard also defines the contents of each sentence (message) type (SiRF Technology, 2005)

GPS RADIO SIGNALS

GPS satellites transmit two types of radio signals: Coarse Acquisition (C/A) and Precision (P/Y). C/A-Code is known as the Standard Positioning Service (SPS) and is the type of signal that is allowed for civil GPS receivers. C/A-code is transmitted at a frequency of 1575.42 MHz. P-Code is known as the Precise Positioning Service (PPS), where the U.S. military is the primary user of P/Y -Code transmissions, which is an encrypted form of the data. The P-code signal is transmitted at 1227.6 MHz. Accepted methods for generating the C/A-code and P-code were established by the satellite developer in 1991 (Rockwell International corporation, 1991) .

The NMEA 0183 standard calls for data communication in the form of coded "sentences." Each sentence begins with the character "$" and ends with a carriage return and line feed (<CR><LF>).Between the beginning and end of each sentence are "fields" of data, each field separated by a comma. There are many different sentences. Table 1 illustrates the NMEA 0183 output messages.

Table 1: NMEA 0183 output messages.

Option	Description
GGA	Global Positioning System Fix Data
GLL	Geographic position Latitude, longitude,
GSA	GPS receiver operating mode, satellites used in the position solution, and DOP values.
GSV	The number of GPS satellites in view
MSS	Signal-to-noise ratio, signal strength, frequency, and bit rate from a radio-beacon receiver.
RMC	Time, date, position, course and speed data.

RMC GPS FIX DATA MESSAGE STRUCTURE

NMEA data is sent as comma-delimited “sentences” which contain information based on the first word of the sentence. There are over fifty kinds of sentences, yet an interpreter really only needs to handle a few to get the job done. The most common NMEA sentence of all is the “Recommended Minimum” sentence, which begins with “$GPRMC” as indicated next:

```
$GPRMC,<hhmmss>,<A|V>,<ddmm.mmmm>,<N|S>,<dddmm.mmmm>,<E|W>,
<kkk.k>,<ddd.d>,<ddmmyy>,<ddd.d>,<E|W>*hhcrlf
```

After the sentence name, the time (in Greenwich) is presented in hours, minutes and seconds. The next field is an 'A' or 'V' character, where A indicates a valid position, and 'V' indicates an invalid position warning. The field after that is the latitude, which is expressed as a 2-digit number of degrees (00 to 89 range), followed by the number of minutes expressed with 2 digits to the left of the decimal point and 4 digits to the right in the range 00.0000 to 59.9999 minutes. The next field is 'N' or 'S' to indicate North or South latitude (relative to the equator). The next field is the longitude, which is expressed in similar fashion, except that there are 3 longitude degree digits in the range 000 to 179 degrees, followed by the longitude minutes and the 'W' or 'E' hemisphere (relative to Greenwich England). The next field is the ground speed in the range 000.0 to 999.9 knots (a knot is 1.152 miles per hour). The next field is the heading or direction expressed in degrees with respect to true north in the range 000.0 to 359.9 degrees. The next field is the UTC date expressed as a 2-digit date (01-31), 2-digit month (01-12), and 2-digit year (00-99). The next field is the magnetic variation in degrees in the range 000.0 to 180.0 degrees; this variation quantifies the difference between "true north" and the "magnetic north" indicated by a compass. The next field is the direction of the magnetic variation; westerly magnetic variation adds to the true course. The '*' checksum indicator, hexadecimal ASCII checksum, and carriage return/linefeed complete the sentence. An example of "$GPRMC sentence is:

$GPRMC,040302.663,A,3939.7,N,10506.6,W,0.27,358.86,120598,,*1A

The sentence contains everything our GPS application needs: latitude, longitude, speed, bearing, satellite-derived time, fix status and magnetic variation (see table 2).

Table 2: RMC Data Format.

Name	Example	Description
Message ID	$GPRMC	GGA protocol header
UTC Time	40302.663	hhmmss.sss
Status	A	A = Valid V = Invalid
Latitude	3939.7	ddmm.mmmm
N/S Indicator	N	N=north or S=south
Longitude	10506.6	dddmm.mmmm
E/W Indicator	W	E=east or W=west
Ground Speed	27	
Course Over Ground	358.86	
Date	120598	Horizontal Dilution of Precision
Checksum	*A	
<CR> <LF>		End of message termination

PRAYER TIME ALGORITHM

To calculate the prayer times the latitude (B), longitude (L), and the reference longitude (R) of the location are needed. B and L will be obtained from GPS and R is calculated by multiplying 15 by the difference between local time and GMT (Basic time zones are 15 Degrees of longitude apart: 360º/24H = 15 Degrees/H). We also need to know two astronomical measures called the declination angle of the sun (δ) and the real time-mean time difference, also known as the equation of time (T). The Earth is tilted by 23.45° and δ varies plus or minus this amount calculated by the equation (Cooper, 1969):

$$\delta = 23.45° * Sin\left[\frac{360}{365}(d - 81\right] \quad (1)$$

The equation of time is a correction to be added to the apparent solar time, as read on a sundial, to obtain mean solar time, as commonly used (Parr & Gold, 1972) This difference is a consequence of tilt of the Earth's orbit. The following equations are used to calculate the five daily prayer times (Chen, Soh, Tan, & Tahira, 2008) :

$$Z = 12 + \frac{(R - L)}{15} - \frac{T}{60} \quad (2)$$

$$U = \frac{1}{15} * ArcCos\left[\frac{Sin[(-0.8333 - 0.0347 * Sin(H)^{0.5})] - Sin(\delta) .* Sin(B)}{Cos(\delta) * Cos(B)}\right] \quad (3)$$

$$V = \frac{1}{15} * ArcCos\left[\frac{-Sin(G) - Sin(\delta) * Sin(B)}{Cos(\delta) * Cos(B)}\right] \quad (4)$$

$$W = \frac{1}{15} * ArcCos\left[\frac{Sin\{ArcCot(1 + Tan(B - \delta)\} - Sin(\delta) * Sin(B)}{Cos(\delta) * Cos(B)}\right] \quad (5)$$

Where:

$$\delta = \frac{180}{\mu} * \{ 0.006918 - [0.399912 * \text{Cos}[\beta]] + [0.070257 * \text{Sin}[\beta]] - [0.006758 * \text{Cos}[2 * \beta]] + [0.000907 * \text{Sin}[2 * \beta]] - [0.002697 * \text{Cos}[3 * \beta]] + [0.001480 * \text{Sin}[3 * \beta]] \}$$

$$T = 229.18 * \{ 0.000075 + [0.001868 * \text{Cos}[\beta]] - [0.032077 * \text{Sin}[\beta]] - [0.014615 * \text{Cos}[2 * \beta]] - [0.040849 * \text{Sin}[2 * \beta]] \}$$

$\beta = \frac{J * 360}{365}$ *, and J is the day of year (*e.g. J=0 for Jan 01, and J=41 Feb 10*)*

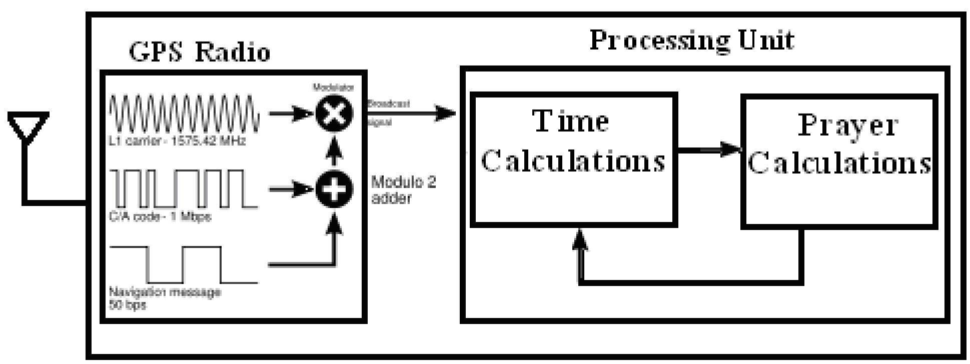
B= latitude of place
L= longitude of place

R= reference longitude (i.e. TIME BAND x 15)
H= height above sea level in meters
δ = declination angle of sun from celestial equator
T= equation of time
G= twilight angle (=18 Degrees)
FAJR = Z-V
ZUHR= Z
ASR = Z+W
MAGHRIB = Z+U
ISHA = Z+V

SYSTEM DEVELOPMENT AND TEST SETUP

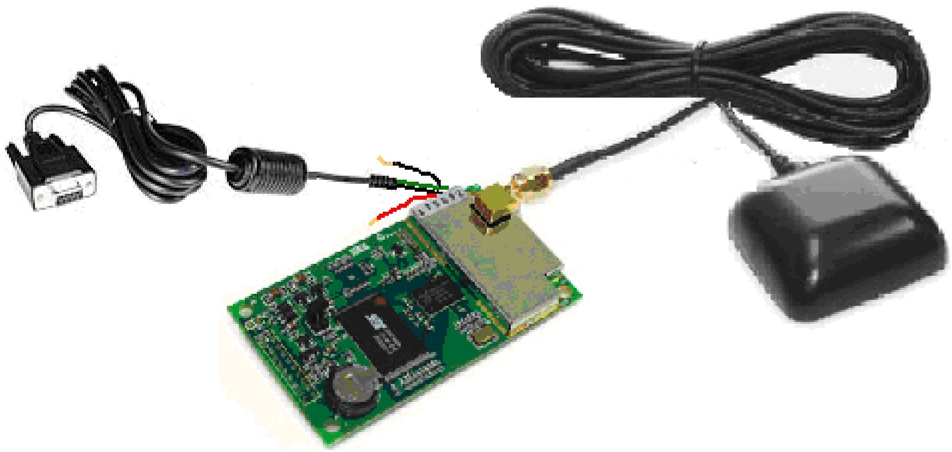
The proposed system consists of two main units: the GPS Receiver and the Processing Unit (see figure 2). The GPS receiver will provide positioning, navigation, and timing services to the processing unit. The processing unit will look for a valid GPRMC sentence from the GPS receiver, calculate time, calculate the "upcoming" prayer time, and then provide the name of the "upcoming prayer" and the estimated time left for that prayer (the use of estimated is due to the fact that the aircraft in motion, so the time left will change based on change in time and change in position). However, information technology infrastructure and processes tend to produce efficient and higher quality results (Evans & Neu, 2008), thus the system could be tuned to produce definitive estimates.

Figure 1: In Motion Prayers Time Detection System.



A GPS Radio receiver was obtained, configured and connected to a laptop for testing purpose. The system contains three different components: The GPS radio, the GPS antenna, and RS232 cable (see figure 3).

Figure 3: The GPS Receiver.

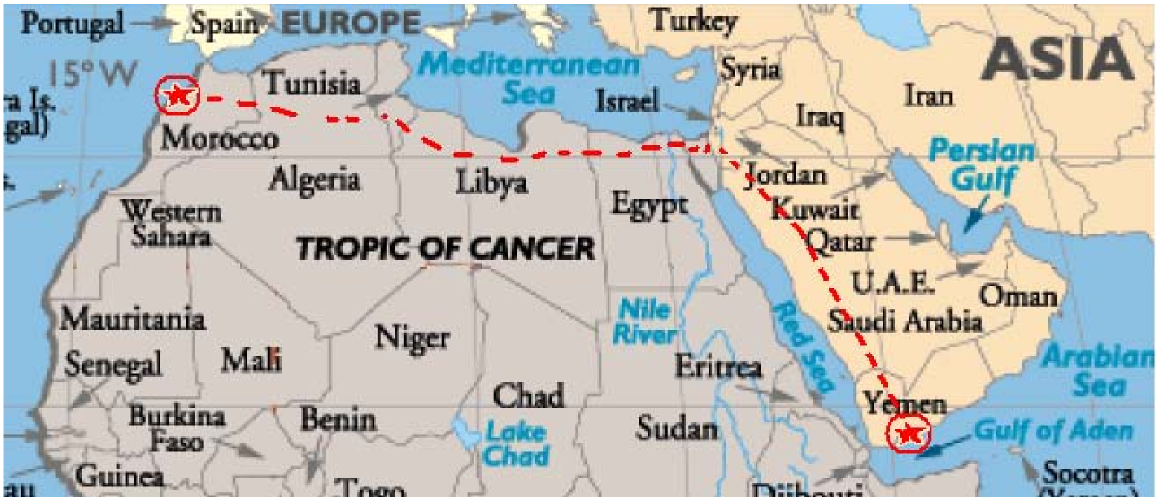


System tests were conducted on the designed system for functionality. These tests are needed to validate both the application design, and verify that the application meets the functional requirements (Nindel-Edwards & Steinke, 2007). To fully realize the potential of GPS acquisition and updating, and to simulate a test while in motion, it is necessary to use a signal simulator to test and verify the research algorithms, due to the fact that the qualifications of the research investigators are critical to the evaluation process (Tesch, Ireland, & Liu, 2008). Skylab GPS Simulator 2.0 is used for that purpose. The Skylab GPS Simulator provides a complete suite for all GPS simulating needs. The Simulator uses the international standardized protocol NMEA-0183 for GPS data exchange. The Skylab GPS Simulator provides the simulation of a GPS receiver on several interfaces. Furthermore Skylab GPS Simulator provides several input methods for GPS data: Manual Input, Map Input, Logfile Playback, and Forwarded Input (Skylab Mobilesystems, 2007). This research will apply the Map Input method.

The map input method lets the user choose a position visually from a map, where several points will be selected and then the simulator will produce the NMEA sentence for the selected location.

An airplane trip was designed to be simulated where the starting point was Adan, Yemen, and the destination was Rebat, Morocco (see figure 4 for trip details). It shall be noted that for this testing, the initial time was the only GPS time to be used since the GPS fix feeds were developed manually by clicking the mouse over the desired location on the map, therefore the elapsed time would be seconds, and thus it would be unrealistic to calculate based on that. Hens, a function were developed to calculate new time based on calculated change in distance (Time = Time + distance/800) where the airplane speed was assumed to be at 800Km/Hr.

Figure 4: Map presentation of the simulated trip (original map source World Atlas, 2008).



TEST RESULTS AND CONCLUSIONS

The test was conducted at 5:00 GMT on February 14, 2008. The traveling distance was around 700 Kilometers and was to take 8,5 hours during which three different prayers of the five daily prayers would be performed. The test results are illustrated in table 3. As the test results indicates, promising results were obtained.

Table 4: Calculated upcoming prayers for the simulated Aden to Rebat Trip.

Location Name	LATITUDE	LONGITUDE	Next Payer Time
Aden,Yaman	12.75944	44.98306	4hrs 12 min until zuhur
Mecca, Saudi Arabia	21.48306	39.74944	3hrs 11 min until zuhur
Medina, Saudi Arabia	24.46889	39.61389	2hrs 47 min until zuhur
Tabūk,Saudi Arabia	28.38306	36.58306	2hrs 19 min until zuhur
Maan, Jordan	30.19972	35.73361	2hrs 5 min until zuhur
Amman, Jordan	31.9456	35.9255	1hrs 51 min until zuhur
As Suways, Egypt	29.96694	32.55028	1hrs 24 min until zuhur
Cairo, Egypt	30.04972	31.36611	1hrs 12 min until zuhur
Siwa, Egypt	29.18361	25.51694	42 min until zuhur
Banghazi, Libya	32.18361	20.05028	1 min until zuhur
Tripoli, Libya	32.81639	13.13278	3 hrs 13 min until asar
Gabes, Tunis	34.01694	10.50028	2 hrs 23 min until asar
Gafsa, Tunis	34.40028	8.71694	2 hrs 11 min until asar
Constantine , Algeria	36.365	6.61455	1hrs 38 min until asar
Oran,Algeria	35.69111	-0.64194	36 min until asar
Fas ,Morocco	34.05028	-4.9738	2 min until asar
Rebat,Morocco	34.0206	-6.8244	2hrs 24 min until maghrib

Table 4: Calculated vs. Actual upcoming prayer For Jordanian Cities.

City	Calculated time*	Actual Time*
Irbid	9:48	9:50
Ajlun	9:48	9:48
Jarash	9:46	9:50
Zarka	9:47	9:50
Zarka	10:49	10:49
Amman	10:46	10:49
Amman	10:47	10:49
Madaba	10:52	10:50
Shawbak	12:58	12:59
Tafila	12:57	12:59
Ma`an	12:55	12:57
Aqaba	3:19	3:22

* GMT Time

To farther test the accuracy of the system, the hardware was installed on a vehicle and was driven around different cities in Jordan for collecting data and comparing results with publicly announced prayer time. A summary of the collected data is listed in tables 4.

The proposed system has shown its capability to employ GPS for one more civilian application and provide accurate calculations for prayer time while in motion. Although the collected data indicates one to three minutes time difference between actual and calculated time, this should not be considered as an issue. Prayers are usually preceded by "Athan" that takes between 2 to 3 minutes to complete anyway.

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