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An Efficient GPS and GSM Based Tracking System For Educational Institutions

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ABSTRACT
Tracking systems are one of the most popular types of modern technologies worldwide for monitoring personal belongings in indoor and outdoor environments. Nowadays, the tracking systems are being utilized in various trends and purposes to trace the location of high-value items, such as jewelry, vehicles, cellular telephones, laptops, handbags, …etc.This scientific paper presents a novel positioning tracking system to monitor the faculty members' personal belongings at various university institutions of Egypt.The proposed Android-based tracking system consists of two important parts: locator and tracker. The locator includes a hardware device for locating the personal belongings of the faculty members. On the other hand, the tracker includes an Android app installed on the smartphone devices of the faculty members to enable them to remotely monitor and manage their personal belongings from anywhere at any time. The system evaluation process is carried out at two levels. At the 1st level, the viability of the proposed Android-based tracking system for use in real world environments is verified, and the result of this level shows that the proposed tracing system is broadly applicable for tracing the personal belongings of the faculty members in open environments. At the 2nd level, the accuracy of the proposed tracing system in locating the personal belongings of the faculty members is verified, and the result of this level indicates that the maximum error of the proposed tracing system in reading the location of the faculty members' personal belongings is in the allowed global scope.
Keywords: Educational Institutions, Tracking Systems, GPS, GSM, Android Apps, Validity Test, Accuracy Test.

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I. INTRODUCTION

The life requirements make people spending more time out of their home during normal conditions to engage in different forms of life activities, such as work, shopping, dining, entertainment, fitness and social services [1-7].

Nowadays, with the increasing daily tasks performed by the individual, he is exposed to more stress and tension, which over time can negatively affect his memory efficiency, causing of forgetting various personal items, such as house keys, car keys, paper documents, events, ... etc [8].Therefore, object tracking technologies are becoming more popular and useful tools for monitoring tangible and intangible belongings [9,10].

Object tracking refers to the process of verifying the location, status, and value of tangible and intangible personal belongings in both indoor and outdoor work environments [11-14], and it is not only limited to tracking devices or tools, but also includes people, for example an employee can be tracked to measure productivity, analyze activity sequences, discover travel paths and improve safety[15].

Typically, a common tracking system consists of software running on a computer or mobile device that reads the requested location information through one or more location-tracking technologies connected to the target personal belongings. Practically speaking, the tracking software can track personal belongings in real time and display their geographic location on a map, update their data and send notifications when they need maintenance [16].

Through different types of organizations around the world, many tracking methods based modern scientific studies are now available to monitor the location of personal belongings [17]. The most important of them are GPS, RFID, Barcode, Global Trade Item Number (GTIN), … etc[18].

In today's world, the spread of mobile phones as portable devices has led to many innovative systems that serve our daily activities, most notably tracking systems [19]. These types of systems often consist of a GPS (Global Positioning System) receiver, a microcontroller and a GSM (Global System for Mobile Communications) enabled modem [20].

This paper proposes the design and development of a GPS and GSM based system that allows faculty members in various university institutions of Egypt to track their personal belongings in real-time through a new app installed on their Android smartphones.

The remaining parts of this paper are structured as follows: Section II reviews the background of the study and major related works. Section III defines the problem of the study. Section IV presents the proposed tracking system. Section V provides tests and results of the proposed tracking system. Concluding remarks and future works are presented in the last section.

II. BACKGROUND & RELATED WORKS

In the literature, various methods for tracing belongings and items have been explored. In Part-1 of this section, we will focus on reviewing the most important methods that were used in the proposed tracking system. While in Part-2, we will present a number of previous studies related to the current research.

A- GPS & GSM Technologies

In fact, GPS and GSM technologies are the technical backbone of various tracking systems including the current one. A brief description of both is given below.

A.1 GPS Technology

GPS is the key technology for capturing the location of an object and consists of a network of twenty four American satellites, which were formerly used for military services and then became available for business use. These satellites continuously produce and send radio signal with short pulses to the GPS receiver, which takes the signal from at least three satellites to compute the distance and utilizes triangulation method to calculate 2D location coordinates (latitude and longitude) or at least four satellites to calculate 3D location coordinates (latitude, longitude and altitude)[21].

A.2 GSM Technology

GSM is a digital cellular network widely used by mobile phone users in various countries of the world, where the subscribers exceeded one billion users in more than 210 countries by a 70% percent total market share of the world's digital cellular subscribers. GSM provides many useful features making it the most used technology among its peers such as, TDMA (Time Division Multiple Access) and CDMA (Code Division Multiple Access).Among these significant features the use of TDMA technique to transmit signals, the use of encryption technique to guarantee secure phone calls, the use of SMS (Short Message Service) service for text messaging and paging and allows call forwarding, call waiting, and multi-party conferencing. In addition, it provides other standard services such as data networking, caller ID and enables the user to simply change SIM card from one mobile device to another.Numerous published scientific studies confirmed that the GSM technology operates in frequency bands vary from country to country, where it operates in 2900 MHz (890 MHz - 960 MHz) frequency bands in Europe and Asia while in the United States it operates in 1.9 GHz (1900 MHz) frequency band [22].

B- Related Works

In the scientific literature, a large number of tracking systems has been suggested to serve various sectors of society. We will highlight some of the published research papers relevant to our topic in the following:

1- A study entitled "Design and Implementation of a Smart System for School Children Tracking", conducted by "Dawood Zahi Khutar et al (2021)", suggested a tracking system to enable parents to know the location of their children at any time and inform them with a message if the children surpassed the allowed area. In the suggested system, the accurate location of the child in a certain area is initially discovered by identifying the latitude and longitude coordinates through the GSM radio navigation system.Thereafter, the mobile phone receives all the information of the child's location via the GSM modem [23].

2- A study entitled "GPS Based Smartphone Application: Real Time Bus Tracking System for Educational Institutions", conducted by "Tanzila Islam et al (2019)", suggested a bus tracking system for android smartphones to enable students, employees and the teaching staff members of the educational institution to easily and precisely locate the institution buses. The suggested system composed of two major parts: client side and server side. The client side presents a number of facilities to the system user to enable him to remotely monitor the bus of the educational institution through mobile network or WI-FI (Wireless Fidelity), while the server side presents the correct location of the bus to the server. Both sides of the users can see the real position of their bus within a few moments of the update period, which reduces unnecessary user trouble and waiting time [24].

3- A study entitled "College Bus Information System Using GPS and GSM Technologies", conducted by "Chaudhari Priyanka et al (2018)", suggested a bus tracking system to monitor the college bus location using GPS and send message to student using GSM. The suggested system provides many advantages, including remote monitoring of different types of vehicles such as

taxis and buses, and automatically sending the bus location on demand without any human intervention, which saves time and reduces human effort [25].

4- A study entitled "Women Employee Security System Using GPS and GSM Based Vehicle Tracking", conducted by "Poonam Bhilareet et al (2015)", suggested a female employees security system that provides alerts and messages when they face any emergency situation, like rape from drivers or friends, theft, ... etc. The suggested system provides a combination of GPS and GSM in a device for tracking vehicles that transfer female employees working in night-time shifts via specialized software, and the vehicle location information presented by the hardware device can be displayed on Google Maps using the internet services [26].

5- A study entitled "GPS/GSM Based Bus Tracking System (BTS)", conducted by "Christeena Joseph et al (2013)", suggested a tracking system to determine the location of the faculty bus by the mobile phone. The suggested system integrates a GPS and GSM modem to locate the bus via SMS sent to a pre-specified phone number. The end user of the suggested system does not need an external server or internet connection to know the location, so it is more cost-efficient than the current conventional tracking systems [27].

III. PROBLEM DEFINITION

Contemporary challenges, especially economic ones, impose major burdens on the individual to ensure decent living conditions for his family members. Unfortunately, these burdens may negatively affect the attention and concentration of the individual, particularly with limited income, which may lead to him losing some of his private belongings while working, shopping, entertaining, ...etc.

In higher education institutions, a faculty member performs various tasks, whether academic or administrative in his college. Furthermore, sometimes he contracts with other colleges or universities for teaching or administration, which requires him to move between these institutions to fully accomplish his assigned responsibilities and duties.

With the increasing responsibilities that fall upon the faculty member shoulder inside and outside his college, the amount of stress, anxiety and fatigue also increases, which may affect the member's attention and concentration leading to the loss of his important personal belongings such as, car, laptop, mobile phone, suitcase, ... etc. Therefore, developing an efficient tracking system to help the faculty members keep track of their personal belongings in and out university institutions has become an urgent needed.

In response to the above, this research paper proposes a GPS & GSM based real-time tracking system to remotely monitor the personal belongings of faculty members in various Egyptian universities.

IV. PROPOSED SYSTEM

Generally, the proposed Android-based tracking system includes a set of interacting and interrelated elements and components.Scientifically, there are several alternatives to explain the novel tracking system.One of the best alternatives is to present the details of the developed tracking system in separate subsections within a simplified form as follows:

A- System Overview

The proposed Android-based tracking system composed of two major parts.Part-1, is a locator which is a man-made hardware device consisting of GPS module and GSM modem and that is attached to the personal belongings of the faculty member to send the exact location of his belongings upon request. Part-2, is a tracker which is an Android application installed on the smartphone of the faculty member to obtain the latitude and longitude that corresponds to the location of the missing item of the faculty member and display it on Google Maps.The outline of the developed Android tracking system is shown in Figure.1.

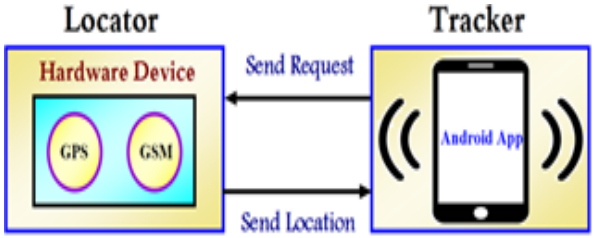

Fig.1: Proposed Tracking System

From the figure above, the tracking device and its components are initially attached to single item of the faculty member's personal belongings that may be lost or stolen.

When the faculty member needs to determine the location of his missing personal belongings, he sends a location request message to the tracking device via the Android application preloaded in his smartphone.

Once the tracking device receives the locating message, it replies with the requested location derived from the latitude and longitude coordinates using the GPS module to be passed through the microcontroller using the GSM shield and displayed as a text message on the smartphone screen of the faculty member.

B- System Development

The proposed Android-based tracking system was developed using a combination of hardware components and application software. Below, we will provide more information on both parts.

• Hardware Components

To design the tracking device, a set of physical components were used. The most important of them are the following:

- Sim808 module, which is used as a dual function (GPS and GSM).
- Arduino Nano, which is used as a microcontroller board, where it has a compact size and mini USB cable than the Arduino UNO.
- SIM-Card Holder, which is used to hold a phone number that send and receive SMS messages related to the location of personal belongings of the faculty members.
- Lithium Battery, which is used to supply the power to the components of the tracking device.
- Charger Circuit, which is used to recharge the used Battery when its power gets low.
- LED Lighting Lamp, which is used as a performance indicator to check the status of the tracking device. When any problem is occurred, it lights up and sends an alerting message to the tracking Android application installed on the smartphone of the faculty members.

• Application Software

To develop the tracking software, a number of programming tools were used. The most important of them are the following:

- Android Studio, which is used to build an Android application, that allows faculty members to remotely track their personal belongings.
- Arduino Development Environment (IDE), which contains a text editor for writing the Arduino code using C programming language and upload it to microcontroller board to be executed for achieving the communication between the Android smartphone of the faculty members and the GSM shield of the tracking device.

C- System Implementation

To allow the faculty members of the university institutions to use the proposed Android-based tracking system, an easy interaction Graphical User Interface (GUI) is designed. The key screens of the suggested GUI will be explained in an easy to understand way as follows:

When the faculty member-side Android tracking application is lunched, the login screen shown in Figure.2 will appear to allow the faculty member to enter his name and phone number which will be used later to receive the precise location of the missing item.

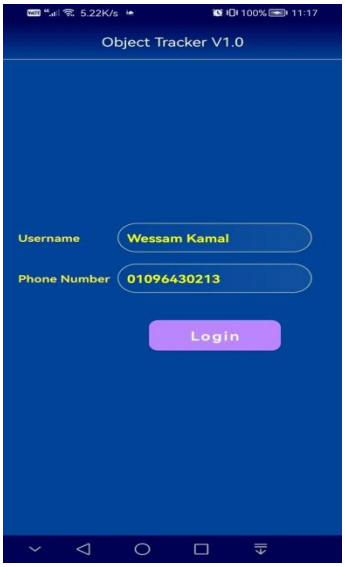

Fig.2: Login Screen

After the login data is entered, the main screen shown in Figure.3 will appear to allow the faculty member to choose the category of the missing item.

Fig.3: Main Screen

Once the category of the missing item is selected, the connection screen shown in Figure.4 will appear to enable the Android application to automatically connect with the tracking device plugged into the missing item.

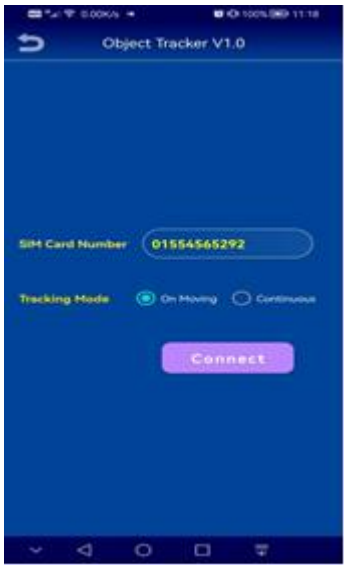

Fig 4: Connection Screen

After the number of the SIM card inserted into the tracking device is entered and the tracking mode is selected, the connection process is performed and the tracking screen shown in Figure.5 will appear to enable the faculty member to determine the GPS coordinates of the missing item on Google Maps.

Fig 5: Tracking Screen

The above screen is divided into two main parts. The top part of the screen displays the location details of the missing item, such as real-time, latitude and longitude. While, the bottom part of the screen uses Google Maps to display the locations that the missing item has moved between and to mark the last location it settled in.

V. EXPERIMENTAL TESTS & RESULTS

To analyze the efficiency of the proposed Android-based tracking system, it was subjected to a series of experimental tests, which were conducted at two levels. Both levels are explained in more detail in the following:

A- Validity Test

The main goal of validity test is to ensure the viability of the proposed Android-based tracking system for application inside and outside different universities. The test scope included the four major aspects: content quality, design quality, organization quality and user interface quality.

Once the final prototype of the proposed tracking system was developed, it was referred to a number of specialists in computer science from Mansoura University for determining its validity in tracking the location of the personal belongings of the faculty members in and out the university.

To define the approved and disapproved aspects of the proposed tracking system, each member of the evaluation team was asked to fill out a printed copy of the performance appraisal form which involved a number of Likert scale questions covering the evaluation scope already mentioned above.

To analyze the evaluators' responses, the questionnaire forms were gathered, filtered and analyzed by quantitative statistical methods and the overall frequencies and percentages of approval and disapproval for pre-defined evaluation aspects were calculated, presented in detail in Table.1 and summarized in Figure.6.

Table 1: Results of Validity Test

Evaluation Area	Approval		Disapproval	
	F	%	F	%
Content Quality	47	94	3	6
Design Quality	45	90	5	10
Organization Quality	48	96	2	4
User Interface Quality	49	98	1	2
Total	**189**	**---**	**11**	**---**
Overall Average	**---**	**94.5**	**---**	**5.5**

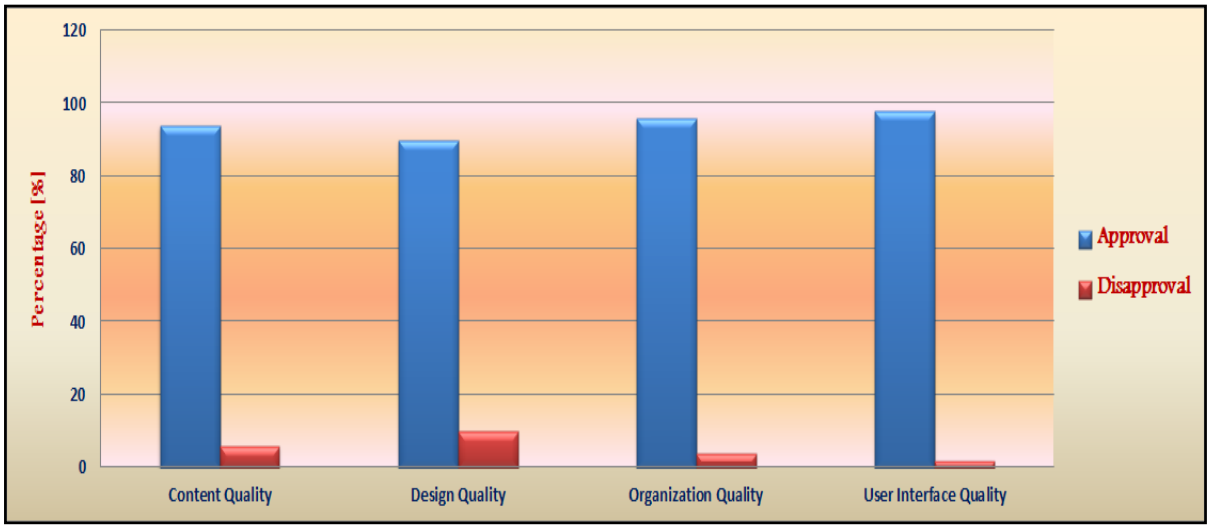

Fig. 6: Outcomes of Validity Test

Generally the above results show that, the overall percent of approval responses (94.5%) for identified evaluation aspects were greater than the overall percent of disapproval responses (5.5%).

The results also show that, the total approval responses differs from one aspect to another, where the total approval of the content quality is 47 frequencies with 94 percent, the total approval of the design quality is 45 frequencies with 90 percent, the total approval of the organization quality is 48 frequencies with 96 percent and the total approval of user interface quality is 49 frequencies with 98 percent.

The numerical analysis of the obtained findings show that, the overall average percentage of approval responses for predetermined evaluation scope is 94.5%, which indicating a high level of agreement among the evaluators on the applicability of the proposed tracking system for widespread use in monitoring and managing the personal belongings of the faculty members in various university institutions.

B- Tracking Accuracy Test

After completing the procedures of testing the validity of the proposed Android-based tracking system for use on a large scale in university sector, it has subjected to another kind of experiment called tracking accuracy test. The main goal of this test is to estimate the accuracy of the proposed system in monitoring the personal belongings of the faculty members in open environments.

This test was conducted on a sample of faculty members from the branches (Mansoura - Mit Ghamr - Miniat Al Nassr) of Faculty of Specific Education, Mansoura University. Firstly, the tracking device was attached to a single large-sized item of the personal belongings of the faculty member, such as handbag, backpack, laptop bag, ... etc. Secondly, the motion of the faculty member inside and outside the Mansoura university was monitored to detect the missing item, if any. Thirdly, when the faculty member loses any personal belongings, he uses the faculty member-side Android tracking application installed on his smartphone to locate the missing item using Geographical coordinate points provided by the GPS module installed in the tracking device. Fourthly, the same procedures were repeated with the rest of the test sample one by one and the location coordinate points obtained from the GPS module were accurately recorded.

To estimate the accuracy of the proposed Android-based tracking system, the distance values in meters between the latitude and longitude points obtained from the GPS module of the proposed tracking system and the actual latitude and longitude points obtained from the Google Maps were calculated and presented in details in Table.2.

Table 2: Results of Tracking Accuracy Test

Place of Application		Received Location by Proposed Tracking System		Actual Location on Google Maps		Distance (M)
City	**Street**	**Latitude**	**Longitude**	**Latitude**	**Longitude**	
Mansoura	**Meshaal**	31.0373419	31.3797868	31.037356910329056	31.379786887056245	**1.67**
Meit Ghamr	**Treaty Square**	30.6378589	31.2868903	30.637908975965974	31.286970374959512	**9.5**
Miniat Al Nassr	**Hospital**	31.13179750	31.65368472	31.13170750115611	31.653684725996996	**10**
Mansoura	**Portsaid**	31.04256898	31.38111886	31.042568989289276	31.381048860462485	**6.67**
Meit Ghamr	**Court**	30.7158885	31.2675523	30.71593952902415	31.267542302800514	**5.75**
Miniat Al Nassr	**Engineer**	31.1204528	31.6493757	31.12049289222356	31.649386902789015	**4.58**
Mansoura	**El Geish**	31.03629171	31.39438813	31.03624171870129	31.394238131627045	**15.3**
Meit Ghamr	**Culture Palace**	30.7202641	31.2522231	30.72026414733866	31.252210104649553	**1.24**
Miniat Al Nassr	**Central**	31.14176857	31.65144834	31.141838570681088	31.651448343623656	**7.78**

The above results show that, there is a high convergence in meters between the Geographical coordinates obtained from the GPS module of the proposed Android-based tracking system and the real-world Geographical coordinates obtained from Google Maps, which in essence means that the accuracy of the results was not affected by various barriers, such as weather disturbances, tall buildings, real-time satellite signal interference at the time of measurement.

Furthermore, the results indicate that the maximum measured positioning uncertainty is 15.3 m, which is classified as an excellent level according to the findings published in the paper no [28], which confirmed that the maximum allowable error in reading the locations of the moving items in open and wide Geographical areas should not exceed 100 meters.

According to the previous results, the proposed Android-based tracking system is really accurate enough in locating the personal belongings of the faculty members inside and outside the higher education institutions.

Finally, it can be concluded that the proposed Android tracking system is a positive contribution to the current object tracking systems.

VI. CONCLUSION & FUTURE WORK

This paper effectively utilized advantages of the integration between GPS and GSM technology to provide a new solution for securing the personal belongings of the faculty members across wide Geographical areas in various Egyptian universities.

The proposed solution included a hardware part, which is a tracking device, and a software part, which is an Android based application.The GPS module of the tracking device is utilized to obtain the geo-location data of the personal belongings of the faculty members and this data is transmitted wirelessly over a long distance upon request via the GSM shield of the tracking device to an Android application preloaded on the mobile devices of the faculty members to enable them to monitor their personal belongings remotely.

The proposed Android-based tracking system allows the faculty members to easily track the location of their personal belongings 24/7, where

they just have to send a location request message from the Android application to instantly receive the latitude and longitude coordinates for the location of their personal belongings with the ability to view them on Google Maps.

The evaluation of the proposed Android based tracking system was conducted at two levels. In the validity level, the applicability of the proposed tracking system on a large scope was tested, and the results obtained were very satisfied. In the accuracy level, the maximum error of the developed monitoring system in reading the location of the personal belongings of the faculty members was verified, and the results obtained indicate that the faculty members' personal belongings were tracked with the minimal tracking error.

Future work aims to enhance the proposed Android-based tracking system. The improvement plan focuses on encrypting the Geolocation data of the personal belongings of the faculty members retrieved by the GPS module to be available only to users who have been granted decryption privileges.

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