Intelligent Vehicular Security System using Sensors and GPS

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***Abstract*—The problem of car thefts and cars crashing due to careless parking are common issues of unattended public parking lots. This paper presents an intelligent car security system which provides security to automobiles against thefts and crashing that happen in parking lots. The main parts of the proposed system are the Global System for Mobile Communications (GSM) and Global Positioning System (GPS) modems, a camera, a sensor and microcontroller. The design of the proposed system provides a highly secure, flexible, reliable and cost effective system. One of the benefits of the proposed system is when a crash happens to the car in any parking, the system immediately communicates with the owner through a Short Message Service (SMS). Moreover, the motion sensors will detect any vibration such as theft or crash and instantly capture the picture of the incident. The system also saves the picture of any damage caused to the vehicle as an evidence for further investigations. A prototype of the proposed system has been implemented and tested. The test results show that the system is working properly, can monitor the parking area of the vehicle, supply the necessary information for any car in case of theft and crash, and is very useful in accidents.**

Keywords- Microcontroller; Security; GPS; GSM.

I. INTRODUCTION

An automobile is always a precious possession to its owner either because of its functionality or as a prestige symbol. It is often seen that people do not hesitate to put in their hard earned money to buy the best car that they can afford. In fact, the owner needs to do whatever possible using available technologies to protect and safeguard their car. Moreover, wide ranges of gadgets are available on the market which can be used in this regard and may be considered as a solution to this problem. However, all available gadgets are open to series of restrictions and criticisms. Specifically, all of these gadgets cost a lot and each one of them has its own merits and demerits, such as either not being able to perform the desired task effectively or performing in a limited way by failing to cover the whole gambit of security [1].

It is well known that the careless parking often leads to damage to the nearby vehicles and this commonly happens in public parking lots where vehicles are parked for long time or when they are unattended. In addition, theft attempts are also common in such places. It is really a difficult problem that one cannot figure out or control. No one can anticipate the situation of his/her car at most of the parking time and how such incidents occur, and whose fault it was. In fact, it is a common problem faced by all vehicle owners/users who park their vehicles in public parking lots.

The damage caused by such incidents often ranges from simple to severe crashes leading to lost money, time and effort of the owner/user. Hence it is highly desirable to have an automatic alarm system attached to the car which gives full information about any incident when it happens and that can be used simply by the vehicle user to identify such problems.

This paper presents the design and development of an intelligent, cost-effective, and smart car parking security system which provides complete information about theft attempts and crash incidents that happen in parking lots due to careless parking of vehicles. The scope of this paper is to solve a problem faced by general public by developing new smart security systems for the vehicle to detect if someone crashes it and also to protect it from theft.

The paper is organized as follows: Section II presents the related work. The requirements analysis and system overview are defined in Section III. In Section IV, the experimental setup is described. Section V presents the results and analysis and finally the conclusions are given in Section VI.

II. RELATED WORK

A plethora of works have been done on developing the technical modalities for car security systems while in motion or parked [2]. The literature pertaining to car automated parking, car monitoring and car security systems using various techniques and methodologies has been studied and analyzed.

Rashidi et al. [3] proposed a car monitoring system using the Bluetooth security system. The main thrust of the system is on the efficacy of the Bluetooth system to prevent the car from being encroached upon or being involved in a theft. It can be configured and accessed through smart mobile phones using the Bluetooth communication module with an intelligent built-in alarming alert where the car user can turn on or off. The triggering of an alarm would send an intruder alert message to the user's mobile phone. So, there is a good possibility to save the car from being stolen.

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Balajee et al. [4] used an automobile security system based on face recognition structure using Global System for Mobile Communications (GSM) [5] network. The authors developed a car security system by using a Global Positioning System (GPS) [7] module, a GSM, a tiny face detection webcam and a control module. The webcam is hidden in the steering wheel of the vehicle. The system detects the face in the vehicle during the time when someone is in the car. It also makes an alarm sound if that option is opted. After detecting the face in the alarm period, one alarm signal will be sent to the central control system if the face does not match the saved face in the memory. In the silent alarm mode, different modules will be at work to inform the user of the vehicle and the police about the intrusion and the possible theft. In the latter case, it will inform the precise location of the vehicle through GPS. The GSM module transmits the information about the location through Short Message Service (SMS) [6].

Miguel et al. [8] designed a Bluetooth/ General Mobile Radio Service (GMRS) car security system with a randomly located movement detective device by using a system that links the Starter Disable Unit (SDU) and a Randomly Located Device (RLD). It uses GMRS to generate warning messages. The system works in such a way that when the driver activates the system and leaves the car, it would be in a monitoring state through establishing a connection between the Bluetooth, the RLD and the SDU. The GMRS transmission is activated to transmit the alert message and simultaneously activates the SDU function in order to prevent the possible theft. This action is initiated if the RLD notices preset vibration levels, then it implies that there is an intruder inside the car.

Indeed, there are a lot of problems facing car security and information systems in each individual system. In order to summarize the above literature, the problems are classified under few main categories. The problem of expensive components would make the whole system expensive as has been observed by most of the car security systems such as intelligent car park management system based on Wireless Sensor Network (WSN) [1]. Also, high data rate transfer is another problem [4]. It is well known that any developing in security system should take into account the social responsibility of not annoying the peace and tranquility of the neighborhood [3]. Moreover, the security system should be as unobtrusive as possible besides being cost effective, user friendly and more importantly robust in performing the security coverage. Currently all the system are supposed to work with the minimum human interference as possible. It may worth mentioning that most of shortcomings that have been faced in the above systems have been successfully solved in the proposed system design.

III. REQUIREMENT ANALYSIS AND SYSTEM OVERVIEW

This section discusses the requirements of the car security system in general and from costumer perspective in particular. The main goal of the present paper is to develop a cost-effective security system that protects the car against any damage and/or theft. The requirements from the user's point of view are given below:

- The system should be sensitive enough to detect any kind of damage.
- The system should be able to save data as evidence for analysis and future use.
- The system response should be fast enough to instantly capture the action.
- The system should be user-friendly, easy-to-fix, reliable and cost-effective.
- The user should be able to retrieve the saved data easily.

In accordance with above requirements, the system should use high performance but less expensive components. The cost of this system is about 120 USD in Sultanate of Oman. Furthermore, the system must be convenient for the users to fix and use, in addition to being of low initial and maintenance costs. Most importantly, it must have acceptable levels of robustness, accuracy and precision. The components of the security system are:

1) Microcontroller PIC16F887: this device has been used due to its many features. This PIC is easier than other PIC's in respect to the system setup and configuration points of view [11]. In addition to the multitasking feature, it comes at a low price and is easily available in the local market.

2) XYZ sensor: it allows detection of vibration in three directions. It is chosen for many reasons including low power consumption, accuracy and easiness of interfacing.

3) GPS and GSM modems: the GPS provides geographical location by using space-based satellite navigation system. GSM modem allows the system to contact the GSM network by using a subscriber identification module (SIM) [10] card. The GPS and GSM work together to send the details regarding the state of the car and its location to the users.

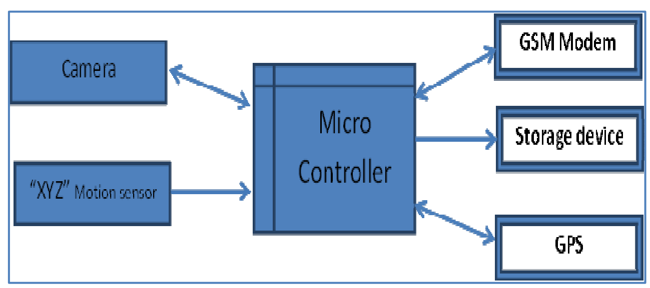

Figure 1. System Block Diagram.

4) The Camera: it is used to capture the photos of the car [9]. It is simple in order to reduce the system cost and can be bought from any electronic company.

An overview of the proposed system is given in Figure 1. The main idea of the system is to protect the unattended car while it is parked for a while. Sensors are used in order to detect any movement near the vehicle. Once any significant movement is detected, the sensors send appropriate signals to the microcontroller, which in turn will send the signal to the camera. The images taken will be saved in the storage device. At the same time, the user of the car will be informed of the movement via SMS. The security system will be activated once the car is parked and in the absence of the user. For the energy consumption, there is no need to use an extra charger or batteries since it is using the car battery in order to reduce its cost. This system is switched off automatically when the car engine is on to reduce the power consumption.

IV. EXPERIMENTAL SETUP

The proposed system has been implemented in prototype. The user activates the security system to detect any significant motion when the car is in the parking condition. This is done by using two sensors on each side of the car. The camera is fixed in the car and will capture the event to be used as an evidence in future.

These sensors are located near the right front wheel and left rear wheel in order to detect any vibration around the car**.** To enable capturing the whole scene**,** four cameras are used in the prototype to cover all four sides. Each Camera is covering one side of the car. In Figure 2, A, B, C and D represent the positions of these cameras.

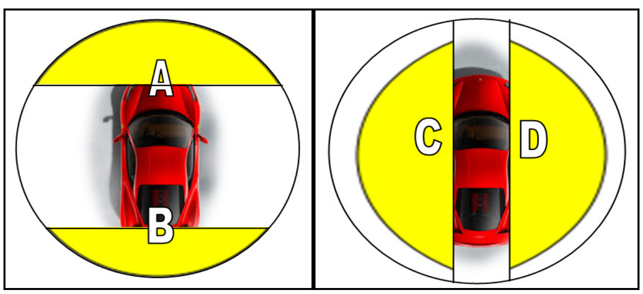

Figure 2. Cameras Locations.

For the GPS and GSM systems, if the car is stolen, the car owner sends SMS messege to the GSM system in the car to request the car location. The GSM system stores the mobile number and takes the location of the car using the GPS system and it sends back the car location information by SMS messege to the same number.

V. RESULTS AND ANALYSIS

The intelligent car security system was built to be of high accuracy, robustness, secure and also to be convenient to the users, and meets the user requirements. Thirty tests have been carried out in day light and low light conditions. A total of sixty incidents have been made and tested at different angles of the car. The results were analyzed using four performance parameters. Displaying of car license plate in the captured picture is considered as the most important parameter. The other parameters are the coverage of car angles and the overall perceived clarity of the captured picture. Capturing the picture of the third party who made the incident is also taken as a parameter, though is not very important.

The accuracy index of the system is evaluated by identifying different weights for each parameter according to its importance. The parameter display of license plate in the captured picture is given 50% weight being the most important one because it identifies the plate details of car that is responsible for the accident. The coverage of car angles parameter is determined by the sensors, which are kept at all sides of the car and sense any damage to the car, so it is given 35% weight.

TABLE I. PERFORMANCE PARAMETERS

No.	Parameter	Percentage of Importance
1	Display of License Plate in the Captured Picture	50%
2	Coverage of all Sides	35%
3	Overall Clarity of the Captured Picture	10%
4	Display of the Third Party Driver in the Captured Picture	5%

The overall perceived clarity of Captured picture is given 10% weight. Capturing the picture of the third party who made the accident is given 5% weight as it is the least important parameter. The various parameters and their weights are given in Table 1.

The result of the first parameter 'display of license plate' is further divided into three types as given in Table 1, according to perceived quality of numbers and alphabets in the plate to make the system simple and cheap:

- Type One-Good, if both numbers and alphabets on the plate are easily readable.
- Type Two-Average, if either number or the alphabets on the plate are readable.
- Type Three-Poor, if both of them are not readable.

TABLE II. TEST RESULT

No.	Parameter	No. of Tests Applied	No. of Passed Tests	Perceived Image Quality Types: Good	Average	poor	Percentage of Tests Passed
Day Light							
1.	Display of License Plate in the Picture	30	25	7	16	2	83%
Low Light (Evening)							
2.	Display of License Plate in the Picture	30	20	5	8	7	66%

The number of the Passed Tests is less than the overall Applied Tests due to the quality of the camera used in the tests and its position. The number of the Passed Tests at Day time is more than the number of the Passed Tests at the Evening Time (low Light) because the camera does not support the night vision mode.

The Percentage of Passed Tests at Table 2 is calculated by dividing the number of Applied Tests to the number of the Passed Tests.

The AI (Accuracy Index) of the system is calculated by using the following equation:

$$AI = \begin{pmatrix} \text{Persentage of Passed Tests for the Parametr 1} * \\ \text{the Weight of Parameter 1} \\ + \\ \text{Persentage of Passed Tests for the Parametr 2} * \\ \text{the Weight of Parameter 2} \\ + \\ \text{Persentage of Passed Tests for the Parametr 3} * \\ \text{the Weight of Parameter 3} \\ + \\ \text{Persentage of Passed Tests for the Parametr 4} * \\ \text{the Weight of Parameter 4} \end{pmatrix} \quad (1)$$

Using the test result from Table 3 and the above equation, the accuracy index for the day time (light view) and for the low light have been calculated as follows:

$AI\_{LightView} = (83x50\%)+(100x35\%)+(100x10\%)+(50x5\%)$

$= 88.6\%$

$AI\_LowLightView = (66x50\%)+(100x35\%)+(53.3\ 10\%x)+(16.6\ x5\%)$

$= 74.16\%$

Thus the accuracy index of the system at day light condition is 88.5% and at low-light condition is 74.16% and the OAI (Overall Accuracy Index) of the system is 81.3% which is calculated by using the following equation:

$$OAI = (AI\_LightView+AI\_LowLightView)/2 \quad (2)$$

TABLE III. TESR RESULTS

No.	Parameter	No. of Tests Applied	No. of Passed Tests	No. of Failed Tests	Percentage of Tests Passed
Day Light					
1.	Covering All Sides of the Car	30	30	0	100%
2.	Overall Clarity of the Picture	30	30	0	100%
3.	Display of the Third Party in the Picture	30	15	15	50%
Low Light (Evening)					
4.	Covering All Car Sides	30	30	0	100%
5.	Overall Clarity of the Picture	30	16	7	53.3%
6.	Display of the Car Driver in the Picture	30	5	25	16.6%

It is found that the system can cover easily more than 300m of the road, but the system has faced only one problem, namely the problem of interfacing between the transmitters. This problem can be solved in two ways: First, by reducing the transition power and organizing the transition location precisely and second, by making two different coding systems for each side of the road.

The above calculations and analysis were done in the prototype. The next stage was implemented in a module on a real car. In addition, in this stage we have checked the functionality status of the system in general.

From Table 3, it is observed that the number of Applied Tests is greater than or equal to the number of Passed Tests, which was related to the measurement that were taken by the camera, which depended on the camera position and quality. For the Low light measurement, the camera does not support the night vision mode, so the number of the Passed Tests compared to the overall Applied Tests has been reduced relatively. The percentage of Passed Tests has been calculated and given in Tables 2 and 3.

On the basis of the above observation, we can conclude that the system is generally good and can be improved by using a camera that supports night vision mode. Also, the location of the cameras can be modified in order to increase the system accuracy index.

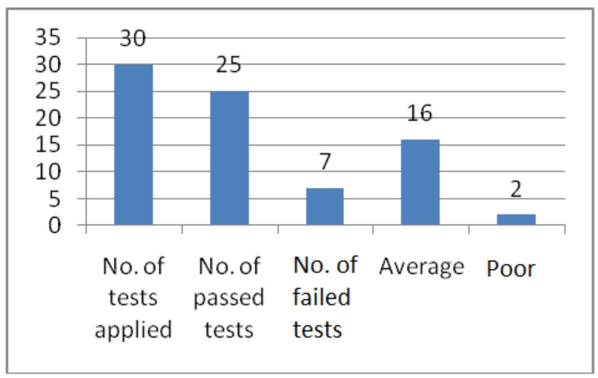

Figure 3. Display of License Plate in - Day Light.

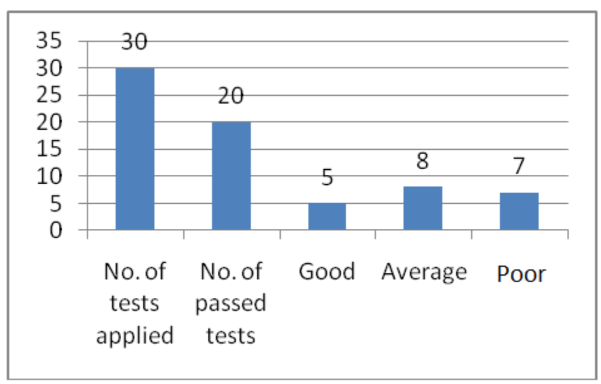

Figure 4. Display of License Plate in - Low Light.

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In order to study and analyze the results more specifically, separate graphs were drawn for the above cases and given in Figures 3 to 7 . From Figures 3 to 7, it can be observed that the performance of the camera is much better at working in day light condition than in low light condition. In other words, the clerity of the displayed tests is 100% (in day light), whereas the clarity of the displayed tests is 53.3% (in low light).This means that the utilized camera was not supporting low light mode and at the same time it indicated the necessity of providing some support to the night camera mode. This shortcoming can also be overcame and the system can be improved if we change the type and location of the cameras.

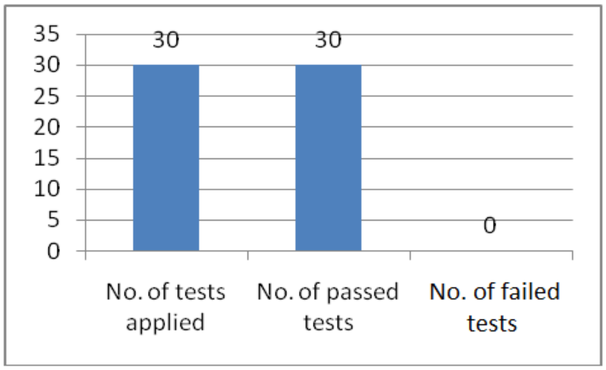

Figure 5. Covering all Car Sides.

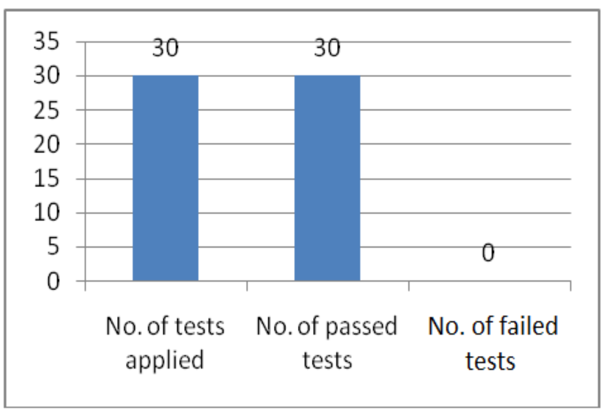

Figure 6. Overall Clarity of the Captured Picture - Day Light.

The results of testing the sensitivity of the sensors are demonstrated in Figure 5. Form Figure 5, we observed that the sensors are working perfectly and detecting any vibration in all corners with 100% of clarity.

The results of the third party driver are displayed in Figures 8 and 9. The test shows that the clarity ratios are 50% in day light and 25% in low light. The computed ratios are low because of the heating and sometimes the third party may be driving in the reverse mode. It is possible to increase these percentages by using a camera that supports low light mode.

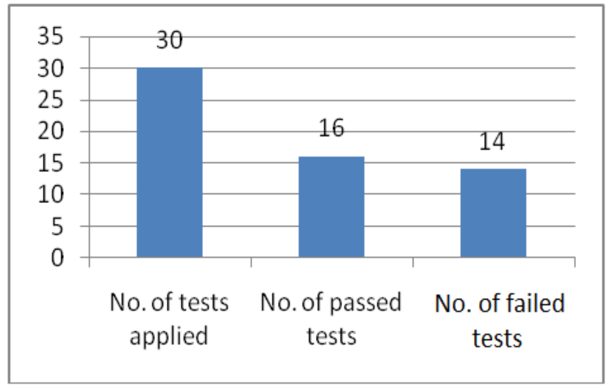

Figure 7. Overall Clarity of the Captured Picture - Low Light.

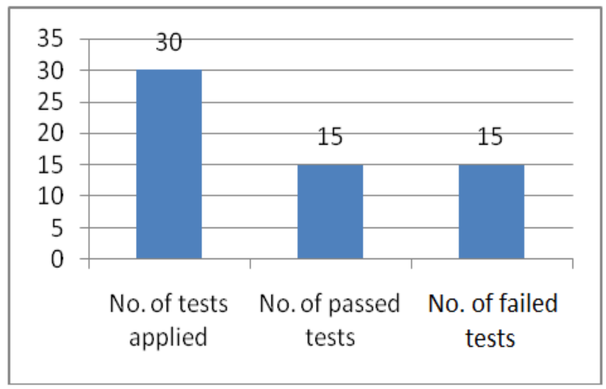

Figure 8. Display of the Third Party in the Picture - Day Light.

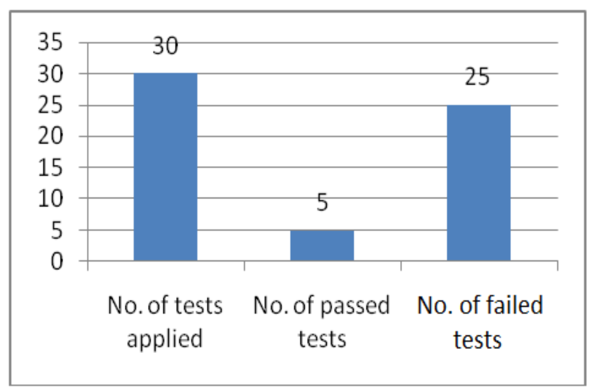

Figure 9. Display of the Third Party in the Picture - Low Light.

VI. CONCLUSION AND FUTURE WORK

The main objective of this paper is to develop an intelligent car security system that protects cars against theft attempts and gives vital information including pictures of crushing incidents that happen at parking lots due to careless parking. The system is easy to use and provides information without the need for human involvement. This system helps the car user to know about any crash at the parking lot by sending the information to his/her smart phone which are captured by the sensors and the cameras. In the event of theft, the location of car can be identified with the help of GPS tracking which is built in the system. The system is secure, reliable, flexible and affordable. Results based on a number of tests conducted at different conditions show that the system provides accurate results. Furthermore, it is observed that the accuracy index of the system at day light is better than at low light conditions. In future work, it is proposed to capture not only pictures, but also short video of the incident as an enhancement to the system and high camera quality with high resolution night-vision capabilities will be used at different positions. The number of the cameras will be increase. The other area of future work is to attempt reducing the interference between the transmitters from different cars. It is recommended to design directional antennas or special type of signal jammers. The GSM modem can be upgraded with GPRS or 3G capabilities so that a low resolution picture or video clip of the incident or the intruder could be sent to the car owner.

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