UNIQUE PAPER IDENTIFICATION NUMBER (UPIN): C1-009

Development of Camera-Based Low-Cost Real-Time Internet Controlled Wireless Unmanned Vehicle for Smart Factories

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Abstract

Over the last decade, automation in factory environment has been a very active area of research and development. However, the exorbitant cost of automation has dithered deploying such processes in the industries. A prime example is the transportation of raw materials and final products from/to storage and shipment points within the factory which require the use of manually and locally operated vehicles. This bottleneck in the production, mobility, monitoring and transportation of products can be enhanced with the help of recent advancements in wireless and multimedia technologies. This paper proposes and develops a low cost, real-time internet controlled wireless based unmanned vehicle for smart factories. The connectivity is provided through GSM and the remote monitoring of the vehicles is enabled using a high resolution pocket-sized camera. A simple low cost prototype has been developed which is currently being used to carry light load objects within a campus environment.

Keywords

GSM Modem, way2sms API, GRUVEO video, Android Device Manager, Ultrasonic Sensors, Arduino-Uno.

1. Introduction

Automation in industries and factories has played a greater role in the process of making a system sustainable in large-scale. Notably, menial yet important tasks such as carrying loads from one location to another, inspecting certain areas (otherwise not possible through CCTV) etc. are aspects which can be automated. Further, there is a need for developed unmanned vehicles which can carry out these tasks efficiently with some control from remote location. Theoretically, remote control of vehicles can be done through several methods such as Infrared, RF, Blue-tooth, Wi-Fi, etc. The main concern with these methods is that they are not necessarily extremely reliable in terms of transmission of information without any loss of data. Moreover, these communication methods are confined to certain distance which puts a significant limitation on their practical applications. To overcome these limitations, a real-time Internet-controlled wireless based unmanned vehicle was developed in such a way that provides a wide-range of wireless control ability.

2. Design and Structure of Implementation

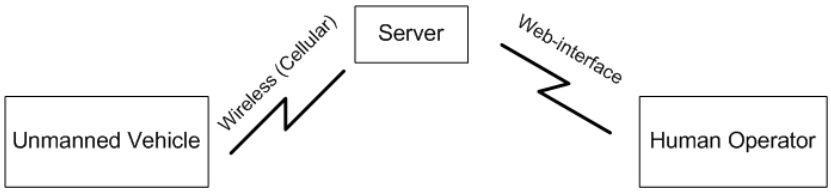

Fig. 1 Block diagram of the Entire Setup

This unmanned vehicle is controlled by a human operator in a web by watching the real-time video around the unmanned vehicle. The block diagram of the entire flow is as shown in Fig. 1. There are three major components to the design.

2.1. Unmanned vehicle

Apart from the vehicle itself, unmanned vehicle has the following features:

a) An inbuilt GSM module through which it transmits and receives the instructions wireless.
b) In order to provide a back-up for any breakdown in connectivity, a dual SIM based module is provided wherein the 2nd GSM based data connectivity served as backup.
c) The vehicle has high resolution mobile camera which tracks the environment all 120 degrees.

2.2. Human Operator

The second major component is the human operator. All actions are given by the operator to the vehicle by watching the real-time video around the unmanned vehicle. The operator communicates with a central server through web-interface. Any information from the vehicle reaching the server is accessible to the human operator through the web-interface and vice-versa.

2.3. Web Server

Server plays a major role to convert the operator's command given in the web client into SMS using way2sms API which was programmed by PHP script and sends the message to the unmanned vehicle (In-built GSM). Further, it also streamed the live video which was captured around the vehicle. This live video streaming was done by the GRUVEO video calling API.

3. Details of Experimental Setup

In the design of web-interface controlled unmanned vehicle, the web interface as shown in the Fig. 2 was developed by using PHP. As mentioned above, a way2sms API was used to send the commands as SMS to the GSM module embedded in the unmanned vehicle. Moreover, in order to make the vehicle understand and comprehend the instructions, an Arduino-Uno micro-controller board was used. This Arduino-Uno

plays a key role to control the motor drivers of the vehicle and communicating with the GSM module for updating of instructions and move the vehicle according to received instruction. Additionally, the GPS tracker in the mobile was used to find the exact location of the robot by using Android Device Manager.

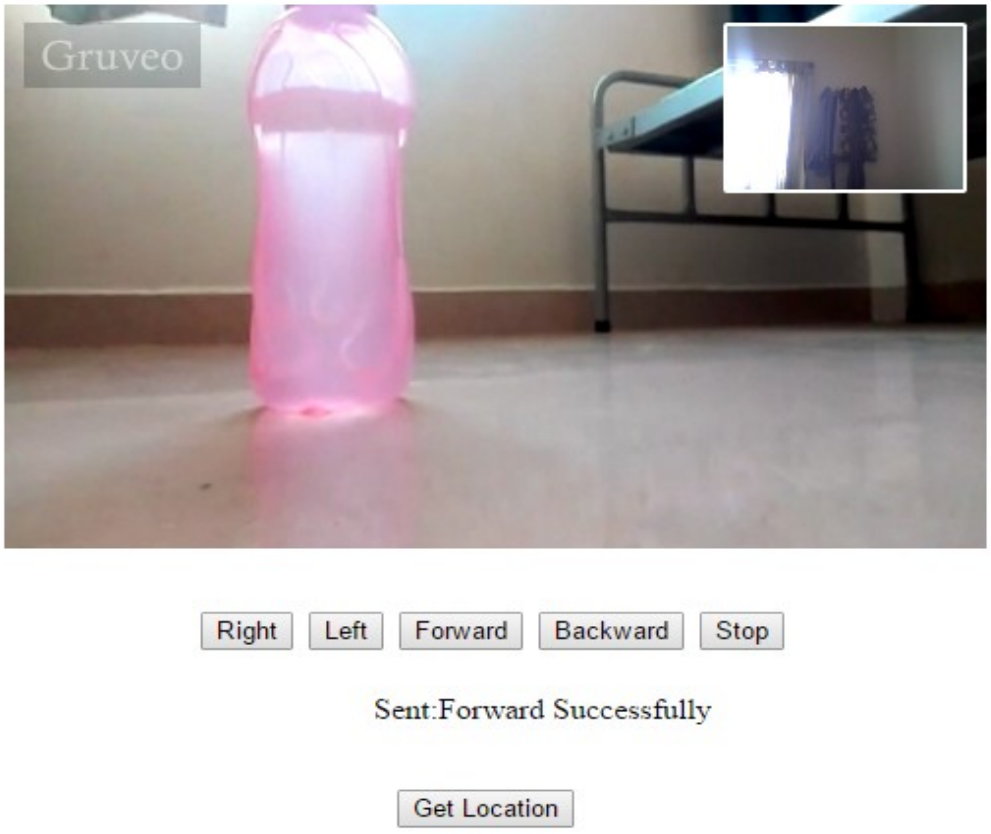

Fig. 2 Developed Web Interface

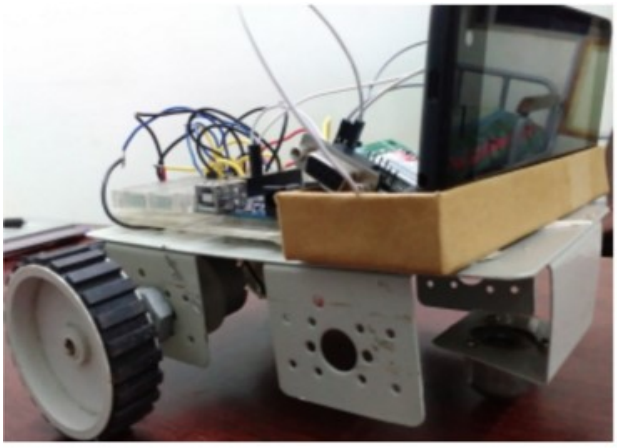

Fig. 3 Developed Unmanned Vehicle

The snapshot of the 'under-development' unmanned vehicle is shown in Fig. 3. It can be seen from Fig. 3 that the mobile camera in the front of the unmanned vehicle captures the information about the environment and sends it to the server. Further, the location near the camera is for pay-load, i.e., to carry the goods from one place to another.

4. Major Aspects in this Work:

1. Obstacle Detection: While the unmanned vehicle is moving, the detection of any stationary or moving object in its vicinity is done using Ultra-Sonic sensors/detector.

2. **Vehicular Data Analytics:** Once the information about the neighboring vehicles and the environment of the unmanned vehicle reaches the operator, the task is to analyze this information in real-time. However, this has not been completed yet till date. The major challenge lies in in the design of algorithms/techniques that would enable providing recommendation to the operator in real-time.

3. **GPRS/Web Connectivity:** It deals with how the connectivity is retained and how the information exchange takes place continuously between the human operator and the unmanned vehicle. This will also provide details on how the operator's keys are configured to send the information to the unmanned vehicle.

4.1 Obstacle Detection

In most cases a path planner, giving a prior description of the unmanned vehicle workspace, makes the task of an unmanned vehicle easier to execute the desired missions. The action of an unmanned vehicle in an unstructured environment is not possible, if it does not have an ability to cope up with the changes in the environment. Without knowing the surroundings, it is not possible for the unmanned vehicle to navigate around. The major change in the environment includes the presence of new obstacles. So, for an unmanned vehicle, sensor fusion is very important to perceive its surroundings. Using sensor fusion, the unmanned vehicle capabilities is improved allowing a real-time reaction to avoid obstacle detection. In this regard, an ultra-sonic sensor is used for obstacle detection and embedded with these sensors. The ultrasonic sensor always releases an ultrasonic wave. If the wave collides with an obstacle in front of the unmanned vehicle, the wave will bounce back to the sensor. If the receiver receives this reflected wave then we can be sure that there is an obstacle in front of the robot.

Further, the time difference between the transmission of the ultrasonic wave and the reception of the reflected wave is calculated. Since the speed of the sound wave is known, the distance of the obstacle from the unmanned vehicle is calculated by multiplying the speed of the wave and time difference.

4.2 Vehicular Data Analytics

Once the information about the neighboring vehicles and the environment of unmanned vehicle reaches the server, the data is processed using image and video

processing techniques - frame difference technique for stationary objects and Gaussian mixture model for moving objects applied on live streamed video in web server. The distance between obstacle and vehicle is estimated and a recommendation is provided to operator.

4.3 GSM Based Connectivity

GSM modems are wireless modems that work with external supply and have one or more serial data connections (typically RS-232 or USB) for access by an external processor (or computer). Typically, they connected to computer through a serial cable or USB cable. Computers use AT commands to control modems. With these AT commands one can perform different SMS based operations.

Features of GSM Modem:
1. It can be interfaced to system using USB cables.
2. Programmable with AT commands.
3. It also provided with SIM socket and antenna connector.

5. Discussion of Results and Performance Evaluation

This developed unmanned vehicle was tested over the range of 5-6 km in different networks. While accessing the unmanned vehicle from web interface, it takes more time (~6 seconds) to send the SMS compared to mobile SMS (~4 seconds).This is because of conversion of the user given command into SMS by way2sms API that takes a additional time for data transmission. Further, the operator controlled the vehicle remotely through different keys, which when clicked, sends an instruction to the unmanned vehicle (In-built GSM) which then understands the instruction through Arduino-Uno micro-controller. The keys and the functions are shown in Table 1.

Buttons	**Implicit Instruction**	**Result**
Right	#R	Right Direction
Left	#L	Left Direction
Forward	#F	Front Direction
Backward	#B	Back Direction
Stop	#S	Stop

Table 1. Command to Control the Developed Vehicle

6. Concluding Remarks

In this paper, an unmanned vehicle controlled wirelessly using web-interface is proposed, designed and developed as a low-cost entity for smart factory environment. There are three novel aspects in the remote-controlled vehicle – these include remote

connectivity through wireless/web interface, automatic detection of obstacles using sensors and importantly, a real-time recommendation engine that will enable the human operator to seamlessly control vehicles. A prototype under development in the institute has shown that such unmanned vehicle can easily carry small loads/products in a low-range factory environment. It is anticipated that such commercial-grade vehicles can be used for several applications outside smart factory environment, such as residential townships, hospitals and other in-campus environment.

Acknowledgment:

The authors acknowledge other students who have been involved in developing some other parts of this work, especially in the prototype development.

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