# Li-Fi Data Access for Solar Robots in Cloud Environment

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**Abstract: Robotic vehicles are being researched in great numbers in recent times due to their immense potential to automate processes thus making the life of human beings simpler and less sophisticated. Traditional robotic vehicles have been making use of conventional radio frequency for their operation for a wide range of applications. However, with the increase scarcity in availability of radio frequency spectrum, alternate medium of communication are being sought after one of which is the visible light communication (VLC) also known as Light Fidelity (Li-Fi). This research article proposes a movement control mechanism with the help of control signals communicated over the visible light medium incorporating a solar panel to collect the light pulses. The novelty in the proposed work is brought about by invoking the services of cloud computing environment with a set of predefined instructions stored in the cloud to enable remote issuance of control signals to the robotic vehicle. This greatly satisfies the primary objective of robotic vehicles related to their remote nature of deployment where human presence is undesirable or not possible. Control is achieved by means of a Raspberry Pi processor enabling a faster computation time justified from the results observed in this experimental model.**

**Keywords —*Cloud Computing, Light Fidelity, Microcontroller, Solar Panel, Voice based control, Visible Light Communication***

## I. INTRODUCTION

Communication technologies have undergone a great deal of revolution in the recent past with most of the techniques aimed at making the access of services required by the consumer at the earliest time possible and also to simplify the sophisticated lifestyle of the consumer [1]. One such innovation in the past decade is the numerous research contributions brought about in the fields of robotics. Robotics has greatly mimicked the real life scenario of human beings with enhanced capabilities to perform almost any real time function done by a human being. They have to a great extent minimized the necessity of human presence in undesired locations especially in areas of defense sector to monitor hostile activity across border, hospital scenarios and industrial automation sectors [3]. Research in artificial intelligence and their subsequent application to these robots have made the robotic platforms think to a limited extent and provide a response to a specified input. One such widely used branch of robotics is the development and deployment of robotic vehicles for various applications such as mine sweeping, hostile territory surveillance, monitoring scenes of natural disasters etc [9]. The functioning of robotic vehicles either based on artificial intelligence or human controlled methods involve the utility of the scarcely available radio frequency spectrum for communication [2] [12]. Due to increasing number of wireless gadgets and technologies making use of RF spectrum which is already scarce, alternate methods of communication medium have been researched resulting in findings of the well-known visible light communication model (VLC model) [6]. Since light is abundant in nature, it can be exploited to a great extent which has formed the basic motivation behind this research work [6]. Light pulses from a powerful LED light source are modulated in accordance with the control signals and transmitted in the VLC medium which is received by a detector circuit. Based on the reception and recognition of the control signal after detection phases, a controller is used to navigate the mobile robotic platform [7]. The receiver side is replaced with the conventional photo diodes with a solar plate collector for collecting the light pulses and transmitted them to the detector circuit thus providing a completely green channel of communication. It could be further seen from literature that communication methods involving VLC [4] eliminate human hazards due to harmful radiations from the RF signals and also form a part of renewable system as light energy is abundant in nature [10] [11]. The novelty in this research work is achieved by using a cloud based storage system to access the commands at will by the user located in a centralized base station away from the remote location of the mobile robotic platform which is characteristic of its merits.

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## II. Problem Definition

Robotic vehicles are purely meant for a remote nature of deployment in areas where human presence is not possible or not desirable. A robotic navigation in a remote location requires control signals which cannot be delivered by human presence each time which may defeat the ultimate purpose of their unmanned remote deployment. Hence, by incorporating the merits of the well-known cloud based system, navigation of the robotic vehicle is provided by accessing commands from the cloud database at will by the user located at the base control station. Another aspect of the design involves utilization of a suitable environment friendly communication medium/spectrum unlike the conventional RF spectrum which provides harmful radiations to the surroundings. This is eliminated completely by using the hazard free and also abundantly available light energy by using concepts of visible light communication. Remote nature of deployment demands that the receiver modules are powered by alternate renewable sources of energy as their movement requires a great deal of power which is not quite possible with conventional limited battery power provisions. They are also not cost effective. Hence a solar panel is used to collect the light pulses replacing the conventional photodiode which requires a separate power supply.

## III. PROPOSED WORK

A general flow of the proposed robotic navigation module is illustrated in figure 1 shown below.

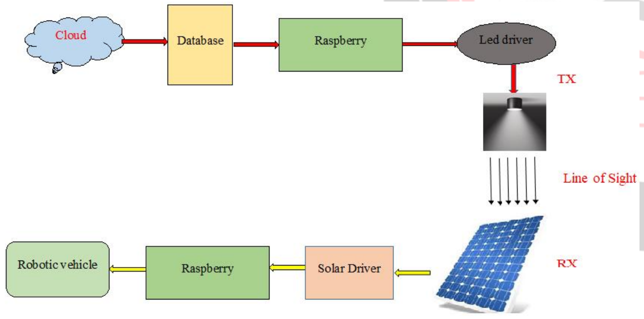


**Figure 1 Illustration of proposed robotic vehicle navigation system**

As seen from figure 1, it could be seen that the input signals are the commands or control signals which are 'FORWARD', 'REVERSE', 'LEFT', 'RIGHT', 'STOP'. Earlier systems have implemented the schemes using a voice based system which demand the presence of human being at the site of deployment. In a remote nature of deployment, cloud based storage system are quite indispensable in providing the requested commands from the base station at will and at any point of time. Cloud services are the recent trend in boosting the communication technologies into the near future by providing services at any point of time from any place on the globe. In the proposed case, the commands received from the cloud based storage system are modulated with the high frequency light pulses using a Raspberry Pi processor which issues appropriate driving voltages to the LED light source. The LED light source issues the light pulses in accordance with the control signals given from the Pi controller and the modulated light pulses are transmitted through the visible light communication channel. On the receiving side, the incoming light pulses are collected by a miniature solar panel and detected by the receiver Pi controller based on a mapping strategy and issues control signals accordingly to the mobile robotic vehicle. A flow process depicting the proposed work flow for the Cloud based navigation of robotic vehicle using the solar panel is depicted in figure 2.

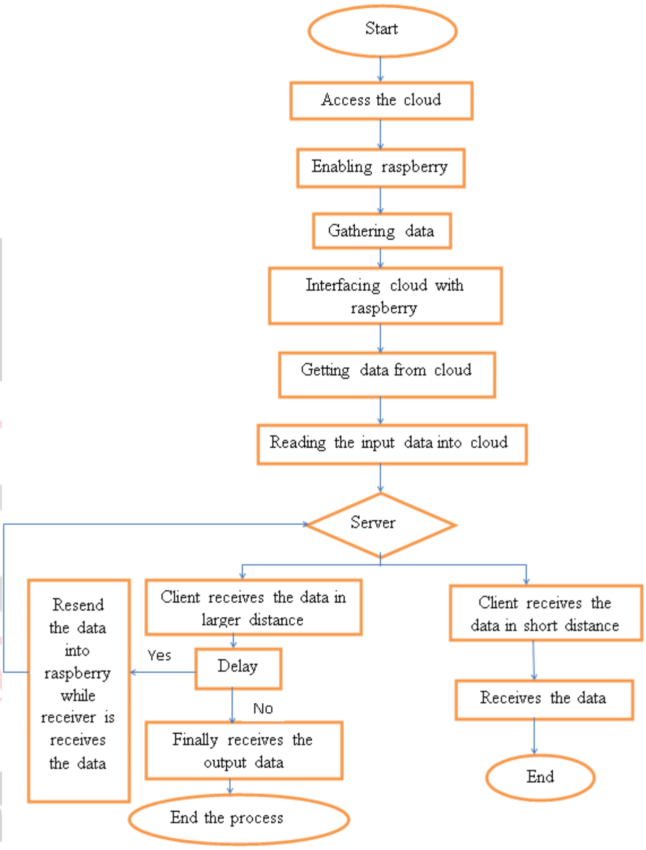


**Figure 2 Flow process of the proposed Cloud based navigation of robotic vehicle**

From figure 2, it could be seen that in the proposed work, the module is set up in a master slave mode with respect to the cloud and client raspberry pi. When the required command is given from the raspberry pi-cloud interface, the cloud provides the requested service to the client in which delay plays a vital role. Delay is more pronounced if the distance of access is quite large which may be attributed to several causes such as traffic congestion, unavailability of resources, lag in online access etc. in a typical scenario the delay is nearly zero as depicted from figure 2 and the retrieved command is modulated by raspberry pi to drive the LED driver to emit the digital pulses.

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## IV. RESULTS AND DISCUSSION

Raspberry Pi has been utilized in the proposed work which form the backbone of the entire module right from receiving the control signals from the raspberry – cloud interface down to the issue of control signals to direct the movement of the robotic vehicle. A typical raspberry Pi processor is depicted in figure 3.

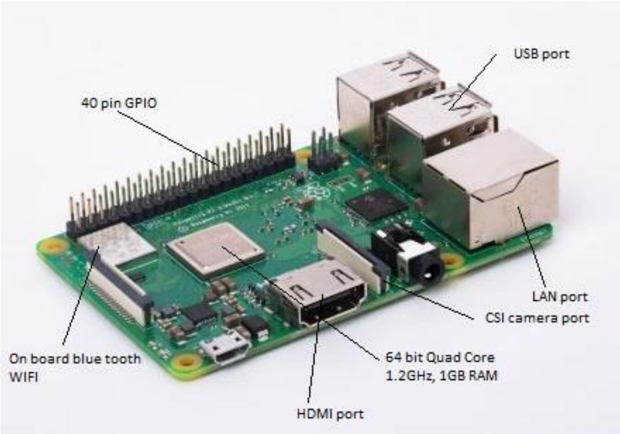


**Figure 3 Illustration of the Raspberry Pi Processor for the proposed navigation control**

A few points of merits over choosing Raspberry Pi over conventional controllers is due to its cost effective efficiency, and provision of ports and interfaces with state of the art WIFI and HDMI communication. Additional merits include the storage in the form of a SD card in the controller. The processor is quite fast and provides a quick response to the input as it is equipped with a powerful Quadcore 1.2GHz processor with an inbuilt 1 GB RAM. The programming in the proposed work is done using Raspbian which is a variant of the well-known Linux which is well compatible with Raspberry Pi. It is quite portable and suitable to be mounted on moving robotic vehicles as it overall size is just less than 50g with dimensions measuring 85.60x56.5mm.

Raspberry PI issues instructions to a powerful set of 4 DC motors rated at 150rpm equipped with a powerful L298N driver module. It records a power consumption of 25W at an armature voltage of 20V. The receiver is equipped with a miniature solar panel whose parameters are listed in table 1 shown below.

**Table 1 Receiver solar panel ratings**

| Parameter | Value |
|---|---|
| Model | KS-5649-8 |
| Dimensions | 24.8 x 9.7 x 1.1 mm |
| Illumination | 200 LUX |
| Short circuit current | 1.7 µA |
| Operating Voltage | 1.5V |

The solar panel used in the proposed work is depicted in figure 4 shown below.

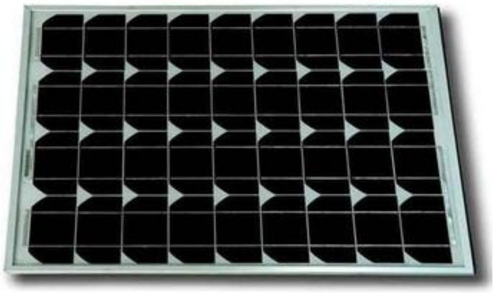

**Figure 4 Illustration of miniature solar panel used in proposed work**

As mentioned in previous sections, Raspbian has been used as the operating system to program the Raspberry Pi to receive the command signals from the cloud server. Utilization of Raspbian and subsequent programming requires Python 3 to be enabled. Based on the request sent to the server, the cloud data available at the hypertext terminal window is depicted in figure 5. In the proposed work, for experimentation purpose, five different controls have been stored in the cloud which include 'LEFT', 'RIGHT', 'BACKWARD', 'FORWARD', 'EXIT'. The first two commands require direction coordinates which are depicted in the HT terminal window shown in figure 5. 'EXIT' terminates the running programming thus halting the process.


**Figure 5 Hypertext terminal windows for the proposed work using Raspbian-Python 3**

Figure 6 depicts the set of available controls given to the user to choose from.

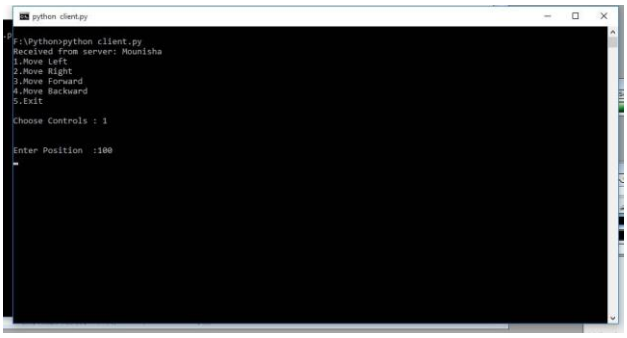


**Figure 6 Input select window given to the Cloud server through Python 3**

Based on the input selected as in the above case to be '1' corresponding to 'LEFT' movement by '100' coordinates

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the response obtained in the HT terminal window is depicted in figure 7.

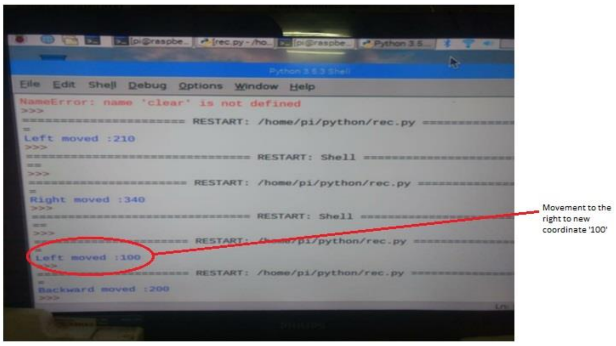


**Figure 7 Response window to the input 'LEFT'**

A typical reflection in the transmitted HT window is depicted in figure 8.

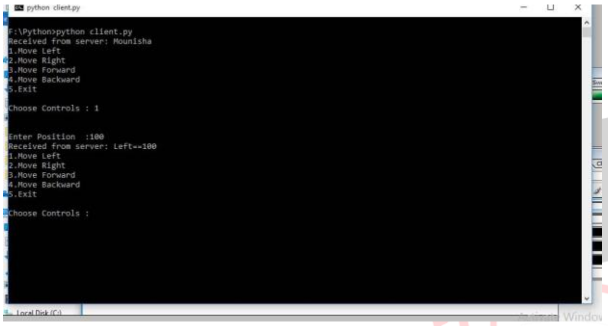


**Figure 8 Response window to the input 'LEFT' at base station HT**

Figure 8 depicts the response window of the HT at the transmitter end after the robot has navigated to the new position based on the command issued from the received pulse from solar panel. In utilizing the cloud the time taken for issuing the instruction to the client for three different instructions has been plotted in figure 9.

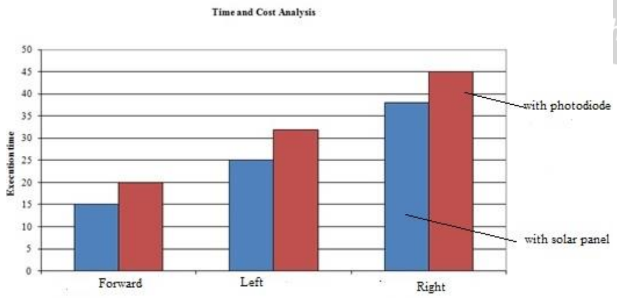


**Figure 9 Time analysis plot of Cloud based access by client**

The cost analysis pertains to the experiment carried out with and without solar plate collector in the receiver side of the overall module. It could be seen that blue plot corresponds to the time taken with solar plate and red plot corresponds to time taken with conventional photodiode. Superior and optimal performance is reported in the case of solar plate collector.

## V. Conclusion

A Raspberry Pi based navigation of a robotic vehicle based on visible light communication and a solar panel to receive the light pulses has been proposed and experimented in this research article. The novelty in the proposed work has been introduced in the form of integrating cloud based service model to store a set of predefined command signals and issued on demand by the client or consumer. The retrieval is achieved by a Raspberry Pi – Cloud interface using a SaaS model based approach and the execution time for each instruction fetched from cloud has been tested and presented in the observations. The proposed work drastically reduces the time of issue of instruction to the time of execution of the instruction as cloud based services are quite fast and offer a safe approach. Moreover, they are more secure and less prone to atmospheric disturbances and offer a better level of recognition. More over the implementation of solar panel in replacement to the conventional Photodiode reduce the power consumption along with possibility of reuse of power from solar irradiation as a future scope of research. The proposed model works well in a line of sight communication and best suited for small to medium scale indoor environments.

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