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Smart Cloud Robot Using Atmega Controller and Raspberry Pi Processor

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***Abstract*—Cloud robotics is an emerging field that is centered on the benefits of converged infrastructure and shared services of a cloud computing environment. In this paper, a system is designed with an autonomous robot to sense environmental data such as temperature, humidity, and air quality, along with GPS coordinates and store them on the cloud. The mobile robot is controlled using an Atmega16 microcontroller and communicates with the cloud via a Raspberry Pi. A private cloud is set up using MQTT that provides Infrastructure as a Service. The collected data are stored in a MQTT server which could be viewed through a suitable Android Application and can be used to create awareness about the environmental changes of the location under study. A proof-of-concept prototype has been developed to illustrate the effectiveness of the proposed system.**

***Index Terms*— Cloud Robotics, MQTT server, Raspberry Pi, Mobile Robot, GPS.**

I. Introduction

Cloud robotics is an emerging field that merges the concepts of cloud technologies and service robots. It is a disruptive technology based on the advantages of rapid fall in costs of servers, data centers, and broadband access, inexpensive cloud storage, and distributed computing. Internet is used to complement the capabilities of the robots by relieving them from on-board computation-intensive tasks and enable them to provide effective services on demand. Robotics is a technology that deals with the design, construction, operation, and application of robots, as well as computer systems for their control, sensory feedback, and information processing. The human operator may manipulate the robot from a distance by sending commands and receiving information via communication network. Robotic systems have brought significant economic and social impacts to human lives over the past few decades. Recently, robotic systems are utilized as data-gathering tools by scientists for a greater understanding of environmental processes. Robots are also being designed to explore deep oceans, to track harmful algal blooms, monitor climatic condition ns, and to study about remote volcanoes [1], [2].

Cloud is a service provider that provides services such as infrastructure, software or resources. Infrastructure as a Service (IaaS) models an organization that outsources the resources required for its operations, including storage and networking components. While the cloud computing paradigm was originally developed in the cyber world and applied software as a service (SaaS), in the last few years it has been extended to the cyber-physical world, including vehicles like cars and people with Smartphone's, and robots like ground vehicles and unmanned aerial vehicles [3].

Recently, researchers have started to merge cloud computing concepts with mobile robotics, e.g., [4], [5]. This approach has been particularly useful in the context of computation-intensive applications like image processing and cognition needed by mobile robots as these tasks take up space, power, and incur high costs. The cost and complexity of performing the basic functionalities such as sensing, actuation, and control in a single robot increases exponentially. Therefore, the cloud robot system efficiently provides different types of support. An interesting related technological development is the emergence of Robots as a Service (RAAS), analogous to system oriented architecture [6].

In spite of the significant potential of cloud robot systems, much of the research in literature has focused mainly on cloud-based operation of robot manipulators or arms. For example, Kehoe, et al [7] have applied the cloud computing concept to a manipulator mounted on a mobile robot system. Their technique performs object recognition, poses estimation and grasping of common household objects with the aid of Google Goggles Image Recognition System and stores the results on a MQTT Server. Kamei, et al [8] have proposed the use of cloud networked robots for providing multi-location daily activity using on-board manipulators to support elderly and disabled people. Use of vision-based servo control of manipulators with distributed computing has been proposed in [9].

More recently, robotics researchers have turned to the applications of cloud computing in individual and wirelessly networked mobile robot systems. Real-time path planning for mobile robots using computation-intensive evolutionary algorithms on the cloud has been studied in [10]. Use of cloud- based multi-core graphic processing units for analysis of 3D perceptual changes in robot texture images for purposes of navigation has been made in [11].

A number of mobile robotic systems have been developed in recent years for monitoring climate variables both terrestrial and underwater, harmful algal blooms and

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volcanoes. Mobile robots with on-board environmental sensors offer several advantages - low cost, ease of automation, wide operational range, and flexibility - in the monitoring of wide geographical areas [12]. Indoor and outdoor environmental monitoring using mobile robots has been considered by several researchers, e.g., [13], [14]. Small mobile robots called Boebots have been built to capture image that will be processed by a cloud setup using Microsoft windows Azure [15].However, these robots are very small in size, and so not well suited for either indoor or outdoor real-world environments.

A standalone low cost device for transmitting data with touch screen display had been built using Raspberry Pi and Bluetooth [16]. A robot to recognize voice had been developed using Google voice API and Raspberry Pi [17]. Raihan et. al. [18] had developed an economical automated toll system that work by processing images using Raspberry Pi. The system was developed as an alternative to the more costly system using RFID.

In this paper, a robot is designed to move autonomously in the open space and to monitor the environmental conditions. The sensor data collected by the robot are stored in a MQTT Server that could be also be displayed in an android based mobile as well. Since very large amounts of spatio-temporal environmental data are collected in the process, a MQTT Server is used for economical storage, analysis, and retrieval of the data. The cloud environment is set up using MQTT eclipse server. The Raspberry Pi microcontroller is used in the robot for communicating with the MQTT Server, while an Atmega-16 Microcontroller is used for control of the robot.

II. Review of Environmental Monitoring System

Air quality and pollution monitoring technologies have so far been quite expensive, and beyond the reach of countries like India. Such monitoring systems have been adhoc or needed stationary constructions, with manual fetching of the data, storage, and retrieval. Even with wireless transmission of round-the-clock data to the server, the measurements are mainly applicable to the immediate vicinity of the station. For example, a recent report in the New York Times reported that for a city of 20 million population New Delhi have only six state of-art monitoring stations [19].

Researchers at the University of California in Berkeley in USA have developed an urban sensor network to provide real-time, neighborhood-by-neighborhood measurements of carbon dioxide. The prototype network employs 40 sensors spread over a 27 square-mile grid [20]. Though the system uses off- the-shelf environment sensors to lower the cost from $250,000 (~ Rs. 1.5 crores) for a traditional monitoring station to $12,500 (~ Rs. 7.5 lakhs) it is still prohibitively expensive to use in India.

Previously, we have developed a low-cost mobile urban air quality monitoring system for Madurai city [21]. The developed system was fitted in school buses to monitor pollution in the city. More recently, the authors have developed a network of three robots (one master and two slave robots) wirelessly connected to monitor the environment [22].The robots moved around autonomously on a flat surface and submitted the collected data to a MQTT Server. A laptop computer was fixed in the master robot to communicate with the MQTT Server.

In the present work, we have replaced the laptop which is used for communication with Raspberry Pi, a microcontroller of low cost. The advantage of this proposed system is that the microcontroller is of low power and light weight, and consumes very less power when compared to laptop. The system developed in this project is completely based on open source hardware Atmega-16 and Raspberry Pi and MQTT Eclipse Server.

III. Architecture of Smart Cloud Robot

The architecture of the proposed smart cloud robot system is shown in Fig. 1. The mobile robot is of wheeled type that is easy to navigate indoors, but can also be used for navigation on smooth outdoor surfaces. The robot may be scaled up in the future with more powerful motors and rubber wheels for operating in uneven outdoor terrains. The robot is made to move in a fixed path using Atmega-16 and GPS. The robot communicates the sensor readings to the MQTT Server using Raspberry Pi. In this experiment, temperature and humidity sensors were used to observe the changes in the environmental conditions.

IV. Implementation Details

The schematic diagram of the mobile robot architecture is shown in Fig. 2.The mobile robot is operated with a gel acid battery powering the 12 V DC servomotors, through an H- bridge motor driver under PWM outputs from the Atmega-16. A GPS shield is mounted on the Atmega-16 to tag the latitude and longitude coordinates of the robot's position in addition to readings from a temperature/humidity sensor. The Raspberry Pi connected with the Atmega-16 communicates the reading of the sensors to the MQTT Server through Wi-Fi. The robot is equipped with an ultrasonic sensor to measure the distance between the robot and an obstacle. On detecting an obstacle the robot takes action such as move reverse direction or rotates and then move. Atmega-16 is based on an Atmel AVR processor, with on-board support for analog inputs, analog or pulse width modulation (PWM) outputs, and digital input/output [23].The microcontroller may be interfaced to a personal computer or a Raspberry Pi for programming and data acquisition through a USB port.

The Atmega-16 board is programmed in a C-like integrated development environment, with built-in example code known as *sketches*. Extensive built-in libraries are available with custom code for various applications.

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Atmega-16 can be used for creating interactive objects or environments. The microcontroller boards can be either built by hand with the help of hardware reference designs (CAD files) or purchased preassembled.

Temperature sensor and humidity sensors are connected to the board to observe the variables in the environment. The Global Positioning System (GPS) is a satellite based navigation system that sends and receives radio signals. GPS receivers acquire these signals and provide Information. Using GPS technology we can determine location, velocity round the clock in any weather conditions anywhere in the world. We need to interface Atmega-16 Uno with GPS [24]. The location of the robot is tracked in Google maps with Trimble Studio as depicted in Fig. 3.

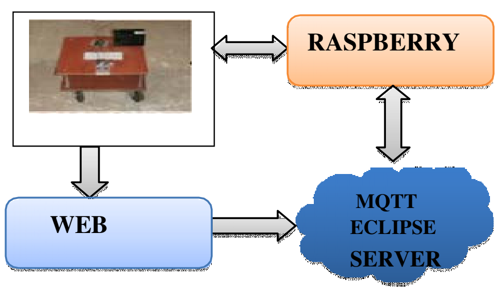


Fig. 1. Schematic of Proposed System

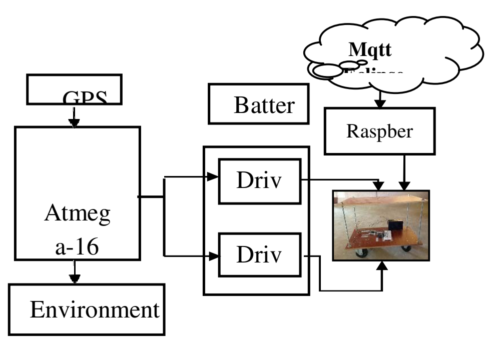
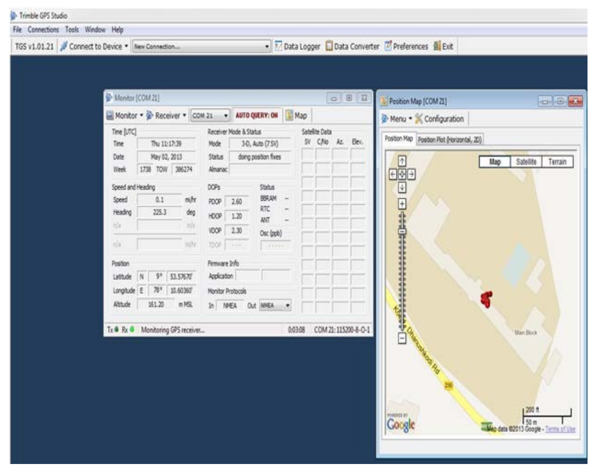


Fig.2. Mobile Robot Control Architecture

Ultrasonic sensors work on the principle of radar evaluates attributes of a target by interpreting the echoes from radio or sound waves respective [25].In this paper, ultrasonic sensor is used for obstacle detection. The object sensor is placed in the front side of the robot model to navigate and automatically detect if any obstacle is present. The maximum coverage range of sensor is 2 to 250 centimeters. It has a Broadcom system on a chip (SoC), Which includes a 700 MHz processor, Video Core IV GPU, and a RAM of size 256 MB or 512 MB. It uses an SD card for booting and persistent storage. The Raspberry Pi is a credit-card-sized single-board computer which is used to communicate with the cloud operating system, MQTT. Raspberry Pi is based on the Linux platform which supports the functionality of cloud environment. The sensor readings are stored in the MQTT Server once every minute via wireless communication using a Wi-Fi dongle device and Raspberry Pi board.

Fig. 3. Location of GPS Receiver as Viewed in Trimble Studio



V. Setting up the Cloud

A private cloud was setup to provide Infrastructure as a Service (IaaS) using MQTT. MQTT is a cloud operating system that manages a network of virtual machines and offers computing resources on demand. Flexibility is an important advantage of MQTT, and it is possible to design the cloud as per the user specifications and resource availability. A web interface is provided to manage the computing resources throughout the datacenter.

Figure 4 shows the conceptual architecture of an MQTT cloud. The Cloud Dashboard is a user interface for the administrators and clients (robots) to access and automate the resources in the cloud. Typing the host ip address in the browser opens the dashboard of the cloud. The MQTT dashboard is a graphical interface for administrators and users to access, control and allocate the resources in the cloud [26].The dashboard is just one way to interact with MQTT resources. It provides an overall view of the size and state of the cloud. Dashboard can be used to create users, projects, and assign users to the project to set limits on the resources. Keystone provides identity service by maintaining a central directory of users mapped to access the MQTT services and authorizes the users. Neutron is an MQTT networking system used for managing networks and IP addresses and it ensures that the network will not be a bottleneck in a cloud deployment. The jobs submitted to the cloud platform are processed by Nova, which is the main part of the IaaS. Swift is a scalable redundant storage system. Files are written to multiple disks present throughout the datacenter. The resource usage overview in the dashboard of a cloud setup using a single machine is

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illustrated in Fig. 5. The number of instances running, usage of virtual CPUs, and RAM are displayed in the dashboard. A webpage was created for displaying the environmental data. Only authorized users can login into the webpage. These are industrial-strength, MQTT that collectively can be used to develop, deploy and run web applications. After logging in, the user may view the sensor readings shown in Fig. 5.server-side programming platform).A graphical user interface (GUI) is developed for storage and retrieval of the environmental data. For ease of understanding, the values can be shown graphically for periodic intervals such as weeks, months, etc., and comparative summaries provided as column/bar charts or in tabular form.

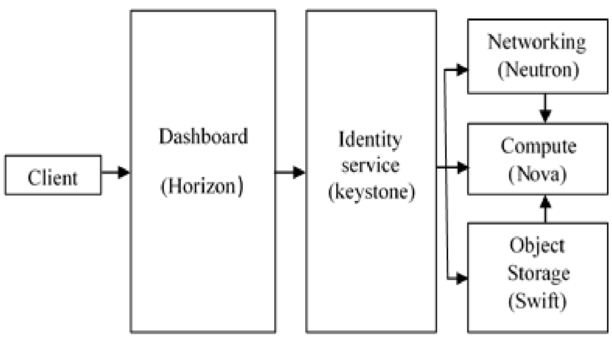

Fig 4 Conceptual Architecture of MQTT Cloud

VI. RESULT AND DISCUSSIONS

The robot was run and tested in the campus; the readings taken by the robot were uploaded to the MQTT Server and displayed using a suitable android application. The robot could run smoothly on flat concrete surface and the robot had troubles in moving on an uneven surface due to lack of powerful driving motors. Raspberry Pi was mounted on a small robot for collecting as well as performs basic processing of data. Fig. 6 shows the pictorial representation of environmental data collected over a period of four months. Robots of the type proposed here can work effectively in remote places to collect data, alone or in teams. Further on-board cameras may also be mounted on the robots and used to perform surveillance. Statistical analysis of the data variation over space and time can be performed, along with data mining and analytics of the environmental data. As shown in Table 1, the cost of the proposed mobile robot for environmental monitoring is around Rs. 10000. The proposed system is quite cost effective when compared to other existing methods that require more number of hardware accessories.

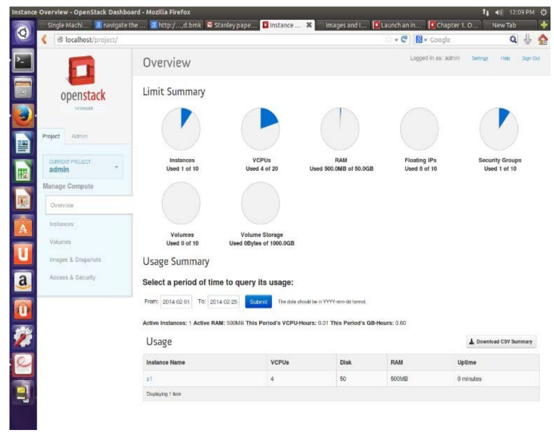

Fig.5. Dashboard depicting Utilization of Resources in Cloud

TABLE. 1. COST OF PROPOSED SYSTEM

Component	Approximate Cost in Indian Rupee
12V Battery	1000
Atmega 16 Uno	1850
Raspberry Pi	4100
Temperature/humidity sensor	200
Other sensors	500
2 DC Motors	800
Electromechanical Components	2000

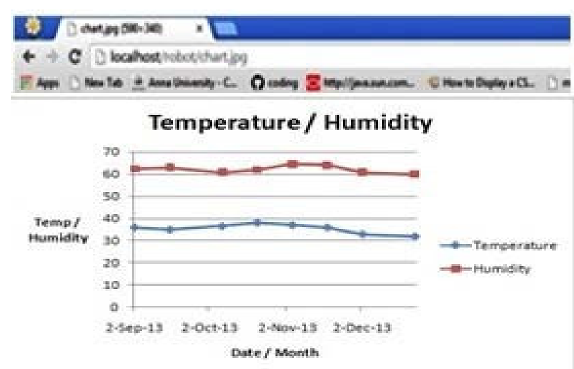

Fig. 6. Display of Temperature/Humidity on MQTT Server

VII. CONCLUSION

In this paper, we have proposed a design of a smart cloud robot to monitor the environmental condition of a remote place. A prototype has been developed and tested in our campus to illustrate the effectiveness of the proposed methodology. The system submits the collected data to the cloud as well as displays it on the web for further investigation. Storage is one of the challenges of the mobile robot, which is being addressed in thiscontribution.

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VIII. FUTURE WORK

In further work, the environmental monitoring robot may be extended for intrusion detection. On-board camera may be installed on the robot to capture images which could be submitted to the cloud for real-time processing. The image processing software available in the cloud, such as Google Object Recognition Engine could be used to identify the objects and report to officials if any intruder is found.

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Authors Biography

Bobin Rose N S was born on 1989.He has attended an international conference at Tamizhan College of Engineering and Technology, Nagercoil on the topic of Smart cloud robot. Currently He is a PG Scholar at Mar Ephraem College of Engineering and Technology in the department of computer science and engineering. He had completed his UG at St.Xaviers Catholic College of Engineering, Nagercoil in the Department of Computer Science & Engineering. . His area of interest is working on Networking ,Mobile Computing and cloud computing

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