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Remote Controlled Mapping

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***Abstract*: Three-dimensional mapping is the process of gathering location information so that the locations and possibly the attributes of the object can be presented in a form that has 3 dimensions (XYZ) that can interpret by a user. It is a technology used to turn objects, often irregularly shaped, into a display surface. These objects may be complex industrial landscapes, such as buildings, small indoor objects or theatrical stages. It helps obtain a precise picture of terrain – including all of the buildings and natural components of the terrain giving it a sense of size and depth combined with other information related to the environment mapped.**

Here, we intend to propose a secure remote-controlled three-dimensional mapping robot using an ultrasonic transducer. The robot is controlled wirelessly using Bluetooth to the desired area that needs to be mapped. The ultrasonic sensor then measures the physical parameters of the desired location, which is used to make a 3D map of the area by feeding them into specialized software. The main motivation behind this work is to address the problem of remote terrain mapping of places that are inaccessible to humans. The proposed solution can be used to investigate pipelines and explore riverbeds. It can also be used by the country's security forces to detect intruders and for probing for signs of life in case of natural disasters. It helps understand the environment under study and this information can be further stored and analyzed at times of need.

***Keywords*: Atmega 2560, Bluetooth, Mapping technologies, MeshLab, Motor drivers, Processing, Ultrasonic transducer.**

1. Introduction

Remote sensing is the art of obtaining information about an area through a device that is not in contact with the surface. Remote terrain analysis (RTA) is one of the crucial aspects in the study of topography of any region. The method of using sensors for 3D mapping for remote sensing has various advantages over manual processes. This includes greater accuracy, easy data acquisition for large areas, and ease in continuous monitoring, reduced fieldwork and secure access to remote locations that are inaccessible or dangerous. The field of remote sensing and analysis provides a large number of challenges and there are many methods how each of these can be approached. Sound navigation and ranging (SONAR) sensing is a beneficial and efficient method for sensing. Being light, robust, SONAR sensors find high-end applications in various fields. In spite of the accuracy of the information provided by SONAR sensors in locating and tracking targets, they lag behind in providing adequate information about the nature of the detected objects, are expensive and cause harmful radiations affecting human health. Another highly efficient technique used in the field of 3D mapping is light detection and ranging (LiDAR), which uses laser light to take measurements. The plot obtained has high point density and high spatial resolution. However, it is an expensive and complex system. A simple and integrated system that can move to a remote location, analyze the terrain and then transmit back useful information to the administrator wirelessly is not yet available. The motivation behind the work is to create such a reliable yet cost-efficient mapping system that can be easily deployed in any location. By substituting high-end sensor equipment that is used in currently deployed systems such as LiDAR sensor with an ultrasonic sensor, the same three-dimensional data can be obtained with fewer hassles. This work addresses the problem of accessing and sensing remote areas where it is difficult or potentially harmful for direct human approach and presence. The aim is to detect and map a 3D space and make this plot available to a person located elsewhere.

Basic sections of the mobile robot include:

1. Ultrasonic transducer-Transmission, Reception
2. Atmega2560- Microcontroller
3. Sensors – MQ135, MQ9, PIR
4. Bluetooth for wireless transmission
5. User interface application
6. Servo, stepper motors
7. Mapping software-, Processing MESHLAB

Through this work, we intend to create an entire 3D sensing and mapping system. The ultrasonic sensor which will take measurements of the area will be mounted on servo motor on a user-guided, 3D mapping mobile robot. The robot is equipped with its own power supply, a control system to control the sensors at all times, a set of stepper motors for scanning the environment, a wireless communication system for data transmission and geared motors to control the motion of the entire robot, thus making it an independent, standalone unit. The user end unit is capable of sending control signals to the bot in a wireless manner and receiving the data from the ultrasonic sensor. Algorithms for data analysis, plotting are created and coded on C platform and certain specialized mapping software. The further section gives a detailed literature review and background theory of each of the major modules used in this work. This includes mapping and plotting in 2D and 3D, the communication system between the senders and mapping system. A detailed analysis on the hardware design, which is how each of the hardware components used in this work is assembled and configured. This covers the setup and usage of ultrasonic sensors, geared DC and servo motors, stepper motors, Atmega2560, additional environment detection sensors. The working model covers the development and coding of the mapping system, building the user-guided 3D mapping robot, algorithm for terrain mapping. The obtained results and discussion of the whole work along with its future scope have been further discussed in detail.

2. Literature Survey

For this project, there were two methods for mapping to choose from: electromagnetic energy and sound waves. To decide between these two technologies, they must be compared and contrasted to see which would be better suited to this project.

Teng Long, Tao Zeng et.al [1] presents radar as an electronic device that uses radio waves to determine the range, angle, or velocity and thereby can be used for real-time positioning, imaging, detection and recognition of targets. With the development of ultra-wideband technology, synthetic aperture technology, signal and information processing technology, the radar coverage, detection accuracy and resolution have been greatly improved, especially in terms of one-dimensional (1D) high-resolution radar detection, tracking, recognition, and two-dimensional (2D) synthetic aperture radar imaging technology. Meanwhile, for the application of radar detection and remote sensing with high resolution and wide swath, the amount of data has been greatly increased. Pavlo Denysyuk, Vasyl Teslyuk et.al [2] presents LIDAR technology as an effective method of collecting data about the distance to surrounding objects. This technology is to obtain environmental information through active optical systems. Using the LIDAR sensor allows you to build a two-dimensional, or three-dimensional space map. We can achieve the anthropomorphic behavior of the system with the help of an artificial neural network, or more simple algorithms. Jinbo Chen et.al [3] introduces a comparison of conventional and SONAR based technologies in surveillance and inspection of underwater pipelines. The journal presents the inefficiency of conventional optical devices in turbid and harsh conditions compared to Sonar. William C. Vergara [4] differentiates active and passive sonar. An active sonar sends out sound pulses called pings, then receives the returning sound echo whereas passive sonar sets receive sound echoes without transmitting their own sound signals. Shadman Fahim Ahmad et. al [5] focus on the working principle of ultrasonic transducer HCSR04.Ashort pulse 10uF is needed to trigger input for the sensor to start ranging. The module will start by sending out a burst of ultrasound at 40KHz and raise it to echo. The distance is calculated by the time taken of the reflection of the ultrasound to reach the sensor. In simpler words it is the time interval between initial signal sent and echo signal received by the sensor. From technological point of view, the easiest way to measure the distance to objects in the environment is to use an ultrasonic sensor. However, there is an imperfection in this type of sensor, that lies in the "blind zone", it occurs when the sound wave is reflected from surfaces at too large angles, because of this the sound does not return to the receive.

The basic principle behind all these technologies is that a wave of energy is sent out from a transmitter, reflects off of surfaces, and a receiver then picks up the reflected wave. The distance between the sensor and the surface can be calculated based on the time difference between sending and receiving the wave.

3. Proposed System

A. Working Principle

The basic principle behind these technologies is that a wave of energy is sent out from a transmitter, reflects off of surfaces, and a receiver then picks up the reflected wave. The distance between the sensor and the surface can be calculated based on the time difference between sending and receiving the wave. This project focuses on mapping individual rooms in hazardous environments, where the layout of the room cannot be determined by sight, by using one of these mapping technologies. The objective of this project is to design and prototype a basic 2D and 3D mapping device. It must contain a wireless transmission system to communicate to a computer outside the room, which will generate the map.

A simple and integrated system that can move to a remote location, analyze the terrain and then transmit back useful information to the administrator wirelessly is not yet available. The motivation behind the work is to create such a reliable yet cost-efficient mapping system that can be easily deployed in any location. By substituting high-end sensor equipment that is used in currently deployed systems such as LiDAR sensor with an ultrasonic sensor, the same three-dimensional data can be obtained with fewer hassles. This work addresses the problem of accessing and sensing remote areas where it is difficult or potentially harmful for direct human approach and presence. The aim is to detect and map a 3D space and make this plot available to a person located elsewhere.

The ultrasonic sensor which will take measurements of the area will be mounted on servo motor on a user-guided, 3D mapping mobile robot. The robot is equipped with its own power supply, a control system to control the sensors at all times, a set of stepper motors for scanning the environment, a wireless communication system for data transmission and geared motors to control the motion of the entire robot, thus making it an independent, standalone unit. The user end unit is capable of sending control signals to the bot in a wireless manner and receiving the data from the ultrasonic sensor. Algorithms for data analysis, plotting are created and coded on C platform and certain specialized mapping software.

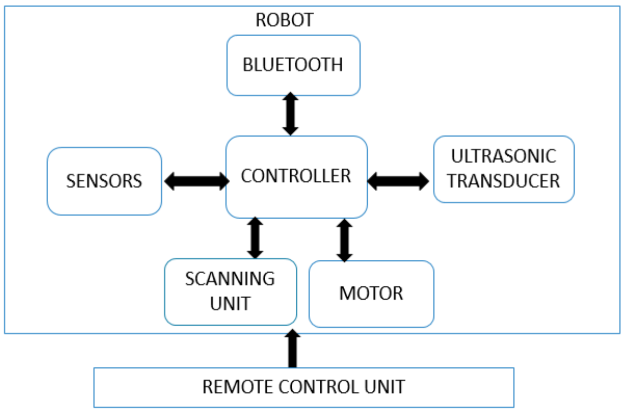

Fig. 1. Block Diagram

B. *Control Board*

The Arduino Mega 2560 is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started. The Mega is compatible with most shields designed for the Arduino Duemilanove or Diecimila.

The Arduino Mega is the addition to the Arduino family. This board is physically larger than all the other boards and offers significantly more digital and analog pins. The MEGA uses a different processor allowing greater program size and more. The Mega2560 differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the ATmega16U2 programmed as a USB-to-serial converter. The Mega has four hardware serial ports, which means maximum speed if you need a second or third (or fourth) port. The Arduino Mega works in the same way the Arduino Uno does but the difference is that it uses ATmega2560 microcontroller and has a greater number of digital pins, analog pins.

The circuit consists of a microcontroller Atmega2560, an ultrasonic transducer HCSR04, 4 sensors (IR, PIR, MQ9, MQ135), a Bluetooth module HC-05, 4 motor driver IC's L293D,4 servo motors of 100 rpm,2 stepper motors, Card reader module, voltage regulator 7805, 16 MHz crystal, capacitors (2 22 pF,1 100uF),10K resistor, battery (1 12V rechargeable battery, 2 9V, 1 5V) and push button. The ultrasonic transducer's echo and trigger pins are connected to the 15 and 5 pins of microcontroller. The IR sensor is connected to the analog pin 97 of microcontroller. The MQ9 and MQ135 sensors are connected to the analog pins 95 and 96 of the microcontroller. The PIR sensor is connected to the 7 pin of microcontroller. The Bluetooth module is connected to the 45 and 46 pins of microcontroller. The two motor drivers connected to servo motors of the movement unit are connected to 23,24,25,26 and 1,16,17,18 pins of microcontroller and other two motor drivers connected to the stepper motors of the scanning unit are connected to 73, 74, 75, 76 and 71, 72, 60, 59 pins of microcontroller. The card reader is connected to 19,20,21,22 pins of microcontroller. The crystal is connected to the 33 and 34 pins of microcontroller along with 2 22pF capacitors. The push button is connected to the 30 pin of microcontroller along with a 10k resistor and 100uF capacitor.

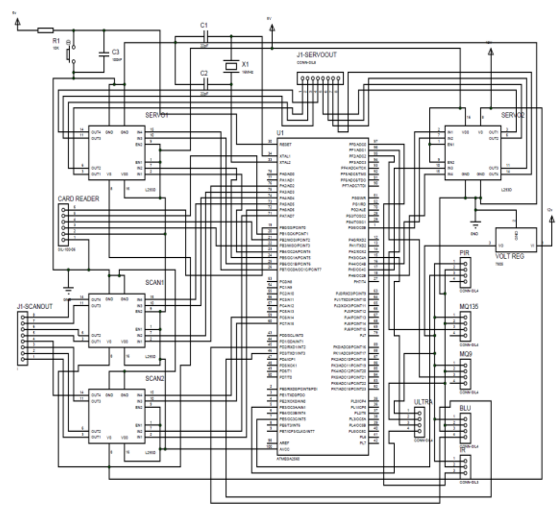

Fig. 2. Schematic of Control Board

The Atmega2560 is a low power, high performance CMOS 8-bit microcontroller based on enhanced RISC architecture. It provides highly flexible and cost effective embedded control applications. The microcontroller has 100 pins and combines flash memory, 8KB SRAM86 general I/O lines, general purpose registers, real time counter, PWM, 4 USART's. It has high processing power and can be used to design complex projects. It finds number of applications like automation and security, temperature sensing and detection, robotics, IOT, digital electronic circuits and many more.

L293D is a dual H-bridge motor driver IC. In its common mode of operation, two DC motors can be driven simultaneously in forward and backward directions. When the enable pin is high the driver is enabled, the output become active and work in phase with inputs. The input pins are connected to microcontroller and output pins are connected to motors.

The ultrasonic transducer uses sonar to determine distance to object. It offers excellent non-contact range detection with high accuracy and stable readings. It has Echo, Trig, V_{cc} and ground pins. The project utilizes it to get a 2D polar plot.

An infrared sensor is used to sense certain characteristics of its surroundings. It does this by either emitting or detecting infrared radiation. Infrared sensors are also capable of measuring the heat being emitted by an object and detecting motion. The Gnd, V_{cc} and analog out of the sensor is used. It is utilized in the project to get an approximate 3D plot**.**

The PIR, MQ9 and MQ135 sensors are used to detect motion and ambient atmospheric conditions. PIR is connected to the digital and MQ9, MQ135 to the analog pins of microcontroller. The sensors are driven by the regulated 5 V from the voltage regulator 7805 IC.

The servo motors which works on PWM (pulse width modulation) principle and is used in the project to provide motion to the desired terrain. Stepper motor is a brushless DC motor that rotates in steps. This is very useful because it can be precisely positioned without any feedback sensor, which represents an open-loop controller. It is used in the scanning unit to get the 3D characteristics of an object/area. The servo and stepper motors are connected to the output pins of L293D motor IC's. The servo motors are driver by 12 V supply and stepper motors by separate 9V supply with appropriate connectors.

HC-05 is a Bluetooth module which is designed for wireless communication can be used in a master or slave configuration. It has Vcc, Gnd, RX, TX and State pins, out of which first four pins are utilised. This module works on 3.3 V. We can connect 5V supply voltage as well since the module has on board 5 to 3.3 V regulator.

The SD card module is used to store the coordinates of the object obtained from the IR sensing mechanism. The module has V_{cc}, Gnd, CS, MOSI, MISO and CLK pins.

C. 2D Mapping unit

This section involves the Ultrasonic transducer, which sends the trigger signal to the area under desired mapping. The echo signals received provides information about the distance from the obstacle as well as the presence of the obstacle.

The values obtained from the ultrasonic transducer are then fed into a specialized Software Processing using a wired communication. Thus, the software provides a real time 2D map of the area scanned. This 2D plot obtained provides information about the distance from the obstacle, detection of any obstacle as well its movement.

D. 3D Scanning Unit

The IR sensor mounted over a scanning unit placed at the front-end of the wheeled robot, scans the area to be mapped. The values obtained from the sensor are then used to obtain a 3D map.

The sensor continuously scans the area both in the horizontal as well as the vertical direction simultaneously. The movement of the scanning section involves a horizontal full-length scan followed by a step increase vertically of the unit to scan the next step horizontally. In this manner a large no of values is obtained by the series of scans. These values are then translated into a specialized Software-MeshLab to obtain the corresponding 3D map of the scanned area or obstacle.

E. User Interface application

For the remote-controlled movement of the robot an application- Bluetooth terminal has been used. This application can be easily installed in a mobile phone and is used for the controlled movement of the bot.

The control commands are wirelessly transmitted to the Bluetooth module on the bot. Also, the presence of an obstacle, distance from an obstacle, successive values of the atmospheric conditions, human presence, are constantly updated and can be viewed over the interface for user convenience.

In the presence of an obstacle the interface displays the following text- 'ALERT: OBSTACLE DETECTED' and the bot stops automatically at a safe distance of 35 cm from the obstacle. Following are the control commands: 'W'-FORWARD,'S'-BACKWARD,'A'-LEFT,'D'-RIGHT,'P'-PAUSE, for its user-controlled navigation. The atmospheric condition of the area is obtained from the sensors 'MQ9'-POISONOUS GAS SENSOR, 'MQ135'-AIR QUALITY SENSOR in terms of their respective presence in percentage. The presence of any human/living organism is detected by the 'PIR' sensor on board.

F. Software Implementation

1) Processing Software

Processing is an open source graphical library and integrated development environment (IDE)/playground built for the electronic arts, new media art, and visual design communities with the purpose of teaching non-programmers the fundamentals of computer programming in a visual context.

Processing uses the Java language, with additional simplifications such as additional classes and aliased mathematical functions and operations. In the proposed design, this software has been used in order to map the values obtained from the ultrasonic transducer.

Using the distance, average-value of sensor reading obtained from the transducer, this software successfully maps a 2D polar plot. The polar plot obtained on the monitor, provides information regarding the presence of any obstacle in the mapped area, the detection of moving objects and the distance from the obstacle.

2) Meshlab

MeshLab is a 3D mesh processing software system that is oriented to the management and processing of unstructured large meshes and provides a set of tools for editing, cleaning, healing, inspecting, rendering, and converting these kinds of meshes. MeshLab is free and open-source software.

This software provides a 3D plot of the scanned area using specific codes such that the translation from a 2D to a 3D system are obtained.

The values obtained from the IR sensor, used for scanning the obstacle are converted into a 3-cordinate system using specific translation codes to obtain a 3D map.

4. Final Product

The fig. 3. shows the final hardware implementation of the proposed wheeled robot. The entire robot covers a space of 10x10x8cm, weighs a total of 0.5kg.

The extended top-end represented by (1)- shows a mounted ultrasonic transducer over a servo-motor, used for the 2D mapping. The front-end represented by (2)- is composed of 2 CD-drivers placed perpendicular with respect to each other to fulfill the scanning mechanism, and are mounted on by an IR sensor for obtaining the 3D map.

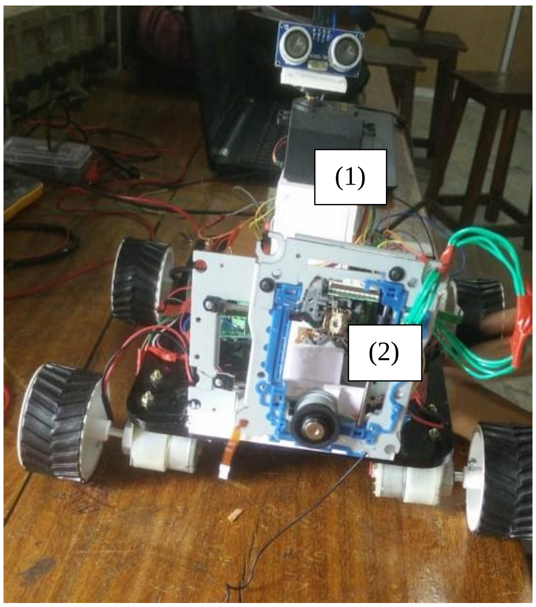

Fig. 3. Hardware implementation of proposed design

5. Results

The following fig. 4. shows the 2D plot obtained from the processing software based on the readings calculated by the ultrasonic transducer.

The fig. 4. corresponds to the 1st scan of the area by the transducer.

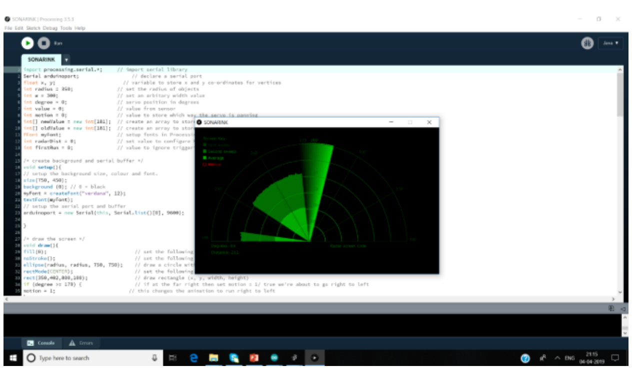
Fig. 4. PROCESSING software 2D map of scanned area

The next fig. 5. corresponds to the plot after 2 scans of the same area.

Observations are as follows:

The black region between the green peaks represent the absence of the obstacle. Green regions detect the presence of the obstacle and their distance from the bot. After the 2nd scan, the 2 scan values are compared and any deviation in them, helps infer the movement of the obstacle. Thus, the fig shows the red circles corresponding to regions where the obstacle is in motion. The obstacle movement detection is also successfully obtained.

The distance and average values of the transducer are also displayed simultaneously alongside the left corner of the plot.

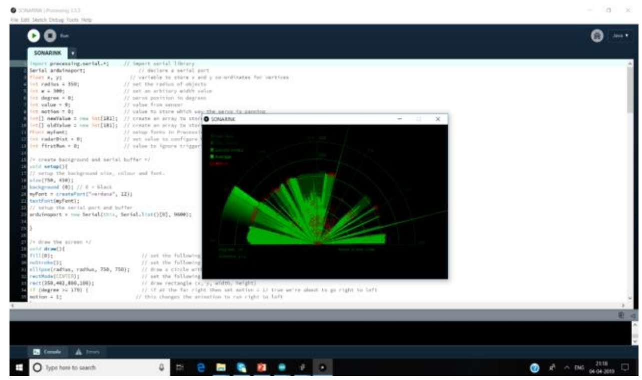
Fig. 5. PROCESSING software 2D map obstacle movement detection

The 3D plot obtained from MeshLab is shown below in the fig.6 The values obtained from the various scans of the region and obstacle by the IR sensor have been used to obtain the 3D plot the obstacle.

The fig. 6. shown below represents the 3B image of a curved path/ obstacle placed in front of the bot for test purpose.

Due to noise factors, vibrations in the system, noise incurred during value translations, the plot obtained is not apt enough. This leads to the realization that a better specialized software is needed to filter out the noise of the system, translate values of sensors with minimal error and thus obtain a much more efficient 3D plot the obstacle

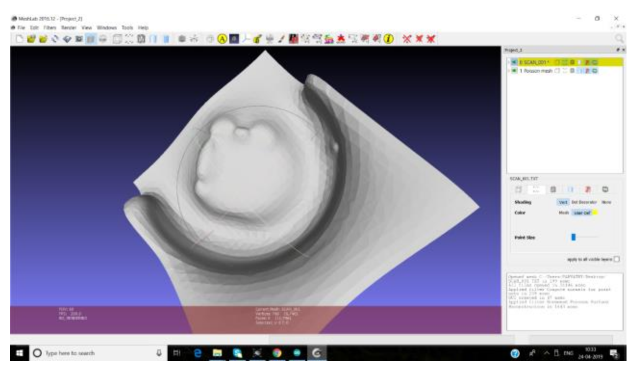
Fig. 6. MESHLAB software 3D plot for a curved path as an obstacle

This fig represents the user interface on the Bluetooth application used for the control and monitoring of the sensor values to determine the conditions of the mapped area. The command is given via this application and the sensor readings are displayed as shown in the fig.

During scanning however, the distance value is preset to 0. The presence of an obstacle, the presence of human, various sensor readings and the control commands together make the wheeled robot an efficient system which is remote controlled.

Fig. 7. Bluetooth terminal application user interface on mobile phone

6. Conclusion

We created a device that can go to a remote area and create a 2D, 3D map of it, which can be used for remote sensing applications. The device can move according to the instruction provided by administrator and sense the real-time environment under consideration for its temperature, humidity, human presence, presence of poisonous gases. Provision for storing these plots for later retrieval is also provided. Since memory in the bot is limited, the provision for storing this plot is made on a local server with the administrative system as host. All readings are taken in terms of distances to obstacles. The bot is capable of traveling in rugged terrains and creates a hemispherical plot, spherical plot using certain specialized software where the readings are accurate to ± 3mm. The readings for the plot are taken in spherical coordinates and converted to Cartesian coordinates for plotting onto 3D provision for 2D as well as 3D plot has been made where the administrative system is given full control of the bot.

The proposed design can be used to investigate pipelines and explore riverbeds. It can also be used by the country's security forces to detect intruders and for probing for signs of life in case of natural disasters. It helps understand the environment under study and this information can be further stored and analyzed at times of need.

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