Real-Time Map Building using Ultrasound Scanning

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Abstract - *The robots of tomorrow will be required to negotiate a multitude of environs, indoor and outdoor, varying in topography, possibly without human guidance. A prerequisite for intelligent navigation is the presence of a map or representation of the surrounding environment. The challenge is to create a device that can enable a robot to learn a new environment by sensing its surroundings and building a representation of it, while keeping in mind the specific requirements of mobile robots viz. low power draw, minimal weight and minimal post-processing of data. A device that uses a scanning ultrasonic range sensor to gather information about the environment was proposed. The device has moderate resolution at small-to-medium ranges and generates the map in real-time allowing the human operators to visualize the data as it is captured. The image represents the plan view of the environment. It is inexpensive in terms of power consumption, weight and price. The platform is highly extensible i.e. it can easily be made to work with higher resolution sensors, laser ranging and capture 3D data.*

Key Words: Real time mapping, Lab View, Ultrasonic sensor, Scanning device, Echolocation,.

1. INTRODUCTION

With mobile robots becoming more pervasive in daily life, it is not very hard to imagine a future where robots replace humans in performing all manner of mundane or dangerous tasks, with minimal human intervention. Personal robotic butlers, autonomous fire-fighters and soldiers, military drones for reconnaissance and attack while straight out of science fiction, seem fairly inevitable. Indeed, even today we find that mobile robots are being used for tasks such as vacuuming (IRobot Roomba), lawn mowing (Husqvarna Automower), load carrying (Boston Dynamics BigDog) and industrial automation. Currently, robots are not preferred for domestic/military use as the relatively poor performance, limited functionality and high cost of operation are hard to justify when cheap, effective low-tech alternatives exist. But with time, as the low-power processors, sensors and other specialized hardware employed in robots become more widespread and economies of scale are setup, their cost will drop. Cost and ethics aside, a few technical problems must be solved before the widespread adoption of autonomous mobile robots. Currently, humans feature prominently in the control loop in the form of a remote tele-operator. As humans are further removed from the equation, the robots will need to be imbued with sufficient intelligence to perform the tasks autonomously. Mapping is second nature to humans. We create cognitive maps of our environment and are capable of efficient navigation. Mapping is a fundamental problem that needs to be solved for true robot autonomy to be realized. In order to move effectively the robot must be able to construct a map of its environment, be able to localize itself in it, and then decide an appropriate path to its destination. Stimulus based response, where reactions are triggered solely by current external conditions is adequate only for the very simplest of tasks. For more complex motion, it simply will not do.

Once mapping is combined with localization and motion planning, the robot will be capable of autonomous motion.

2. BACKGROUND

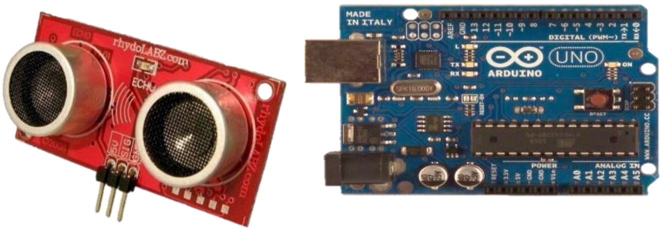
The range sensor in question uses the time-of-flight (TOF) or echolocation method for range calculation. The TOF method is simply a method to measure distance to a target by measuring the time it takes for sound/light to travel to the target and back. The measured time is representative of traveling twice the separation distance and must therefore be reduced by half to result in actual range to the target. The advantages of TOF systems arise from the direct nature of their straight-line active sensing. The returned signal follows essentially the same path back to the receiver. Furthermore, the absolute range to an observed point is directly available as output with no complicated analysis required, and the technique is not based on any assumptions concerning the planar properties or orientation of the target surface. The three main types of TOF techniques are RADAR (RAdio Detection And Ranging), LIDAR (LIght Detection And Ranging) and SONAR (SOund Navigation And Ranging).

Ultrasound range sensing was chosen due to the ready availability of low-cost systems and their ease of interface. The power requirements of ultrasound systems are minimal and they have good resolution at small-moderate distances. At present, the best ultrasound sensors have an effective range of 10m with options for water and ingress protection to allow for outdoor usage.

2. SYSTEM CONFIGURATION

The setup consists of an ultrasonic sensor module, Arduino UNO micro controller development board and servo motor.

Ultrasonic pulses are sent in the certain frequency. It has an effective range of 2cm to 2m. It operates in the bi-static mode with separate transmitter and receiver transducers,



(a) (b)

Fig -1: (a) Ultrasonic sensor module, (b) Arduino UNO micro controller development board.

placed side by side. With a power draw of less than 0.1W, it is ideal for mobile use. The TOF is calculated by built-in circuitry and is sent to the microcontroller as a Pulse Width Modulated (PWM) signal. The Arduino is a microcontroller development board and functions as a Data Acquisition (DAQ) device. It controls the servo, sensor and takes care of data transmission. It functions autonomously, with the PC only serving to start the program and act as a data sink. Commands and data are sent through USB.

3. IMPLEMENTATION

The ultrasonic sensor module is mounted on a carousel connected to the servo motor. As the servo rotates, the sensor module gathers range data about its surroundings.

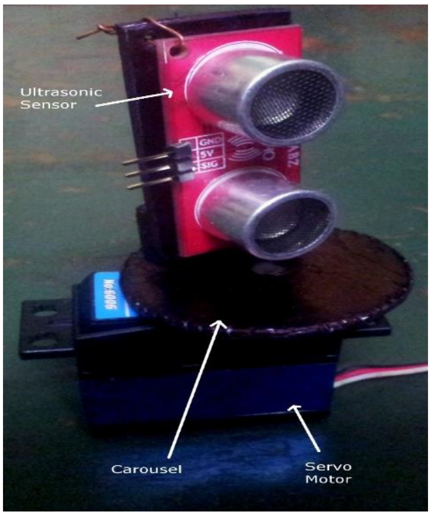


Fig -2: Ultrasound scanning platform

The Arduino has been programmed to rotate the servo, trigger the sensor, receive the data from the sensor and send it to the PC via USB. Once the PC receives the data, a LabVIEW program parses and plots it as an image.

These steps are performed in a synchronised sequence. The device is currently capable of capturing 180 data points over a 180-degree field, with a minimum scanning duration of 1.8sec.

3.1 Lab VIEW

A LabVIEW program was designed to parse and visualize the data acquired by the Arduino. It plots the data as a polar graph from 0-180 degrees. Objects beyond range of the sensor are plotted at a certain distance. The Arduino, while connected to the PC via USB, appears as a virtual Serial device connected to a COM port. 'VISA resource name' allows the user to select the port number. The program allows the image and data to be exported to the hard drive in the form of a jpeg and spreadsheet file respectively. A variation is done to acquire a composite image. , the flat surface was not detected as being flat; rather it appeared as an arc of a circle with its center being the location of the sensor.

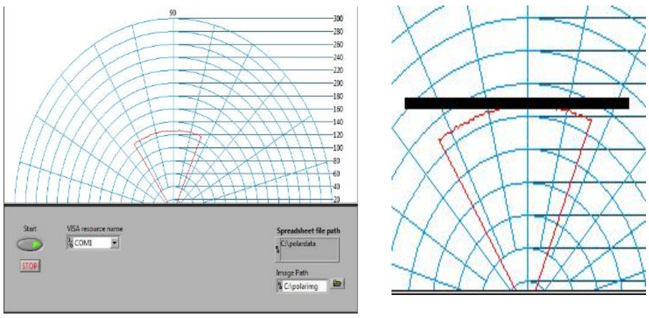


Fig -3: (a) Lab View polar plot of a flat plate,
(b) Comparison of plotted image with actual object (actual object represented as black overlay)

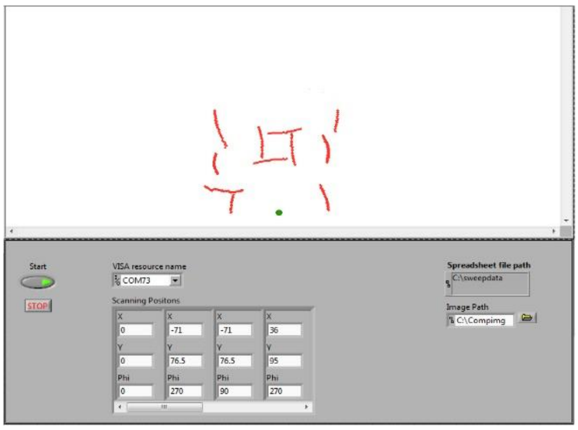
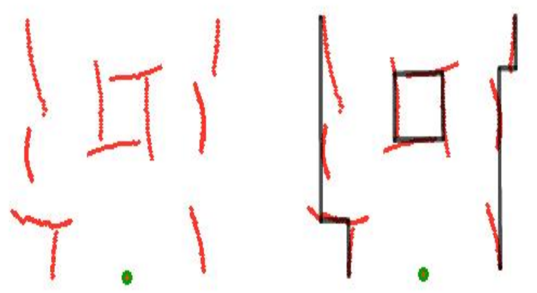


Fig -4: Scan of the test setup, visualized with the help of the composite image

A constructed test setup was subjected to multiple scans and the resulting scan was produced. The image produced is a fairly good representation of the actual setup and suggests that with a few improvements, the unit can be used to produce more accurate and detailed maps. The problem of flat surfaces being detected as arcs, occurs here as well.



(a) (b)

Fig -5: Scan of the test setup, visualized with the help of the composite image (Module positioned Manually)

4. DISCUSSIONS

1. The sensor cannot accurately measure the distance to an object that: is a) more than 2 meters away, b) that has its reflective surface at a shallow angle (<45 degrees) so that sound will not be reflected back towards the sensor, or c) is too small to reflect enough sound back to the sensor. In addition, objects that absorb sound or have a soft or irregular surface, may not reflect enough sound to be detected accurately. The unit is not recommended for outdoor use. Ingress protection can be made a feature in future iterations.

2. The main cause of inaccuracy in the plotted maps is due to the width of the ultrasound beam. The authors' hypothesis is that due to the large angular spread, the sensor keeps detecting the shortest distance to the target object within its spread (the intersection of the sensor axis and the flat surface, when the angle between them is 90 degrees) even though it faces a different portion of the surface. This results in the formation of arcs instead of straight lines. This can be ameliorated by using a higher resolution sensor that produces a narrower beam. However, even a high performance sensor with a mere 2-degree angular spread will cover approximately 30cm at a range of 10m. Attenuation effects also lead to loss of signals at distances greater than 10m.This suggests the usage of LIDAR for high precision or long range measurements. Adopting these systems will come with their own disadvantages such as the need for precision timing circuits and added cost.

3. The servo motor used only allows 180 degrees of rotation, in 1 degree steps. It could be replaced with a stepper motor which allows for continuous 360-degree rotation and permits sub-degree angular control.

4. The velocity of sound is taken as a constant in the range calculation. In actuality, the speed of sound is a function of temperature and to a lesser extent, humidity. The percentage error (of v_{sound}) over the sensor's operating range of 0 to 70 ° C is significant, in the magnitude of 11 to 12 percent. The incorporation of temperature sensors to account for air temperature is essential for accurate measurements.

5. In its current form, the program requires that the sensor must be manually lifted and moved to various predetermined positions and orientations. For the device to be of real use, it should reflect data from a positioning device. Typical dead-reckoning methods can be used to find position relative to the starting point. This could be done by measuring the rotation of wheels of the mobile platform using an odometer. Inertial navigation methods such as GPS or gyroscopes are attractive alternatives.

6. By turning the sensor upwards and moving the platform, the unit can be made to capture 3D data, with each scan producing one section of a multi-section wireframe/mesh model. This might be of considerable use when surveying caves, studying depositions inside of pipes and navigation for an aerial micro-robot.

7. Sensor resolution increases with frequency. It is also affected by the accuracy of the time-measuring circuits in the sensor. However, a trade-off exists between resolution and effective range, with resolution decreasing as range increases. Therefore, a balance between the two must be found as per the given requirements. A lower frequency sensor should be selected for longer.

5. CONCLUSION

The visual programming paradigm is a sea change when compared to conventional programming. The benefits are numerous. A more natural way to program when compared to text-based interfaces. Improved readability of large programs when compared to the conventional programming paradigm allows for easy debugging. Instead of manual positioning, if the test module's location and position are synchronized using a rover or a flying device like quad copter, 3D imaging of the surrounding with increased accuracy is possible. Even with a host of limitations, the preliminary results look promising.

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