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Planning and execution of a centralized method for localization of many nodes

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ABSTRACT

In this study, a centralized solution for multi nodes localization is provided. A beacon is placed near the environment's mid-lower edge to facilitate this method. This beacon has a built-in rangefinder that can scan its surroundings to determine how far away a detecting node is. The beacon is also equipped with a remote control to help identify the detecting node. The architecture used here consists of two nodes, with eight cells in each, and a 5 mm infrared (IR) transmitter and TSOP4P38 IR receiver in each cell. If the beacon ID has been received by an IR receiver, the node ID will be sent back to the beacon by the transmitter belonging to the same cell. After collecting data from identified nodes and beacon readings, the findings of this estimation of the visible nodes' position and orientation will be stored in the central computer. Different distances between the nodes and the beacon have been examined with various experimental outcomes. Also, numerous rotation angles at the beacon have been experienced to examine the performance of the introduced strategy.

1. INTRODUCTION

For the purpose of display or further processing, a sensor is described as a tiny instrument used to detect or measure specified physical quantities and transform them into human-readable signals through a predefined relationship. In addition to measuring temperature, light, humidity, motion, pressure, and sound [1, 2], sensors are utilized for a wide range of other parameters. Localization is a major problem in a system with several nodes. Because the data would be spatially meaningless without position, it is important that the information acquired from sensor nodes contain their location in order to offer a better understanding of the observed sensor environment [2, 3]. Object tracking, monitoring, and all applications that necessitate rapid and efficient data routing, such as transporting firemen to an emergency site, or military concerns, are just a few of the many domains where the positioning feature gives new prospects [4], [5]. Depending on the method used to find the nodes, localization may be classified as either centralized or distributed [6, 7]. Distributed architectures allow each node to determine its own location by exchanging data with its neighbors, but this design has the drawback of requiring extra hardware at each node for position determination [8, 9]. Most of the calculations needed to determine the location of each node are handled by a centralized unit in a centralized architecture, which also receives all incoming data. The fundamental drawback of this approach is that if the central unit fails, the whole system would collapse [10]. As a result, the scalability problem struggles from the centralized structures. Large-scale networks [11], [12] may cause congestion in the central processing unit. Because of the importance of localization in wireless sensor networks, selecting sensors for communication and distance measurement will remain challenging so long as localization is utilized [13].

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A camera, laser scanner, linear variable differential transducer (LVDT), ultrasonic, or infrared sensor may all be installed on a node and used to calculate distance [14], [15]. Numerous uses call for inexpensive distance sensors with high precision. Although the LVDT, laser scanner, and camera are precise, they are prohibitively costly [16], [17]. Infrared (IR) and ultrasonic (US) sensors are convenient for measuring distance because of their precision and low cost [18], [19]. However, distance computation isn't always enough for localization; some methods depend on node connections to ascertain node placements, while others want knowledge of the identities of the sender and recipient.

Once again, we need inexpensive sensors to enable infrared sensor nodes in an indoor system to communicate with one another [20]. Experiments show that the HC-SR04 ultrasonic sensor is the best for determining distance, while the TSOP4P38-IR receiver with a remote control circuit is the best for achieving communication among nodes in interior situations [21].

In another work, a hybrid indoor method was presented that mixes distributed and centralized systems. This strategy utilizes links between nodes to construct a tree-like structure, with the beacon at its center. Each node in the tree uses data passing through it to determine its position [22]. Other works employ a centralized design to generate two tables from the data gathered during scans performed by beacon and visible nodes. Invisible nodes have been identified with the use of these tables in the past [23]. The locations matching method is used to implement yet another piece of paper. This method is meant to be used in the creation of a system for identifying and locating objects of various hues. The system contains two beacons with long-distance IR sensors to acquire the absolute positions estimates of items. In this system, each item has varied surface color and different reflectivity factor [24]. Another study equips the surroundings with a distant infrared sensor, which it uses to scan the robots and determine, without prior knowledge of their IDs, where and in what direction a number of team robots are located. The IDs of these robots are derived by comparing the orientation received from the distant infrared sensor with the relative orientation recorded using onboard sensors [25]. This study will demonstrate how the centralized strategy may be implemented using the HC-SR04 ultrasonic sensor and the TSOP4P38 IR receiver with a remote control circuit. Each beacon and node's electrical circuitry and physical architecture are discussed in this study. The communication between the beacon and the nodes is also covered. Section 2 provides a comprehensive overview of the system, while Section 3 analyzes the findings and draws conclusions. Section 4 will provide a summary and last thoughts.

2. RESEARCH METHOD

Each of the four parts—nodes, beacon, computer, and data recording software—make up our suggested multi-node system. Located smack dab in the center of the lower border of the frame, the beacon can scan the area, communicate with each node, and learn their unique identifier. The data will be sent to the computer through USB. This is required so that the data recording program can generate the nodes based on their estimated locations and identifiers, as shown in Figure 1.

Hardware 2.1: The Core Components

One beacon and two nodes make up the system's hardware. The board has a length of 80 cm and a width of 80 cm, and all the items are arranged on it. Below is a description of the physical layout of the beacon and nodes, along with the circuits that power them.

2.1.1 The Organization of Nodes

We earlier indicated that the system had two nodes. Figure 2 shows that there are three distinct components to each node. The node base is the initial component; it has two wheels and two balance screws. In the event that we need to move the node, a servo motor is connected to each wheel. The second piece is a white cylinder 11 cm in height that allows the beacon sonar to scan the node. There are two layers making up the top third of the node. As shown in Figure 3(a), the first layer was partitioned into eight cells to house four 5 mm IR transmitters and four TSOP4P38-IR receivers. As can be seen in Figure 3(b), the second layer consists of the node roof. This layer contains a 9 V battery, a control board, and a relay attached to a remote-control circuit to pick the node identification code. The first layer, which includes the relay with remote control circuit, will serve as the basis for the communication system.

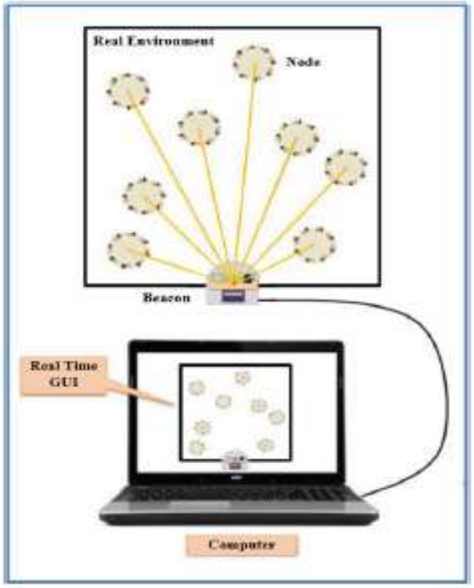

Figure 1. Experimental setup infrastructure

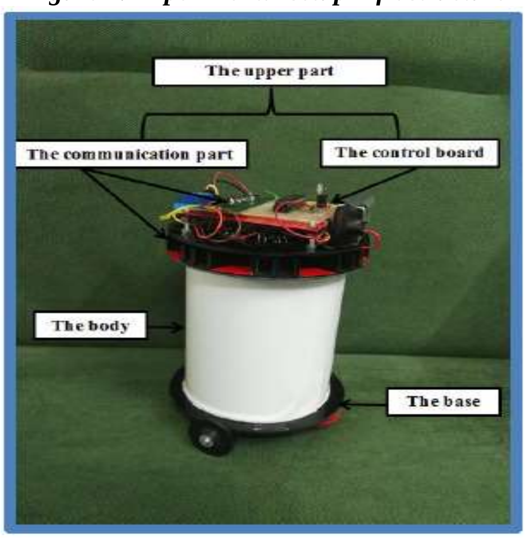

Figure 2. Illustration of node parts

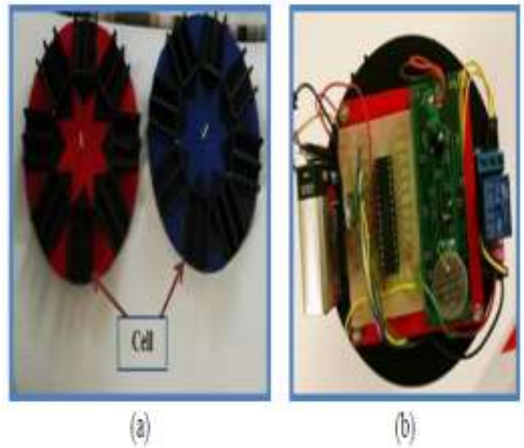

Figure 3. The top section of node (a) first layer and (b) second layer

An ATMEGA328P microcontroller is installed on the control board of the node architecture. In order to achieve its high throughput of up to 1 MIPS per 1 MHz, the low-power CMOS 8-bit microcontroller ATMEGA328P makes advantage of the cutting-edge reduced instruction set computer architecture. The microcontroller has 32 GBs, each of which contains eight bits. There is additionally 1 KB of EEPROM, 2 KB of SRAM, and 32 KB of flash program memory. Input/output lines number 23, and the microcontroller needs 1.8 to 5.5 V to function.

The control board incorporates a 16 MHz crystal and two 22 pF capacitors to provide an external crystal oscillator. The crystal oscillator is responsible for providing the clock signal that keeps the microcontroller in time with the rest of the system. The microcontroller's operations may be sped up by utilizing an external oscillator, even though the ATMEGA328P has its own 1 MHz internal oscillator. On the other the micro... Finally, the control board incorporates a voltage regulator to reduce the 9 V from the battery to the 5 V required by the microcontroller, TSOP4P38 IR receiver, and relay. Figure 4 shows a schematic representation of the top layer of a node.

Figure 5 depicts the beacon's three-part construction. The IDs of the nodes and their distances from the beacon are determined using these pieces. A breakdown of each section is provided below. The sonar, the first component, finds nodes and calculates distances between them. This component is a servo motor-mounted HC-SR04 ultrasonic distance sensor that can be rotated around a full 360 degrees. Two screws secure the servo to a square plastic board. The objective of this section is to feel the nodes, compute

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the detection angles, and determine the distance between the beacon and each of the nodes.

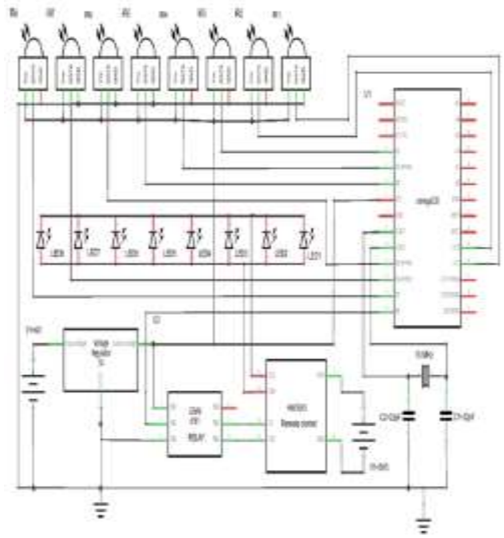
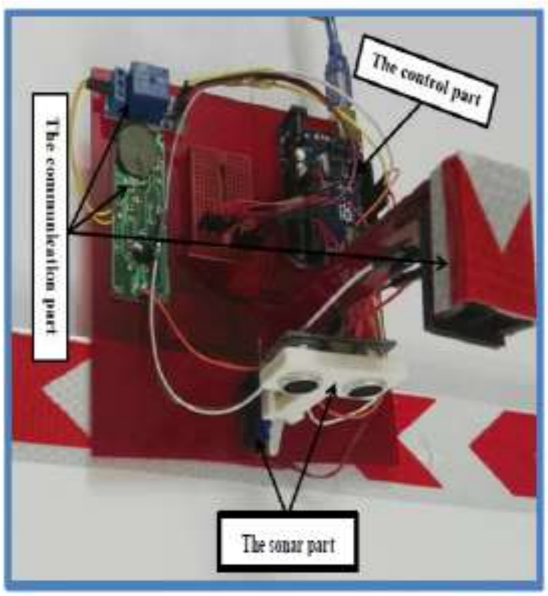


Figure 4. the node upper part schematic diagram



Components of the beacon, shown in Figure 5.

A relay is linked to a remote-control circuit in the second section, which both reside on the same square plastic board as the first. When it receives a signal from the beacon control, the relay functions as a switch to complete the remote-control circuit. By connecting the remote's circuit, the beacon ID will be sent through an infrared transmitter of only 5 mm in diameter. The 5 mm IR transmitter and the TSOP4P38 IR receiver are installed in a cell that is fastened to the servo motor, and the ultrasonic sensor is rotated by the servo motor. The TSOP4P38 is an infrared receiver used to collect the nodes' identifiers. The communication component manages the process of data exchange between the nodes and the beacon.

The third and last portion is the control part. An Arduino Uno on the plastic square represents this section. It's worth noting that the Arduino Uno board contains both digital and analog inputs and outputs (14 and 6, respectively). This set has a 5 V operating voltage and a 16 MHz clock speed. A 32 KB flash memory and a 2 KB SRAM round out the storage options for this Kit. The control component is necessary for the operation of the communication and sonar components. Figure 6 is a schematic showing the connections between the various beacon components and the Arduino pins utilized.

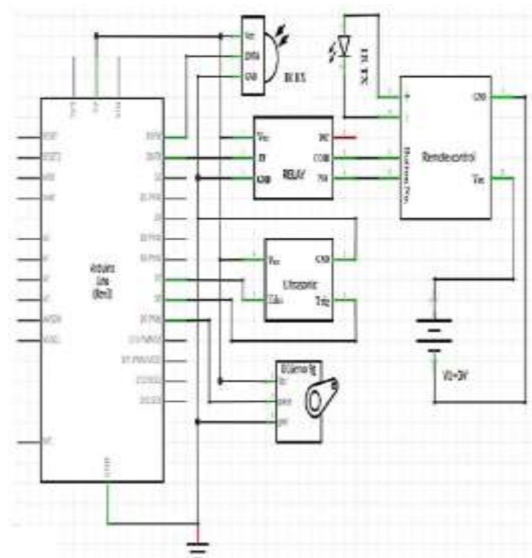


Figure 6: The blueprint for the second beacon. Data-logging software

The controller is the system's command center, while the software is its nervous system and animating force. For the 2010 Olympic Games, the Visual Basic for Applications (GUI) program was used (Figure 7). When the button is pressed, the sonar component of the beacon is rotated from 0 to 1800, turning on the light. When the sonar is reset to 00, it will begin collecting data again. The functionality of the beacon and the nodes may be shown in two distinct ways using this program.

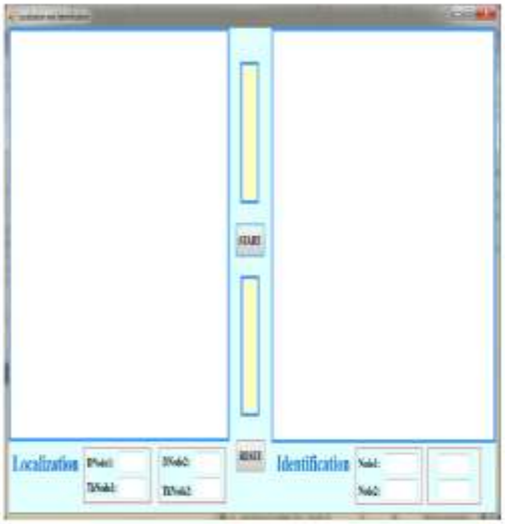


Figure 7: The system software's graphical user interface

2.2.1. The technique based on beacon

A node's detecting angle and distance (its polar coordinates) from a beacon may be determined using this method. The beacon-based procedure's flowchart is shown in Figure 8(a). When you press the button, the serial number of the command is shown on the screen's. The Arduino microcontroller decodes the serial data, instructing the servo motor to spin at 1800 rpm while simultaneously turning on the ultrasonic sensor's. The ultrasonic device broadcasts eight pulses of sound waves per degree and listens for a return signal. In the event that the pulses are reflected by an object, the IR transmitter will be activated and the beacon ID will be sent. The servo will go on to the next available setting if this is not done. Distance, detecting angle, and node ID will be sent to the serial monitor and made available to the visual basic software if (and only if) the node ID is received by the beacon receiver's. Iterate steps 2-4 until the servo motor reads 1800, at which point the node counter should be reset to 1. Using this information, the Visual Basic program will pinpoint node if's coordinates, color it according to its ID, and render it on the screen's. When the nodes counter does not equal the total number of nodes, then the counter will be increased by one and step 6 will be repeated.

3. RESULTS AND DISCUSSION

One of the nodes was put 32 centimeters away and at a 48-degree angle, labeled red, and given the code 0xFF18E7 in order to test the system. We placed the second node 89 degrees from the beacon and 56 centimeters distant. Paragraph 9: The Paragraph 9-Digit Code Figure 9: The Paragraph 9-Digit Code. The program was then run, and the results are depicted in Figure 10; from this figure, we can determine that the distance, ID, and angle for the red node are 32 cm, 0xFF18E7, and 48 degrees, respectively, and that they are 56 cm, 0xFF9867, and 89 degrees, respectively, just as they are in the real world. Figure 11 depicts both the GUI results and the real-world surroundings once the scan is done. Distances and angles are predictably well estimated by the algorithm. The nodes' locations and hues were accurately shown. Successful communication between nodes and the beacon is another feature of the system.

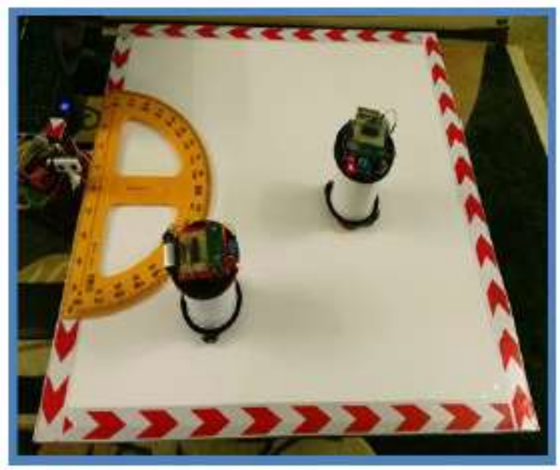


Figure 9: The physical setting in which the scan was performed before it began.

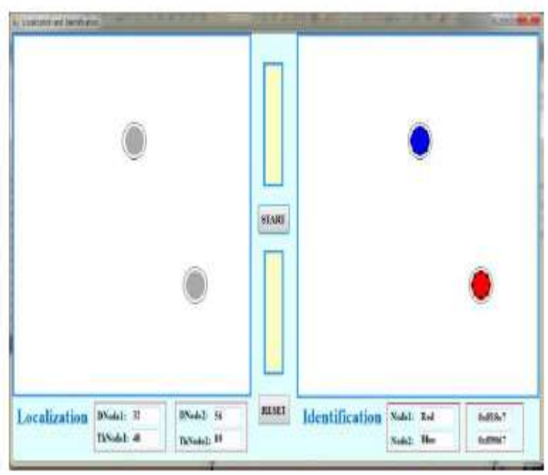


Figure 10: Debugging Outcomes for a Graphical User Interface

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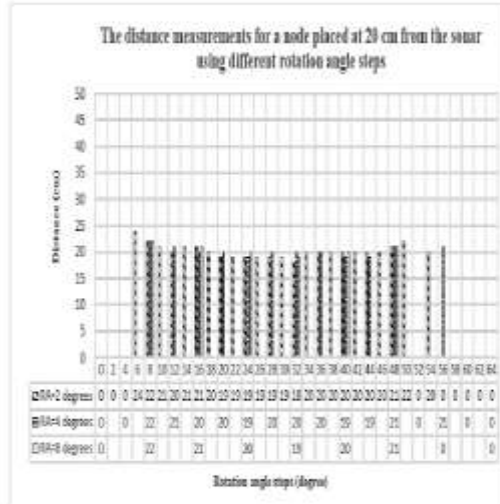
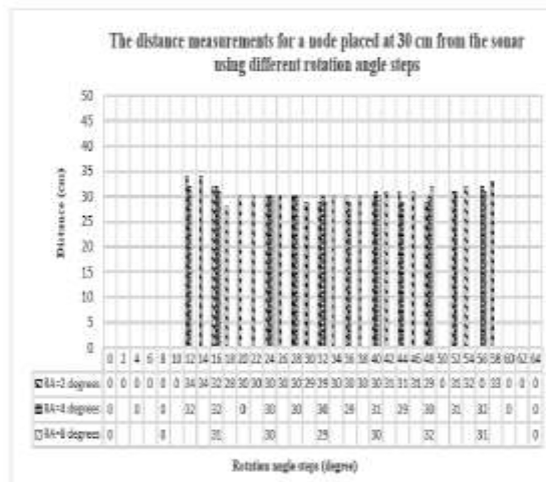
Figure 11: The state of the environment after the scanning and debugging processes

In Figures 12(a) and 12(b), we see the results of distance measurements made with a node placed 20 cm and 50 cm from the sonar, respectively. Two, four, and eight degree rotations were employed to premeasured the distances along both curves. If the RA parameter is set to 2, for instance, the beacon will rotate by 2 degrees at each stage of its scan. Figure 12(a) shows that the ultrasonic identifies the node at a distance of 20 cm at RA = 2 degrees (blue bars), RA = 4 degrees (red bars), and RA = 8 degrees (green bars) for a total of 48 measurements. Figure 12(b) is similar to Figure 12(a), only the node is 30 centimeters away. This process was repeated for further distances of 40 and 50 centimeters. All the graphs demonstrated that distances are measured most precisely when the ultrasonic sensor is positioned directly in front of the node being detected.

Figure 13(a) explores the impact of the rotation angle step on ultrasonic reading accuracy, and we'll utilize the aforementioned curves to determine the percentage of correct readings. Different distances were measured, and the proportion of exact readings out of total measurements, excluding zeros, was computed. If the RA is 2 degrees and the distance between the node and the sonar is 40 centimeters, then 7 of the 19 readings will be correct, for an accuracy percentage of 37%. For comparison's sake, the percentages for the 4 and 8 degree brackets will be 36% and 33%, respectively. As a result, the proportion of accurate readings improves with each successively smaller increment in rotation angle.



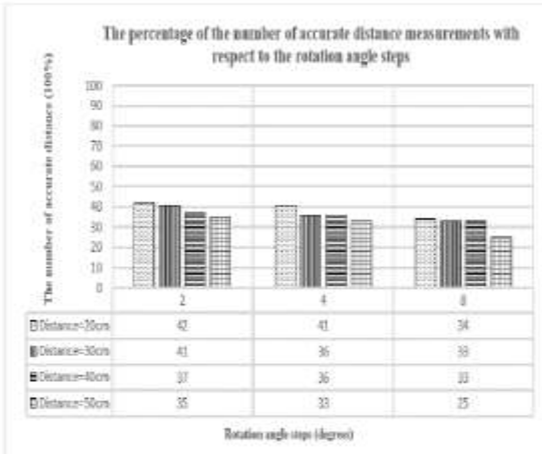
(a)



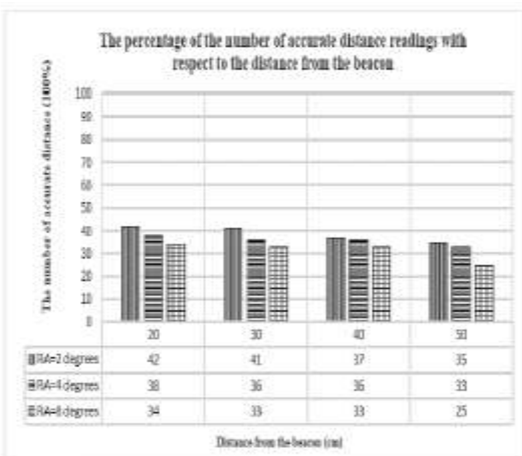
(b)

Figure 12. The measurements of distance for a node positioned at (a) 20 cm and (b) 30 cm from the sonar using 2, 4, and 8 degrees of rotation angle steps

Figure 13(b) depicts the results of a study into the correlation between the node's placement distance and the impact of that distance on the precision of ultrasonic measurements. It seems to reason that the nearest node would have the best accuracy. When the RA is 2 degrees and the distance is 20 cm, for instance, 10 out of 24 readings will be correct, for a 42 percent accuracy rate. Using the same rotational step at a distance of 50 cm, we find that 35% of our measurements (7 of 17) are accurate. This implies that the proportion of accurate readings will grow as the distance between the node and the ultrasonic sensor decreases. Figures 13(a) and 13(b) show that the most precise measurements are those that pinpoint the node's precise location. The nodes' precise coordinates were determined using these measurements and a little of Visual Basic code.



(a)



(b)

Figure 13 shows the correlation between (a) the rotation angle steps and (b) the distance to the beacon in terms of the percentage of successful distance estimations.

4. CONCLUSION

In this research, we looked at how a centralized strategy may be put into practice for a multi-node locating and identifying network. In this study, pinpoint estimates of node locations were achieved. In addition, high-quality connections were established between the nodes and the beacon. Accuracy of distance measurements was evaluated at several rotation angles of 2, 4, and 8 degrees. Our research led us to the conclusion that reducing the rotation angle steps enhances location estimation accuracy at the expense of an increase in scanning time. As a consequence, reduction the rotation angle step leads to increase the number of accurate readings and thus raising the accuracy %. The proportion of successfully determined distances from the beacon was also investigated. We found that accuracy was greatest when we were physically closest to the beacon. This happens because there are more readings for each rotation angle step at the node closest to the beacon. Finally, we determined that the precise position measurements had the highest percentage of accuracy at every distance and rotation angle.

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