Wireless Sensor Network-based Navigation for Human-Aware Guidance Robot

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I. Introduction

The act of guidance, such as showing someone where a particular exhibit in a museum is or where a particular table in a restaurant is, is something we do on a daily basis without thinking much about it. However, robots must make many decisions in order to accomplish this task. How far away is the human? Which way the destination? We propose a system that utilizes a Wireless Sensor Network in order to perform navigation indoors. The robot is also equipped with a vision-based tracking system that allows it to monitor the human's position relative to the robot.

In this paper, we will first discuss the wireless network system and how it is used to navigate the robot. Then, we will discuss how our system integrates network information with the information from the vision system to properly perform guidance. Finally we will discuss our experiment and future plans.

II. Navigation System

Our system utilizes a wireless sensor network made of Crossbow MicaZ Motes[1] to perform navigation through indoor environments. In recent years, sensor networks have been used for a variety of applications. They are small, ad-hoc, and scalable. These qualities make them ideal for use in existing structures. Using this type of network for a navigation system makes it easy to integrate into an existing museum or restaurant without having to modify it.

For our system, firstly a map representing the room is programmed by hand. We used OpenGL to construct a 3D representation of the room and program the location of the Motes within the space accordingly. The system then utilizes ray-tracing to determine the direction to the goal from each Mote, or a direction towards the goal that avoids walls. Figure 1shows an example map with several Motes (Mote1-6) and a goal Mote. The arrows indicate the direction that particular Mote is implying the goal is in. In the event ray-tracing shows an intersection with a wall, the system decides the best angle that will take the robot around the wall.

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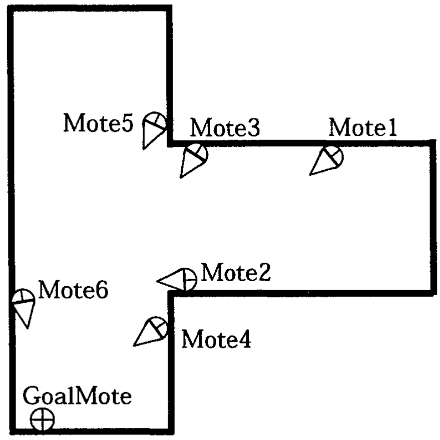

Figure 1: Map Example.

$$\begin{cases} \vec{V} = \sum \vec{m}_n \\ \vec{m} = s \cdot \vec{d} \end{cases} \quad (1)$$

Equation 1: Weighted Sum

While it appears, at first glance, that the system is simply using triangulation to estimate position, this is not the case. Rather, the system polls Motes within range for the direction to the goal. These directions are then combined in a weighted sum, Equation (1), to derive the ideal direction for the robot to proceed in. The weights of this sum are the Mote's respective signal strengths, i.e. the closer the Mote is to the robot, the more impact that Mote's suggestion has on the derived direction.

One drawback to the use of Motes and other radio-based systems for navigation is that radio-waves are influenced by environment. As such, the raw signal strengths recorded by the system are initially rough. In order to smooth out the signal strength, we created a filter that compares the deviation of an average, A, of past signal strengths with the deviation of A and the newest signal, S, as shown in Equation 2. We then check if the difference between these two deviations, r, is less than some constant. If it exceeds it, we assume the newest signal is incorrect and discard it.

$$r = (dev(A,S) - dev(A)) \quad (2)$$

Equation 2: Deviation Filter

In figure 2, we show an example reading from one Mote as the robot moves from four meters away, to one meter away. The first graph shows a jagged signal for the raw signal strength, and even an erratic average. However, note that the deviation remains relatively steady. Taking that into account, we designed the deviation-checking filter. The second graph in figure 2 is the same data subjected to our filter. There is a marked improvement in the smoothness of the average signal strength, using which; we were able to produce signal results that are reliable enough to provide navigation for our system

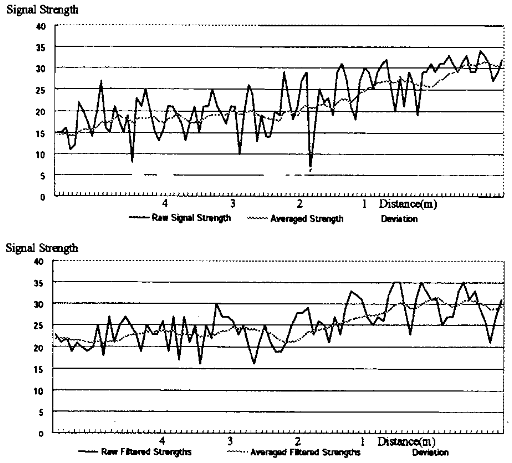

Figure 2

III. Human-aware Guidance System

A key point for any guidance system is that of human awareness. If the robot is not ensuring that the human is properly following, the robot is not performing guidance, but rather is simply navigating. For our system, we included a vision system that uses the CamShift algorithm [2],[3], in order to track a human. The system infers a size of the human based on the area it takes up in pixels and continuously updates a ratio between the current size and the size at the start of the guidance. If that ratio falls beneath a certain threshold, the system decides the human has strayed and takes steps to correct this.

The system begins by waiting for a human to enter the cameras frame. After recognizing the human and initializing the tracking routine, the robot waits until the human designates goal. The robot then uses the pre-programmed map to calculate the directions for each mote and then proceeds to follow the network's suggestion. In the even the vision system reports a problem with the following human; first, the robot will simply stop, wait, and ask the human to come closer. If still the ratio is too low, the robot will use the vision system to track the human in an attempt to close the distance between itself and the human. If the robot has simply lost all sight of the human, it will stop and wait while notifying the human that it can no longer see them. Once the distance is closed and the human is determined to be following again, the navigation resumes seamlessly.

IV. Experiment

In order to test the system, we ran an experiment in a simulated room environment, Figure 3, modeled in 3D as shown in Figure 1. Our robot Chamuko was equipped with a PC, and Mote to interface with the network. In addition, a single webcam was used for the vision system. The network was created using seven Motes, dispersed in a pattern as shown in Figure 1. Chamuko was equipped with no collision avoidance, in order to emphasize the efficacy of the network navigation system. We ran two types of runs, with the human following properly and also where the human would make a wrong turn and walk in another direction. In each run, the robot was able to track the human and maintain an average distance while successfully reaching the goal. While the actual distance to the goal at the point the robot would stop varied, it was always within sixty centimeters, which we feel accurate enough for the setting in which we envision our system being used.

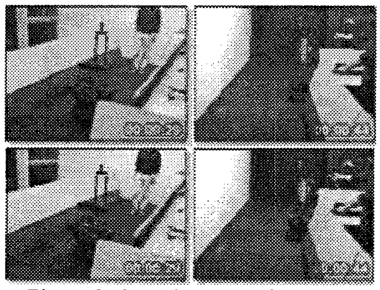

Figure 3: Experiment Environment

V. Conclusion and Future Work

The ability to perform guidance is an important skill that robots will require as they become more commonplace in our everyday world. Our system provides the ability to perform navigation using wireless sensor networks and human-awareness for guidance via a vision system. A benefit of using the network is easy installation into existing buildings. Moreover, the scalability of the network makes it able to be used in large buildings.

Our future plans include improvements to the map builder, the interactions, and the filter. We hope to make the system able to generate the 3D map automatically without having to be programmed by a human. We also hope to include more interactions, giving the human the ability to change destinations or ask the robot to wait verbally. And finally, we hope to improve the filter by making the thresholds dynamic as opposed to the static constants used now.

VI. References

[1] www.xbow.jp
[2] G.R. Bradski, Computer video face tracking for use in a perceptual user interface, Intel Technology Journal, Q2 1998.
[3] Allen J.G, Xu R.Y.D, Jin.J.S: Object Tracking Using CamShift Algorithm and Multiple Quantized Feature Spaces. Proceeding of the Pan-Sydney area workshop on Visual information processing (2003) 3-7