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Robot Localization Using Overhead Camera and LEDs

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Abstract

Determining the position of a robot in an environment, termed localization, is one of the challenges facing roboticist. Localization is essential to solving more complex problems such as locomotion, path planning and environmental learning. Our lab is developing a multi agent system to use multiple small robots to accomplish tasks normally completed by larger robots. However, because of the reduced size of these robots, methods previously used to determine the position of the robot, such as GPS, cannot be employed. The problem we are facing is that we need to be able to determine the position of each of the robots in this multi agent system simultaneously. We have developed a system to help track and identify robots using an overhead camera and LEDs, mounted on the robots, to efficiently solve the localization problem.

Introduction

One of the prevalent problems that arise when dealing with robots is the issue of localization. Evaluating the robot's exact location in space is an intricate task because the robot has to account for environmental factor, such as changes in lighting and terrain, and also for the continuous movement of the robots. When dealing with multi-agent systems, especially one using small scale robots, there needs to be a means for distinguishing and communicating between the devices.

Background

The previous method used for tracking robots involved the implementation of 2D bar code tags, similar to the popular QR codes (Olson, 2010). For this method, four bar code sheets are attached to the head of a robot (Figure 1). These sheets serve as an identification code for the robots to differentiate between each other. The tags were enlarged to enable robots to identify each other from a faraway distance using a camera mounted on their heads. The advantage of using this method is that it made it easy for the robots to identify each other relatively quickly. The cameras were able to detect the bar code and it provided various stages of distortion and a mild amount of obstructions.

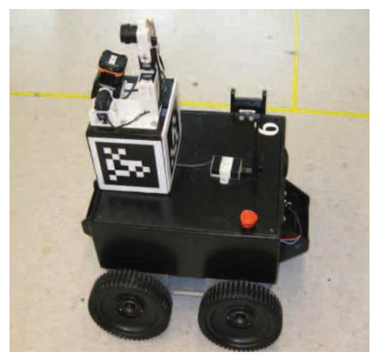

Figure 1 : Robot with 2D Bar Code Tags

Unfortunately, that method proved inadequate when dealing with smaller robots. The 2D bar codes were very limited in their effectiveness. Each barcode was a static image, which could convey a single message (the robot identification number in this scenario). However, in our proposed multi agent system, the robots would be too small for the current barcodes to fit on them (Figure 2). Furthermore, reducing the size to make it fit on the smaller robots ended up preventing the overhead camera from reading and processing the bar code's information correctly.

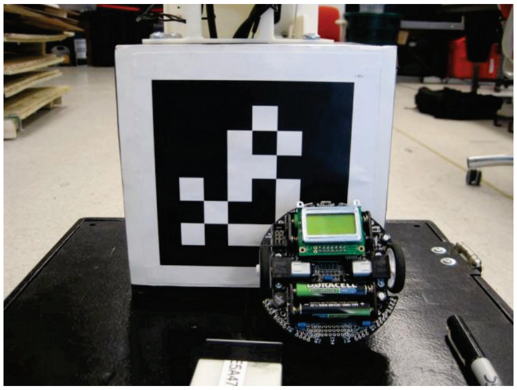

Figure 2: Smaller Robot compared with the 2D Barcodes

Image Segmentation

To address the issue of localization when dealing with smaller robots, we have decided to utilize LEDs (light emitting diode) as an identifier. LED poses many benefits for working with smaller systems. One benefit of using LEDs is the fact that they are cost effective. When working with a myriad of robots, using more expensive localization equipment is inefficient and would decrease the effectiveness of the research. More research dollar must be allocated for this equipment thus decreasing your overall budget. LEDs, on the other hand, are very inexpensive and can be easily acquired. In additional to cost effectiveness, LEDs are also versatile. Not only can they be used to identify robots and distinguish them from each other, but they can also be used to output other for detecting the signal of a specific object of interest.

For our system, each robot is equipped with three LEDs (Figure 3) and a camera (not shown). These lights would blink out a unique binary pattern that indicates the identification of a robot. The overhead camera is then used to decode this binary pattern and determine which robot was currently in view.

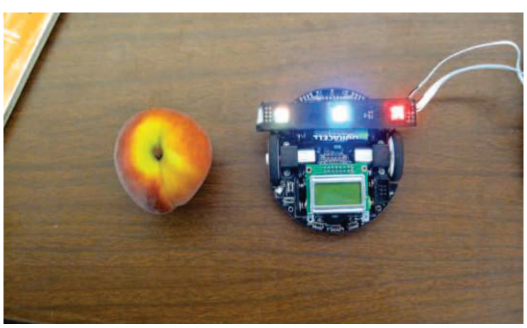

Figure 3: The Smaller Robot with an LED beacon attached

Through image processing techniques our system segments images from the camera to locate the areas of interest (AOI). First, the images from the camera are extracted and read in as buffered images. These buffered images are then converted into 2D arrays of pixel objects. These pixel objects store the red green blue (RGB) value of the points along with the x and y coordinates, and id numbers. After the image has been converted, the array is then passed through a filter which identifies all points of interests (POI), which are the points that have RGB values within the predetermined threshold for the LEDs, and removes all other pixels from the arrays. By truncating the irrelevant pixels, we increase the efficiency of locating the LEDs in the image because we limit the number of pixels used in the processing.

For pinpointing the midpoints of the LEDs, our system implements the union find algorithm. Initially each pixel in the image is assigned a unique id number. Then, after looping through the array pixels, any neighboring pixels, pixels with x and y-coordinates with one point away, with similar RGB values is assigned the same id number. By this, we essentially segment the pixels by their RGB values. After image segmentation, we average out the x and y coordinates of the groups of pixels to get their midpoints. Figure 4 displays an image with three LEDs being segmented to locate their midpoints (Seemann, 2002).

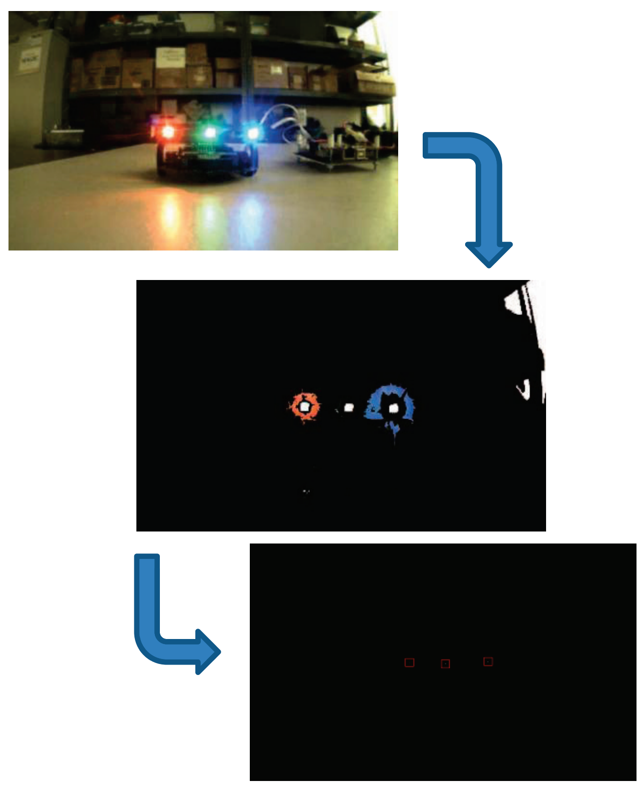

Figure 4: Segmenting the LED Mid Points

Lexicographical Code

While all data transfer should be accompanied by some error correction, in our case it was critical since we were trying to gather data from an inconsistent source, which in this case is our blinking LED strip. Factors such as latency, glare, color desensitization and differences in environmental lighting, though not uncommon, may cause the camera to register data contradictory to the actual transmitted value. As such, it was imperative that we account for this situation.

We amended this situation by using lexicographical codes (Conway & Sloane, 1986). Also known as lexicodes, they are a list of binary patterns in which all elements of bit length n are at a minimum of d hamming distance from all other elements, where hamming distance is the number of bit position in the two strings that differ. Lexicodes are significant because they can correct (d-1)/2 bit errors and detect d/2 bit errors. For example, using lexicodes with hamming distance 5, two bit errors can be corrected and 3 bit errors can be detected. Larger hamming distances allows for more error flexibility, but required greater bit lengths to be used effectively.

000	X
001	
010	
011	X
100	
101	X
110	X
111	

Figure 5: Selecting 3 bit lexicodes with a hamming distance of 2 (3h2)

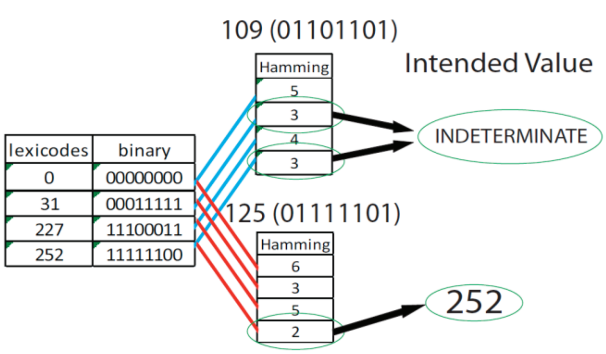

Figure 6: Finding the correct values for 2 numbers in an 8h5 scheme

We were able to generate a list of accepted lexicographical codes, which would be loaded onto each robotics. Our tracking system is able to recognize and extract LED from the rest of the image and begin to decode the binary messages.

Conclusion

The system works well in a controlled environment where we are able to manipulate the light to our specific preference. There are still unresolved issues that we have taken note of, such as, tracking the LEDs in any scenario. How do we keep the brightness of the image consistent? Also, what happens when there are false positive lights? These are questions that we will address in further research.

Acknowledgement

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