Honours Project Proposal

Luke Ross
Supervisor: Dr. Karen Bradshaw
Department of Computer Science, Rhodes University

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1. Principal Investigator

Investigator - Luke Allan Ross
Supervisor - Dr. Karen Bradshaw

Contact details:

- g09r5654@campus.ru.ac.za
- 072 137 9440

2. Project Title

The project is titled: **Fiducial Marker Navigation for Robotic Systems**

3. Statement of the Problem

It seems that as technology advances, robotics are becoming more common in everyday life. Robots are being used to perform tasks such as cleaning houses[1], helping out in hospitals[2] and playing soccer[3]. In order for robots to behave in this way a level of autonomousness is required. According to [6, p. 260], algorithms which make use of fiducial markers perform best compared to various other techniques used to achieve autonomousness. Today fiducial markers are used in Augmented Reality, Medical fields such as radiotherapy [7, 3] and many others. Therefore the purpose of this project is to add to the field of fiducial marker navigation by using a fiducial marker to guide a robot along an obstacle course. Since the robot will be following a marker through an obstacle course, this project will also involve research into search algorithms which can be used to evaluate paths based on measurements from the surrounding environment.

4. Objective of the Research

The first objective regarding this research project is to recognize a fiducial marker accurately using a webcam. After this has been achieved, the second objective, researching and implementing the robot's navigation logic, can be started. The second objective for this project can be split into four stages. These stages are stated below, starting with the initial stage and ending with the final stage:

- The robot follows the fiducial marker in a straight line
- The robot follows in the direction of the marker while the markers movement consists of turns

[1] http://www.robotshop.com/robotic-floor-cleaners.html
[2] http://www.used-robots.com/robot-education.php?page=robots+in+the+hospital
[3] http://www.robocup.org/

- Obstacles are added to the robot's environment, blocking its path. The robot finds a path to the fiducial marker avoiding these obstacles

- The robot loses sight of the fiducial marker. It uses maze solving methods and thus wanders until it gains sight of the marker again

Some paths between obstacles will be too small for the robot to pass through and therefore a different path will need to be chosen.

5. History and Background

Fiducial, or fiduciary markers are bar-code like images containing simple patterns that technology such as a robot which has a camera attached to it can easily recognize. The patterns on these markers usually consist of black and white coloured squares or other simple shapes which make them easier to identify as these colours contrast nicely in most environments. For example, a robot can navigate through a certain area provided that fiducial markers are placed tactfully in that area. The robot can then use its camera to identify the markers, interpret meaning from them if such a meaning is encoded into the markers and the robot by using toolkits such as ARToolKit[4] or Artag[5], and then calculate a direction in which to move. The robot can also localize itself with respect to its surroundings.

One of the main uses of fiducial markers is in treating prostate cancer. When treating, doctors need to have an accurate view of the prostate gland. Often this view is not sufficient and so gold fiducial markers are placed in the prostate to enhance vision. [1]

According to [5], in order for fiducial markers to be accurately recognized, some factors should be considered when designing the markers. These include the shape of the fiducial, the colours to use in the fiducial image, and the size of the image and the border. The shape of the fiducial should emit four points. Any image that emits four points is sufficient. The simplest of these shapes is a square and due to its simplicity, computational advantages are noted. The fiducial image can contain most colours, but is best if a monochrome colour is used. This is because a monochrome image is easier to recognize against bright, contrasting backgrounds. This too gives computation advantages as the algorithms are simpler. The size of the fiducial is dependent on the resolution of the camera being used. The border of the marker should be at least 13% of the fiducial markers width. Other important, but more technical criteria concerning the marker are as follows:

- There should be no ambiguity when determining the markers position and orientation relative to a camera

[4] http://www.hitl.washington.edu/artoolkit/
[5] http://www.artag.net/

- Markers should not favor certain orientations
- If multiple markers are used in the system, they must all be unique
- Simple algorithms that are not intensive need to be used to locate and identify the marker quickly. For these algorithms to be used, the marker itself needs to be designed with this intent in mind

These criteria apply when using the ARToolKit library. [5]

There are many search algorithms used in the navigation of mobile robots such as the D* [9, 8] and the more common A* [4] search algorithms. The D* algorithm [8] consists of three primary functions: PROCESS-STATE, MODIFY-COST and MOVE-ROBOT. These three functions can be used in such a way as to allow for a robot to find the lowest-cost path through an unknown environment that may consist of obstacles. Simply put, initially a map is created which consists of the direct path to the goal and then as obstacles are encountered the map is updated according to the algorithm. D* is dynamic in that it allows for the goal state to change whilst the solution path is being traversed. This is the only feature that is different between the D* and the A* algorithm. Most search algorithms are very similar and differ only slightly depending on the situation that they are is used in [2].

6. Approach

In order for the webcam to identify and for the robot to interpret meaning from the fiducial marker, the ARToolKit library will be used along with C++. To start with, research on fiducial markers and the ARToolKit library needs to be done and the necessary implementation concerning the recognition of the marker needs to be put into place. Once this has been accomplished, the robot's movement can be programmed. The robot that will be used is the WifibotLab Lidar. All the programming, and thus processing, will be done on the Wifibot itself. This should not be an issue due to the Wifibot's hyper-threaded dual core processor. The first phase with regards to movement will be for the robot to move along a straight path following the fiducial marker. This should be quite simple using the Wifibot manufacturer's control libraries which will need to be called from the robot itself. Next, some investigating needs to be done concerning how to implement the rotation of the robots webcam in the correct direction as to always keep the fiducial marker in sight as it deviates from a straight path.

The detection of obstacles will be done using the Wifibots lidar technology. This piece of hardware allows for distance measurements of nearby objects to be retrieved. From these, algorithms will need to be implemented on the robot such that it can navigate efficiently whilst avoiding the obstacles. Research will need to be done into this field before implementing can take place.

This system will be implemented and tested in a certain environment. This environment will be a room or a hall in which the obstacles will be placed. Initially, the obstacles will be objects that have simple shapes such as boxes or tupperwares. This should simplify the lidar readings and thus ease the navigation process. Once the robot can choose a route through these simple obstacles successfully, more complex objects can be used. Artificial lighting is another reason why an inside environment is preferable as this simplifies the recognition of the fiducial markers.

7. Requirements

7.1 Hardware Requirements

- WifibotLab Lidar
- TP-Link Wireless Router (So that the robot can be accessed over Wi-Fi from a personal computer)
- Access to a personal computer

7.2 Software Requirements

- C++
- The ARToolKit Library
- Linux: Ubuntu 10.04.3 LTS

8. Progression Time-line

Shown below is a table which contains the deadlines concerned with the project.

Deadline	**Event**
15 April 2012	Webcam recognizing fiducial markers
20 April 2012	Experiments complete and fiducial marker chosen
01 May 2012	Significant progress towards website
28 May 2012	Literature review and plan of action completed and handed in
22 June 2012	Robot moving using C++ and manufacturers libraries
30 June 2012	Robot following marker in a straight line
08 July 2012	Robot following marker with turning involved
14 July 2012	Measure lidar readings accurately
07 August 2012	Project presentation 2
12 August 2012	Robot can navigate around single obstacle
26 August 2012	Robot following marker through obstacle course
02 September 2012	Robot wanders when out of sight
17 September 2012	Short paper completed and handed in
29-31 October 2012	Final oral presentation
02 November 2012	Thesis completed and handed in
05 November 2012	Research website complete
21/22 November 2012	Final research oral examination

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