Final Year Project Proposal

Robot Soccer (Vision Sub-system)

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Introduction

With the rapid development of computer industry, many computer applications developed at the same time to improve our quality of lives dramatically. One of the most trivial applications that improves our lives is the automation by robot. The definition of Robot by The Robotics Institute of America (RIA) is “A robot is a re-programmable, multi-functional manipulator designed to move material, parts, tools, or specialized devices through variable programmed motion for the performance of variety of tasks.”

Robot construction seems to be impossible for the public as the equipments and the skill need is expensive and hard to learn. Of course, what I am telling is before the invention of Lego Mindstorms™. With the help of Lego Mindstorms™, the development of robot soccer seems more feasible for general users.

Another aspect of computer application that makes the use of robot action much better is computer vision. Computer vision can be defined as “A branch of artificial intelligence and image processing concerned with computer processing of images from the real world. Computer vision typically requires a combination of low level image processing to enhance the image quality (e.g. remove noise, increase contrast) and higher level pattern recognition and image understanding to recognize features present in the image.” (hostingwork.com)

Machine vision (computer vision) has been studied for tens of years and which is still one of the most challenging topic for researchers. The application and development of computer vision is widely studied and deployed especially in the military and industrial expert system. However, with the advance performance of personal computer, the topic becomes more common to home users. One of the funniest applications of computer vision and robot system is, of course, robot soccer.

This proposal suggests ways for developing a combined system with computer vision and robot elements. As this year is not the first year of developing such robot soccer system. Successful experience has been learnt from previous student which will be discussed in the background review later. This proposal consist of five main parts, background review on last year FYP achievement and the defect of the system; area of system that will be improved; methods which will be used to develop the system; schedule of each phase of development; references.
Background review

Similar projects in other University

Relevance project is studying in other university, of course, not necessarily using Lego Mindstorm™. Take two examples from the universities in Hong Kong. The City University of Hong Kong (CityU) and The Chinese University Of Hong Kong (CUHK).

There is an informal organization under the department of computer of CityU about the development of robot soccer. The organization is called Robotics Laboratory. Detail information can be found at http://csresearch.cityu.edu.hk/content/index.pl/home.

CUHK already developed the “kick action”. Detail can be seen here: http://www.cse.cuhk.edu.hk/~mywong/Soccer2.mpg

In The Hong Kong Polytechnic University

The robot soccer project start two years ago and I am the third session of student selected the study area on the topic. Here is the summary of achievement made last year:

Last year achievement

The autonomous mobile robot “RoboSoccer” is developed using the LEGO® Mindstorms™ RIS 2.0. A CCD camera is installed in the robot to capture images for the “brain” software to carry out image processing and analysis and hence the position of this tennis ball can be found. After the robot grabbed the ball, it will communicate with the teammate to exchange the latest location each other. Then, the robot will decide to bring the ball to the goal or pass the ball to the teammate.

Ball detection technique used is color histogram with spatial recognition. Color histogram technique means the vision system analysis the captured screen on color base. The color of the football playground is black, the ball used is yellow. The vision system calculates the color of the screen. If color other than black is detected, the system will assume that represent the existence of the ball. Spatial recognition technique is dividing the screen vertically into different regions. If the system finds out that the left most region return value that the ball exists, the robot will turn left and move fast forward. At the same time still detect which region the ball exists. If the ball exists in several of the middle regions, the robot knows that the ball is right in front of it and start the “grab the ball” action.
The “grad the ball” action consists of two parts, raise up the arm; move forward and put down the arm to grad the ball.

After grading the ball, the robot will communicate with the “brain” and find out its position and its teammates position. If its own position is near to the goal than that of its teammate, it will push the ball to the goal; otherwise, it find out the position of its teammate and pass the ball to it.

Defect of the system

The approach used encounters several limitations. One of the most obvious limitations is that the vision system can only run under a “well-controlled” condition. The background color of the football playground is black, it is because it have the largest “color distance” with the color of the tennis ball. The computation accuracy increase as a result. If there is any obstacle or enemy in the same playground, with color other than black and appear in the same screen, the system deployed cannot make distinction between them.

Another limitation is that the light source can seriously affect the recognition accuracy. For example, if the light is spot with an angle to the playground, the wall of the playground will project a shadow on the field and it probably makes the recognition system generate “ball exists” signal in the related regions as the color seems “different” with different parts.

The other defect of the system is time required to search the ball. In the best case, the system needs 17 seconds to determine whether the ball exists. And for general cases, it needs around 20~30 seconds to process the captured screen. The time required to location the ball seems to be too long if the robot really in a soccer match.
Problem statement

Fixing last year limitation

To develop the vision system of the robot soccer that can perform its particular functions under “normal situation”. The functions of robot soccer include at least five basic elements, navigation of the robot itself; the search and recognition of ball; approaching the ball and grabbing it; locating the goal after grabbing the ball, bringing the ball to the goal or kicking the ball into the goal. “Normal situation” should be defined as different color of background, existence of teammates, enemies and obstacle.

To develop the vision system that can recognize balls, teammates, enemies and obstacle under “normal light condition”. “Normal light condition” should be defined as light with different color, brightness and angle of projection. Of course, the primary condition is that a normal person can distinct those enemy clearly in the captured screen.

To shorten the average recognition time from 20~30 seconds to 10~20 seconds. Obviously, the computing time will be heavily depends on the speed of the processor. I believe it is reasonable to limit the computer type to a desktop or notebook personal computer.

Enhancement beyond past years’ result

Improving the computer vision ability

The vision system should be able to distinct ball, teammates, enemies, obstacle and goal when all exist in the same screen. All the above five parties exist in the same screen seems to be possible in real world.

To find a straight line between the robot and the goal and trigger the “kick” action. Kicking a ball to a goal is a great advantage for attacking because the speed of the ball must be faster than that of the robot bringing the ball to the goal. This can reduce the chance of being defended.

To know the robot itself have already bypass an obstacle or enemy. The robot, then, can change to another state which is find a straight line between itself and the goal.
Methodology

Techniques applied in computer vision include many different areas and each of it has different implementation methods and characteristics. In order to have the best result on objection recognition of the robot, I would like to proposal several different methods to perform the recognition progress.

Ball detection

Circle detection algorithm

There are many circle detection algorithm exist. Here I proposal several of them may be tested. They are Hough transform [1], Fast finding and fitting algorithm to detect circles [2], orientation matching [3], Content-based retrieval technique [4]

Thresholding

Thresholding is the separation of objects or regions in an image based on pixel graylevels above or below a selected (threshold) value. The following mathematical formula can be a representation of thresholding:

\[
g(x, y) = \begin{cases} G_0 & \text{if } (x, y) > T \\ G_b & \text{if } (x, y) \leq T \end{cases}
\]

The image processed should be in two colors, black and white. If we can correctly choose the threshold value, the ball should be in white while others object is in black.

![Fig 1 – Original Picture](image1)
![Fig 2 – the same picture After Thresholding](image2)
Thresholding + Outlining

Perform the same process on the picture, after the picture transformed to black and white, we can compare the pixel's value with the other pixel next to it. If it is the same (both are black or both are white), the system output a white pixel; if it is not the same, the system output a black pixel. Then, the edge of the ball will be outlined.

Fig 3 – Picture after Thresholding  
Fig 4 – Picture after Thresholding and Outlining

Obstacle Detection

Same as circle detection algorithm, many different methods and ways have been proposed on the web. Time has to be used to investigate the efficient and effectiveness of those algorithm especially when it is running in a personal computer.

Real Time Obstacle Detection on Non Flat Road Geometry through ‘V-Disparity’ Representation [5]

Appearance-Based Obstacle Detection with Monocular Color Vision [6]

Straight Line Detection

Effective Line Detection With Error Propagation [7]

Combination of the above methods

Combination of the above different technique may be possible, as each technique has it own pros and cons. Combining them in a suitable manner should help to improve the recognition accuracy and speed.
Schedule

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References


[2]: 0-7803-4403-0/98 © 1998 IEEE

[3]: 0-7695-1183-X/01 © 2001 IEEE

[4]: 1051-8215/98 © 1998 IEEE


[6]: Proceedings of the AAAI National Conference on Artificial Intelligence, Austin, TX, July/August 2000

[7]: 0-7803-6725-1/01 © 2001 IEEE


[10]: Computer Vision and Applications – A guide for students and practitioners, Bernd Jahne & Horst Haubecker ISBN: 0-12-379777-2

[12]: Machine Vision Algorithms in Java – Techniques and Implementation, Paul F. Whelan and Derek Molloy

[13]: 計算機視覺 – 計算理論與算法基礎, 馬頌德 & 張正友
ISBN: 7-03-006070-9

[14]: Dav Baum’s Definitive Guide To Lego® Mindstorms™, Dave Baum
ISBN: 1-893115-09-7