International Journal of Computer and Information Technology (ISSN: 2279 – 0764)
Volume 05 – Issue 04, July 2016

Novel Design of a Two Dimensional Cartesian Robot with Real-Time Image Recognition

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Abstract—**In this research, a two dimensional Cartesian robot is designed and built that is applied as a robotic air hockey table. An air hockey disc is put into play, the machine can attempt to score against the opponent and defend against subsequent attempts to score on the robot's goal. An Arduino compatible vision system is designed to track the direction of the puck and extrapolate its movement by using two successive points of reference. This extrapolated movement is the basis of the robot's movement. Once the trajectory is found, three DC stepper motors are used to control the end effector of the robot, using a belt driven system. The end effector can be positioned to a point that intersects with the disc's trajectory in order to successfully defend the goal.**

Keywords- Cartesian robot; real-time image recognition; DC stepper motor

I. INTRODUCTION

Air hockey is one of the most favorite games that emerged in the early 70's of the last century, an annual world championship encompasses the popularity of this game [1-2]. Air hockey requires at least two players and this introduces a problem [3]. In this case, lack of manpower makes it difficult for a person to play by themselves. However, this would allow a person obtain professional training without assistance if the condition was not required. This brings us to our view of the problem, robotics is a revolutionary technology and we want to prove that it can promote industrial and social development [4-10]. Robotics is also a self-evolved system that boosts automation to a higher and more intelligent level which allows us to gain new understanding by solving the aforementioned issue. Building an automatic air hockey system based on robotics is essential to address the current condition of the air hockey game. Therefore, a robotic air hockey table is proposed in this project in order to address the problem. The ideas, methodologies, and detailed measures which are proposed in this research plan are very valuable and can be applied to other similar robotic design concepts as well as similar games such as foosball, table tennis, etc.

The design of the system must align with our three objectives:

1. The robot must be able to consistently return a strike from the human.
2. The robot should be beatable.
3. The mounting system should allow the robot to be easily taken apart.

II. PROBLEM STATEMENT AND INITIAL GOALS

A. *Problem Statement*

The problem is described as follows:

- Air hockey requires at least two players
- This makes it difficult for a person to play by themselves, let alone to obtain professional training without assistance
- Building an automated air hockey system is essential to address the current drawback of the game
- To emulate a real human player, a multiple DOF robotic arm is efficient but rather expensive to afford
- A 2-DOF motion platform with rather low cost will be used to execute the similar function of a robotic arm

B. *Initial Goals*

- Build a 2-DOF robot that can move along x-y axes and successfully defend against a human playing air hockey
- Develop an HMI for different difficulties and tracking of score
- Integrate a wireless control method (phone app or wireless controller to move robot)
- Scrap the scope creep and get the main functionality working
- Construct the belt-driven pulley system, piece together the robot and fully integrate the vision system
- Overall, aiming to create a fully functioning robot that is able to play air hockey against a human opponent.

Following figure shows the CAD model of the proposed automatic air hockey system.

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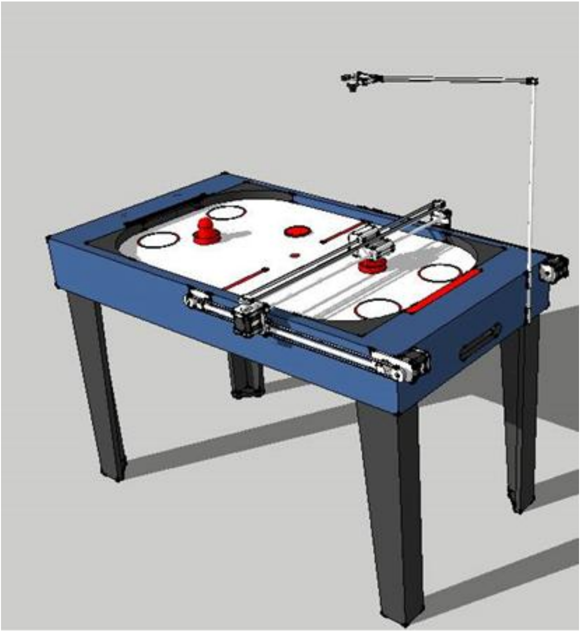

Figure 1: CAD model

III. SYSTEM CONFIGURAITON AND SPECIAL CASES

A. System Configuraiton

As the key components, an Arduino and Pixy CMUcam5 vision sensor will track the direction of the puck and extrapolate its movement by using two successive points of reference.

The end effector will move to a point that intersects the puck's trajectory in order to successfully defend the goal.

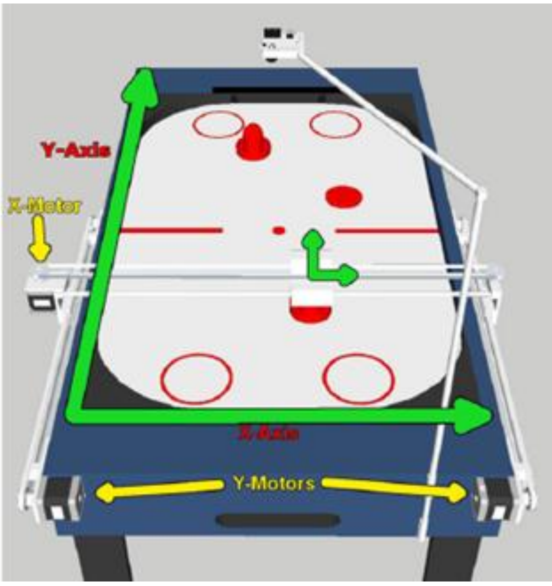

Figure 2: Conceptual design of vision system

The table used in this design is shown in the following figure.

Figure 3: Real table

Following figure shows the detailed components that are used in this project. It includes:

- Microcontroller: Arduino Mega
- Motors: NEMA 17 Stepper Motors (1 for x-axis, 2 for y-axis) with A4988 Drivers
- Tracking System: Pixy CMUcam5

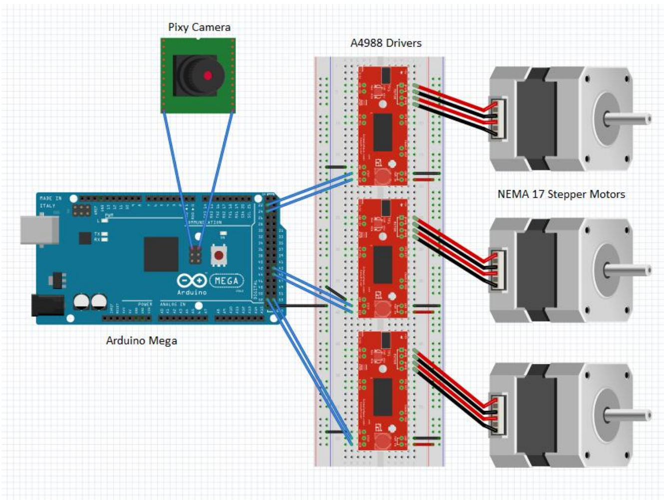

Figure 4: Detailed components

B. Special Cases

It has no problem to use the equation in figure 5 to calculate the position 3. If between position A and B, the puck does not hit the wall and bounce back (as shown in figure 6), the equation does not apply.

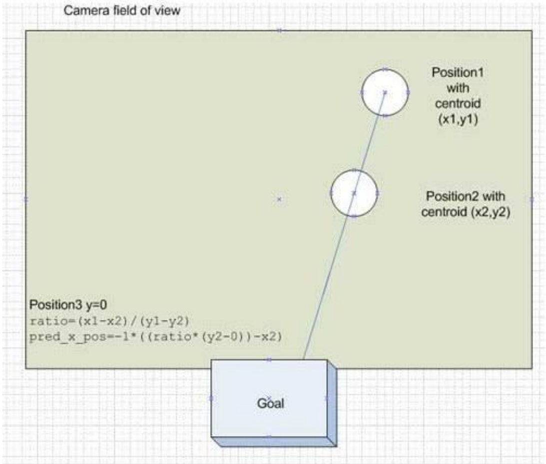

Figure 5: Generaly case

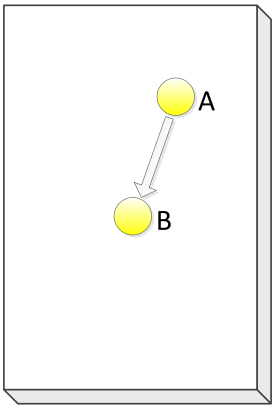

Figure 6: Scenario 1 for special cases

There are some scenarios where the equation cannot be applied to directly. For example, in figure 7, if the camera obtains position A before hitting the wall, and position B before hitting the wall, obviously it needs to use other position's information to predict the value of x when y=0.

For Scenario 3, the calculated value of x when y=0 is outside of the table. So the positions of reference A and B should be re-selected too.

How to make the algorithm more robust to cope with different scenarios efficiently, effectively and precisely, is also one of the key points of this project.

Besides, following issues should also be considered,

- Bounce prediction
- Must account for instant changes in system
- Integrating Arduino Mega and Visual Basic

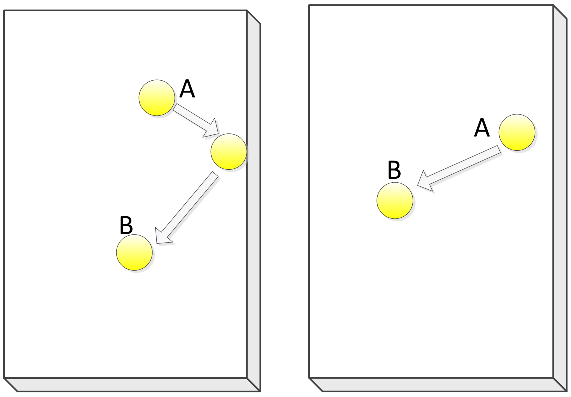

Figure 7: Scenarios 2 and 3 for special cases

IV. Logic Flow, Human Machine Interface and Implementation

A. *Logic Flow*

The logic flow diagram is shown in the following figure.

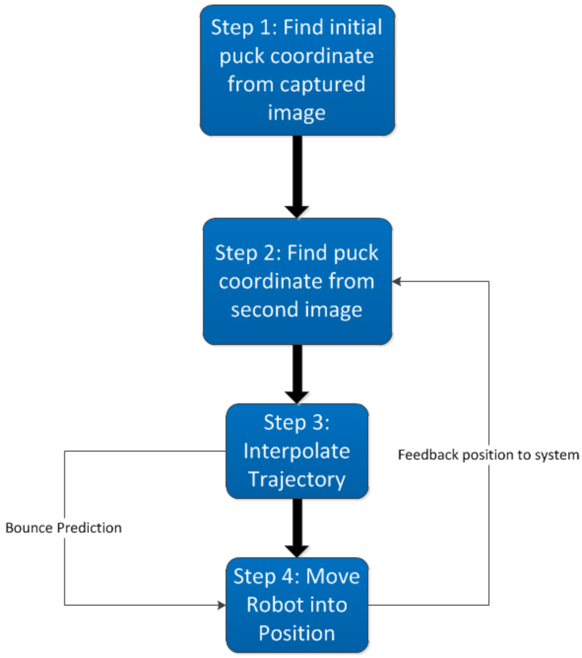

Figure 8: Logic flow

B. *Human Machine Interface*

Two play modes are programmed in the human machine interface, namely the automatic mode, the manual stick mode and the manual GUI mode.

There are also three difficulty levels, namely the easy level, the intermediate level and the hard level.

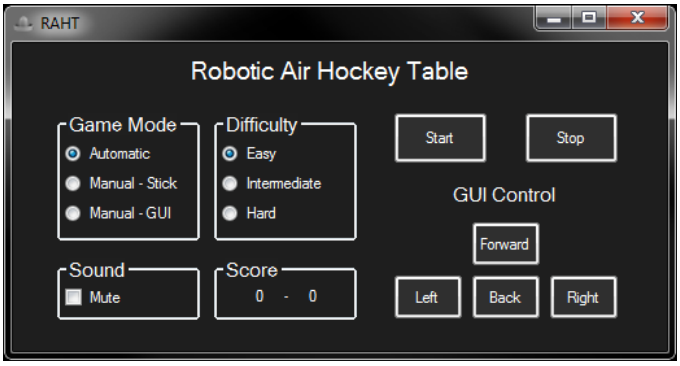

Figure 9: Human Machine Interface

The GUI controls the puck to move to four directions on the plane, namely left, right, forward, and backward.

C. Implementation

Figures 10 and 11 show the setup for the experiment and the HMI, respestively.

Figure 10: The setup for the experiment

Figure 11: HMI

The real-time position of the puck can be observed and calculated. Figure 12 shows what the camers can see. Once the target is tracked, it will be converted into a reduced image as shows in figure 13.

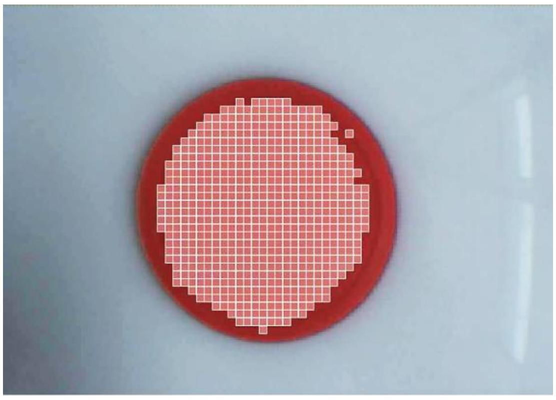

Figure 12: Object tracking - full image

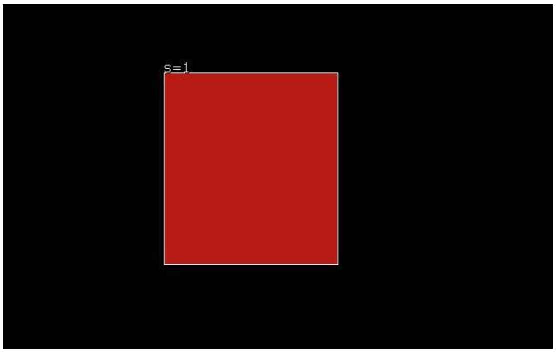

Figure 13: Object tracking - reduced image

Once the position of puck is precisely detected, the controler receives the feedback informaton from the vision system and it commnucates with the motor to take related actions.

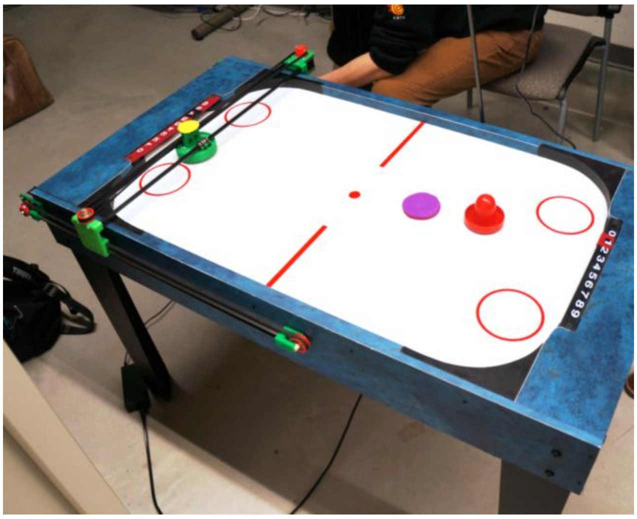

Figure 14: Example of experiment result

V. Conclusions

To emulate a real human player, a multiple degrees-of-freedom (DOF) robotic arm is efficient but expensive to afford. In our research, a 2-DOF motion platform with rather low cost is proposed to execute the similar function of a multiple DOF robotic arm.

The proposed methodologies and related research that could also be valuable for designing robots for other similar games (ping pong and foosball for example):

- Sorting (letting certain colored items through, and blocking others)
- Could be converted into a Cartesian pick-and-place robot
- Recreation
- Education
- Introduce programming to children in a fun and interactive way

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