September 17th, 2001

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
V5A 1S6

RE: ENSC 340 Project Proposal for an Automated Air Hockey Player

Dear Dr. Rawicz

The attached document, ENSC 340 Project Proposal for an Automated Air Hockey Player outlines our project idea for ENSC 340. The project’s goal is to design and build an automated air hockey player. The project includes a sensor system to locate a puck, an electromechanical device to hit the puck and an intelligent algorithm for strategic play.

The purpose of this proposal is to provide our project objectives, an overview of the suggested design solutions, sources of information regarding our project, potential sources of funding, and a tentative project schedule. This proposal explains reasons for choosing our final design solution among many possible design solutions and also provides a projected budget for the project.

JACK’D Games consists of five brilliant, creative, experienced, and hard working fourth-year engineering students who love to incorporate work and play. David Boen is our CEO, with Judy Cha as External Officer, Alex Kwan as Internal Officer, Clarence Wong as Financial Officer, and Kevin Yoon as Engineering Officer.

Should you have any questions or concerns regarding our proposal, please contact us via email, 340-jack@sfu.ca.

Sincerely,

Judy Cha, External Officer

Enclosure: ENSC 340 Project Proposal for an Automated Air Hockey Player
Proposal for an Automated Air Hockey Player

Submitted by: JACK’D Inc.
Dave Boen, Judy Cha,
Alex Kwan, Kevin Yoon,
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Submitted To: Andrew Rawicz
School of Engineering Science
Simon Fraser University

Steve Whitmore
School of Engineering Science
Simon Fraser University

Date: September 17, 2001
Executive Summary

Our project is to design and build a successful air hockey player robot. This involves many aspects of engineering – a sensor system to detect the location of the puck, a micro-controller with a smart algorithm to process the sensory input information and generate corresponding output, and an electromechanical system, a mallet actuator, to act upon the output given by the micro-controller. Upon considering many possible design solutions for the sensor system and the mallet actuator system, a photoelectric sensor system and a robotic player have been chosen since we think they are most effective and easiest to learn about and implement.

The projected budget is approximately $1,400, 20 percent of which is a reserved contingency fund. Most of the money for this budget will come from a variety of funding programs. Our realistic and flexible schedule maps the critical milestones and ensures the steady pace of our progress with the project.

Although time and financial restrictions inhibit us from achieving the high level of mechanical and software complexity that we would like in a superior air hockey player, we believe that the general specifications of our current project possesses more than enough technological challenges to overcome. Furthermore, we believe our project will be a definite attraction to future engineering students and can be taken on as a continuous project passed down from class to class since there is much potential for feature addition and optimization.
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## Glossary

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<th>Term</th>
<th>Definition</th>
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<tbody>
<tr>
<td>Mallet</td>
<td>The striker piece that is used by the player to strike the puck.</td>
</tr>
<tr>
<td>Rink</td>
<td>The arena surface in which the game is played.</td>
</tr>
<tr>
<td>Goal</td>
<td>The horizontal slots on either side of the rink.</td>
</tr>
<tr>
<td>Centerline</td>
<td>The line the runs along the center of the rink. Parallel to short-side of rink.</td>
</tr>
<tr>
<td>Rack</td>
<td>The device laid across the short side of the rink to guide the HockeyJACK’s mallet.</td>
</tr>
<tr>
<td>Arm</td>
<td>The device that extends from a servo motor located behind the rink to the rack in order to control the lateral position of the mallet.</td>
</tr>
<tr>
<td>RAMA</td>
<td>or Rack-Arm-Motor Apparatus™, consists of the 3 components that make up the mallet controller mechanism.</td>
</tr>
</tbody>
</table>
1 Introduction

“The tension in the hall was palatable. Jack focused it’s skill on aiming the puck at the opponent’s goal. With one final goal, Jack would win the tournament. At his opponent’s signal, the puck dropped onto the table with a sharp crack and the game rapidly recommenced…”

One table game captures attention like no other. It attracts players of all ages with its simple rules and fast pace. It has virtually no learning curve and yet provides hours of entertainment. It is placed prominently in nearly every arcade and movie theatre. The game is Air Hockey. Our team has decided to use this game as the premise for our contribution to the never-ending technological quest of making a machine that approaches human mental and physical activity. That is, we have chosen to make a robotic arm that plays air hockey.

The game of air hockey consists of two players. Each player holds a mallet, a round-shaped striker, and stands on one end of the table. There is also a lightweight plastic puck that floats on the table surface, which is made virtually frictionless by tiny air holes and a circulation mechanism inside the table. The object of the game is to hit the puck with the mallet, directing it to the goal. Each successful score is a point and the first player to reach seven points wins the game. Because of its simple rules and game design, air hockey can be played at a very high speed. That is why Air Hockey is often called the fastest table sport in the world with a recorded puck speed as high as 81mph! Figure 1 depicts an Air Hockey table.

Figure 1: Air Hockey Table
Simple rules and a two-dimensional playing area make it plausible to construct a robotic opponent for the game of air hockey. But many challenges lie in such an endeavor, such as speed, for instance. Can the arm respond as quickly as a human player? Can it locate the puck and predict its trajectory? Can it react properly and deflect the puck towards the opposing goal?

There are many related and potential applications for the robot arm. In addition, it will be an excellent demonstration tool for attracting students to the field of engineering. We hope you will share our enthusiasm in this unique and challenging project.

In this proposal document, a system overview will be presented as a more detailed look at the mechanics behind the robot arm. Possible design approaches are also presented followed by the proposed design solution. We have also listed sources of information, and budget and funding information that outlines the available support. Finally, a description of our team organization and schedule timeline is provided to ensure the successful completion of our project.
2 System Overview

Figure 2 illustrates a basic overview of the robotic air hockey system. Sensors mounted above the table in two linear formations gather information about the puck’s trajectory. The central processing unit analyzes the sensory information and generates output signals to the hockey player actuators, which control the hockey striker.

![Air Hockey System Overview](image)

The processing unit executes preprogrammed instructions in response to the puck’s trajectory and striker’s position, or possibly manually entered motion commands from a terminal.

Figure 3 illustrates the basic elements of the air hockey system.

![System Block Overview](image)
3 Possible Design Solutions

There are several methods one could employ to construct an air hockey player. Mechanisms that can control the mallet and mechanisms that can detect the puck come in many forms. A few approaches are discussed in some detail and the merits and drawbacks of each are weighed against each other to come to a final design solution.

3.1 Mallet Actuator

3.1.1 Pneumatics
The mallet is the main component of the air hockey player that physically controls the puck. Which mechanism would best suit the physical speed and range required of a worthy opponent? Pneumatics is one way in which a mallet actuator could be implemented.

A rack of two pipes pumping air in opposite directions placed laterally behind the rink could serve as the mallet arm’s source of power. Capable of moving left and right the arm can meet a puck coming from any direction. The use of an air power source, however, requires some type of intermediate lock to stop the arm at the desired position making its motion uneven. Because the arm is driven on the constant opposing forces of the air source, the speed and ability to quickly change direction may also suffer. Another drawback to this approach is the requirement of tight air seals that are affected by minimal friction. Such a design would be difficult to devise. A material like rubber for example would provide a good seal, but has a high friction coefficient.

3.1.2 Magnetism
A somewhat unorthodox method of mallet arm control uses magnets placed beneath the rink floor. The movement of a magnetized mallet would be controlled by individually activated electromagnets installed in the HockeyJACK’s side of the rink. A line of electromagnets could be activated in succession pulling the mallet towards the desired location and eventually striking the puck.

Although it does not lack ingenuity, this method is lacking control reliability. The use of magnets to drag the mallet across the board would almost definitely result in very discrete motion where the mallet would stop at one magnet before that magnet could be deactivated allowing the next magnet to attract it. Severe renovations are also called for making this approach difficult to adapt to new tables. Furthermore, the use of powerful magnets may prevent wearers of pacemakers from playing with our ingenious creation. This is simply unacceptable. HockeyJACK must be enjoyed by users of all ages.
3.2 Sensors

3.2.1 Laser
In order for the mallet actuator to function properly, a sensing mechanism is required to determine the position of the puck. One way, which was briefly considered, required the use of lasers. Two lasers placed a short distance from each other on one side of the rink and two light sensors placed on the opposite side would be sufficient to determine the speed of the puck. The fine beam that only a laser could provide would be useful in precisely capturing when the puck crosses a certain point in the rink by breaking this beam. However, on top of being quite expensive, a laser could not capture the position of the puck and a trajectory could not be mapped.

3.2.2 Pneumatics
An alternate method calls for pneumatics once again. Several pneumatic sensors could be mounted on a rack that rests on the walls of the rink. Thus, when the puck passes under its location can be detected. However, the air coming from the sensors could potentially alter the course of the disk. An alternative would be to integrate the sensors into the floor of the rink itself where they would actually help maintain a frictionless surface.

3.2.3 Red/Infrared light
An alternate method utilizes two lines of several light sensors laid across the bottom of the rink. Although this scheme requires more sensors, the light sensors allow us to determine the time interval between the puck’s crossing of each of the lines, as in the laser method, as well the locations at which the puck passed the sensor line. From this information, we can calculate the trajectory as well as the speed.
4 Proposed Design Solution

While the approaches described in the previous section have their merits, they do not all follow a few of the major qualities we wanted of our design:

1) Adheres to the rules of air hockey.
2) Easily adaptable to various air hockey tables.

The second condition in particular is violated by half of the proposed solutions. That is, the design should not be so fully integrated with the table that it can’t be easily moved to another. Upon considering these issues, our proposed design calls for the use of a fully robotic mallet actuator and some type of photoelectric sensor.

The most effective control method, and the one that most closely mimics the motion of human players, involves the use of robotics. Purely servo motor-driven, the mallet arm ensures smooth motion and accurate positioning. Our proposed design requires a rack mounted on the walls of the rink to move the mallet arm from left to right. Although this motion is limited, it provides the simplest range of motion for quick processing and accurate control. The exact nature of the control mechanism is still in the design phase.

A robotic arm reduces the number of motors needed to control the puck. Pneumatics requires pistons and compressors to generate the compressed air, while magnetics require large magnets drawing high currents. The robotic arm approach is by far the easiest and most manageable design approach.

Sensing the position of the puck will then be done by the use of photoelectric sensors mounted on a rack like that described in the pneumatic sensor proposal. These sensors will have no effect at all on the course of the puck as it passes under. Some issues that remain to be considered are the exact type of sensors to use and how to make the sensing mechanism as insensitive as possible to the ambient lighting.
5 Sources of Information

Literature and textbooks will contain information on related theories. They contain concrete information that can be applied to specific parts of the project. Reference books provide numerical and practical information. They are useful for comparison and application purposes. Websites are also an excellent hub for related knowledge. There are many robot enthusiasts that exchange information on the Internet. Alternative solutions and timesaving tips can be found at many sites.

The faculty members at Simon Fraser University will be another resource that we will be taking advantage of frequently. Their many years of expertise in related areas will be of great help. In particular, Mr. Gary Houghton has experience in various forms of mechanical design. Mr. Patrick Leung has extensive knowledge in microcontrollers and their applications. Finally, Dr. Bill Gruver and Dr. Shahram Payandeh have research interests in the fields of control and robotics.

Also, there are existing groups of students who have engaged in other robotic projects. The past experience of these students will be a guiding rod for our project. For example, the ARG team designed an autonomous helicopter for rescue missions. Also, Mr. Derek Young’s battlebot is a remote-controlled robot capable of rapid locomotion and movements. Finally, the old MIROSOT team had soccer-playing robots, a complete solution possessing vision, locomotion, striking mechanism, and team strategy. The advice and suggestions of these SFU students will be very valuable for this project.
6  Budget

Table 1 illustrates the projected budget that our prototype model will cost. Costs are itemized and as detailed as possible to generate a close estimate. Shipping fees are also considered in this budget. In addition, 20% of the estimated costs will be added as contingency funds.

<table>
<thead>
<tr>
<th>Items</th>
<th>Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Hockey Table</td>
<td>$150</td>
</tr>
<tr>
<td>Structural Materials</td>
<td>$200</td>
</tr>
<tr>
<td>Actuators</td>
<td>$100</td>
</tr>
<tr>
<td>Sensors</td>
<td>$300</td>
</tr>
<tr>
<td>Microprocessors and Prototype Boards</td>
<td>$200</td>
</tr>
<tr>
<td>Electronic Components</td>
<td>$50</td>
</tr>
<tr>
<td>Cable and Wires</td>
<td>$50</td>
</tr>
<tr>
<td>Power Supplies</td>
<td>$50</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>$50</td>
</tr>
<tr>
<td>Sub-Total</td>
<td>$1150</td>
</tr>
<tr>
<td>Contingency Funds (20%)</td>
<td>$230</td>
</tr>
<tr>
<td>TOTAL</td>
<td>$1380</td>
</tr>
</tbody>
</table>

Table 1: Projected Budget for Prototyping
7 Funding

Numerous sources of funding are considered since the budget required to accomplish our project is quite high. Most of the funding information was obtained through Internet searches. After considering many different funding programs, we have chosen five whose application criteria we fit. The five funding programs are listed below with the reasons why we are eligible for them.

Engineering Science Student Endowment Fund was established to encourage undergraduate engineering science education. It may be given annually for projects proposed by SFU engineering science undergraduate students. Upon studying the four categories, we feel that our project fits the description of the category B - Entrepreneurial, C - Class and D - Miscellaneous.

BC Knowledge Development Fund is a funding program supported by the government to support and encourage projects in technology and science in the post secondary education institutions. Since our project deals with sensors and computer controlled electromechanical system and Simon Fraser University is a well-known post secondary institution, we are more than eligible to apply for this fund.

More information can be found at www.aett.gov.bc.ca

Another government supported funding we are considering is New Opportunities Fund by Canada Foundation for Innovation (CFI). This fund is similar to BC Knowledge Development Fund. The information about this fund was found at www.innovation.ca

NSERC also has numerous funding programs for undergraduate students. Undergraduate Student Research Awards (USRA) is especially for undergraduate students who carry projects in universities. We believe our project has enough technological challenges that a USRA applicant requires. The information about this fund was found at www.nserc.ca

Lastly, the BC Advanced Systems Institute was established to support university research programs. Our project has a heavy research aspect and thus could qualify for some funding. Information about this fund was found at www.asi.bc.ca
Figure 4 shows a preliminary schedule of projects tasks. Major milestones set the pace of the project and they serve as intermediate goals to keep the project’s momentum. This timeline will be updated as the project progresses.

Figure 4: Project Timeline
9 Team Organization

JACK’D Games was formed on September 1, 2001 by five brilliant 4th year engineering science students at Simon Fraser University – David Boen, Judy Cha, Alex Kwan, Clarence Wong and Kevin Yoon. Each co-founder has various expertise and experience from their different backgrounds in industry and educational focuses. Their contributions will allow a smooth integration of the project.

To ensure continuous progress is kept throughout the project period, each member is assigned with primary responsibilities. David Boen, Chief Executive Officer, is responsible for hosting weekly meetings and maintaining an overall progress level of the project. Judy Cha, External Officer, takes care of ordering parts and makes sure there are sufficient supplies for development at all times. Alex Kwan, Internal Officer, has a duty of setting realistic schedules and enforcing deadlines. Clarence Wong, Financial Officer, is in charge of governing the project expenditures to keep them within budget. Kevin Yoon, Engineering Officer, is responsible for system design and integration.

In order to maximize the overall efficiency, the project is divided into three segments: mechanical design, actuators/sensors interfacing, and automation control. Three team members will specialize and lead the implementation in each of these areas. The remaining two members are assigned to aid and overlook two of the three areas such that they will be able to lead system integration in the final stages of our project. In addition, these two system integrators will be able to backup the main designers in case they are away.
# Project Proposal

## 10 About Co-founders

<table>
<thead>
<tr>
<th>Name</th>
<th>Role</th>
<th>Background and Skills</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>David Boen</strong></td>
<td>Chief Executive Officer</td>
<td>David is a fourth-year electronics engineering student at Simon Fraser University. From his previous industry work, he has gained experience in digital hardware development. Along with his knowledge on microprocessors, his skills make him a perfect fit for handling the hardware interfacing.</td>
</tr>
<tr>
<td><strong>Judy Cha</strong></td>
<td>External Officer</td>
<td>Judy is in her fourth-year majoring in engineering physics. She accumulates a year of working experience in signal processing, failure analysis, and embedded systems. Her strong background in electronic physics and software skills make her a strong candidate in dealing with the sensors and algorithm sections.</td>
</tr>
<tr>
<td><strong>Alex Kwan</strong></td>
<td>Internal Officer</td>
<td>Alex is a fourth-year engineering physics major at Simon Fraser University. He has had co-op experience worldwide as he worked at Infineon Inc., Austria. His international technology awareness is a valuable addition to the team. With his enthusiasm in making prototype models and quick-learning personality, he becomes a solid contributor in the actuators and sensors areas.</td>
</tr>
<tr>
<td><strong>Clarence Wong</strong></td>
<td>Financial Officer</td>
<td>Clarence Wong is a fourth-year engineering student specializing in the electronics option. He has gained expertise in RF electronics and digital hardware design from his work experience. His hands-on experience in electronics qualifies his contributions to the hardware development portion.</td>
</tr>
<tr>
<td><strong>Kevin Yoon</strong></td>
<td>Engineering Officer</td>
<td>Kevin is studying in his fourth-year of the systems engineering program. With over a year of industry experience in digital hardware development, software automation, and embedded systems, he is capable of directing and leading the system integration process. In addition, his mechanical background will provide solid support in the mechanical design of the project.</td>
</tr>
</tbody>
</table>
11 Conclusion

One of the most important aspects of human life is entertainment. To seek entertainment, people in generations have developed countless arts, games and sports. In past days, games and sports involved human interactions with other human beings. But today, we are seeing game play taking another form - that is, human interactions with computers –providing entertainment in a more exciting, thrilling, and electrifying experience.

Air Hockey should be no exception since this particular table game is one of the most popular games found in virtually every arcade and movie theater complex. This is precisely why we chose to create an automatic air hockey player that will challenge human players and will provide entertainment that will surpass any kind of entertainment that ever existed in the world!

“… and with effortless ease, Jack scored it’s final goal of the evening. Jack’s human opponent muttered, ‘I’ll get him next time.’ and quietly shut off power to the robotic controller. Jack was as silent as a ghost when it’s human partner trudged away in defeat – but somehow it knew he would be back again for more.”