A9 - Legal and Regulatory Analysis

Year: 2023 Semester: Fall Team: 16 Project: Autonomous Air Hockey Robot

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1.0 Regulatory Analysis

To support the launch of the Autonomous Air Hockey Robot, several regulatory standards must first be met. Given the target market associated with this project as well as the expected usage cases, UL and FCC requirements are to be considered and satisfied. Furthermore, Apache 2, BSD, and PSF software licenses will need to be recognized and leveraged accordingly.

**1.1 - Underwriters Laboratory (UL)**

Human-robot interaction is a well-recognized concept demonstrated by the Autonomous Air Hockey Robot. Global safety standards continue to develop as human-robot interaction continues to grow, making the Underwriter’s Laboratory (UL) regulations of high relevance to this project. The UL is an internationally recognized safety-science company that enforces product safety regulations.

The Autonomous Air Hockey Robot features several mechanical and electrical components that lead it to require UL certification. The UL offers *Robotic Safety, Security, and Performance* testing and certificationwhich includes the regulation of automated linear robots such as the Autonomous Air Hockey Robot [1]. This regulation involves the following evaluations [2]:

**1.1.1 - Functional Safety Evaluation**

Passing UL regulations will involve a full verification process of the project’s concept and system design. Considering the nature of the Autonomous Air Hockey Robot, this evaluation will focus on the robot’s gantry system and user interface, as these functional mechanisms pose the highest safety concerns. To support the team’s success in passing the functional safety evaluation, it is imperative that the team publishes documentation on system design and testing methods with the release of the product.

The two regulations associated with passing the functional safety evaluation are **ISO 13849/IEC 62061.** These regulations imply that the robot must withstand a risk analysis, a system integrity analysis, a fault tree analysis, a probability of dangerous failures calculation, and a safety assessment.

The team has begun documentation including the organization of all schematics, bill of materials, and block diagrams associated with the project. This work supports the eligibility to undergo a functional safety evaluation as described above.

**1.1.2 - Risk of Fire, Electrical Shock, and Injury Technical Evaluation**

The Autonomous Air Hockey Robot involves the employment of two separate power supplies in addition to two high-power stepper motors. These components lead the device to warrant a technical evaluation related to the risk of fire, electrical shock, and injury.

**1.2 - Federal Communications Commission (FCC)**

Given that this product uses a high-performance microcontroller, the robot is expected to generate notable electromagnetic interference (EMI). Additionally, the microcontroller being used operates with a clock frequency of 48 MHz. Given this, the product must comply with the regulatory standards set by the Federal Communication Commission (FCC). Because the Autonomous Air Hockey Robot will be marketed commercially to be used in residential environments, this product is classified under Class B - digital device.

As a Class B device, this product is subject to withstanding a verification process and certification process[3]. This will involve the team connecting with local radio frequency emissions labs to test the product for radio frequencies to ensure that the product passes FCC standards. Following this, the team will be expected to document the results and submit a certification request to the FCC. This certification request will involve filing FCC form 731 and submitting the corresponding emissions test report and service fee. Upon receiving a grant of certification, the marketing process can begin.

**1.3 - Software Licensing**

In addition to the federal regulations described above, the team will need to consider software licensing prior to marketing the Autonomous Air Hockey Robot. The software licenses that are applicable to the team’s project include Apache 2 license, BSD license, and the PSF license agreement. The Apache 2 license is a free software license available to all for distribution and modification. With this in mind, the team does not face concern for any royalties or other legal obligations. The team will be sure to include a copy of the Apache license in the final software [4]. Similar to the Apache 2 license, both the BSD and PSF licenses are free permissive licenses with minimal legal restrictions. Once again, the team will include copies of the BSD and PSF licenses in the final software before marketing the product.

2.0 Legal Liability Analysis

2.1 Analysis of Patent 1 - China Patent CN105922275A [5]

**Patent Title:** Air hockey robot based on movement sensor

**Patent Holder:** 彭良秀葛华孔, 子祥田应仲

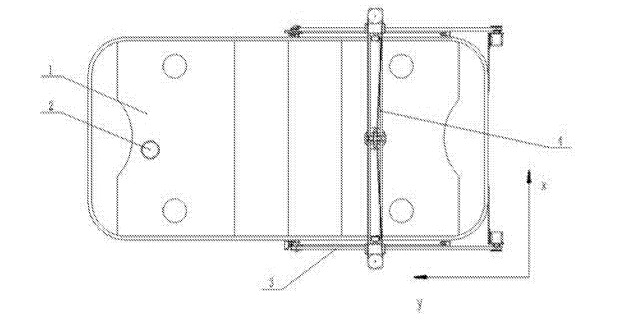
**Patent Filing Date|Publication Date:** 06/04/2016 | 09/07/2016

**Summary:**

The given patent protects the development of a robot that uses a movement sensor to control the x-direction and y-direction automatic striker systems that sit upon an air hockey table. These striker systems are to be mounted upon the table so that an air hockey ball can be adjusted in the x and y directions achieving millimeter-level precision within an instant. The robot described throughout this patent would be of simple and small size, and the movements of the robot would be smooth. The invention also includes the connection to an off-table computer.

The provided patent describes the movement of the robotic technology to involve electric motors and an integrated sensor that uses MEMS technology. Additionally, a gyro sensor and a geomagnetic sensor would be used to identify the moving puck’s angular velocity and orientation. Data from the sensors are to be sent to the computer, which controls the motions of the motors. This invention is designed for man-machine confrontation.

Figure 1 shows the mechanical design of the protected invention, in which four motors control the X and Y movement of an air hockey mallet. The puck in Figure 1 is equipped with various movement sensors to provide the computer with position and acceleration data.



*Figure 1: Movement Sensor Air Hockey Robot Sketch*

**Analysis of Potential Infringements:**

When considering the similarities and differences between the Autonomous Air Hockey Robot versus the invention described above, there are few legal concerns to be acknowledged. While the invention described above is similar to the team’s project in that it (1) is composed of rails in the X and Y direction, (2) uses a computer to analyze positional data of a puck in motion, and (3) is designed for human-robot interaction, there are many differences distinguishing the two robots.

Firstly, while the above invention does use mechanical rails to control the X and Y directions of an air hockey mallet, this mechanical system consists of 4 motors and 2 pulleys. This gantry system differs from that used in the Autonomous Air Hockey robot as the Autonomous Air Hockey robot uses just two motors and 4 pulleys. Additionally, the Autonomous Air Hockey robot makes particular use of *stepper* motors, further differentiating it from the project above. The choice of motors is imperative to the functionality of the Autonomous Air Hockey robot, as it contributes to the precision of the system as a whole.

The patent above protects the use of a computer in the construction of an air hockey robot. This poses a legal concern to the Autonomous Air Hockey robot given the robot’s use of a computer to support data analysis. With this said, the computer described in this patent serves a different function than the computer used in the making of the Autonomous Air Hockey robot. While the patent above defines the computer’s role to analyze sensor data and control motors, the Autonomous Air Hockey robot relies on the computer for image analysis, computer vision, and serial communication. The Autonomous Air Hockey robot leverages a microcontroller to control motors, which is an intentional design decision meant to improve the functionality of the system.

Key differences between the above invention and the Autonomous Air Hockey robot include the use of a camera sensor, the overall size of the project, and the use of a microcontroller. All in all, potential infringements to be considered include:

1. The use of a computer in the making of an air hockey robot
2. The use of and X-direction and Y-direction system to control an air hockey pallet

While the concerns above remain significant, the technology used in the Autonomous Air Hockey robot remains different from that used in the patent analyzed given its unique use of computer vision and a large-scale 2-motor gantry system. Additionally, the Autonomous Air Hockey robot is to be used by air hockey hobbyists and enthusiasts, in which the context of the Autonomous Air Hockey robot further differentiates it from the described patent.

2.2 Analysis of Patent 2 - South Korea Patent KR20220105068A [6]

**Patent Title:** Air hockey robot for single

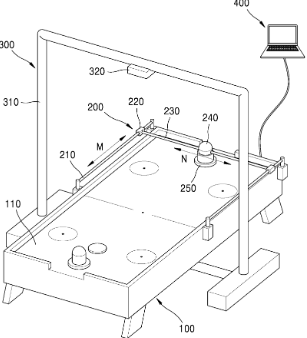
**Patent Holder:** 정웅희공형구, 이승한장영하

**Patent Filing Date|Publication Date:** 01/19/2021 | 07/26/2022

**Summary:**

The invention protected under this patent involves a personal air hockey robot composed of a table, a camera module, and a processing module. This invention is intended to support single-user enjoyment of air-hockey so that users can improve game accuracy on their own. The camera module used in this application is mounted above the air hockey table and is used to photograph the movement of a hockey puck. This invention also includes a pole module in which poles are mounted to the table to allow movement in the forward, backward, left, and right directions. The camera module transmits displacement data to a processing module, which then controls the movement of the pole module.

The processing module defined in this patent refers to a Raspberry Pi module, Arduino board, and Raspberry Pi camera module. The Raspberry Pi module uses OpenCV to process image data, and transmits that data to the Arduino board.. The Arduino board then controls the pole modules to displace the air hockey mallet. Figure 2 illustrates the design of the invention protected under this patent:



*Figure 2: Illustration of Air hockey robot for single*

**Analysis of Potential Infringements:**

The invention protected under this patent poses several concerns of potential infringement, most of which relate to functionality rather than implementation. Firstly, the described invention is intended for air hockey hobbyists and enthusiasts, which matches the end user description of the Autonomous Air Hockey robot. Additionally, the invention described makes use of a camera module and processing module to control the movement of an XY gantry system. This leads to the following concerns for potential infringement:

1. The use of a camera module and OpenCV to control the directions of a gantry system
2. The creation of a single person robot for air hockey enthusiasts
3. The use of a processing module to manage data received from an image module

While there does exist the above concerns, the Autonomous Air Hockey robot remains unique through its differentiated application of the above functions. Firstly, the Autonomous Air Hockey robot uses a personal computer for processing, in contrast to a Raspberry Pi module. This difference leads the Autonomous Air Hockey robot to experience higher processing times, which distinguishes it as a robot capable of matching varying skill levels. Furthermore, the Autonomous Air Hockey robot uses a global shutter 120 fps camera module in contrast to the Raspberry Pi camera module used in the invention protected under this patent. Once again, this difference leads the Autonomous Air Hockey robot to be compatible with versatile skill levels, allowing the product to be marketed to a wider audience. The use of the STM32F091RCT6 further differentiates the Autonomous Air Hockey robot from the device protected under this patent, as the STM32 microcontroller allows for faster response times and for serial communication over UART.

In addition to the electrical differences between the Autonomous Air Hockey robot and the device protected under this patent, there are several mechanical differences making the Autonomous Air Hockey robot a unique product. Firstly, the robot protected under this patent is small in size and can fit on top of a desktop. In contrast, the Autonomous Air Hockey robot fits upon a standard sized air hockey table, improving the training opportunities of air hockey hobbyists and enthusiasts. Additionally, the Autonomous Air Hockey robot is designed to provide accurate and precise performance, in which stepper motors are used to facilitate this. The use of stepper motors offers a product that can challenge a human player, which is not a function protected under the given patent.

2.3 Analysis of Patent 3 - US Patent US7854669B2 [7]

**Patent Title:** Trajectory detection and feedback system

**Patent Holder:** Alan W. MartyRidge McGheeThomas A. Edwards

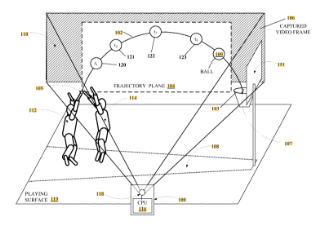
**Patent Filing Date|Publication Date:** 08/21/2006 | 12/21/2010

**Summary:**

The technology protected under this patent involves a disclosed device used for trajectory detection and feedback communication. This invention is a system that can detect one or more objects in motion. The system is also capable of analyzing the position and trajectory of the detected moving objects so that feedback relating to the moving objects can be transmitted to a human for evaluation and analysis.

The given invention uses machine vision to detect trajectories of varying moving objects, which can include a basketball, a golf ball, or an air hockey puck. The trajectory parameters can be used to provide a human with information relating to their performance.

This system is designed to be used recreationally or professionally, and it serves as a training device for athletes. To transmit feedback, an auditory system is used so that human players can listen to the data relating to their performance. Furthermore, the system described may make use of various sensors to generate the trajectory information. Figure 3 illustrates the technology protected under this patent.



*Figure 3: Illustration of Trajectory detection and feedback system*

**Analysis of Potential Infringements:**

While the use of a trajectory detection and feedback system is used in the Autonomous Air Hockey Robot, there exists several differences between the invention protected under this patent and the Autonomous Air Hockey Robot. Firstly, this patent protects a general technology involving sensors and computer vision. While this type of technology is used in the Autonomous Air Hockey Robot, the technology is applied with a different intention. This patent protects the use of a trajectory detection and feedback system in which feedback is audibly transmitted to allow human players to adjust their performance accordingly. In contrast, the Autonomous Air Hockey Robot uses a feedback system to control an electrical system composed of motors and pulleys so that a puck in motion can be blocked and attacked. Additionally, the feedback system used within the Autonomous Air Hockey Robot is *only* capable of detecting *one* puck in motion in a classic game of air hockey. This technology is individualized for a specific game and context.

While the invention under this patent does pose concern of potential infringement, the team behind the Autonomous Air Hockey Robot might look into licensing agreements to avoid said infringement. For example, if the technology under this patent is commercialized, it is possible that the technology can be integrated into the Autonomous Air Hockey Robot without violating copyright. All in all, the Autonomous Air Hockey Robot is an invention for air hockey hobbyists and enthusiasts and is novel in its niche application, while the Trajectory detection and feedback system is broad and not unique to the air hockey industry.

3.0 Sources Cited:

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[5] “CN105922275A - air hockey robot based on movement sensor,” Google Patents, https://patents.google.com/patent/CN105922275A/en?q=%28air%2Bhockey%2Brobot%29&oq=air%2Bhockey%2Brobot (accessed Oct. 28, 2023).

[6] “KR20220105068A - air hockey robot for single,” Google Patents, https://patents.google.com/patent/KR20220105068A/en (accessed Oct. 28, 2023).

[7] “US7854669B2 - trajectory detection and feedback system,” Google Patents, https://patents.google.com/patent/US7854669B2/en (accessed Oct. 28, 2023).