A11 - Ethical and Environmental Analysis

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

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Assignment Evaluation: See the Rubric in the Brightspace Assignment

1. Environmental Impact Analysis

The air hockey robot consists of a wide variety of parts that have a range of environmental effects. The robot mainly consists of two stepper motors and motor drivers, a custom PCB design, gantry system, an air hockey table, some 3d printed parts using resin and plastic filament, a camera, and a 24V power supply. This project doesn’t consist of any batteries since everything is powered by a wall plug. There are environmental concerns at every stage of the project’s life cycle.

The Stepper motors have the greatest environmental impact during the use and end or life cycle. [1] Manufacturers have an incentive to reduce costs for their products, which can result in inefficiencies for the motors that increase their environmental footprint. Manufacturing an electric motor, like a stepper motor, often involves extraction of natural resources, transportation, and processing. A combination of copper, steel, impregnating varnishes and compounds, cover enamels, and a variety of materials for electrical insulation (paper, cardboard, polyester films and ribbons, stratified plastics, plastic material, mica, asbestos).

The greatest environmental impact factor of a motor is during the use cycle and is dependent on its efficiency. Motors are designed to have a lifespan of about 15-20 years, so it’s important that they’re efficient with the power they’re given. The less electricity used for a motor’s operation means that less emissions are needed to power it. Electric motors consume 43% - 46% of global electricity, which means about 6040 Mt CO2 emissions per year. Pollution is mainly caused by overheating, generation of external magnetic fields, noise, vibration, and emissions of volatile substances from electrical materials.

The end-of-life stage for electric motors often involves recycling the major components of the motor like steel, aluminum, and copper. Plastics used in the motor can’t necessarily be recycled all the time and can contribute to waste production. To help mitigate environmental impacts from the motors, we will get them from an eco-friendly manufacturer and minimize their usage by optimizing the software pathing for the air hockey robot.

Printed circuit boards (PCBs) have plenty of potential environmental impacts mostly in the manufacturing and end of life phase of their life cycle [2]. Manufacturing PCBs contributes the highest shares to freshwater aquatic ecotoxicity potential (FAETP) and ozone layer depletion potential (ODP) due to the emissions that occur from manufacturing them. Fabrication materials that are often used are copper, glass fiber, epoxy resin, and deionized water. The following table details the inputs and outputs for a 1m2 PCB board for both the fabrication and manufacturing processes. A majority of the waste comes from the etching process of removing copper from the surface of the board, so an efficient etching process is important.

A table of information with numbers and text

Description automatically generated with medium confidence

Figure 1. Aggregated inventory data for 1 m2 ready-to-use PCB production (fabrication of board + manufacturing of PCB) [2]

The use phase of a PCB’s life cycle doesn’t have a major impact on the environment as there aren’t a ton of emissions present during its use. However, during the end-of-life phase, PCBs face a few potential dangers. For one, they aren’t biodegradable and can often end up in landfills or as waste. PCBs can be recycled by separating the copper and other components from the rest of the board, but only the metals can be recycled. The other components can’t necessarily be recycled and would produce some waste.

To reduce the environmental impact of the PCBs made for this robot, an efficient manufacturer should be chosen that can keep their emissions low compared to the competition. The PCB design itself should also stay compact and small to minimize resource usage and use more eco-friendly materials.

This air hockey robot consists of some 3d printed components that also pose some issues. Most filaments for 3d printers can be recycled which helps alleviate some of the environmental effects of these materials. However, these plastics aren’t biodegradable and can waste away in landfills. 3D printing is also much more energy intensive than other types of manufacturing and can use 50-100 times more energy to produce an object of the same weight [3]. This increase in energy leads to more emissions for the power consumed. There are some filaments that are also biodegradable which would help with the biodegradation issue. The key is going to be getting a material that meets the structural and thermal needs of the system that is also biodegradable. Recycling old materials is also a viable option to reduce the environmental impact of the system.

A good way to extend the lifetime of our air hockey robot is to make the whole system modular with replaceable parts. This is a large product, so buying a whole new system if something breaks isn’t the most environmentally friendly thing to do with the potential waste that can occur. This can increase the lifetime of the product and allow for future upgrades to the system.

1. Ethical Challenges

There are a few considerations to keep in mind for the ethics of an air hockey robot. First and foremost is safety. There are a number of moving parts like spinning motors, moving belts, and rail systems. Any one of these parts can collide with people, get objects stuck in them, lock up, break in unintentional ways, and many more. Keeping a system like this away from human contact is a good idea to make sure no one gets hurt, and this can be simply done by using a warning label for people to keep their distance from the robot. There will also be an emergency shut off switch that can cut power to the motors and stop everything from moving. To prevent the motors from overextending themselves and sending the rails off of the system, limit switches will be in place to stop the system from going beyond certain points.

Another point on safety is the impact forces of the air hockey puck going across the table. If the robot hits the puck very hard, there may be some physical harm to a player if their fingers or if something else is on the table. This can happen from time to time on a regular hair hockey table, but the issue is magnified against the robot who can hit much harder than a human player can. Because this issue is inherently built into the air hockey table design, warning labels to clear the surface of the table and watch for exposed fingers will be present.

The robot uses a camera for puck detection and has to analyze the images to find the puck. Privacy is important, and something may accidentally get recorded under the camera that shouldn’t be. This shouldn’t be an issue since the camera’s data is only sent to a computer that analyzes the live feed from it and doesn’t store any of the image data. The computer only analyzes the images by looking for a puck and determining what directions to send to the motors to play air hockey.

In the interest of fair competition and accessibility to all players, a skill level system will be in place to make sure that everyone can have fun against the robot. People like fair competition, so a variable skill level for the robot will provide players the chance to play competitively against the robot.

3.0 Sources Cited

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[2] E. Ozkan, N. Elginoz, and F. Germirli Babuna, “Life cycle assessment of a printed circuit board manufacturing plant in Turkey,” Environmental Science and Pollution Research, vol. 25, no. 27, pp. 26801–26808, Sep. 2017, doi: <https://doi.org/10.1007/s11356-017-0280-z>.

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[3] Perch Energy, “3D Printing: Eco-Friendly & Sustainable? (Not Quite) | Perch Energy,” www.perchenergy.com, Sep. 17, 2022. https://www.perchenergy.com/blog/innovation/is-3d-printing-eco-friendly-sustainable

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