Pancake Printer

Cyber-Physical Systems and the Rise of Consumer E-Waste

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

There is a saying that 'breakfast is the most important meal of the day'; however, a 2011 study showed that "31 million Americans skip breakfast every day" (HuffPo, 2017). This can have a significant impact on health and energy levels, especially in children (Berkey et. al, 2003). The technical aspect of this project aims to encourage more people to eat breakfast by creating a device that will allow the user to almost entirely automate breakfast preparation to save time and energy in the morning while incorporating unique imagery to engage various audiences.

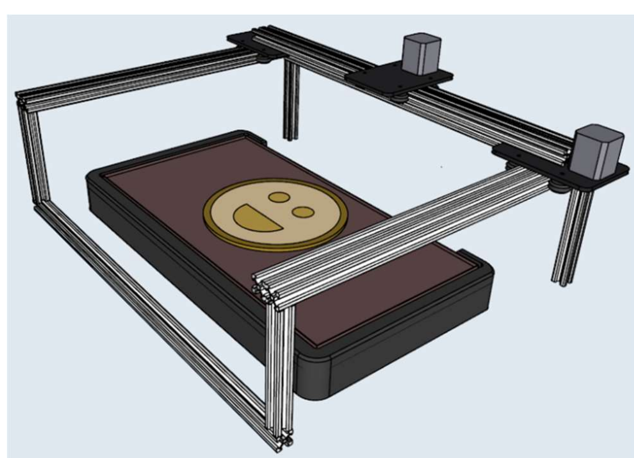
When creating systems which are meant to integrate into the daily routines of consumers, it is important to consider how consumers will interact with the product along the entirety of its lifecycle. Equally important is considering the impact the product's life cycle will have on other non-consumers and the environment. Therefore, the STS component of this project will investigate the relationship between various sociotechnical actors and their role in managing electronic waste that results from consumer-facing cyber physical systems.

Technical Topic

The purpose of this project is to combine elements of computer vision, pathing algorithms, embedded systems, and consumer-centered design to develop a 3D food printer (Lui et. al, 2017). The system is applied to pancake art to introduce inconsistency into the design in order to show proof of concept of 3D printing with variable mediums (Luo et. al, 2019). Additionally, this specific application of a kitchen appliance allows for more consumer-centered design, which would ultimately serve to develop a machine that could be commercially available and desirable to consumers within the use case.

The process begins with a web application that is hosted on a Raspberry Pi that can be connected to from any device via WIFI. This application will allow the user to submit an image of their choosing or select an image from a set of provided simple images. The image processing is done within the Raspberry Pi (Pi). The resolution of the image is reduced to 300x300 pixels and switched to grayscale to simplify the processing. The image is processed with computer vision using OpenCV (OpenCV). First, the algorithm must find the edges of the image so that it can later be turned into a solid and connected pancake. Then, the major features are extracted to form the image. The edges and the features are put into groups that will be processed together. These are then converted into a series of simple instructions: move while dispensing, move without dispensing, and wait.

The physical system consists of a carriage system, a dispensing setup, and a temperature control unit. The carriage system contains a metal frame that supports the movement and two stepper motors (one for the x direction and one for the y). The dispensing set is two vessels for batter and cleaning solution, a peristaltic pump, and food-grade tubing connected to a 3D printed thin nozzle that is used to extrude the batter. The temperature control unit consists of a commercially available griddle and a relay switch to keep the temperature within a desired range.



With the image processed, the instructions are sent to the physical system via UART to the MSP430 microcontroller. The institutions tell the motors when and where to move and the pump when to be on. The edges and the darkest parts of the image will be laid down first, then wait 30 seconds for it to darken. This will continue for every layer, with the lightest layer covering everything within the edges to complete the full pancake. Then, the user will be notified when to flip the pancake to finish cooking the other side and completing the process.

STS Topic

Cyber-physical systems, like the one being developed, are present in all facets of life. From smartphones, to cars, and even some light bulbs, these products make life easier with smart technology and automation, allowing people to think less about their daily routines. Often, they are so seamlessly integrated that it can be easy to ignore the technology altogether (Giller, 2020). However, this can also be dangerous. As the prevalence of these products grows, it cannot be forgotten that they came from somewhere and must go somewhere after they are no longer in use. These systems are extremely complex, making it difficult for consumers or governments to intervene in the manufacturing process. There is significant fragmentation in the production process that makes practices difficult to trace.

Building off this foundation, the following analysis will investigate the major factors that contribute to and parties responsible for the lifecycle of electronic waste.

There are thousands of companies which produce products with a similar life cycle. The first step of this life cycle is the extraction of raw materials from underdeveloped countries. These materials are then used to fabricate electronic devices, namely microchips. Next, the devices are used to develop systems like smart light bulbs and cars. Eventually, the products are retired from use and go to a landfill or an attempt is made at recycling them. If the product goes into a landfill, it begins a new life cycle as garbage which may take centuries to decompose. If it gets recycled, it will likely get shipped to a small foreign community (Campbell & Christensen,

2016) where people are paid to extract its valuable reusable elements, while the rest still often ends up in a landfill (Wroclawski, 2015).

On the production side, ethical issues can arise in a few ways. Starting with the central raw material, silicon dioxide. It needs to be mined and refined. The mining of this critical material is based on extractive practices taking place in smaller economies which typically exploit workers and remove resources (Pellow, 2004). The end result is that these smaller communities are often left with no sustained economic activity in the long run. As the components are manufactured and combined into a complete system, there is either little to no ability for consumers or government agencies to track a specific product's production to determine if ethical labor practices are being implemented throughout the entire process. There is also often little diversity in the production of similar products for consumers to be able to use their purchasing power to force out suppliers that do not align with their values. Furthermore, from the company perspective, using non-recyclable materials or designing readily-disposable products which are difficult to recycle or reuse is another large problem from the beginning of a product's life cycle that needs to be addressed (Semuels, 2019).

Towards the end of a product's life cycle, there are two major problems with the production of e-waste: lack of resources for consumers and unethical practices by state and local waste management companies. There is a stark lack of resources available to consumers that want to recycle (EPA). Few people know how or when to contribute to these programs because in many areas, there are only a few days a year to recycle these products and it can be far away or during inconvenient times (Morgan, 2021) which prevent people who want to recycle from doing so. Even if they are able to utilize this resource, this method places the burden on consumers to be diligent in their efforts with little to no incentive. For materials that do make it to the recycling process, much of the waste gets transported via inexpensive labor to waste processing facilities in low-income areas where there are no environmental protection laws (Campbell & Christensen, 2016). Typically, only a small portion of the products (about 17%) get reused and the rest end up in landfills or are incinerated (Narishkin, Cameron, Appolonia, & Barranco), leaving the natural air and water sources in these disadvantaged communities tainted with toxins.

New corporate policy must be developed to lessen the impacts of cyber-physical systems and their waste on the planet and its resources. Furthermore, this corporate policy must also comprehensively address the social and political dimensions of these production processes. As such, it is vital that said policy introduces elements of environmental justice into practice to protect marginalized people from being disproportionately disadvantaged.

Centering Earth Systems and Engineering Management (ESEM) (Allenby, 2007) as the key framework for analyzing civilian, corporate, and government philosophies and policies to determine the root of the problem will be the core research focus as this is foundationally an engineering specific waste management issue. However, emergent behavior and the principle-agent problem (Agarwal, 2021) with regards to new policy and practice adoptions will also be considered because it is also a greater societal problem.

Research Questions and Methods

The technical thesis and STS synthesis coalesce on the idea that the designers and supporters of these systems are at least somewhat responsible for the impacts they have on the world and people around them. Due to the complexity of these products, it is difficult to isolate products and companies that are being unethical in production, and there is no simple solution to the problem. However, by relying on the sociotechnical triangle of government, corporations, and consumers, a comprehensive solution will be developed.

The STS synthesis will investigate the current practices from consumer, corporate, and governmental perspectives surrounding the production, integration, and disposal of cyber-physical systems. This will be done using current national and local policy documentation as well as case studies about individual practices regarding waste. In combination with this, the impacts of these technologies at different stages in the product life cycle, determined through medical and environmental impact studies conducted near production and dumping sites, will be used to develop social, ethical, and political changes that can be explored and implemented.

Conclusion

After developing a consumer-facing pancake printer from a technical perspective, the STS synthesis will then approach the device from a social and ethical angle to provide a comprehensive outlook of the system. This will investigate the current practices from consumer, corporate, and governmental perspectives surrounding the production, integration, and disposal of cyber-physical systems. For there to be any visible change in this situation, it needs to be targeted from these different perspectives because they all work together to create the environment that caused the problem in the first place. By analyzing these causes to see how they interact will be helpful in understanding recommendations to solve the problem. Incorporating elements of environmental justice within the scope of direct actionable practices, procedures, and legislation is the goal in order to prepare for how this issue will grow in the upcoming years.

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