Prospectus

Design of an Air Guitar: S.H.R.E.D

(Technical Report)

Responsibilities in Sustainable Production and Recycling

(STS Research Paper)

Presented to the Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

Erik Haukenes

Fall, 2019

Department of Electrical and Computer Engineering

Signed: _____

Approved: _____ Date _____

Prof. Sean Ferguson, Department of Engineering and Society

Approved: _____ Date _____

Prof. Harry C. Powell Jr., Department of Electrical and Computer Engineering

I. Introduction

In a consumer economy based upon the production of goods, smart ways to manage waste are important for the health of our society and planet. Our blueprint that aims to look at how waste is collected using IoT devices, can go one step further to look at how it is created and recycled. IoT devices eventually become waste themselves, and as such it is important to look at how e-waste is produced, handled, and recycled.

E-waste in general can be especially dangerous to humans, because it can contain highly toxic heavy elements, and is often crudely dealt with in underdeveloped countries because e-waste contaminants pollute the surrounding farmland and agriculture (Awasthi, 2016). Children especially are vulnerable to e-waste with one example coming from the Chinese city of Guiyu, the largest e-waste collection site in China. Guiyu children are experiencing a number of serious health problems as a direct result of "informal and nonstandard e-waste recycling activities" (Zeng, 2016).

In a perfect world the responsibility of e-waste production and recycling would fall fairly upon consumers and producers with government intervention, however e-waste and pollution remains a global hotbed issue. Therefore, it is important to answer the question of why e-waste is such a problem in our global society, and how a holistic system for managing e-waste can be designed in which all stakeholders act responsibly in order to create a safe and sustainable life cycle for electronic products.

II. Technical Topic: Design of an Air Guitar - S.H.R.E.D.

S.H.R.E.D (Sensor Handheld Rock and Roll Electronic Device) is a musical instrument designed to give musicians the experience of playing an air guitar, while providing a realistic sound. The project will involve a phone application that takes the finger positions of the user to determine the chord being played, as well as a distance sensor to determine which frets along the neck of the guitar are being played. An accelerometer will be used to determine when the guitar is being strummed, and all of the sensor and phone application data will be relayed to a National Instruments myRIO board via a printed circuit board with wired connection to the accelerometer and phone. The myRIO board then creates soundwaves for a variety of instrument types using signal processing techniques such as the Karplus-Strong string synthesis algorithm.

Our capstone group chose to create a musical instrument due to interest in learning how to play guitar without paying for expensive equipment. Traditional guitar strings can often be painful for beginning musicians who have not developed calluses, making a touchscreen based input appealing to beginners. The S.H.R.E.D air guitar is also suitable for musicians wanting to practice in public or quiet spaces, as it is compatible with headphones, and is much smaller than a normal guitar allowing for greater portability as it will fit comfortably in a backpack.

Projects that attempt to replace or substitute for a physical musical instrument are fairly common, however our project differs in several key aspects from prior inventions. One product currently on the market, the Kurv Guitar, innovates on how electronic handheld device inputs control musical intonation and note-playing, however their product strays into the realm of being a 'new' musical device rather than a substitute for an existing one, the function our device aims

to provide. Specifically, the Kurv Guitar functions via a hand-held button-operated device in the user's left hand and a motion-controlled guitar 'pick' in the controller's right hand. Through a combination of button presses and moving the pick in a specific orientation, users are able to mimic playing a guitar. However, the system through which a guitarist would normally change octaves via moving their hand up/down the neck of the guitar has been fundamentally changed and is a definite distinction found in our project, alongside no physical button press for note selection.

Misa digital is another company developing digital guitars with alternatives to standard strings. Their guitars are full sized, and use a capacitive fretboard that runs up and down the entire neck of the guitar. In order to play notes a string is not plucked or strummed, but a touch screen is tapped where the sound hole would be on a normal guitar in order to produce a sound. Their device can produce a variety of instrument sounds depending on the setting, however they have not implemented accelerometer based strumming into any of their products like we plan to with ours.

In developing our capstone project, it is important to approach the design with a sustainability mindset, as the batteries and circuitry that will be used in our design fall squarely under the umbrella of e-waste. As engineers we want to design and manufacture a product that can be easily recycled when it reaches the end of its lifecycle, and work with relevant stakeholders to take responsibility for e-waste produced as a result of our product.

III. STS Topic:

Currently, e-waste is the biggest waste stream and the fastest growing at 3% to 5% per year. Almost 50% of e-waste is consistently exported to poorer countries, and even more undocumented e-waste is transferred illegally (Cucchiella 2015). Illegal goods are transported under the guise of being usable for the people in these poorer countries, but often it is non-functional materials being illegally transported to avoid the more expensive costs of legitimate recycling methods. Some products are recycled by unauthorized parties at their end destinations using crude ineffective methods such as burning or acid baths that damage the environment (Chi 2014), and the rest of the products end up as pollution causing health and safety risks to the environment and people living in them (Vidal 2013).

E-waste is being produced at this increasing rate in part because of the short life cycle of products on the market. Companies go through yearly product cycles, and older models of consumer electronics are phased out because of proprietary monopolies on expensive repairs to devices that are still usable (Root 2019), and planned obsolescence of devices that forces customers into buying the latest model of a new product (Sarhan 2017). Generally, the lifespan of a mobile phone for a customer in China was less than three years due to a demand for new styles and technology (Yin 2014), showing that it is a symbiotic relationship between companies and consumers that lead to the creation of more and more products.

Not only is e-waste increasing in overall volume, but technological complexities in e-waste products used to increase quality and durability make the materials that are most valuable

significantly harder to recover through a recycling process (Tansel 2017). Products therefore need to be designed with e-waste recycling in mind. Research and modeling has been used to take product characteristics and predict how well it will separate and flow through a recycling chain (Schaik 2010). A system to analyze electronic goods and their recycling potential should be industry standardized, and producers held responsible for creating products that are easily recyclable.

To some extent, producers are held responsible for what they create. Extended producer responsibility (EPR) is a program concept that uses financial incentives for manufacturers to create products that are easily recycled. EPR can also make producers pay the cost to manage the waste their products create at the end of their lifecycle, either through their own firms, or through external organizations known as producer responsibility organizations (PROs) (Mayers 2013). EPR has been implemented in many countries around the world such as China, the US, and the countries of the European Union, and mainly applies to e-waste, plastics and packaging, batteries, and automobiles. The effectiveness of these legislation inadequate, however, due to the extreme complexity of product and waste systems, and a lack of oversight on producers and PROs (Mayers 2013). Some of the other big difficulties in implementing an EPR system is that the government may have difficulty managing producers if they are either too large and powerful, too small and fall under the radar, or if a company mainly imports their products. EPR also incentivises producers to overreport their e-waste collection and recycling for financial gain (Kojima 2013).

Designing better collection methods and recycling streams of e-waste can be a part of the solution, preventing old devices from ending up in landfills because of consumer negligence. In a survey of the citizens of Taizhou city, the most important incentives for recycling products that would become e-waste were financial incentives, and free/convenient collection (Chi 2014). The Chinese government has also tested trade-in discounts of 10% for buying new large appliances, however the survey ultimately showed that informal collection of e-waste still dominated. An integrated system for collections has been suggested for combining waste collection from all sources, and a formal e-waste recycling collection which uses the best available techniques for the most difficult and valuable to recycle materials (Chi 2014).

Providing consumers with incentives to e-waste recycling would likely help with the problem, however holding them responsible would be less than ideal. In a survey, less than 50% of consumers agreed to pay for 0-5% of the cost for the recycling of their mobile devices, and overall environmental awareness was low amongst those surveyed (Yin 2014). It was suggested that to involve consumers in the recycling process, a recycling fee be embedded in the cost of the device, and to improve public education about recycling practices (Yin 2014).

As of right now, there is no perfect solution to e-waste management and recycling. It is apparent that the problem exists on many different levels that permeate through layers of society. There are consumers with a lack of education or mindfulness about the harm that the products they buy cause the world, and producers who are only concerned with increasing their profit by creating more and more goods. Governments are unprepared to legislate and take actions that are necessary to solve the e-waste crisis, and the collection methods in place are inefficient and unable to maximize the value of the products that are actually recyclable. Changes need to be made on a global level to standardize the way electronics are produced and recycled, and more

importantly to change the way we think about e-waste as a society to truly make a lasting impact in the name of sustainability and our environment.

IV. Bibliography

1. Awasthi, A. K., Zeng, X., & Li, J. (2016). Environmental pollution of electronic waste recycling in India: A critical review. *Environmental Pollution, 211,* 259–270. doi: 10.1016/j.envpol.2015.11.027
2. Chi, X., Wang, M. Y., & Reuter, M. A. (2014). E-waste collection channels and household recycling behaviors in Taizhou of China. *Journal of Cleaner Production, 80,* 87–95. doi: 10.1016/j.jclepro.2014.05.056
3. Cucchiella, F., D'Adamo, I., Koh, S. L., & Rosa, P. (2015). Recycling of WEEEs: An economic assessment of present and future e-waste streams. *Renewable and Sustainable Energy Reviews, 51,* 263–272. doi: 10.1016/j.rser.2015.06.010
4. Kojima, M., Yoshida, A., & Sasaki, S. (2009). Difficulties in applying extended producer responsibility policies in developing countries: case studies in e-waste recycling in China and Thailand. *Journal of Material Cycles and Waste Management, 11*(3), 263–269. doi: 10.1007/s10163-009-0240-x
5. Mayers, K., & Butler, S. (2013). Producer Responsibility Organizations Development and Operations. *Journal of Industrial Ecology, 17*(2), 277–289. doi: 10.1111/jiec.12021
6. Root, T. (2019, July 3). Apple effectively has a monopoly on fixing your iPhone. There's now a fight to change that. Retrieved November 8, 2019, from https://www.vox.com/the-goods/2019/7/3/18761691/right-to-repair-computers-phones-car-mechanics-apple.
7. Sarhan, A. (2017, December 22). Planned Obsolescence: Apple Is Not The Only Culprit. Retrieved November 8, 2019, from https://www.forbes.com/sites/adamsarhan/2017/12/22/planned-obsolescence-apple-is-not-the-only-culprit/#684e505b3cf2.
8. Schaik, A. V., & Reuter, M. A. (2010). Dynamic modelling of E-waste recycling system performance based on product design. *Minerals Engineering, 23*(3), 192–210. doi: 10.1016/j.mineng.2009.09.004
9. Tansel, B. (2017). From electronic consumer products to e-wastes: Global outlook, waste quantities, recycling challenges. *Environment International, 98,* 35–45. doi: 10.1016/j.envint.2016.10.002
10. Vidal, J. (2013, December 16). Toxic E-Waste Dumped in Poor Nations, Says United Nations. Retrieved November 8, 2019, from https://ourworld.unu.edu/en/toxic-e-waste-dumped-in-poor-nations-says-united-nations.
11. Yin, J., Gao, Y., & Xu, H. (2014). Survey and analysis of consumers behaviour of waste mobile phone recycling in China. *Journal of Cleaner Production, 65,* 517–525. doi: 10.1016/j.jclepro.2013.10.006
12. Zeng, X., Xu, X., Boezen, H., & Huo, X. (2016). Children with health impairments by heavy metals in an e-waste recycling area. *Chemosphere, 148,* 408–415. doi: 10.1016/j.chemosphere.2015.10.078