Thermo-Stasis: A User-Controlled, Temperature-Regulated Compartment

Technological Evolution and Food Safety Practices

A Thesis Prospectus
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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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STS Prospectus

Introduction

Every year, foodborne illnesses cause over 420,000 deaths, in which 30% of them occur among children under 5 years old (World Health Organization, n.d.). In America, 1 in 6 people fall ill due to foodborne related issues. The technical project I am working on aims to alleviate some of the concerns regarding foodborne illnesses by creating a device to store food where users can choose the temperature. This device is a portable, temperature-regulated compartment where the temperature in the chamber can be set by the user via buttons. Users can see the actual and the desired temperature inside the compartment as those values will be shown on a Liquid Crystal Display (LCD) screen. The device will maintain the temperature that is set in the compartment, unless the users interact with the buttons.

The inspiration behind this project comes from a need to store food at a desired temperature, especially when the tools we use for this purpose are not safe enough nor are they convenient. Furthermore, foodborne illnesses are extremely relevant in a collegiate environment since many of my peers and I have had our fair share of food-poisoning experiences. Hence, the STS research topic I am studying relates to the relationship between technological evolution and food safety practices: how new technologies assist with better food safety practices, how the need for better food safety practices pushes for more innovations, how food safety practices vary among different social groups, and how they affect the health aspect of humans. Without proper nutrition, our body would fail to fully support the activities we do, which ultimately affects our productivity and ultimately our mental and emotional health. My STS research will focus on the effect of technological evolution on food safety practices, how it affects different social groups, and ultimately how those practices affect these individuals' health long-term.

Technical Topic

The objective of our technical project is to create and design a temperature-regulated compartment where users can increase or decrease the desired temperature for the compartment. The device will be in the shape of a box, with a lid, where the outer case is plywood with an inch of insulation on the inside of the compartment. The desired temperature and actual temperature of the device will be displayed on the LCD screen. The buttons will increase or decrease the temperature by 1 degree Fahrenheit per press. The LCD screen and buttons will be coordinated with the heating and cooling components via an MSP430 microcontroller. The device will be using Peltier modules as the main component to create cooling and heating. The Peltier modules are thermal control modules that have P-N semiconductors sandwiched between two metal plates. When applying a current differential to a Peltier module, one metal plate will become hot by radiating heat, while the other metal plate will become cool by absorbing heat. This allows the device to be able to heat or cool the compartment depending on the set desired temperature versus actual temperature of the device. If the polarity of the Peltier module is flipped, then the hot plate will become cold, and the cold plate will become hot. From there, the Peltier thermoelectric cooling element will be set to either heating or cooling mode, using an H-Bridge, an electronic circuit that switches the polarity of the voltage applied to a certain component. The heat/cold generated by the Peltier device will be distributed inside the compartment through air circulation with an internal fan and heatsink, and the excess cold/heat will be pulled from the Peltier device by an external fan and heatsink. The device will run off a 12V battery for portability, and the battery can be recharged by being plugged-in to an outlet for future use.

The MSP430 microcontroller is the brain of the device in that it helps communicate between the user's interface and the hardware. It will also control whether the Peltier modules will perform heating or cooling by making use of an H-Bridge, so it can reverse the polarity of the current through four transistors. The microcontroller will take user inputs through the buttons to adjust the set temperature to maintain and it will display both the current as well as the set temperature on the LCD screen. By reading the temperature data from the temperature sensors in the compartment, the internal heatsink, and the external heatsink, the microcontroller will send those data to the fuzzy control algorithm, which will output the appropriate operation mode, heating or cooling. The fuzzy control algorithm will also output the appropriate duty cycle for Pulse Width Modulation (PWM) signal to power the Peltier modules, which determines how often the PWM signal will run.

The microcontroller will also control the fans using a transistor interface for power. It will also use both the temperature data from the heatsinks and the lid status (whether the lid is opened or not) to determine the power delivered to the fans. The fans' power, like the Peltier modules' power, will be controlled through PWM signal. The components that are utilized in this project, such as the Peltier modules, the MSP430 microcontroller, and the LCD screen, require different power supplies. Therefore, a linear regulator is necessary to regulate how power from the battery is distributed within the device.

Some potential issues include the power supply management as the heating and cooling systems can draw a large amount of power. Assembly of the prototype is also a challenge since the team must be very careful in the design placement to ensure the heating and cooling components work independently and do not affect the temperature of the other compartment. Additionally, verification of the heating/cooling system's functionality can pose challenges since this process has certain margins of error, which ultimately can increase the level of difficulty of the testing process.

STS Topic

Research Question

The primary objective of my research is to analyze the relationship between technological evolution and food safety practices, how its effects vary among different social groups, and how it affects aspects of their lives, which includes physical, social, and psychological wellness. According to the World Health Organization, over 33 million lives are lost globally because of unsafe food consumption all over the world (WHO, n.d.). Additionally, a 2015 study from Robert Schaff, an Ohio State University professor, estimated that foodborne illnesses cost over 55.5 billion per year in medical treatment, lost productivity, as well as illness-related mortality (Shaw, 2018). There is a high need for better food safety practices as foodborne illnesses are not only damaging to individuals' health, but they also pose major damages to food businesses. Hence, technological solutions were sought out to elevate the way food is stored and monitored. Some notable technological innovations for better food safety include sensors to ensure food is being stored at the proper temperature, digital auditing tools to better analyze records and data of the food's status. These are just some of a few examples of how technological solutions were sought out due to social needs, which in this case is the need for better food safety practices. My research will delve deeper into the matter by studying relevant social groups, as well as utilizing STS frameworks such as Social Construct of Technology (SCOT) and Actor-Network Theory (ANT).

Relevant Social Groups

One of the main social groups that are directly affected by the effectiveness of food safety practices is the restaurant industry. According to the National Library of Medicine, the cost of a foodborne illness outbreak ranged from "$3968 to $1.9 million for a fast-food restaurant, $6330 to $2.1 million for a fast-casual restaurant, $8030 to $2.2 million for a casual-dining restaurant, and $8273 to $2.6 million for a fine-dining restaurant" (Bartsch et al., 2018). The damages and financial losses that restaurants endure outweigh the typical cost of prevention measures, hence motivating more research on safety control measures in the restaurant settings. Another group that is affected by foodborne illnesses is school and university dining programs. A report from the General Accounting Office (GAO) states that over 28 million students receive meals daily from the federal school meal program (United States General Accounting Office, n.d.). Hence, providing safe meals is highly prioritized as younger students are more at risk of getting foodborne diseases. More relevant social groups will be explored throughout the research to see how their needs for food safety affect technological innovations, as well as how they seek out technological solutions to fulfill the extent of their food safety needs.

Methodology and STS Frameworks

Most of this research will be conducted via reading relevant articles and research papers. The first area of research is to determine the common causes for foodborne illnesses, whether that is due to improper food storage, lack of accessibility to avoid non-contaminated food, and more. Once the causes are determined, the second area of research is to figure out under what circumstances and settings do foodborne illnesses occur. Do people mostly get foodborne illnesses from getting food out? Is it due to a common type of food that they eat? After analyzing the circumstances in which foodborne illnesses originate, the third area of research is to identify the social groups that commonly involve in the circumstances as mentioned above. Once the social groups are found, the next step would be to explore what safety precautions and technological solutions they usually seek out and if there is a common trend among their practices. How often do restaurants and the mass food production industry face foodborne illnesses breakouts? What action do they take to overcome that, and what technology do they seek out to resolve these issues? How does that differ from when schools or universities face foodborne illnesses breakouts? SCOT and ANT frameworks will be utilized to evaluate the social groups and their needs in pursuing technological innovations for better food safety.

Timeline

- January 2023
  - Research on foodborne illnesses causes and where they happen.
- February 2023
  - Research on how certain groups resolve foodborne illnesses outbreaks and what technology they seek out, if at all.
  - Research to see if certain food safety technological solutions are innovated due to certain foodborne illness cases.
- March 2023
  - Evaluate which social groups get access to certain food safety technological solutions and the effect of those solutions on the social groups' health.

Key Texts

- "School Meal Program: Few Instances of Foodborne Outbreaks Reported, but Opportunities Exist to Enhance Outbreak Data and Food Safety Practices"
  - This text is a 2003 report from the General Accounting Office regarding foodborne outbreaks in school meal programs, and what actions have been taken by the federal, state, and local government to overcome those issues (GAO, 2003). The report provides numerous statistical data on how often the outbreaks happen, not only in schools, but also in restaurants and private homes.

Additionally, the report also provides details on current methodology that is being used to ensure food safety. This text is beneficial for research as it provides an incredible number of insights on the topic I'm exploring, which includes the cause of foodborne illness in schools, food safety practices in schools, as well as important statistical data.

- "Estimated Cost to a Restaurant of a Foodborne Illness Outbreak."
  - This text is a study by Bartsch et. al. on the cost a restaurant faces when there is an outbreak of foodborne illness (2018). The study considers how different types of restaurants, which include fast food and fine dining, approach the outbreaks as well as how much the cost to overcome the outbreaks between different restaurant types. This text is insightful in analyzing how the cost and repercussions restaurants face would be a pushing factor for them to seek out better food safety practices. It also helps when comparing with how other social groups respond when facing the same issues.
- "How Technology Is Elevating Food Safety Practices and Protocols"
  - This text is from a Retail Food Safety Forum that discusses how technology assists with the elevation of food safety practices among restaurants and retail spaces (Shaw, 2018). It outlines some technological solutions that are already utilized in the restaurant industry such as temperature sensors. This text is beneficial in providing some examples of the technological tools that are adapted to prevent foodborne illnesses outbreak.
- "Long Term Health Consequences of a Foodborne Illness"

- This article from Penn State University explores certain long term health consequences from a foodborne illness that one can have (McDonald, n.d.). The article outlines statistical data on foodborne illnesses cases, mortality, and productivity loss. It also outlines common microorganisms that cause illnesses, as well as possible long-term effects, such as reactive arthritis, an autoimmune disorder causing painful and swollen joints, or Hemolytic Uremic Syndrome (HUS), “a severe, life-threatening illness and is the leading cause of acute kidney failure in children under the age of five.” (McDonald, n.d.). This article is critical in identifying the long-term effects that foodborne illnesses have and the high-risk individuals such as the elderly and young children.

References

Bartsch, S. M., Asti, L., Nyathi, S., Spiker, M. L., & Lee, B. Y. (2018). *Estimated Cost to a Restaurant of a Foodborne Illness Outbreak*. Public Health Reports (Washington, D.C. : 1974). https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5958383/#:~:text=We%20estimated%20that%20the%20cost,varying%20from%20a%205%2Dperson

World Health Organization (n.d.)., *Estimating the Burden of Foodborne Diseases*. https://www.who.int/activities/estimating-the-burden-of-foodborne-diseases#:~:text=Each%20year%20worldwide%2C%20unsafe%20food,under%205%20years%20of%20age

McDonald, S. (n.d.). *Long Term Health Consequences of a Foodborne Illness*. https://extension.psu.edu/long-term-health-consequences-of-a-foodborne-illness

Shaw, F. L. (2018, July 20). *How Technology is Elevating Food Safety Practices and Protocols*. https://foodsafetytech.com/column/how-technology-is-elevating-food-safety-practices-protocols/

United States General Accounting Office. (n.d.). *GAO-03-530 School Meal Program: Few Instances of Foodborne Outbreaks Reported, but Opportunities Exist to Enhance Outbreak Data and Food Safety Practices*. https://www.gao.gov/assets/gao-03-530.pdf