The T/L Controller

Machine Learning Based Lighting and Thermostat Controller

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ORNL's Jump into STEM Competition

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1 Abstract

This report describes the steps taken to conceptualize and implement The T/L Controller, a Machine Learning based lighting and thermostat controller. The team that created the device consists of James Whitfield (Software Engineering/Computer Science) and Destiny Currie (Industrial Engineering/Mathematics), Dual Degree Engineering students at Clark Atlanta University. It was created for and submitted to Oak Ridge National Lab's Jump into STEM competition under the Smart Sensors and Controls category, and was submitted to Dr. Olu Oolatidoye for his Engineering Graphics course.

This report details all of the resources used to create and manage this device, the impact the device will have, cost analysis and material analysis for mass production, and the results of our prototype.

2 Introduction

2.1 Jump into STEM

Jump into STEM is a competition hosted by the Oak Ridge National Lab (ORNL) in tandem with the National Renewable Energy Laboratory (NREL) that challenges students to create and implement a solution for a problem within 3 predetermined topics. The topics given are follows:

- Smart Sensors and Controls for Residential Buildings
- Designing a Healthier and Energy-Efficient Air Distribution System
- Pushing the Envelope with Wall Retrofit Designs

2.2 Smart Sensors/Controls

The team chose "Smart Sensors and Controls" to focus on. This objective as defined on the Jump into STEM website is to "develop an innovative solution that uses sensor data in residential buildings to reduce energy use, improve occupant comfort, and/or increase grid responsiveness". Solutions in this category but take into account IOT (The Internet of Things) as well the integration of sensors and technology.

3 The T/L Controller

The solution created by the team is the "T/L Controller", a device which can control and monitor the different Bluetooth lights as well as the thermostat within a house in a per-room basis. It uses Artificial Intelligence (AI) and Machine Learning to find the patterns of the occupants within a house, and create a personalized experience through automatic control based on these patterns and energy efficiency. For example, the device will shut off lights at times that it has learned no one will be in the house.

This device includes a Mobile Application which will allow Real Time controls from any location, allow manual planning of events, and send out prompts to a user that will suggest energy efficient practices or make the users aware of a wasteful habit. A Web Site has been created that allows real-time controls and manual planning, but also includes the ability to modify your account and household (adding Rooms/Lights/Account Information/etc.). All of these features are available on the device itself as well via its touch screen interfaces.

3.1 Artificial Intelligence

While the device will use Artificial Intelligence to make decisions based on the habits of the user, manual override will always be possible and the device itself will understand when and when not to push its own patterns automatically. Machine Learning's role in the device is to make the device self sufficient and constantly improving. The device picks up from past mistakes and improves on that with every decision made, so the longer it is used in a household the more accurate it will get.

3.2 Design

The Controller consists of:

- 3D printed shell
- Bluetooth & WiFi connectable computer (ie. Raspberry Pi, Arduino)
- A compatible touch screen + smaller display screen
- Three front facing buttons + a dial

The device's mentioned are 20cm x 15cm, with a depth of 2cm, and includes a cord for powering the device extending from the top. All other components are within the 3D printed shell.

3.3 Cost Analysis

Component	Quantity	Cost Each	Total Cost
Raspberry Pi 3 B+	1	$35.00	$35.00
3D Printer Filament	500 grams	$25/kilogram	$12.50
Touch Screen	1	$25.00	$25.00
Dial	1	$1.50	$1.50
Buttons	3	$0.50	$1.50
		Total:	$75.50

The cost or production for a T/L Controller is about $75.50, but that number can be cut down significantly if a cheaper computer or touch screen is used instead. At this cost a controller cold at $199.99 will yield a $124.49 profit.

3.4 Market

Integrated systems and controls are needed to improve energy efficiency through the sharing of data while also opening infinite possibilities once sensors start working together. An example of this would be that a smart microwave could connect to a smart TV, sending out silent prompts to a user at night that their food is done so that it doesn't disturb others. The IOT Market has accelerated in growth, and the trend is only continuing. By 2020 the market is set to increase to 5.8 billion endpoints, a 21% increase from 2016. The issue that comes with the growing market is that the devices of one company often have little to no compatibility with the devices of others, making them useful only separately.

The T/L Controller allows the connectivity and control of any brand of Bluetooth lights in a home. This is best for the consumer, as they do not need to stay loyal to any brand in order to use Bluetooth lights to their full potential. Many people will not make the switch to smart lighting or a smart thermostat unless they know there is an easy to use way to control them all, both with and without a mobile device.

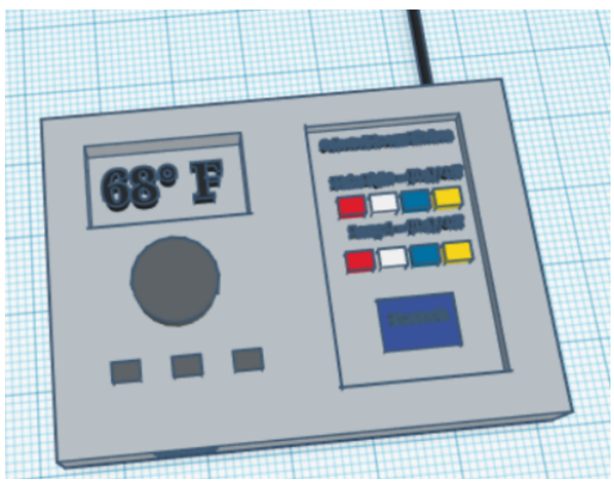
There are several smart thermostats and several smart light controllers on the market, but the T/L Controller brings the best of both into one device. The fully digital design allows changes to be made without needing to send anyone into the household, as they can be sent out as updates. The T/L Controller balances user comfort with energy efficiency, when most competitors focus on one or the other.

4 Methodology

In brainstorming for the competition, the team came up with two possible solutions to two different problems within the given challenge. The first of these ideas was a hub that can read information from water sensors, light bulbs, thermostats, and other sensors within a household so that a homeowner can better understand where their money is being spent. The second of thee ideas is the T/L Controller, which was chosen over the first due to the idea being more focused. It's the less complex of the two, and the most plausible in terms of physical representation.

4.1 Models

About 3 models were created for the device during production. The first model was created using the free software TinkerCAD, and was used as the preliminary design for the device.



The second model was also created using TinkerCAD, and built on the preliminary with defined dimensions, curved edges, and a thinner design. The dimensions of this model were used to determine the final dimensions of the product.

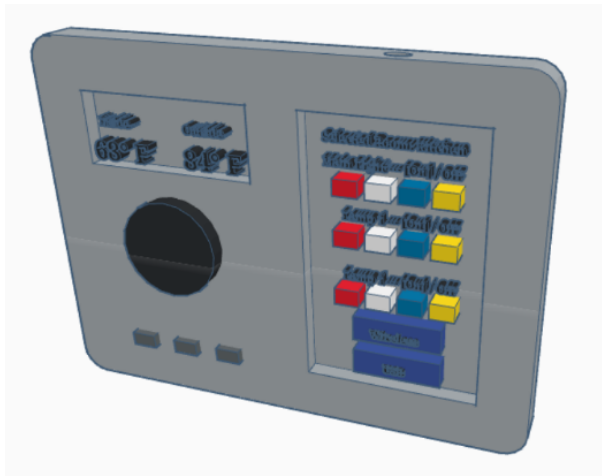


Figure 1: Secondary design of the T/L Controller

The third model was created using SolidWorks, a professional 3D modeling tool (licenses were granted by Clark Atlanta University). This model was used for official schematics and dimensioning, while a modified version was used as the 3D printed shell needed for production of the device.

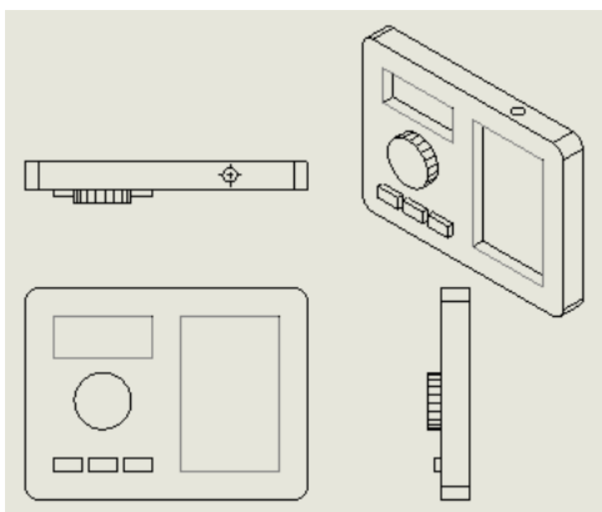


Figure 2: Isometric view of the SolidWorks model

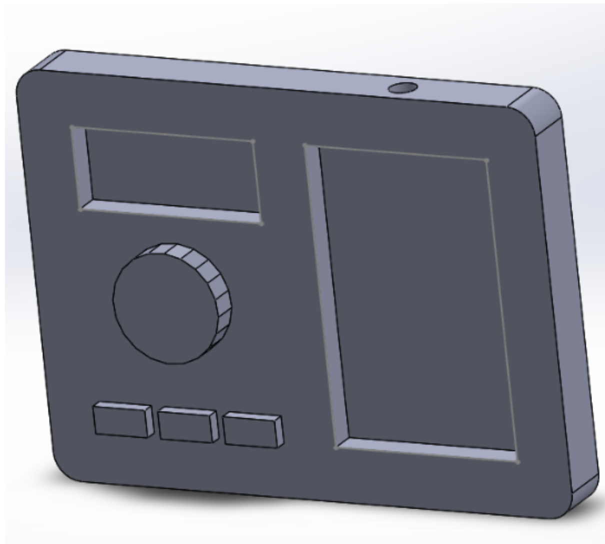


Figure 3: Orthographic views of the SolidWorks model

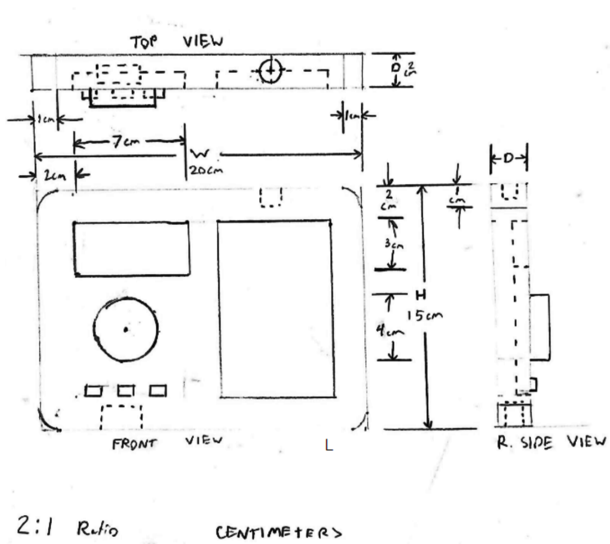


Figure 4: Dimensioned sketch of the device, based on the models above

4.2 Programming

Three applications were created to implement this device, a Python 3 application that the device runs on, a Java/PHP based Android application, and a HTML/PHP based web application. All code was created and customized by the team, and all three application are built around a SQL database hosted on a local XAMPP server for testing.

The Android application was created using Google's own android development software, Android Studio. Along with the java of the app itself, several PHP files were used as connectors from the application to the database, enabling easy modification and retrieval of information. The application was tested directly during development on two devices: a Google Pixel XL and a Google Pixel 3a XL.

The web application was completely developed on the IDE Netbeans, and tested on Google Chrome both on PC and mobile. The front-end (visual) aspect was done with HTML, while the back-end was done with a combination of PHP and JavaScript. The Bootstrap library was used, which allowed easy scaling of different elements. This made sure the website is functional and appealing on all devices and screen sizes.

The application used on the device itself was created using Python 3, along with PHP connectors for database connectivity. This application is to be ran on a Linux environment, which every T/L Controller will run on.

4.3 Prototype

The prototype was created to be as similar to the final product as possible. It uses the same dimensions scaled down, and uses a screen/computer similar to what a proper version would. It uses a Rasbperry Pi 3 B+ and is enclosed in a modified version of the SolidWorks model that can hold the screen and the computer within it. The prototype is made to work locally (Phone, Website, and Device must be on the same internet connection), but all three can connect to and control the database at the same time. The prototype uses completely digital controls and only uses one screen, while the final product would have a few analog controls (dials and buttons) for the secondary temperature only screen.

4.4 Presentation

Along with the device itself, A Virtual Reality representation of the device has also been prepared. It allows a user to walk through a 3d modeled home and control a virtual version of the device to simulate how it would work within an actual household.

5 Results/Discussion

Since the scope of the solution chosen was fairly small/focused, the components needed to create the device were easily purchased/found. Although the Artificial Intelligence has not yet been properly implemented, all of the controls that were desired have been programmed properly and tested. All of the applications would work online if connected to a server, and the applications work on all devices. The production of the T/L Controller has been successful, and with more needed documentation the idea can be patented and manufactured properly

If distributed properly the T/L Controller could be in every household, giving every home incentive to not only switch to Bluetooth lights and a Bluetooth thermostat, but to also make energy efficient choices that can help sustain the Smart City initiative.

5.1 Future Changes

Future iterations of the T/L Controller would improve on what is already implemented (Speed, Responsiveness, Efficiency) as well as add new features.

More smart devices could be controlled by this device in the future, and it is possible the T/L Controller could become a hub for everything in the home, rather than just the lights and temperature. A smaller controller may also be included with future versions so that remote control is possible without a mobile device or computer.

The applications can also include easy to digest statistics about energy usage via visually pleasing graphs and charts, allowing users to see the patterns the device uses to make decisions.

6 Conclusion

The T/L Controller has the potential to not only improve how people live, but also save enough energy to power the future of Smart Cities. It could also cut cost for both renters and homeowners as less energy is being utilized.

This project allowed the team to brainstorm, implement, and finalize a project that included many different topics and skill such as Design Thinking, Software production, 3D Modeling, Designing, and Artificial Intelligence. The steps taken through the Design Process will prepare the students for future engineering endeavors.