Development of Low-Power, Gesture-Controlled LED Matrix

Impacts of Technology on Learning Outcomes in Underprivileged and Rural Areas

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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

In 1986, Hewlett Packard invented light-emitting diode displays. What started as a very rudimentary design with only red LEDs has since become nearly ubiquitous in today's society. They are now found in TVs, monitors, phones, smart watches, and clocks, to name a few. It is also becoming more common for people to make their own displays for decorative use because they can be programmed to display a seemingly infinite number of pleasant-looking patterns. Through a simple Internet search, it is evident that there is no shortage of hobbyists creating their very own LED matrices for personal use (LED Matrix Wave Moves with Hand, n.d.). This could be attributed to the fact that there are a wide variety of easy-to-use microcontrollers (MCUs), such as the Raspberry Pi Pico and Arduino, and LED lights becoming cheaper to manufacture. Most of these hobbyist displays use store-bought LED displays or strips because they are easier to control than a custom matrix with individual LEDs. However, even more hardcore hobbyists have built their own displays using a combination of individual LEDs, MCUs, and printed circuit boards (PCBs) (Nagendra Babu et al., 2019) (Bouazza et al., 2016). The aforementioned displays are an interesting art piece and proof-of-concept, but ultimately have no other real-world applications. My Capstone group believes that there are other applications (not including artistic purposes) for these displays, such as educational purposes.

As technologies such as these become more widespread, it is important to analyze the unintended consequences that they can have on society around them. One example of this is the advent of new technological programs (ie: Google Chromebook programs) being implemented in most K-12 classrooms across the U.S. While these technologies have significantly improved classroom efficiency (to those that can afford them), it is important to remember that some areas may have more access to these costly resources than others. Those school districts that cannot afford these programs will fall behind compared to those that can. The idea that there is a growing gap in learning outcomes between those who do and those who do not have access to this technology is known as the digital divide. I intend to analyze how the inability to use technology in impoverished classrooms can lead to worsened learning outcomes for students and how those learning outcomes can have drastic effects on the surrounding community. I will also propose potential solutions that school districts that suffer from the divide will be able to implement.

Technical Discussion

As mentioned before, thanks to the advent of new technologies, creating an LED display from home has never been more feasible. While this is a great development that allows more people to become interested in Electrical and Computer Engineering (ECE), there are still some limitations and drawbacks that should be addressed. One of the issues is that these displays are costly to operate for several hours of the day because of the power-hungry nature of LEDs. Another issue is that there are no gesture-controlled LED displays that are widely available for interaction. While there are certain developments with dot matrices, such as wireless control and gesture control, their scope is generally extremely limited and lacks important levels of interactiveness (Vogel, 2021) (Nagendra Babu et al., 2019). This project will provide solutions to both of these issues by being low-power and gesture controlled, allowing users to have it on for hours at a time without worrying about how much it will cost to power, and allowing for a fun way to engage with one's decor. Because of these novel considerations, there are several new potential applications for these displays, such as engagement in K-12 settings.

The issue with current LED matrix displays is that they require an exceptionally large amount of power to illuminate several hundred LEDs on the display. This large power draw can make powering them for several hours a day very costly. My capstone project seeks to provide a low-cost, low-power alternative to these LED matrix displays. The most important parameter when trying to mitigate this issue is paying close attention to the current draw on each LED. Since these displays often use hundreds of lights, even a marginal change in the current draw of the LEDs can result in saving power and money (ie: a matrix with LEDs that draws 50 mA of current will have twice the power draw, and twice the cost, of a matrix with LEDs that draws 25 mA). My capstone team centered our project around the use of lights that draw 25 mA of current each, and then identified the parts needed to make these lights functional. While 25 mA does not sound like a lot of current, it is important to consider that there will be 500 LEDs in the project, so in the event that all lights are turned on, the matrix would consume 12.5 A of current. This is far more than a standard wall outlet can provide, and it would certainly blow a fuse. The solution to this is to use LED drivers that can turn each row of LEDs on and off very quickly so that only one row is actually consuming power at any point in time. The drivers will toggle the rows at a rate that is too fast for the human eye to visualize, so there will be no significant visual changes. These drivers will significantly reduce the current consumption to approximately half an amp, a decrease of two orders of magnitude.

In addition to being low-power, the display will also allow the user to change the color of the lights through gesture controls, acting like a “digital canvas.” The idea of using hand tracking software to draw on a computer is not a new concept. There are already “Virtual Drawing Boards” that have been developed, which consist of a laptop camera to sense the user’s hand movements and a Python program to process the data (Telsang et al., 2022). The program then draws the corresponding sketch on the drawing board. This project was not used to drive any LEDs, but it demonstrated the concept of using real-time motion detection to generate a drawing.

There are currently no gesture-controlled LED matrices of this scale (over 500 LEDs) that also seek to minimize power consumption.

The use of sensors to control which LEDs are on and off will introduce a level of intractability not previously seen in similar prior art. As mentioned before, these displays are commonly used for decoration because of the creative designs that can be displayed. Taking both of these ideas into consideration, my group believes that we will be able to engage K-12 students with this project to get them interested in ECE. Teachers are constantly looking for ways to engage their students in the classroom while ensuring that the students are learning meaningful material. This project satisfies both of these requirements because it will be entertaining to draw on and look at, and it will also allow these students to learn more about what ECE means and what real-world applications can look like. The final deliverable of this project includes a pamphlet for the students that gives a diluted overview of how the system works and how the components interact with one another.

STS Discussion

In a world where technology's role in our lives is ever-growing, it is surprising that as of 2020, two-thirds of children from the ages of 3 to 17 did not have internet access at home. UNICEF also says that, globally, 41% of urban children have internet access, but only 25% of rural children have access. One of the takeaways from these facts is that, without the implementation of programs to make internet access more widespread, these percentages will continue to fall. While the US has implemented programs to increase internet access across the nation, such as the Affordable Connectivity Program (ACP), there is still a rising need for technology that is widely accessible to all students. As such, there is a demand for low-cost technologies that can help bridge the expanding digital divide. I will be analyzing how lack of internet access can worsen educational outcomes to rural and impoverished communities.

Technology is constantly being adapted and integrated into the classroom environment. Since the advent of computers, school districts have been eager to find new ways to instruct students and make learning more engaging altogether. Chromebooks are now in over 85% of school districts across the United States (US), as they provide a straightforward way to share assignments, readings, and any software that a teacher may need in their classroom (Pearson, 2019). While these expensive programs have proven to assist classroom learning across the nation, they are widely unavailable to rural and impoverished areas that lack internet access. It has been shown before that digital learning does provide better learning outcomes than traditional learning, which means that if nothing is done, students in these communities will fall behind their counterparts in more urban and developed areas (Lin et al., 2017).

The US spends upwards of $1 Trillion of its federal budget each year on education, given that education provides knowledge and skills that allow students to: become independent and gain financial autonomy (level of education is highly correlated to level of income, with an R^2 of 0.433), among others (Hanson, 2023) (*Income and Education by County*, 2017). Consequently, if there are learning opportunity gaps in areas that lack internet access, the citizens need to be made aware of this so that they can influence local and State government actions to mitigate this gap. Otherwise, these students will be more likely to have to take lower paying jobs, making it harder for them to move out of their community, and making their children more likely to share similar experiences.

As mentioned, one of the large contributing factors to the growing digital divide is poverty level. Nearly 45% of adults with lower incomes do not have Internet access at home

(Vogel, 2021). It unfortunately follows that communities with lower median incomes will have less access to the internet, and therefore worse learning outcomes compared to more affluent communities. This, however, disproportionately affects African American and Hispanic people since these groups have higher levels of poverty (18.8% and 15.7%, respectively) within them compared to Asian American and Caucasian people (both 7.3%). These disparities are, in part, why schools with a majority of African American students are less likely to have classroom level internet access compared to predominantly Caucasian schools (46% compared to 31%) (Creamer, 2020) (Gorski, 2005). These learning outcomes within communities have been researched and proven to be related to higher levels of incarceration: nearly 70% of prison inmates in the U.S. cannot read at the Fourth-grade level (Education Writers Association, 2022).

Evidently, there are lots of negative consequences that are related to the growing digital divide in America. A potential solution to this is for the county-wide education system to survey each school to determine if there is a significant difference between the students' at-school and at-home internet access and can then budget accordingly. This way, there is a dynamic year-by-year reallocation of funds between schools to ensure those that may be falling behind can quickly catch up. Another potential solution would be to have workshops put on by school districts in order to teach parents and students on how to use laptops and surf the internet. As a result, these students will feel more comfortable using the internet, ensuring they do not fall behind other students at the school who feel more comfortable using technology (Tarman, 2003).

This problem is worth investigating because, from an ethical perspective, it is not just for people to live a certain life just because of where they were born, the color of their skin, or their socioeconomic status. The digital divide has, since the dawn of the internet, divided people into "information poor" and "information rich," those who are able to access information through the internet, and those who cannot. During the course of STS 4500, many topics were discussed, but the main idea that brought them all together was ethics and technology. This digital divide is perhaps one of the best ideas of an unintended consequence of technology, and it is about time this consequence is mitigated.

Research Question and Methods

My Capstone group's main focus is to apply novel concepts and ideas to LED matrices, which have existed for quite some time. Specifically, we are going to add the ability to control the individual lights through gestures, as well as making sure the display is low-power. This will be done by trial and error with many tests and simulations so we can verify that the controls are working properly, and the matrix is not consuming an excessive amount of power. To evaluate the gesture controls, we will first make sure that we can turn on each light by itself using MCUs, and we will then incorporate the data from various sensors that can track hand movements to turn on the corresponding LEDs. We also anticipate that using LED drivers to refresh the lights will sufficiently reduce power consumption. To properly verify this we will be closely monitoring the output of our power supplies and making note if it goes above our anticipated threshold.

Due to the nature of my STS Discussion, it will not be feasible to implement any potential solutions in regard to mitigating the effects of the digital divide. Instead, I will be researching previously proposed solutions and investigating them. Specifically, is there any data that can back these previous solutions, analyzing the effects of these solutions if similar programs have been implemented in other countries already, and whether or not the solution seems feasible. With these various rigorous questions, the unfeasible solutions can be disposed of and perhaps a feasible and novel idea can be proposed to help.

Conclusion

By the culmination of this semester, my Capstone group will have successfully built a gesture-controlled LED matrix that allows users to draw on it by using their fingers through the use of sensors. One of the final deliverables for this project will include a pamphlet that can be used to instruct K-12 students more about ECE, and get them more interested in Science, Technology, Engineering, and Mathematics (STEM) classes. We believe this is feasible because the matrix will be enjoyable to interact with and will show students the "fun" side of engineering. My STS final deliverable will include detailed outlines of how the U.S. can reduce the effects of the digital divide through county-wide programs. This will in turn allow equal learning opportunities for all students, regardless of race or socioeconomic status.

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