## **Purdue ECE Senior Design Semester Report**

## **(Team Section)**

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| **Course Number and Title** | ECE 477 *Digital Systems Senior Design Project* |
| **Semester / Year** | Fall / 2019 |
| **Advisors** | Prof. Thottethodi, Todd Wild |
| **Team Number** | 1 |
| **Project Title** | IntelliFace |

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| Senior Design Students – Team Composition | | | |
| Name | **Major** | **Area(s) of Expertise Utilized in Project** | **Expected Graduation Date** |
| Rtvik Sriram Bharadwaj | CmpE | Software, PCB, Assembly, Hardware | Dec 2019 |
| Ishaan Ahuja | CmpE | Hardware, PCB | Dec 2019 |
| Pratyaksh Sharma | CmpE | Software | Dec 2019 |
| Abhay Sasidharan | CmpE | Hardware, Soldering | May 2020 |

**Project Description:** Provide a brief (2-3 page) technical description of the design project, as outlined below:

1. Provide a general description of the product to be delivered by this design project.

The Intelligent Interface (IntelliFace) is a digitally enhanced mirror interface that serves to help its users to get a jump start on their day. In addition to its base function as a dressing mirror, the user can interact with the mirror using a gesture sensor and a face identification system built-in to unlock the device and display useful data including the headlines, their emails, the day’s weather, the room temperature, stocks to watch in the NYSE, and a motivational quote to start the day off on the right note.

1. What is the purpose of this product? For whom is it intended?

The product is meant for indoor use in a home with individuals that seek to get essential tasks out of the way before getting ready to leave for the day. While the device is best suited for usage by families due to its personalization and security using a facial recognition module, any individuals that care to get a boost to their startup regimen can find a place in their home for the IntelliFace.

1. Describe how the engineering design process used to create your product was utilized in this project. Include how you were able to develop and conduct appropriate experiments, analyze and interpret data, and use engineering judgment to draw conclusions related to the development of your product.

At its inception, the team separated the project’s tasks into hardware, software, and design components and assigned one person to each, and one to manage tasks, provide support as necessary, rotating roles when necessary. Hardware calibration was an arduous task, with mandated rigorous testing of individual parts, handling power requirements, data transmission, heat dissipation amongst other tasks, each tested individually before integration and final testing. After conducting tests on several parts, we settled on the TCRT5000 IR Emitter/Receiver module for gesture detection, a PDV-P8104 LDR for ambient light detection, and a TMP36 Temperature Sensor to handle these tasks, along with various other components including DC Barrel Power, the LD1117AV33 Linear Power Regulator, and an array of capacitances and resistors. Software was written and tested iteratively, with each iteration building upon the success of a previous feature all backed by version control and continuous testing in different environments. Completing the packaging involved testing material integrity, before settling upon a material and design, many of which were stress tested by hand.We arrived at these methods from our internship experiences at various companies handling hardware and software based products.

1. Describe the design constraints, and resulting specifications, incorporated into your product (list a minimum of 3).

One of the design constraints we had to take into account was making the product water resistant, as vapor droplets that come into contact with the display surface could render the product an electrical hazard. We used waterproof wood glue and gypsum to seal the cracks to prevent water from entering.

To ensure that the design was affordable, we used recycled wood sourced from mass retailers that made the assembly affordable, as well as opting for a cheaper mirror with sharp edges that we polished to make safe. By building and running the neural network on the Jetson, we also shaved off costs that are associated with using a cloud based neural network.

Running a multi-person facial recognition neural network was required to ensure that unauthorized access was necessary, and required a lightweight Keras CNN based upon the Inception ResNet Model developed by Google AI. This not only isolated the product from the issues that come with cloud based recognition, but also guards the security of the users.

1. Describe how each of the following factors influenced your design specifications and constraints.

**Health, Safety, Safety, and Welfare:** It is critical that the safety of the user is kept intact and to achieve this, the product does not feature any sharp edges and fire hazards with an on-board power regulator to handle surges. The production of the system has also been rigorously tested for safety violations, and to that end, higher quality PCB vendors and recycled wood and glass suppliers that follow EPA Emission Regulations and DOL Labor statutes have been chosen to supply parts.

**Global:** The product currently only supports English, as the team currently operates only in the United States and is the most commonly spoken language globally, and stock market data covering NYSE as it is the most prominent, and news spanning sources that are American, European and South-East Asian. Future iterations of the product can easily be changed over the air to support the preferences of global audiences using appropriate language choices for each region, as well as allowing for more personalization.

**Cultural:** During the fragmentation of our requests network, we were careful to exclude news sources which have had a history of misinformation and offensive content that serve to denigrate other people and display a lack of cultural sensitivity.

**Social:** While researching production and distribution requirements, we discovered that certain countries like Singapore and Brunei feature more stringent safety standards than the U.S DOL currently lists, as well as emission requirements. Also in consideration were ongoing and expected trade wars, trade embargos between the United States (product assembly) and India, China (part production).

**Environmental:** Some of the environmental considerations we took into account were acid runoffs from PCB etching, wood recycling costs and its effects, minimizing plastic usage and maximizing recyclable materials, and simple disassembly for easy disposal.

**Economic:** To compete with other similar Enhanced Digital Mirror Interfaces, it was of utmost importance that the product be more affordable than its counterparts. Hence, we opted to use smaller PCBs which cost less to manufacture, the NVIDIA Jetson Nano as opposed to the more powerful and expensive Jetson TX2 to drive the user interface, and sturdy but affordable materials.

1. Describe the appropriate engineering standards incorporated into the creation of your product.

The Engineering Standards in place in our product are the IEEE 1224.1-1993 for handling distributed systems with multiple asynchronous requests, the IEEE 12207-2017 standard for product lifecycle management, the IEEE C37.240-2014 Standard on Cybersecurity Practices for control systems.

1. Describe the final status of your product.

The final prototype has been completed, with an white antique wood paneled mirror front with plywood side covers. The mirror performs all IR gesture reads, and accurately reflects the temperature and light conditions in the room and adjusts accordingly. The Face Recognition Module is also complete, currently identifying the team members and a few beta testers.

1. Describe the makeup of your project team and how you were organized to establish goals, plan tasks, and meet the objectives of this project.

The team settled on the AGILE Methodology to delegate tasks and responsibility of completion, and had weekly sync-up meetings in person to report progress and decide on next steps and logistics. Whenever a team member required help, two team members will finish up on it to get back on schedule. We aimed for a Week 14 Completion, and planned ahead and left a week spare for PCB errors if it was needed.

1. Did your project require the production of any written documentation other than this document (i.e., manuals, educational materials, etc.)? If so, describe the types, composition, and nature of the audiences for whom these materials were intended.

The product required a User Manual that detailed every feature of the product, as well as usage methods and debugging methods to root out any errors if they appear, while addressing possible nits that the user may have.

1. Describe the types, composition, and nature of the audiences in attendance for the final oral design review. Discuss how you prepared for this audience.

The Final Design Review audience members will comprise of the course staff and other teams enrolled in the course reviewing our team, and we intend to omit details and instead present the full picture, and the overall architecture as the audience is all of an ECE Background and is expected to understand the function without going over every single component.

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| **Name** | **Major** | **Area(s) of Expertise Utilized in Project** | **Expected Graduation Date** |
| Rtvik Sriram Bharadwaj | CmpE | Software, Hardware, PCB, Assembly | December 2019 |

**Individual Reflection:** Provide a brief (1-2 page) individual reflection of the design project, as outlined below:

1. Describe your personal contributions to the project.

I co-wrote peripheral reader on the STM32, the STM32-Jetson USART, and the IR gesture parser. I completed the PCB for the Primary Board, and contributed to the mirror dashboard. I also completed a large segment of the software integration scripts, as well as Jetson Jetpack Kernel changes to shut down all modules until the wake request from the STM32 arrives. I have also managed the team’s finances, ordering components, submitting expense reports, delegating tasks, and the physical construction of the product including woodworking and assembly.

1. Describe how your contributions to this project built on the knowledge and skills you acquired in earlier course work.

The knowledge gained from ECE 255 and ECE 202 were peripheral to completing the PCB layouts and schematics, as well as working out power requirements for the project. The work covered in ECE 364 and ECE 463, especially with the Python and C HTTP requests library were essential to handling the networking aspects of the project. Software segments of the project involved handling threads and accessing objects without causing any locks, and knowledge of mutexes, spinlocks and deadlocks from ECE 30862 were pivotal to ensuring that this worked seamlessly.

1. Describe how you acquired and applied new knowledge as needed to contribute to this project. What learning strategies did you employ to do so?

Most concepts were well documented on online forums such as StackOverflow and publicly available lecture slides covering each topic. Detailed information on operating systems, namely the NVIDIA Jetpack OS, was available on the NVIDIA Developers Site as well as various other support forums, and I reverse-engineered the changes that needed to be made. Most other nits were recurring issues in the networking aspect of the project, and known issues with the NVIDIA Jetson Nano (of which there are plenty). Concepts on the STM32 which were foreign to me required a good read of the concerned areas in the STM32 Family Reference Manual and the Architecture Manual. Tkinter dashboarding required significantly more work, mostly gleaned from online tK documentation, PyPi Manuals, and open-source development logs. EAGLE PCB Design was learned by rigorous tutorials from YouTube and ECE 477 recommended resources, as well as practice and iterating often and as necessary using the feedback provided by the course staff.

1. Discuss your ethical and professional responsibilities as they relate to this engineering design experience.

It is an ethical requirement to minimize power consumption and material wastage where possible, and while this device is meant to be run all the time, it was important to minimize its footprint. We have achieved this by modifying the heavy NVIDIA Jetpack OS to support only the tasks necessary for us, shutting off any peripherals we have deemed unnecessary, by only using recycled wood for the physical construction, and opting for a PCB vendor of higher cost and quality which guarantees that labor practices in use are compliant with the American Department of Labor standards. It is also our responsibility to provide the user with an absolutely secure user experience as the interface features multiple compromisable device and to ensure security, we have opted for standard AES-256 encryption with HMAC on all transactions, and an in-situ only internal system access. For safety, the product also acts as a passive temperature alert system, notifying the user of temperature abnormalities and responding to webhook requests for information of data including temperature, humidity, and news.

1. Consider what the impact of the product of this engineering design experience could have in economic, environmental, societal, and global contexts. Discuss how you would make (or did make) an informed judgement as to your product’s impact in each of these four contexts?

The module has been built to be easily recyclable with a long lifespan before discard, and with over-the-air updates, it can easily function as an exercise mirror, similar to many that are becoming popular in the market. With a significant growing market share for home-based exercise appliances, the system, if scaled sufficiently, can grow rapidly. Some of these companies include MIRROR and Peloton, together boasting a combined market cap of nearly USD 10 billion. With an extremely high priority placed on environmental and safety standards, the mirror is comprised entirely of easily disposable materials that can be recycled easily, and have been prepared in conditions that are compliant with rigorous testing by the EPA and DOL. Economically, the product is extremely competitive compared to its nearest competitor MIRROR, which has a base price of US$1495 with a monthly subscription, while ours is planned to retail at less than US$500, with a production cost of only US$350. The idea of a digitally enhanced mirror serves to increase the productivity of individuals by augmenting a simple daily routine, getting ready in front of a mirror, with relevant information needed to start the day, and with improvements, the mirror can do much more than that.

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| **Name** | **Major** | **Area(s) of Expertise Utilized in Project** | **Expected Graduation Date** |
| Ishaan Ahuja | CmpE | Hardware, PCB | December 2019 |

**Individual Reflection:** Provide a brief (1-2 page) individual reflection of the design project, as outlined below:

1. Describe your personal contributions to the project.

## I was mainly responsible for the hardware side of the project namely programming the STM32F0 since my role was that of the Hardware Engineer. I programmed the STM32F0 to read all the peripherals connected to it namely the temperature, LDR, and IR sensors. I used the ADC channels to read all the components data and used the datasheets for the components to decode the values in °C, volts, and cm. I also helped Abhay write the UART communication since he was having some trouble with it. I was also responsible for completing the Eagle schematic and layout for the sensor board. This was all done during the first 3/4th of the semester. For the remaining time, I decided to help every team member with whatever they were doing, if they needed help, namely helping out with woodworking and packaging and getting the gesture recognition to work properly.

1. Describe how your contributions to this project built on the knowledge and skills you acquired in earlier course work.

## Since my 4 years here at Purdue ECE, I have learnt a lot about hardware and software engineering. The course that I took previously which was the most help to me in this project was ECE 36200. ECE 36200 gave me a very strong foundation and understanding of how the embedded system works from the inside and how all the peripherals work like I2C, UART, SPI, PWM, ADC, and DAC to name a few. Since I was responsible for programming the STM32F0 Microcontroller, the knowledge gained in ECE 36200 had a direct impact on how I would approach programming a microcontroller that I have never used before. Hence, I had to use all the knowledge and skills that I had learnt in ECE 36200 in this project.

1. Describe how you acquired and applied new knowledge as needed to contribute to this project. What learning strategies did you employ to do so?

## There were a lot of new things I had to learn to do during the course of this project like learning how to make Eagle schematics and layout properly, soldering, sawing, and woodworking. The main learning strategy I use is basically this: If someone can help you, great, otherwise Youtube to the rescue. For the Eagle schematics and layout, I learnt it from Youtube since no one in our team had ever dealt with PCB software before. I learnt all about traces, wires, layers and other stuff in the software. I was responsible for making the schematic and layout for the sensor board so this knowledge had a huge impact on that. For soldering, I learnt it from Rtvik, and Abhay since both of them knew how to solder but I also had to take help from Youtube for new things which no one knew how to do like drag soldering for instance. Even though I eventually did not get very good at it, I was able to solder one component onto the sensor board namely the temperature sensor. For the sawing and woodworking, I used Youtube to learn how to do it. I helped Rtvik to saw some wood required for packaging.

1. Discuss your ethical and professional responsibilities as they relate to this engineering design experience.

## My main ethical responsibilities were basically that to not look at the code for other smart mirrors out there for reference if we got stuck somewhere because then your mind starts to think like the other person and then your code would likely end up looking similar to theirs which would be considered plagiarism. Also, the other ethical responsibility was to make sure that we are not making software which is easily hackable. Since we are using the camera and the device is connected to the internet, we need to make sure that no pictures are taken and sent to some server for illicit use other than the ones we are sending to a Slack channel for communication between user and IntelliFace. The main professional responsibility was to make sure that the product is user-friendly and safe for use at all times.

1. Consider what the impact of the product of this engineering design experience could have in economic, environmental, societal, and global contexts. Discuss how you would make (or did make) an informed judgement as to your product’s impact in each of these four contexts?

## Economic: Our product was made in $350 while our biggest rivals price for the smart mirror is $1495. This is a huge difference as with just 10% profit we could sell this product at $385 which is very cheap compared to our rivals product. Environmental: Our product was made with recyclable things except for the PCB’s and hence is almost fully recyclable. It is also made very durable so it would take a long time to wear-off. Societal: Everyone in our society needs a smart mirror so they can easily check up on important things in the morning like emails, stock prices, and other stuff. Global: Since our product is made in a very cost efficient manner and is very cheap considering the rival, almost everyone could afford it and it would change the way people look at mirrors forever.

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| Pratyaksh Sharma | Cmp E | Software | Dec 2019 |

**Individual Reflection:** Provide a brief (1-2 page) individual reflection of the design project, as outlined below:

1. Describe your personal contributions to the project.

## Being primarily responsible for the Dash and UI part of IntelliFace, I played a key role in making sure that the product works as desired. I designed the whole layout for the UI design which involved coming up with an effective interactive GUI that would also communicate with different APIs to display the necessary updated data on the Dash when a known user is identified after the facial recognition log in. This process also involved the software integration and testing which played a crucial role to ensure that the product is holistic and error free.

1. Describe how your contributions to this project built on the knowledge and skills you acquired in earlier course work.

## The programming experience I gained at Purdue has helped me a lot for this class. Two classes explicitly, ECE 364 and ECE 29595 helped me a lot for this project. I gained GUI experience first in ECE 364 when we worked with Qt Designer and PyQt to design a finite state machine GUI. Both of these courses also made me proficient in Python which helped me a lot while coding the GUI for IntelliFace (also in Python). Above all, the prior coursework helped me to think systematically and cover all the edge cases while designing a system which I believe is extremely essential when designing a full end to end product.

1. Describe how you acquired and applied new knowledge as needed to contribute to this project. What learning strategies did you employ to do so?

## We decided to go ahead and work with the Tkinter library in Python for the UI and Dash design. This was a completely new library and none of the team members had any prior experience with the same. Thus, being primarily responsible for the UI, I decided to familiarize myself with this new library. I had to read up the online doc page for Tkinter and play around with it. This helped me to become comfortable with the different features of Tkinter (label, frames, padding, buttons, etc). Once I was confident, I designed the layout for the Dash and began with the coding. There was a lot of learning involved as I was coding the UI too and this was the primary technique I used whenever I had to work with a new library. I also familiarized myself with new libraries in Python which I had to use as the system became more complex and holistic.

1. Discuss your ethical and professional responsibilities as they relate to this engineering design experience.

## Designing a full end to end product professionally involves a lot of testing. Any product will need to handle the external conditions and any other edge cases that might be thrown at it. Thus, while designing the smart mirror, we tried to add the facial recognition functionality only for the members of the team as this would sort of give this product a restricted and secure access. This is an extremely important component of carefully designed software/hardware products and is an ethical and professional responsibility of the team designing the same. Also, while working with the auxiliary functionality which we added recently, we planned to use a safe messaging service to deliver the picture taken by the camera to a restricted “Slack” channel. All these features need to be integrated and tested carefully before the product can be launched into the market.

1. Consider what the impact of the product of this engineering design experience could have in economic, environmental, societal, and global contexts. Discuss how you would make (or did make) an informed judgement as to your product’s impact in each of these four contexts?

## Economically speaking, IntelliFace is cheaper compared to other similar products in the market which can have a price of upto 1000$. IntelliFace could be sold for roughly half the price which gives it an edge over its competitors. This can also make IntelliFace a product that will be installed in almost all smart homes in the future and this will make it a daily product. The packaging used for IntelliFace is also very simple which will make it a product that is easy to recycle or replace if it encounters any issues. Also, displaying news, stocks, weather and other smart data on the mirror keeps the intended user connected with the outside world globally. In this way, IntelliFace covers the economic, environment, societal and global contexts as asked in the question..

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| **Name** | **Major** | **Area(s) of Expertise Utilized in Project** | **Expected Graduation Date** |
| Abhay Sasidharan | CmpE | Hardware, soldering | May 2020 |

**Individual Reflection:** Provide a brief (1-2 page) individual reflection of the design project, as outlined below:

1. Describe your personal contributions to the project.

## Over the course of this semester, I have personally contributed to the project in a variety of areas. Upon the commencement of this undertaking, it was my responsibility to get the USART communication working. This is so that the microcontroller can communicate with the Jetson Nano. Subsequently, I worked on PCB assembly. This entailed ensuring that the parts were soldered on properly, performing conductivity tests, certifying that the parts were not damaged, etc. Later in the semester, I dabbled with the software side of things in order to recognize whether the gesture being detected by the sensor was a long gesture or a short gesture. At the last stage, I worked on the physical build and packaging of the mirror, which involved a certain amount of woodworking.

1. Describe how your contributions to this project built on the knowledge and skills you acquired in earlier course work.

## While designing and building IntelliFace, I was able to bring together the numerous pieces of knowledge and skills that I acquired throughout my undergraduate degree. For instance, making the Jetson and microcontroller communicate via USART put ECE 362 (Microprocessor Systems and Interfacing) knowledge to work. While helping with the PCB design, I had discussions with Todd about the current being sunk by different devices, selecting the appropriate resistor values to manage the operating voltage of devices, etc. This allowed me to implement ECE 201 (Linear Circuit Analysis) knowledge. Finally, I was able to use the knowledge that I acquired in Python programming from ECE 364 (Software Engineering Tools Laboratory) for the software side of things and for detecting long/short gestures.

1. Describe how you acquired and applied new knowledge as needed to contribute to this project. What learning strategies did you employ to do so?

## Most of the knowledge that I acquired from the project involved an interactive learning approach. I was able to gain extensively from interacting with my teammates, the course staff and people in other teams. There are several things that I simply learned on the fly by observing the methods used by other people. Moreover, I used a hands-on learning approach, which involved plenty of trial and error. For example, I learned the instructions on how to solder the parts onto the PCB from the course staff, but it took 4 failed attempts to finally get the main board right.

1. Discuss your ethical and professional responsibilities as they relate to this engineering design experience.

## This engineering design experience requires understanding the scope and limitations of the project. It is paramount that user-experience is given utmost priority. It is also important to lay out the operating conditions and to plan out how to respond to potential design failures. Furthermore, it does not suffice that the device is user-friendly and engaging; it is also important that the product is safe to use. Another responsibility that is taken during this engineering design experience relates to user-privacy. It needs to be guaranteed that the camera data that is used for facial recognition is not used with malicious intent.

1. Consider what the impact of the product of this engineering design experience could have in economic, environmental, societal, and global contexts. Discuss how you would make (or did make) an informed judgement as to your product’s impact in each of these four contexts?

## Projects similar to IntelliFace are currently present in the market and the concept of a smart mirror seems to have significant demand. Hence, in economic contexts, it seems that honing the product of this engineering design experience can yield benefits to a variety of consumers. This impact can also be recognized with regard to societal and global contexts. It is evident that IoT concepts are being used throughout the world and with developments like 5G, several simple household items can be augmented. Compared to other products on the market, the production of IntelliFace is inexpensive. However, it still provides a reasonable amount of functionality for users who want to make their household devices smart, but cannot afford high-end products. From an environmental standpoint, it is clear that the power consumption of the devices that we are using are minimal. In addition, the material that is used to build IntelliFace are either recyclable or biodegradable.