My-Flection

Members: Ramzi Hamdalla, Wonho Kang, Jeremy Ryu, and Yun Lee

Department of Electrical and Computer Engineering, Carnegie Mellon University

Abstract—**My-Flection is a smart mirror aiming to help students increase their productivity by helping them start their morning on the right foot through outfit recommendations. We aim to provide a smooth and efficient experience for the user by analyzing their torso and recommending an appropriate outfit based on what they are wearing. By analyzing the color of the clothing, the current weather and availability of clothing in the user's wardrobe, the user can interact with our smart mirror using an app to receive an appropriate outfit recommendation smoothly and quickly.**

***Index Terms* — Nvidia Jeston Xavier NX, OpenPose, Arducam, OpenCV**

I. Introduction

College students struggle with many challenges everyday. From the numerous assignments and job search struggles to meeting with friends and going to parties, there are many tasks that keep college students constantly busy. Knowing this we want to help students be more productive by helping them get prepared for their day in the morning. The morning is one of the busiest times of the day and there often are times when people are rushing to leave home to get to class or a meeting. We want to address this challenge by helping students choose their outfits in the morning. People who especially struggle with choosing the "right outfit" for themselves will benefit most from this system as it allows them to smoothly get ready in the morning and help make decisions.

We plan to achieve this by creating a smart mirror that analyzes what the user is wearing on top and recommends appropriate pieces of clothing that go with the top. The user stands in front of the mirror wearing a certain color top and the smart mirror will analyze the torso and detect the top color. Based on the weather, available clothing in the user's wardrobe, and a standard outfit color palette, the smart mirror will recommend an outfit that fits their current clothing.

We accomplish this by implementing computer vision technology to do the analysis and using a user-driven database to provide a more personalized user experience. These two major pieces of technologies will allow the user to comfortably and quickly choose an outfit to their liking.

An example of technology similar to this would be the LG ThinQ Fit mirror, which fits clothing to you by analyzing the body dimensions. Although this technology seemed innovative and was presented at CES 2020, it does not necessarily help with the productivity of the user and moreover makes them feel uncomfortable by measuring body part dimensions. What we aim to do with our smart mirror is the opposite of this as we want to allow the experience to be user-centered so that they feel the most comfortable and efficient when using our product.

II. Use-Case Requirements

Our use-case requirements are driven by providing our users with the most smooth and comfortable experience. We plan to achieve this by focusing on areas the user would be affected the most when interacting with our device. To prioritize a smooth and enjoyable experience, our requirements focus on convenience, time efficiency, and accuracy of the device. We also identified potential areas where our user's experience may suffer in order to decide which metrics are needed to guarantee an enjoyable experience. As a result, our use case requirements are mainly divided into four primary areas which include app response time, outfit recommendation time, detection accuracies, and storage capacity. Each area is essential in creating a smooth experience for the user.

Requirement	Predicted Value
Database Latency	< 200 ms
Database Input Time	< 1s
Outfit Recommendation	< 5s
Torso Detection Accuracy	> 99%
Color Detection Accuracy	100% (Within range)

Table 1. Use-case requirements

Table 1 is a chart of use-case requirements. We believe it is important to create an application that will promptly respond to the user so that they can have a comfortable experience. The quantitative requirements we set for this area are the database latency at under 200ms and the database input time at under 1s. These are all reasonable delays that occur when using the mirror as delay times on most applications strictly fall under a second not to lose the user's attention and patience.

The second area we focus on is outfit recommendation time. We want the entire process of the outfit recommendation to take less than 5 seconds. This metric was chosen as we thought 5 seconds would be the upper limit for maintaining someone's attention as they are waiting.

Thirdly, in terms of detection accuracy, we wanted to set specific requirements for torso detection and color detection. First, we want torso detection accuracy to be above 99%. The reason behind this is that our entire project is centered around the device being able to detect the user's torso and analyze the piece of clothing. For color detection, we aim for a success rate of around 100%, as even though we understand that there may be some variables in lighting that can change color shades and present issues with color detection, we have implemented an LED system to normalize the lighting, and hope to be able to consistently give the user accurate results.

III. Architecture and Principle of Operation

A. Physical System

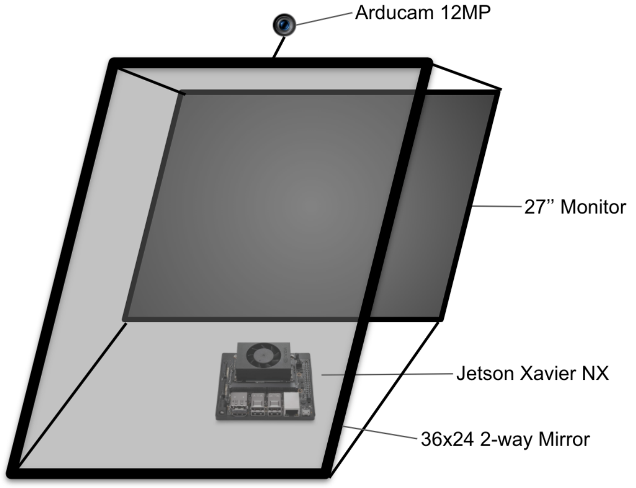


Fig. 1.System drawing of an overall physical system

The diagram of the physical system sketch which entails all hardware components of the project is illustrated in Figure 1, and Figure 2 is how our project turned out in the end. As demonstrated in the diagram, an Arducam will be placed on top of the two-way mirror along with a monitor, and a Jetson Xavier NX placed behind the mirror. Arducam will take a snapshot of a user standing in front of the mirror. The image will be sent to Jetson which is in charge of necessary computations including analyzing the user's torso and top color with relevant software. The analysis results will be fed to the outfit recommendation algorithm which will output recommendations based on a wardrobe database stored in an cloud database and real-time weather information collected from the internet. As a final step, the outfit recommendation will be displayed through the monitor that the user can view.

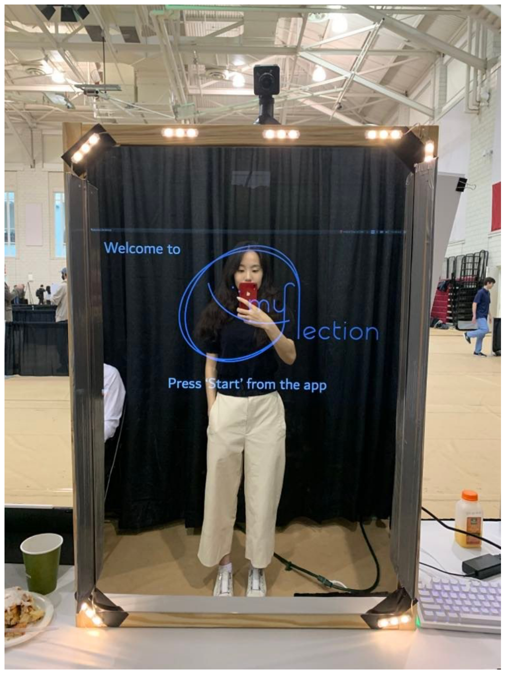


Fig 2. Completed smart mirror

The Arducam 12MP and Jetson Xavier NX are off the shell from the ECE inventory, and a 27-inch monitor and 36x24 2-way mirror have been purchased. The size of the mirror reflects the expected size of the final product. The monitor has been chosen to be smaller than the mirror but big enough for the user to easily view the recommendation display.

B. Block Diagram - System Architecture

The block diagram in Figure 3 demonstrates the overall system architecture. The project is done mainly in software, and system architecture can be divided into three parts: user interface, computer board, and internet. The user interface is composed of a camera, application, and monitor, which will communicate with the computer board through physical wire connection, wifi connection, and physical wire connection, respectively. While the camera only takes inputs from the user, the monitor outputs display results, and the application will both input and output basic signals and wardrobe information.

The application is used as a general controller of the entire system, which has the most interactions with the user. The main features of the application include 1) turning the mirror on and off, and 2) adding and deleting items of the user's wardrobe. Additionally, there are lighting controls on the side of the frame of the mirror. When adding items to the user wardrobe, users will take a picture of the item and fill in types of clothing(e.g. shorts, jeans, t-shirt, long sleeve shirt) through the itemization form. Then, the app will transmit the picture

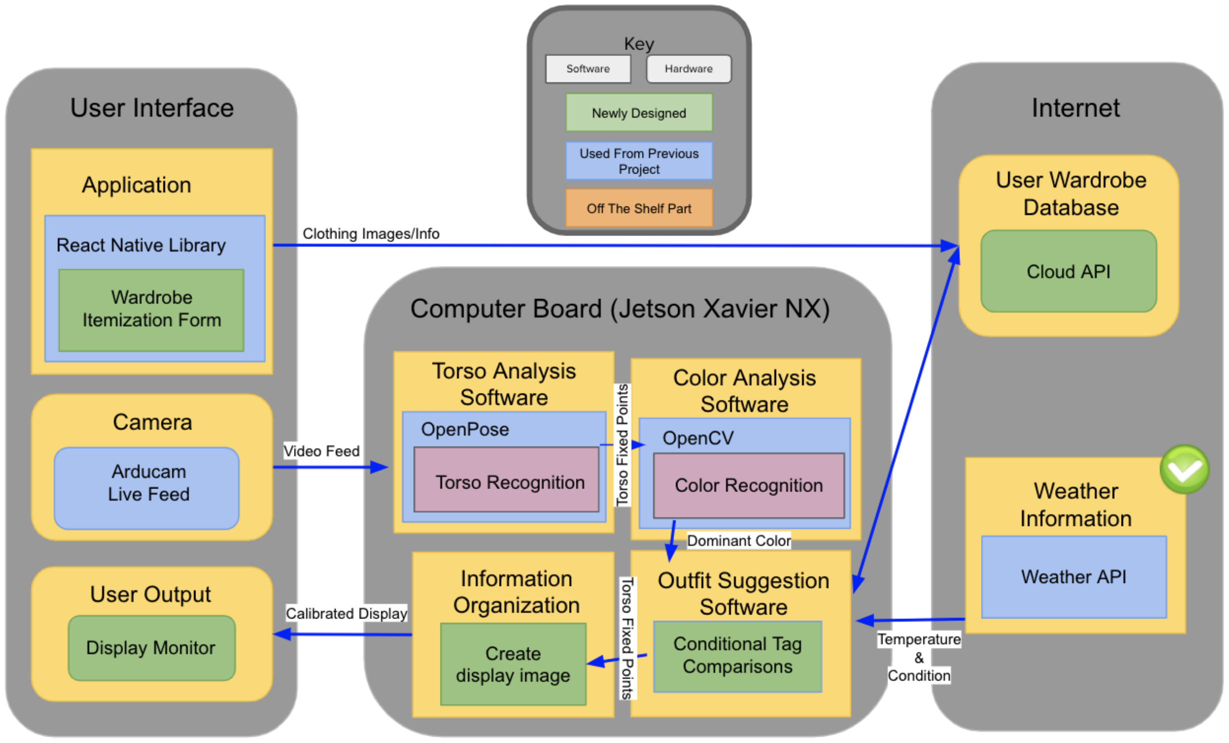


Fig. 3. Overall system block diagram

and form to Jetson, which will detect the item color and put the item data into the user wardrobe database in CV format. Users can delete items from their wardrobe when the items are unavailable and they can also weigh items differently based on their preferences using the application as well.

With the wardrobe database created, users can get outfit recommendations by turning on the mirror and standing in front of it for the mirror to recognize what the user is currently wearing as their top. Based on the user inputs, the camera image, and the wardrobe, Jetson 1) organizes the user wardrobe database, 2) analyzes torso, 3) analyzes top color, 4) collects real-time weather information, 5) recommends outfits, and 6) creates a monitor display for the recommendation.

As mentioned above, the user wardrobe database will be in CV format containing item color, type, availability, and preference weight. Torso and color analysis will be done through open-source APIs OpenPose and OpenCV, respectively. The real-time weather information will be collected through the internet from weatherapi.com which provides weather forecasts based on geolocation information. With the user top color data, weather information, and the user wardrobe, the outfit recommendation algorithm will generate a set of applicable outfits reflecting the weather and user preferences. The basics of the algorithm will be color coordinating charts that provide aesthetic color pairs for outfits. The charts will be organized in CV format grouping colors that match with one another and stored in an SD card.

A set of outfit recommendations will then be displayed to the monitor. During this process, Jetson will pull out corresponding clothing images and information stored in the database. These will be calibrated and modified suitable for the display. The user can get through the recommendations and pick a recommendation or part of a recommendation that they enjoy to wear for the day.

IV. Design Requirements

The use case requirements, as demonstrated in Table 1, can be categorized into three main components: speed, accuracy, and storage capacity.

A. Speed

Speed will all be tested as a timestamp upon a start of an initial process subtracted to a timestamp upon completion of the final process

- Database latency: The metrics will be measured for the retrieval of data from the database in a cloud based spreadsheet with data stored in CV format for outfit recommendation and monitor display image calibration. The following equation will be used:

  (timestamp upon a successful data retrieval response) - (timestamp time upon data retrieval request)

- Database input: The metrics will be measured for modifying the CV format wardrobe database stored in a cloud database. Database input speed will be measured for adding and deleting a piece of clothing from the database. The following equation will be used:

(timestamp upon a successful modification of data reflected in the database) - (timestamp for database input request)

- Outfit recommendation: The metrics will be measured for the entire period of the outfit recommendations from starting torso detection to outputting recommendation results to the monitor. The equation is as follow:

(timestamp of recommendation results display) - (timestamp for torso detection start)

B. Accuracy

- Torso detection: The metrics will measure the capability of identifying the user torso standing in front of the mirror in a stable position within a distance range of 1m~2m, assuming the proper lighting. It will use mAP(mean average precision in percentage) for object detection. The equation is as follow:

$$mAP(\%) = \frac{True\ Positive}{True\ Positive + False\ Positive} \cdot 100$$

- Color detection: The metrics will measure the capability of identifying RGB values of a piece of outfit for user top detection and adding an item to the wardrobe. Assuming the use of the same LED lighting environment, the RGB value of a dominant color of a piece of clothing will be measured. The equation is as follow:

$$Color\ accuracy\ for\ a\ value = \left(1 - \frac{actual - detected}{actual}\right)$$
$$Color\ detection\ accuracy(\%) = \frac{1}{3} \cdot (R\ accuracy + G\ accuracy + B\ accuracy) \cdot 100$$

V. Design Trade Studies

Design tradeoffs were considered for most of our hardware components of our smart mirror and the user interface. Most of our choices, if not all, were driven by our use-case and the use-case requirements.

A. Computation Hardware - Jetson Xavier NX

The most important aspect of our project is to provide a fulfilling and smooth user experience with our smart mirror. In order to achieve this, it is crucial that the single-board computer we use is able to process live video feeds efficiently. The two options we were considering were the Jetson series and the Raspberry Pi. The Jetson series, specifically the Jetson Nano and Jetson Xavier NX, were designed for AI/ML applications because of their incredible GPU capabilities that significantly outperform the Raspberry Pi. However, the price tag attached to the Jetsons were on the pricier end in comparison to the Raspberry Pi. On the other hand, the Raspberry Pi has been around for a longer time than the Jetson Nano and Xavier which could potentially benefit us more in terms of better documentation and demo projects. After weighing the tradeoffs between using the Jetson Nano/Xavier vs. Raspberry Pi, it was apparent that using the Jetson Xavier would be the best design choice. One of the stretch goals of our project is to apply AI/ML models to our smart mirror which would allow it to analyze, recognize, and learn user's outfits without the need to create key tags in the wardrobe database. Also, our torso detection software, OpenPose, requires NVIDIA GPU compatibility for a smooth experience. Therefore, the NVIDIA Jetson Xavier NX would be the best choice for achieving all our use-case and design requirements.

B. Communication - Wifi

Though the Jetson Xavier NX may boast its incredible computation capabilities, our project will be ineffective if the method of communication to and from the single-board computer is buggy. There were three main options we took under consideration when deciding upon a method of communication between the components of our project and the Jetson Xavier NX: bluetooth, wifi, and wires. The option of using wires was crossed out early because although it is the easiest to set up, our project places a huge emphasis on user experience, so the potential trouble of dealing with messy wires behind or around the smart mirror is highly undesirable. As shown in the block diagram in Section III. Architecture, there are several components of our project that require communication with the Jetson Xavier. Most importantly, the National Weather Service API exists on the Internet which can only be accessed via a wifi compatible chip on the computer board. Another thing to note is that bluetooth is only effective at close distances. If a user were to have a separate wardrobe in another room and the mirror in his/her bedroom, then it would be an annoyance to bring all the clothes to the bedroom and then take photos of them to upload to the database. Therefore, using a wifi chip would significantly decrease this trouble as wifi allows for communication over large distances. Finally, we realized that setting up bluetooth or wifi communication would not be difficult for either as the Jetson Xavier NX we received from the 18-500 inventory already had a WIFI/BT card that came with it.

C. *User Interaction - Mobile App*

Three alternatives were discussed when working on our design choices for how the user would interact with the smart mirror. This interaction includes turning on and off the mirror, controlling the LED lighting around the mirror, and inputting the user's wardrobe into the database. Initially, we wanted our smart mirror to be touch-compatible. This seemed like the most intuitive choice as "smart" in "smart-mirror" indicates the presence of a touch screen. However, this idea was quickly scrapped when we realized that buying an IR sensor for the entire smart mirror display was too expensive and unnecessary as the user wouldn't need to touch all parts of the smart mirror and swiping motions on the screen were not a part of our user interaction. Understanding that the smart mirror would only need touch compatibility on specific points on the display, we then considered adding capacitive touch sensors to these specific parts of the smart mirror display. However, this would add more wires and circuitry to the smart mirror that may end up becoming a mess. Furthermore, having the user constantly walk up to the mirror, touch the mirror screen, and then walk back into the camera's field of view would be far too inconvenient and defeats the main goal of our smart mirror's smooth user experience. Therefore, after weighing out all these tradeoffs, it made the most sense to create a very simple mobile app that would allow the user to perform all interactions with the mirror in one collective place. This app would allow the user to turn on and off the mirror as well as control the LED lighting at any distance which prevents the issue of having to walk back and forth to and away from the mirror. Better yet, inputting the user's wardrobe through an app is the simplest method. The user takes a photo on his/her phone, uploads the photos to the app, and the app sends this data to the backend database via API calls. For our final demo, we also added a feature where upon pressing a button on our app, the outfit recommendation process would automatically begin. This feature is a crucial component of our product because it ensures that the user would be able to stand still in front of the mirror, click a button on his/her mobile phone, and get an outfit recommendation without needing to do any other work.

D. *Database - Wardrobe Itemization Form*

Two possibilities were brought up when our team was discussing how exactly the computer would obtain the correct outfit from the wardrobe database and what information the database would contain. Our team's initial approach was to implement or use existing image analysis algorithms/models that would analyze the pictures of the clothing that the user inputted and match it with the outfit recommendation output. One potential problem with this design approach is that it requires even more computation which would increase the time it takes for the user to receive an outfit recommendation output on the smart mirror display. We found that this increase in output time would be more undesirable in comparison to the user spending a little more time when inputting his/her clothes into the database. With this in mind, our team decided to place our efforts on creating a wardrobe itemization form that the user would essentially fill out. This form would prompt the user to provide information about the type of the clothing, the color, the season, and a photo of the piece of clothing. Hence, when the outfit recommendation says it wants, for example, a black shirt, then it would query the database by applying the filters, for example, color = black and type = shirt. This entirely gets rid of the hassle when it comes to heavy computations and the error-prone nature of solely analyzing the picture of the clothing. This wardrobe itemization form is a Google Spreadsheet that exists in our team's capstone Google folder. We decided to use Google sheets because the Restful API for sending POST and GET requests was relatively simple and had solid documentation.

E. *Database - Media Library*

Besides the wardrobe itemization form, the user is responsible for uploading photos to our database. There were no solutions online that allowed us to input the raw image data into the Google spreadsheet cell, so some design tradeoffs were made here as well. Our first solution was to create a local database that would exist on the server side, such as a localhost, and use existing React Native libraries that would be able to store raw images or image data. One potential disadvantage of this approach that we quickly discovered was that the server would have to be running on our Jetson as well as downloading image files from the request body that would be sent from the client side. This would significantly increase computational costs. Therefore, we decided to use a free cloud service called Cloudinary that supports an API which the user can use to upload photos to a media library and receive as a response the image url for the uploaded image. This image url was then inputted into the database.

F. *OpenCV - C++*

OpenCV is used to analyze the snapshot of the user's torso in real-time. It is already well-known that OpenCV is compatible with the Jetson Xavier NX, so the only choice we had to make was what language we would use to implement the image processing and analysis. Our team was more familiar with Python, so we initially decided to stick to a language that we were more comfortable and familiar with. However, after receiving feedback from our proposal presentation, we realized that there could be a severe bottleneck that would obstruct our use-case requirements if we used an interpreted language (Python) over a compiled language like C++. C++ is well-known to be very fast and is used as the primary language in most trading firms due to its speed. Therefore, we decided to use a C++ implementation over a Python one because it is much more important to reduce the risk of long computation times as this would worsen the user's experience.

G. Camera - Arducam

The option of choosing a camera that would provide a live video feed for torso analysis was dependent on whether we valued exceptional quality or ease of setup. The former would have been a professional photography camera. The reason we chose to go with the Arducam is because it was already in the 18-500 inventory and its quality was good enough for image processing and analysis. Also, as mentioned earlier, it is relatively easier to set up with the Jetson Xavier NX.

H. Torso Detection - OpenPose

No trade offs were considered for the torso detection software we would use. The reason for this is because previous projects in past semesters had used OpenPose for torso detection and it proved to be very successful with high detection accuracy. Moreover, it accomplishes our design requirements of being able to recognize and analyze fixed points on a user's torso which allows for smoother and well-rounded testing as well.

I. Color Detection - OpenCV/ Matplot Library

No trade offs were considered for color detection. We originally considered our original design of using an open-source API called ColorThief. This API turned out to be not compatible with our system in the integration process so we ended up using an OpenCV library and sk-learning software module that would help us determine the dominant color of an image. This algorithm was found to be extremely accurate as well as having similar runtime as the ColorThief API that we had previously planned on using thus it did not affect the overall runtime of the outfit recommendation.

VI. System Implementation

Software Specifications

A. OpenPose

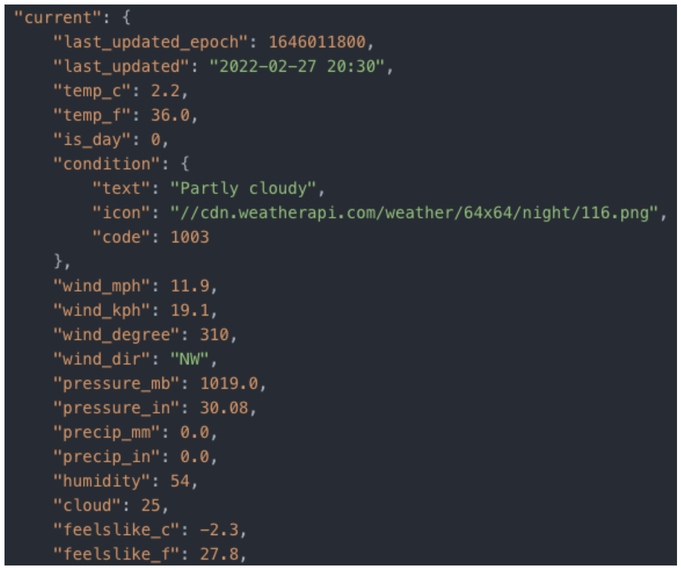
OpenPose is a real-time multi-person system to jointly detect human body, hand, facial, and foot keypoints (in total 135 keypoints) on single images. The main feature of OpenPose our project uses is its ability to take in a webcam as an input and a basic image with keypoint displays as a PNG output. This can be achieved either through the command-line demo provided in the repository or using the API. We will connect the software to our hardware (Jetson Xavier NX) and use Linux for our OS to run the API.

B. OpenCV / Matplot Color Detection

We had to pivot from our original idea of using the Color Thief API for dominant color detection due to compatibility issues that were brought up during the integration process. We ended up using an OpenCV / Matplot library that uses the k-means algorithm to determine the dominant color of an image. It uses k-means clustering to extract the colors of the pixel clusters from the flattened image. This algorithm was found as an open source online and proved to be accurate and fast when we tested it.

C. WeatherAPI.com

We plan to use the current live weather condition as well as the temperature to differentiate between an outfit recommendation of short pants vs. long pants and later on shirt vs. jacket. We want to receive live, correct data on what the current weather conditions are like in the user's current location. WeatherAPI.com is a powerful fully managed free weather and geolocation API provider that provides extensive APIs that range from the real time and weather forecast, historical weather, Air Quality Data, IP lookup, and astronomy through to sports, time zone, and geolocation. We have created a unique API key that will be used to make GET requests. An example of a response body is shown in Figure 4. We will extract the temperature, precipitation, and condition fields in the response body.



```
"current": {
    "last_updated_epoch": 1646011800,
    "last_updated": "2022-02-27 20:30",
    "temp_c": 2.2,
    "temp_f": 36.0,
    "is_day": 0,
    "condition": {
        "text": "Partly cloudy",
        "icon": "//cdn.weatherapi.com/weather/64x64/night/116.png",
        "code": 1003
    },
    "wind_mph": 11.9,
    "wind_kph": 19.1,
    "wind_degree": 310,
    "wind_dir": "NW",
    "pressure_mb": 1019.0,
    "pressure_in": 30.08,
    "precip_mm": 0.0,
    "precip_in": 0.0,
    "humidity": 54,
    "cloud": 25,
    "feelslike_c": -2.3,
    "feelslike_f": 27.8,
```

Fig. 4. Part of response body with HTTP request http://api.weatherapi.com/v1/current.json?key=68227f9c42464760a68131452 22802&q=15213&aqi=yes

D. *Mobile Application*

We used React Native to create our mobile application that allows the user to interact with the smart mirror. The mobile application has four screens: home screen (inputting tags), choose/upload photo screen, choose formality screen, and start outfit recommendation screen. The mobile application was built with Expo Go which was also very efficient for testing purposes. There was a Node backend server running in the background of the Jetson as a background process and was responsible for being the middleware when it came to running the local automation script file. The app also sends posts requests to the Google Sheets API for the tags and image url and the Cloudinary API for the actual photo file. Screenshots of the app are shown below. The leftmost image shows the user inputting tags based on options in a dropdown menu. The middle image shows the screen after a user has chosen a photo in his/her gallery thereafter pressing upload photo. The rightmost image shows the button the user should press when attempting to start the outfit recommendation process.

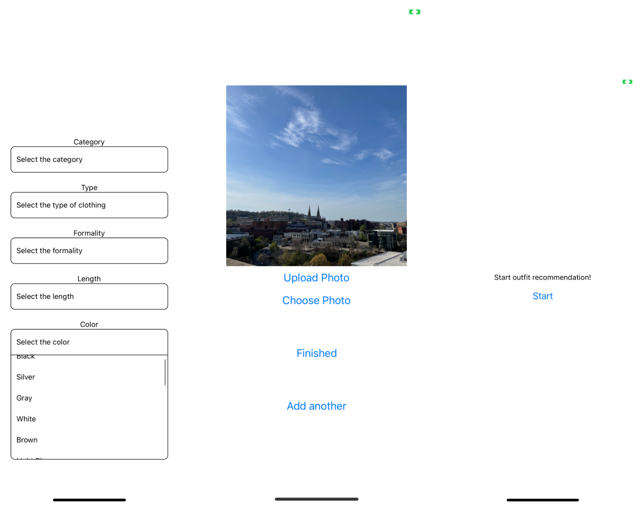


Fig. 5. Application User Wardrobe Input Form

Hardware Specifications

E. *NVIDIA Jetson Xavier NX*

As mentioned in our design requirements and design tradeoffs, we are using the NVIDIA Jetson Xavier NX as our single board computer that will handle all the processing power necessary for live video capture from our Arducam which will then be fed into OpenPose as well as computation of outfit recommendations. The 16GB NVIDIA Jetson Xavier NX module we have has a 384-core NVIDIA Volta™ GPU with 48 Tensor Cores, 6-core NVIDIA Carmel ARM®v8.2 64-bit CPU, 6 GB 128-bit LPDDR4x, and a WIFI/Bluetooth chip.

F. *Arducam B0250*

We are using the Arcudam B0250 for the smart mirror camera that will take in a live video feed of the user standing in front of the mirror. This video feed will be used for analysis with OpenPose. The frame rate of the camera is 1920×1080 @ 60fps 4032×3040 @ 30fps. Resolution is 4056(H) x 3040(V) 12.3MP. A field of view (FOV) of 65° (H). The camera comes with a customized metal enclosure, a tripod stand, and a set extension adapter for the Jetson Xaver NX.

G. *Two-way mirror*

We are using a two-way mirror for our smart mirror because it allows for a monitor to be placed behind the mirror and show a display to the user at the same time the user is checking himself/herself in the mirror. The mirror is 36 x 24 inches.

H. *Monitor Display*

Behind the mirror is a monitor display that will show the outfit recommendation photo to the user. This monitor is an HD monitor with dimensions of 8.33 x 20.05 x 24.41 inches. It weighs 11.49 pounds and has a resolution of 1920 x 1080. The dimensions of the monitor were specifically chosen so that it would have the same width as the mirror. This allows for the monitor to cover more than the top half of the mirror.

VII. Test, Verification and Validation

We have the following metrics that we wish to test and track as design specifications for our project:

- Database Latency
- Database Input Time
- Torso Detection
- Color Detection
- Outfit Recommendation Time

Our design specifications were picked with the users comfort and experience in mind. Ideally we want to improve all of these metrics to a point where we believe the user will be reasonably satisfied.

We have similar reasoning for testing our detection design specifications, as well as similar tests. Additionally, we have similar reasoning for testing various time metrics, and similar tests for how to track and record the time it takes for those various design specifications, resulting in repetitively similar tests. Most of our detection system tests include inputting varied inputs into our algorithms, and manually sorting the successful tests from the failed tests. Our timed tests will mostly rely on using computer code to get accurate and precise results that we can use for definitive results.

A. *Tests for Database Latency*

This test shows the time it takes for the mirror to receive a response after clicking the button "Start outfit recommendation" which would run the automation script. The test trials show an average of around 3.33s.

Trial #	**Time Taken**
1	3.2s
2	3.6s
3	2.9s
4	3.0s
5	3.5s
6	3.9s
7	3.3s
8	3.4s
9	3.3s
10	3.2s

Table 2. Latency

B. *Tests for Database Input Time*

These values show the time taken for a request to be sent along with a response back to the client when uploading tags and photos. This averages to around 1.1366s for uploading tags to Google Sheets and 1.1669s for uploading photos to Cloudinary.

Trial #	**Time Taken**
1	1.794s
2	0.997s
3	1.037s
4	1.574s
5	0.881s
6	1.04s
7	1.159s
8	1.186s
9	0.868s
10	0.830s

Table 3. Latency for tags uploads

Trial #	**Time Taken**
1	1.424s
2	1.502s
3	1.027s
4	0.735s
5	1.173s
6	0.881s
7	1.598s
8	1.373s
9	1.085s
10	0.871s

Table 4. Latency for image uploads

C. *Tests for Torso Detection*

These values show the accuracy of our trials when testing the ability to spot the user's torso 10 times in an environment with a solid background without people and with controlled lighting.

Trial #	Accuracy
1	100%
2	100%
3	100%
4	100%
5	100%
6	100%
7	100%
8	100%
9	100%
10	100%

Table 5. Torso Detection Trial Accuracy

D. Tests for Color Detection

These values show the accuracy of our trials when testing the ability to decipher the user's color in an environment with a solid background without people and with controlled lighting.

Trial #	Accuracy
1	100%
2	100%
3	100%
4	100%
5	100%
6	100%
7	100%
8	100%
9	100%
10	100%

Table 6. Color Detection Trial Accuracy

E. Tests for Outfit Recommendation Time

This shows the recorded time it took for images to appear on the mirror from the moment the start button was pressed on the client application over 10 trials.

Trial #	Time Taken
1	10.857s
2	12.988s
3	11.098s
4	9.735s
5	10.643s
6	9.881s
7	10.624s
8	9.512s
9	10.520s
10	11.085s

Table 7. Outfit Recommendation Trial Times

VIII. Project Management

A. Schedule

As shown in Figure 6 in the appendix, we have provided a fully detailed planned schedule split by days and weeks, with the team responsibilities and our various plans organized at the bottom of the figure.

B. Team Member Responsibilities

As a team, we have divided responsibilities depending on the specialties of each member. Jeremey is specialized in software, and as such his main responsibilities include configuring our outfit analysis algorithms, our color analysis algorithms, and our torso analysis algorithms.

Ramzi is specialized more in hardware, as such his main responsibilities will consist of configuring the hardware implementation of the smart mirror, and the user interface.

Wonho is specialized in software with additional experience in hardware, and his main responsibilities will consist of working on the user interface and the hardware implementation, as well as the outfit analysis, and combining these differing aspects of the project.

Yun is also specialized in software, and as such her main responsibilities additionally include configuring our outfit analysis algorithms, our color analysis algorithms, and our torso analysis algorithms.

C. Bill of Materials and Budget

Our Bill of Materials is stated below in the appendix in Table 2.

D. Risk Management

Many of the challenges that were presented to us throughout the course of this project were tied with compatibility issues. First and foremost, the early stages of our project were difficult in that all of us were unfamiliar with the Linux OS that came with the Jetson Xavier NX and the learning curve was steep. Setting up OpenPose and OpenCV to work on the Jetson system was also challenging as there were many errors linked with the installation of different libraries and packages. At one point, we mitigated these issues by resorting to our plan B alternatives which were using trt-pose instead of OpenPose and switching out our Arducam to ensure hardware compatibility. Fortunately enough, we were able to get OpenPose running with the Arducam after long sessions of debugging and re-mounting the Jetson Xavier.

Another challenge that posed potential risks was integrating the app with the mirror. React Native doesn't allow bash scripts or commands to be run directly on the client side as it supposedly results in security issues. We successfully mitigated this potential risk by creating a middleman server with localhost that would listen on port 3000 for any GET requests and if so, then it itself runs the local automation.sh script. The button click on our app sends this GET request to the localhost server.

The mirror UI we built initially was built using Electron. However, we ran into a huge problem where Electron would not build on the Jetson. We had two alternative approaches to resolving this problem. First, we tried building Electron so it could be used as a webapp instead of a built distribution. This ended up conflicting with the Jetson's environment again so we ended up using a very simple mirror GUI using Python tkinter. This alternative was a lot easier to debug and present because the outfit recommendation script was in Python so all we had to do was add a bit of code to render a display using tkinter within the same file.

IX. Ethical Issues

There can be a few ethical concerns with our project which can be divided into three big categories: camera, user wardrobe, and the nature of outfit recommendations. There are security concerns due to the use of a camera when detecting the user's torso and analyzing top colors. The camera is always powered on, connected to the Jetson, and the Jetson hosts a local server available for the mobile app. These connections of camera-Jetson and Jetson-localhost can cause potential security issues. However, we are not too concerned about it as all connections and activities are done locally within the Jetson. Although the camera is always powered on, it cannot operate without running a specific command line, and the local server runs within the Jetson as well. Unless the Jetson gets hijacked from external sources, which we believe to be unlikely and out of our control, there is no significant risk to security.

Besides the use of a camera, processing the user's wardrobe can cause security issues as well. Due to compatibility issues with the react-native mobile app, which is a controller for the user wardrobes, we had no choice but to use the internet connection to upload the user wardrobe information and clothing pictures. The wardrobe information and clothing pictures are stored in cloud-based platforms—Google Spreadsheet and Cloudinary, respectively. As these platforms are running on their servers, not locally, but we load user personal information on them, this may cause security issues. We decided to use these platforms as we trust their security protocols; however, if their servers get hijacked, our user information may be at risk as well.

In terms of the nature of outfit recommendations, the purpose of our project is to assist users with fast and convenient outfit recommendations so that they can dress according to the weather and popular color schemes. However, these standards can hinder users' tastes and individuality. Although we tried to have extensive combinations of color schemes, some users' characters may not be reflected in the standards we provide. On top of that, because we provide "top combinations", if the user wants to dress up otherwise, it may make them doubt their choices and hinder their individuality. Providing a "widely-conceived" best outfit may benefit the majority of users, but it is also important to respect the user's tastes and characters. To improve this issue, if we are given future opportunities to enhance our project, we would like to add more procedures that can assist with reflecting user individuality in outfit recommendations.

X. Related Work

Our project was initially inspired by DIY smart mirrors that are made using Raspberry Pis. However, they only displayed simple information such as weather and your daily schedule and did not have much new content showing on the screen. Also, these types of smart mirrors do not do that much computing within the mirror itself or actively interact with the user. There are other smart mirrors such as the LG ThinQ smart mirror that tailors the outfit to your body as well as the ECE capstone project from spring 2021 that presents a smart mirror that warps the clothing to fit the user. However, there is no smart mirror on the market that necessarily gives outfit recommendations based on what you are currently wearing.

The biggest difference between common DIY smart mirrors and our project is the interaction between the user and mirror as well as the computing process that goes in the mirror. Our goal is to allow the user to easily and efficiently access this process information, in the form of outfit recommendations, and provide the smoothest experience for the user.

XI. Summary

Our smart mirror is a device aimed at improving the mornings of college students, who often lack the time or mental power to make careful decisions about their outfit in the early morning. By absorbing the user's wardrobe, and analyzing a little data on what they want to wear for the day, we can provide them with a full recommendation on how to complete their outfit in little to no time at all.

Although it may be slightly pricey, the mirror has a huge impact on how the student starts their morning, and helps them stay fashionable without needing to divert attention away from their studies and how they are spending their time.

We struggled with many challenges during the creation of our smart mirror. Primarily among them, we struggled to put together a mirror UI that was simple and satisfying for the user. Additionally, we struggled with providing a low recommendation time due to the large amount of algorithmically complex information we had to compute to analyze what the user was currently wearing. As a result we struggled to make some of our use-case requirements that we had set out for ourselves as we worked on our project.

Additionally, our project was heavily constrained by the time constraints placed on each of us individually, and as a group, as we keep up with regular presentations, and external factors. This meant that we didn't have the time to include a lot of features that we had originally envisioned as part of the smart mirror.

Despite all of these factors, we believe we were able to provide a viable smart mirror that displayed our concept properly, and satisfied many of its users as we demod it with its functionality as a quality of life, time saving home improvement for your average college student.

We learned a lot about how to utilize other modules in order to quickly and efficiently implement the features we desire in the way we envision them, and we all learned a lot about how to manage time so that we can work productively as a team to put together the parts and pieces of our project.

Looking back, if there was something we could have done differently, we would have looked into the mirror UI much earlier, as well as having paid more attention to the compatibility of certain modules and hardware components. These were both issues that came up later in the project, and that cost us a lot of time to figure out how to deal with the barriers they represented when trying to get our mirror to work smoothly.

We have several ideas for possible future works that would improve upon our mirror. The first idea we have is to implement functionality with the mirror so that it can also analyze the user's legs to provide the user with recommendations. Our mirror currently provides its recommendations purely off of the user's torso, but we believe that adding this function would be a great addition for users who may already have bottom in mind, but want a top as a recommendation instead. Additionally, we believe that expanding our mirror to be able to provide recommendations for accessories, such as suit pieces, hats, umbrellas, and etc., would be beneficial to the user.

We also hoped that we may be able to simplify the input form for the user's wardrobe. By providing a system that can analyze the user's clothes just from a picture, we hope that our users will be able to more conveniently input their wardrobe to our database. Lastly, we thought that it would be nice to create a system that rates how much the user likes certain clothing, and improves the recommendations it provides over time. By implementing a user rating system for the clothing, or by using an algorithm that pays attention to multiple users to find trends and improves its sense of fashion over time, we believe that we could make better recommendations to the user.

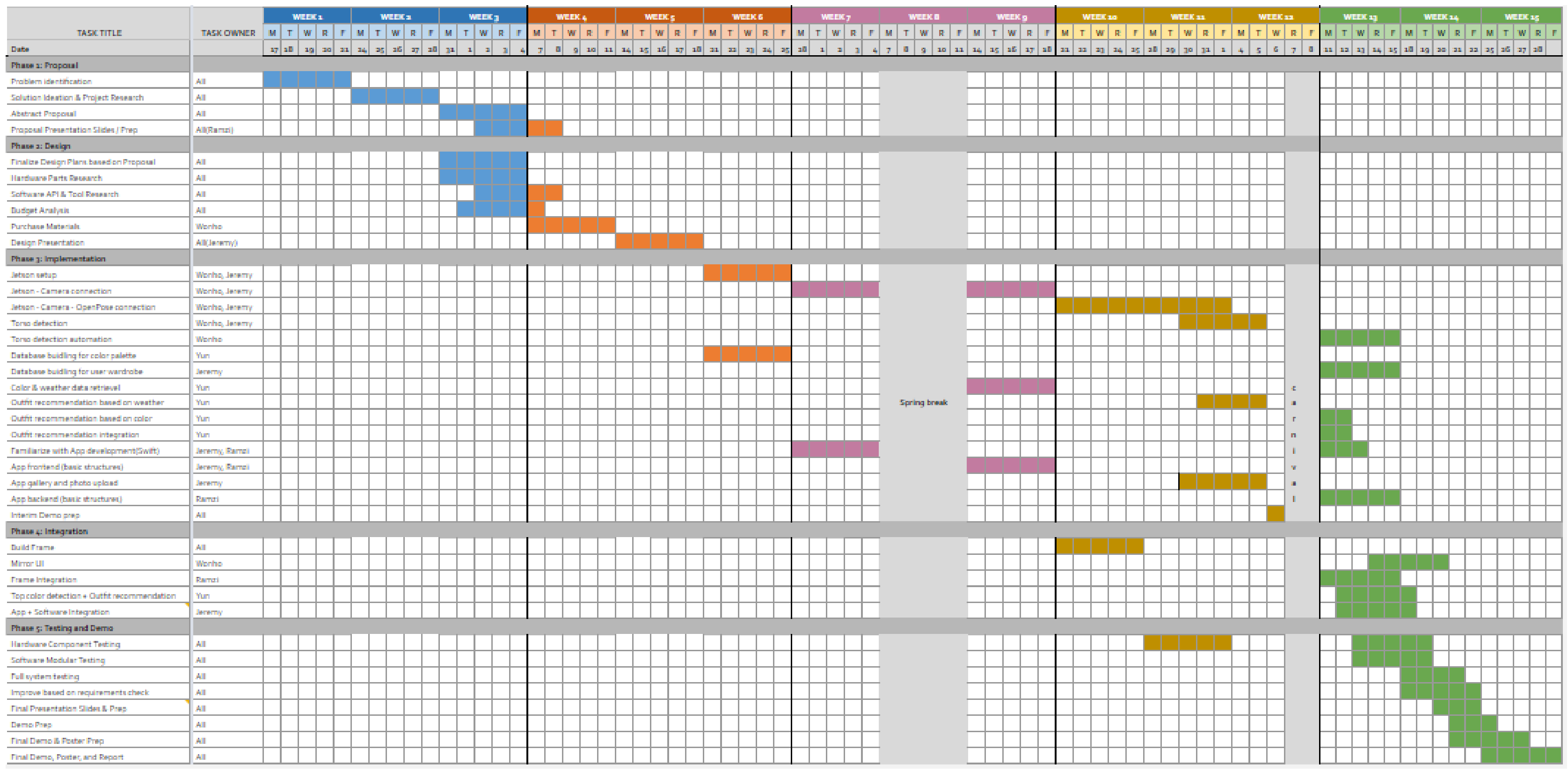
Glossary of Acronyms

LED - Light Emitting Diode
UI - User Interface

References

[1] CNET, *CNET: David Priest*, Accessed on Mar 3, 2022, [Online]. Available: https://www.cnet.com/home/smart-home/smart-mirrors-just-make-you-hate-yourself/
[2] https://cmu-perceptual-computing-lab.github.io/openpose/web/html/doc/index.html
[3] https://lokeshdhakar.com/projects/color-thief/
[4] https://www.weatherapi.com/

Appendix



TASK TITLE	TASK OWNER
Date	
Phase 1: Proposal	
Problem identification	All
Solution Ideation & Project Research	All
Abstract Proposal	All
Proposal Presentation Slides / Prep	All(Ramzi)
Phase 2: Design	
Finalize Design Plans based on Proposal	All
Hardware Parts Research	All
Software API & Tool Research	All
Budget Analysis	All
Purchase Materials	Wonho
Design Presentation	All(Jeremy)
Phase 3: Implementation	
Jetson setup	Wonho, Jeremy
Jetson - Camera connection	Wonho, Jeremy
Jetson - Camera - OpenPose connection	Wonho, Jeremy
Torso detection	Wonho, Jeremy
Torso detection automation	Wonho
Database buidling for color palette	Yun
Database buidling for user wardrobe	Jeremy
Color & weather data retrieval	Yun
Outfit recommendation based on weather	Yun
Outfit recommendation based on color	Yun
Outfit recommendation integration	Yun
Familiarize with App development(Swift)	Jeremy, Ramzi
App frontend (basic structures)	Jeremy, Ramzi
App gallery and photo upload	Jeremy
App backend (basic structures)	Ramzi
Interim Demo prep	All
Phase 4: Integration	
Build Frame	All
Mirror UI	Wonho
Frame Integration	Ramzi
Top color detection + Outfit recommendation	Yun
App + Software Integration	Jeremy
Phase 5: Testing and Demo	
Hardware Component Testing	All
Software Modular Testing	All
Full system testing	All
Improve based on requirements check	All
Final Presentation Slides & Prep	All
Demo Prep	All
Final Demo & Poster Prep	All
Final Demo, Poster, and Report	All

Fig. 6. Schedule with milestones and team responsibilities

Item	Manufacturer	Model Number	Source	Cost
Nvidia Jetson Xavier nx			ECE Inventory	$0
Arducam B0250			ECE Inventory	$0
36x24 Two-Way Mirror	SPEEDYORDERS		Amazon	$192
27-inch HP Monitor	Hewlett Packard	M27ha	Amazon	$174.08
16 GB micro-SD card	Sandisk	SDSQUAR-016G-GN6MA	Amazon	$8.83
2 2"x10"x8' Wooden Planks	Home Depot		Home Depot	$47.54
Logitech C270 HD Webcam	Logitech		Amazon	$17.99
SELFILA Led Vanity Mirror Lights Kit	selfia		Amazon	$15.99

Table 7. Bill of Materials and Budget

Budget	$600
Total Costs	$456
Available Budget	$144

Table 8. Costs and Budget Available