

This is an example of a fairly good, well written report. It is not perfect, but can be used to show you the basic expectations.
This document may not include all of the necessary content. Please refer to the assignment for full details of what is expected from you.

Homework 1: Needs Assessment & Problem Formulation

ECE 2799

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1. Introduction

Our objective is to design a smart home device that utilizes Internet-of-Things (IoT) to improve interactions between the customer and the product through enhanced usability and pleasure. We decided to create a smart mirror that makes mornings a little less hectic. A smart mirror displays information on the mirror that users can use to preview their day, make sure they brush their teeth long enough, and more handy features. Specifically, users can get all their critical morning information such as weather, traffic, commute time, and news headlines.

We did market research to see if this was a product that could easily integrate into the rapidly growing smart device market. We not only looked into the smart device market, but also the mirror market to see if a core part of our product still had a sizeable audience. Additional research needed to be done to determine customer requirements. We sent out surveys to the general public to gauge product preferences.

Product requirements were determined based on customer requirements, cost of production, and overall feasibility. Through discussion, we found a middle ground where we believed the customer, the distributor, and the engineers would be happy. Product specification was determined based on our product requirements. We knew which major parts would be needed to successfully build our smart mirror.

We believe our product has market appeal because it provides accessibility and pleasure to an item almost everyone uses daily. The smart mirror can be a great addition to minimizing the crazy notification filled lives of a user's morning. It can blend seamlessly into a daily routine by utilizing simple user interactions with the mirror. A quick glance while brushing teeth or fixing hair reduces clicks on phones saving time and increasing users' focus and productivity.

2. Market Research

Every product needs a market in order for it to have a chance of succeeding. Often times, the market may already be saturated with other very similar products. We had to determine which market our smart mirror would fit into and whether or not our product could differentiate itself from the competition.

Our first step in determining our market was to see if other smart mirrors were already being sold to consumers. From there, we were able to figure out which features were common across multiple products as well as a general price range. Along with searching for purchasable products, we also looked for DIY smart mirrors to see if there were additional designs and features other users created.

The next step we took in conducting market research was to find statistics on the two major components of our product - mirrors and smart home devices. We looked for statistics including revenue, growth, and user base. A growing market often means new products can be

introduced with success so it was vital for us to determine if creating a smart mirror would be viable.

Searching for smart mirrors online produces few results of currently purchasable smart mirrors. Finding specific details on product specifications and features was much more challenging than expected. Evervue was one of the only companies that delivered a product similar to the one we had in mind. Their smart mirror is called the QAIO Mirror and the cheapest model starts at \$999. Figure 1 shows their Single Sink Mirror model (“QAIO Single Sink,” n.d). Evervue offered a few features that were uncommon such as two TV screens built into the mirror as well as built in light bars that span the height of the mirror on either edge. The QAIO Mirror also featured a touchscreen as well as a wireless keyboard and remote. Philips showcased a smart mirror that connected to their toothbrush and shaver but other features were hard to find. Panasonic even showcased a smart mirror style product in 2016 that was never announced or released.



Figure 1. QAIO Single Sink Mirror

Features that were common among DIY projects and the QAIO mirror were speakers and microphones as well as some version of voice control. It was easier to find DIY smart mirror projects than it was to find products that could be bought or brought to market soon.

We were able to find many market statistics on Statista relating to smart home devices. The market definition of the smart home segment *Control and Connectivity* is “essential equipment (connected and remote-control devices) and services that are part of an intelligent home network” (“Control and Connectivity,” n.d). Products which are included in this category

are smart speakers such as Google Home as well as central control and communication units. Programmable control buttons and smart plugs for the control of non-smart devices are also included in this category. The smart mirror fits this segment of the smart home market closest. Additionally, the smart mirror can be categorized as an integrated smart home device. An integrated smart home device is a control and connectivity device that has connections to at least one other smart home segment. For example, a smart speaker on its own is a stand-alone smart home device while a smart speaker that also allows users to connect to and interact with security cameras is an integrated smart home device. With either Amazon Alexa integration or Google Home integration, the smart mirror would be able to access features in other segments.

We looked into revenue, number of households with smart home devices, penetration rate, and user base for Smart Home devices in the *Control and Connectivity* segment. The statistics we are looking at are for the United States and specifically for integrated smart home devices. The forecasted revenue in 2018 alone is US\$4567m and it is expected to nearly double by 2022. Though revenue is steadily increasing, the revenue growth percentage is expected to drop from 24.7% in 2018 to 14.7% by 2022. The number of households which have smart home devices is expected to increase from 26.5 million in 2018 to 55.7 million homes by 2022. The penetration rate shows the percentage of smart home households in relation to all private households in our select market. By 2022, it is expected that 42.8% of all private households in this select market will be smart home households. Medium income and high income users are the most common. User data comes from Statista's Global Consumer Survey. All the statistics mentioned above are from Statista ("Control and Connectivity," n.d).

We looked into the other major component of our product, the mirror. From Statista ("Furniture Today," n.d), we found a statistic that shows the share of American households by the type of wall art purchased in 2016. While mirrors were not the highest in terms of share of households that purchased them, 27% of American households still purchased mirror(s) in 2016.

We determined that there was still room in the market for a smart mirror. The revenue for smart home devices is expected to continue increased in each and the number of smart homes is expected to keep increasing. Due to these two statistics, we believe customers are still looking to purchase smart home devices in the Control and Connectivity segment. We believe that the revenue growth rate is decreasing since single smart home devices are increasing the tasks that it can do. We think that less devices are purchased per household but more households are looking to become a smart home. Furthermore, over a quarter of American households purchased mirrors in 2016 which is a large demographic that may be interested in a smart mirror.

As mentioned above, the base smart mirror cost can be very high. The smart mirror market is willing to bear very steep prices and we believe that we can gain market presence if we can produce a similar smart mirror at a lower cost. Since a majority of smart home device users are medium to high income users, we believe that the high prices of smart mirrors doesn't impact us greatly. We can enter into smart mirror market, by aiming to create a quality product that is cheaper and more accessible for the customer.

3. Customer Requirements

We conducted a survey to gauge areas of specific customer requirements. We sent the survey to friends and family. Demographics ranged from older and younger individuals. In total, we received 26 responses. The areas we looked at regarding customer requirements were features, price, and design.

To start, we first came up with a list of features that a user might be interested in. In the survey, we asked the respondent to indicate the features they would find useful. Figure 2 below shows the results of the percent of respondents that indicated a feature would be useful.

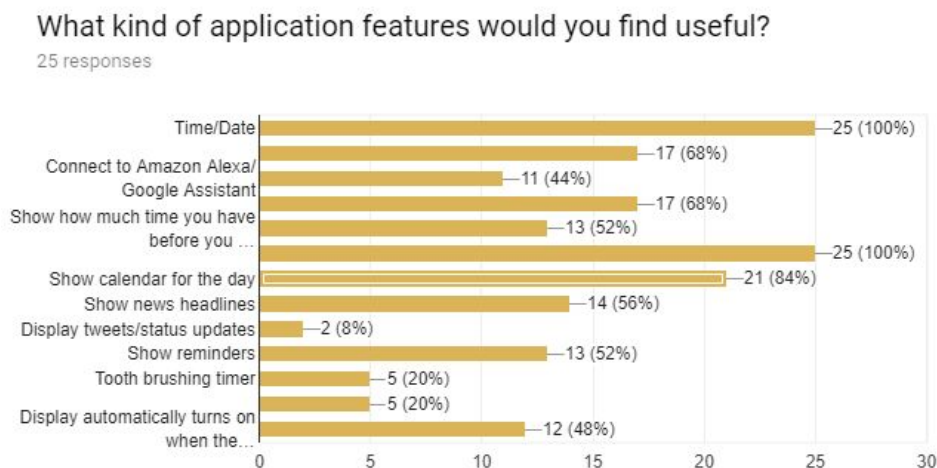


Figure 2. Percent of respondents indicating feature usefulness. ($n=25$)

The results from this question show that our product idea has a lot of potential in the features users would like. To build on this question, we included an open response to determine if there were any additional features that end users would like. These responses gave more ideas to practical and entertainment features. Practical features included an ability to dial 911 in case of emergency, anti-fog, and weather alerts for severe storms. Entertainment features included vocab words, YouTube for makeup tutorials, and stock market conditions.

Another area of interest for us to gauge was the price. We worded our question carefully to reflect what one would expect to pay, not if they would pay that much. We determined our price ranges by researching similar products in the market research phase. Figure 3 below shows the responses to smart mirror pricing. This showed that users have reasonable expectations as to how much our product would cost. Ideally we would like to keep the cost under \$300.

If you choose to complete a survey, be very clear about your demographics, number of respondents and the major conclusions that can be drawn from your survey.

What price would you expect a smart mirror to have?
25 responses

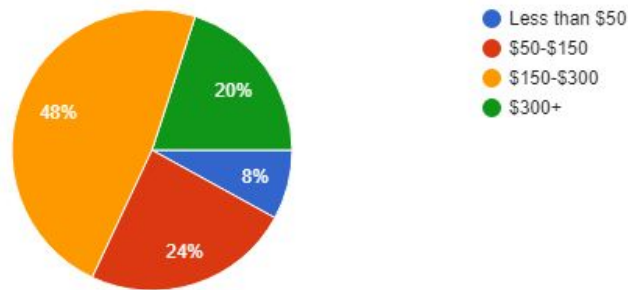


Figure 3. Percent of respondents indicating price (n=25)

The last important area for us to gauge was overall design of the smart mirror. This includes interactivity, as well as any concerns users would have. For interactivity, we were surprised to see that 48% of respondents preferred a touch screen. This surprised us because we thought about fingerprints on the mirror and initially thought a touchscreen was completely unreasonable. The next highest ranked method of interaction was voice control at 16%. Figure 4 below shows the comprehensive interaction response.

How would you prefer to interact with a smart mirror?

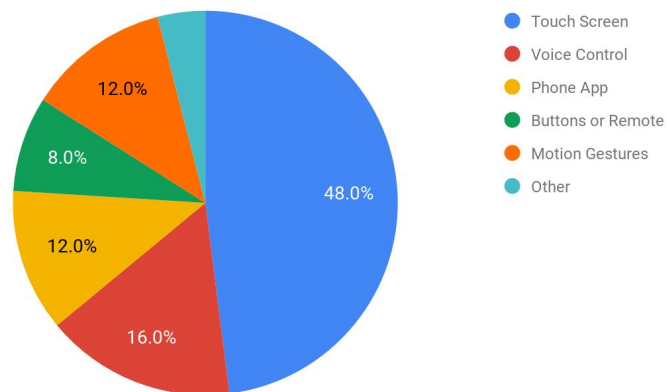


Figure 4. Percentage of preferred interaction methods

Another design decision we wanted insight on was whether the display should cover the whole mirror or be limited to a quadrant. 64% said the display should be limited to a portion, while 36% indicated the display should be full screen. This result was in line with what we were originally thinking. Lastly, we wanted to address any concerns users would have about smart mirrors. The biggest theme we noticed was security and privacy with 35% of responses

indicating this concern. Another theme we noticed was electrical safety with 23% of responses indicating this concern.

Overall, we narrowed our responses to implicit and explicit themes we identified in our survey. These themes helped shape our final customer requirements. Firstly, we noticed that users are interested in both entertainment and practical functions. This shows that our product idea is not only entertaining, but will also be used practically. Next, we recognized that our product will have to be friendly to interact with. Also, we found that users would expect to pay a reasonable amount considering the cost to manufacture a smart mirror. Finally, we confirmed our initial assumption that our product will have to be secure. Some points such as interaction and application features came as surprises to us, however price and display held up with our original idea.

4. Product Requirements

We derived product requirements to expand on the customer requirements we generated above. We mapped the product requirements to the customer requirements. Figure 5 below shows the mapping.

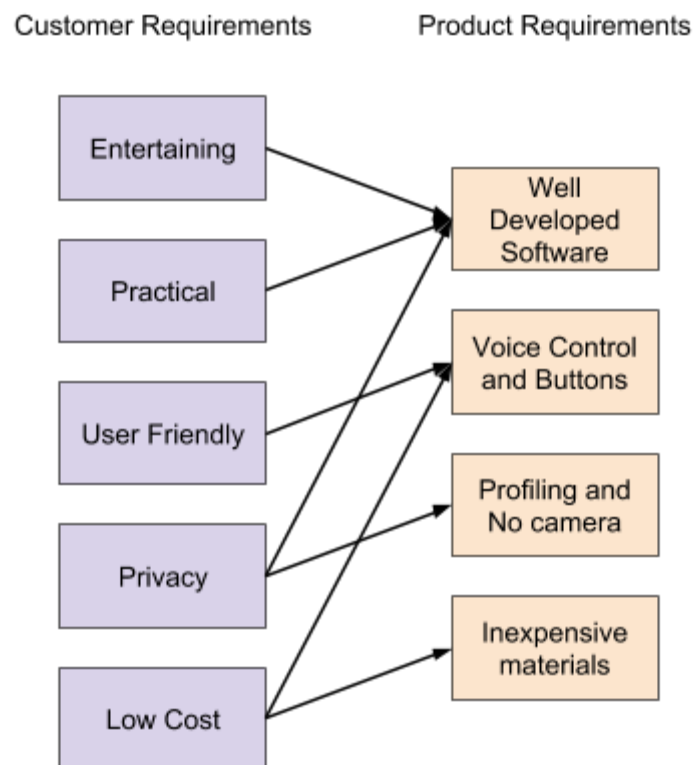


Figure 5. Customer to product requirement mapping

The primary product requirement is well developed software. This requirement will ensure that our product is competitive and guarantees an easy user experience. This correlates

directly to our customer requirement of being entertaining and practical. Entertainment and practicality will be the most impacted by our smart mirror software operating smoothly and efficiently.

Following the importance of software is the product's ease of use. Our smart mirror software could be the most highly optimized and feature rich out there. However if the user has an impossible time interacting with it, the product will not succeed. Therefore, we've determined that we need to integrate voice control and buttons as the primary method of interaction. We have also considered touch screen technology, however this poses a large design constraint that would damage other product requirements more than it would benefit interactivity. A touch screen is not feasible for the primary reasons of increased cost (about 2.5x the cost without a touch screen), questionable functionality if the mirror becomes foggy, and limiting the material and size of the mirror to the size of the touchscreen.

Privacy is also an area of concern since our primary use of the smart mirror will be in the bathroom. To address this concern we decided to implement profiling and will not be implementing a camera. We will be using the 'Netflix' method of profiling where there are no passwords on user account profiles. If time and cost permits, we would like to look into the feasibility of touch identification or voice recognition. By not including a camera, we can ensure that the smart mirror will not "spy" as some of our survey respondents indicated this concern.

Finally, cost optimization is an important product requirement. There are smart mirrors out there at very high prices. We would like to make our smart mirror affordable to people's expectations. Therefore, materials and features we choose to implement will be influenced by this customer requirement. Overall we would like to keep the smart mirror design and implementation less than \$300. Figure 6 below shows a basic rendition of the design.

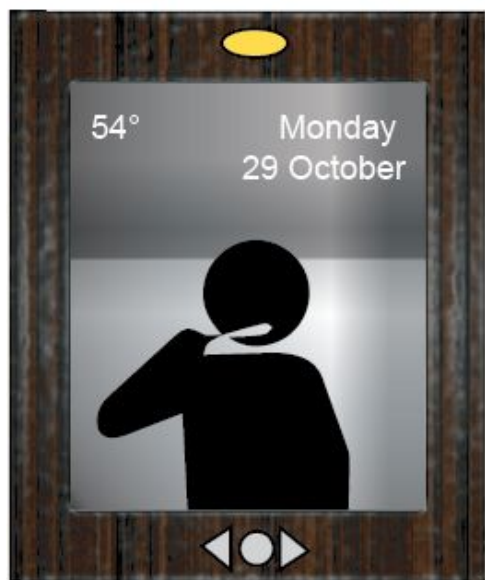


Figure 6. Concept design of the smart mirror, we've included opacity here to show where the screen will be mounted

5. Product Specifications

Using our product requirements which were formulated from market research and customer input, the product specifications of a smart mirror were determined:

- Two-Way Mirror
- System on Chip(SoC)
- Display Monitor
- Speakers
- Microphone
- Light Sensor
- Buttons
- ON/OFF Switch

The three major components to a smart mirror product are the two-way mirror, a System on Chip(SoC), and a display monitor. The mirror must allow the light of the monitor through when the monitor is on but otherwise look like a simple mirror. The System on Chip needs to control the display and connect with all other external peripherals. The display monitor needs to connect to the SoC and display any features that the customer wants. Without these components, the product would not be a smart mirror.

There are three types of mirror that are available for use with this type of application. Two-way mirror film, acrylic, or glass each have their own advantages and disadvantages. The film is the cheapest but is the easiest to break or tear. Using the film could cause seams in the mirror and a customer touching the film could easily break it making it less viable for a product being sold. Acrylic is much stronger than either of the other two options. It more closely resembles a regular mirror and can be more easily modified which would help greatly working on a prototype. However, it is more than twice the cost of the film(“Acrylic Two Way,” n.d.). Lastly, glass is flatter than acrylic and easier to clean. However, it is not as transparent as acrylic and may not allow the display to shine through as easily. It is also twice as expensive as acrylic and harder to work with although it looks the cleanest. (“Glass Two Way,” n.d.). Deciding between these options will be difficult although we believe we will use acrylic based on preliminary research of its ease of use and similarity to normal mirrors.

The next most important component is the System on Chip. It must have a display out capability, preferably HDMI as that is the most commonly used display connector for a monitor. It must also have the ability to run Linux or some other operating system to allow us to add new software features more easily. On-board WiFi and Bluetooth are also advantageous as they allow for wireless connectivity. Each of these requirements makes a SoC much more viable than a microcontroller. An SoC is much more likely to have the ram, memory, and connections to other peripherals needed although some of the more advanced microcontrollers have the capability

(“Selecting a Microcontroller,” n.d.)The most used SoC for DIY smart mirror applications is the Raspberry Pi 3 as it has each of these requirements, is well supported, and is relatively cheap at approximately \$35.

The last requirement for a smart mirror is a display monitor. The two major aspects of a monitor which need to be decided on for a smart mirror application are the display size and display connection. Most modern monitors have an HDMI connection which is what is desired to make the display simpler to connect with. The display size component is much harder to determine. In our customer survey, the customer wanted the display to only take up a portion of the mirror which means the display can be smaller than the mirror itself which saves heavily on cost. Therefore, the display could use up to the entire horizontal portion of the mirror and whatever vertical portion that the monitor size allows.

Beyond the three major components of a smart mirror, more hardware can be added to make the design more user friendly. These components are ones that would improve user interaction and guarantee privacy. First of all, a voice control system would allow the interact with the mirror. This requires a microphone and speakers. The microphone would be used to accept voice commands and could also allow the design to interact with Alexa or Google Assistant through voice. The speakers would also help with user interaction in the same manner, and also allow music integration with the smart mirror, something many customers wanted.

A system of buttons can be used to allow a second manner of interaction. Multiple different manners of control are always helpful for a customer. It would also help in case the voice control was not working or a customer wanted to improve their privacy by disabling voice control.

Light sensors within the smart mirror would allow the smart mirror to turn on when the light in the room was on. This would both save power and allow the user another level of privacy that the smart mirror is not always on. This would be a selectable mode allowing greater user control. This was one of the only further additions users wanted when answering the survey

Lastly, in terms of privacy and security, a dedicated on/off switch will be implemented. The customer can disable their smart mirror whenever they desire. When done so, none of the smart mirror will be active and it will function as a regular mirror for their home. Figure 7 below shows the input and output peripherals. The SoC is responsible for handling all of these operations.

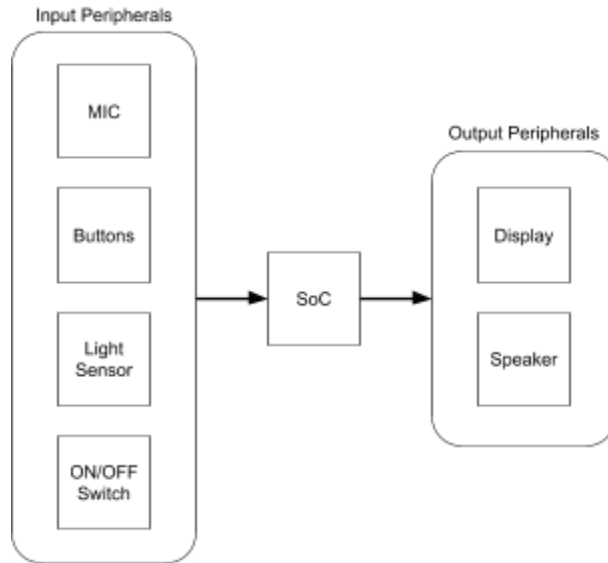


Figure 7: Block Diagram of Smart Mirror

The other component to the design of the smart mirror is the mirror frame and structure to hold the electrical elements in place. This can be done out of wood or other building materials. In our case, wood will be used as it is the easiest and cheapest material to work with. The front can be stained to be aesthetically pleasing and match the interior of a room. Extra supports will be needed in the back to support the weight of the monitor and allow for the other components to be bracketed into place.

Lastly, the power system in place will most likely be from a wall outlet. The average monitor uses significantly more power than a battery would be able to output. Electrical safety wise, the outlet is also protected in a bathroom by more strict standards which further protects the consumer in the case of electrical problems. A representation of the smart mirror internals can be found below in Figure 8.

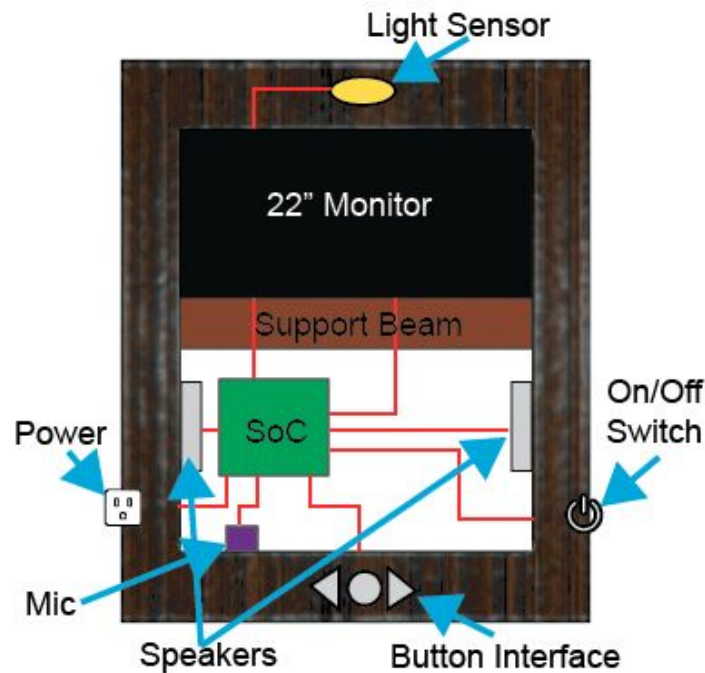


Figure 8: Smart mirror internals concept

6. Conclusion

Market research has shown that a smart mirror could be used in the market. Many people are purchasing smart home products and a smart mirror could extend the smart home market into a greater area of the home. Smart mirrors are made up of three significant components that make it a smart mirror. Without a display, System on Chip, and a two way mirror, a smart mirror can not be made. After that, any additions reflect customer requirements.

Customer research shows that a user wants the design to be entertaining, practical, easy to use, and secure while trying to keep the cost low. The customer wants to be able to easily interact with the mirror which leads into a voice controlled system which requires a microphone and speakers. Buttons are also added in case the customer wants another way of controlling the mirror while in front of it. In terms of privacy and security, a dedicated on/off switch will be included to allow the user to turn off the “smart” aspect of their mirror whenever they would like and just use a normal mirror. This also means no cameras can be included because of privacy issues in a bathroom, even if one of the customers in our survey wanted the “ultimate mirror selfie.” Each of these specifications are necessary to appeal to customers. The only remaining hardware aspect included in our specifications is a light sensor because 48.1% of the individuals in the survey wanted the ability to have the mirror turn on with the light in the room. No other hardware aspects were wanted beyond a touch screen panel for control.

A touch screen would be very hard to implement and may not have the same advantages that the customer thinks it would have. For example, a touch screen may not work if the mirror fogs up. Since users likely don't have previous experiences with this style of smart device, they may not have accounted for these minor issues. The touch screen would also add an immense amount of cost. Its cost alone of approximately 2.5 times a normal monitor would cause the cost of the smart mirror itself to be much greater than \$300, the amount the customer said they would pay. Despite the advantages a touch screen might have for usability, it would not be feasible to use in such a time-constrained project.

Entertainment and practicality are largely software implementations of the customer wanted features. Date and time, weather, calendar, commute time, and news headlines are all necessary to complete the project. We also feel that implementing Google Voice or Google Assistant is necessary to the project because of the voice recognition and control capabilities. Google is known for having some of the best voice recognition software which would ensure painless user interactions. Google Voice is also bundled into Google Assistant so the use of Google Assistant potentially simplifies our software development.

Some features that would be good extensions of the necessary features are music integration, specific voice commands such as "Mirror, mirror, on the wall...", and Amazon Alexa integration. Each of these is much more risky and could be largely unnecessary. Google Assistant may provide connection for music integration to Spotify and specific voice commands but if not, adding those to the smart mirror would be much more difficult. Amazon Alexa would not be necessary at all if Google Assistant was used as they provide similar functionality.

Overall, a smart mirror would be a good addition to the smart home network. It provides information for users when wanted and a mirror otherwise. A cheaper smart mirror could work well in the market as some of the cheapest smart mirrors are around \$1000. If we kept the cost below \$300 while still providing essential features, our smart mirror could do well with customers.

Be sure to always include references. There should be enough information in this section to go find the resource without difficulty.

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