Smart Mirror Project

FINAL REPORT

BY

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Abstract

Facial Attractiveness measurement is a controversial topic everyone has their very own opinion on. Using technology, a unified measurement system can solve the differences in opinion and provide an overall measurement everyone can agree upon. This project created a smart mirror that rates the user's attractiveness. The hardware is a mirror with added computational devices to perform this task. Underneath the mirror, a combination of a laptop screen and a raspberry pi is used for computational hardware. The raspberry pi performs all computing tasks. The Smart Mirror has a bunch of features that enhance the user experience with a key core function. The Key function is activated via voice control. The Smart Mirror features a feature rich user interface and a voice assistant for additional assistance. The attractiveness rating is a system based on partial machine learning and statistical analysis. Facial landmarks are identified by a machine learning system that is trained to identify 64 landmarks in an image. Once this data has been generated, statistical analysis then is used to compare the values of the user to the data set of 100 attractive females under 30. The system output is a percentage that shows the similarity of the user face against the dataset.

Introduction

Mirrors, invented many years ago, here to serve mainly one purpose, to reflect everything that is across from one. Fridges, invented years ago, here to serve only one purpose, to keep food fresh by cooling it down. Door locks, also invented years ago, made to serve mainly one purpose, to keep an object locked. All the above listed objects, and may more, have been used for mainly to their own simple purpose. Yet technology has been growing and expanding day by day.

Fridges for example, have certain bits of technology, that display useful information in form of a small interface on their doors. That Information displayed varies from fridge to fridge. Most of them however display temperature controls and temperature information on their displays. Samsung, one of the market leaders in electronics, have taken fridges, a simple purpose utility machine, and turned it into something that can be fun and interactive and house more features than its original simple purpose by introducing common technologies into their machines. Some of their machines even take this concept further and introduce technologies into these types of objects that would be even unimaginable 60 years ago, e.g. their so called "Smart Fridge". A simple fridge with a built in micro computing system and a touchscreen interface where the user can interact with their fridge operating system run by android.

It always depends on how the technology is used. Some objects do not have technology introduced like a Samsung "Smart Fridge" has. Simple locks, have also had their introduction to modern technology however they are very different. "Smart Locks" work by having an electronic ID card close to the lock, if that ID card has a permission to open the lock, the lock will automatically open, if not it will stay shut.

If locks, fridges, watches and many more had their introduction to electronics and technology why can't mirrors. Almost certainly every human, that has experienced the 21st century, has had their interaction with mirrors at least once in their life. For some people Mirrors are even an object, they interact with on a day to day basis. Therefore, this project will focus on turning a simple mirror into something that would be useful in more than just one way using technology.

Feature and problem description

Technology can be introduced to simple objects in multiple ways and forms. Companies and technologic enthusiasts have their own descriptions of what an object needs to be of something used modernly. Often Major Companies, giants in the technology industry, such as Samsung, JTV and Kenwood use the term “SMART” when they expanded something with a simple purpose to something with multi purposes. However, the definition of “SMART” can be different from person to person or project to project. This Project will follow its own definition of “SMART”. The Mirror itself will have multiple features with one key feature, which will be its main feature.

People look into mirrors to view their appearance and judge their attractiveness. This mirror will have an Artificial Intelligence features that measures a user’s attractiveness in real time, so that they can improve on it. Each person in the world, has their own opinion and definition about attractiveness. At times people see something attractive, that other people do not think is attractive, which can lead to Controversy. This project will aim to unify these opinions and give a direct definition and measurement of how attractive somebody is. With that information measured and defined, the project could take this measurement data and push it a bit further. With that data, e.g. programs can pass that to users and they can rate weather the information is accurate or not. Another example, match people who have an equal amount of attractiveness rating measured and let them get in contact with each other. There is a wide range of expansion for this project.

Additional features?

If time permits this project will also aim to provide additional features to the user. Users will be able to view instant quick information upon walking up to the Mirror, that will assist them for their day.

Quick Information and additional features will target to include:

- Time and Date
- News Snippets and Headlines (Global and local)
- Weather Forecast for the day
- Snapshot Mode (Including viewing of previous taken pictures)
- Gesture Control
- Voice Assistant Control (Featuring Google Now or Amazon Alexa)
- Clothing Suggestion
- Calendar expansion, displays future events on the mirror (e.g Dentist Appointment)
- Horoscopes
- Food Suggestion based on regional favorites

Chapter 2: Literature Review

SMART MIRROR OVERVIEW

What are smart mirrors? smart mirrors are normal mirrors with added technology. Most smart mirror projects are carried out by companies such as Samsung and Panasonic or even individuals and hardware Enthusiasts. In the current market, smart mirrors make a very rare appearance, as there is no clear standard or even a clear product that dominates the scene. However, companies such as Samsung and Panasonic specifically create smaller products and proof of concept models for specific Companies and Electronics Fairs. For hardware fairs and electronic shows Samsung and other smaller companies demonstrate their product that can be potentially introduced to the electronic market, but most of the time it does not enter the market.

Smart mirrors by Samsung

Figure 1 ML55E by Samsung

Samsung currently makes smart mirrors for the fashion industry and for businesses on demand. Their range varies between different products suited for different needs and tasks. One of their most popular model used and commonly seen during fashion fairs in New York, is the ML55E [1]. This is a unique piece of hardware, that focuses on bringing a more digital and interactive way for customers to engage with products. The ML55E [1] portrays the customer in real time like a mirror with capability to overlay anything digitally. This digital content can be anything possible, e.g. information to the product or even any sales advertisement infographics. At fashion shows, this smart mirror has been appearing commonly ever since its official release in 2016. There, the mirror was used differently. Most fashion fairs have utilized the mirror to emulate a cover of a magazine in real time. Paid models, prepared and dressed, then walk up to the mirror setup and then pose in front of it. With a perfect setup that includes good lightning and a suitable background the result does indeed look like a live version of a magazine cover. Fashion experts can then make changes based on what they view and try out different things they wish in real time without making much effort. The hardware in the ML55E is not only used in the ML55E. The main processor used in the ML55E is the same used in their older Smart TV models. The display is a simple 55-inch LED display with a silver reflective coating in between layers and for the connections, it does support every standard connectivity port you can find on a modern TV. The hardware in the ML55E by Samsung is not what makes it unique, its rather the software support that Samsung designed for the product. Samsung provides special designed software to interact with the mirror itself such as an app that runs on Samsung smartphones.

Figure 2 Samsung transparent OLED Mirror

However, this is not the only smart mirror Samsung manufactures. Besides the ML55E they have made for the fashion industry, there was one more notable product concept [2] that was demonstrated in South Korea back in 2015. That concept was more advertised towards regular consumers, but it did not enter the market officially. Samsung have used a transparent OLED screen on top of a regular bathroom Mirror.

The Smart Mirror had an overlay and that overlay viewed basic Information, such as time and date, social notifications and calendar event information. Samsung mostly excels with hardware rather than software, this can be seen with most of their products.

Panasonic smart beauty mirror


Figure 3 Panasonic Smart Beauty Mirror

Panasonic have also made some smart Mirror Products. Their general idea was to improve the general purpose of the mirror in the bathroom. One of their Mirrors that they have demonstrated at the CEATEC Fair in Japan, was specifically aimed for Makeup and Beauty. The "Beauty Mirror" [3] by Panasonic had multiple features, one of their main core features was to view everything on your face, from Blemishes to dark spots and other unnecessities. This is useful to users, so users can either try to hide it with makeup or try to improve on that area with skincare products that the mirror suggested. The display of the mirror also added white bars on the side of the interface window, this is so the user has a natural source of light shining directly at the face, while the mirror reviews the users face. Besides the beauty feature it also has additional entertaining features, such as "draw on your face" which essentially allows you to draw things like a moustache on your face or try on certain makeup such as lipstick colours and others. This additional feature is not made by Panasonic, but the mirror supports Android apps, the makeup app was made by the makeup company Naked.

Smart mirror project by individuals (diy projects)

Inspired by companies and concepts developed by society, hardware enthusiasts have also created their own inspiration of smart mirrors and demonstrated these projects on the internet. These projects are unique and different from each other. Most projects vary from each other, because they focus on executing different tasks. Therefore, these projects are very interesting to mention, because overall, they also take a giant part of shaping the future of smart mirror products. They demonstrate their own interpretation of what a smart mirror does and should do, and this is where people working in companies and future smart mirror projects get their inspiration from.

Figure 4 Smart Mirror DIY Project

The Hardware in these individual projects also varies but the general Idea of the concept is fixed. For a smart mirror, you generally need a computing interface, a reflective mirroring component and a display component. The techniques and component combination can vary, however for the general production of a smart mirror, the concept yet remains a bit similar.

On the Internet there are also tools and platforms to develop on. www.MagicMirror.builders, a community for magic mirror software development, have gathered and created the Magic Mirror framework, which is the current popular standard for these projects. Most of these projects use this Development Framework and create features and their own version of it. The framework is developed on JavaScript and is open and publicly available on GitHub. The features developed by individuals presented are very different from what the ML55E and Panasonic beauty mirror does. Their approach is to have multiple features and applications to be supported by their smart mirrors.

Weather it is voice commands via a smart assistant or even something completely different like gesture support, someone may have developed something like this, on a basic level. One of the most common products that is created by hardware enthusiasts is a smart mirror that only displays the needs of basic information during your daily routine at the bathroom. This is where Samsung have gotten their inspiration of their OLED smart mirror.

Attractiveness Theory

Introduction

Why are we looking at mirrors? There are multiple answers to this question, none of them are wrong. Ultimately it can be any reason, but mostly we want to review our attractiveness and view how others see ourselves. The Image we see is then judged by our consciousness and we make decisions based upon that image. We usually change our hairstyle, apply makeup or even consider getting skincare products to improve on our face or other parts on our bodies for the future.

At times after seeing ourselves in mirrors, we ask other people for a second opinion, because sometimes we view ourselves differently based on personality and how we feel on that specific day. We get that second opinion and throw it in our decision-making formula.

People view attractiveness differently and unique, this means that each person on their world has their own general view on attractiveness. This does not mean it is not possible to understand what people generally think is attractive. In the past it has been attempted multiple times by different cultures and people. In the past course of our history, there have been different approaches that try to find a specific way of defining what is attractive or not. As an example, different neuroscientist have their own believes on what features make a face attractive. According to a journal paper by Thornhill and Gangstad (1999, pp. 453), "facial attractiveness and what people generally find attractive comes from our genes, rather than our psychology". They believe that people around the world discriminate their potential mates based on attractiveness and we subconsciously influence our psychological view of someone by our genes. From an evolutionary view we subconsciously select someone that might increase our gene propagation. This statement however is very critically viewed because of many reasons. For example, how would this work with people who find someone with the same sex attractive.

For this neuroscientist claim that people get influenced by multiple factors, our genes are partially responsible for our decision, but there are more factors involved. In history certain cultures had their own general opinion on attractiveness. Ancient Greek mythology believed that the more symmetrical the face is of someone, the more attractive that person is. Even in drawings, artists have always aimed to have their drawing of humans to be even and symmetrical. As the public in ancient Greek appreciated artwork more with realistic and beautiful even symmetrical faces. But besides Historical and Genetical factors, a big key to attractiveness is also personal preferences. There is no doubt that every person on this world is unique in their own specific way. People have their own tastes and likes, and it varies from person to person.

Overall searching for a specific formula for overall general attractiveness is very complicated as there are many factors included, however it is not impossible.

Attractiveness measurement

After going over the historical, psychological and social views on Attractiveness in this review, this part of the document will go over Attractiveness Measurement. As described and reviewed earlier Attractiveness measurement is something quite complex and very difficult to measure, due to the many factors that are involved. For some, it might sound ridiculous that technology is able to measure something controversial and complex as attractiveness, however it has been attempted by others in the past.

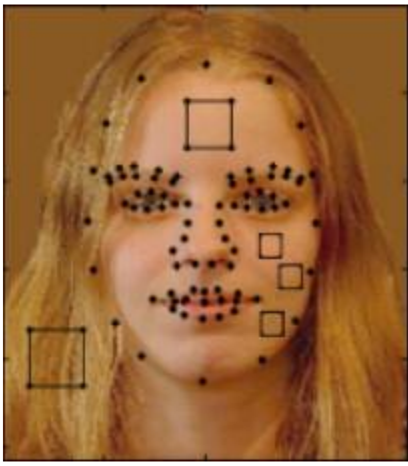


Figure 5 Facial Data provided by the facial extractor of the machine learning model.

At first, before the use of electronical measurement, scientists and researchers have started their research by finding patterns in survey results. This is what Cunningham (1986), has done. Back in 1986 she gave male subjects 50 images of females. The subjects then would have to provide a rating of the features they think is attractive. The most notable features that came across most ratings were:" large eyes, small nose and small chin". Another few notable characteristics were:" small cheekbones, narrow cheeks and a large smile". This was also not the only study Cunningham's team have performed, their second study, based on the results of the first study, have questioned the subjects on what they would have done with the females in the picture and therefore have identified a pattern on what personality type would be most likely to be attracted to other personality types. However, this was only physical measurement performed by individuals who have taken their time to be a subject for testing in a research project.

For something this complex used in modern times, it would simply prove as inefficient in time. A more automated system would prove to be more efficient, as an automated system can simply perform more accurate and faster than humans. Therefore, scientists have started using and developing automated systems to perform these tasks. Distributed systems across multiple areas are also an efficient way to gather information like measurement data from more than just one region. This is also helpful to understand a wider view on capturing the definition of attractiveness and beauty on a global scale.

Kagian et al. (2008), successfully achieved to create a machine learning based model that measures physical attractiveness. This model focuses on identifying patterns across facial images and reveals it via a dataset. This Dataset revealed and marked all points on the image. These markings would reveal anything on the face, both negative and positive. The data from the images would then be taken and compared to a different data set. The second data set would have the images and scores of people that are considered attractive stored. This dataset would also store the average value of an image stored, this will be the value used for comparison against the first dataset. The result proofed that this model was almost exactly like a mean human rating of an individual's face. It identified the negative and positive features of a face and according to these features, it provided a final measurement score of the face.

Every person on this world has a different face, even twins, while their faces are similar, they do have minor differences that cannot be seen properly the first time we see the person. A system based on machine learning, something what Amit Kagian et al. (2008) [11] and his team have done, seems to offer the right solution to this subject. However, it is not the only solution researchers, developers and scientists have attempted. There were other solutions that offered an alternative to a fully machine learning based system. For example, a group of developers from Akiira Media Systems (2014) Deep self-taught learning for facial beauty prediction. Neurocomputing, 144, 295-303 have developed an artificial intelligence-based system that simply takes in raw images of female subjects and offers a human like measurement of given data. Their approach was to simply analyse the image from pixel to pixel and use artificial intelligence to gather information and try to recognize parts of the face. The measurement was scaled to what other subjects have voted to be attractive.

While this seems to be a sophisticated system, this system still has its flaws. One of the main issues this system has, was that the images were limited on what was acceptable or not. Images needed to follow a certain restriction given by the developers for the system to work. Another major issue also was that the system would eventually become outdated. Humanity changes over time, so do our tastes and other parts of our life. The system may proof to be effective in 2010 but may provide inaccurate results in 2018. Therefore, most people working on computational measurement of facial attractiveness choose to develop a system based on machine learning, due to the simple fact that other types of systems need constant adjusting, while machine learning based system constantly learn and improve over time with data added.

Time passes, new technologies get introduced and people improve with their work. The previous projects mentioned were projects from the past, a more recent project by Zhang Lei et al. (2017) and his research team have had a more manual approach. Their developed System was measuring facial attractiveness via facial geometry. The system accepts an image as data, the system lets you select the following "Nose, mouth, ears, eyes and chin". Through an Image Map, it then measures marked points on the face with the "1:1" geometric even image map. The closer the marked areas are with the image map, the higher the attractiveness score is. Their research provided a dataset and a database that contains the score of the test-subjects. In their research they also describe how attractiveness is all about facial geometry and this is what inspired them to capture computational attractiveness. While this does not really seem like a modern and advanced system, it does do an excellent job of capturing accurate information via manual input. Manual input also prevents potential computational malfunction, which is useful especially with all these other systems that utilize machine learning as their core. While it may prevent potential issues with computational malfunction, it does open the potential of human error. Another issue with this is, that this system does not account for other factors that create "attractiveness", it simply tries to see if a face is geometrical even. A sophisticated system must account for every bit of detail and not simply one factor.

Most of these research projects have shown clearly that it is possible to measure attractiveness via computational means. The main issue that is seen in these projects, is that attractiveness is not just simply about numbers and calculations. Humanity is individual and different. A huge part in attractiveness is also the individual opinion of a person reviewing what they consider is attractive as in "beauty in the eye of the observer". Researchers have attempted to bypass this issue with tagged data that then gets sent through a machine learning system. The system would then create a pattern of what people generally think is attractive. However, even with this solution, it can result in inaccurate data. Data can be tagged wrongly and with a bunch of falsely tagged data and then an invalid pattern can be created. Essentially therefore developers and researchers working on computational facial attractiveness use predefined dataset of a specific ethnic to train systems. This dataset would have both “unattractive” and “attractive” image samples and then it would be used to train a machine learning based system.

Reviewing these projects, it turns out that most of these projects create accurate end results, but it simply seems as something is missing to achieve something complete and useable on a day to day basis.

Project approach to attractiveness measurement

For the sake of the project, the attractiveness measurement will focus on facial attractiveness, rather than a full body review.

A good approach to solve this problem, would be to analyse characteristics of the users face and the face of the model and compare values. Facial analytics reveal everything about the human face. From this type of data, we could read what makes our face so unique compared to others. This information can be recorded by a system that reviews and identifies faces within an image. Once the information has been recorded it can then be used against a statistical model of people who are considered attractive. The difference between the user face and the statistical model would show a % difference.

A different approach would be to utilize machine learning to get a grasp what users think is beautiful and ugly. The System would review a bunch of tagged data, that is “attractive” or “not attractive”. After this, the system would then proceed to create a pattern from the facial data acquired, and then be able to decide if the user is attractive or not.

To acquire the tagged data, another source of tagged images would be required. For this a separate application would be beneficial to be developed. The Application would be simple, users would receive different pictures of different users, and the community would then decide if the person in the picture is attractive or not. The Data gathered from the application would allow the system to learn what people think is attractive and then create a pattern for the attractiveness measurement. Another way of acquiring tagged data is to utilize the hotlist of the popular website “hot or not”. “Hot or not” is a website that allows users to rate other users facial image and grade them with a “hot or not” scale of 1-10. The “hotlist” is the list that shows the top candidates with the highest score on the website. The hotlist provides images and score for research purposes, making it an alternative of acquiring tagged data. This data can then be used to train a machine learning based system to create a model of facial attractiveness.

There are many more solutions to measure attractiveness. Machine Learning is usually a high rewarding approach, due to the system evolving after multiple uses, however at the beginning, the system proofs to be mostly inaccurate and after some time of usage it becomes more precise. Where a System that measures a multiple of factors related to attractiveness and then provide a score based on these factors, offers high and accurate data all the time of usage. Both solutions are viable for this project. The next step would then create a platform where this System can perform on.

Chapter 3: Hardware Specification and Requirement Analysis

Introduction

This document will specify and inform about hardware design choices and the implementation of hardware for the smart mirror prototype.

For the prototype to be fully working and useful, it will need to fulfil certain factors. These are the factors listed:

- **Portability**
  One of the main factors is portability. Mirrors are light and portable. They can be almost used anytime and everywhere. Therefore, the smart mirror prototype must also be very portable. This is why the smart mirror prototype will aim to be not bigger than a standard bathroom mirror. Bathroom mirrors usually come with the size of H45 x W60 and this will be size the smart mirror prototype will aim for.

- **Lightness**
  Besides being portable, the smart mirror prototype should also aim to be light. Lightness is another factor that needs to be considered when choosing hardware. Lightness is important because a heavy mirror will be hard to place and position. A light mirror can be placed and used anywhere. Lightness also plays a minor role for portability.

- **Security**
  Since the smart mirror is utilizing electricity and hardware components that utilize electricity, it should be important that the mirror is safe. This project aims to be able to be used everywhere, therefore it should attempt to be secure and should not be the cause of a hazard. In order to make sure that the prototype is secure, hardware components will be coated with protective anti-static plastic and isolating electrical tape.

Scopes:

- Prototype mirror + frame
- Rasberry PI and camera Setup
- LCD Display setup

Design

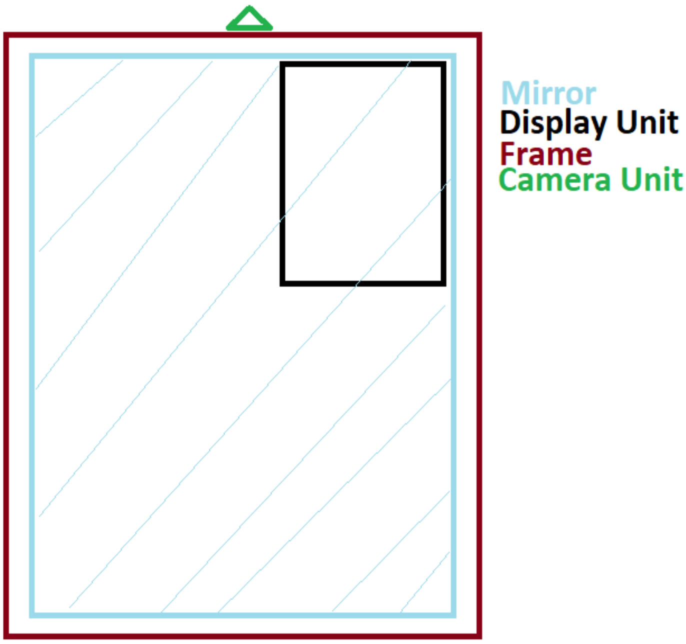


Figure 6 Hardware Design Plan

This chapter will discuss the design scopes and what is required to have a successful prototype mirror that can work with the software developed.

The first and most important component that is required for the smart mirror prototype is an actual mirror or anything that is capable to act like a mirror. A smart mirror would not be a smart mirror without a reflective interface. The reflective interface is what makes the mirror a mirror. Therefore, anything that can act like a normal mirror or even a working mirror itself should work for this prototype. As the smart mirror would have electrical components installed, it would be a benefit if the mirror component would have room and capacity to hold some components. It would be also much of a benefit if the mirror component would have a frame or something like a frame that would give it some durability. People interact with mirrors and mirrors can break fast and with the added technology added to the smart mirror it simply adds another layer of potential hazards. A frame would act for added security to prevent health and safety hazards and any potential damage to the smart mirror.

The second important component needed would be a set of electrical components that the software can utilize. For the software following components are required:

- Computing Interface
- Camera
- Display Component
- Microphone (for user interaction with the smart mirror via voice assistant)
- Speakers (so the voice assistant can reply to the user)

For this anything that matches the requirement factors can be utilized. This means that the hardware choices need to be portable, light and secure. Mirrors can be used everywhere and anywhere, therefore a smart mirror should be able to do this too. The electrical components should be hidden behind the reflective component, this includes any wires. The user should simply see the mirror reflection and partly the overlay coming from the display unit.

The next bit of the document is documenting and evaluating design choices.

Mirror and frame

There are several options that the prototype can use to fulfil the mirror half in “smart mirror”. One way to do this is to simply take a mirror and modify it to be a smart mirror. The benefits of this would be that the mirroring reflective interface would be 1:1 (or what the mirror specifies). One drawback to this would be that the mirror would simply be a mirror and that would mean that the mirror most likely has very less room to install electrical components. Another Drawback to this option would be that the thickness of the reflective coating of the mirror would be so thick, that the electrical display component of the smart mirror would have trouble shining through, which would lead to limited visibility. A workaround for this drawback would be to utilize a one-sided mirror, however these special types of mirrors are high in costs and usually weight more than a regular mirror. As price and usability is limited to this option an alternative design choice has been taken for this project.

For this Project the mirror has been made through a modified picture frame. The frame used is called “Ribba” and it is made and sold by IKEA. The frame has a W50 x H50, making it an ideal size for it to be placed anywhere. “Ribba” also has a sturdy wooden frame all around making it very sturdy. Inside the frame it offers a lot of room for components to sit inside.

Figure 7 "Ribba" by IKEA

“Ribba” also comes with a plastic cover at the frontside preventing anything to enter the frame. The only thing missing for “Ribba” to be utilized for the prototype is that “Ribba” is a picture frame and not a mirror, meaning it does not reflect anything like a mirror. Therefore, another reflective component is needed and combine with “Ribba” for it to be used in the prototype. The plastic cover offers a great surface for it to be turned into a mirror, as the cover has already been prepared to be used with the frame.

While the modified version of “Ribba” was covering the mirror and aesthetics, the remaining half of the prototype was not yet installed, the next part of this document will talk about the hardware design and choices that turn “Ribba” into the smart mirror prototype. For the computing hardware required there were two main components needed: A computer or computing interface that allows interaction with the user and a display unit for visual representation.

For the computing hardware there were multiple options available. While looking over options, the above-named factors that shape the project helped deciding. After reviewing two options were available, the Raspberry PI 3 model b and the Arduino. Both options were viable for the project, however for the project the Raspberry PI 3 was more suitable.

Raspberry pi 3 setup

Figure 8 Raspberry Pi 3

The Raspberry Pi 3 was selected for the project.

Hardware:

This minicomputer offered everything the project needed with the added capability of expansion on its board. The core of the raspberry pi 3 is powered by a powerful 1.2 GHz quad-core ARM Cortex A53 (ARMv8 Instruction Set) Central Processing Unit, a Broadcom VideoCore IV @ 400MHz for its GPU and 1GB LPDDR2-900 SDRAM for memory. Besides its core the raspberry pi 3 also offers almost any basic connection port this project needs, from 4 built in USB ports, a HDMI port and an option for gigabit ethernet to wireless interconnectivity methods such built in 802.11n wLAN and Bluetooth 4.0 the raspberry pi 3 covers almost anything. The Raspberry pi 3 also offers connectivity for other electronical components through its 40-pin general purpose input output. For storage the raspberry pi 3 supports any micro SD card. Additionally, a Camera will be needed for the smart mirror. The camera covered will be the raspberry pi 3 v20 camera module, which offers a 1080p picture.

Software:

The raspberry pi 3 was always a very popular choice for software development under minicomputer projects. The hardware offered on the raspberry pi 3 always attracted many developers with minicomputer projects over time and therefore the support for minicomputer software development projects was always very popular and big on the raspberry pi. Companies and Enthusiasts support this platform and for the smart mirror software developed for this project will run also very well on the raspberry pi 3. The raspberry pi 3 supports any operating system that supports the ARMv8 chipset. Special OS have been ported for the raspberry pi 3, such as ubuntu Core, windows 10 and any Linux distro. The raspberry pi 3 also offers its own open source version of Linux "NOOBS" preinstalled on SD cards to be used, which is what the project and prototype will utilize. "NOOBS" will be modified for the needs of this prototype.

LCD controller setup

The next key component needed for this prototype and project will the display computing unit. For the main requirement, the display unit needs to be suitable for the design factors listed and it needs to be able to be viewed through "Ribba". For this there were two options available: A full computer display without its cover or a laptop screen. Looking over the design factors, a full computer display was not suitable for this project and prototype. Full computer displays are both heavy and too big and therefore the design choice was to go ahead with a laptop display.

Laptop displays are mainly designed to be used with laptops, however with additional hardware it is possible to make use of laptop displays with the raspberry pi 3. For this task a LCD controller board was required. Controller boards are not something that are marketed and sold directly by the companies. Hardware enthusiasts mainly create them their selves for their own general purpose. Luckily for the Display the projects utilize; a LCD controller board was available for purchase and selected for the project and prototype.

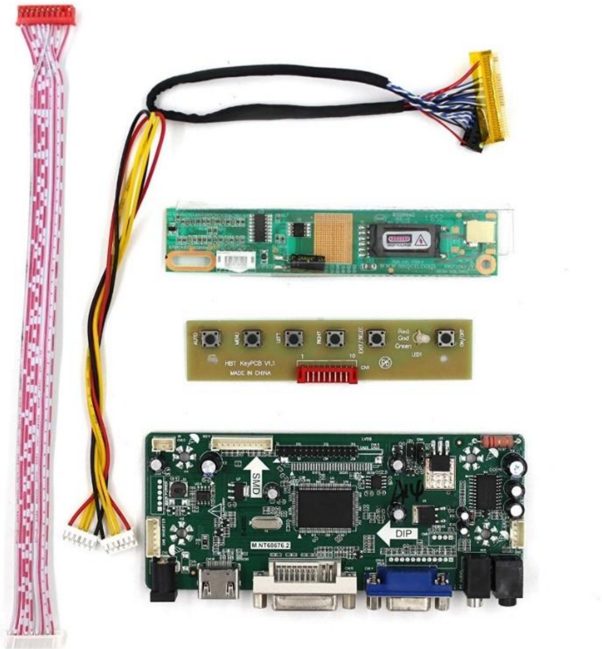


Figure 9 LCD Controller Board for LTN141AT07/2/

The LCD controller board [6] is a set of combined hardware. The main component is the controller board itself. It comes with a 5v input, DVI input, VGA, HDMI and a 3mm headphone jack. On the board there are various chipsets that regulate connection ports as well as graphical output. Connected to the main controller board there are two separate boards. One of them is a small board with buttons. These buttons are made for the display to be controlled. It features a menu button, + button, - button, a power button and a LED light to view if the monitor is on or off. The second board connected to the main connection is a board that focuses on regulating and converting electricity. From this board the LED of the laptop screen will be connected. This board makes sure the LED gets enough voltage required and not too much to overcharge it. The Laptop screen will be connected to the main controller board via a 24 pin LVDS connector cable. The button board and the board that regulates electricity is connected to the main board.

DISPLAY SETUP

Figure 10 Samsung LTN154X3 - L01

For the laptop screen itself almost anything could've been used. For this project prototype specifically, the Samsung LTN154X3 – LO1 has been selected. The Samsung LTN display offers a simple 15.4" LCD display that can be modified. The most important part on why this display is specifically selected is that this display is powered by a powerful backlit white LED in the back. The LED in the back offer high brightness, which is needed in this project to shine the display through mirror in the front. The glass in the front of the display also offers a reflective interface which in addition to the mirror will be beneficial.

Installation and implementation of hardware

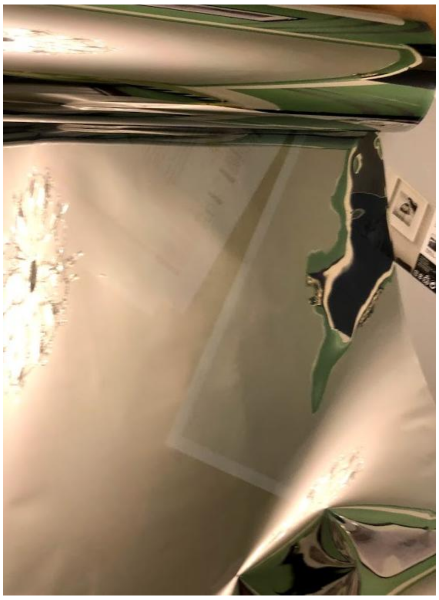


Figure 11 Reflective Coating

The next and final step for the smart mirror prototype was to combine hardware choices and create the actual prototype. The order on preparing the individual hardware components is not that big of an importance, however it would be of a benefit to start with the frame and mirror first. This is what I have done, I have started on preparing “Ribba”. “Ribba” had no reflective surface as it is a picture frame and not a mirror. Therefore, “Ribba” needed to be modified before it could’ve been used for the smart mirror prototype.

Making the plastic cover reflective like a mirror is not a difficult task. For this a special coating is needed to make the picture frame cover reflective. Something like this has been attempted and made, but not for picture frames. Car passenger side windows get additionally coated with reflective coating after purchase. This is where the inspiration for the reflective coating has come from. The idea was to modify the plastic cover of “Ribba” to make it reflective. To make it reflective, the plastic cover of “Ribba” has been covered with a reflective silver window film. The Silver reflective film overlays on top of the plastic cover with a silver layer and the silver reflects anything 1:1 just like a mirror. This combination allowed the project to utilize “Ribba” for the prototype. “Ribba” now is the body of the smart mirror and allows for a safe installation of the smart components to work with the mirror.

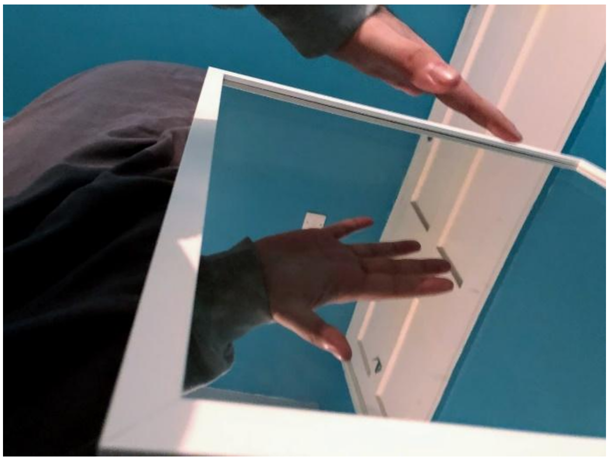


Figure 12 modified version of “Ribba" with reflective silver installed

After installing the plastic panel with the reflective coating, “Ribba” was working exactly like a mirror, making it perfect for the smart mirror prototype. It offers room for the hardware to be installed and the thick wooden border improves security.

The next task was to add the rest of the electrical components with the modified mirror. This was a slightly difficult task. The first step was to prepare and test the display to work with the additional LVDS converter board. Tested before installation it proofed that the board was working just as intended with the display unit. Once completed with testing of the components, the components needed to be secured. The idea was to cover it with some sort of protection coating. For the project I utilized electrical tape and anti-static electric plastic. The components were attached to the backside of the display unit, since the wires were short in length.

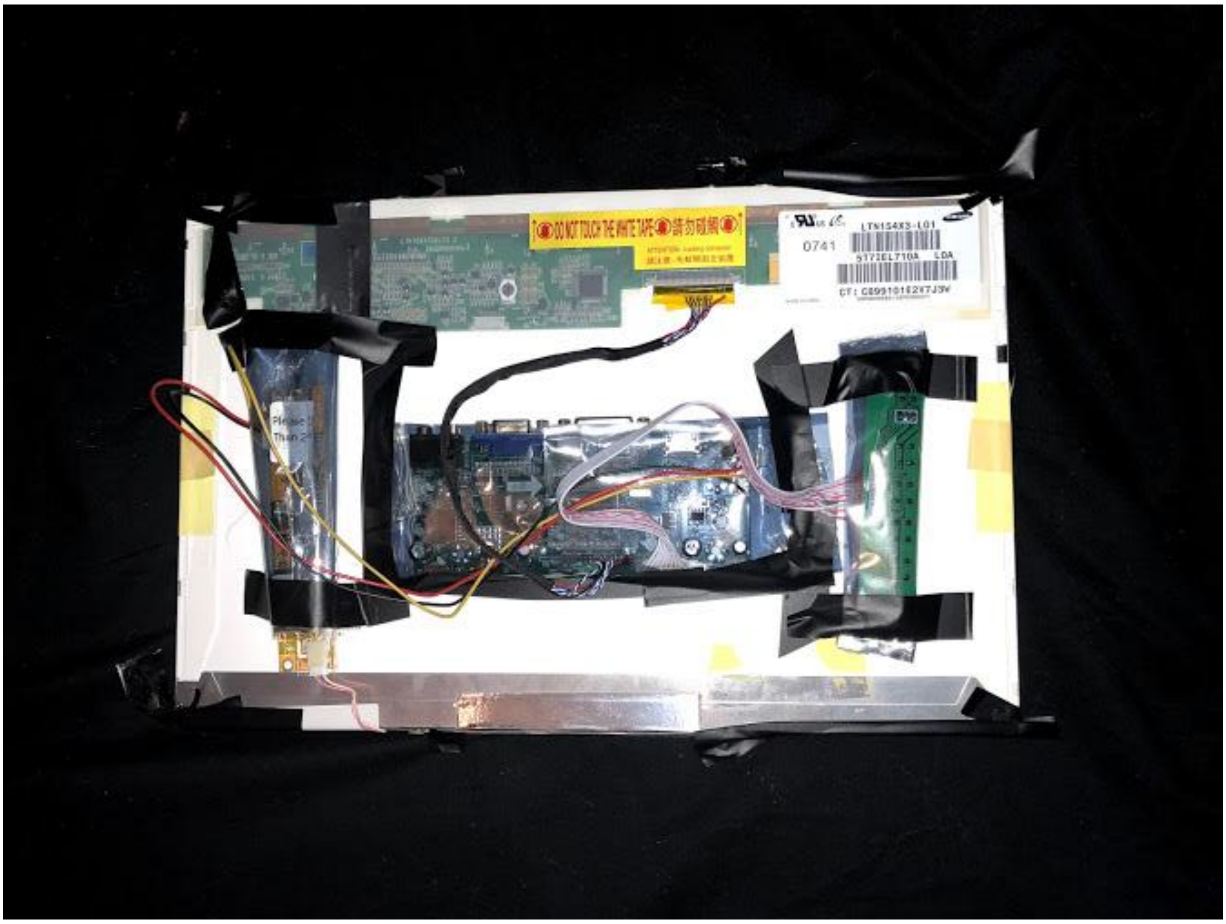


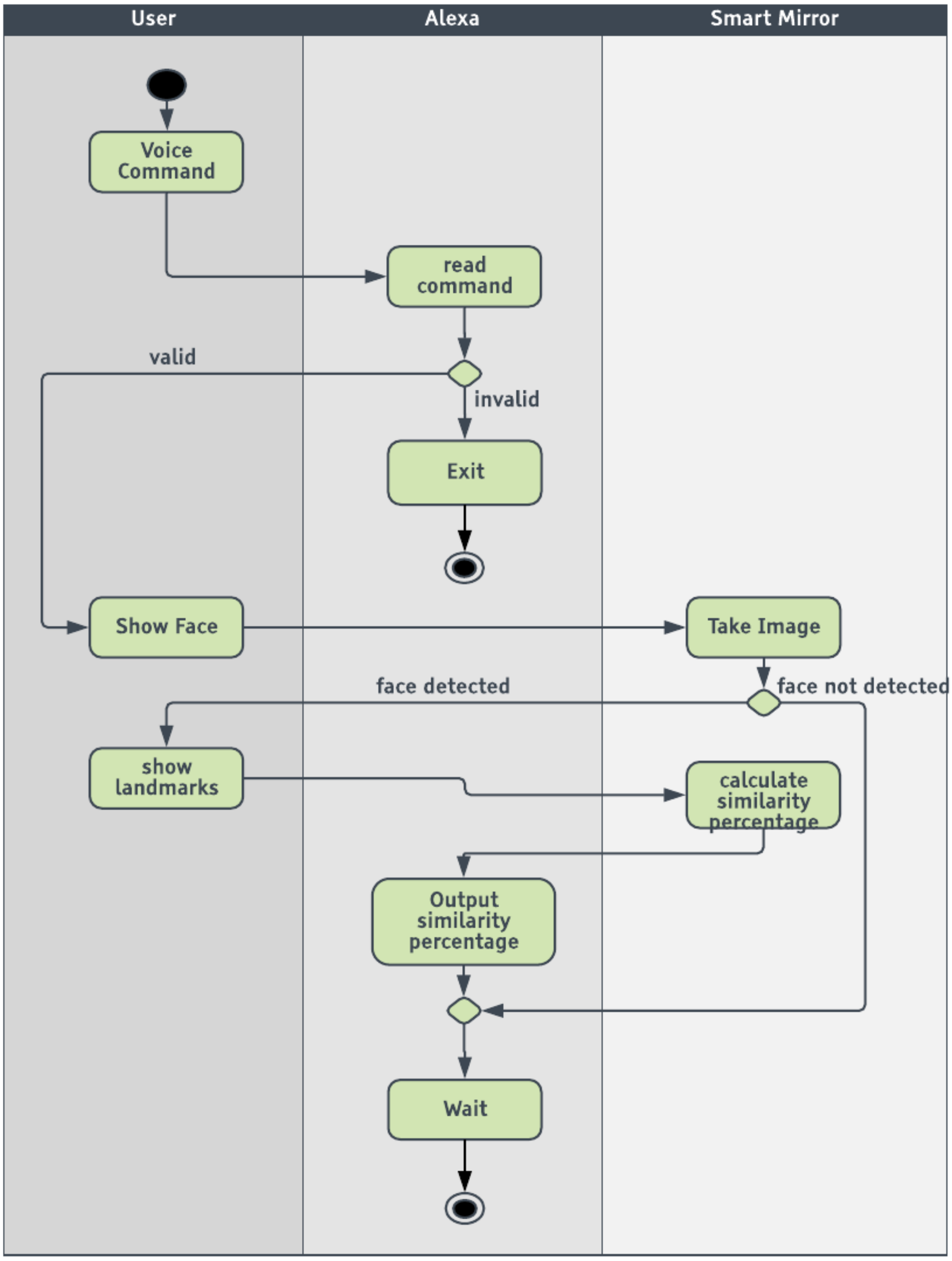
Figure 13 Modified display setup

The image in figure 13 shows all components of the display unit connected and together it can now be attached to the backside of the mirror and the raspberry pi 3. During installation to the mirror, there were some complications. The backside of the display was pure LED. As intended because the display needs the strength of the led to shine through the back of the mirror to the front.

However due to the strength of the LED, the backside of the display also illuminated the inside of the frame, making it so reflections are more difficult to see. To overcome this, I simply covered the backside of the plastic panel of “Ribba” with some thick black parchment paper. The only area left out was the frontside of the display. This allowed for only the display area to be illuminated and it also greatly improved lightning of the reflection in low light situations. The additional paper also allowed for an easy installation of the display unit. I used double heavy duty industrial tape attached with some covers to hold the display unit in place. Secured and attached it does not move around at all.

After this the final step was to attach the raspberry pi and the camera unit to the prototype, which would sit inside of “Ribba”. The extra-long wires allowed for a very simple installation right next to the display unit setup completing the final prototype. The prototype is now awaiting software installation.

Software design



This activity diagram shows a run through of the system. First the user walks up to the mirror. As Alexa is always on standby the user can simply call "Alexa" to get the voice assistants attention. When the user says "mirror mirror on the wall, who is the fairest of them all" Alexa will trigger the system to execute the main core function to measure the user's attractiveness in the smart mirror. The smart mirror takes an image of the user and analyses and draws the detected facial landmarks on the user image. This new image will be shown to the user. Once the preview has been closed the smart mirror will then calculate the similarity percentage, which will then be outputted by Alexa to the user. Once that process is complete Alexa transitions back into an idle state, where the next command can be read by Alexa.

User interface design

For the core functionality of this system, the Initial user interface would require very few requirements. The System must be triggered to be used effectively. Therefore, this would be the only requirement.

The system has two input devices one being the camera and the last input device is a small microphone. The camera is only active, when the user is triggering the system. Since the system has limited computing power, the camera would be a resource intense triggering requirement. If we were to use the camera with gesture control as a trigger to execute the main system, it would take up even more VRAM of the Raspberry PI 3 than it already has. Currently the main functionality of the attractiveness rating consumes up to 120mb of VRAM, while the raspberry Pi 3 struggles at a VRAM consumption of 130mb.

During development I have also noticed that the camera module stopped working when I tried to save up 130mb of VRAM for the main attractiveness rating. Concluding, this means that due to limited computing power, using the camera as an input device main trigger, is a bad idea.

This leaves the project alternative input device as a choice to be set as the main trigger. For this project I have purchased a USB microphone as an alternative input device. This could allow the system to be triggered by voice command. The nice thing about voice command is that it is universal, anyone can trigger the system and it does not require a lot of processing power. The Keyword detection can then run a script that executes the main function.

As for the actual user interface, it would just tell the user via a small sentence on what score has been achieved. This entire project is themed after Disney's movie Snow White, so therefore the mirror should act the same way. E.G the user walks up to the Mirror and says "Mirror, mirror on the wall, show me who is the fairest of them all", the mirror would then start executing the main function and output the results on the main screen. The mirror would then draw the output on the display saying something like "you're X % close to the fairest of them all"

If time permits this output would be part of the Magic Mirror Framework. The Framework has a set location for extensions and additional modules. The side functionality would also take display on the main screen.

Software implementation

This chapter of this report will focus on reporting the implementation process and the issues that have occurred during Software development.

Once the hardware platform has been developed, the next step was to create a software platform with a core feature. For the development to be carried out, it needed some preparation beforehand. It was to define what exactly the core function is. After long reviewing of work and evaluation of other projects. The Idea was to calculate facial attractiveness of woman under the age of 30. Due to limited time and resources, the idea was to focus on the main function first and then develop a user interface afterwards.

After reviewing previous work, I got a brief overview of what kind of techniques are available to carry out this task and have created a roadmap on how this can be achieved and what needs to be done for this main function to succeed.

Camera

The first step was to utilize the raspberry pi camera to take a simple image of the user. I did this by utilizing the raspberry picamera library in python and created a function that would do the following:

- Preview what the camera sees
- Take an image after a few seconds
- Save the image

It is very simple and does its job. However, after I have worked with the camera for a few times, I noticed some issues. The first issue was that the camera would take up a lot of VRAM while use. This would mean that I would be limited in that resource if I were to create a UI that utilizes that resource. I noted this down and worked further.

Image Analysis (facial detection, facial landmark detection)

Once the Image has been taken, the next step would be for the system to understand what is on the image. For a human its very simple to understand images and what exactly is on them. However, for a computer this is quite tricky. There are multiple tools and techniques that specialized on computer aided vison and artificial intelligence to carry out this task.

One of these methods would be to utilize pixel analysis. Pixel analysis is the method of identifying patterns on an image via pixel analysis. What this means is that the system is looking through each pixel and then try to make some sense of it, as pixels can have different values. With this technique you could identify different things such as facial features or even objects. One major drawback to this is that, you would need to try to teach the system what its looking for and that it would require quite some processing power to do so.

Another option was to utilize a library by Intel called OpenCV. OpenCV stands for open computer vision and it's a library that has functions that focus on real time computer vision. In other words, it makes sense of the image that the computer views. After further research into OpenCV, I concluded that this was the way to go. OpenCV had a bunch of additional functionality, besides offering to detect faces within images, that was useful to this project. It also had a wide community that actively worked on improving OpenCV. A drawback to utilizing OpenCV was that development was mainly done in a programing language called C++, however after further research I was able to find a port of this in Python.

C++ development could work on a raspberry pi, however I decided for a python based approach would be to develop in Python. This is also the approach this project utilized. OpenCV enabled to detect faces within pictures easily, the additional functions offered further support in this project. OpenCV's community was also quite useful. There have been extensions made for OpenCV that allowed for easy facial landmark detections. DLIB is a community project based on OpenCV that extends OpenCV's toolkit further. DLIB is a toolkit with various machine learning based algorithms. Now if you pass a facial landmark predictor through DLIB it will determine facial landmarks in the system.

Combining DLIB, OpenCV and python code I've developed a system that would take any image as input, calculate and define facial landmarks, return an array full of coordinates in a text file. This text file would be my output I could use for further calculation.

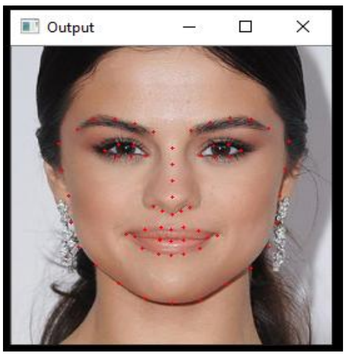
The perfect face

Once there was some data retrieved the next step was to try to compare that dataset to something. The systems aim was to measure facial attractiveness of females under 30 years old. This class of females is usually considered very attractive and usually people tend to have their own opinion on what they consider to be attractive. To compare the users, face to this category, there must be some data to measure against. For this there was no simple solution. Reviewing further work done by other scientists there were some methods discussed.

A great method would be to let the machine decide if the users face is attractive or not. This can be done via machine learning. Machine learning would need specific training for this and a dataset to do so. Due to the development time and scope of this project, this was not a suitable option. It would require some time for me to learn how to develop and train a model based on machine learning as well as a tagged dataset. However, there were other methods that could achieve the same for less time. If time permits in the future I could compare the suggested machine learning approach against the approach I chose for this project.

One of these methods was to create a morphed face of a bunch of models under the age of 30 what society considers attractive. The issue with this would be that creating this image might be a bit trickier than it appears to be. There is a bunch of problems in this. Morphing multiple faces does not create the ultimate attractive face, it rather creates a close to average face that is the result of multiple models morphed together.

That morphed face would look beautiful by no means; however, it is not the best solution to solve this issue. A better solution would be to use statistical analysis. This project has used statistical analysis to compare the users face to the faces of multiple models. Before a comparison can start there needs to be some data to be generated. As DLIB and the iBUG300w Facial Landmark detector model generates facial coordinates of the users face there coordinates of facial landmarks can be used as a starting point of



calculation. The landmarks drawn on the user face create in a way a digital version of their face. The detected landmarks get drawn on the user image that has been taken and an output with the image will be displayed

The detected landmarks produce a X and Y value of each landmark. This information will be split and stored separately. This would produce two documents, one for the X coordinate and one of the Y coordinate. This is the information one can use to compare against some dataset.

This project has its very own unique dataset. Since the mirror currently compares the user face against attractive females under the age of 30, the dataset of this project is based on this category. So, for the comparison this project utilized statistical analysis. The task was to create a statistical model the user can compare its face to. To do this, this project has utilized the same techniques of facial landmark detection, but on a larger scale. To train the model, I decided to get 100+ Images of attractive Caucasian female models under the year of 30. These images would then go through the training system. The training system prepares the images first to be the right size and then uses that new data to calculate facial landmarks within. This data would be taken by the system to create Variance, mean and standard deviation for every coordinate of each of the 100+ images and facial landmark X and Y coordinate. The training model would save its information in a document. With the statistical model finally trained, the values of the user would finally have something to compare against.

The final step of this system would be to simply compare the users face against the statistical model. For this task the system would simply count how many standard deviations each x and y coordinate differentiate from the statistical model. If the coordinate standard deviation is higher than 2 standard deviations of the statistical model, the system would flag that landmark X or Y value as an anomality point. If the users face has a lot of anomality points, it means that the users face does not have a close match with the faces of the statistical model. If the user has less or 0 it means that it is a close match with the statistical model, meaning the user is attractive according to the statistical model condition it compares against.

The great thing of this system is that, if the system changes the images of the statistical model and retrains it, you could compare the users face against anything that has a face. As an example, if you feed the statistical model images of babies, you could train the system to check if the user face is like that of a baby. The system can also be trained to an individual. E.G. feed the statistical model images of a superstar, you could see how closely the users face is to that superstar.

The actual final output the user receives is a % calculated how close the face of the user is to the statistical model.

User interface and user experience

For the user interface, this project has utilized the MagicMirror framework. The framework provides the user with basic day to day information. The Interface is black and white, so therefore it doesn't interfere too much with the reflection of the user on the mirror. The interface provides the user with the following:

- Local Weather Information
- Time and Date
- News Headlines
- Compliments

The framework is programmable and can list further modules the community has worked on. Users can even create their own functions by programing them. For the User experience Alexa has also been installed on the mirror. Alexa is a voice-based web assistant by Amazon. It can learn custom skills and execute custom code if programmed correctly. For this project Alexa can execute the main function upon hearing the following words "Mirror, Mirror on the wall, who is the fairest of them all". Alexa then should reply a few moments later with the output in percentage saying:" Hmm, I shall see, you are % *USER SCORE* close to the fairest of the land". Besides the main function Alexa can also reply to basic tasks, such as looking up things on the internet, make orders on amazon, carry out simple calculations, play back the news and provide traffic and weather information. Alexa and the magic mirror framework require an internet connection and run on startup.

Chapter 4: Testing and Result

As this project relies on constant activation and usage by the user, it always needs to be working and fully functional. There are very few testing techniques that properly test this. For this project the best testing method would be a mature between unit tests where their unit tests test the core foundation of the key function. The second testing method would be to simply test the system how it reacts in different users. As the System is trying to compare the users face to attractive females under the age of 30, different users should be expected to have some results. For this it would mean that a male user over 30 to have a very low score and a female which is attractive to be unattractive and a young female under 30, which is seen as attractive, to have a very high score.

Unit Testing

For Unit testing I have used the Unit testing module in python. I have conducted 3 Unit tests:

- 1st Test executes the main function and compares it to the output to have the same values

- 2nd Test checks if the formula that checks for Standard Deviation difference matches and calculates correctly

- 3rd Test checks if the formula for the final output to be the calculated correctly

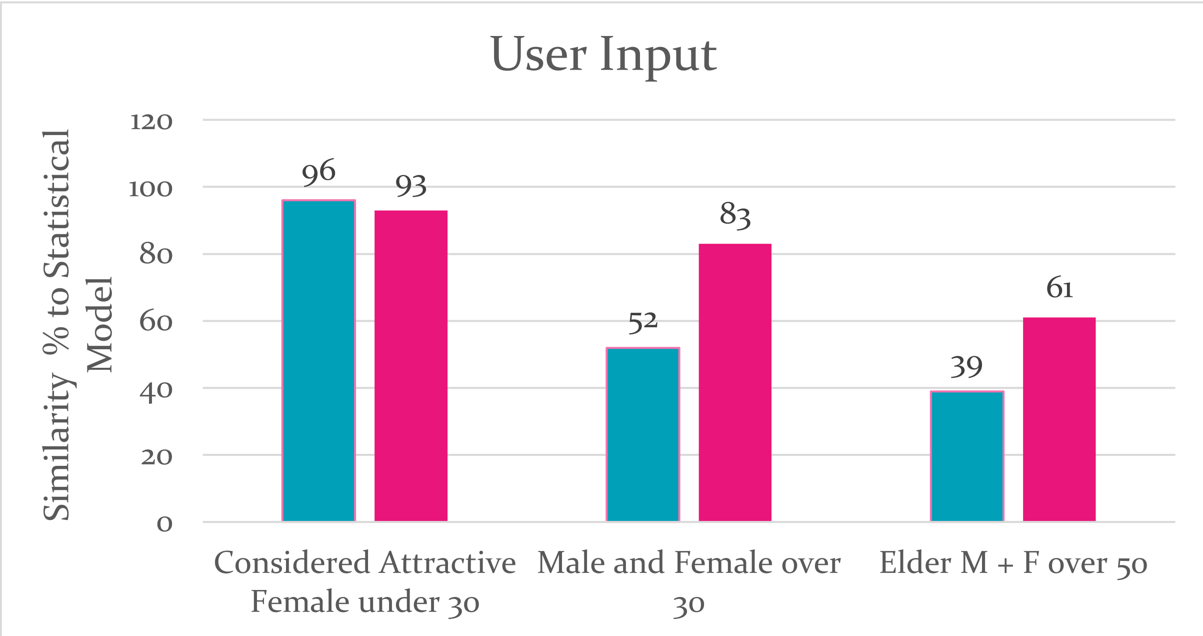
Result:

```
.
----------------------------------------------------------------------
Ran 3 tests in 2.808s

OK

(opencv-env) C:\Users\reday\Documents\GitHub\FMP_MagicMirror>
```

All Tests have reported correctly and returned TRUE.



This graph visualizes how the different categories in user perform. From this graph you can see that female users tend to have a slight score increase over male users. This makes sense since the system is looking for specific female facial structure as it has been trained for This makes sense, as male and female facial structure tends to be biologically different. This graph also demonstrates that age does matter in facial attractiveness. Older users tend to have a lower score than younger users. However, this is not always the case, since people from person to person can have different genes and some faces might look younger for the age.

Looking over the performance of users, this graph clearly visualizes that females who match the statistical models requirements, get a high score, where users that do not meet the statistical model requirements do not.

Evaluation

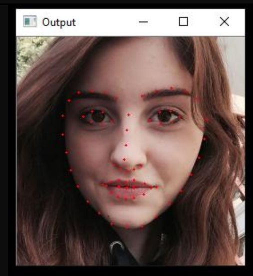
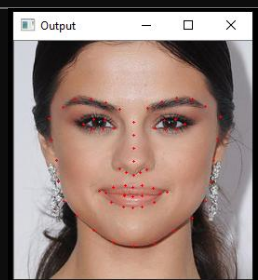
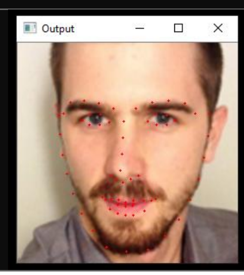
In this part of the document it will manually execute the system and compare different output results. The Evaluation is based on selfies friends and family have produced as well as images produced by the raspberry pi camera module via a live test of master.py.

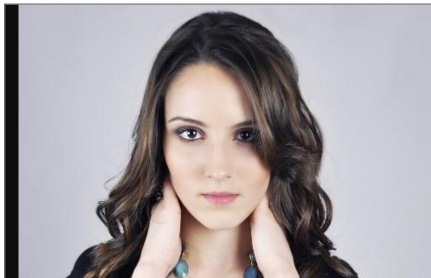
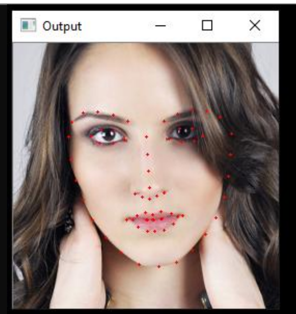
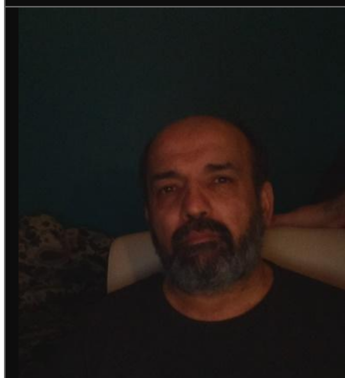
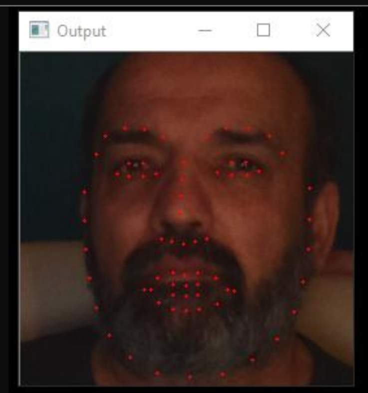
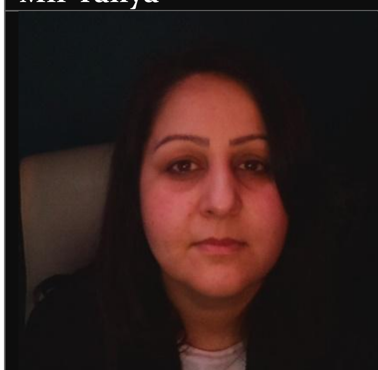
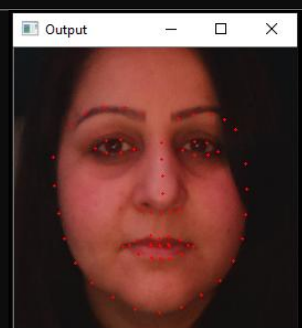
This test is a demonstration of different user categories the system might face. The demonstrate how the core function operates and handles different images as well as lightning conditions and image types.

The first few tests were a manual input of the images through the system. The system would take the image, analyze it and return an output. It would be just as the person in the image would walk up to the mirror and try to run the main function. The final last tests were real life examples of how the system would perform. In these two tests, I've shown the final prototype to the user and let them fully interact with it. At times the system would overheat and not respond fully, however after cooling down every feature worked well. This also includes the user interface functions as well as Alexa's side functionality. Alexa does not respond, when the system overheats.

Compiling time of the platform is also quite slow. Due to the hardware of the raspberry pi, compiling time averages around 14 seconds. This is something that can be improved upon in the future. A solution to solve this would be to utilize a server connection to the smart mirror and letting the server perform all calculations. Servers are equipped with better hardware and could compile and provide an output within 1 second. Therefore, it would drastically shorten the wait time the user has to wait to receive the final output

Here is a case scenario results:

Image	Facial Landmarks	Anomalous Points	Result (Similarity to model)	Evaluation
 **Chantal Steiner**		5	96.32352941176471 %	As her picture is part of the Statistical model (and since she is incredibly beautiful), she was expected to have a high similarity. With 96,32 % this is true and an accurate result.
 **Selena Gomez**		8	94.11764705882354 %	Another user who has a different image in the statistical model. Expected her to have her result to be high % and with 94,12 % this is true.
 **Random Guy**		52	61.76470588235294 %	As he is man, age under 30 and since the statistical model is based on 100 attractive females under 30, it is expected for him to have a slight lower percentage. With 61,76% this proofed to be true.

 **Random Woman**		27	80.14705882352942 %	Here is an image of a random woman. Her age is unknown, however judging her facial landmarks she seems likely to be above 30 and she is not part of the statistical model. Her score should be high, however not high enough to be very close to 100%. As her result was 80,14% this seems a very accurate.
 **Mir Yahya**		82	39.70588235294117 %	My Dad is male, and he is old. As the statistical model is based on attractive females under 30, I believe his score to be very low. Note: His right eye as well as his lips are not matched by the iBug 300w model, however due to the face alignment, eyes and partial use of lips do not accurate Standard Deviations regardless.
 **Nooria Yahya**		61	61.029411764705884 %	My mother is female, and she is old. All parts of her face have been identified accurately. Her result should be expected to be low too, however it should be slightly higher than people in her age category, as the model is based of females and females are biologically alike.

Conclusion and further work

Overall reviewing this Project, it has come quite far, and it has been successful.
The attractiveness measurement works really well. It produces an accurate result and the core function offers future improvements which can make this project even more effective and sophisticated. The Alexa voice assistant is also quite handy. Besides being the main trigger of the user interactivity, Alexa offers some more assistance functions and features ultimately giving a richer user experience to the user.

While it's not the best and stable project it does have some flaws. In the future further points can be improved upon:

- Statistical Model Improvements
  - Offer other categories (Babies, Elderly People or even Teenagers)
  - Offer more accurate information (Facial Region of differences)
  - Offer more facial landmarks (currently only offers 64 points)

  The statistical model offers more room for improvement, while it proved itself to produce accurate results, the System can be pushed further to provide a more detailed report of the user's face. Currently also the model provides facial landmark coordinate of 64 points. With a different and better facial landmark detector, it could provide more information about the user's face.

  As the facial landmarks are coded by coordinates, I could improve this system by defining what coordinates belong to what actual part of your face. For this I could have a set of coordinates to be part of the specific face part. This would help identifying critical areas in the face and potentially lead to a graphical display of critical regions of the user's face

  The Statistical model is also limited to one category, for a more sophisticated use for all types of users, more categories would be required.

- Improved User Interface
  - Currently acts upon voice recognition and gives a poor visual interface
  - Project aim was to provide an additional UI with features from the MagicMirror Framework

  The UX and UI is quite limited there is plenty of room of expandability.

- Improved Hardware
  - Better looks, improved display and computational hardware

Since this Project was limited in time and founding, a better choice of hardware could've been made. The raspberry pi is a microcomputing system that does not have a lot of power compared to a full computing system or even a laptop. Compiling and processing time is quite long and slows down the experience of the user. Overheating is also an issue with the current load of the work and the hardware capabilities.

Another alternative that could help performance would be to link this system to a web service. Users would upload images via their mirror to a web server where the web server, with powerful hardware, return the output of the calculation back. This would improve hardware performance massively.

References

Boing Boing. (2018). DIY smart bathroom mirror. [online] Available at: https://boingboing.net/2016/02/04/diy-smart-bathroom-mirror.html [Accessed 16 Apr. 2018].

Cunningham, M. (2018). Measuring the physical in physical attractiveness: Quasi-experiments on the sociobiology of female facial beauty.

Displaysolutions.samsung.com. (2018). Mirror Display ML55E | SMART Signage | Samsung Display Solutions. [online] Available at: http://displaysolutions.samsung.com/digital-signage/detail/848/ML55E [Accessed 16 Apr. 2018].

Forbes.com. (2018). Forbes Welcome. [online] Available at: https://www.forbes.com/sites/karenhua/2016/10/07/panasonic-smart-mirror-shows-you-your-face-flaws-and-helps-you-fix-them/%237f313fd53204 [Accessed 16 Apr. 2018].

Kagian, A., Dror, G., Leyvand, T., Meilijson, I., Cohen-Or, D. and Ruppin, E. (2008). A machine learning predictor of facial attractiveness revealing human-like psychophysical biases. Vision Research, 48(2), pp.235-243.

Mail Online. (2018). Samsung's smart MIRROR shows weather and traffic as you brush teeth. [online] Available at: http://www.dailymail.co.uk/sciencetech/article-3118491/Samsung-s-smart-MIRROR-shows-weather-traffic-information-Facebook-notifications-brush-teeth.html [Accessed 16 Apr. 2018].

TechCrunch. (2018). What is a smart mirror and why do so many companies think you want one?. [online] Available at: https://techcrunch.com/2017/01/17/smart-mirror/ [Accessed 16 Apr. 2018].

Thornhill, R. and Gangestad, S. (1999). Facial attractiveness. Trends in Cognitive Sciences, 3(12), pp.452-460.

Valenzano, D., Mennucci, A., Tartarelli, G. and Cellerino, A. (2006). Shape analysis of female facial attractiveness. Vision Research, 46(8-9), pp.1282-1291.

Zhang, L., Zhang, D., Sun, M. and Chen, F. (2017). Facial beauty analysis based on geometric feature: Toward attractiveness assessment application. Expert Systems with Applications, 82, pp.252-265.

[8] Dario Riccardo Valenzano, Andrea Mennucci, Giandonato Tartarelli, Alessandro Cellerino, Shape analysis of female facial attractiveness, In Vision Research, Volume 46, Issues 8–9, 2006, Pages 1282-1291, ISSN 0042-6989,

[9] Swami, V., & Furnham, A. (2008). The psychology of physical attraction. New York: Routledge/Taylor & Francis Group.

Gray D., Yu K., Xu W., Gong Y. (2010) Predicting Facial Beauty without Landmarks. In: Daniilidis K., Maragos P., Paragios N. (eds) Computer Vision – ECCV 2010. ECCV 2010. Lecture Notes in Computer Science, vol 6316. Springer, Berlin, Heidelberg

Akira Media Systems, Gan, J., Li, L., Zhai, Y., & Liu, Y. (2014). Deep self-taught learning for facial beauty prediction. Neurocomputing, 144, 295-303.

Lisa DeBruine. (2017, December 4). Webmorph (Version v0.0.0.9001). Zenodo. doi:10.5281/zenodo.1073696

Davis E. King. Dlib-ml: A Machine Learning Toolkit. Journal of Machine Learning Research 10, pp. 1755-1758, 2009

Pulli, K., Baksheev, A., Kornyakov, K. and Eruhimov, V. (2012). Real-time computer vision with OpenCV. Commun. ACM, 55(6), p.61.

Ribba by Ikea

Silver Reflective Window Film by Aktive Film

Modified "Ribba" by Reday Yahya

Magicmirror.builders. (2018). MagicMirror². [online] Available at: https://magicmirror.builders/ [Accessed 16 Apr. 2018].

Raspberry PI 3 - https://www.raspberrypi.org/products/raspberry-pi-3-model-b/

Raspberry Pi 3 model b Specifications - https://hackaday.com/2016/02/28/introducing-the-raspberry-pi-3/

Hotornot.com. (2018). [online] Available at: https://hotornot.com/ [Accessed 20 Apr. 2018].