MEMORANDUM

TO: **Dr. Theresa Conefrey**
FROM: **Théo Arrouye, Jackson Centeno, Morgan Fleshren, Jackson Tseng, and Christopher Woo**
DATE: **March 4, 2020**
SUBJECT: **Transmittal of the Draft Report on State of the Field of Facial Recognition**

Attached to this memo is our report reviewing the state of the field of facial recognition. This report provides an overview of the current state of facial recognition as integrated into our society. It also serves to provide a fundamental understanding of how facial recognition is implemented in the context of real world applications. The focus of the paper started with facial recognition (see appendix A for our original proposal); however, we found the most interesting cases of facial recognition were in institutional use. This refinement of scope can be found in our progress report (see appendix B).

Facial recognition is a subset of visual, classification machine learning in which photos of faces are converted into biometric data. This biometric data identification innovation provides undeniably faster identification, is cost-effective compared to other biometrics in most situations, and is arguably more secure. For these reasons, institutions have been eager to experiment with facial recognition, yet cautious of the privacy and viability risks.

The purpose of this report is to inform the reader of the effectiveness of facial recognition in real world applications. Building an understanding is vital to spreading ideas of facial recognition to other sectors, as well as promoting productive, secure innovation to our society. In addition to that, we hope a comprehensive report will quell common concerns over privacy as well as teach the advantages of facial recognition.

Thank you, Dr. Conefrey, for your guidance as a professor and instructor. The comprehensive breakdown of each section of a formal report was instrumental for constructing a professional, educational document. Also, thank you Dr. Boyd for the presentational seminar demonstrating the effective use of the comprehensive Santa Clara University library database.

Facial Recognition
State of the Field Report

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Introduction

Background

Facial recognition technology has improved dramatically in recent years, particularly with the advent of artificial intelligence (AI). Facial recognition software allows users to match captured photos or videos against a database of photographs to identify the person(s) in said photo or video. As this technology has become easier and more practical to implement, there has been growing interest from institutions to implement facial recognition for a variety of uses. Police departments, for example, are enticed by the ability to quickly identify suspects from security footage. Others worry about the privacy implications of having this technology widely available. The rise of facial recognition has coincided with the availability of low-cost, miniaturized camera technology. Together, the two technologies offer the opportunity to track individuals across large areas on a mass scale. This idea makes many people uncomfortable.

Advances in artificial intelligence have made possible feats such as a computer program that can teach itself how to play board games such as Go, chess, and shogi with no human intervention (Ouellette, 2018). They have also, however, sparked fears about machines "stealing our jobs" and militaries deploying killer robots. Many of these fears come from a lack of knowledge about the underlying technology. While it is true that artificial intelligence is capable of learning and performing increasingly complex tasks, current systems still lack the ability to generalize - a crucial component of human intelligence. A system may be able to teach itself Go, but that same system couldn't also teach itself how to create a spreadsheet in Excel. Your average human, on the other hand, can teach themself an infinite number of concepts and tasks.

Purpose

In this report we will demonstrate some of the benefits and applications of facial recognition powered by artificial intelligence. While we understand the fears surrounding the technology, we believe that there are positive, ethical applications for it as well. First, we will provide background information describing how facial recognition technology is implemented. Then, we will review and analyze modern applications of facial recognition. The main focus of our report is how facial recognition is being applied by institutions such as governments.

Methodology

We gathered our journal sources by performing searches in the Engineering Village database and Google Scholar. For popular sources, we simply used Google. Our initial search terms returned hundreds of results but we were able to narrow our search down to get a more reasonable number of results. We did this using limiters in the database search functions. Each member selected several sources based on the abstract, and reviewed it for relevance. We then analyzed the sources and compiled our research notes.

Basics of AI

Defining AI

Even today, the term *artificial intelligence* is loosely defined. At the most basic level, it refers to intelligence demonstrated by an artificial (non-living) being such as a computer. The natural comparison to draw is with *natural intelligence*, as seen in humans. Intelligence is defined as "the ability to acquire and apply knowledge and skills" ("Intelligence," 2020). AI is

typically viewed as one of two classifications: strong AI, and weak AI. Strong AI is the holy grail — AI capable of general reasoning and human-like reasoning at a level that surpasses natural intelligence. Unfortunately, this level of AI is currently out of our reach. Instead, what we have today is weak AI — "highly specialized algorithms designed to answer specific, useful questions in narrowly defined problem domains" (Huang, 2019). The board-game learning computer program described in the introduction, for example, falls into this category; in that case, the specific question is "how do I win?" and the problem domain is inherently limited by the relatively simple rules of the games. These programs are impressive in their own right, but are far from demonstrating the kind of general intelligence that defines strong AI.

Researchers generally agree that the techniques that have brought us these impressive weak AIs are unlikely to scale to the creation of strong AIs (Huang, 2019). Despite this, the advent of new techniques in recent years has led to a marked increase in the capabilities of machines, and the weak AIs we have today are capable of feats that were impossible in the past. Two of these techniques, machine learning and deep learning, are thrown around as buzzwords quite liberally. In the following sections, we'll break down what these terms mean and why these techniques represent breakthroughs.

Machine Learning

Machine learning is a specific way of teaching machines intelligence. Rather than write down all the rules of the problem, you try to build a system that can figure the rules out for itself. Say you want a program to determine whether a picture is a cat or not. You could try to come up with a bunch of rules for determining whether a picture contains a cat and hard code these into

your program. But that process would be very time-intensive and hard to scale. What if, instead, you could just show your program a bunch of pictures with and without cats, and let it come up with its own rules based on these examples.

This concept underpins machine learning. The more data you have to show your AI, the better it can make its rules and the more accurate it will be. But how does the program actually *learn* from these examples? In order to store this learning, you need a *model* — a computational representation of the learning (Huang, 2019).

Let's look at a simple example of a model provided by Haomiao Huang (B.S. from Caltech and Ph.D. from Stanford). In Figure 1, we see a basic model for determining how sweet a fig is. The input data is the softness of the fig.

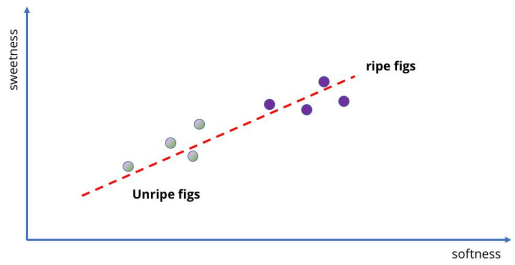

Figure 1 - Simple Model for Determining Fig Sweetness (Huang, 2019)

As you can see, this model is very simple. You choose some samples of figs with varying softness, see how sweet they are, then put them on a graph and draw a linear best-fit line. This line is the model. In theory, the more samples you collect, the more accurate this model will be. As the data becomes more complex, however, so too must the model. Take a look at Figure 2, where Huang now adds samples for rotten figs. These figs are softer than a ripe fig, but far less sweet. This discrepancy breaks the simple linear model.

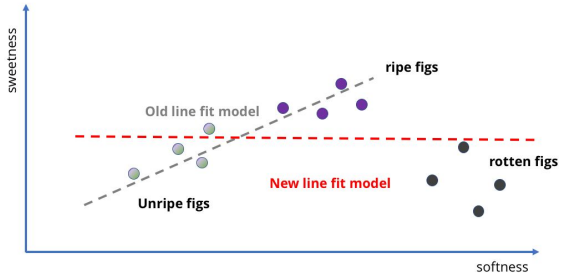

Figure 2 - Fig Sweetness Linear Model with Additional Data (Huang, 2019)

No matter how many samples are collected, this linear model will never be able to accurately determine the sweetness of figs if rotten ones are included. To handle this more complex data, the model must be made more complex. In Figure 3, we see how Huang handles this example situation by adjusting the model to a quadratic fit rather than a linear fit.

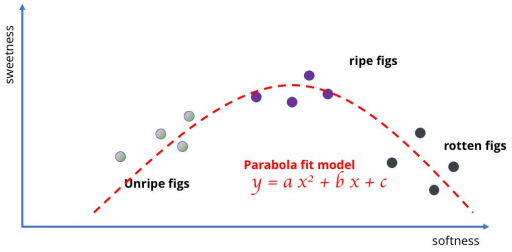

Figure 3 - Quadratic Fit Model for Fig Sweetness (Huang, 2019)

With this improved model, you should be able to accurately predict fig sweetness, even for rotten figs, given enough sample data. This simple example demonstrates the importance of choosing the proper model for machine learning. As Huang puts it, you "need a model that is sophisticated enough to capture really complicated relationships and structure but simple enough that [you can] work with it and train it" (2019).

Deep Learning

Deep learning is a subset of machine learning that uses *deep neural networks* as the model. Neural networks are algorithms loosely modeled after the neural structure of the human brain, hence the name. They are designed to recognize patterns and make predictions. To do so, they are organized into layers; each layer performs a set of computations and passes the output to the next layer (Huang, 2019). Stacking these layers allows you to perform more complex computations. A *deep* neural network, then, is a neural network with many layers, allowing for powerful models.

Basics of Facial Recognition

The basic idea behind computer recognition of objects is simple - break complex objects into simple objects, and simple objects into primitives. A face is made up of eyes, a nose, a mouth, etc. These in turn are made up of circles and lines. So, to recognize a face, you must recognize a pattern of eyes, noses, and mouths. To recognize an eye or a nose, you must recognize patterns of circles and lines. This kind of segmentation lends itself well to the concept of layers in neural networks - one layer can recognize the patterns that make up eyes and noses, and pass that on to the next layer which can recognize patterns of eyes and noses that make up a face.

Facial Recognition in Institutions

Facial Recognition in Education

Facial recognition technology has become increasingly integrated into school campuses in a bid to increase security systems and prevent dangers such as school shootings. Facial recognition is a tool that can be used to help prevent school shootings by identifying and tracking an unknown perpetrator on campuses faster. It is best used in addition to traditional methods of campus safety such as safety officers. One school has camera recognition software with "video object classification trained to detect gun-shaped objects, alongside more subtle forms of 'anomaly detection' such as students arriving at school in different-than-usual clothes, bags and other apparel" (Andrejevic, 2019). The software gives administration a better chance at stopping a shooter because it will identify when and where an unauthorized person enters campus, thus allowing the administration to contact the police and monitor where the students and staff are.

Another application for facial recognition in educational systems is automated attendance. This is estimated to save teachers up to 2.5 hours of time each week as the system automatically marks attendance. The larger the group of students, the higher the time savings will be. Facial recognition is also becoming popular in online schools as it can ensure academic integrity virtually and help proctor examinations remotely (Andrejevic, 2019).

Additionally, facial recognition has been used for emotion analytics. This type of program is used to track the students' engagement and comprehension of the material based on their facial expressions. Successful student learning is generally reflected through facial expression patterns. This allows the teacher to get a report of how well the students are comprehending the material based on categorized facial expressions. As stated by Dewan in

Andrejevic's journal article, there is a "growing interest in the face as a 'continuous and non-intrusive way of … understand[ing] certain facets of the learner's current state of mind" (Andrejevic, 2019). The ability to understand and record these facial expressions gives teachers a better sense of what is going on in the students mind.

Lastly, while all this new technology for facial recognition in education seems impactful and beneficial, there are concerns with the use of this technology in a public space. One such concern is misidentification by the machine. The software is trained off an existing dataset, which can lead to bias and discrimination by the machine's decisions if the dataset is skewed racially or otherwise. For example, machines have consistently failed at recognizing African American people accurately because the software has typically been trained with very few people of color (Andrejevic, 2019). Another challenge is identical twins, as their facial features are much closer making it harder for the software to distinguish them. It is hard to have a machine identify everyone correctly, and many systems train only with data on certain demographics (Andreejevic, 2019).

Facial Recognition in Governments

With the advent of better facial recognition software and improved camera technology there are many opportunities for governments to improve their work with facial recognition. Facial recognition helps the government increase security and prevent crime by identifying individuals. For example, there are some states within the United States which have scanned drivers license photos to create a database of people allowing easier identification of criminals by the police force (Ghaffary, 2019). It is also used in many airports as an additional security

measure to screen passengers before their flights. Facial recognition helps validate the travelers' identities quicker than the traditional method of humans. This adds an extra layer of security and reduces wait times for people crossing the border (Carlos, 2018). Another use of facial recognition is Amazon's Ring camera products. These products allow law enforcement to access camera feeds and recordings, which helps police identify and locate recent package thieves and criminals (Ghaffary, 2019). In general, the US police force is eager to start utilizing more facial recognition technologies because it helps them stop crime.

Facial recognition seems to be purely positive, however, there is opposition to government forces, such as the police and FBI, using facial recognition. There are groups pushing to ban government use of facial recognition, because they think that government surveillance with facial recognition is too oppressive of the right to privacy (Ghaffary, 2019). In Figure 4 we can see a map of the current use of facial recognition surveillance in the United States.

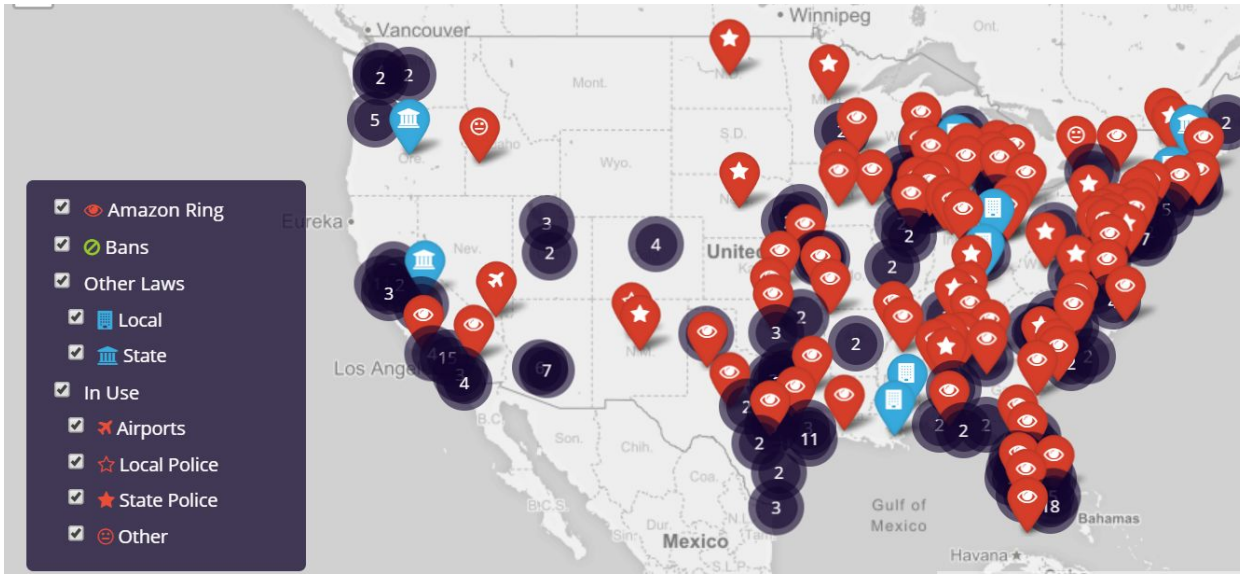

Figure 4 - US Face Recognition Surveillance Map by Fight for the Future campaign (Ghaffary, 2019)

The map above shows facial recognition in many of the major cities, but it is not present in all states. In general facial recognition software is growing for government use, but some local governments have reservations about implementing it. Some cities such as San Francisco, California, and Somerville, Massachusetts, have completely banned local law enforcement from using facial recognition (Ghaffary, 2019).

Facial recognition also has uses in border control, such as providing a more secure identification check. This allows border control to quickly identify those entering/exiting/near the border (Carlos-Rica, 2018). Traditionally, the quality of the check is derived from the agent performing the check. A full check means they must check the validity of any paper identifications as well as match the person to the papers. The use of facial recognition would speed up the process of matching the person to the identification. Integrating facial recognition into border control would be a fairly easy process, given that those crossing the border are already required to possess the proper identification.

Looking to the Future in the U.S.

Examples in India

Countries such as India have begun expanding on their facial recognition technology after seeing the effectiveness of its implementation. India has over 300,000 missing children largely due to human trafficking. In order to reunite them with their families, India is using facial recognition to match the children they found with photos of the children who went missing. This has proven to be beneficial, with almost 11,000 missing children matched in the system

already (Zaugg, 2019). Given the US has a similar issue with human trafficking, maybe the US should head down this route in the future.

Examples in Nigeria

In Nigeria, Sotonwa and Oyeniran explain that the old-fashioned way of taking attendance is time consuming and often leads to impersonation. Facial recognition offers a solution. Their specific situation uses a "multi-algorithm approach" and employs "bimodal biometric techniques" (Sotonwa & Oyeniran, 2019). This approach is becoming popular throughout the world, except for the United States. All people have distinguishable traits, whether it is their face shape, space between eyes, mouth shape, or iris. In Sotonwa and Oyeniran's study, they evaluated the existing facial recognition system in Nigeria for taking attendance. In their study, "the recognition time for the input image was approximately 2.00 seconds" and the FAR (false acceptance rate - the rate that the "system will incorrectly accept an attempt by an unauthorized user") came out to 0.2% - only 2 out of every 1000 images were falsely accepted (Sotonwa, 2019).

People choosing to use the state health insurance program in Kwara, Nigeria will also find themselves using facial recognition. Chris Burt writes that two years ago "[t]he government of Kwara State in Nigeria partnered with SmilePass to launch a Universal Health Insurance Program which will provide primary medical care to three million residents with facial recognition" (2019). The process is fairly simple. Each citizen first uploads a profile picture then fills out personal information using their phone. This data allows citizens to be recognized at clinics by a machine and fees will be subsidized accordingly (Burt, 2019). This saves time for the

patient, and removes much of the work a secretary would have to do to check somebody in and verify personal information. It also speeds up the insurance coverage process, since the state insurance program will instantly deduct up to 70% of the fees as soon as the patient is identified (by facial recognition) as a citizen of Kwara, Nigeria.

Example in Finland

Integration of facial recognition into airports still provides the necessary secure identification of the typical airport, while actually improving upon several traditional methods. First, facial recognition would solve the traffic congestion born of bottlenecking customers through traditional security points. This is especially important when considering that by 2036, Duman anticipates airports will see 7.8 billion passengers per year (2019).

One case study at Helsinki Airport in Vantaa, Finland explored the use of facial recognition in security measures (Duman, 2019). Conducted by Finavia Finnair and consultancy Futurice, the study is aimed at analyzing the customer experience as well as the return on investment. As airports are high-risk environments, the study was only able to be conducted alongside traditional security measures. However, the study aimed to create a security model in which customers were only stopped if needed; paper identification would only be required if issues arose with facial recognition.

This model begins with the user downloading a mobile app and uploading a picture to begin a profile. The mobile app is advantageous to this model because it can begin even before users arrive at the airport and it aligns with building a data relationship with the customer. In surveying users, 95% rated the app positively for “ease of use” (Duman, 2019).

Additional insights of the Helsinki experiment include an innovative balance between employee and machine interaction. The model used in the experiment would have the customer drop bags off at a kiosk while the attendant would discreetly confirm identification, allowing for more time spent providing customer service. The routine identification is left to the facial recognition system. The experiment stressed the use of facial recognition as a tool for the employees to provide better service -- not simply as a cost-efficient replacement for employees.

The most important attribute of facial recognition within an airport is its ability to reduce congestion by providing faster identification. This model is also more secure, as it monitors customers before *and* after passing through the entrance. Additionally, faces are unique and thus more secure to identify with than a small, paper identification that can be easily forged. Another advantage is touch-free interaction which deters the spread of diseases. Travelers are more susceptible to diseases from other places that their immune systems are not used to. Eliminating an avenue of contact helps reduce the risks of these diseases.

An overarching concern with this kind of system is data privacy. In the Helsinki experiment, many steps were taken to assuage customers' fears, resulting in an 80% approval in terms of privacy (Duman, 2019). The recognition tool has additional safeguards to anonymize any people who are outside of the designated areas. Additionally, the people who are scanned have their photos converted to an untraceable biometric ID.

Example in China

Primary and secondary schools in China are implementing facial recognition to "better grasp the emotions of learners, thus introducing emotional teaching in education, which helps to

improve teaching effects" (Li, Liu, Gong, & Jing, 2019). Li continues to explain that due to lack of energy, teachers are often unable to identify and accommodate for the various emotional states of their students. Not only is facial recognition used to gauge bad moods, but it is also used to monitor current attitudes towards the current material and teaching method. Teachers are able to instantly know whether or not students are captivated by the lesson, as well as track the students' understanding of the material. Students looking confused are most likely not understanding the material, and students exemplifying confidence typically are comprehending the material. Facial recognition can even "predict the difficulty of video tutorials and student viewing speed" (Li et al., 2019). Once again, by judging how well the audience understands the material, the teacher can speed up or slow down accordingly. For a video tutorial, this can be useful for the person making the tutorial, so they can add more details or slow down where necessary before publishing the tutorial.

The flowchart below shows Li's proposed classroom facial recognition idea flow. The image is first acquired, then put into a gallery of other photos. After gathering all the information they can gain from the other faces that have already been added to the gallery, normalization (applying a bell curve) occurs. Then the system pulls out facial features such as their eyes, nose, mouth, etc. and classifies them into their feature groups. With this, they can find potential matches for the individual features based on the attendance database, and then fuse together the results to find the final, correct match. The system then puts the attendance information for each day into the semester report for each student.

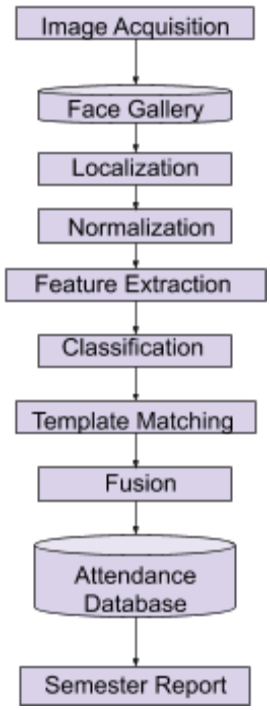

Figure 5 - The Proposed Framework for Computerized Student Attendance Management System (Li, 2019)

Conclusion

The level of artificial intelligence that we have access to today is not something that people should be concerned about. Since it can only process information that it has been programmed to process, this technology poses no threat beyond its programmed nature. Additionally, facial recognition has been proven to have many positive applications ranging from increasing school attendance to decreasing crime. With the vast variety of applications of the technology, there are many who support its expansion as well as many who do not. Noting that it is important to have clear communication with local communities when implementing facial recognition devices, we believe it is a technology that can be used to benefit society. Facial recognition can and *should* be installed in locations that would allow law enforcement agencies

to more effectively tackle crimes. Countries such as China, Nigeria, Finland, and India have all taken steps towards expanding their implementations of facial recognition. In turn, they have reaped the benefits outlined above.

Recommendations

It is recommended that people should not fear the growth of artificial intelligence or the use of facial recognition. Artificially intelligent facial recognition poses no threat to us when it is being used for the correct reasons. The technology can be used to further advance school systems and security control in America and can be used to decrease crime rate in high-crime areas. Through all the benefits, it is still important that this technology is well-regulated and laws are put in place to ensure that it is being used properly.

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Appendix A: Project Proposal

DATE: **Feb 6, 2020**
TO: **Dr. Theresa Conefrey**
FROM: **Théo Arrouye, Jackson Centeno, Morgan Fleshren, Jackson Tseng, and Christopher Woo**
SUBJECT: **Project Proposal**

Problem

General misunderstanding/misinformation of what artificial intelligence and facial recognition are cause unnecessary fear

Solution

Researching to explain the implementations of artificial intelligence and facial recognition.

Rationale

Due to the general misinformation on the ideas and implementations of artificial intelligence and facial recognition, the general public may be unaware of the current state of AI and may have irrational representations of what AI is capable of. Our group is researching A.I. and facial recognition in order to explain their uses and benefits to society at its current state and capabilities.

Significance and Relevance

Facial recognition is a rapidly growing field. Due to the way that the media has presented it, people have split opinions on whether or not it should be expanded or stopped. There is a growing movement calling for governmental regulation of the technology. Some fear the technology could further erode freedoms. It is important to clear up the myths about the technology and its implementations of artificial intelligence.

Work Schedule

Week 6: February 9 - 15	Write rough draft of progress report with bibliography
Week 7: February 16 - 22	Continue editing draft of progress report
Week 8: February 23 - 29	Finalize progress report
Week 9: March 1 - 7	Revise draft report
Week 10: March 8 - 14	Finalize final version of final report before final's week and oral presentation (finally)

Task Breakdown

Basic explanation of the technology behind facial recognition	Jackson Centeno
Collect research, Paper drafts	Team
Editing	Chris Woo, Théo Arrouye
Presentation script/setup	Morgan Fleshren, Jackson Tseng
Turn documents in	Jackson Tseng

Research Methods and Methodology

The research of this project will be conducted through the Association for Computer Machinery digital library, the EngineeringVillage database, and the IEEE Xplore platform. These resources offer scholarly peer reviewed articles and journals to research from, and offer the most recent groundbreaking work taking place in the field of AI. We will refer to technology within the last four years as the field of AI is rapidly changing.

Scope

- Focused on the impact on people
- Impact on society
- Brief on what artificial intelligence and facial recognition are
- Why AI is not actually bad/scary
- How we will inform people/society

Appendix B: Progress Report

DATE: **Feb 25, 2020**
TO: **Dr. Theresa Conefrey**
FROM: **Théo Arrouye, Jackson Centeno, Morgan Fleshren, Jackson Tseng, and Christopher Woo**
SUBJECT: **Progress Report Memo**

Purpose:

Our final report is intended to demonstrate the benefits of AI-powered facial recognition. We do so by reviewing and analyzing modern applications of facial recognition. We also look at how facial recognition is being applied by institutions such as governments. This memo is a progress report detailing what our group has completed so far. It is also intended to provide readers with details on what work remains to be completed leading up to the final report.

Changes:

Our original topic that we had agreed upon was to analyze various modern approaches to facial recognition that have been tested. However, this proved to be too broad in scope and was later changed to the benefits that facial recognition provides when applied in institutions.
Our current sources are more geared towards our previously agreed-upon topic. We plan on researching more on the benefits of facial recognition as well as the history of facial recognition in order to complete our final report.

Key Terms:

1. **AI (Artificial Intelligence)**

   Intelligence demonstrated by machines, not humans. Any technology that solves problems like a human would.

2. **ANN (Artificial Neural Network)**

   Nodes that work together to produce a result. Each node is responsible for some part of the problem, so when combined into a network they can solve the whole problem.

3. **CNN (Convolutional Neural Network)**

A deep neural network that has numerous applications within facial recognition.

4. **DL (Deep Learning)**

   Machine learning tasks that use neural networks with multiple layers.

5. **FKP (Facial Keypoint(s))**

   Points that are marked throughout the face, mostly around the eyes, nose, mouth, and face shape. These points create a unique signature, which is how faces can be recognized.

6. **ML (Machine Learning)**

   A subset of AI. Most AI applications are built with ML. ML is the supporting technology. This technology aims to create algorithms and models that computers can use to perform a specific task without using explicit instructions, but rather relying on patterns and inference instead, much like how humans learn.

7. **MNIST (Modified National Institute of Standards and Technology)**

   A benchmark dataset that can be applied to algorithm comparison (performance, cost).

8. **PFE (Probabilistic Facial Embeddings)**

   A method for facial recognition that allows for more uncertainties such as a blurry or low-quality image.

9. **RNN (Recurrent Neural Network)**

   A neural network with loops; it uses previous information for making future decisions.

Current Status:

Work Completed:
- Project proposal
- Work schedule
- Found sources that will be used in the final report
- Scoped

Work in Progress:
- Reviewing sources
- Gathering information and data to be used in final report
- Project outline
- Finalizing the direction of our project

Work to be Done:

- Finish writing the draft
- Edit and revise the final report
- Create the oral presentation