Analysis of Masked Facial Recognition Algorithms
(Technical Paper)

Use of Facial Recognition in Modern Society
(STS Paper)

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Computer Vision is defined as the field of study which focuses on the development of methods and techniques for computers to understand the content of digital media such as photos and videos. (Brownlee, 2019, para. 1) Although humans can easily analyze and annotate an image, it is much more difficult for a computer to do the same. The general goal of computer vision is for a computer to extract useful information out of images/videos, which has been worked on by CV researchers for the past four decades (as cited in Brownlee, 2019, para. 30). Facial recognition is a subfield of computer vision, where a computer determines the identity of a person given an image of the persons face.

In the past few years, the field of computer vision has seen great successes, with improvements in computing technologies leading these advancements (Singh, 2019, para. 2). My state of the art report and my tightly coupled STS research will look at recent developments in computer vision technologies, analyze the issues arising from its introduction into everyday society, and discuss my findings in the report. For my state of the art report, I will research notable papers published in artificial intelligence and machine learning journals to construct a report on state of the art computer vision technologies. I will analyze the architecture used and the results obtained in these papers to perform an analysis of the improvements of computer vision algorithms. The tightly coupled STS research paper will investigate literature discussing cases of facial recognition applied in different environments and analyze the potential ethical and societal impacts resulting from the issues of bias, privacy, and trust with facial recognition. Using Actor Network Theory, potential solutions for these issues may be revealed for engineers to take into consideration when continuing research in computer vision. As my project is a state

of the art report, my technical project will be completed in the spring and my technical advisor will temporarily be Professor Aaron Bloomfield from the Computer Science department.

COMPUTER VISION FOR FACIAL AND OBJECT RECOGNITION

Computer Vision is a subset of artificial intelligence and machine learning where researchers teach a computer to extract meaningful information from an image (Brownlee, 2019, para. 14). Because of advancements in artificial intelligence and machine learning, new techniques are being applied to computer vision to develop more and more accurate and versatile algorithms, many of which match or even surpass human vision in some tasks (Mihajlovic, 2019, para. 3). For example, in Figure 1, the computer vision algorithm developed by Liu et. al., dubbed the Single Shot Detector, detects the tennis player, the tennis racket, the spectator, and some of the spectator chairs (2015, p. 33). The left chair, which evaded detection, evidences the minor flaws in these systems which keeps them from matching human perception. Of course, this is just one example of the Single Shot Detector in action. There are numerous other computer vision systems each with something different in its implementations which makes it perform differently in some form.

Figure 2: Computer Vision Algorithm Identifying Objects. Example of a Computer Vision Algorithm Identifying Significant Objects (Liu et. al., 2015)

The importance of computer vision is not confined to just understanding internal architecture, but also to understanding the wide variety of applications of computer vision. One of the most notable application today is in Tesla's self driving technology (Peregud & Zharovskikh, 2020, para. 13). Tesla's autopilot assistance started off only with capabilities for lane correction and self-parking, however, Tesla has recently introduced full self-driving capabilities due to their development of their computer vision algorithm integrated into their self-driving system (Peregud & Zharovskikh, 2020, para. 14). Another prominent application of computer vision both ubiquitous and eludes conscious thought is Face ID. Essentially every modern smartphone sold today has Face ID, regardless if the manufacturer is Apple, Samsung, etc. Apple first revealed Face ID in 2017, and has since improved upon it further with other corporations adopting it for their own uses (Peregud & Zharovskikh, 2020, para. 4). Even though these systems are used by a great majority of first-world citizens, most have little to no understanding of how they actually work. To understand the potential risks and consequences a particular technology has personally, a basic understanding of the technology's functionality is needed.

The state of the art report consists of reading both low level discussions of general computer vision technology and contemporary research articles to create a scholarly article that caters to readers with all degrees of knowledge about computer vision. Certain articles such as Brownlee's "A Gentle Introduction to Computer Vision" (2019) and Klosowski's "Facial Recognition is Everywhere" (2020) have information suited for a more general audience whereas articles by Cheng et. al. (2019) and Liu et. al. (2015) provides far more advanced details about specific computer vision systems. In this discussion, I will look at the similarities of leading computer vision systems also discuss what aspects of these systems make them unique from each

other. Through performing this research and writing my analysis, I hope to better understand computer vision technology and the role computer vision has on society and I hope to help others do the same.

USE OF FACIAL RECOGNITION IN MODERN SOCIETY

Computer vision is not a new technology, with its origins dating back to more than forty years ago (as cited in Brownlee, 2019, para. 30). However, only in the past decade has developments in computing technology allowed its widespread usage in everyday life. As with almost any new technology, people are fearful for the consequences its introduction into society may have. In this case, those concerns may be warranted. Among the different applications computer vision has in society, one that has important and numerous concerns that needs to be addressed is facial recognition. The principle that a computer can identify a person is simple and straightforward, but the usage of facial recognition introduces concerns about its ethics. Because it's a relatively new and unique technology with rapid growth, it is hard to foresee backlash against its usage. For example, in an excerpt of Klosowski (2020):

> Facial recognition's first dramatic shift to the public stage in the US also brought on its first big controversy. In 2001, law enforcement officials used facial recognition on crowds at Super Bowl XXXV. Critics called it a violation of Fourth Amendment rights against unreasonable search and seizure (para. 12).

It can be seen that the use of the technology in public was not well received. Because computer vision had minimal interaction with normal people in society, understanding the consequences is difficult without previous experiences. Now, there has been enough use that experts are aware of its usage and can analyze computer vision in context and predict ethical and societal concerns with its use.

Of course, computer vision also has its merits that that can be balanced with its consequences. In a scenario outlined by Kuflinski for catching criminals:

> Back in 2009, there were approximately 30 million surveillance cameras in use in the US, and now the number has grown exponentially. Imagine if these cameras, which reportedly captured an average of 4 billion hours of recording in a single week, were integrated with a facial recognition system (para. 5).

Having a system that can pinpoint a criminal in a crowd of people anywhere in a city would greatly help in keeping a city safe. However, there are many discussions where the government has the capability of tracking your every movement through technology, and these were generally seen in a negative light. Having cameras track your whereabouts permanently is what many consider a gross violation of personal privacy, an issue analyzed in the STS research.

A CASE BY CASE ANALYSIS

In my STS research, there are three issues with facial recognition use to be examined: bias, privacy, and trust. Bias refers to how an algorithm may be more inclined to make decisions towards one social or ethnic group, privacy refers to breaches of our right to personal privacy, and trust is the relationship between the user of facial recognition and the system itself. These issues need to be studied in different use cases to understand the various impacts they have on user populations. For example, Martinez-Martin (2019) mentions how a biased facial recognition algorithm can misidentify a disease in a patient, which may lead to a misdiagnosis (p. 185). As seen on the following page in Figure 2, the situations I will be researching are the usages of facial recognition technology in healthcare, education, and law enforcement, and each situation shares the same issues regarding facial recognition but may have different impacts.

In each case, studying the negative impacts the issues with facial recognition have and taking preventative measures is necessary for a better integration of facial recognition in society. For these situations in particular, there is a power dynamic where one social group holds power over another. This leads to more significant and potentially harmful effects the three issues may have when used. Each situation will be analyzed independently, with an independent discussion

of ethical and societal effects bias, privacy, and trust issues with facial recognition introduce, and an overarching compilation of these cases will be performed comparing and contrasting the results of each case analysis.

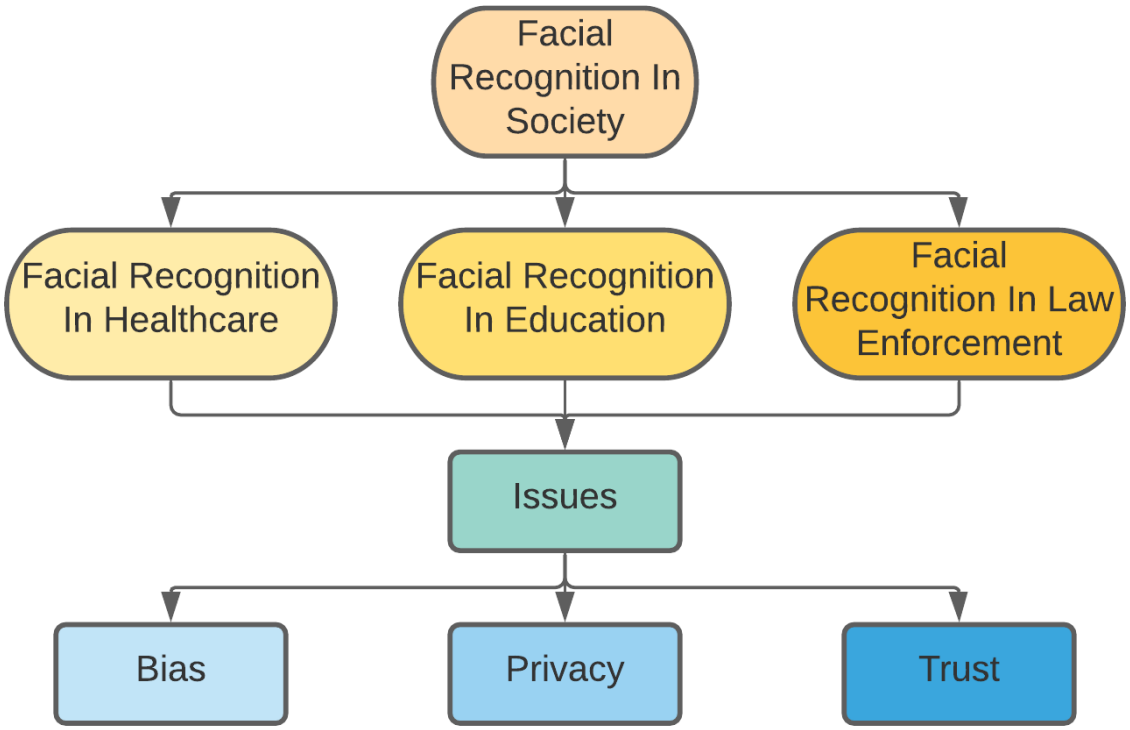

Figure 3: Use Cases and Issues with Facial Recognition. Analysis of the Issues of Bias, Privacy, and Trust in Healthcare, Education, and Law Enforcement (Shen, 2020)

APPLYING ACTOR NETWORK THEORY TO FACIAL RECONGITION

The approach I will be taking in STS research will be Actor Network Theory. Actor Network Theory is a constructivist approach to the sociology of science, where knowledge production takes place as a result from interactions between different groups of actors. (Fioravanti & Velho, 2010, p. 1) As seen on the next page in Figure 3, the model is a network

centered around computer vision with numerous actors; researchers, companies, law enforcement, education, healthcare, and policy makers.

Facial recognition, a subset of computer vision systems, lies in the center because it is an avenue for each social group to interact with another in this network. Each social group has its own interaction with facial recognition: researchers develop computer vision systems, companies market them, lawmakers regulate them. An interaction between any of the two social groups is different from any other pairing of social groups, but every pair is connected through facial recognition. Understanding the relationships and the interactions between these different actors is necessary to analyses the effects the issues facial recognition has impacts these actors, and helps propose solutions to these issues.

The STS research project details my findings in a scholarly article first with an examination of different cases of facial recognition use in society and the ways bias, privacy, and trust issues affect users, followed with an Actor Network Theory analysis of the interactions between different actors to propose potential solutions to the issues with computer vision and facial recognition.

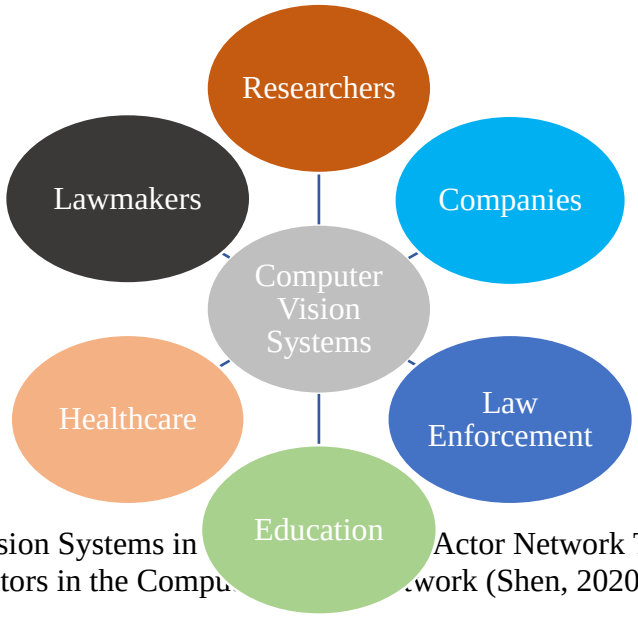

Figure 4: Computer Vision Systems in Actor Network Theory. A Visual Depicting Different Actors in the Compu work (Shen, 2020)

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