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Face Session

Introduction
The 2016 edition of the Global Identity Summit (GIS) will come at a unique time in federal circles, as it will be 50 days before a presidential election and 123 days before the new President takes office. Clearly, this is a very busy time for all federal officials, as they will be working with transition teams to explain current capabilities and draft plans for the next administration to implement.

The GIS Planning Committee is using the 2016 conference to assist agencies during this critically important transition period. This information will be equally useful to the private sector as it develops its future strategies. The Planning Committee’s ultimate goal is to gather and publicly post information that explains current capabilities and issues, provides a vision of future capabilities, and develops initial concepts for public and/or private activities for the next five years.

The Planning Committee has identified approximately 20 critical identity topics to focus on at the 2016 GIS. Within each topical session, speakers will present information on the current state as well as discuss needs and priorities for the future. The session moderator will then invite feedback from audience members via an open floor and/or targeted workshops. This paper serves as a read-ahead on one of these topics, so that GIS attendees can be prepared to participate in onsite discussions.

Introduction to Face Recognition
The term “biometrics” comes from the Greek words “bio” which means life, and “metrics” which means a system of measurement. The Merriam-Webster definition of “biometrics” is the measurement and analysis of unique physical or behavioral characteristics (as fingerprint or voice patterns) especially as a means of verifying personal identity.

For most of modern human history, the primary physical characteristic used for verifying identity has been the face. Recent research suggests that physical traits of human faces have evolved in a way to make each person look unique. Also, we know from research in neuroscience and cognitive sciences that people have developed powerful face perception abilities. Our ability to perform face recognition varies significantly; a few people have prosopagnosia (face blindness), while others are dubbed super face recognizers. Also, recent research suggests that dogs apply enhanced neural processing when viewing human faces.

Computer science is a relatively recent field of study. While automatic face recognition has been a vibrant area, only very recently has there been success in “teaching” computers to accurately

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1 http://news.berkeley.edu/2014/09/16/human-faces-are-so-variable-because-we-evolved-to-look-unique/
2 http://www.huffingtonpost.com/entry/dog-perception-human-faces_us_56d8a654e4b0000de403d313
recognize faces appearing in natural, unconstrained settings. The advent of deep learning has revolutionized face recognition and sparked our ideas of what is possible. Deep learning and the ability of computers to learn from massive amounts of data have renewed interest in artificial intelligence (AI), and moved AI from science fiction, to being envisioned potential reality. While human-like performance in face recognition alone is not a strong indication that AI will arrive soon, it is a natural precursor. Dr. Fei Fei Li, director of Stanford Artificial Intelligence Lab, makes the case that computer vision is a necessary precursor to AI. Face recognition is the most studied object recognition task in computer vision. We make the case that automatic face recognition is a centerpiece to computer vision, and a precursor to other computer vision tasks:

- Expression and emotion recognition
- Person action recognition
- Object recognition
- Scene understanding.

Just as face recognition and other face processing has been instrumental in human evolution, it will be a major component in the advent of AI, as depicted in the diagram below.

Figure 1: Face Recognition Core

3 http://www.wired.com/brandlab/2015/04/fei-fei-li-want-machines-think-need-teach-see/
Face Session Topics

The Face Session at the 2016 Global Identity Summit focuses on three areas:

1. Applications of face recognition in law enforcement
2. International partners and their adoption of face recognition
3. Evaluation of cutting-edge face recognition research.

There will be six invited talks, two in each category.

- Sergeant Edwin Coello, New York City Police Department, Facial Identification Section. Edwin Coello will discuss how face recognition is instrumental to solving many crimes for the NYPD. He will demonstrate several real-life use cases of how face recognition technology and research were used to enhance the NYPD’s capabilities. He will also touch on his collaboration with the National Institute of Justice.

- Dr. Richard Vorder-Bruegge, Federal Bureau of Investigation, will focus on the approach taken by one-to-one examiners, the challenges they face, and some of the issues with current software approaches.

- Col. Michael Kelly, 3rd Forensic. Michael Kelly, a former Colonel of the U.S. Marine Corps, is Regional Director, North America, at 3rd Forensic. He will discuss the establishment of the super recognizer unit within the Metropolitan Police of New Scotland Yard. He will give several success stories of the use of face recognition for enhancing public safety.

- Dr. James Wayman, San Jose State University, will describe his latest collaboration with the Australian government for deploying face recognition technology at a large scale in order to speed processing at international airports and other border crossings. He will also discuss other face recognition use cases.

- Dr. Patrick Grother, National Institutes of Standards and Technology, will provide an update on the Department of Homeland Security Non-cooperative Face Recognition Programs, including the challenges of CHEXIA and FIVE.

- Dr. Nathan Kalka, Noblis, will describe new data collections for evaluating unconstrained face recognition, and give the test protocols for face detection, subject clustering, and automatic face recognition. Dr. Kalka will give the latest results from evaluating the IARPA Janus Program.

Face Recognition, Now and into the Future

Face recognition has become a much more widely used technology in government, law enforcement, and in the private sector. Many social networking companies provide face recognition capabilities to their users (e.g., Google Photos, N-Tech FindFace). Also, automatic face recognition has established uses in government. In a growing number of situations (i.e., frontal faces), the performance of automatic face recognition rivals that of humans, and computer implementations scale well beyond the practical limitations of manual operators. Still, its accuracy is not consistently at human performance.

As pointed out in the figure above, in order to develop accurate face recognition in naturally occurring, unconstrained settings, it is necessary to model (explicitly or implicitly) faces across several factors:

- Pose
- Illumination
- Expression
- Aging
There will be theoretical limitations. We can think of obvious ones such as very low resolution. It is a simple application of the pigeonhole principle that uniquely matching single red-green-blue (RGB) photos with dimensions 20 x 20 to each of 7 billion people is not possible. If each color channel has eight bits, then the total number of unique RGB photos with dimensions 20 x 20 equals:

\[
(256^3)(20^2) = 6,710,886,400.
\]

By the pigeonhole principle,\(^4\) at least two out of 7 billion people must have identical RGB photos.

Improving face recognition in the context of expression will lead to improved expression tracking and emotion recognition. Understanding face recognition in the context of aging may improve understanding of age estimation and aid prediction of our appearance years into the future. This application is important for locating missing children.

**What Are the Limits and Goals of Face Recognition?**

We should be asking now what are our goals for face recognition performance. Several research papers have claimed to exceed human performance in automatic matching; however, experts realize these claims do not apply in any general context. Still, as face recognition algorithms improve dramatically, we need to ask what are the limits of automatic face recognition, and how much we should invest to push performance across smaller margins of error. As the computer algorithms approach or surpass human performance, it will be necessary to update our entire research and development process to move the needle even further. It may not be easy to rely on basic human annotation, since the computer algorithm ground truth may surpass manual ground truth. This will raise the cost of obtaining more accurate ground truth, so that we know when there is a slight, but meaningful bump in performance. In some cases, it may be necessary to guarantee ground truth during collection, and avoid dependence on human annotators. What level of accuracy improvement is worth the added investment? Since humans vary significantly in their ability to recognize faces, should algorithms target super recognizer performance? Do human super recognizers reach some type of theoretical limit in face recognition? Above, we listed several factors that inhibit face recognition. Do these real-world factors lead to a limit in performance that is not obvious from preliminary statistical analysis of face space, or the manifold in which face imagery lies?

It is important that we begin to address these questions now. The government and the face recognition research community continue to collect new, harder data sets for evaluating performance. Researchers often report incremental improvements in results many years after the data set has been public. For an extremely difficult unconstrained data set, it could be that 100% accuracy (or 99% accuracy) is a sure sign that the algorithm is overfitting to that imagery. This should be determined prior to investing millions of dollars pushing automatic face recognition into a territory where every half of a percent in improvement in accuracy will be very costly.

\(^4\) https://en.wikipedia.org/wiki/Pigeonhole_principle
Many Ways to Image a Face

We have not discussed other technologies used to deploy face recognition, or other types of face processing. Many types of technologies may be used for face recognition, including 3-D laser scanners, structured-light 3-D scanners, light-field cameras, stereoscopic cameras, non-visible light cameras, and polarimetric cameras. It is important to understand the differences among these technologies, and the impact on accuracy under various conditions. 3-D capture devices, or 4-D when movement is included, may improve face recognition and raise the theoretical limit beyond many conventional 2-D image or video capture devices. It is important that the government keep an accurate picture of face recognition performance across many modalities, and forecast where technology is headed.

The Next Five Years Are Extremely Critical for Face Recognition Research

While uses of face recognition have grown dramatically and performance has improved to rival humans in some situations, there is still a long way to go before face recognition reaches a saturation point in most naturally occurring, unconstrained settings. Several Chinese universities and companies have reported substantial advances, as has a Russian company (N-Tech). Also, some U.S. companies have shown similar progress, but, in general, these companies do not sell capabilities to the U.S. government. It is more important than ever that the United States invest in face recognition research so it is not left behind, either in access to underlying face recognition technology or in nurturing expertise in this highly technical field. The U.S. government (USG) has many needs for face recognition, and often has the requirement to tailor it toward specialized applications and environments. In many cases, source code for a system is needed for deployment and maintenance.

Differences between USG and commercial use cases:

1. Verification – For applications involving high-throughput physical access control, commercial deployments are more comfortable operating at a lower False Reject Rate at the expense of a higher False Accept Rate to provide a positive customer experience.

2. Large Search – USG systems require a significantly lower False Positive Identification Rate at a corresponding high True Positive Identification Rate than customer applications, given the national security mission.

3. Watch List – This is currently in limited use in security applications in the commercial sector (e.g., theft prevention, casinos, banking). However, probes (and most gallery images) are collected under controlled environmental conditions inside commercial facilities. Matching unconstrained probes against gallery subjects with only unconstrained imagery is not a commercial use case.

4. Clustering for Forensic Investigations – This is not a current commercial use case. For timely response to national security or public safety events, the USG must often triage large volumes of media.