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Cognitive Radios Will Adapt to Users

Face Recognition Technology

By Danna Voth

Facial recognition is an important human ability—an infant innately responds to face shapes at birth and can discriminate his or her mother's face from a stranger's at the tender age of 45 hours. Recognizing and identifying people is a vital survival skill, as is reading faces for evidence of ill-health or deception.

Improving significantly in the last several years, technologies that can mimic or improve human abilities to recognize and read faces are now maturing for use in medical and security applications. The 2002 Face Recognition Vendor Test (FRVT 2002) demonstrated a significant improvement in face recognition capabilities, and researchers have developed systems to tackle some of face recognition's more interesting challenges. These systems include one that can distinguish between identical twins.

3D face recognition system

This spring, researchers at the Technion, Israel Institute of Technology in Haifa, presented a new twist to face recognition technology—a 3D system based on "bending invariant canonical representation." Michael and Alexander Bronstein are electrical engineering graduate students and twin brothers. While working on a project headed by their professor, Ron Kimmel, and with the help of lab engineer Eyal Gordon, the brothers decided to try to create a face recognition system that could distinguish identical twins, a difficult problem for most face recognition systems. "The fact that my brother and I are twins was inspiration for this invention," says Alexander.

The team developed a system that treats the face as a deformable object, as opposed to a rigid surface, and uses a range camera and a computer. The 3D system maps rather than photographs the face, capturing facial geometry as a canonical form, which it can then compare to other canonical forms contained in a database. The system can compare surfaces with a high fidelity level, independent of surface deformations resulting from facial expressions.

Kimmel and his former student, Asi Elad, invented the idea of bending invariant canonical forms about three years ago. Michael explains Elad's work as "a generalization of the work of Eric Schwartz, who proposed the use of a mathematical method known as multidimensional scaling for analysis of the brain cortex. A smart use of fast numeric algorithms (joint work of Kimmel and James Sethian) resulted in a very elegant algorithm, which Elad tested on surface recognition problems." Kimmel suggested using bending invariant canonical forms in face recognition a year ago, Michael says.

The process of capturing canonical forms occurs in three stages (see Figure 1). At the first stage, the system acquires the face's range image and texture. At the second stage, it converts the range image to a triangulated surface and preprocesses it by removing certain parts such as hair, which can complicate the recognition process. The mesh can be subsampled to decrease the amount of data. The choice of the number of subsamples is a trade-off between accuracy and computational complexity. At the third stage, the system computes a canonical form of the facial surface. This representation is practically insensitive to head orientations and facial expressions, significantly simplifying the recognition procedure. The system performs the recognition itself on the canonical surfaces.

How is this new system better than others? Alex says that their 3D method gives more information about the face, is less vulnerable to makeup and illumination conditions, and fares better than other face recognition systems. Michael points out that other systems are more sensitive to facial expressions, while their 3D system can handle facial deformations. They tested a classical 2D face recognition algorithm (eigenfaces), a 3D face recognition algorithm, and a recently proposed combination of 2D and 3D recognition, and their system fared best. "On a database of 157 subjects, we obtained zero error, even when we were comparing two twins," Michael says. "Obviously, a larger database is required for more accurate statistics, yet by extrapolation we can predict results significantly outperforming other algorithms."

FRVT 2002

Certainly security is one of the chief uses of face recognition technology, and understanding the state of the art in biometrics is key to designing effective applications. The National Institute of Standards and Technology (NIST), together with DARPA, the National Institute of Justice, and several other federal agencies, sponsored FRVT

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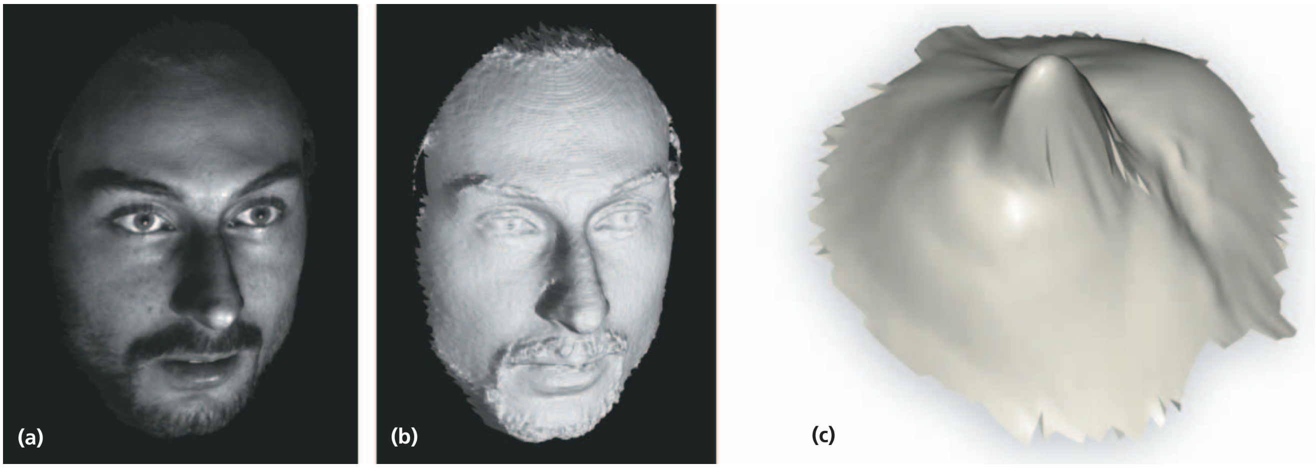

Figure 1. Three stages of facial recognition: (a) the range image and texture; (b) the preprocessed surface; (c) the canonical form.

2002, which tested commercial face recognition accuracy and identified numerous characteristics for optimizing face recognition technologies' performance, as well as areas for future research.

Looking at 10 mature face-recognition systems, FRVT 2002 tested them on three basic tasks: identification, verification, and watch-list screening. Identification involves matching a biometric record from a single subject probe against an entire database of similar biometric records to determine the record owner's identity—a one-to-many comparison. The verification process confirms that a person is who he or she claims to be by matching the biometric record against that of his or her claimed identity—a one-to-one comparison. Verification rates are offset with false accept rates, and verification performance is described by the two statistics. Watch-list screening is typically the most demanding task, involving two steps. First, a system must detect if an individual is even on the watch list, then, if so, correctly identify the individual.

Compared with similar tests performed two years earlier in FRVT 2000, the FRVT 2002 results show a significant improvement in face recognition systems' verification capabilities, indicated by a 50 percent reduction in error rates. For the best systems tested in FRVT 2002, the top-rank identification rate was 85 percent on a database of 800 people. With a false accept rate of 10 percent, the top two systems turned in a verification rate of 96 percent. For the best system using a watch list of 25 people, the detection and identification rate was 77 percent.

FRVT 2002 found that facial recognition systems attempting verification tasks provide accuracy comparable with fingerprints. For facial recognition, the best packages available provide a 90 percent probability of true verification with a 1 percent probability of false verification. This is a helpful finding: The November 2002 report "Summary of NIST Standards for Biometric Accuracy, Tamper Resistance, and Interoperability" notes that, "within the intelligence community, facial data is often the only biometric data that has been and is currently being captured. Face data is one key source for watch lists, and in many situations fingerprint data cannot even be captured to use in constructing a watch list."

FRVT 2002 showed that facial recognition accuracy varies according to different factors, which might help in planning better applications and designing future research. Several image characteristics affected results. First, as you'd expect, accuracy drops as time increases between the acquisition of the database image and the presentation of the newest image because people age and change in appearance over time. NIST reported that performance degraded at approximately 5 percentage points per year. In addition, the study found that indoor lighting changes didn't make an appreciable difference to the top systems' accuracy, although face recognition from outdoor imagery showed a considerable drop in performance, with the best performing systems turning in a recognition rate of 50 percent.

The FRVT 2002 also compared the rates for still and video images and found, contrary to expectations, that recognition performance using video sequences was similar to the performance using still images. For images with nonfrontal presentation, FRVT 2002 examined the use of *morphable models*—a technique of taking a facial image from any angle and projecting what the subject might look like facing forward. There was a dramatic improvement in performance using the morphable models. One of the top three systems increased its performance from 26 percent on nonprocessed, nonfrontal images to 84 percent on morphed images.

The size of the database used for identification or watch-list screening significantly impacted results. The experiments showed that identification performance decreases linearly with respect to the logarithm of the database size. NIST reports a similar effect for the watch-list task—as the watch list size increases, performance decreases. The FRVT 2002 overview states that, "In general, a watch list with 25 to 50 people will perform better than a larger size watch list."

For the first time, the test covered the effects of demographics. The results reported that males are easier to recognize than females and that older people are easier to identify than younger people. For the top systems, identification rates for males were 6 percent to 9 percent higher than for females. For every 10 years increase in age, on average identification performance increases approximately 5 percentage points.

Reading faces

Although recognizing faces is important to such security applications as financial verification (ATM and credit cards), biometric locks, and passport or visa control, reading faces has important uses in medicine and security as well. A team of scientists at the

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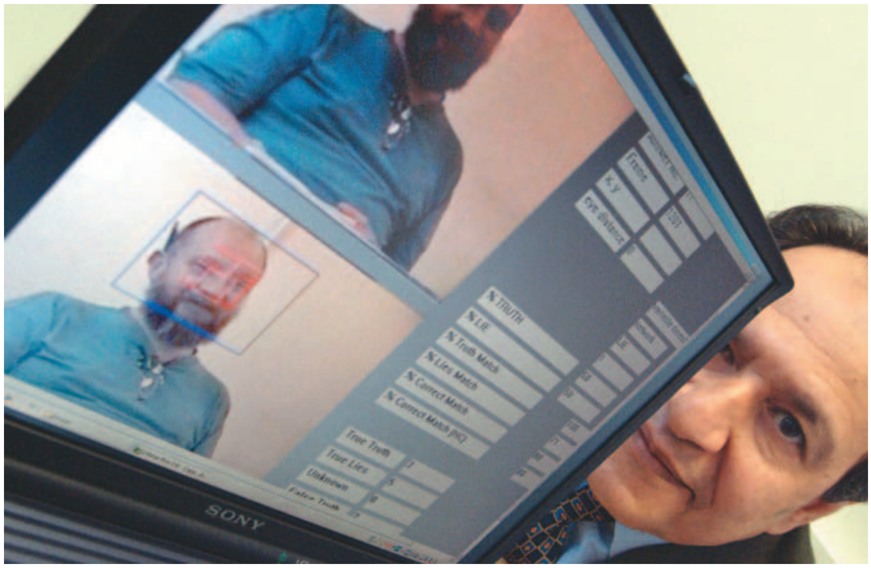

Figure 2. A subject onscreen undergoes scrutiny from Zuhair Bandar's Silent Talker.

Centre for Adaptive Psychological Profiling at Manchester Metropolitan University is developing technology that can help doctors study the autonomic nervous system and a patient's psychological state or help interrogators detect deception. Zuhair Bandar, Janet Rothwell, Jim O'Shea, David McLean, and D.J. McCormick have developed, after five years of work, a system they have dubbed the Silent Talker, which observes and classifies a subject's nonverbal behavior during an interview and detects deception.

Inspired by a challenge to monitor audience reaction in sales presentations, Bandar realized it should be possible to make inferences about people's psychological and emotional states by analyzing their outward behavior with AI. "This stimulated a series of discussions with psychologists, which revealed the full potential for psychological profiling," O'Shea says.

The team developed a system that observed 24 behavioral channels, such as eye contact events, gaze, or body movements that occurred as a subject was interviewed. Using many channels makes it more possible to discover meaningful patterns, and it is impossible for a human to control so many behaviors simultaneously. Able to handle multichannel data, the Silent Talker's AI component decides which data is redundant, noisy, or important and detects patterns across the channels to provide classification accuracies.

The project involved evaluating and developing the neural networks for image processing, such as locating the subject in the frame. "We chose artificial neural networks (ANNs) because they are ideal for the image processing used in the early stages and highly suited to the type of classification task involved in the later stages," says O'Shea. At the same time, the team was reproducing a well-defined psychological experiment to observe and classify deception with 40 subjects.

The team digitized videos of the interviews from these experiments to provide training, validation, and testing data for the system (see Figure 2). They developed further neural networks to locate particular features such as the eye and classify their state (for example, "eye shut"). Finally, they developed neural networks to combine all the information earlier stages provided and classify the subject's behavior.

Combining the practice of psychological profiling with the power of AI, the Silent Talker has demonstrated approximately 87 percent accuracy in classifying complete interviews as truthful or deceptive and over 70 percent accuracy in classifying periods of deceptive demeanor during the interview, O'Shea says. "This is vastly superior to humans and superior to most of the quoted figures for other systems."

The team plans to further develop the technology. "It is a very effective, but not infallible technology," O'Shea says. "The system inherits the generally perceived weakness of ANNs—that they cannot explain how they reach their decision." Plans to improve the system include tuning the code to implement real-time operation, producing a wider range of neural networks to look at culture-specific, nonverbal behavior, and producing systems that can explain how they reached the classification.

It will be interesting to see where face recognition technology will take us next. Outdoor image analysis, projection of age changes, performance in larger databases, and comparisons of different expressions will improve, as will our capabilities to detect deception and other emotional states. This will bring advances in medicine and security as we automate our vital faculty of recognizing and reading faces.

Cognitive Radios Will Adapt to Users

By Terry Costlow

Software radios have emerged in recent years, providing a level of programmability so that communications products, such as cell phones, can automatically switch from one frequency or transmission scheme to another when the primary technique is unavailable. Now that they are moving into the marketplace, a few long-term planners are already looking at the second or third generation of software radios, a concept that's known as *cognitive radio*.

Cognitive radios are adaptive and extremely programmable, learning users' preferences and automatically adjusting to changes in the operating environment. Military researchers want the security and versatility these techniques can provide, while consumers could benefit by having cellular phones that relay the cheapest way to send a message.

One of the better-known proponents of this concept is Joe Mitola, a consulting scientist at Mitre, a nonprofit research group in Bedford, Mass. He's been working with researchers at MIT, DARPA, Sweden's Royal Institute of Technology, and multiple IEEE committees to set the stage for cognitive radios.

One of the first tasks is creating an *ontology*, a set of terms ensuring that researchers from various disciplines are using the same terms for the same operations and equipment. "This will truly take an interdisciplinary effort," Mitola says, noting that different users of radio spectrum will use different terminology.

A big part of the work to be done using that common language centers on ways that cognitive radios program themselves. To be successful, these radios must passively learn user preferences and do many things without forcing users to program them. Mitola explains that if the user tunes to a certain radio station in the morning, the system must automatically remember that station and time of day.

"The word *passive* is key. If we make the user program all the nodes, you'll see this end up with 12 blinking lights just like a VCR," he says.

One application will be cell phones that determine the best way to transmit messages. He cites an example where communicating on a home campus can be cheaper than from a remote site. "If you're on the way to work and want to send a message with a 10-Mbyte attachment, the radio might suggest waiting four minutes until you're in the building, where it could be sent for free," Mitola says.

Another potential application is in the military, where finding the best communications scheme and security or encryption level can be critical. DARPA is already supplying some funding, and Mitola predicts that defense funding will increase, which could catalyze the technology's adoption.

Because the radios will do many things automatically, Mitola says that the system will need a certain degree of security. He's therefore thinking about biometric identifiers that would ensure the radio isn't being used by someone else when it sends a message to certain people or on certain frequencies.

Mitola, who is credited with helping create the foundations for software radio, doesn't expect to see a big market for cognitive radios in the near future. "It may be a decade away," he says. ■

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