AcSys Biometrics

AcSys Biometrics Corp.

Face Recognition Comes of Age

A White Paper

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Executive Summary

The wired – and wireless – world of universal and instant access to data and other resources has made security an increasingly hot topic within enterprises of all sizes. Before the Internet Revolution of the mid-1990s, the focus of enterprise computing was on data security rather than on data access. Only the technically advanced were permitted, or even knew how, to gain access to online corporate information. But the Internet changed the rules, and all forms of e-business became business as usual, seemingly overnight. Today's organizations, however, cannot afford to be complacent about security. As the technology of universal access improves, so too does the technology available to those who wish to subvert the organization's security measures.

Given that companies feel the need to provide increased access to information in order to remain competitive and become more efficient, it is little wonder that these companies are also searching for new, more advanced ways to ensure the security of their resources.

Such companies are finding that security based on traditional means of identification is never more than one step ahead of the potential intruder. No matter how stringent you make your security policies, if you rely solely on passwords or access cards, your facilities, accounts, data, and hardware are vulnerable. Passwords are revealed or guessed. Access cards are stolen. People neglect to log off.

Biometric Security

Biometrics is the ultimate in accountability. Forensic science can use biometric evidence, from fingerprints to DNA, to identify individuals with near infallibility. However, such means of identification are not quick, nor are they cheap. The difficulty so far for biometrics has not been in measuring accurately, but in scaling to the point where the solution is *practical* (it can deal with large numbers of subjects), *efficient* (it does not require an inordinate proportion of available resources or time), and *cost-effective* (the solution is not prohibitively expensive to implement and maintain).

AcSys Face Recognition

Face recognition technology comes of age with the introduction of the AcSys Face Recognition system (AcSys FRS). It provides a practical, efficient, and cost-effective means of applying face recognition biometrics within enterprises of any size. It uses Holographic/Quantum Neural Technology (HNeT™) to provide a practical, scalable and highly accurate solution that actually improves its ability to differentiate individuals as the size of its database increases. HNeT also makes efficient use of both computing and administrative resources in an *n*-tiered client/server environment. It is cost-effective, because it is a software-based solution that can run on conventional hardware and does not require specialized video cameras. Much of the system's implementation and maintenance is automated: its ease of implementation, integration, and use mean that it makes cost-effective use of your human and network resources.

AcSys FRS represents a revolutionary approach to human identification and security. It applies advanced HNeT software development philosophy and technology to facial biometrics for quick and reliable determination of human identity. It provides a scalable security solution that integrates easily with existing security systems using standard network protocols and non-proprietary data formats.

Implementation Scenarios

AcSys FRS suits any scenario in which there is a need to safeguard resources from unauthorized human access. In some cases, this potential has already been realized. Others are only time and resources away.

Today

AcSys FRS is at home in any of the following scenarios.

1. Controlled Access to Sensitive Facilities - Do you need to know who is entering your building, and when? Do you need to be absolutely certain that the people attempting to access your facility are who they claim to be?

The AcSys FRS Access Control application ensures that the identity of each person entering your facility has been confirmed accurately and logged. Nobody can enter using a stolen access card. Each entry event is recorded in an audit log along with an image of the person entering. You can review logs from within your building or remotely via the Web. You can search logs by time, by user, or by camera.

2. Accurate Time and Attendance Statistics – Do you need complete and accurate time and attendance statistics to process payroll? Do you need to reduce or eliminate time-clock abuse by hourly employees?

The AcSys FRS Time & Attendance application ensures completely accurate time and attendance statistics. No employee can log any other employee in or out.

3. Secure Automatic Banking Machines and Debit Transactions – Do you require a security layer in addition to client card technology?

The AcSys FRS ABM solution matches debit card information to a pre-established user template to ensure that only the card's owner can access the owner's accounts.

4. Ultimate Protection for Collocation Data – Does your collocation facility have airtight security down to the cabinet level? How confident are your clients in your ability to secure their data from unauthorized access and tampering?

The AcSys FRS Collocation solution tracks access to each cabinet and lets you set permissions at the camera level so that only authorized personnel can access the servers in the specified cabinet.

Tomorrow

We are committed to working with our business partners to develop new and innovative applications for our technology. Applications currently under development include:

1. Web-cam face recognition – Promote telecommuting within your organization with confidence. Control remote access to corporate resources through a Web camera. Add AcSys FRS to teleconferencing capability and Virtual Private Networking to create a secure, effective, and efficient telecommuting environment.

2. IT Security – load user profiles automatically based on biometric input. Lock out intruders. Reduce the number of passwords to remember and misplace. Record the identities of people working on computers and retrieve that information from audit logs.

3. Unobtrusive Surveillance – AcSys FRS uses parallel processing and its ability to track multiple users simultaneously to achieve quick, effective, and efficient one-to-many identification of unwelcome visitors.

The ABCs of AcSys Face Recognition

AcSys FRS is a biometric technology that uses sophisticated artificial neural network (ANN) computing and mathematical abstractions based on a large number of facial characteristics to verify or identify individuals.

A biometric may be defined as a measurable ('metric') characteristic, whether physiological or behavioral, of a living organism ('bio') that can be used to differentiate that organism as an individual. Biometrics are not new: fingerprinting, for example, has been around for a long time and remains one of the foundations of modern forensic criminology.

What is relatively new is the application of advanced computer technology to make biometrics a practical solution in situations where the accurate and timely determination of identity is essential.

Face recognition is one of the many means of biometric verification and identification that have been discussed in the technical and popular media in recent years. Other recognition biometrics include speech, fingerprint, hand, signature, iris, and retina. All of these, however, share the same basic set of authentication requirements and functions.

Biometric Fundamentals

Biometric applications based on face recognition, like all biometric applications, use the following functions to achieve their ends:

- Enrollment
- Training
- Verification
- Identification

When an individual "enrolls" in the system, the system "trains" on the user. When the enrolled individual provides input to the system, the system either "verifies" or "identifies" the individual, depending on the system's configuration and the implementation scenario in place. The following sections detail these functions and how AcSys FRS handles them.

Enrollment

Before the system can differentiate an individual, it must have a database record, or template, of that individual. The template is a mathematical abstraction based on a set of images of the individual. The act of capturing images of an individual and creating the template to represent that individual is known as *enrollment*. It is important to note that the biometric template does not actually contain images of the individual: it is a mathematical abstraction created by comparing the captured images.

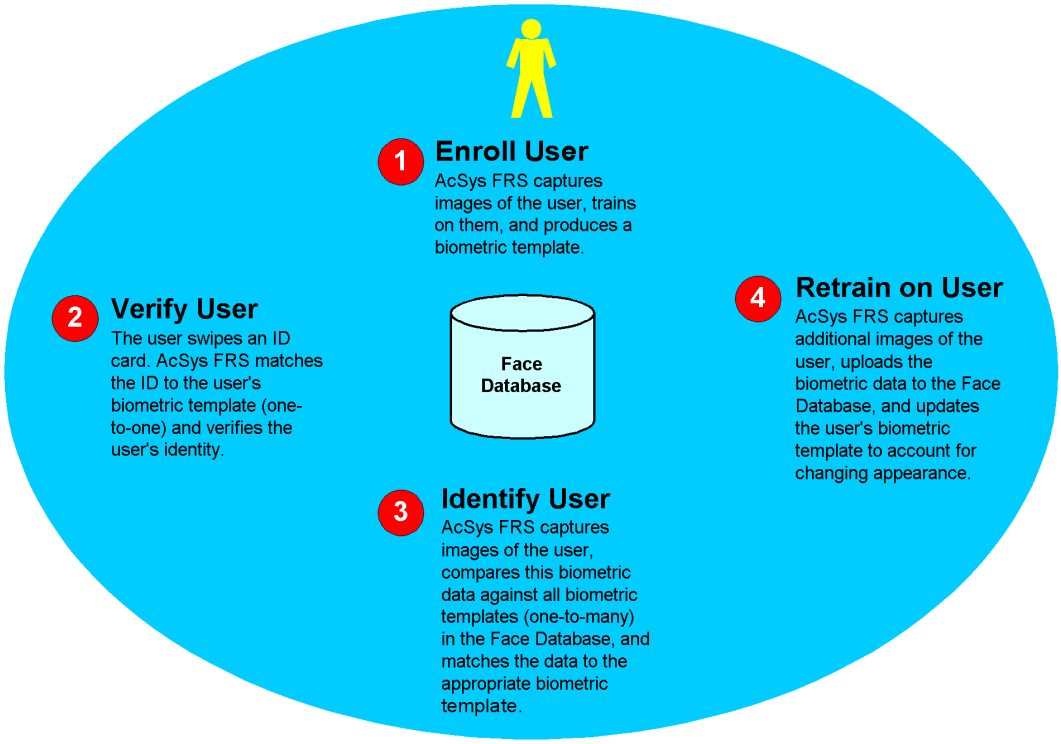
Training

After an individual has enrolled, the system performs an operation on the individual's database record known as *training*. The system "trains" on a user by comparing the biometric sample of the user to the set of facial images within the Training database and refining its understanding of the complexities that define the user's face. This comparison allows the system to "learn" to differentiate the user from all other users. Training may

require the system to run through the database a few times to eliminate near matches and make identification of the user virtually certain. The end result is a biometric template that represents the user in the Face Database.

Because the system must have a collection of images representing other individuals from which to differentiate the individual, AcSys FRS ships with a large training database of images against which to build biometric templates.

Because people change – a face is variable rather than constant – AcSys FRS provides automated retraining. In effect, the system continues to learn and refine its ability to recognize individuals as they change.



Verification

Verification occurs when the individual provides both biometric and non-biometric input and the system verifies the biometric evidence against the non-biometric. For example, an individual might swipe a card that represents him as “John Smith”. The individual then stands in front of a video camera and the system captures images and compares them against the mathematical abstraction, or template, of John Smith on record. If the individual is indeed the John Smith on record, the system verifies his identity. This verification scenario is also known as “one-to-one” face recognition, because the system matches one user to one database record.

Identification

Identification occurs when the individual provides only biometric input and the system compares that biometric input against all biometric templates on record to determine the individual’s identity. For example, an individual steps in front of a camera and the system captures multiple images of him. The system then compares this biometric sample against the biometric templates in the Face Database and eliminates templates until it is virtually

certain of a match.[1] When the system matches the sample to a record, then the system identifies the individual as the person represented by the database record. Systems that identify in this manner are said to use "one-to-many" face recognition, because they compare one individual to many biometric templates in order to certify the user's identity.

Biometric Resources

The study of biometrics is both deep and wide. We have provided some fundamentals in this paper, but there are ample resources on the Web to help you gain a greater understanding of emerging biometric technologies and applications. For example:

- AcSys Biometrics (www.acsysbiometrics.com)
- The Biometric Consortium (www.biometrics.org)
- Avanti: The Biometric Reference Site (homepage.ntlworld.com/avanti/)

[1] In a *one-to-many* test with 185 users enrolled and 150 intruders, AcSys FRS was 99.8% accurate in identifying the correct users and intercepting intruders.

The AcSys Biometrics Technology Advantage

AcSys FRS receives its decisive technological advantage from Holographic/Quantum Neural Technology. This advantage provides the following benefits to the company that implements AcSys FRS versus other systems:

- High-speed training
- More efficient tracking
- No exotic hardware requirements
- Compatibility with existing network infrastructure
- Low administrative overhead
- Ease of implementation
- Ease of integration
- Ease of use

> **Note:** *AcSys Biometrics owns the exclusive worldwide HNeT license for Face and Speech Recognition applications.*

High-speed Training

HNeT gives AcSys FRS applications the ability to train more quickly and accurately than any other face recognition system on the market today or in the foreseeable future. Almost all face recognition systems use artificial neural network (ANN) computing models, but the ANN model represented by HNeT is far more sophisticated than the back-propagation model used by these other face recognition systems.

AND Corporation, the developer of HNeT, used the Monte Carlo test to compare HNeT's ability to learn with that of a standard back-propagation model using genetic search methods. The Monte Carlo test is accepted by many neural network experts as one of the more rigorous and unbiased tests that can be used to evaluate artificial neural networks. It provides a random statistical test method that can be used to evaluate three aspects of operation:

- The stimulus-response memory capacity of the system
- The recall accuracy of the trained cell
- Learning speed

AND Corporation ran three series of tests using 100, 500, and 1,000 stimulus-response patterns respectively.

- At a storage density of 100 patterns, HNeT was 100 times more accurate and 2,000 times faster.
- At a storage density of 500 patterns, HNeT's speed and accuracy was virtually unaffected, while the back-propagation system approached saturation.
- At a storage density of 1,000 patterns, HNeT's training achieved convergence after only 15 seconds, while the back-propagation system was making virtually no progress toward convergence after 20 hours of training.[2]

[2] See AND Corporation's Web site (www.andcorporation.com) for details on the Monte Carlo test.

HNeT learns as a child learns. Its knowledge and ability to interact with its world grow with each new stimulus-response pattern.

Because of the system's speed and efficiency, training is not an onerous, one-time task. Instead, AcSys FRS continuously retrains on individuals to update the user's template and maintain the system's accuracy. If an individual passed through the same portal over a fifty year period (even if only occasionally), AcSys FRS would continue to recognize him or her, because the user's template would be updated continuously as he or she grew older and changed in appearance.

More Efficient Tracking

Tracking is a measurement of the system's ability to recognize facial patterns within an image, and to follow those patterns as they move back and forth or from side to side within the view of the camera.

AcSys FRS's HNeT-based tracking is both faster and more accurate than other systems. It looks at a face in the same manner that you or I look at a face. When you meet a friend named Bill on the street, you gather an overall impression of his face and make a judgment of its "Billness" (its "Gestalt", as one school of cognitive psychology would express it). Similarly, AcSys FRS forms a mathematical description of the relationships between a large number of facial characteristics and uses that mathematical description to determine a probability that the face on screen belongs to a person represented by a template in the database. Because the template is the product of multiple images captured at multiple angles and ranges, it can recognize faces with a high degree of probability, no matter how the face is presented.

> **Note:** *The current iteration of AcSys FRS can track and identify four individuals simultaneously.*

No Exotic Hardware Requirements

AcSys FRS is primarily a software solution. Although the various applications and implementations require hardware components such as video cameras and card readers, these peripheral do not differ from those in use in existing security systems. In fact, AcSys FRS can usually be implemented as an additional layer on top of an existing security solution using existing hardware.

Unlike some hardware-based solutions that require special cameras with tracking circuitry, AcSys can operate on the video feed from a home video camera or an inexpensive Web camera mounted on top of a monitor. Recommended minimum resolution is 320 x 240 (i.e. 240 lines of video feed), which means that most existing security cameras are sufficient.

Compatibility with Existing Network Infrastructure

AcSys FRS can be implemented on a stand-alone PC or using an *n*-tiered client/server architecture. It uses no proprietary data formats or protocols.

Low Administrative Overhead

Most of the work involved in building the AcSys FRS database of user templates is automated. Once a record (name and ID) exists for a user in the database, manual setup is done. The system enrolls the user automatically on first use, and continues to retrain on the individual to account for changes in appearance and to improve the accuracy with which it verifies or identifies.

Ease of Implementation

AcSys FRS can be implemented with card readers, door-lock technology, or other such peripherals as a stand-alone security solution, or it can be implemented as an additional layer on top of an existing security solution. Implementation can be simplified through phased enrollment of users.

Ease of Integration

AcSys FRS leverages existing network technologies, architectures, and protocols. Because it can be implemented as a Microsoft® ActiveX® control, your in-house developers (or our experienced development team) can integrate AcSys FRS with custom applications designed to meet your particular requirements. Microsoft ActiveX technology leverages the Microsoft Component Object Model (COM) to let software components interact regardless of the programming language in which they were created. What this capability means in real terms is that the applications for the AcSys Face Recognition System are virtually limitless.

Ease of Use

Automated enrollment means that users do not have to spend their valuable time meeting with administrative personnel before they can start using the system. The speed with which AcSys FRS verifies or identifies individuals means that the system becomes virtually transparent to users after first use. Automated retraining occurs with no inconvenience to users or administrators.

What is HNeT?

Holographic/Quantum Neural Technology (HNeT) is a development framework, methodology, and computing philosophy modeled on the workings of the human brain. Much of the literature describing HNeT uses terminology derived from neurophysiology, including concepts such as neurons, cortical cells, cell assemblies, and synapses.

HNeT was developed by John Sutherland, Chief Scientist for AND Corporation and AcSys Biometrics. Sutherland studied how single neuron cells operate – how they learn stimulus-response memories instantly in real time, and how a single neuron cell with only a few synapses can learn abstractions, such as a human face, a spoken word, or a hand-printed letter. He then studied the way these individual cells interacted with each other in cell assemblies to provide parallel processing and exponential gains in learning speed.

Electronic Brains

When the first computers were built, people began almost immediately to regard them as electronic brains. The analogy is easy, but, as is often the case with analogies, it is also misleading. Public imagination was at odds with scientific reality. The hardware and software combination which we commonly construe as a computer, as wondrous as it is, was not designed to operate like the human brain. This simple truth derives from the fact that those who fashioned the computing paradigm that took hold in the second half of the twentieth century had a very limited understanding of how the brain actually works, and even less concept of how to implement such functionality.

The leap from the workings of the human brain to computer technology is short conceptually, but very long and involved technically. The complexity of neural operations is not surprising when you consider the length of time over which the human brain has developed. Applying this complexity to computing is nothing short of revolutionary.

Artificial Neural Networks

HNeT applies our knowledge of neurophysiology and human cognition to computing processes. HNeT is a result of years of research into artificial intelligence (AI), the possibility of developing machine intelligence comparable to human intelligence.

The old ‘computer-as-brain’ analogy operates at a macroscopic level. Brains and computers both process information, but that is the extent to which the analogy holds true. More recent advances have come about through imitations of the brain’s activities at the cellular (microscopic) level. Leveraging the work of neurophysiologists, computer scientists have begun to develop computing models based on the interaction of a variety of neural cell types within neural networks. The brain consists of a vast array of such neural networks. Artificial neural networks (ANNs) are simplified computing models of these biological neural networks.

Most computers still use an algorithmic (linear, step-by-step) approach typified by centralized processing and designated memory storage locations. In contrast, ANNs use parallel processing and distributed, synaptic memory allocation to learn, memorize, and create relationships amongst data.

ANNs are more efficient at handling large amounts of complex data, because:

- Their mode of operation more closely resembles the non-linear realities of the world in which we live.
- They are better at eliminating informational noise and positing missing data.
- They build data relationships without imposing external, artificial algorithms.
- They achieve superior predictive accuracy.

HNeT versus Back Propagation

However, not all ANNs are created equal. The most common type of ANN uses the back-propagation model. This type of model commonly uses genetic searching to mutate potential solutions to problems until it finds an optimal solution. Such back propagation systems cannot approach the sophisticated learning capabilities of HNeT.

HNeT has been in existence for over 10 years, but it has been slow to gain wide acceptance, largely due to the complex and abstract nature of Hilbert mathematics, upon which both quantum mechanics and HNeT are based. It has only been recently that the academic mainstream has realized how Hilbert space can be extended from quantum mechanics to the realm of practical information processing. Quantum mechanical concepts of *enfolding* and *quantum parallelism* can be applied not only to energy and matter, but to describe how single neuron cells are capable of learning vast amounts of stimulus-response information in *real time* - enfolding this information onto the same storage structures (i.e. computer RAM). A single holographic/quantum cell is capable of learning stimulus-response patterns or "memories" exponentially faster, and far more accurately, than the traditional back-propagation neural networks.[3]

Real-time Learning

Within the holographic/quantum process, a single cortical cell provides real-time learning, resulting in dramatic speed and accuracy improvements over slower and structurally more complex back-propagation/genetic neural networks. Traditional neural networks have little in common with actual cells encountered in neurophysiology. More importantly, these traditional models are exceptionally slow in learning, and have very limited storage capacities for stimulus-response information.

HNeT allows a synthetic neuron cell to learn tens of thousands of stimulus-response memories in less than a minute, and respond to tens of thousands of stimulus patterns in less than a second. AcSys FRS combines large numbers of holographic/quantum neural cells into cell assemblies, much like the cell assemblies found in the human cortex, to process myriad images simultaneously and provide a highly reliable means of differentiating individuals.

The neurological system consists of four principle areas: the cerebral cortex, cerebellum, brain stem, and spinal cord. Each area is comprised of indigenous cell types and associated neural pathways. In people, most output signals from the brain originate from the large pyramidal axons of the neo-cortex. An important aspect of holographic/quantum neural technology is that it imitates the way neo-cortical cell assemblies learn and enfold several 10s of millions of stimulus-response memories onto the same cortical cell

[3] See the earlier description of the Monte Carlo test on page 6 for a more detailed study of the differences between back-propagation models and HNeT.

elements within the brain. As the number of cells increases within the assembly, there is an exponential increase in information storage capacity. This property is unique to holographic/quantum neural cells.

Stimulus-response Patterns and Memory

We can represent a stimulus-response pattern or "memory" as a set of values reflecting conditions or states measured within an external environment (e.g., pressure, temperature, brightness). During stimulus-response learning, holographic/quantum neural cells associate or "map" one set of analog values (i.e. the stimulus field) to another set of values (i.e. the response). Mapping these relationships across a time span results in spatio-temporal models, of which HNeT can construct a virtually limitless variety. The neural cell actually remembers these patterns, and is able to produce the correct response when presented with a new stimulus.

The mechanism for holographic storage displays a capacity to achieve extremely high information densities, because large numbers of stimulus-response memories can be enfolded onto the same set of scalars (in other words - computer RAM). These stimulus-response memories are also learned on one exposure sequence (i.e. one epoch), providing the capability for truly real-time learning.

Conclusion

Whether you manage data, facilities, or people, the security of corporate resources can never be far from your mind. No security solution can guarantee absolute immunity from intruders, because security is all about reducing, rather than eliminating, vulnerability and risks to the organization. You need to judge what is an acceptable level of risk for your organization and then do everything in your power to ensure that you maintain the security necessary to protect your resources against existing and potential threats.

Biometric security is the ultimate in accountability, but you must judge a biometric solution according to three key criteria. Such a solution must be:

- **Practical –** It must be able to handle current volume and scale to projected volume.
- **Efficient –** It must operate within acceptable resource allocation guidelines.
- **Cost-effective –** It must not be prohibitively expensive to implement and maintain.

AcSys FRS meets and exceeds these requirements. It uses Holographic/Quantum Neural Technology (HNeT™) to provide a practical, scalable and highly accurate biometric security solution. HNeT also makes efficient use of both computing and administrative resources in an *n*-tiered client/server environment. It is cost-effective, because it is a software-based solution that can run on conventional hardware and does not require specialized video cameras. Much of the system's implementation and maintenance is automated. Its ease of implementation, integration, and use mean that it makes cost-effective use of your human and network resources.

Biometric security based on face recognition is no longer merely the wave of the future. With AcSys FRS, face recognition has come of age. AcSys FRS successfully applies Holographic/Quantum Neural Technology to the challenge of facial biometrics. Leveraging HNeT, AcSys FRS is able to provide a practical, efficient, and cost-effective face recognition system for multiple applications, and for enterprises of all sizes.

AcSys FRS features:

- Unsurpassed tracking and training capabilities
- High performance without proprietary hardware, data formats, or protocols
- Ease of implementation, integration, and use

Contact Us

Contact us if you want to find out more about the possibilities for AcSys FRS within your organization.

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Frequently Asked Questions

How accurate is AcSys FRS?

In a *one-to-many* test with 185 users enrolled and 150 intruders, AcSys FRS was 99.8% accurate in identifying users and intercepting intruders. Dependability is even higher in *one-to-one* mode. A security system combining AcSys FRS with one or more other technologies such as access cards or passwords is virtually infallible.

Is AcSys Biometrics an ASP?

An application service provider (ASP) provides hardware and software infrastructure, as well as administration and maintenance services, generally on a fee-per-use basis, to companies wishing to outsource potentially hardware-, software-, administration-, and maintenance-intensive portions of their businesses. Use of an ASP is usually transparent to users. Most credit card transactions over the Web use ASPs to ensure the highest possible level of security.

Providing face recognition services over the Web is a natural fit for AcSys Biometrics, but realizing such a venture would require a large investment in infrastructure, human resources, and time. In the short term, we will examine opportunities to partner with existing and emerging ASPs specializing in Web-based transaction processing.

With which companies are you currently partnering?

If you review the recent press releases of NEXUS (formerly HCI), the parent company of AcSys Biometrics, you will see announcements of business relationships with Global TeleMedia International Inc. (and their subsidiary, BentleyTel.com), Logicon Inc., Nortel Networks, and Guardall North America.

Can AcSys FRS distinguish identical twins?

It has differentiated 'identical' twins. Identical twins are never completely identical, but if a person cannot distinguish them, there is the possibility that AcSys FRS will not distinguish them, because AcSys FRS distinguishes faces in the same way that people distinguish faces. We can confidently say that AcSys FRS distinguishes identical twins better than most people do, because it is better at finding minute differences that might be 'below the radar' of the average person.

How does AcSys FRS deal with variations in lighting?

Variations in lighting are an important issue in face recognition technologies in general, but such variations are not as critical for AcSys FRS as they are for other face recognition systems, because:

- AcSys FRS features normalization routines that help it adapt to variations in lighting.
- AcSys FRS retrains automatically on individuals to account for changes in appearance
- AcSys FRS does not rely on facial characteristics that are most affected by variations in light (e.g., flesh tones).

What plans does AcSys Biometrics have for speech recognition applications?

Given the time and resources, AcSys Biometrics will use HNeT to develop speech recognition applications. HNeT will allow a computer using our software to "understand" connected language. Essentially, the computer will learn English and other languages in much the same way a child does, and it will quickly develop the ability to parse sentences (that is, to understand syntax – the way sentences are constructed). However, semantic understanding is another issue entirely.

In general, the short-term objectives of speech recognition are:

1. To verify or identify the speaker
2. To reproduce spoken language as written language

Computerized understanding of the semantic content of speech, and the development of machine intelligence that can generate semantic content in the same manner as humans do, have been long-term objectives of artificial intelligence (AI) research since Alan Turing proposed his eponymous test for machine intelligence in 1950 (Turing, A. M., "Computing Machinery and Intelligence," *Mind*, 59, 433-560).

While we believe that HNeT will be a valuable resource in the quest for semantic machine intelligence, this quest is outside the scope of our current research and plans for commercial speech recognition products. Instead, we will focus on the verification and identification applications of speech recognition.

How much does it cost?

Early adopters of technology frequently pay a higher price to gain a technology advantage. Such higher prices are generally necessary to fund development efforts. When main-stream businesses begin to adopt the technology, the cost of implementation falls rapidly. This pattern applies to AcSys FRS as well, but it is mitigated by the many advantages AcSys FRS provides.

In general, AcSys FRS will be cheaper to implement and maintain than most other face recognition solutions because:

- It is a completely software-based solution, thus avoiding the high implementation costs associated with proprietary hardware.
- It leverages a superior development platform, thus making more efficient use of processing power and computer resources.
- It has extremely low administrative overhead due to automated enrollment and retraining thus making more efficient use of human resources.

Glossary of Terms

AI	See *artificial intelligence*.
algorithm	A sequence of instructions describing a step-by-step process used by a processing engine to solve a particular problem.
ANN	See *artificial neural network*.
application service provider	(ASP) An application service provider provides hardware and software infrastructure, as well as administration and maintenance services, generally on a fee-per-use basis, to companies wishing to outsource potentially hardware-, software-, administration-, and maintenance-intensive portions of their businesses. Use of an ASP is usually transparent to users. Most credit card transactions over the Web use ASPs to ensure the highest possible level of security.
artificial intelligence	(AI) The area of computer science that attempts to reproduce aspects of human thought on computers. It can also be seen as an attempt to solve by computer any problem that a human can currently solve more efficiently. An example of such a problem is the attempt to design a machine to process human language. Such a machine would learn, understand, and speak a human language as well as humans can.
artificial neural network	(ANN) An artificial neural network applies artificial intelligence principles to learn from experience.
ASP	See *application service provider*.
attempt	The submission of a biometric sample to a biometric system for *identification* or *verification*. A biometric system may allow more than one attempt to identify or verify.
automatic enrollment	AcSys FRS allows you to phase in your implementation on top of an existing security solution by gathering biometric samples of your users unintrusively over a period of time. In this automatic enrollment scenario, the system would gather a set of images each time the user swipes his or her card, and training would occur with each swipe. Over a period of time, the system would unintrusively gather a sufficient biometric sample on each user to perform accurate *verification* and *identification*.

automatic retraining	The ability of AcSys FRS to continue to learn after initial *training*. Automatic retraining compensates for changes in appearance over time. See also: *training*.
back propagation	A learning *algorithm* that uses gradient information to modify network weights and thus decrease the value of an error function on each subsequent test of input values.
biometric	A measurable ('metric') characteristic, whether physiological or behavioral, of a living organism ('bio') that can be used to differentiate that organism as an individual.
biometric data	Information extracted from a biometric sample and used to build a biometric *template*, or to compare against a previously created biometric template.
capture	The act of taking a biometric sample.
collocation	Collocation houses provide secure data storage services, usually for backup purposes.
comparison	The process of comparing a biometric sample with a previously stored biometric *template* (*one-to-one*) or templates (*one-to-many*).
decision threshold	The acceptance or rejection of biometric data is dependent on the match score falling above or below a threshold. The threshold is adjustable so that AcSys FRS can be more or less strict, depending on the requirements of any given implementation.
enfolding	The process in HNeT whereby stimulus-response information or 'memories' are superimposed onto the same set of complex *scalars*. These complex scalars form the artificial neural cell's cortical memory.
enrollment	The process of collecting biometric samples from a person and storing them for training.
face recognition	The visual perception of familiar faces.
false acceptance rate	The probability that a biometric system will incorrectly verify or identify an individual or will fail to reject an impostor.
false rejection rate	The probability that a biometric system will fail to verify or identify an enrollee.
FAR	See *false acceptance rate*.
FRR	See *false rejection rate*.

genetic searching — A search technique using an evolutionary algorithm which generates each individual from some encoded form known as a 'chromosome' or 'genome'. Chromosomes are combined or mutated to breed new individuals.

Hilbert space — A metric space that is linear and complete and (usually) infinite-dimensional. A complete infinite-dimensional vector space on which an inner product is defined. Named for German mathematician David Hilbert (1862-1943).

holographic storage — A method of achieving extremely high information densities by *enfolding* large numbers of stimulus-response memories onto the same set of *scalars* (in other words - computer RAM). These stimulus-response memories are also learned on one exposure sequence (i.e. one epoch), providing the capability for truly real-time learning.

identification — The *one-to-many* process of comparing a submitted biometric sample against all of the biometric templates on file to determine whether it matches any of the templates and, if so, certifying the identity of the individual providing the sample. The biometric system using the one-to-many approach is seeking to find an identity within a database rather than to verify a claimed identity. Contrast with *verification*.

intruder — A person who submits a biometric sample in either an intentional or inadvertent attempt to pass himself or herself off as another person who is an enrollee.

matching — The process of comparing a biometric sample against a previously stored template and scoring the level of similarity. An accept or reject decision is then based upon whether this score exceeds a pre-established threshold.

neural plasticity — The pruning of cortical memory elements and associated synaptic connections, and the growing of new cortical memory elements and associated synaptic connections. The concept of neural plasticity is central to HNeT's ability to learn in real time.

neurophysiology — The branch of neuroscience that studies the physiology of the nervous system.

numerical analysis — The branch of mathematics dealing with methods for obtaining approximate numerical solutions of mathematical problems.

one-to-many	Describes the technique of comparing a biometric sample against all biometric templates in a database. The one-to-many technique is used in *identification*.
one-to-one	Describes the technique of comparing a biometric sample to a single biometric template. The one-to-one technique is used in *verification*.
quantum mechanics	The mathematical framework governing the microscopic world and specifying the behavior of matter and energy in fundamental processes.
real-time learning	The ability of a system to learn immediately from experience. AcSys FRS displays real-time learning in the way that it trains and retrains on individuals.
scalar	A single number, as opposed to a vector or matrix of numbers.
stimulus-response memory	A set of values reflecting conditions or states measured within an external environment (e.g., pressure, temperature, brightness). During stimulus-response learning, holographic/quantum neural cells associate or "map" one set of analog values (i.e. the stimulus field) to another set of values (i.e. the response). Mapping these relationships across a time span results in spatio-temporal models, of which HNeT can construct a virtually limitless variety. The artificial neural cell actually remembers these patterns, and is able to produce the correct response when presented with a new stimulus.
template	Data which represents the biometric measurement of an enrollee. This data is used by AcSys FRS for real-time comparison against biometric samples.
tracking	The act of finding a facial image within a larger image and following it as it moves within that larger image.
training	AcSys FRS trains on a user to refine its understanding of the complexities that define the user's face and to build a biometric template for use in verifying or identifying th user.
verification	The process of comparing a submitted biometric sample against the biometric template of a single enrollee whose identity is being claimed. Contrast with *identification*.

wave packet equation

HNeT derives its quantum analogy from the wave packet equation found in quantum mechanics. This equation relates to the superposition of energy waves of slightly differing angular frequency. This superposition of harmonics defined by the wave packet produces an energy envelope. The wave equation is used within quantum mechanics to describe the physics of photons, electrons, protons, and other particles. Operation of the holographic/quantum neuron cell within the (much simplified) linear model follows a form similar to the wave packet equation.