LivDet 2015: Liveness Detection Competition 2015
Stephanie Schuckers, David Yambay, Joe Skufca
Fingerprint recognition systems are vulnerable to artificial spoof fingerprint attacks, like the molds made of silicone, gelatin or Play-Doh, etc. Suspicious presentation detection systems, such as liveness detection, have been proposed to defeat these kinds of spoof attacks. In 2013, U of Cagliari and Clarkson University hosted the third competition to test software-based and hardware-based Fingerprint liveness detection algorithms. This competition was organized according to the following: Part I—Algorithm-based: Included distribution of a dataset of spoof and live images for training and evaluation of submitted algorithms on a sequestered database and Part II—System-based: Included submission of a hardware/software system device which returned a liveness score and evaluation based on spoof samples and live subjects. Results were presented at ICB2013. Numerous groups submitted to this competition, with increasing interest from the community. LivDetIII also included the inaugural iris liveness detection competition with LivDet 2013-Iris. Iris systems have shown a weakness to attacks by a client obscuring their natural iris pattern with a patterned contact lens or the use of printed iris image. Clarkson University partnered with Warsaw University of Technology and Notre Dame University to create an initial iris liveness detection competition. LivDet 2013-Iris only included a Part 1: Algorithms. The dataset of spoof and live iris images from this competition has been made available to researchers. We propose to host LivDet 2015. LivDet 2015 will be composed of Part I—Algorithm-based, with training/testing datasets, and Part II—System-based, which allow submission of hardware/software systems. Both parts will be for both fingerprint and iris systems. Analysis of performance will enable knowledge of the state-of-the-art in the field, as technologies begin to emerge. As additional component, we will develop an experimental plan for a LivDet-Voice competition. Speaker recognition systems are known to be vulnerable to play-back attacks, voice conversion, speech synthesis, or mimicking attacks. Such spoofs are non-trivial to develop and execute. To support inclusion of a Voice component to future LivDet competitions, we will use a small component of project funding to develop audio-spoof methodologies and competition protocols.

Credibility Assessment On The Go: Evaluating a Tablet-Based Concealed Information Test
Jim Marquardson, Jeffrey Proudfoot, Mark Grimes, Justin Giboney
People frequently deceive others by concealing information. The Concealed Information Test (CIT) is a method of conducting credibility assessment interviews. Interviewees are presented with stimuli while physiological and behavioral variations are measured. Innocent people react randomly to the stimuli while persons concealing information have distinct physiological responses when presented with crime-relevant information. Physiological cues are often measured using the same sensors as the polygraph. We propose building a tablet-based CIT application. The application would automate interviewing and use the tablet’s microphone, accelerometer, and gyroscope to distinguish levels of arousal that indicate deception.

Methods for producing cancellable and secure templates for Face Recognition
Venu Govindaraju, Sergey Tulyakov (UB)
We seek to extend the work done in generation and matching of privacy preserving fingerprint templates to other biometric modalities such as faces. Unlike fingerprints, faces exhibit a high degree of variation arising from pose, illumination, age, facial hair etc. and exact matching of features like minutiae points from fingerprints is not feasible. As such, face recognition has been largely approached using holistic methods such principle component analysis and linear discriminant analysis followed by approximate matching of the projected feature vectors. Given such a scenario it is difficult to use highly secure one way hash functions to protect the templates since matching accuracy would deteriorate severely in the absence of exact matches. Several algorithms have been proposed for protection of face
templates but fall short in either providing the security hash functions provide, give out information about the distribution of the true templates or require additional user specific information. We believe that using localized features from sub regions of the face we can achieve exact matching between regions of the template and thus provide the high security of one way hashes without giving out any information about the distribution of the original user data. We propose the detection of meaningful key points in the face region and designing and extracting features suitable for hashing (high security) as well as high matching accuracy. Experiments comparing the performance of several localized features and quantization techniques and a theoretical analysis of the security provided will be performed.

**Face Liveness Detection**  
Anil K. Jain
With the growing popularity of face recognition, particularly in unattended (e.g., access control) and consumer applications (e.g., mobile phone unlocking), there is an urgent need to prevent spoof attacks, such as printed photo or replay video attacks. The face unlocking application that comes with Android phones can be easily circumvented by these simple attacks. More sophisticated attacks involve 3D face masks. While several face anti-spoofing methods have been published, they are not robust. As an example, face liveness methods trained on Idiap database perform poorly on CASIA database. The objective of this research is to leverage multiple face spoof databases to design a (i) robust, (ii) accurate, and (iii) real-time face spoof detector.

**Heterogeneous Face Recognition: Still-to-Video Matching in Real-World Scenarios**  
Guodong Guo (WVU)
Heterogeneous face recognition (HFR) is an emerging topic in Biometrics, for both academic research and real-world applications. The study of HFR is motivated by the advances in sensor technology development that make it possible to acquire face images from diverse imaging sensors, such as the near infrared (NIR), thermal infrared (IR), and three dimensional (3D) depth cameras, and also motivated by the demand from real applications, e.g., the recent IARPA’s Janus Program requests HFR in its Phase III. In addition to the typical HFR, some other emerging face recognition problems can be categorized into HFR as well. For instance, the matching between makeup and non-makeup faces [3,4], between faces from digital photos and video frames, or faces of high and low resolutions [2]. Currently commercial biometric systems cannot deal with HFR well [1]. In this project, we will overview the developed methods for various HFR problems, and then focus on a specific HFR problem, called still-to-video (S2V) face recognition in the real-world scenarios (containing a variety of variations, e.g., quality, resolution, pose,...). This problem has not been well-studied yet [5].

**Security Analysis of Fingerprint Matching Systems**  
Venu Govindaraju, Atri Rudra (UB)
With the increasing popularity of fingerprints to secure data, there is a greater need to secure fingerprint templates. Fingerprint template security has been studied and there are many systems claiming various level of security. These systems are analyzed using a wide variety of techniques with varying rigor and accuracy. Since the techniques used are so different, it is difficult to compare the security of any two schemes, even if the schemes themselves are similar. This project will work towards solving these issues and lead to an accurate way of measuring and comparing the actual template security of such systems. We will start this project by analyzing existing systems with template security. During this phase, we will develop rigorous proofs for the security of these systems if they are lacking. We will then take the proofs developed during this phase to generate ways to prove the security of other systems. Our goal will be to develop a generic way to analyze arbitrary systems based on a list of properties a system should have. For each property, we will provide thorough analysis of its impact on template security. Given these properties and analyses, we will develop a template scheme that can be used to develop systems with already proven security. Throughout, we will have a strong focus on the balance between theory and practice as both are necessary for a fingerprint matching scheme that claims template security.
An interviewing chat bot for enhancing voluntary information disclosure

Ryan Schuetzler, Mark Grimes, Justin Giboney, Joey Buckman, Jim Marquardson, Judee Burgoon

As automated agents become more pervasive in information gathering (e.g., in a medical office, or during a fraud investigation), it is important to understand how they compare to human or survey-based methods of information solicitation. This research will investigate the design of a chat bot for soliciting sensitive information from individuals. We will create a chat bot that provides a dynamic interview using content analysis to create individually-customized follow-up questions in order get people to disclose information that they initially withhold.

Validating the Representativeness of Samples from Sequestered Biometric Data Sets

Bojan Cukic, Mark Culp (WVU), Michael Schuckers (St. Lawrence)

As the application of biometrics in identity management systems grows in scale, the accuracy of performance prediction requires the use of adequate population / data samples. Such samples can be assembled through careful data collection or through the informed selection from existing biometric data sets. The proposed research will concentrate on the second approach: validating the representativeness of a given test sample for the performance prediction of large, but possibly sequestered, identity management data set. Such test sample could be created from the sequestered data set, or come from outside sources. The representativeness of biometric samples for performance prediction, somewhat surprisingly, has not been directly addressed in research. Because biometric technologies deal with human subjects, collections are relatively expensive and rely upon convenience sampling [1]. But recent literature clearly indicates that the performance of biometric algorithms can be clearly biased by gender, age and even ethnic group participation in the sample [2]. We have exploited this observation in prior research with the goal of minimizing sample size for performance prediction of face recognition through stratified sampling [3]. A proactive method for performance prediction from random sampling using the variability control technique generally known as reliability assessment charts allows biometric performance assessment [4], but it does not guide the selection of adequate test samples – human subjects. Regardless of the approach, if bias is present in the test sample, the statistical projections of system performance will likely offer misleading results and lead to inaccurate conclusions. For this project, we have been offered access to a large biometric repository of identity management data, Data Set A, in three modalities: face, fingerprints and iris. We will be work together with the custodians of the sequestered US Government identity management data set, the Data Set B. For each modality, starting with face, we plan to identify the biometric quality and population factors that drive the distribution of match scores in data sets A and B. We will achieve that by using a minimal sample size from sequestered Data Set B. We will develop a statistical definition of biometric data set “representativeness” with respect to the ability to predict performance within the specified error bounds.

Biometric Aging in Children

Dan Rissacher, Ph.D.; Stephanie Schuckers, Ph.D.; Laura Holsopple; Patty Rissacher, M.D.

In this project we will collect biometrics (fingerprint, footprint, iris, face, hand vein, voice) in children age 0-18 years over multiple visits. The data will be analyzed towards multiple goals: 1) Earliest age of modality’s viability 2) Variability of modality with age 3) Developing models to account for age-variations 4) Development of age measurement metrics. The search for age-determination metrics will include data already obtained with a modality (e.g. iris features, vein Measurements) and data that could easily be simultaneously collected (e.g. pupil or eyeball size).

Improving User Perceptions of Identification / Authentication Technologies: Empowering Users with Control to Reduce Privacy Concerns

David Wilson, Jeffrey Proudfoot, Ryan Schuetzler, Bradley Dorn, Joe Valacich

New technologies designed to improve identification and authentication accuracies are continuously developed and adopted for use by government agencies conducting security operations. Interactions with these systems are often mandatory, raising privacy concerns about the data that is collected. These technologies are often designed and implemented with little emphasis on how user perceptions of these technologies may influence their performance. We propose that a new area of research should be emphasized, namely, how to reduce the anxiety/concern of individuals regarding the disclosed information. This project will examine one such strategy: measuring the effect of restoring
Cross-Device and Cross-Distance Matching Face Recognition using Cell Phones with Enhanced Camera Capabilities

Thirimachos Bourlai

Standard face recognition (FR) systems compare new facial images or probes with gallery pictures to establish identity. They typically perform well using good quality, visible band cameras, when lighting is good, and subjects are cooperative and close to the camera. However, many law enforcement and military applications deal with mixed FR scenarios that involve matching probe face images captured by difference portable devices (cell phones, tablets etc.) and at variable distances against good quality face images (e.g. mug shots) acquired using high definition camera sensors (e.g. DSLR cameras). Although most portable devices (cell phones, tablets etc.) operate in the visible band, the problem of cross-scenario matching, e.g. matching face images captured by difference camera sensors and devices and at different conditions (indoor, outdoors, variable distances) is open area for research. This is also known as the heterogeneous FR problem and a potential solution will enable interoperability by adding a device-independent matching component. While there are baseline studies reported in the literature, where face images captured from different devices are matched against visible good quality face images [1-6], to our knowledge, there is no study reported where all face datasets available are simultaneously collected (i) using variable portable devices that have the capability (sensors) to acquire mid-range (>10 meters) face images (e.g. Samsung S4 Zoom with 10x optical zoom, Nokia 1020 with a 41MP sensor etc.) and (ii) at different standoff distances. In this work, we will investigate the benefits of cross-device and cross-distance mobile-based face recognition. Our proposed work will investigate answering the following questions: (1) Can we efficiently match mid-range outdoor (>10m) face images captured by cell phone/tablet devices to their good quality, indoor, visible counterparts? (2) Can we repeat (1) when standoff distances vary (e.g. 10 meters outdoors vs. 2 meters indoors)? (3) What is the maximum operational distance of the aforementioned cell devices with long range camera capabilities or, in other words, what is the maximum stand-off distance where FR rank-1 scores are still acceptable (e.g. > 98% on a target of 100 people)?

Multimodal Biometrics for Long-term Active User Authentication

Venug Govindaraju/Ifeoma Nwogu

Computer systems are extremely vulnerable to “masquerading attacks” where an unauthorized human or software impersonates a user on a computer system or network. Standard methods to authenticate a computer/network user typically occur once at the initial log-in. These involve user proxies, especially passwords and smart cards such as common access cards (CACs) and service ID cards, all of which suffer from a variety of vulnerabilities. By actively and continually authenticating a user, intruders can be identified before they hijack the user session of an authorized individual who may have momentarily stepped away from his/her console. We therefore propose to investigate multi-modal biometric-driven authentication processes. The biometrics methods we will investigate include combining face recognition, recognition based on keystroke dynamics and mouse movements of the user at the terminal, and lastly, the intrinsic, language-usage attributes of the user.

Improving Writer Identification/Verification for Mobile and Touch Environments by Modeling Writer Styles

Venug Govindaraju/Srirangaraj Setlur/Sergey Tulyakov

With the increasing use of touch-based handwritten text input for smartphones, tablets and other touch screen surfaces, online writer identification and recognition are becoming critical needs for a variety of applications. We believe writing style represents a shared component of individual handwriting. Thus a person’s handwriting can be a priori conceptualized as an individual-specific combination (determined by a person’s physiology - genetic factors) of a shared pool of writing styles (often determined culturally - memetic factors). We explicitly model this theoretical framework using a Latent Dirichlet Allocation based approach for the task of writer identification [3, 4]. By using LDA we can efficiently model a large superset of writers by using a significantly smaller subset of writing styles. As LDA is a
generative model, writers who are not in the original corpus may also be identified from the existing learned distribution of writing styles. The LDA-based model overcomes the limitations of scalability and extensibility of other approaches [1, 2] which is critical in the online domain. We propose to adapt and test this model on handwritten input on mobile platforms.

Deception Detection Using Computer Expression Recognition

**Judee Burgoon, Steven J. Pentland, Nathan Twyman**

Facial movement and expressions can be a measure of emotion and cognitive strain and a possible sign of deception in screening and interviewing scenarios. Most deception research utilizing facial expressions has compared groups of deceptive/guilty innocent/truthful subjects. The proposed project will conduct analyses within subjects, looking for deviations from their own truthful baseline when responding deceptively. As a further innovation, the investigation will test whether facial movements function as telltale indicators during a concealed information test. If so, they can be added to the arsenal of nonverbal cues of criminal knowledge and malintent.

Multi-channel physiological simulator: Extension

**Edward Sazonov, Timothy Haskew and Stephanie Schuckers**

The goal of the original project was to create a physiological simulator for testing of polygraph equipment. The designed simulator is capable of simultaneous and time-synchronous playback of recorded physiological signals such as respiration (2 independent channels), electrodermal activity (1 channel), and cardiovascular activity as observed by a blood pressure cuff (1 channel). The goal of the current extension is to build 3 additional simulators and tests them for repeatability of results.

Covert Detection of Strategic and Nonstrategic Deception Cues with a Bogus Concealed Information Test

**Jeffrey Gainer Proudfoot (UA), Judee K. Burgoon (UA), Aaron Elkins (Imperial College, London / (UA), Nathan Twyman (UA)**

Interpersonal Deception Theory (IDT) contends that “Compared with truth tellers, deceivers (a) engage in greater strategic activity designed to manage information, behavior, and image and (b) display more nonstrategic arousal cues, negative and dampened affect, noninvolvement, and performance decrements.” A recent Concealed Information Test (CIT) study using visual stimuli found that those concealing information fixated on the center of the screen and exhibited longer responses latencies compared with the control group of truth tellers throughout the test, regardless of whether target or nontarget stimuli were presented. This unexpected finding suggests that a new interviewing technique (adapted from the CIT) may be feasible for use in identifying strategic and nonstrategic indicators of deception. Because this adapted technique can use bogus target items, it may be more feasible for adoption and use in the field.

Fingerprint Identification: A Longitudinal Study

**Anil Jain (MSU)**

Fingerprint identification is based on two fundamental premises: (i) persistence and (ii) uniqueness of the ridge pattern. Although a number of statistical models have been proposed to demonstrate fingerprint uniqueness (individuality), the persistence of fingerprints has been generally accepted based on anecdotal evidence. In this study, our objective is to (i) formally study the impact of elapsed time (time span) between two fingerprint impressions on genuine match scores, (ii) model the fingerprint longitudinal data with multilevel statistical models, (iii) identify additional predictive variables of genuine match scores (e.g., subject’s age, gender, race, changes in image acquisition method (inked or livescan), etc.), and (iv) quantify the impact of these factors on genuine match scores. The null hypothesis we want to test can be stated as follows: Fingerprint identification accuracy does not depend on the time span between the query and reference print.

Fusing Biometric and Biographic Information in Identification Systems

**Arun Ross (MSU), Anil K. Jain (MSU), Don Adjeroh (WVU), Bojan Cukic (WVU)**

Multibiometric systems consolidate evidence provided by multiple sources to establish the identity of an individual [1]. Typically, these sources correspond to the biometric traits of an individual such as face, iris, fingerprint and palmprint.
We propose to investigate the problem of combining non-biometric, biographic data (such as name, age, gender, ethnicity, nationality, etc.) with biometric information in order to render better decisions about the identity of individuals. Such a research effort is warranted due to the potential use of mixed data (i.e., biometric and non-biometric) in large-scale identity management systems such as US-VISIT (now OBIM), TWIC and E-VERIFY. Further, social media sites such as facebook, linked-in, and twitter have both biometric (viz., face images) and biographic details of an individual. However, the role of biographic data in establishing the identity of an individual in large-scale systems has hitherto not been studied. This project will undertake a systematic study to establish the utility of combining biographic data with biometric information to establish identity.

**Touch DNA: Fusing Latent Fingerprint with DNA for Suspect Identification**

*Arun Ross (MSU), Anil Jain (MSU), Jeremy Dawson (WVU), Tina Moroose (WVU)*

Touch DNA refers to the genetic sample left behind by a suspect in a crime scene. Typically, this may correspond to a few skin cells adhering to a surface touched by the suspect. For example, a criminal may touch an object leaving behind a latent fingerprint as well as skin cells or sweat pertaining to that fingerprint. Processing and analyzing the DNA extracted from these cells in order to establish human identity is challenging and prone to error due to (a) the limited number of cells that are available (and, consequently, low-yielding DNA), and (b) the inevitable sample contamination that occurs due to sample exposure and the extraction and storage processes. In this project, we seek to develop methods for performing suspect identification that combines touch DNA with latent fingerprints obtained from a crime scene. In this scenario, both the DNA and the fingerprint are expected to be of low quality, i.e., they are inherently corrupted and, therefore, less reliable when used independently for suspect identification. The goals of this work are to: (a) develop an understanding of how low-copy DNA processing methods impact signal quality (b) develop advanced signal processing and matching routines for extracting identifiable data from these two potentially corrupted modalities (i.e., fingerprint and DNA); (c) implement a fusion framework that combines these two modalities in order to identify a suspect; and (d) execute a performance evaluation framework for gauging the efficacy of the proposed signal processing and fusion schemes.

**Hardware Accelerator Approach Towards Efficient Biometrics Cryptosystems**

*Chen Liu and Stephanie Schuckers*

Biometric cryptosystems combine biometrics and cryptography at a level that allows biometric matching to effectively take place in the cryptography domain. This is practically attractive to cloud computing scenario when strong emphasize is put on the integrity of the biometric data (templates). Even though biometric cryptosystems can provide enhanced level of security, the need to access and process the data at ideally real-time for large datasets poses great challenge. We propose to design specialized hardware accelerators to meet the computation demand associated in design and implement such systems. We propose to design customized hardware accelerator in the form of IP (intellectual property) correspondingly. The work will be developed using hardware description language and implemented on FPGA (Field Programmable Gate Arrays) platform. We will validate our proposed approach by comparing the difference in terms of performance, power consumption and energy efficiency against the traditional approaches without hardware accelerators. This research project will facilitate the efforts to make biometric cryptosystems more widely deployed in security identification for both industry and government, targeting at the future cloud-computing platform.
CITeR 2013

Bacterial DNA as a Human Biometric Identifier
Jeremy M. Dawson (WVU - LCSEE), Letha Sooter (WVU - HSC Basic Pharmaceutical Sciences)

The goal of this project is to develop a method of bacteria-based identification that can overcome the degradation and throughput issues associated with human STR analysis. The presence of bacteria on human skin has a negative connotation in the realm of health and hygiene. However, recent research into the variations of these bacterial colonies in individual people has led to the application of human bacteria as an identification tool. Because bacterial colonies remain viable and multiply on surfaces, bacterial DNA is often more robust to environmental exposure than that of deposited human epithelial cells which are used to obtain human DNA. Recent studies of human skin bacterial composition based on gender, body location, time, and even washing habits, indicate little to no colonial variability for a single individual within these parameters, and high diversity among small groups (~20) of human subjects. The specific aim of this project is to examine the population(s) of hand bacteria colonies within a group of 200 individuals. The findings of this study will provide the basis for the development of biometric identification techniques based on human bacterial signatures.

Face Recognition with Significant Aging and Photo Quality Variations
Guodong Guo (WVU), Jeremy Dawson (WVU) and Bojan Cukic (WVU)

Human identity management is important in visual surveillance, security, and law enforcement applications. As an important biometric cue, face recognition is very useful for non-invasive identification of non-cooperative users. However, there are great challenges in developing robust face recognition systems. The great challenges include facial aging variations and image quality changes among others. For example, in the enrollment, a high quality face photo can be captured, while in recognition, the query face images can be captured by cameras with different qualities (i.e., inter-platform operation), or appeared in different formats, e.g., passports, social media, photo scan, newspapers, etc. Furthermore, the subjects in query can often have ages different from the gallery with significant facial appearance changes. Thus in many real applications, face recognition suffers from coupled aging variations and all kinds of photo quality variations. In this work, we will develop new methods for face matching robust to aging and photo quality variations. The FBI BCOE database will be used to validate our techniques and build a benchmark.

Improving Latent Fingerprint Matching Accuracy: Role of Feedback from Exemplar Prints
Anil K. Jain, Michigan State University

Latent fingerprints have served as an important source of forensic evidence for identifying suspects. However, latent fingerprint impressions are typically of poor quality with complex background noise which makes feature extraction and matching of latents a significantly challenging problem. In this research, we propose incorporating “top-down” information or feedback from an exemplar to refine the features extracted from a latent with the eventual aim of improving the latent matching accuracy. The refined latent features such as ridge orientation and frequency, after feedback, are used to re-match the latent to the top-K candidate exemplars and resort the candidate list. The objectives of this research include: (i) devising systemic ways to use information in exemplars for latent feature refinement, (ii) developing a feedback paradigm which can be wrapped around any latent matcher for the purpose of improving its matching accuracy, and (iii) determining when feedback is actually necessary to improve the baseline latent matching accuracy.

Automating Interoperability Enhancement for Fingerprint Sensors
E. Marasco, B. Cukic (WVU)

Interoperability within complex biometric systems enables seamless operation in spite of the variations introduced by different capture devices. Increasing competitiveness within the fingerprint sensor market makes the reliance upon a single sensor vendor economically and technically unwise. Our initial experiments show that even for a specific sensing technology, different arrangements of sensing elements cause varying distortions in the biometric data. In many
practical scenarios (US Visit, law enforcement, etc), users are enrolled using a 500 dpi optical sensor (most with a sensing area of 1.2” x 1.2”), but there is no guarantee that the same device will be used to capture the probe. In 2012, we carried out a large-scale data collection (500 users) using nine different fingerprint devices and a set of ink prints. Some of the devices are included in the CJIS certified products list. We found that the genuine match scores generated by comparing biometric samples captured using the same device were generally higher than when devices were different. These score fluctuations exist even between the devices included in the CJIS list. We also found that device diversity leads to an increase of the false non-match rate. The impact is higher when the gallery is of low quality. The objective of this project is to develop automated tools that reduce the impact of the lack of interoperability on the matching performance. The image quality of a fingerprint image is affected by the fingerprint’s condition, user’s familiarity with the device, user interaction, acquisition technology and characteristics of the device. We will model the qualitative information about a fingerprint from the device id and quality measures. In addition to the clarity of the ridge and valley patterns we plan to use minutiae count, alignment and number of paired minutiae as interoperability model parameters.

3D Face Acquisition using a Smartphone

*D. Adjeroh, M. Piccirilli, G. Doretto, A. Ross (WVU)*

Recently, the acquisition of 3D face has gained significant interest, given the improvements in human recognition using 3D facial features. Though various 3D face scanners exist today, data acquisition using portable mobile devices still remains a critical challenge. Yet, various applications in biometrics, public safety, security, and mobile health stand to benefit from progress on this front. Our primary goal in this project is to create a hand-held portable system for the acquisition of 3D faces using a simple smartphone. The basis of our approach is the concept of 3D shape from structured light [1, 2]. While the field of 3D scene analysis has been studied for decades, the technology to support the type of information needed for 3D shape from structured light only became available relatively recently. Our approach for acquiring a 3D face using a smartphone equipped with only an RGB camera is as follows: (1) We will collect 3D information of the face by just illuminating it with the desired pattern and invoking algorithms for 3D reconstruction through structured light. We propose to use a small illuminant which can illuminate a scene up to 3 meters with a good contrast. It will have the form factor of a cellular phone, will be portable, and will have enough battery life to guarantee a few hours of acquisition. (2) The illuminant will connect to the cellular phone, providing us the capability to build a sophisticated structured-light system that can withstand different variabilities in the acquisition environment.

Benefits of Cross-spectral (visible, NIR and LWIR) and Cross-Distance Face Recognition In Non-Ideal Environments

*S. Schuckers, T. Bourlai, and F. Hua (Clarkson and WVU)*

Standard FR systems compare new facial images or probes with gallery pictures to establish identity. They typically perform well in the visible band, when lighting is good and cooperative subjects are close to the camera and without facial expression. However, many law enforcement and military applications deal with mixed FR scenarios that involve matching active (0.9 - 2.5 microns) and passive (3-5 or 7-14 microns) infrared (IR) probe images against all images (e.g. mug shots) in a visible gallery database. This is also known as the heterogeneous problem. While there are studies reported in the literature where either NIR or thermal images are matched against visible ones [1-6], to our knowledge, there is no study reported where all face datasets available are simultaneously collected (i) in three different bands, covering the visible, active and passive IR bands, and (ii) at different standoff distances. In this work, we have the advantage of utilizing an existing multi-spectral, multi-distance dataset to investigate the benefits of cross-spectral, cross-distance, and cross-expression face recognition. This is basically one sub-dataset collected as part of the Clarkson's ‘Un-constrained Biometrics at a Distance’ project, namely the ‘Multi-spectral Face Dataset’. In particular, the dataset contains visible, NIR and LWIR face data captured under ideal (neutral facial expression) and non-ideal (varying facial expressions) scenarios at 7ft, 17ft, 25ft and 35ft standoff distances. Our proposed work will investigate answering the following questions: (1) Can we efficiently match long wave infrared (LWIR) and Near Infrared (NIR) face images to their visible counterparts? (2) Can we repeat (1) when standoff distances varies (i.e. cross-spectral, cross-distance)? (3) Can we repeat (1 and 2) when facial expression varies?
Fingerprint Texture Modeling for Synthetic Fingerprint Generation and Liveness Detection

Stephanie Schuckers, Peter Johnson (Clarkson)

We propose a fingerprint texture modeling framework to be used for synthetic fingerprint generation as well as fingerprint liveness detection, i.e., discriminating between live and fake fingers. Texture characterizing features can be modeled from real fingerprint images. The texture characterizing features proposed here include ridge intensity along the ridge centerlines with multiple frequency components, ridge width, ridge cross-sectional slope, ridge noise, and valley noise. The measured features can be linked to synthetic generation approaches in order to create synthetic fingerprint texture which is statistically representative of a particular real fingerprint database. Additionally, with statistical representations of the texture features, a more robust model for fingerprint liveness detection can be created. Liveness detection often requires large sets of training data to achieve good performance. With this more robust model of texture features, it is likely that training set size could be greatly reduced.

Lie to Me, Chatter Bot Style

Joseph R. Buckman, Justin Scott Giboney, Mark Grimes, Ryan Schuetzler, Judee K. Burgoon (University of Arizona)

Deception in computer-mediated communication (CMC) can be especially prevalent because deceivers can freely edit their messages to make them more persuasive or believable. To investigate the unique indicators of this type of deception, we will create an online chat bot program that conducts an interview. We will combine the text-based indicators available with chat interfaces (e.g., keystroke data) from Derrick et al. (2012) with the deceptive linguistic cues in synchronous and asynchronous CMC found in Zhou et al. (2004) to identify whether these combined features provide more accurate classification of truthful and deceptive responding.

Remote Heart Rate Identification to Detect Deception

Justin Scott Giboney, Jeff Proudfoot, Ryan Schuetzler, Steven Pentland, and Judee Burgoon (University of Arizona)

Heart rate can be a measure of stress, arousal and emotion, all correlates of deception. Many screening and interviewing scenarios could benefit from the ability to remotely measure heart rate, however, the ability to do so has not existed until recently. The purpose of this project is to test the accuracy of a newly identified methodology of remotely measuring heart rate (from MIT). This new methodology leverages video analysis software to identify changes in color saturation in the face, indicative of changes in blood density below the surface of the skin, which are associated with pulse activity. The focus of this project is evaluating the heart rate accuracy of this software and the deception detection accuracy of output.

Matching Methods for Privacy Preserving Indexed Fingerprint Templates

Venu Govindaraju, Atri Rudra (Buffalo)

The feature set indexing (also known as bag of features, or bag of words) methods are getting popular in computer vision applications, and have been shown to outperform all other indexing methods for fingerprint templates. In our recent work we combined such indexing methods with privacy preserving fingerprint templates created by fuzzy vault method. Although the algorithm has satisfactory indexing performance, the matching accuracy based on such indexed templates is worse than that of traditional fuzzy vaults or other fingerprint matching methods. We believe that matching accuracy decrease is due to two factors: (a) discarding the spatial relationships between features in the indexing method and (b) the bin quantization not allowing the calculation of the informative matching score between features. The solution of keeping the alternative fingerprint templates and performing second stage matching to confirm the indexing results, suggested by previous works on fingerprint indexing, might not be feasible since such templates could violate privacy property, especially when combined with index information. Instead, it might be possible to improve performance by keeping additional specific information addressing two factors in stored templates and using it for refined second stage match. We propose to investigate the use of two types of additional information: mean positions and directions of features, and the differences between features and quantization bin centers. The theoretical studies on privacy preservation and experimental studies on matching performance will be conducted in this project.
Soft Biometrics for Mobile Smart Environments

_Venu Govindaraju/Sergey Tulyakov (Buffalo)_

One of the key desirable properties of a smart environment is the ability to track the location of each person, and in this project we assume that such an environment is being modeled using the video data captured by mobile or wearable cameras. As an example, emergency response team personnel could be investigating a vehicle crash scene using wearable cameras and a networked computer system would reconstruct the model of the scene and track the positions of injured persons. In this project, we would like to investigate the use of soft biometric features for person tracking in such environments. The distinguishing characteristics of the problem is the intermittency in the person’s observations and variable positioning of video cameras, which might require the use of novel soft biometric features. For example, it might be difficult to determine frequently used soft biometric traits of the height and gait due to insufficient observations of person’s walking and uncertain position of the camera. The technique of subtracting the background to determine the profile of the person might not be available as well due to changing camera positions. Instead, we propose to use the set of session soft biometric features, such as skin, hair and clothing colors, skin marks, feature descriptor vectors associated with interest points (e.g. SIFT, SURF), etc. Such features will be extracted and positioned with respect to tracked face position and will enhance the traditional face biometric matcher. The use of multi-frame matching and score fusion algorithm for smart environment tracking will be investigated as well.

Cloud-Empowered Mobile Biometrics

_Matthew Valenti and Arun Ross (WVU)_

As biometric systems mature, two conflicting challenges have emerged. On the one hand, surges in enrollment have dramatically increased the computing requirements. On the other hand, the desire to implement biometric identification on mobile, handheld systems has reduced the amount of computing power available to the end users. These two requirements can be simultaneously met using cloud-computing resources, such as Amazon’s Elastic Compute Cloud (EC2), which allows computing to be treated as a utility. However, it is not yet clear when and how to best leverage cloud computing for biometric applications. Furthermore, the risks of cloud-computing based biometric systems have not been fully characterized, and research needs to be directed towards mitigating these risks. In this work, we will investigate the use of cloud-computing technologies for performing biometric identification and related tasks. The goals will be to identify appropriate uses of cloud technology, quantify their risks, and explore methodologies that minimize risk. A proof-of-concept mobile facial recognition system will be developed, which uses the concept of visual cryptography to ensure the privacy of the database.

Matching Iris Images against Face Images

_Arun Ross (WVU)_

We consider the problem of matching color (RGB) face images obtained using a digital camera against near-infrared (NIR) iris images obtained using an iris scanner. This problem is especially relevant in the context of matching iris images against legacy face databases in order to establish identity. However, there are several challenges that have to be addressed. Firstly, the spatial resolution of the iris in the RGB face image can be significantly lower thereby offering limited biometric information compared to that of the iris obtained using a dedicated iris scanner. Secondly, the difference in spectral bands (RGB versus NIR: the cross-spectral problem) and sensors (face camera versus iris scanner: the cross-sensor problem) can introduce photometric variations in the corresponding iris images. These variations will be especially pronounced for dark-colored irises whose texture cannot be easily discerned in the RGB domain. Thirdly, due to effects of human aging, there may be anatomical differences in the corresponding face and iris images. This work will explore the possibility of addressing these challenges and designing robust segmentation, feature extraction and matching algorithms for matching face images against iris images.

Towards Low Cost, Deployable Thermal Biometrics: Achieving Cooled Camera Performance from Next Generation Uncooled Devices

_T. Bourlai, J. Dawson and L. Hornak (WVU)_
In thermal-based face recognition investigations, the selection of infrared (IR) detectors [1] is frequently critical in producing key trace evidence for the successful solution of human identification problems [2]. The two detector technologies most commonly used for face examination currently are cooled (Photonic IR) and uncooled (e.g. micro bolometers). Acquisition of thermal face imprints is used as the first step in the analytical process of identification and comparison of thermal imaging characteristics of human faces (e.g. subcutaneous face patterns etc.). The main issues in the acquisition of face images regarding the usage of IR detectors include the following facts: (1) Cost-Size-Deployability: the usage of high sensitivity detectors (photonic IR) with low noise results is high image quality; but this requires cooling the detectors (which makes direct photon detection) and, thus, the complexity as well as the size and inability for easy deployment of such detectors increases. (2) Temperature Calculation: certain IR cameras (mainly the uncooled ones) do not have built-in software that allows the users to focus on specific areas of the Focal Plane Array (FPA) and calculate the temperature. (3) Variable FOV Optics: the selection of camera components is critical in producing accurate readings and it is highly dependent on the experience of the camera user. In this work, we will extend the capabilities of an existing uncooled system, by determining which camera lenses can be used to improve the image quality of the uncooled detector, and build software to convert gray level values to temperature for each pixel within the FPA. An evaluation study will follow that will determine that temperature readings are statistically similar to those acquired when using a high-end uncooled detector that will provide ground truth data.

Detecting and Tracking Facial and Sub-Facial Regions in Thermal Image Sequences

*T. Bourlai, Bojan Cukic (WVU)*

The first goal of this work is to explore a new tracking paradigm. We will utilize the face tracking capabilities of an existing visible-based system (MS Kinect) to accurately perform face tracking on data captured from a low cost thermal-based camera system, before recognition (using full or partial faces) is performed. The second goal of this work is to test whether we can develop the necessary software platform to allow simultaneous face tracking when using two thermal sensors (placed at different angles to the face) assisted by two Kinect sensors. The third and final goal is to investigate the feasibility of extracting and using full frontal face images captured by the low quality thermal sensors to perform FR. The results will be compared to those computed when applying the same FR algorithms to full frontal face images captured by high quality thermal sensors.

Sample Size Estimation and Stratification for Large Biometrics Databases

*Mark Culp, Thirimachos Bourlai, Bojan Cukic (WVU)*

One of the critical steps underlying the progress in biometric research is the ability to project biometric test results to very large operational data sets. Biometric collections and test data selection typically follow the examination of operational needs leading towards the design of scenarios. In our prior work in the area of research [1], we investigated stratified sampling and developed a sample size estimation approach using distance-based measurements for a closed-set identification. Theoretically, we validated that the match similarity scores follow a variation of the Gumbel distribution. This approach has strong merits for small-scale databases and our empirical work demonstrated these qualities. For large open databases (~100+ million), three key problems emerge, not addressed in [1]: (i) identification errors are costly (i.e., 0.1% is huge), (ii) if the database is large enough and open then the probability of a match goes to one even if the match is not in the database and (iii) the approach in [1] becomes unstable. The most fruitful approach to address the first and second issue is to constrain the scores and study these distribution characteristics. New distributions will be more robust to the costly error problems of large databases. In addition, the proposed work will address sampling characteristics for large open set biometric identification, the most challenging problem in biometrics. An empirical investigation will be performed to compare different face matching algorithms, which will provide insights on bridging the theoretical distributional tools to the practical ones and challenging applications of analyses to large databases. Finally, in this regard we plan to investigate alternative stratification strategies to better assess the effect of incorrect meta data in sampling.

Biometrics in the Cloud: Development of a Biometric Research Data Portal Testbed  
*(Application to NSF Fundamental Research Program)*
Bojan Cukic, Stephanie Schuckers, Judee Burgoon, Michael Schuckers (WVU, Clarkson and Arizona)

Storage of identifying images have long been a critical privacy threat of any biometric or credibility assessment program. Institutional Review Board provides guidelines for collection and distribution in order to provide protections for the volunteer subjects. Data sharing is possible, but permissions can be limited. In research practice, there is a need to provide larger, more diverse sets of data that can serve as reasonable community benchmarks. Combining data from multiple datasets may be necessary to achieve representative samples. Models are emerging in other fields that enable sharing of research data through cloud based architecture. We propose to study cloud-based architectures and develop a Biometric Research Data Portal. This portal will provide tiers of access for both (1) storage of data for retrieval and (2) processing of algorithms. By uploading algorithms instead of downloading data (in some cases), the dataset is not revealed to the user, thereby protecting sensitive data. More powerful cloud processing architectures can be put to the task in order to reduce run-time. Statistical performance summaries can be returned to biometric algorithm developers in order to indicate algorithm performance but reduce revealing personal information.

Tattoo Sketch to Tattoo Image Matching

Anil K. Jain (Michigan State)

Tattoos engraved on the human body have been successfully used to assist human identification in forensics. Tattoo pigments are embedded in the skin to such a depth that even severe skin burns often do not destroy a tattoo. For this reason, tattoos helped in identifying victims of the 9/11 terrorist attacks and the 2004 Asian tsunami. Criminal identification is another important application because tattoos often contain hidden information related to a suspect’s criminal history (e.g., gang membership, previous convictions, years spent in jail, etc.). The current practice of tattoo matching and retrieval, based on ANSI/NIST classes (keywords), is prone to significant errors due to limited vocabulary and the subjective nature of tattoo labeling. To improve the performance and robustness of tattoo matching and retrieval, we designed and developed the Tattoo-ID system. This system automatically extracts features from a query image and retrieves near-duplicate tattoo images from a database. In many scenarios, an image of the suspect’s tattoo is not available. Instead, the victim or a witness, who has seen the tattoo on the suspect’s body, is able to describe the tattoo to the police. We call a drawing of the tattoo based on this description as tattoo sketch. The objective of this research is to develop techniques to match a query tattoo sketch to a large collection of tattoo images in law enforcement databases.

Image Enhancement for Iris Recognition from Incomplete and Corrupted Measurements

Joachim Stahl and Stephanie Schuckers (Clarkson)

Our current work on our “Image Enhancement for Iris Recognition from Incomplete and Corrupted Measurements” project can be expanded to dramatically improve its performance and usability. The proposed extension will achieve this in two steps: First, by investigating what is the minimum number of iris data from a subject needed to have a reliable recognition (via mosaicking). In particular we will apply this for a small sub-region of the iris, which would allow us to stop processing further images in a video sequence when enough information has been collected on a per-sub-region basis. Second, we will adapt our current mosaicking and inpainting algorithms to take advantage of our findings in the first step, and further improve performance by subdividing the processing of different iris sub-regions using parallel processing techniques. In summary, this project will produce a more efficient solution by simultaneously reducing unnecessary processing (first step) and distributing the processing (second step).

Biometric Identification with a Remote Microwave Thoracic Radar

Daniel J. Rissacher, Ralph E. McGregor, William Jemison, Stephanie Schuckers (Clarkson)

Radar systems have shown success in measuring cardiac and pulmonary activity and could be promising tools to provide biometric identification data. However, the biometric content of these radar signals have yet to be fully explored. In this project, we will apply a 2.4GHz radar system already in use in our laboratory to collect data from human subjects. The radar has been developed internally and preliminary data have proven its capability to detect cardiac signals. Two novel algorithms will be developed and applied on this data to determine the promising directions for future work: 1- An algorithm to identify the human subject amongst the pool of other human subjects using the radar data, 2- An algorithm
that will provide real-time heart rate and heart rate variability (HRV), which could be used for some applications as a measure of anxiety.

Mobile Interviewing Agent

**Ryan Schuetzler, Justin Giboney, Mark Grimes, Jim Marquardson, David Wilson (Arizona)**

Rapid portability of our kiosk-based AVATAR system is hampered by its sheer size. However, we realize that there is huge potential for leveraging the technology in a more portable way. We propose to bring the AVATAR concept to a mobile, tablet-based platform and validate built-in sensors (i.e., camera, microphone) for their potential use in identification contexts. The focus of this project would be the actual porting of the AVATAR to the mobile platform, laying the groundwork for future projects to investigate additional sensors (e.g., accelerometer) and uses for a mobile identification Kiosk.

Detecting Impostership through Soft Biometrics and Cognitive Metrics

**Judee Burgoon, Joe Valacich, Nathan Twyman, Jeff Proudfoot, Mark Grimes (UA), Stephanie Schuckers (Clarkson)**

An experiment will partially replicate one conducted with EU border guards on detecting impostership and malintent among hooligans attending a mass public event. Participants will be UA students ostensibly planning to attend the UA-ASU football rivalry game. Imposters will purport to be an ASU fan intending to disrupt the rival team’s activities and will be present false documents. The main objective will be to determine which sensor(s) can best detect false identities and (in)ability to maintain a false cover story.

**CITeR 2012**

Impact of Cosmetics on the Matching Performance and Security of Face Recognition

**Antitza Dancheva, Arun Ross, Guodong Guo (WVU)**

Motivated by the need for deploying highly reliable face recognition systems in both commercial and security applications, we seek to initiate research that studies the impact of cosmetic alterations on face recognition. At the same time, we aim to develop novel algorithmic solutions that allow for robust face recognition in the presence of such cosmetic alterations which, when properly used, may result in concealing a person’s identity. Recent work has focused on plastic surgery [1, 2], and specifically on how it can impact the reliability of facial recognition. However, such surgical alterations are generally costly and permanent. On the other hand, the non-permanent cosmetic alterations tend to be simple, cost efficient, non-permanent and socially acceptable; at the same time they have the potential to radically change appearance. Specifically such alterations can (a) alter the perceived facial shape by accentuating contouring, (b) alter the perceived nose shape and size by contouring techniques, (c) enhance or reduce the perceived size of the mouth, (d) alter the appearance and contrast of the mouth by adding color, (e) alter the perceived form and color of eyebrows, (f) alter the perceived shape, size and contrast of the eyes, (g) conceal dark circles underneath the eyes, and (h) alter the perceived skin quality and color. In addition to the aforementioned effects, make-up can also be used to successfully camouflage wrinkles, birth moles, scars and tattoos. All the above suggest that cosmetic make-up techniques can greatly impact automated face recognition methods. In this work we will investigate the impact of cosmetics on commercial face recognition systems. Furthermore we will develop methods to (a) detect the presence of cosmetics on a human face image, and (b) perform face recognition in the presence of cosmetic alterations.

Utilizing Low-Cost, Portable Depth Cameras for Face Recognition

**Guodong Guo, Arun Ross, Bojan Cukic (WVU)**

Human identification via faces is important in security and law enforcement applications. With advancements in sensor technologies, a number of new sensors are available for face image acquisition. In this project, we will explore the recently developed depth cameras for face recognition. Unlike the expensive, time-consuming laser range scanners, or the fragile stereo vision systems that suffer from the inability to match homogeneous, non-texture regions, depth cameras are low-cost, real-time, and portable. There are two main categories of depth cameras: one based on the time-
of-flight principle and the other based on light coding. While the development of these cameras is still ongoing, a few commercial products are available [1]. Our goal is to determine if these cameras can be successfully used for face recognition. Furthermore, we will study the correlation between visible light face images and depth images. In essence, we wish to address the question: Is it possible to utilize depth cameras for face authentication without reenrolling all the subjects?

Latent Fingerprint Quality Assessment
Anil K. Jain (MSU)
Latent fingerprints found at crime scenes have long history as forensic evidence to identify suspects and convict them in courts of law. Latent fingerprint identification procedure commonly follows the ACE-V protocol: Analysis, Comparison, Evaluation, and Verification. Due to poor quality of latents, it is inevitable for latent examiners to assess the latents to determine whether sufficient ridge information is present in the image and mark all the available features on the latents in the analysis phase. Towards achieving “Lights-Out” identification mode for latents, we propose an automatic latent quality assessment algorithm to divide latent fingerprint images into several categories based on their quality level. This will help determine the degree of human intervention needed for each category in latent identification. The objectives of this research include (i) developing an algorithm to automatically estimate quality of input latent fingerprint images, (ii) demonstrating the correlation between latent quality and matching performance, and (iii) determining the degree of human intervention needed to handle the latents according to the quality level.

Automatic Segmentation of Latent Fingerprints
Anil K. Jain (MSU)
Latent fingerprints (latents) are one of the most important sources of forensic evidence in criminal prosecution. Latents are typically partial prints with small area, poor quality and complex background noise. As a result manual intervention is needed to localize or segment latent prints. Therefore, there is an urgent need to develop an automatic latent segmentation method as an initial step towards “lights out” latent identification. The objective of this research is to (i) develop an algorithm to automatically segment latent fingerprints, (ii) demonstrate an improvement in matching accuracy as a result of this segmentation, and (iii) report confidence levels of segmentation results to indicate if manual intervention is necessary or not.

A Pre-Processing Methodology for Handling Passport Facial Photo
T. Bourlai (WVU)
In many security applications, the problem of matching facial images that are severely degraded remains to be a challenge. Typical sources of image degradation include low illumination conditions, image compression, out-of-focus acquisition etc. Another type of degradation that received very little attention in the face recognition literature is the presence of security watermarks on documents (e.g. passports). Although preliminary work in the area has mitigated certain challenges (removal of noise present on documents) [1,2] the image restoration part requires more attention to further overcome missing information from face images due to image de-noising. In this work we examine the effects of a preprocessing methodology that mitigates the effects of security watermarks on passport facial photos in order to improve image quality and FR overall. The types of images that will be investigated are face images from passport photos. The proposed project will focus on answering the following questions: (1) How do original passport face photos affect recognition performance? (2) Which pre-processing algorithms effect recognition performance the most? (3) What are the optimal conditions that FR is feasible under different levels of pre-processing using our novel algorithm?

LivDet III: Liveness Detection Competition 2013
Stephanie Schuckers, David Yambay (Clarkson)
Fingerprint recognition systems are vulnerable to artificial spoof fingerprint attacks, like the molds made of silicone, gelatin or Play-Doh, etc. Suspicious presentation detection systems such as liveness detection have been proposed to defeat these kinds of spoof attacks. In 2011, U of Cagliari and Clarkson University hosted the second competition to test
Software-based and hardware-based liveness detection algorithms. This competition was organized according to the following: Part I—Algorithm-based: Included distribution of a dataset of spoof and live images for training and evaluation of submitted algorithms on a sequestered database and Part II—System-based: Included submission of a hardware/software system device which returned a liveness score and evaluation based on spoof samples and live subjects. Results were presented at BCC 2011. Four groups submitted (two universities, two companies). We propose to host LivDet III. LivDET III will be composed of Part I—Algorithm-based with training/testing datasets and of Part II—System-based which allow submission of hardware/software systems. Both parts will be for both fingerprint and iris systems. In addition, we propose to lead an international collaboration by allowing organizations to provide datasets of spoof and live images for Part I and by working with multiple international testing organizations to provide a testing setup of submitted hardware systems for Part II. Analysis of performance will enable knowledge of the state-of-the-art in the field, as technologies begin to emerge.

Experimental Analysis of Automated Latent Fingerprint Systems

Stephanie Schuckers, Megan Rolewicz (Clarkson)

Latent fingerprints can be a key piece of evidence in order to isolate suspects in a crime and/or build a case against an individual. Latent fingerprint examination is typically a labor intensive process performed by an expert extensively trained in fingerprint examination. Recently automated systems which provide for on-site latent imaging and latent fingerprint matching against a reference database have become available. Few studies have been performed which considers the efficacy of mobile latent fingerprint systems. Recently, Stockton Police Department has started using a mobile biometric device to capture latent fingerprints at crime scenes. In a pilot study, they collected 144 (out of 200) latent fingerprints using both the automated device and manual lab methods. The result was that with the device there were 28 confirmed hits as opposed to 37 hits using the lab method. The biometric device however confirmed these 28 hits in approximately 2-5 minutes as opposed to 20-40 hours or days as would be true in a laboratory setting. The purpose of this study will be analyze factors which contribute to the difference in performance between the automated mobile system and manual examination through a complementary field and laboratory study.

Speaker Recognition Techniques for the NIST 2012 Speaker Recognition Evaluation

Jeremiah Remus (Clarkson)

The NIST 2012 Speaker Recognition Evaluation (SRE) is the latest in the ongoing series of speaker recognition evaluations that seek to support the development and advancement of speaker recognition technology. The NIST SRE is well-established and draws participants from many prestigious institutions active in speech research. Entry in the NIST 2012 SRE provides an opportunity for CIteR to participate in the exchange of state-of-the-art ideas and techniques for speaker recognition.

Resilience of Deception Detection Sensors

Nathan Twyman, Ryan Schuetzer, Jeffrey Gainer Proudfoot, Aaron Elkins, Judee Burgoon (UA)

The primary objective of this study is to examine the limitations of certain psychophysiological and behavioral indicators of veracity in a rapid-screening environment. Rapid screening examinees can use countermeasures, or methods designed to “beat” the test. Anecdotal evidence suggests that using multiple heterogeneous sensors will significantly decrease countermeasure effectiveness; we aim to test this hypothesis directly in a rapid screening context.

Testing the Use of Non-Invasive Sensors to Conduct the Concealed Information Test: Comparing the Accuracy of Oculometric, Vocalic, and Electrodermal Cues in Detecting Familiarity with Persons of Interest

Jeffrey Gainer Proudfoot, Judee Burgoon, Nathan Twyman, Aaron Elkins, Jay F. Nunamaker (UA)

Oculometric technology (e.g., eye tracking) continues to be a valuable tool utilized in a variety of research disciplines. Extant research suggests that the duration of eye gaze fixation points can be used to identify familiarity (in a face-recognition context). Schwedes and Wentura (2011) found that subjects fixated on familiar faces longer than unfamiliar faces when presented with six images simultaneously. The purpose of this research is to use an adapted methodology to
compare the classification accuracy of an oculometric-based CIT to the standardized CIT approach (using a polygraph device to measure electrodermal responses (EDRs)). An experiment will be conducted in the context of a security screening checkpoint, and will thus be more representative of a high-stakes environment. This research will provide valuable insight on the reliability and feasibility of deploying eye tracking systems to security environments to identify individuals possessing knowledge of criminals, terrorists, and others possessing mal-intent.

**Integrating Physiological Measurements with Avatars for Effective Deception Detection**

*Thirimachos Bourlai, Arun Ross (WVU)*

Recent research in deception detection has focused on the set of Avatars, where an animated computer-generated talking head (an embodied agent) interviews a subject by asking a series of questions. The Avatar then records the ensuing verbal responses in an audio file for future analysis. The use of an Avatar can potentially mitigate issues related to biases (e.g., cultural, economical, personality related etc.) encountered when a human agent interviews a subject. In this work, we will extend the capabilities of an existing Avatar system, by designing a method to capture the physiological state of the subject (via EDA, PPG and thermal sensors) during the course of the interview. The goal of this exercise is to synchronize the recorded audio responses to the Avatar’s generated questions with physiological measurements (e.g., facial thermal imaging recording) of the subject thereby facilitating a broader range of analysis leading to effective deception detection. For example, the Avatar system could be trained to repeat a question if the physiological measurements suggest an anomaly during the course of the subject’s verbal response. Indeed, by integrating physiological measurements with verbal responses, the Avatar can automatically learn to dynamically customize the series of questions, thereby enhancing the capability for automated deception detection.

**Stratified vs. Convenience Sampling for the Statistical Design of Biometric Collections**

*Mark Culp, Thirimachos Bourlai, Bojan Cukic (WVU)*

One of the critical steps underlying the progress in biometric research is the collection of data, i.e., single or multiple modalities, such as face, iris, fingerprints etc. Collection usually follows the examination of operational needs leading towards the design of scenarios, and the IRB approval process. There is no theory that would help those collecting biometric data determine how many subjects need to be recruited. Typically, an arbitrary number that meets the project’s financial constraints is agreed upon. The recruitment of subjects (e.g. data collected in [1, 3]) is based on local advertising and willingness of individuals to participate. In statistics, this approach to recruitment is called convenience sampling. It is known that convenience leads to selection bias, which hinders the statistical analysis and may mislead the results and the conclusions resulting from the study. Hence, the accuracy and risks associated with recognition performance estimated in ensuing biometric studies can be compromised. Stratified random sampling (SRS) is a technique designed to reduce selection bias, thus lowering the study’s risks and offering to improve the validity of study’s conclusions. In addition, when the SRS is performed properly, the experimenter can estimate the sample size necessary prior to sampling, which is practically useful and may reduce the cost of collection. The proposed project addresses the following questions: (1) How can a biometrics researcher use existing “large” data sets to generate stratified samples? (2) When the SRS is used in the biometric studies, what practical benefits results from minimizing selection bias? (3) Can we offer a cost effective strategy for using SRS sampling in future studies? To answer these questions, based on the analysis of anonymized participant data from recent large scale collections at WVU, we will compare two samples (stratified and anonymized participant data from recent large scale collections at WVU), we will compare two samples (stratified and convenience) and apply the lessons learned to the upcoming IR-thermal face recognition (FR) data collections, funded by CITEr [2].

**Fingerprint Recognition Using Commercial Digital Cameras**

*Arun Ross, Jeremy Dawson, Thirimachos Bourlai (WVU)*

Traditionally livescan fingerprint images have been acquired sing contact methods where the fingertip of the subject explicitly touches a platen. However, in recent year, contactless methods for fingerprint acquisition have been developed based on the principles of 3D optical imaging (e.g., GE and FlashScan3D), spatial phase imaging (e.g., PhotonX), and ultrasound imaging (e.g., Optel). The main drawback of these methods is that they require the finger to
be very close to the sensor for successful acquisition. Recent advancements in COTS imaging hardware make it possible to observe fingerprints in high-resolution hand images captured at distances of up to 2 meters. In this work, we will investigate the possibility of performing fingerprint recognition at a distance of up to 2 meters based on images acquired using Commercial Off The Shelf (COTS) SLR and/or cell phones cameras. Further, we will develop image processing and feature extraction algorithms for (a) matching fingerprint images acquired using digital cameras against each other; and (b) matching fingerprints acquired using digital cameras against livescan fingerprints obtained from traditional sensors (e.g., Crossmatch Guardian).

**Modeling IrisCodes: New Approaches to Iris Individuality and Classifications**

*Arun Ross and Mark Culp (WVU)*

Iris recognition systems aim to obtain texture information from iris images. To facilitate this, a Gabor filter is convolved with a normalized rectangular iris image and the ensuing phasor response is quantized into a string of ‘0’ and ‘1’. This string is incorporated into a binary matrix referred to as an IrisCode. Surprisingly, despite its widespread use in operational systems, very few studies have attempted to understand and directly model the IrisCodes. In this work, we approach the problem by computing Generating Functions for IrisCodes. The main idea is to generate the underlying IrisCode of ‘0’ and ‘1’ by controlling a few parameters. The parameters will guide how we would expect each IrisCode to be generated, which in turn give us deeper insight into the distribution of the underlying IrisCodes. Such an approach will provide significant benefits to the iris recognition community: (a) Synthetic IrisCodes can be generated for predicting the performance of large-scale biometric systems such as UIDAI; (b) Novel methods can be designed for classifying and clustering IrisCodes based on these Generating Functions; (c) Models for understanding the individuality of the iris can be developed; (d) Application-specific IrisCodes can be designed based on template size requirements; and (f) Generating Functions can provide new insights into iris-based cryptosystems.

**Simultaneous Recognition of Humans and their Actions**

*Guodong Guo, Arun Ross, Bojan Cukic (WVU)*

Human recognition is important in many law enforcement applications. Significant progress has been made in human identification and verification in the past two decades; however, human identification is still a challenging problem, especially when operating in an unconstrained environment with non-cooperative users. In many security and surveillance scenarios, individuals are observed to be performing various actions, rather than standing still. So identifying humans in action is a typical scenario in non-cooperative biometrics. In this work, we will design algorithms that can not only identify individuals but also determine their corresponding actions in a video. An advantage of this research is that the biometric system can process a query involving both identity and action (e.g., retrieving all videos in a database containing the waving action of a particular individual), rather than the identity-only based query supported by traditional systems.

**Generating a 3D Face Texture Model from Independent 2D Face Images**

*Arun Ross (WVU) and Anil Jain (MSU)*

In several law enforcement and military biometric applications, multiple 2D face images of a subject are acquired during enrollment and/or authentication (e.g., mug shot face images of a subject in a booking station). Typically, in these scenarios, both the frontal- and side-profile images of the face are obtained. However, since the frontal and side-profile images are independently acquired, the “registration” or “alignment” between them may not be known. In this project, we will design methods for registering and combining the frontal and side profile face images of a subject in order to generate a composite 3D shape and texture of the subject’s face. The 3D model will encompass both the geometrical structure and visual appearance of the face. While previous studies in the literature have explored the use of stereovision techniques or expensive 3D face scanners for generating 3D or 2.5D face models, the proposed work will further advance the state-of-the-art by designing the following: (a) methods for generating 3D textures from multiple independent 2D face images; (b) GUI for visualizing the 3D texture by allowing the operator to articulate the model; (c) face aging models that exploit both 3D and 2D information; and (d) efficient algorithms for matching 2D images against
3D texture models in real-time. This research will result in novel face recognition algorithms that are invariant to pose and possibly expression changes.

**Understanding the Science Behind Biometrics: A Systematic Review**

*Arun Ross and Bojan Cukic (WVU)*

The past two decades has seen a substantial increase in biometrics activity accompanied by the deployment of several biometric systems in diverse applications ranging from laptop access to border control systems. The increased use of biometric solutions in DoD military applications, and the inclusion of biometric evidence in military and criminal courts, necessitates a careful examination of the scientific basis for biometric recognition. In particular, there is an urgent need to systematically review the scientific literature to determine if some of the common assumptions made about biometric traits with respect to criteria such as universality, uniqueness, permanence, measurability, performance, acceptability and circumvention, is borne out in the academic literature. Thus, the purpose of this study is to (a) survey published academic papers that address the basic science behind various biometric modalities; (b) identify gaps in existing research and the implications on operational system risks; and (c) provide recommendations for further research and deployment.

**Image Enhancement for Iris Recognition from Incomplete and Corrupted Measurements**

*Aaron Luttman and Stephanie Schuckers (Clarkson)*

Human identification when the subject is unaware of being analyzed is a problem of growing importance. Capturing and analyzing iris data for recognition in such scenarios brings a new set of technical problems that are not present in controlled imaging environments. When iris images are captured in an uncooperative environment, the image data is often incomplete – in the sense that parts of the iris may be occluded or simply outside the image frame – as well as corrupted – by standard noise and specular highlighting, often across the entire eye. In order to perform iris recognition, both problems must ameliorated simultaneously. Given a sequence of incomplete images, we will synthesize a composite image using image mosaic techniques. The mosaiced image may still be incomplete, and the missing data will be filled in via variational inpainting, based on the Navier-Stokes equations and very recent work on inpainting with Bayesian estimation. We propose to integrate state of the art image mosaicing with customized, PDE-based image inpainting into a unified system for successful personal identification from composite iris images generated from sequences of partial irises.

**Stand-Off Speaker Recognition: Effects of Recording Distance on Audio Quality and System Performance for Iris Recognition from Incomplete and Corrupted Measurements**

*Jeremiah Remus and Stephanie Schuckers (Clarkson)*

There has been significant success in the development of techniques to use speech as a biometric, and great potential for fusion with other biometrics (e.g. iris, face, physiological) currently under investigation within CITeR. With increasing interest in the collection of biometrics at a distance, it would be beneficial to have a clearer understanding of the sensitivity of speaker recognition systems to the degradation of audio quality when recording at a distance. It is reasonable to expect that distance from the recording device will degrade the signal-to-noise ratio; however most investigations of audio quality and its effect on speaker identification performance have focused on the channel quality (e.g. telephone lines or mobile handsets). While there have been significant efforts within the speaker recognition research community to develop methods for handling session-to-session speaker variability or variations introduced by different microphones, it is unclear how well these solutions can address the problem of speech recorded at a distance. Therefore, we propose to investigate whether current feature decomposition techniques, used to manage inter-session and cross-channel variability, are capable of reducing variability that results from stand-off recording of the speech. We will also assess the ability of published audio quality stands (e.g. ANSI, ITU), as well as subjective assessments, to describe the condition of an audio recording and its ability to be used in a speaker recognition system.

**Identifying Behavioral Indicators of Cognitive Load Associated with Deception and Interview Questions**

*Judee Burgoon and Jeffrey Gainer Proudfoot (UA)*
One theorized basis for indicators of deception is cognitive load. Deceivers are proposed to experience increased cognitive difficulty while manufacturing the producing lies. However, it is possible that some questions actually are more cognitively taxing for truth tellers that deceivers and may therefore lead to false alarms and false negatives when detecting deceit from behavioral indicators. The current study will conduct behavioral analyses on video-recorded interviews from 3 cheating experiences involving unsanctioned deception with high stakes (potential honor code violations). Results will provide more detailed indicators of cognitive taxation associated with deception and with specific questions.

Validating the SPLICE Implementation of Automated Textual Analysis

Kevin Moffitt, Justin Giboney, Judee Burgoon, Emma Ehrhardt, Jay Nunamaker (UA)

Structured Programming for Linguistic Cue Extraction (SPLICE) is an easy-to-use web-based research tool for automated linguistic analysis. SPLICE’s major function is to perform automated textual analysis of ordinary text files and return values for linguistic cues such as the total number of words, dominance, negativity, average word length, and average sentence length. However, many of these cues, including dominance and submissiveness, still lack theory driven validating and even more cues have not been subjected to reliability tests. Given the potential SPLICE has a tool for researchers and end users who want to expand their measures beyond the psychosocial dictionaries found in software like LIWC, we propose to significantly strengthen subjecting the output to reliability tests. In addition, we will provide SPLICE users with the capability of uploading custom psychosocial dictionaries. The end result of this project will be theory driven, reliable tool for the analysis of texts that supports custom dictionaries.

CITeR 2011

Iris Segmentation Quality Analysis: Evaluation & Rectification (Phase 2)

Nathan Kalka, Bojan Cukic, and Arun Ross (WVU)

Traditional iris recognition systems operate in highly constrained environments resulting in the acquisition of an iris image with sufficient quality such that subsequent stages of processing perform successfully. However, when acquisition constraints are relaxed such as in surveillance or iris on the move systems, the fidelity of subsequent processing stages becomes questionable. Research has found that segmentation is arguably the dominant factor that drives the matching performance of iris recognition systems. Therefore, the ability to automatically discern whether iris segmentation failed prior to matching has many applications, including the ability to discard images with erroneous segmentation. More importantly, it provides an opportunity to rectify failed segmentation. In this project we plan to leverage our work from Phase 1 into a unified framework capable of simultaneously evaluating and rectifying iris segmentation, for the purpose of improving iris recognition performance. The framework will be extended to include: (1) Novel iris segmentation evaluation strategies utilizing region, boundary, and contextual information. (2) An additional rectification strategy based on regularization of the iris segmentation search space. (3) A novel segmentation prediction model which automatically selects the segmentation methodology and algorithms most likely to correctly segment the input image.

Effects of Environmental Conditions on Middle to Long Range Face Recognition in the Dark

Thirimachos Bourlai

In military and security applications, the acquisition of face images is critical in producing key evidence for the successful identification of potential threats. The standoff distances most commonly used in face recognition (FR) systems are (a) short-range (<33ft), suitable for applications such as identity verification at access points, or (b) middle-range (<330ft), suitable for applications such as building perimeter surveillance. A middle-range FR system capable of operating only in day-time environments has been proposed recently. In this work we examine the effects of night-time outdoor environmental conditions (illumination variation, temperature, and humidity) on the performance of FR algorithms using middle to long-range Near-Infrared (NIR) imaging systems. We will explore the distances in the range from 30 to ~650ft.

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(the maximum capabilities of the available sensor). The proposed project will focus on answering the following questions: (1) Do night-time outdoor environmental conditions affect recognition performance? (2) Which conditions affect recognition performance the most (e.g., high temperature and high humidity)? (3) What is the operational range that FR is feasible under the different conditions considered?

**Matching Face Images Acquired from Mobile Devices to a Large Gallery**

*Anil K. Jain (MSU)*

As the number of mobile devices equipped with digital cameras continues to increase, so does the opportunity to acquire face images using such devices. Civilians often use these devices to capture identifying evidence from a crime being witnessed. Law enforcement officers in many agencies are now being instructed to use such devices to acquire a face image of subjects when they do not possess identity information or there is doubt about the authenticity of such information. Because of the compact nature of mobile imaging devices, motion blur and focal distortions reduce the quality of face images. Thus, as the opportunity to acquire such useful information grows, face identification technology must be improved to meet these demands with algorithms tailored to match mobile face images to large legacy databases. Proposed research aims to provide solutions to improve the identification accuracy in these mobile identification scenarios.

**Separating Overlapping Fingerprints and Palm-prints**

*Anil K. Jain (MSU)*

Latent prints (fingerprints and palmprints) lifted from crime scenes or IED fragments often contain overlapping prints. Overlapping latents constitute a serious challenge to state of the art fingerprint segmentation and matching algorithms, since these algorithms are designed under the assumption that latents have been properly segmented. The objective of this research is to (i) develop an algorithm to automatically separate overlapping latent prints into component latent prints, and (ii) demonstrate an improvement in matching accuracy as a result of this separation.

**Multimodal Fusion for Stand-off Identity and Intent for 10-25 Metter**

*Stephanie Schuckers (Clarkson), Jeremiah Remus (Clarkson), William Jemison, and Judee Burgoon (U of A)*

Because of limited resources (e.g., number and type of cameras, amount of time to focus on an individual, real-time processing power), determining which individuals to focus on and for how long in surveillance situations is difficult. Anomalous behavioral cues may be considered by stand-off systems for the risk assessment of risk of an individual. Benchmark datasets designating a stand-off multimodal biometric system for purposes of determining identity and intent are needed. We propose to investigate the fusion approaches to measure face, iris, voice and heart patterns through experiments for identity and intent at distances from 10 to 25 meters. This research builds on the growing corpus of data, entitled Quality in Face and Iris Research Ensemble—Q-FIRE dataset which includes the following: (1) Q-FIRE Release 1 (made available in early 2010) is composed of 4T of face and iris video for 90 subjects out to 8.3 meters (25 feet) with controlled quality degradation. (2) Release 2 is an additional 83 subjects with same collection specifications. Release 1 and 2 are currently being used by NIST in IREX II: Iris Quality Calibration and Evaluation (IQCE). (3) At the completion of the CITeR project in July 2011, an extension of the dataset will include unconstrained behavior of subjects on the same set of subjects, entitled Q-FIRE Phase II Unconstrained, out to 8.3 meters. The goal of this project is to expand Q-FIRE to include unconstrained subjects from 10 to 25 meters to characterize recognition at a distance as well as study fusion of multi-modal standoff biometrics with behavioral cues. To support behavioral aspects, we propose to develop and incorporate cardiopulmonary measurements based on newly designed 5.8 GHz radar and our existing 2.45 GHz radar. Previous research has focused on relatively inexpensive, but large beam width, 2.45 GHz system and the quite expensive, with small beam width, 228 GHz radar (which also has regulatory hurdles). We hypothesize that 5.8GHz may have beam width for longer distances of interest, while still remaining relatively inexpensive and unregulated.

**Automated Rigidity Detection in Automated Screening**

*Nathan Twyman, and Judee Burgoon (U of A)*
This study will explore automated rigidity detection in rapid screening. Credibility assessment research has identified rigidity as an indicator of deception. Recently in a mock crime experiment, we used computer vision techniques to measure rigidity automatically and objectively. We also found rigidity could predict guilty knowledge during a Concealed Information Test (CIT). We propose an experiment designed to measure rigidity in a CIT designed for automated screening. An automated agent will conduct the CIT, thereby eliminating interviewer effects.

**Evaluating the Robustness of Eye Tracking to Mental and Physical Countermeasures**

*Ryan Schuetzler, Jeffrey Proudfood, and Jay Nunamker (U of A)*

Eye trackers have been evaluated recently for their effectiveness in rapid, non-contact assessment of credibility and intent. Gaze patterns (Derrick, Moffitt, and Nunamaker 2010), eye blinks (Leal and Vrij 2010), and pupil dilation (Dionisio, Granholm, Hillix, and Perrine 2001) have all been examined and discovered to be somewhat effective. All of these have been able to achieve success rates of 75% or better in identifying deception. However, countermeasures have been shown to be effective against polygraph examinations.

**Heterogeneous Face Recognition**

*Anil K. Jain (MSU)*

Heterogeneous face recognition (HFR) involves matching two face images acquired in different modalities (e.g., visible vs. NIR image). In most HFR scenarios, the gallery images are standard photographs (visible band) and probe images are in non-visible band (e.g. thermal images). This project focuses on heterogeneous face recognition where the probe images are from: (i) near-infrared (NIR) and (ii) thermal-infrared. Improving face recognition performance in these two scenarios will have the following benefits. (i) Ability to match NIR face images to visible galley images is crucial in night time environments or environments with unfavorable illumination. (ii) Thermal face sensor, unlike the NIR sensor, is a passive sensing method which does not illuminate a person’s face. For this reason, in many applications thermal sensing is preferred over NIR sensing. Proposed research will have a profound impact on security by identifying criminals in adverse imaging conditions.

**Generalized Additive Models for Biometric Fusion and Covariate Analysis**

*Mark Culp and Arun Ross (WVU)*

This project concerns the task of assessing the potential impact of covariate factors such as image quality, age, gender, race, etc. on fusion performance. Most existing fusion approaches such as the sum rule and Bayesian methods ignore the covariate factors in model development. Consequently, covariate analysis is typically conducted after the application of the fusion rule, which is suboptimal for the overall goal of fusion performance. To this end, we propose generalized additive models that simultaneously account for covariate factors and their interactions, match scores and quality indices in one unified framework. The proposed model: (a) allows for testing the effect of individual covariates on overall fusion performance (e.g., effect of gender); (b) assesses the complexity of the fusion rule on the score given quality; (c) facilitates statistical interpretation; and (d) addresses a database’s “degree of difficulty” with pair wise model comparisons.

**Feasibility Study of an International Biometrics Data Portal**

*Michael Schuckers (St. Lawrence), Stephen Elliot (Purdue), Bojan Cukic (WVU) and Stephanie Schuckers (Clarkson)*

Use of biometric data for identification and verification has grown rapidly. Research is facing nontrivial problems in addressing scalability, individuality, variations due to age/ethnic/environmental/operation, privacy, novel sensors, impact of time between enrollment and future sample, fusion between modalities, etc. New and order of magnitudes larger datasets are needed to support such research. Currently, most investigators collect data, but may not be able to share it with other researchers or combine dataset from other researchers, due to the inherent privacy limitations imposed by collection protocols. The goal of this project is to begin developing requirements for a data portal which would enable researchers to share data, while provably maintaining appropriate levels of privacy. We propose to explore the issues surrounding the creation of a biometric data portal that will allow biometrics researchers to search and analyze biometric signals/images/samples across collections taken at different locations across the globe.
Facial Metrology for Human Classification

Don Adjeroh, Thirimachos Bourlai and Arun Ross (WVU)

Facial metrology refers to the extraction of geometric measurements of the human face based on certain landmark points (e.g., eyes, lip corners, etc.). For example, the distance between the eyes or the length and width of the face can be viewed as features constituting facial metrology. However, the biometric literature does not adequately discuss (a) the statistics of facial metrology as a function of gender or race; and (b) the potential of automatically extracting landmark points from human faces for performing metrology. The goal of this work is to conduct a statistical analysis of facial anthropometry and understand its potential in human classification and, perhaps, identification. In addition, algorithms will be developed to automatically extract facial landmarks at variable illumination levels, multiple distances and multiple spectral bands. The application of these algorithms can be expected to shed light on: (1) the effect of the above factors (distance, spectral bands, etc.) on the detection of facial landmarks; (2) identification of landmarks that are important for human identification in terms of race and gender; and (3) a statistical understanding of the role of facial metrology in human classification/identification. Applications of the study will include scenarios where a quick appraisal of the identity of a given individual may be needed before he or she reaches a certain check point; in facial forensics; and in cross-spectral face recognition.

LiveDet II Fingerprint Liveness Detection Competition 2011

Stephanie Schuckers (Clarkson)

Fingerprint recognition systems are vulnerable to artificial spoof fingerprint attacks, like the molds made of silicone, gelatin or Play-Doh, etc. Liveness detection or anti-spoofing has been proposed to defeat these kinds of spoof attacks. In 2009, U of Cagliari and Clarkson University hosted the first competition to test software-based liveness detection algorithms. This competition was organized according to the following: distribution of a dataset of spoof and live images for training, submission of a software algorithm which returned a liveness score, and evaluation of submitted algorithms on a sequestered dataset. Results were presented at ICIAP 2009 and resulted in a paper. Four groups submitted algorithms (two universities, two companies). The classification rate of the best algorithm achieved 2.7% error rate. The proposed second competition, LivDet II, reflects a growing interest in anti-spoofing. In addition using public dataset for training software algorithms, we propose to perform testing of submitted system which include liveness combined with an overall hardware system. Commercial entities which have incorporated liveness have optimized these algorithms for their individual systems. Analysis of performance will enable knowledge of the state-of-the-art in the field.

Post Mortem Ocular Biometrics Analysis

Reza Derakshani (U Missouri, Kansas City) and Arun Ross (WVU)

In order to study the impact on match scores and other relevant ocular biometric identification metrics, we will study pre and post expiration subjects over a period of post mortem time span and via observing temporal sequence of ocular biometric captures, and compare them with similar live capture controls in different spectra, visible (RGB) and near infrared. Specific tasks include a) medical analysis & data collection; and b) biometric analysis.

A Standardized Framework for a Heterogeneous Sensor Network for Real-Time Fusion & Decision Support

Aaron Elkins, Doug Derrick, Jeff Proudfoot, Judee Burgoon and Jay Nunamaker (U of A)

This study will begin development and testing of a scalable sensor network framework suitable for fusion and integration in expert and avatar based decision support systems. The emphasis will be placed on a modular agent based architecture that promotes standardized messaging and software interfaces for interoperability of diverse sensors. This study represents the first and necessary step towards integrating disparate sensors into a network for real-time analysis and decision support.

Comparison of Methods for Identification & Tracking of Facial & Head Features Related to Deception & Hostile Intent

Judee Burgoon (U of A), Senya Polikovsky (U of Tsukuba), Dimitris Metaxas (Rutgers), Jeff Jenkins (U of A)
High-speed (250 fps) recordings of participants from a mock smuggling experiment conducted at University of Tsukuba will be analyzed with methods and algorithms developed by Rutgers University and University of Tsukuba. The automated methods from the two laboratories will be compared on tracking accuracy, and both automated methods will be validated against human behavioral observation of facial/head kinesics.

**Establishing Deceptive Behavior Baselines for Eye-Tracking Systems**

*Jay Nunamaker, Doug Derrick, Jeff Proudfoot and Nathan Twyman (U of A)*

We have conducted a pilot experiment that has used eye-behavior to correctly classify 100% of individuals having concealed information about a fake, improvised explosive device (IED). This pilot experiment displayed altered images of the device to participants and those who had constructed the device scanned it differently than those that did not. For this new effort, we propose to examine three discrete questions. First, how persistent is the eye-behavior effect? In the pilot study, the individuals were screened right after they constructed the bomb. We will examine the effect after 24+ hours to determine if it is persistent. Second, we will evaluate if the eye-behavior is different if words are used instead of images. For example, do those that have built the IED view the word bomb in a series of words differently than those that have no knowledge of the IED? Third, we will examine if the effect can be used for places as well as objects. This will involve images of places that “guilty” people have seen and innocent have not. We will design a mock screening environment similar in appearance to checkpoints found in airports, border checkpoints, etc.
A Study of MWIR for Face Recognition & Liveness

Thirimachos Bourlai, Arun Ross and Lawrence Hornak (WVU)

Middle Wave Infrared (MWIR, 3-5μm) is interesting for biometric recognition as it has both reflective and emissive properties. Face recognition in MWIR did not yield promising results (DARPA Human ID Project) due to limitations of the sensor technology available at that time (2001-2005). Given the improvements in MWIR technology in recent years, higher resolution and thermal sensitivity, the proposed project focuses on answering the following questions: (1) Can we extract novel features (facial vein patterns or other subcutaneous information) in MWIR that can be exploited for face recognition? (2) Can these MWIR features be reliably used for liveness detection? (3) Can we match MWIR face images against visible images? (4) Can system performance improve when fusing MWIR and visible imaging modalities?

Cross-Age Face Recognition Based on a Facial Age Estimation Scheme

Guodong Guo, Arun Ross and Bojan Cukic (WVU)

Facial aging can degrade the performance of face recognition. A typical approach to cross-age face recognition is to synthesize new faces at all possible ages. This approach is slow and inefficient, especially when working on a large-scale face database. Recently, human age estimation has become an active research topic. In this project, we investigate how age estimation can help cross-age face recognition. The basic idea is to estimate the age of a test face and to synthesize a face image only at the estimated age rather than generating face images at all possible ages. If this method is successful, it will make cross-age face recognition system computationally efficient and practical.

Enhancement & Quality Assessment Schemes for Challenging DNA Sample Analysis

Jeremy Dawson, Arun Ross, Lawrence Hornak (WVU), Tina Moroose (WVU Forensic Science) and Stephanie Schuckers (Clarkson)

Current rapid DNA analysis systems are based on the miniaturization of standard processing steps and equipment and the use of commercially available reagent kits. Preliminary work indicated several challenges associated with DNA profiles extracted from degraded samples, low-copy-number DNA, and mixtures. In traditional DNA analysis these issues can often be overcome through human oversight and additional time for processing. As rapid DNA systems move from the realms of forensic science into automated biometric screening, these challenges are compounded by system architectures and processes designed to further reduce device throughput times. Our project will advance signal processing methods that will enable the evaluation and extraction of DNA profile information from challenging samples. This approach offers a means of pushing beyond the barriers currently limiting rapid DNA stems, furthering the realization of molecular biometrics systems capable of fulfilling the requirements of rapid, tiered screening scenarios.

Optimizing the Design of Large Scale Biometric Security Systems

Bojan Cukic, T. Menzies (WVU) and Stephanie Schuckers (Clarkson)

We have recently developed a model based analysis method that allows system designers and policy makers to understand the interplay between biometric match rates (corresponding to specific thresholds) and passenger throughput rates at US Visit – type of international border crossings. But in general, understanding the implications of such tradeoffs early and throughout the system development lifecycle is difficult. The goal of the proposed project is to further automate the analysis of large scale biometric system designs. We will utilize our Layered Queuing Network model of the US Visit system and improve its fidelity to reflect the architecture deployed in the field. Since the model executes quickly (we receive estimates for expected traveler wait times, lengths of queues, throughputs for accessing all biometric databases and watch lists, etc., in less than a second), we can explore a large space of system engineering alternatives. Through thousands of controlled parameter changes, guided by a discrete optimization method, we systematically evaluate the cost-benefits of potential system improvements, as well as their relationship to threat levels and the risks of accepting impostors at ports of entry.
Latent Fingerprint Enhancement

Anil K. Jain (MSU)

An irreplaceable functionality of fingerprint recognition is its capability to link latent fingerprints found at crime scenes to suspects previously enrolled in a database of full (plain or rolled) fingerprints. Compared to full prints, which are captured in an attended mode, latents have smudgy and blurred ridge structures, include only a small finger area, have large onelinear distortion, and contain background lines and characters, or even other prints. Due to poor quality of the latents, automatic feature extraction is a challenging problem. This proposal will design and implement techniques (a) for latent fingerprint enhancement with minimal manual markup by utilizing an orientation field model, (b) to suppress the effect of background noise, and (c) to combine fingerprint ridge enhancement with background noise removal to improve the matching accuracy. This will help achieve the goal of lights out mode for latent matching.

Dyadic Synchrony as a Measure of Trust & Veracity

Norah Dunbar (Oklahoma), Matthew Jensen, Judee Burgoon (U of A) and Dimitris Metaxax (Rutgers)

Most deception detection studies have examined either the behaviors of the deceiver or the strategies of the interviewer but few have examined the dyadic variables that combine the deceiver and interviewer such as synchrony, rapport, coordination or reciprocity.

Improving Information Security through Authentication Technology

Jeffrey Jenkins, Grayson Ross, Alexandra Durcikova and Jay Nunamaker (U of A)

Information security garners immense pressure in organizations, resulting in financial loss, damaged reputation, and legal sanctions when breached. Most security breaches are a result of human negligence—a problem that can be alleviated through the use of identification technologies. This study will evaluate the impact of fingerprint scanners and RSA SecurID tokens on IS security, users’ cognitive effort, and secure behavior in a mock-corporate environment. This research will aid researchers in tailoring identification technologies to improve secure behavior in corporations.

Temporal Alignment of Psychophysiological Behavioral Indicators

Kevin Moffitt, Zhu Zhang and Judee Burgoon (U of A)

The UA Mock Crime study has yielded time-coded data from multiple sensors including blood pressure, kinesics, blinks, respiratory rate, and facial movements. Missing are time-coded transcripts from the interviews. This project proposes to align time-coded transcripts with our current dataset. Knowing what a person is saying when their heart rate rises, or when they raise their eyebrows, for example, will help us to interpret our current dataset and give us a more complete picture of what a deceiver is experiencing and thinking.

Non-cooperative Biometrics at a Distance

Jeremiah Remus and Stephanie Schuckers (Clarkson)

Human identification at a distance is an area of growing need and importance. To enable biometric identification at a distance, the growing consensus is that a multi-modal approach for measuring biometric information is needed. In addition to measuring traditional biometric information (face and iris), it may be necessary to consider other signatures that can be easily gathered, such as thermal signatures, gait, soft biometrics, ear, and speech, that may contain useful identifiers. We investigate the sensitivity of a suite of biometrics that would comprise a multimodal dataset to standoff, non-cooperative collection conditions. In early 2010, we completed a collection of face and iris video out to 25 feet with quality degradation controlled at the acquisition level (Quality in Face and Iris Research Ensemble—Q-FIRE). The data is currently used by NIST in IREX II: Iris Quality Calibration and Evaluation (IQCE). The goal of this project is (1) to expand this dataset to include unconstrained subject positioning on same set of subjects, (2) to develop a better understanding of the primary factors that determine the quality of various standoff biometrics, and (3) study fusion of multi-modal standoff biometrics to increase classifier confidence.
Iris Segmentation Quality Analysis: Prediction and Rectification
Bojan Cukic, Nathan Kalka, Arun Ross and (WVU)
Arguably the most important task in iris recognition systems involves localization of the iris, a process known as segmentation. Research has found that segmentation results are a dominant factor that drives iris recognition matching performance. The ability to automatically discern whether iris segmentation failed prior to matching has many applications, including the ability to discard images with erroneous segmentation, but more importantly, provides an opportunity to rectify failed segmentation. This can be further utilized in multi-modal fusion algorithms where quality information is employed to help ascertain match score confidence. In this project, we design a segmentation quality metric capable of predicting and rectifying erroneous iris segmentation. Our quality metric will provide salient information which we can leverage in the selection of appropriately robust iris segmentation algorithm. Alternatively, we can use this salient information to rectify segmentation in an online manner depending on the degree in which segmentation failed. The designed metric will be able to operate independently of the segmentation algorithm being deployed.

Impact on Age & Aging on Iris Recognition
Stephanie Schuckers (Clarkson), Jeremiah Remus, Nadya Sazonova, Lawrence Hornak and Arun Ross (WVU)
There has been limited research conducted to assess the impact of matching time-lapsed iris images (“aging”) and age-induced changes in iris (“age”) on the performance of an iris recognition system. More recent work by Baker et al has shown evidence that the distribution of genuine match scores significantly changes as the time between samples increases (up to four years). However, their research was conducted on a small dataset consisting of less than 30 individuals. While the ideal scenario would be to study a large group of individuals over a significant portion of their lifespan, the practicality and expense of this makes it difficult and expensive. Here we study the impact of age and aging on iris systems in a three pronged approach based on retrospective analysis of data, collection of new data, and establishing a relationship with the larger medical community that regularly collects data on a much larger scale for research purposes. In addition, we devise encoding and matching algorithms to minimize the impact of aging and age on performance of iris recognition.

Multimodal Fusion Vulnerability to Non-Zero Effort (Spoof) Imposters
Stephanie Schuckers (Clarkson), Arun Ross (WVU) and Bozhao Tan (Clarkson)
Multimodal biometric systems have been suggested as a way to defeat spoof attacks. While intuitively the assumption is made that a person must spoof all modalities in the system, no research has considered the case where only one or two modalities are spoofed. In our preliminary work, we consider the performance of fusion strategies if one sample presented is spoofed successfully while the remaining two are not spoofed at all, i.e. the attacker uses his or her biometric sample. We repeat this for the case when two samples are successfully spoofed. We found vulnerabilities in multimodal systems to a partial spoof attack and that these vulnerabilities depend on the fusion strategies, as well as selection of the operating point, as strong factors balancing performance of protection from spoofing. In this work we study standard fusion methodologies and their relative vulnerability to spoof attack, as well as develop fusion methodologies that utilize liveness scores to minimize the threat of spoofing.

Detecting, Restoring & Matching Altered Fingerprints
Anil K. Jain (MSU) and Arun Ross (WVU)
The success of fingerprint recognition systems in accurately identifying individuals has prompted some individuals to engage in extreme measures for the purpose of circumventing the system. For example, in a recent US-Visit Workshop, the problem of fingerprint alteration was highlighted. The primary purpose of fingerprint alteration is to evade identification using techniques ranging from abrading, cutting and burning fingers to performing plastic surgery. The use of altered fingerprints to mask one’s identity constitutes a serious “attack” against a border control biometric system since it defeats the very purpose for which the system is deployed in the first place, i.e., to identify individuals in a watch-list. It should be noted that altered fingers are different from fake fingers. While fake fingers are typically used by individuals to adopt another person’s identity, altered fingers are used to mask one’s own identity. Here, we design and
evaluate 1) automated methods to analyze a fingerprint image and detect regions that may have been altered by the subject, 2) image-processing methods to reconstruct the altered regions in the fingerprints in order to enhance the overall fingerprint quality whilst generating an image that is biologically tenable and 3) matching methods that can successfully match altered fingerprints against their unaltered mates.

**SPLICE: Integrating Agent99, LIWC & Building an Accessible Platform for Future Tool Building**

*Kevin Moffitt (UA), Dr. Judee K. Burgoon (UA), and Jeff Jenkins (UA)*

As researchers continue to automate and extend the extraction of linguistic cues for deception detection and authorship identification to new domains, it will be important to choose a platform that is highly customizable, extensible, and easy-to-use. This project begins the development of an integrated system of automated deception detection tools called SPLICE (Structured Programming for Linguistic Cue Extraction) that meets those criteria. We will begin developing SPLICE by integrating Agent99 cues and LIWC into one common tool and interface. SPLICE will be built using the Python programming language - a flexible, relatively easy-to-learn programming language. The second part of this project makes SPLICE accessible as a Web Service using the REST architecture. The result will be a highly extensible and flexible tool to meet future researchers’ needs.

**Identifying Hidden Patterns from Facial Expressions**

*Koren Elder (UA-CMI), Nicholas Michael (Rutgers), Aaron Elkins (UA-CMI), Judee Burgoon (UA-CMI), Dimitri Metaxas (Rutgers) and Magnus Magnusson (U Iceland)*

This study applies computer vision techniques to videotaped interviews to map facial expressions onto interviewee veracity. Machine learning models are trained to identify different combinations of facial movements and different emotion expressions (e.g. anger, contempt, fear) to determine which ones are associated over time with interviewee veracity. Alternative models are developed from Active Shape Models (ASMs), the Facial Affect Coding System (FACS) and Theme, a software program for uncovering hidden patterns in data.

**Animating the Automated Deception Analysis Machine (ADAM)**

*Doug Derrick, Koren Elder, Jeff Jenkins, and Judee Burgoon (UA-CMI)*

This study integrates an embodied avatar with the Automated Deception Analysis Machine (ADAM) and run a pilot experiment using sixty subjects to test the new agent and the accuracy of the agent recommendations. A participant fills out a pre-survey and then interacts with the system. The avatar asks the person questions and the person types in their responses. The system adapts its interaction depending on the individual differences of the system users and the metrics collected from the responses. Each response is evaluated using the following three factors: 1) Lexical features: diversity, word count, punctuation, average word length, etc; 2) Time: time to create the message, response latency, etc; 3) Edits: number of time backspace is pressed, number of time delete key is pressed, how often is Ctrl-X used, and what was deleted. An inference engine determines the next question in the script. For example, if the response was judged to be vague (few words), the system may ask a follow-up, more probing question on the same topic or if deception was suspected, a rephrasing of the question may be asked in order to elicit additional data to measure.

**Automatic Deception Systems: To Believe or Not to Believe**

*Aaron Elkins, Nathan Twyman and Judee Burgoon (UA-CMI)*

This study explores the interactions between humans and automated deception detection systems. Recent CITeR research has shown that deception detection accuracy does not necessarily improve when a person is given recommendations from a system. Automated deception detection systems are continuously increasing in sophistication and ability to generate reliable recommendations, but these systems are not useful if the recommendations are not incorporated in the human’s decision. This study tests the proposition that human experts may feel threatened or defensive when the system recommendation is contrary to their own judgment. This research investigates a method of encouraging a more objective appraisal of system recommendations and investigates the relationship of more objective appraisals to perceived system credibility and overall accuracy.
Detecting and Extracting Macro-Features in Iris Images

Arun Ross, Larry Hornak and Xin Li (WVU)

The iris exhibits a very rich texture consisting of “pectinate ligaments adhering into a tangled mesh revealing striations, ciliary processes, crypts, rings, furrows, a corona, sometimes freckles, vasculature, and other features”. The randomness of the iris texture and its apparent stability render it a useful biometric. Most iris-based systems use the global and local texture information of the iris to perform matching. The anatomical structure within the iris is seldom used in the matching process. This project pursues the path of inquiry first identified in the Phase II multispectral project to design methods to extract and utilize the macro-features that are visible on the stroma of the iris. The goal is to design a system that can extract and match features across two images of the iris. The work will: (a) provide an alternate way to match iris images; (b) facilitate ways to visually compare two iris images thereby allowing forensic experts to determine the degree of similarity between two iris photographs; (c) potentially be used to locate and retrieve iris images possessing specific macro-features from a large database; and (d) provide an understanding of the individuality of the iris.

Matching and Retrieving of Face Images Based on Facial Marks: Phase 2

Anil K. Jain (MSU)

Facial marks have been studied as means of supplementing global shape and texture information used in commercial face recognition systems. The ability to automatically extract these marks or artifacts from facial images in large face databases will assist law enforcement agencies to rapidly locate human faces. In phase 1, we developed a prototype system to (i) automatically extract facial marks, (ii) designed a simple decision rule for matching facial marks, and (iii) developed a fusion rule to combine mark-based matcher with a leading commercial face matcher, and (iv) showed improved matching performance on a small face database. In Phase 2 we extend our previous study by: (i) incorporating a 3D face model to achieve pose invariance, (ii) enhance the automatic mark extraction method so that it can be applied to low-resolution video frames, (iii) investigate various fusion rules to combine these distinguishing marks with a commercial face matcher, and (iv) show performance improvement on a large (10K) database of operational images.

Models for Age Invariant Face Recognition

Anil K. Jain (MSU)

Facial aging refers to the problem in face recognition where the time difference between the enrolled face image and the query image of the same person is large (typically, several years). It is one of the major sources of performance degradation in face recognition. An age invariant face recognition system would be useful in many application domains such as locating missing children, screening, and multiple enrollment detection. However, facial aging has not received adequate attention until recently and the proposed aging models to compensate for age are still under development. Aging related facial changes appear in a number of different ways: i) wrinkles and speckles, ii) weight loss and gain, and iii) change in shapes of face primitives (e.g., sagged eyes, cheeks, or mouth). These aging patterns can be learned by observing changes in facial appearance across different ages from a set of training subjects. This work will design and implement techniques to (a) perform facial aging modeling in 3D domain using both shape and texture, (b) build separate facial aging models for different genders and ethnicities (Caucasian, African American, and Asian), and (c) use the aging model to compensate for aging to enhance matching accuracy using a commercial face matcher.


Arun Ross (WVU) and Anil K. Jain (MSU)

Multibiometric systems consolidate evidence provided by multiple sources to establish the identity of an individual. The design and performance of a multibiometric system is dictated by several factors, including the number of biometric sources to be combined, the fusion architecture (e.g., serial versus parallel), the mode of operation (e.g., verification versus identification), the cost and response time of the system, and the fusion mechanism employed. Recent research
in multibiometrics has resulted in the development of several algorithms for performing fusion at the data, feature, score, rank, and decision levels. Covariates such as data quality and soft biometrics have also been incorporated in the fusion framework resulting in improved matching accuracy. This work seeks to build a software platform that would provide its user with the ability to experiment with a large number of fusion methods and evaluate the relative performance of these methods on multiple datasets. Since most biometric researchers in academia utilize the Matlab™ platform to develop and test algorithms, the proposed software will be designed in such an environment. However, the graphical user interface (GUI) offered by the tool will be accessible by the broader end-user biometrics community. The salient features of the proposed environment include (a) access to a wide gamut of fusion techniques and methods to address missing/incomplete data; (b) a platform to evaluate multiple competing fusion techniques as a function of covariates; (c) the capability to incorporate fusion modules developed by other researchers; and (d) the development of a wiki website to allow for the collaborative editing of the software.

Large-scale Evaluation of Quality Based Fusion Algorithms
Bojan Cukic, Nathan Kalka (WVU) and Anil K. Jain (MSU)
Performance improvements attributed to fusion are significant and major biometric installations have deployed or plan to deploy multimodal fusion to improve identification accuracy. The deployed fusion algorithms mostly operate at the matching score level and do not always incorporate biometric quality estimates. State of the art multimodal fusion schemes adaptively incorporate quality estimates to further improve the performance. Nevertheless, due to lack of adequate volume of training data, inconsistencies in the acquisition of training and testing data, and highly conflicting unimodal evidences, these systems often do not necessarily achieve “optimality”. The goal of this project is to perform large scale evaluation of face / iris / fingerprint quality based fusion algorithms. We have access to large fingerprint and iris databases for analysis (over 8,000 subjects in each modality). This data comes from collections known to have inconsistent quality. We also intend to acquire as many face images as possible from known collections to chimerically augment the fingerprint and iris data. We will utilize commercial matchers and publicly available quality estimation algorithms. We will evaluate quality based likelihood ratio based fusion algorithm, bayesian belief network fusion algorithm, SVM- likelihood ratio algorithm, as well as well known score level fusion approaches which do not include quality scores (sum rule, max rule, etc). For quality evaluation we plan to use WVU, MSU and our implementation of Daugman’s algorithm for iris, NFIQ and BAH algorithms for fingerprints, Facelt and BAH for face. Empirical results are expected to provide statistically significant evaluations that can guide future research and deployment decisions in multi-biometric fusion.

PRESS (Program for Rate Estimation and Statistical Summaries) version 2.0
Micheal Schuckers (St. Lawrence University) and Daqing Hou (Clarkson University)
Several years ago, we developed (with CITeR funding) the PRESS tool which is now in version 1.1. This tool has assisted many organizations in assessing and evaluating tests for biometric identification including TSA, NBSP, Authenti-Corp, Mitre, NIST. Several developments have occurred in statistical methods for biometrics since that time. We will add these new methods as well as make improvements on the existing methodology used in PRESS 1.1. These improvements include adding new statistical methods for FTE, FTA, MTT and improved methods for FMR, FNMR and ROC’s. Further, we will improve the existing graphical interface.

Economical, Unobtrusive Measurement of Postural Correlates of Deception
Christopher Lovelace, Reza Derakhshani, Gregory King (UMKC) and Judee Burgoon (U of A)
This will be a novel adaptation of force platform technology to the measurement of postural shifts that accompany deception. The straightforward, inexpensive, and concealed ground force platform technology, when coupled with modern non-linear, data-driven signal classification methods, has the potential to provide efficient, reliable, and unobtrusive identification of deception in a security screening environment.
The Effect of Power and Modality on the Detection of Deception
Norah Dunbar, Matthew Jensen (Oklahoma) and Judee Burgoon (U of A)
Many field situations such as rapid screening at portals or the educing of information from witnesses or suspects involves a power differential between the interviewer and the subject. Using Computer-Mediated Communication (CMC) in these areas for initial screening interviews reduces the burden on human, physically present interviewers.

Linguistic Dynamics in Criminal Interviews
Matthew Jensen, Norah Dunbar (Oklahoma), Judee Burgoon (U of A) and Stan Slowik
The proposed research will examine the dynamics of deceptive language and content in high-stakes interviews. We expect that linguistic and context-independent content from high-jerapy interviews will discriminate truthful or apparently truthful responses from ones that indicate deception and that deceptive strategies such as hedging, ambiguity, and equivocation will vary across the course of an interview. This work will explore whether particular phases of an interview (early, late) are more diagnostic than others regarding an interviewee’s truthfulness.

Observational Coding of Deceptive and Truthful Interviewees from Varied Cultural Orientations
Judee Burgoon (U of A), Norah Dunbar and Matthew Jensen (Oklahoma)
It is more difficult for examiners to detect deception by individuals from disparate cultures because if deceiver and receiver differ even in their definitions of what constitutes deception, then they may communicate in ways that complicate detection accuracy. We will examine this issue at a global, impressionistic level that is similar to the unaided general impressions examiners form when conducting screenings and pretest interviews.

Application of Automated Linguistic Analysis to Deception Detection in 911 Homicide Calls
Mary Burns, Kevin Moffitt, Judee Burgoon, Jay Nunamaker (U of A) and Tracy Harpster (Moraine Police Department, Dayton, OH)
This work will analyze calls by ‘guilty’ and ‘innocent’ callers for a proof of concept for detection and of deception/guilt. We will apply our automated linguistic cue analysis and automated transcription tools to transcripts and/or audio tapes of 911 calls to determine guilt or innocence of the caller. Advantages of analyzing 911 statements vs. person of interest statements or interviews conducted by law enforcement officers: (1) 911 statements represent the initial contact between a caller and an emergency response team, including law enforcement, leaving callers little chance to rehearse a false story; (2) because 911 operators are not perceived by callers law enforcement, they may exhibit less controlled behavior and more cues of deception; (3) due to the temporal immediacy of the crime to the 911 call, there may be more active stress on the caller which may cause the caller to ‘leak’ more clues unintentionally; (4) because 911 operators do not interrogate, the statements are objective.

Using Connectionist Modeling to Automatically Detect Facial Expression Cues in Video
Karen Elder, Aaron Elkins, Judee Burgoon (U of A) and Nicholas Michael (Rutgers)
This study will build a connectionist model, using Facial Metrics and the Facial Action Coding System (FACS) to automatically identify facial expressions in videos. The connectionist network model will be trained to identify different emotion expressions (e.g. surprise, anger, happiness, suspicion, neutral, etc.). The model will then be used to map the facial expressions of interviewees captured on video. In the future, these mappings can be used to determine which expressions are reliable indicators of truth or deception during interviews or interrogations.

Collaborative Acquisition of Face Images Using a Camera Sensor Network
Vinod Kulathumani, Arun Ross and Bojan Cukic (WVU)
Network of image sensors combined with biometric systems can form the building block for a variety of surveillance applications such as airport security, protection of critical infrastructures and restricted access to guarded assets. In this project, we focus on the collaborative acquisition of biometric data for face recognition using a network of image sensors. One of the scenarios for using such a system is the distributed in-network detection of an event of interest and
simultaneous face recognition in a dynamic scene. As a basic step towards building such a system, we focus on the following problem statement: Given a set of n cameras deployed to monitor a given area, (0) determine optimal positioning of cameras to maximize biometric information obtained when a single person enters the area, (1) design a distributed algorithm to coordinate the cameras to capture partial views of the face that maximize biometric content and (2) design a distributed algorithm to acquire partial snapshots to construct the full facial image using mosaicing techniques.

**LiveDet 2009–Fingerprint Liveness Detection Competition 2009**

*Stephanie Schuckers and Bozhao Tan (Clarkson)*

Fingerprint recognition systems are vulnerable to artificial spoof fingerprint attacks, like the molds made of silicone, gelatin or Play-Doh, etc. “Liveness detection” has been proposed to defeat these kinds of spoof attacks. We propose to host the first fingerprint liveness detection competition (LivDet2009) in ICIAP 2009. This competition will be hosted in collaboration of University of Cagliari (Gian Luca Marcialis, Fabio Roli, Pietro Coli), also active researchers in liveness detection. The goal is this competition is to compare different methodologies for software-based fingerprint liveness detection with a common experimental protocol and large liveness dataset. The ambition of the competition is to become a reference event for academic and industrial research. This competition is open to all academic and industrial institutions which have a solution for software-based fingerprint vitality detection problem. Each participant is invited to submit its algorithm in Win32 console application. The performance will be evaluated by utilizing a very large data set of “fake” and “live” fingerprint images captured with three different optical scanners. The performance rank will be compiled and published in this site and the best algorithm will win the “Best Fingerprint Liveness Detection Algorithm Award” at ICIAP 2009.

**On the Super-Resolution of Iris Images from Video Streams**

*Patrick Flynn (Notre Dame) and Arun Ross (WVU)*

Current trends in iris recognition deployment expectations include (a) the use of video sensors to acquire video sequences of images, and (b) the need to exploit images acquired under non-ideal circumstances. Currently available iris matchers perform poorly on iris images that are low in resolution. Since non-ideal circumstances may preclude camera repositioning to improve resolution, investigation of resolution improvement through multi-frame integration is a topic of interest. We propose to combine our expertise in image processing, iris imaging, and video analysis to integrate multiple video frames of an iris to form a super-resolution still image suitable for matching. We will explore two scenarios to facilitate super-resolution. In the first scenario, a single camera will be used to acquire a video stream of a live iris (single view system); in the second scenario, two cameras, offset by a pre-determined inter-axial distance, will be used to acquire multiple video streams of a live iris (multi-view system).

**Unconstrained Face Recognition under Non-Ideal Conditions**

*Arun Ross (WVU) and Anil K. Jain (MSU)*

The matching performance of face recognition systems has significantly improved over the past decade as assessed by FRVT/FRGC evaluations. However, the fundamental problem of matching face images obtained using different cameras and/or subjected to severe photometric (e.g., illumination) and geometric (e.g., compression) transformations continues to pose a challenge. For example, it is difficult to match a high-resolution face image obtained under controlled illumination against a low resolution face video hosted at YouTube or a geometrically resized face image posted on the web. In this work, the problem of matching face images whose intrinsic image characteristics are substantially different will be investigated. The goal is to design algorithms that can handle the problem of matching disparate face images of the same individual.

**Phase 1 – Participation in the Multi-Biometric Grand Challenge**

*Stephanie Schuckers (Clarkson), Natalia Schmid (WVU) and Besma Abidi (UTK)*

Fusion of face and iris data at a distance for biometric recognition could be extremely beneficial in places, like airport, port of entry, etc. The Multi-Biometric Grand Challenge goal is to provide various recognition challenges for face and iris
based on still and video imagery. Our previous work includes efforts in face and iris recognition using advanced adaptive algorithmic approaches to account for non-ideal conditions through preprocessing, segmentation, modeling and utilization of global iris quality. We propose to participate in the Multi-Biometric Grand Challenge (MBGC). MBGC has three stages. (1) Challenge 1 data was made available in May 2008. Results were presented in Dec 2008 at a workshop. (2) Challenge 2 dataset with results are presented in Spring 2009. (3) The last stage is the Multi-Biometric Evaluation in Summer 2009. Our approach will be to fuse biometric information from both face and iris extracted over multiple frames. Quality information will be a critical component to select individual frames and to weigh information at the feature/pixel level. Fusion will be considered at the match score level and feature level where PDE-texton maps or other features can be used to jointly encode to obtain robust representation of face and iris.

Evaluating and Integrating Speech Recognition Software into Agent99 for Real-Time Deception Detection

Kevin Moffit, Sean Humphries, Jay Nunamaker, Judee Burgoon and Pickard Burns (U of A)

The successes of automated post-processing of text for linguistic credibility assessment are well-documented. (Zhou et al., 2004, Moffitt et al., 2008). Yet real-time processing of interviews and dialogue using these tools has yet to take place. For real-time processing to occur, words must be transcribed to text as they are spoken. This is accomplished by speech recognition (SR) software. SR software has a history of being inaccurate and difficult to use; however some SR software companies now claim 95% accuracy. The medical industry has now embraced SR software to cut the time in preparing patient reports (Alapetite et al. 2008). Even so, integrating SR into the linguistic credibility process has remained untried and the reliability of SR software as a tool for gathering interview data and dialogue has yet to be evaluated. In this project, we will build a real-time speech evaluation system which integrates SR with Agent99, leveraging software previously developed for linguistic credibility assessment.

Handedness in Detecting Deception in Cultural Interviews

Mathew Jensen (Oklahoma), Thomas Meservy (UM) and Judee Burgoon (U of A)

Kinesic analysis has been successfully used to discriminate truth from deception in numerous experimental settings. A curious finding that has repeatedly surfaced is the predictive value of cues related specifically to the left hand. Two alternative explanations will be addressed in the proposed research. One is that differences stem from brain lateralization (each hemisphere has functional specialization) such that the left hand performs different discursive functions than the right. The other is that the effects are due to handedness and observed left-hand effects pertain only to those with right-hand dominance. We will use data collected on subject handedness to (a) replicate the hand-related effects and (b) determine if they are linked specifically to hand dominance or question type or both.

Looks like Me: Cultural Avatars

Koren Elder, Mark Patton, Aaron Elkins, Carl and Judee Burgoon (U of A)

This study will conduct a lab experiment to empirically test how the gender and ethnicity of avatars can be manipulated to elicit cues that are reliable indicators of truth or deception. The credibility of the avatar and the reactions of the subject will be investigated to determine if there are significant differences based on avatar and subject gender and ethnicity interactions and which avatars best expose deception without creating confounding arousal unrelated to deception. With the increase in use of avatars for kiosks, it is important to understand how the embodiment of an online agent can impact interpersonal communications.
An Acquisition Platform for Non-cooperative, Long Range Ocular Biometrics
Reza Derakhshani (UMKC), Plamen Doynov (UMKC) and Besma Abidi (UTK)
The objective of this proposal is to mitigate this problem by a COTS-based capturing platform that will (a) scan a crowd using multiple, pan-tilt systems, (b) locate subjects’ eyes in near-infrared (NIR) (c) tag each locked-on individual with a NIR pattern for concurrent, multi-subject recognition (d) using burst (lucky) imaging, pick the best high-zoom images of the eye regions by fast quality analysis algorithms for long-range (up to 10m) and simultaneous ocular biometric recognition of unconstrained, freely moving crowds.

Automatic High Resolution Palmprint Matching System
Anil K. Jain (MSU) and Arun Ross (WVU)
Palmprints contain three different levels of information: Level 1 (principle lines, wrinkles and major creases), Level 2 (minutiae points) and Level 3 (ridge contour, pores). While Level 1 features can be extracted from fairly low resolution images (~100 ppi), higher resolution images are needed for extracting Level 2 (~500 ppi) and Level 3 (~1000 ppi) features [4]. Commercial palmprint acquisition systems do have the capability of capturing dual-resolution images (500 and 1000 ppi), but not much work has been done to date in extracting Level 3 features from 1000 ppi images (ANSI NIST document on Extended Feature Set for fingerprint and palmprints [5]). Matching latent (partial) palmprints to full prints is particularly important in forensics application where Level 3 features will play a major role. In this project, we propose to design and evaluate an automated palmprint matching system that uses multiple levels of features.

Culturally Specific Credibility Classification Using Layered Voice Analysis
Judee Burgoon, Aaron Elkins, Douglas Derrick, Josh Hottenstein (U of A) and Dale Tunnell (Forensitec)
These newly available vocal measurements will provide a rich platform for examining the moderating effect of culture on deceptive leakage cues, particularly vocalics. Culture has been virtually unexplored in this context despite its potential to explain some of the individual variability in verbal and nonverbal behavior expressed during deceptive communication. The findings from this research have the potential to improve existing classification models utilizing other behavioral cues to detect deception. The credibility classification model for LVA will be developed using statistical analysis and machine learning algorithms on training data from a recent deception study focused on culture. Additionally, we will provide an empirical evaluation of the new generation of commercial LVA currently in use by law enforcement agencies.

Establishing Chain of Evidence in Biometric Systems
Bojan Cukic, Arun Ross, Nathan Kalka and Nick Bartlow (WVU)
The process of creating such a chain entails at least three types of validation to provide assurance that the collected biometric evidence has not been fabricated, altered or unintentionally mislabeled. These are validation of (a) evidence transmission, (b) content integrity, and (c) source of origin. While modern cryptography can adequately handle the validation of evidence transmission, validation of content integrity and source of origin must rely on other techniques. Biometric watermarking is the process of clandestinely embedding data into biometric images which can be used to assure validity of content. Digital hardware fingerprinting allows for the identification of source hardware from which an image originated. Through analysis of various types of sensor pattern noise and other artifacts, one can determine the technology, brand, model or specific sensor used to capture a biometric image. By utilizing cryptography, watermarking in conjunction with digital hardware fingerprinting and cryptography, a chain of evidence can be created, providing verification of image origination, authenticity, integrity, ownership, and non-repudiation of origin.
Improving the Identification of Fraud by Adding Word Sense Disambiguation to Linguistic Credibility Assessment/Enhancing Fraud Detection by Building Lexicons and through Collocation Techniques
Sean Humphreys, Kevin Moffitt, Judee Burgoon and Jay Nunamaker (U of A)
Automated techniques have been developed to assist in detecting deceit and fraud. However, existing models (e.g. Zhou et al. 2004) rely on proper identification of part-of-speech tags (nouns, modal verbs, adjectives, etc) and can be harmed by ambiguous words. Deceivers are thought to use more ambiguity and hedging language. Computers are not nearly as good as humans at disambiguating words and their parts-of-speech. Errors in these automated tools can cause deception detection models to misclassify statements and documents. Using field data collected from the fraudulent SEC filings and insurance fraud, a linguistic analysis that includes a word sense disambiguator (WSD) will be undertaken to assess credibility and identify distinguishing linguistically cues related to credibility in text-based claims.

Improving Quality Enhanced Biometric Fusion Schemes
Bojan Cukic, Afzel Noore, Nick Bartlow, Nathan Kalka, M. Vasta and R. Singh (WVU)
To design a hybrid fusion algorithm which combines the three approaches along with the uncertainties and precision of individual classifiers to improve the performance in cases of conflicting or missing information. Our hybrid classifier will decrease the computational complexity of resolving cases with conflicting unimodal evidences. Additionally, we will augment existing algorithms through the incorporation of a probabilistic measure of decision dependability which affords the opportunity to perform decision rectification or “reversing” classification decisions likely to be inaccurate. Through careful application of decision rectification, performance of quality enhanced biometric fusion algorithms may be improved. In both the proposed hybrid fusion algorithm and the existing algorithms augmented with decision rectification we expect to observe increases in performance when low quality samples are injected into systems previously trained on high quality subsets. Performance evaluation will be conducted using standard statistical measures (ROC curve) and through cost curves.

Matching and Retrieving of Face Images Based on Facial Marks
Arun Ross (WVU) and Anil K. Jain (MSU)
Face recognition systems typically encode the human face by utilizing either local or global texture features. Local (or part-based) techniques first detect the individual components of the human face, prior to encoding the textural content of each of these components. Global techniques, on the other hand, consider the entire face as a single entity during encoding. However, both these techniques do not explicitly extract wrinkles, scars, moles, and other distinguishing marks that my present in the 2D image of the face. Many of these features are temporally invariant and can be useful for face recognition and indexing. The ability to automatically extract these marks or artifacts from facial images in large digital libraries can assist law enforcement agencies to rapidly locate human faces possessing specific marks. This proposal will design and implement techniques to (a) extract distinguishing marks present of the surface of the face and analyze their distributions, (b) efficiently retrieve face images from a digital database based on these marks, and (c) combine these distinguishing marks with a commercial texture-based face matcher in order to enhance matching accuracy.

Phase 0 - Participation in Multibiometric Grand Challenge
Stephanie Shuckers (Clarkson), Natalia Schmid (WVU), Besma Abidi and Uma Kandaswamy (UTK)
Fusion of face and iris data at a distance for biometric recognition could be extremely beneficial in places, like airport, port of entry, etc. The MultiBiometric Grand Challenge goal is to provide various recognition challenges for face and iris based on still and video imagery. We propose to participate in the MultiBiometric Grand Challenge (MBGC). MBGC has three stages. (1) Challenge 1 data is made available in May 2008. Results are to be presented in Dec 2008 at a workshop. We are processing the data now. (2) Challenge 2 dataset with results are presented in Spring 2009. (3) The last stage is the MultiBiometric Evaluation in Summer 2009. Our approach will be to fuse biometric information from both face and iris extracted over multiple frames. Quality information will be a critical component to select individual frames and to weigh information at the feature/pixel level. Fusion will be considered at the match score level and feature level where PDE-texton maps or other features can be used to jointly encode to obtain robust representation of face and iris.
Psychophysiological Biometrics
Judee Burgoon (U of A), Reza Derakhshi (UMKC), Arun Ross (WVU) and Diane Filion (UMKC)
We will utilize stimulus-response psychophysiological reactions of individuals that can be captured by the typical biometric platforms in order to enhance their performance and security via imposter detection. We will focus on the well known pupillometry, blink, gaze, and other deception-induced gestures of an individual such as hand and head gestures while interacting with the biometric system or an interrogator. In addition to the detection of imposters, the above psychophysiological traits should provide strong anti- spoofing measures. This project would serve as a synergistic project between CITeR- WVU and the new CITeR-UA.

Rapid Assessment Using Kiosk-based Interviews
Mark Patton, Judee Burgoon and Jay Nunamaker (U of A)
This is a first effort to utilize an automated rapid assessment kiosk to evaluate subjects for truth or deception. Subjects will be run through an international airline travel scenario where they will pack bags and proceed through a screening kiosk. Subject may or may not have items which are contraband or illegal for this type of travel. They will be asked a series of screening questions intended to elicit if they have anything to declare or if they are carrying any proscribed items. Their actions during the question and answer interacts will be video tapes, and their audio responses captured, for subsequent analysis. The experiment is intended to determine if standing subjects reveal stress or deception through body movement, if Voice Stress technologies can successfully flag either stress or deception in this setting, or if a fusion of these technologies can reveal stress and/or deception. It is also intended to reveal if there is any material difference based on method of questioning, either a speaking avatar or text on a screen which is read aloud to the subjects.

Sequential Biometric Fusion Involving Incomplete or Missing Data
Arun Ross (WVU) and Anil K. Jain (MSU)
This proposal seeks to address this problem in the context of an identification system by raising two pertinent questions. (a) Can a fusion algorithm be designed such that biometric information is consolidated in a sequential manner (as the traits become available) in order to determine an individual’s identity? (b) Can a score-level or rank-level fusion scheme be designed to work in the presence of partial or incomplete biometric information? We will extend our current approach based on the Likelihood Ratio technique to devise methods that can effectively answer these questions thereby advancing the state-of-the-art in biometric fusion for identification systems.

Iris Recognition Beyond 1000nm: A Preliminary Study
Arun Ross, Lawrence Hornak and Xin Li (WVU)
Most commercial iris recognition systems utilize information available in the 700–900nm spectral band (near-IR). Here, we investigate the possibility of performing iris recognition at higher wavelengths (1000 – 1500 nm, i.e., extended near-IR) to advance the science and technology of multispectral iris analysis in the biometric domain. The goal of this project is (a) to understand the composition of the iris at multiple resolutions using spectral information beyond 1000 nm (much like the Level I, II and III details in fingerprints); (b) to determine if iris segmentation can be successfully accomplished at these wavelengths; (c) to develop anti-spoofing methods by studying the information revealed by various components of the eye at these wavelengths; and (d) to report recognition performance using multispectral information associated with these spectral bands.

Autonomous Interrogation through Synchronous Computer-Mediated Communication
Matthew Jensen, Douglas Derrick and Judee Burgoon (U of A)
We will utilize artificially intelligent “chatbot” technology and advanced text processing algorithms to create a prototype autonomous interrogation system. The artificial integrator will have the ability to interact with a subject via synchronous communication (i.e., chat). In order to conduct the interrogation, the computer-based agent will use a series of internal scripts and a complicated decision tree. The agent will ask questions of the subject, and process the responses in real-time in two ways. First, it will analyze the communication for potential deception using GATE / WEKA libraries and a text-
based deception model. Second, it will weigh the deception measurement and original message content against its decision tree and then formulate its response or next question.

**Hybrid Expert System for Credibility Assement**

*Matthew Jensen, Jay Nunamaker and Judee Burgoon (U of A)*

Among the most discriminating cues to deception are perceptual measures such as observed uncertainty, cognitive load, and non-immediacy. We will incorporate such perceptual measures in an existing prototype that uses linguistic and kinesic analysis for credibility assessment. Such a hybrid expert system would include more of the unique capabilities that are necessary for unobtrusively monitoring interactions for indications of deceit and should improve credibility assessment performance.

**Kinesic Credibility Assessment of Criminal Interviews**

*Matthew Jensen, Judee Burgoon (U of A), Amy Franklin (Rice-Linguistics) and Pete Blair (Texas State U-Criminal Justice)*

Kinesic analysis has been successfully used to discriminate truth from deception in numerous experimental settings. However, these experimental settings do not provide representative levels of deceiver motivation and jeopardy that are present during high-stakes deception. For this project, we will have access to a new dataset that contains interviews captured during actual criminal investigations. Ground truth for all interviews has been established by confession or conviction of the suspect. Using this dataset, we will be able to further probe the capabilities of kinesic credibility assessment by using field data.

**CITeR 2007**

**Recovering the Frontal Facial Image from Surveillance Video**

*Besma Abidi (UTK) and Arun Ross (WVU)*

The objective of this proposal is to construct an optimal frontal view from a series of frames obtained from surveillance video. Two techniques (2D and 3D) will be implemented and compared in terms of real time requirements and performance of a recognition engine. The study will be conducted on a variety of sample videos to mimic various real life scenarios and performance evaluated using existing surveillance databases.

**Quality Based Restitution of Iris Features in High Zoom Images for Less Constrained Iris Recognition System**

*Stephanie Schuckers (Clarkson), Natalia Schmid, Aditya Abhyankar and Lawrence Hornek (WVU)*

This necessity to have short range eye scanner distance poses a serious limitation in terms of their usability. “Iris recognition from distance’ has received limited attention in literature and is a very challenging problem for the following reason: (1) Long range distance degrades the overall iris quality. (2) The effect of various noise elements like motion blur, angular deformation etc. gets amplified with the distance. (3) As distance increases, iris recognition techniques for restoration of important iris features from high resolution iris images for efficient long range iris recognition. Following issues will be studied: (1) Design of eye-scanner distance base adaptive quality metric. (2) Study and analysis of various iris features at different resolutions. (3) Adaptive quality metric based iris segmentation and encoding methodologies. (4) Development of reliable way of formulating distant iris templates using quality restitution of iris features for more dependable recognition with fewer constraints.

**Automatic High Resolution Retrieval of Tattoos for Victim and Suspect Identification**

*Anil K. Jain (MSU)*

Tattoos are imprints on the skin useful for identifying the non-skeletalized body of a victim, or a suspect using a false identity. Tattoos also serve as an indicator of social status, personality, religious affiliations, or criminal organization
affiliation of individuals. A wide cross section of the population bears tattoos, from fashion models to known criminals and gang members. Various law enforcement agencies maintain a database of scars, mark & tattoos for the purpose of victim and suspect identification. For this reason, ‘ANSI/NIST – Data Format for the Interchange of Fingerprint, Facial, & Scar Mark & Tattoo Information’ was released to ensure uniformity in the capture and exchange of tattoo data. This protocol utilizes semantic (category) labels (viz., “human forms and features”, “animals”, “plants”, etc.) to characterize each tattoo entry during data collection; the retrieval is, therefore, primarily based on textual queries. This matching and retrieval method is not only time consuming, but lacks objectivity. Image or pattern-based retrieval, on the other hand, is more appropriate since it lends itself to automated queries based on the content of visual imagery or pattern. We propose to design and build a prototype tattoo matching and retrieval system based on image content and semantic categories.

**Securing Multibiometric Templates Using Fuzzy Vault**
*Anil K. Jain (MSU) and Arun Ross (WVU)*

Template security is critical in biometric system design because stolen biometric templates, unlike passwords, cannot be revoked. A number of approaches, including encryption, watermarking, fuzzy vault and revocable template have been proposed to secure templates. However, these approaches have been proposed primarily to secure a single template. A multibiometric system requires the storage of several templates for the same user corresponding to different biometric sources. Therefore, template security is even more critical in multibiometric systems. While it is possible to apply the template protection schemes individually to these templates and combine the authentication results at the decision level, such an approach is not optimal in terms of accuracy and security. We propose a unified scheme to secure multiple templates by (i) transforming features from different biometric sources (e.g., fingerprint minutiae and iriscodes) into a common representation, (ii) performing feature-level fusion to improve recognition accuracy, and (iii) constructing a single fuzzy vault to secure the fused multibiometric template. We will develop a fully automatic implementation of a multibiometric fuzzy vault that can handle different scenarios such as multiple samples (e.g., two impressions from the same finger), multiple instances (e.g., left and right irises) and multiple traits (e.g., fingerprint, face and iris). We will demonstrate the performance of the proposed multibiometric fuzzy vault in terms of its accuracy and security on public domain (WVU, FVC, CASIA and XMVT) databases.

**Indexing Large-scale Multimodal Biometric Databases**
*Anil K. Jain (MSU) and Arun Ross (WVU)*

Efficient retrieval of pertinent identities from a multimodal biometric database is a challenging task due to the large number of enrolled subjects and the availability of multiple biometric traits corresponding to each subject. Identification systems requiring a short response time will, therefore, be at a disadvantage when searching through the entire database to determine the identity of an individual. This project will explore the design of indexing (or filtering or binning) schemes to define an efficient search and retrieval strategy in multimodal biometric databases. Given the input biometric data of an individual, the goal of indexing is to reduce the search space of possible identities by appropriately partitioning the target biometric database. Further, indexing is likely to increase the overall matching accuracy. While such schemes exist for individual modalities such as fingerprints, multimodal indexing is a yet unexplored problem and has the potential to facilitate rapid and accurate search operations in large-scale multimodal databases.

**CIReT 2006**

**Adaptive Biometric Authentication using Dempster-Shafer Networks: Concepts and Performance**
*Bojan Cukić, Natalia Schmid and Nick Bartlow (WVU)*

This project aims at providing a methodology for designing Dempster-Shafer (D-S) belief networks that optimize identity matching. D-S belief networks can be automatically generated as system parameters and available evidence are
updated. The strength of “knowledge” rests on a justification of belief acquired through the mathematical theory of evidence. Ideally the ability to automatically adapt will allow system performance to reach its full potential. This project will evaluate performance measures in these complex biometric systems, for example robustness and scalability, in order to understand whether the promise of performance improvement is justified. The measures will be compared against achievable limits.

Enhancing Iris Systems using Conjunctival Vascular Patterns
Reza Derakhshani (UMKC) and Arun Ross (WVU)
The conjunctival vascular structure of the eye will be used in conjunction with the iris pattern in order to validate the liveness of the iris, and enhance the recognition performance of an iris system.

Fingerprint Matching Using Level 3 Features
Anil K. Jain (MSU)
Fingerprint friction ridge details are generally described in a hierarchical order at three different levels, namely, Level 1 (pattern), Level 2 (minutiae points) and Level 3 (pores and ridge shape). Although Level 3 features are key for latent print examination and forensics research has shown the viability of using pores to assist identification, current Automated Fingerprint Identification Systems (AFIS) rely only on Level 1 and Level 2 features. With the advances in sensing technology, many commercial live-scan devices are now equipped with high resolution (1000 ppi) scanning capability, allowing additional information besides minutiae, such as Level 3 features to be utilized. We propose a systematic study to determine how much performance gain one can achieve by automatically extracting and matching Level 3 features. Our initial experiments have shown that the use of Level 3 features provide a relative reduction of 20% in the equal error rate (EER).

Multispectral and Multiframe Iris Analysis: Phase II
Arun Ross, Lawrence Hornak and Xin Li (WVU)
Phase I of this project had explored the potential of using multispectral information to enhance the performance of iris recognition systems. In phase II the goal is to develop and implement algorithms that impart the following functionalities to an iris recognition system: iris localization using multispectral information; determining an optimal color space for iris texture analysis and processing; designing new algorithms for extracting novel features from various spectral channels; automatic clustering of iris components based on color information; fusing multispectral information based on eye color; and facilitating interoperability between iris images acquired at multiple wavelengths. By adopting this new research agenda, the PIs expect to advance the science and technology of multispectral iris analysis in the biometric domain.

Video-based Metrology for Automated Human Identity Profiling
Don Adjeroh, Xin Li, Arun Ross and Bojan Cukic (WVU)
In this project, we propose to explore a new direction in human identification that does not rely on predefined patterns. That is, we construct a person’s biometric profile (BP) by extracting metrological information about the individual from a given observation data. Such a metrology-based biometric profile is both dynamic (it varies along with the acquisition environment) and scalable (more measurements imply less uncertainty about the identity). The video metrology–based approach is particularly suitable for some applications where traditional biometrics is not applicable (e.g., masked or uncooperative individuals, or extreme environments, for instance, combat soldiers in full gear in a hazardous environment.

Sequential Testing for Biometric Error Rates
Michael Schuckers (St. Lawrence University)
In this project, we would like to develop and apply the statistical methodology for sequential testing to the testing of bio-authentication devices. Specifically, we are interested in testing whether or not a device’s error rate is below a given threshold. The basic idea of sequential testing, as it applies here, is that periodically testing will be stopped and
evaluation of the error rate at that juncture will be determined. At each such stopping point, there are three options. First, if the error rate is sufficiently low, then the test is terminated and the device is said to meet the threshold. Second, if the error rate is sufficiently high, then the test is terminated and the device is said to not meet the threshold. Finally, if the error rate is neither sufficiently large nor extremely small then the test is continued until the next stopping point.

Encryption of Biometric Templates using Biometrics as the Key

Stephanie Schuckers and S. Kumar (Clarkson)

Biometric information is irrevocable and hence should not be compromised. With the advent of applications requiring transmission of biometric information using public networks for personal authentication, it has become necessary to embed strong security in the system. Previously, key-based approaches have been suggested, but keys are often protected by passwords which often are chosen such that they are inherently weak. Our project studies methods to encrypt a biometric template by using biometric information itself instead of using keys. The proposed systems has these main components: Encoder: statistical template learning for a set of registered users to be used with partial biometric data to formulate encryption key; Simulation of a chaotic channel by mixing different biometric representations based on statistical properties of biometric data; Decoder: design of a blind source separator in tandem with hidden Markov model for fuzzy matching, trained to quantify the information related to the set of registered users; and an evaluation platform to assess system performance on real as well as manipulated database.

Quality Assessment and Restoration of Face Images in Long Range/High Zoom Video

Besma Abidi (UK) and Natalia Schmid (WVU)

The objective of this proposal is to design an efficient algorithm for the evaluation of face image quality in high magnification surveillance videos, then apply adaptive image deblurring and restoration to increase the quality of these face images so they become suitable for recognition. Tests will be conducted using Facelt.

A Dynamic Hierarchical Fusion Architecture for Biometric Systems

Anil K. Jain (MSU) and Arun Ross (WVU)

The performance of a biometric recognition system can be significantly improved by combining multiple classifiers, by utilizing multiple samples during enrollment/authentication, or by including multiple biometric indicators. We propose to design a fusion framework that optimally combines information, possibly in a hierarchical way, pertaining to multiple samples and multiple classifiers (algorithms) in order to maximize the performance gain. To facilitate such a framework, we will investigate, in the context of face recognition, the diversity (as well as quality) of information that is desired in the representative face samples (e.g., variations in pose, tilt, lighting, etc.), the nature of the face recognition algorithms to be combined (e.g., PCA, LFA, etc.), and a dynamic hierarchical fusion architecture that determines the type of information to be fused as well as the fusion algorithm to be employed based on the available input data. We will also compare the performance gain of intra-modal fusion (e.g., face alone) against inter-modal fusion (e.g., face and fingerprint). This study will benefit dynamic surveillance applications and can be extended to include other modalities as well (such as fingerprints and iris).

CITeR 2005

Non-Ideal Iris Recognition: Segmentation and Algorithms

Natalia Schmid (WVU), Stephanie Schuckers (Clarkson), Gamal Fahmy, Xin Li and Lawrence Hornak (WVU)

While current commercial iris recognition systems based on patented algorithms have the potential for high recognition performance, they suffer from the need for a highly constrained subject presentation. This work will explore techniques to adjust to non-ideal images in order to explore methods for iris classification. Non-ideal factors which impact iris recognition include off-angle (horizontal and vertical), noise, rotation, etc. Furthermore, it has been empirically observed
that robust segmentation of iris region is the most crucial factor that influences encoding and ultimately the performance of any decision making iris based systems designed thus far for both ideal and non-ideal images. We will explore approaches for robust segmentation.

Multispectral and Multiframe Iris Analysis: Phase I

_Lawrence Hornak, Arun Ross and Xin Li (WVU)_

Multispectral imaging holds tremendous potential in improving the performance of iris systems while motion characteristics of iris captured by multiple frames are critical to liveness detection. The proposed work has three goals: 1) Enhancement of iris recognition performance through fusion of appropriate spectral band information; 2) Mapping of visible band information to IR enabling the interoperability of IR and visible iris images; and 3) Liveness detection based on detecting signatures such as melanin and elastic deformation of iris. In this initial Phase I study, we propose to experimentally obtain iris images from a collection of representative irises, complete initial analysis of the data, and explore algorithmic approaches in order to address the fundamental need for such a rich set of iris data and determine the merits of further exploration in these three areas.

Cryptographic Protection for Sharable Biometric Test Databases

_Bojan Cukic (WVU)_

Testing of biometric systems has proven to be a complicated task. Recent studies in CITeR and elsewhere demonstrate that large samples are needed to inspire statistical confidence in the validity and repeatability of biometric tests. As a result, many current projects collect their own datasets for the purpose of validating research results. Biometric data collection is a costly activity. Due to the use of human subjects and privacy concerns, Institutional Review Boards impose strict limitations regarding the ability to share biometrics data. The goal of this proposal is to develop cryptographic protocols that will provide the necessary levels of confidentiality of biometric test data. In addition to confidentiality, the protocol will ensure non-repudiated access limited to the group of registered biometric database users. Registration procedure and X-509 type public key certificates will be managed using the cryptographic server. The server will also generate symmetric encryption keys for database entries (biometric image and signal files) and user specific session keys. Key distribution algorithm will ensure that the minimal unit of biometric data sharing can be a single database entry (for example, an image), a subset of entries in a single modality or a multi-modal collection. The last feature of the protocol will be the enforcement of de-identification. The protocol will mask and automatically disallow sharing of humanly identifiable biometric modalities or any other database information that may compromise the privacy of volunteers.

Multi-spectral Fusion for Improved Face Recognition

_Besma Abidi and David Page (UTK)_

The objective of this project is to develop an optimum fusion-based multi-spectral face recognition system by comparing the performances of various combinations of subsets from a large set of spectral responses using two commercially known FR engines (Facelt and FaceVACS).

Robust Surveillance System Utilizing 2D Video and 3D Face Models

_Anil K. Jain (MSU)_

2D face images acquired from static cameras do not contain sufficient information for reliable user identification and difficult in complex environments. We propose to develop (i) a robust face acquisition system at a distance (>30 ft.) using a live video obtained from pan-tilt-zoom cameras, (ii) a face recognition system for the surveillance applications utilizing video and 3D face models, and (iii) a framework to integrate identity evidence with tracking cues (e.g., color and texture) to monitor subjects in challenging environments. The difficulties of user identification in surveillance applications with low quality face images will be overcome by utilizing rich information contained in videos and pose and lighting invariant 3D face models as well as the integration of identity evidence and tracking cues.
MUBI: Continued Development of a Multibiometric Performance Prediction Tool

Arun Ross and Bojan Cukic (WVU)

Multimodal and multibiometric techniques are migrating into mainstream applications. Many different decision level and score level fusion techniques have been described in the literature. But, when it comes to determining the performance benefits of a multimodal approach to specific application, system designers do not have the tools to evaluate and compare different fusion algorithms. An earlier CITeR project developed MUBI, an open source freely available software tool for performance evaluation of decision level fusion of multimodal and multibiometric systems. The only inputs that MUBI requires are the sets of genuine/imposter scores of biometric devices that are considered for system integration. We propose extending MUBI to include several major algorithms for score level fusion. This expansion will require a significant level of redesign of the existing tool. But the benefits of having such a tool clearly outweigh the cost of its development.

Generation of Synthetic Irises

Natalia Schmid, Arun Ross, Bojan Cukic (WVU) and Harshinder Singh, Dept. of Statistics (WVU)

Iris based identification gained considerable attention from the research community in parallel with its public acceptance. A number of iris recognition algorithms have been developed over the past few years. While most iris recognition systems demonstrate outstanding recognition performance when tested on databases of small or medium size, their performance cannot be guaranteed for large scale datasets (order of a few million). The largest database reported thus far consists of 350,000 iris images. In addition, large scale databases are private and thus are not accessible for the research community. As an alternative to physically collected database of iris images we propose to generate a large scale database of synthetic irises using nonparametric Markov Random Field (MRF). MRF is a leading method used in the field of texture synthesis and analysis [1]. Iris is rich in texture. The challenge lies in generating physically feasible irises. This problem can be reduced to generation of two or three different texture patterns for iris and solving boundary problem to unify (we say “stitch”) them. Together with designing a tool that is capable of generating a large scale database of irises, we propose to perform the following three complementary studies. (1) Synthesizing occluded parts of iris images (interpolation). (2) Generating iris images from “partial iris,” randomly located patches of a small size on iris image, (extrapolation). (3) Interpolation of low resolution iris image into a higher resolution image using texture synthesis techniques based on MRF. Performance measures will be developed to evaluate the results of these tasks.

Interoperability, Performance, and Fusion Issues in Fingerprint Sensors

Stephanie Schuckers, Sunil Kumar (Clarkson) and Arun Ross (WVU)

The problem of cross-sensor matching has received limited attention in the literature. Furthermore, little work has been performed to allow comparisons of sensors independent of the underlying algorithm. The goal of this research is to assess and develop techniques to facilitate fingerprint sensor interoperability and to design methods to quantify sensor performance. The following issues will be investigated. (i) Enumerate and study the factors that impede fingerprint sensor interoperability; (ii) Design an image quality metric independent of sensors), that is correlated with performance; (iii) Develop methods to compare sensor performance considering image quality, interoperability, and identified factors including choice of sensor during enrollment; (iv) Devise sensor fusion schemes to increase population coverage, enhance interoperability and improve matching performance. (v) Develop fingerprint representation and matching schemes that would permit interoperability without compromising on performance.

Robust 3-D Face

Anil K. Jain (MSU)

Limitations of 2D face recognition systems are now well-known. These include difficulties with changes in lighting, pose and expression. This has motivated research on 3D face recognition. Our prototype 3D face recognition system (that combines 2D appearance and 3D surface information) achieves 98% accuracy (with 3D models of 100 subjects and ~ 600 test scans) in the presence of pose and lighting variations. But, the performance drops to 91% in the presence of
changes in expression. In this project we propose to estimate the non-linear deformation in the facial surface that is introduced due to various expression changes to make the 3D face recognitions systems more robust.

**CITE 2004**

**Developing the PRESS - Methodologies for Estimating Error Rates of Biometric Devices**  
*Michael Schuckers (St. Lawrence University)*  
The next phase of research on the Program for Rate Estimation and Statistical Summaries (PRESS) will add capabilities to plot ROC curves (both on the original scale and on the log scale), to determine the appropriateness of the Beta-binomial distribution for a given data set, and to estimate the EER. In addition, we plan to do an algorithmic analysis of the software in order to make PRESS more efficient.

**Scaling Analysis of Iris Codes using Large Deviations Approach**  
*Natalia Schmid and Bojan Cukic (WVU)*  
This project explores the scaling and prediction of the capacity of iris biometric systems. We plan to apply the large deviations approach to asymptotically predict the performance of these biometric systems and use the derived results to evaluate performance limits of large-scale identification systems based on iris.

**Multibiometric Fusion at the Feature Extraction Level and Face Indexing**  
*Arun Ross and Natalia Schmid (WVU)*  
This project will develop techniques to perform multibiometric fusion at the feature extraction level. If necessary, feature selection methods will be used to reduce the dimension of the fused feature set. We will also develop an efficient face-indexing (classification) scheme that will rely on the geometric attributes of the human face to narrow the search to a limited number of faces (classes) in the database.

**Strategic Business Directions in Biometrics: Research with Vendors, Government and Corporate Buyers**  
*Virginia Kleist and Richard Riley (WVU)*  
This proposed research will design, plot, and collect a large scale data set related to strategic business issues in the biometrics industry. We will develop an in-depth research tool aimed at surveying perceptions, best practices, and directions from biometric vendors, government, and private buyers. The results should provide a detailed understanding of potential risks and solutions for vendors, government buyers and other users.

**Acquisition and Understanding of Nonideal Iris Imagery**  
*Lawrence Hornak, Xin Li, Gamal Fahmy, Natalia Schmid (WVU), Stephanie Schuckers (Clarkson) and A. Realini (WVU Eye Center)*  
This work will revisit the fundamental information content in the iris and its variability in order to explore means of iris classification and matching through nonideal iris imagery. Automated location of nonideally oriented irises in facial images will be investigated and achievement of imagery of the prescribed quality from lower quality video frame sequences will be explored using deblurring and super resolution techniques.

**Utilizing Soft Biometric Traits for User Recognition**  
*Anil K. Jain and Sarat C. Dass (MSU)*  
The performance of a biometric system can be improved by utilizing ancillary information about the users such as their height, weight, age, gender, ethnicity, and eye color, referred to as soft biometric traits. We will (i) design a prototype recognition system that automatically extracts these soft biometric traits along with the primary biometric (e.g., fingerprint), (ii) develop a mathematical framework for integrating the soft biometric information with the primary
biometric system for improving the recognition accuracy, and (iii) derive variable weights for the soft biometric traits based on their distinctiveness and permanence. Initial experiments show that the use of additional user information like gender, ethnicity, and height improves the recognition performance of a fingerprint system by ≈ 5%.

**Face Image Quality Assessment System**
*Gamal Fahmy, Hany Ammar (WVU) and Abdel-Mottaleb (U of M)*
Poor imaging from biometric systems contribute to the difficulty in detecting features from the image or due to the poor quality of the detected features. While fingerprint identification systems overcome this problem by passing the fingerprint through a quality assessment stage, there are no such techniques for assessing the quality of images for face recognition to determine whether the image is suitable for recognition or not. In this project we develop a prototype that automatically measures the quality of face images for most well known face recognition algorithms.

**On the Independence of Biometric Modalities**
*Jinni Hornak (WVU) and Anil K. Jain (MSU)*
We investigate the degree of correlation between multiple traits in a multibiometric system. It is generally agreed that the performance gain in a multiple classifier system (MCS) is directly related to the extent of independence between constituent classifiers. However, in the context of multibiometrics, no systematic study has been conducted to ascertain the common assumption of independence between multiple modalities. The goal of this project is to develop a framework to conduct such a study and to derive the degree of dependence between various biometric modalities.

**Geometric Coding and Processing of Biometric Images (Phase II)**
*Xin Li (WVU)*
The objective of this project is to continue our investigation of geometric coding and processing of biometric images and demonstrate the potential of signal processing techniques for improving the performance and ergonomics of biometric systems. The research plan for phase II shifts from a single copy case to a multi-copy case, i.e., how to exploit the concept of diversity to improve the coding efficiency and subjective quality of biometric images. Specifically, our study consists of two parts: image registration, which addresses the problem of resolving the geometric relationship among multiple copies and image manipulation, which intelligently processes the image information based on the discovered geometric relationship.

**CITeR 2003**

**Multibiometric Score Normalization**
*Anil Ross (WVU) and Anil K. Jain (MSU)*
The efforts will: (i) systematically study of the role of score normalization in multimodal matching performance, (ii) developing robust and efficient score normalization techniques and (iii) explore automatic template selection and update using clustering principles.

**Solidifying CITeR’s Liveness Core Competency**
*Stephanie Schuckers (Clarkson & WVU), Lawrence Hornak (WVU) and T. Norman (Orthopedics WVU)*
A unique specialized capability and skill set for performing spoofing, cadaver, and liveness testing and detection research has been developed. This project will build this capability; establish a broad-based fingerprint liveness testing resource for members and the biometrics community, and advance liveness performance and research in select biometrics.
Multimodal Biometric Systems: Phase II

*Anil K. Jain (MSU)*

Three different issues in designing a multimodal biometric system are investigated: (i) combine face and iris biometrics to reduce failure to enroll rate and decrease FRR, (ii) combine multiple face recognition approaches to improve the face recognition performance, and (iii) operate a multibiometric system in an identification (cascade) mode.

Biometrics Business Case Study


This proposed research applies prior work in information technology to the specific problem of measuring the cost benefit payoffs from specific biometric technologies. We will link three business issues (measuring the impact of information technology, the performance aspects of expenditures on technology and the specific return on IT investment at the strategic level) to the business case for biometrics investment.

Geometric Coding of Biometric Images

*Xin Li (WVU)*

The objective of this project is to develop new geometric coding and processing algorithms for biometric images (e.g. fingerprint, face, and iris), which will improve the matching performance of existing verification/recognition systems.

A Study of Various Methodologies for Error Estimation in Biometric Systems

*Michael Schuckers (St. Lawrence University)*

Several methods for estimating false accept and false reject rates have been developed and recognized for their potential. Doddington’s Rule of 30, Schuckers’ Beta-binomial approach and the subset bootstrap create inferential intervals that allow the consumer to assess plausible values for the error rate of interest. The goal of this proposal is to compare the quality of estimation for each of these methods against identical data.

Socio-Legal Assessment Study

*Lisa Nelson (Pitt)*

The proposed study is designed to set the groundwork for the generation of social scientific data on perceptions of biometrics and privacy in divergent settings as well as on the policy impact of biometric privacy legislation on consumer confidence and on the implementation of biometric technology.

Statistical Basis of Multimodal Systems

*Bojan Cukic and Harshinder Singh (WVU)*

This work seeks to provide a clear analytical justification for multi-biometrics. Recently, Jain proposed the methodology to select weighting system that increases the probability of correct identification. We seek to generalize and extend this result based on the distributions describing genuine and imposter population.
Study of Liveness Detection for Biometric Devices

Stephanie Schuckers, Lawrence Hornak and Timothy Norman Orthopedics (WVU)
This research investigates determining liveness directly from COTS biometric sensor signals. Previous work performed liveness detection through quantification of the temporal finger perspiration pattern. In this work we (1) Select and secure a broad range of biometric fingerprint systems for liveness testing with IAB input, (2) Undertake liveness/spoof test, explore available physiological info, evaluate algorithmic approaches, and (3) Undertake further study of the perspiration algorithm on fingerprint devices.

Multimodal Biometric System

Anil K. Jain (MSU)
The objective of this project is to design a robust multimodal biometric system that uses a combination of features from fingerprint, hand geometry and face. Data corresponding to three biometric indicators- fingerprint, hand geometry and face - will be collected from a number of subjects. Images pertaining to each modality will be processed to extract a feature vector. The techniques developed in this project will be used to optimally combine the information acquired from these three modalities in order to verify a subject’s claimed identity. The False Reject Rate (FRR) and False Accept Rate (FAR) will be used to evaluate the performance of the system.

Estimation Study

Michael Schuckers (WVU) and James Wayman (San Jose State University)
The goal of this study is to develop methodologies to estimate the variability in false match and false non-match rates for biometric testing. Several methodologies are under development by the participants of this project to develop techniques for estimating false match and false non-match rates. This study continues and combines the work that has been done independently. Specifically, we convert the work that has been done into an appropriate methodology for sample size calculation.

Template Aging Study

Michael Schuckers (WVU) and James Wayman (San Jose State University)
The goal of this study is to follow a group of individuals repeatedly over time to determine how large an effect there is due to the aging of templates. This test will be done for a variety of modalities based on IAB input. A general statistical framework to begin to model and understand template aging is sought.

Issues in Large Scale Biometric Authentication Infrastructure

Bojan Cukic (WVU)
Biometric technologies can improve the overall assurance of an information system by incorporating the uniqueness of personal biometric signatures into the security and safety management. The downside of using biometric signature is the problem of scalability. Digital biometric identifiers present at (transferred to) multiple sites can be intercepted, pooled, analyzed and, generally, misused. We will investigate system design principles that minimize these downsides of biometric technology-based authentication protocols.

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