CITeR IMPACT

A compendium of research highlights of the

Center for Identification Technology Research (CITeR)

2010 Edition v1

Preface

The 2010 Edition of *CITeR IMPACT* highlights 9 research threads within the over 80 research projects cooperatively funded by affiliates of the Center for Identification Technology Research (CITeR) as part of the National Science Foundation Industry/University Cooperative Research Center (IUCRC) Program. These 9 research threads are composed of one or more projects and are highlighted here for their exceptional impact achieved over time. In each case, the work has opened up new areas of inquiry, enabled new fundamental understanding, and/or achieved exceptional transition through impact on systems. The outcomes achieved by these projects are emblematic of the impact that CITeR's cooperative operation as an IUCRC seeks to achieve.

For additional information about the projects highlighted, please contact the faculty members listed at their indicated email addresses or the Center at citer@mail.wvu.edu.

Key listed publications listed are available in the pdf version of this document on the CITeR website www.citer.wvu.edu.

Information on CITeR Datasets referred to in this document can be found at www.citer.wvu.edu/biometric_dataset_collections

CITeR Tools referred to in this document are available for download from the site www.citer.wvu.edu/download_citer_software

CITeR IMPACT is dedicated to the students who day in and day out contribute their ideas and energy to Center research and without whom the impact described here could not have been achieved.

Table of Contents

Biometric Fusion

Anil Jain, Michigan State University, Arun Ross, West Virginia University
jain@cse.msu.edu arun.ross@mail.wvu.edu

Multibiometric systems fuse information provided by different sources: multiple traits or multiple matchers. These systems offer several advantages compared to unimodal systems: significant decrease in recognition error, better resistance to impostor attacks and reduction in failure to enroll rate. With CITeR support, we have developed and evaluated methods for score normalization and handling missing data and proposed a new principled approach to score level fusion based on likelihood ratio.

Outcomes

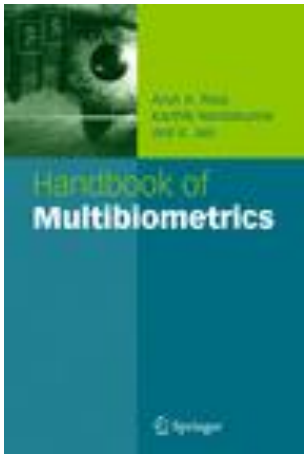
The area of biometric fusion has been advanced by CITeR funded projects at MSU and WVU. These effort have had a significant impact on the biometrics community as evidenced by the sample publications below.

Fusion advances have been captured in two tools available to the community for download through the CITeR website. Multi-Biometrics Performance Prediction Tool (MUBI), developed by Cukic et al,in 2005 is currently available. BioFuse is currently under development by Jain and Ross under CITeR funding and will be available in late 2010.

Key Publications

Two representative publications are given below.

- K. Jain, K. Nandakumar and A. Ross, "Score Normalization in Multimodal Biometric Systems", *Pattern Recognition*, Vol. 38, No. 12, pp. 2270-2285, December 2005. **(cited by 289 based on Google Scholar, received the 2005 Best Paper Award from the Pattern Recognition Society)**
- K. Nandakumar, Y. Chen, S. C. Dass and A. K. Jain, "Likelihood Ratio Based Biometric Score Fusion", *IEEE Transactions on Pattern Analysis and Machine Intelligence*, Vol. 30, No. 2, pp. 342-347, February 2008. **(cited by 45 based on Google Scholar)**
- A. Ross, K. Nandakumar and A. K. Jain, "Handbook of Multibiometrics", Springer Publishers, 1st edition, 2006. ISBN: 0-3872-2296-0.



• Fingerprint Liveness Detection

Stephanie Schuckers, Clarkson University; Lawrence Hornak, West Virginia University; and student team members
sschucke@clarkson.edu lawrence.hornak@mail.wvu.edu

In 2001, one of the initial projects upon which CITeR was founded focused on development of fingerprint liveness (or anti-spoofing) algorithms for prevention of fingerprint spoofing or obfuscation. Additionally, methods have been developed in order to test proposed algorithms based on spoof fingers from a variety of materials (Play-Doh, gelatin, silicon, caulk, wood glue, etc.). Algorithms developed in the laboratory have been based on the distinctive spatial texture characteristics related to moisture of live fingerprint images and specific features that are related to the spoof material characteristics (smudge, ridge width, etc), noise related to material, particularly in the valleys, and histogram characteristics. Image processing and pattern recognition of fingerprint images are used as a purely software based measure to detect liveness.

Outcomes

Key outcomes of this work have included:

- Commercial implementation of anti-spoofing algorithm
- Public dataset of over 10,000 spoof and live images
- First benchmark competition, LivDet 2009Six published journal papers and over ten conference papers with the earliest in 2001
- Methods and performance metrics for testing liveness algorithms
- Four review articles on research in the field

Key Publications

- *Derakhshani R*, Schuckers SAC, Determination of Vitality From A Non-Invasive Biomedical Measurement for Use in Fingerprint Scanners, *Pattern Recognition*, No.2 pp. 383-396, 2003. **(cited by 72 based on Google Scholar)**
- *Parthasaradhi S, Derakhshani R*, Hornak L, Schuckers SAC, Time-Series Detection of Perspiration as a Liveness Test in Fingerprint Devices, *IEEE Transactions on Systems, Man, and Cybernetics*, Part C: Applications and Reviews, vol. 35, pp. 335- 343, 2005.
- *Tan B*, Schuckers S, Spoofing Protection for Fingerprint Scanner by Fusing Ridge Signal and Valley Noise, *Pattern Recognition*, Available online 10 March 2010.

Generating Synthetic Irides

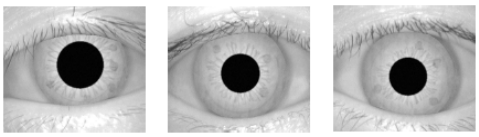
Arun Ross, Natalia Schmid, and student team members, West Virginia University
arun.ross@mail.wvu.edu natalia.schmid@mail.wvu.edu

The biometric literature is now replete with techniques that extract information from iris images in order to represent and match irises. Although most existing iris recognition algorithms claim a very low False Accept Rate, only Daugman's algorithm has been tested on a large proprietary database. There are very few publicly available iris databases. Further, the ones that are currently available contain data pertaining to a relatively limited number of individuals. With the emergence of new iris recognition algorithms, it is imperative that a large database is publicly available in order to evaluate and compare these algorithms on a common platform. Building a large iris database is difficult because the process of data acquisition itself is time consuming and expensive. Moreover, privacy concerns associated with collecting and publicly disseminating biometric images have prevented several organizations from sharing images acquired in real-world operational scenarios. Due to these constraints, the possibility of generating synthetic iris databases is an attractive alternative.

Outcomes

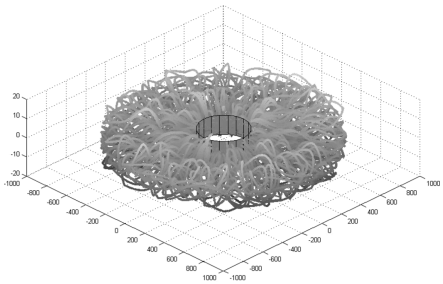
In this project we explored several techniques to generate synthetic irides. Further, we designed measures of realism to evaluate the similarity between synthetic and real iris images. The results of this research include (a) a good understanding of the texture of the iris from a biological perspective, (b) the design of multiple schemes to digitally synthesize the iris texture and to evaluate their efficacy, and (c) the modeling of the iris structure for iris classification and recognition.

The databases generated using the proposed methods have been disseminated to the broader biometric community via the CITeR website.



Key Publications

- S. Makthal and A. Ross, "Synthesis of Iris Images using Markov Random Fields", Proc. of 13th European Signal Processing Conference (EUSIPCO), (Antalya, Turkey), September 2005.
- S. Shah and A. Ross, " Generating Synthetic Irises By Feature Agglomeration," Proc. of IEEE International Conference on Image Processing (ICIP), (Atlanta, USA), Oct 2006.
- J. Zuo, N. Schmid, and X. Chen, "On Generation and Analysis of Synthetic Iris Images," IEEE Transactions in Information Forensics and Security, **2**(1) 77-90 2007.
- J. Zuo, N. A. Schmid, and X. Chen, "On Performance Comparison of Real and Synthetic Iris Images," in Proc. of 2006 Intern. Conf. on Image Processing, Atlanta GA, Oct. 11-14, pp. 305-308.



Iris Quality Measure

Nathan Kalka, Natalia Schmid, Bojan Cukic. West Virginia University;
Stephanie Schuckers, Clarkson University
natalia.schmid@mail.wvu.edu bojan.cukic@mail.wvu.edu sschucke@clarkson.edu

CITeR was one of the first organizations to systematically investigate recognition of iris in non ideal conditions. Encouraged by CITeR affiliates, in 2003 and 2004, CITeR researchers initiated research on acquisition, understanding, and theoretical scale – up limits of non ideal iris imagery. One of the fundamental steps in the research was to develop an understanding of the impact factors like blur, lighting variations, angle and occlusions have on the performance of commercial iris recognition systems and, subsequently, work on the improved iris recognition approaches.

Outcomes

In 2004, WVU research team, partially funded by CITeR, Department of Defense and Lockheed Martin, developed an automated methodology for quality evaluation of iris images. The result included algorithms and tools that evaluated six measures of iris quality and fused them into a single numerical score. Intuitiveness and simplicity of the approach were the bases of its subsequent successes, which include:

- Methods and performance metrics for evaluation of iris quality
- Transition of the iris quality toolset and its use in improving DoD - ABIS system.
- Selection by Booze Allen Hamilton as the method of choice for evaluating iris quality at Biometrics and Identity Management Agency (former BTF)
- Dissemination through NIST biometric quality workshops
- Adoption and use by researchers in US and Europe

Key Publications

- N. Kalka, J. Zuo, N. A. Schmid, B. Cukic, Estimating and Fusing Quality Factors for Iris Biometric Images, IEEE Transactions on Systems, Man and Cybernetics - Part A:Systems and Humans, Vol 40(3), May 2010.
- N. D. Kalka, J. Zuo, V. Dorairaj, N. A. Schmid, and B. Cukic, Image Quality Assessment for Iris Biometric, Proc. 2006 SPIE Conf. on Biometric Technology for Human Identification III, Orlando, FL, April 2006, vol. 6202, pp. 61020D-1-62020D-11. **(cited by 43 based on Google Scholar)**
- Aditya Abhyankar, Stephanie Schuckers, Iris Quality Assessment and Bi-orthogonal Wavelet Based Encoding for Recognition, Pattern Recognition, **42** pp. 1878-1894 2009.

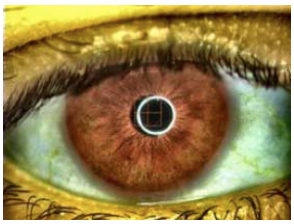
Multispectral Iris Analysis

Arun Ross, Xin Li, Lawrence Hornak, and student team members, West Virginia University
arun.ross@mail.wvu.edu xin.li@mail.wvu.edu lawrence.hornak@mail.wvu.edu

Most iris recognition systems acquire images of the eye in the 700nm - 900nm range of the electromagnetic spectrum. In this work, we examined the texture of the iris at multiple spectral bands including the visible spectra (450nm – 750nm) and the short-wave infrared spectra (950nm – 1650nm). The purpose was to understand the iris structure at multiple wavelengths and to determine the possibility of performing cross-spectral iris matching in tactical scenarios. This research also studied the impact of eye color on iris matching performance and explored different color spaces (e.g., RGB, HSV, L*a*b*) for visible spectra iris recognition. Another significant contribution included the design of an acquisition system to collect images of the eye pertaining to multiple spectral bands.

Outcomes

This set of two landmark CITeR projects – the first in the NIR and the second in the SWIR – have heightened interest in multispectral iris matching both in the academic and government arenas. The results of this research can potentially be used to (a) match color images of the iris against their NIR counterparts, (b) perform quality-based fusion of multispectral iris images, and (c) design anti-spoofing methods for commercial iris systems.



Publications

- C. Boyce, A. Ross, M. Monaco, L. Hornak and X. Li, " Multispectral Iris Analysis: A Preliminary Study," Proc. of IEEE Computer Society Workshop on Biometrics at the Computer Vision and Pattern Recognition (CVPR) Conference, (New York, USA), June 2006.
- A. Ross, R. Pasula and L. Hornak, "Exploring Multispectral Iris Recognition Beyond 900nm," Proc. of 3rd IEEE International Conference on Biometrics: Theory, Applications and Systems (BTAS), (Washington DC, USA), September 2009.
- M. Vatsa, R. Singh, A. Ross and A. Noore, “Quality-based Fusion for Multichannel Iris Recognition,” Proc. of IAPR International Conference on Pattern Recognition (ICPR), (Istanbul, Turkey), August 2010.

Statistical Methods for Biometric Performance

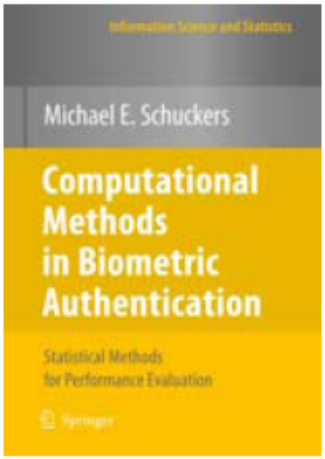
Michael Schuckers, St. Lawrence University
schuckers@stlawu.edu

Across several CITeR projects, we have developed a statistical foundation for the evaluation and assessment of the performance of biometric authentication systems. The early focus of this research was on the false match rate (FMR) and the false non-match rate(FNMR). Additionally we have developed confidence interval methods for the receiver operating characteristic (ROC) curve. Recently, the focus of this work has expanded to include the system measures, failure to enroll (FTE) and failure to acquire (FTA). Schuckers' 2010 book *Computational Methods in Biometric Authentication* proposed a framework for statistical methods for evaluating and comparing FNMR's, FMR's, ROC's, FTE's, FTA's as well as Equal Error Rate's.

Outcomes

Software for the implementation of important biometric statistical methods, the PRogram for Evaluation and Statistical Summaries (PRESS) was developed. The latest version of the tool incorporating the latest methods will be available in summer 2010.

Key Publications



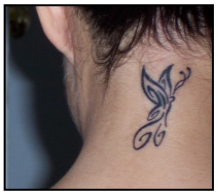
- Schuckers, ME, ***Computational Methods in Biometric Authentication: Statistical Methods for Performance Evaluation,*** Springer, (2010).
- Schuckers, ME, Minev, YD, Adler A, "Curvewise DET confidence regions and pointwise EER confidence intervals using radial sweep methodology", *Proceedings of the 2nd International Conference on Biometrics 2007*, Seoul, Korea (2007). **Awarded 3rd place best paper at this conference.**
- Schuckers, ME "A parametric correlation framework for the statistical evaluation and estimation of biometric-based classification performance in a single environment," *IEEE Transactions on Information Forensics and Security* 4 (2009), 231-241.
- Schuckers, ME, "Theoretical Statistical Correlation For Biometric Identification Performance" in *Proceedings of the International Conference on Acoustics, Speech, and Signal Processing (ICASSP),* (2008).

Tattoo Image Matching and Retrieval

Anil Jain, Michigan State University
jain@cse.msu.edu

Scars, marks and tattoos (SMT) are used for suspect and victim identification in forensics and law enforcement agencies. Tattoos are of particular interest because they are associated with criminal gangs. Current tattoo matching procedure requires a forensic expert to assign a label to each tattoo from the ANSI/NIST ITL 1-2000 standard; this is both time consuming, subjective and not very accurate. With support from CITeR and the FBI Biometrics Center of Excellence, we have designed and developed a tattoo image matching and retrieval system, called TattooID, which accepts a tattoo image as a query and retrieves the most similar (near duplicate) tattoos from a database. No keywords need to be input to the system. Experimental results on an operational tattoo database show excellent retrieval results.

Outcomes



Leveraging proof of concept work established under CITeR funding, FBI COE funding subsequently established the efficacy of the approach with law enforcement. The TattooID system technology was transferred to Sagem/MorphoTrak in January 2010. MorphoTrak plans to release a beta version of the product towards the end of 2010.

TattooID has been extensively covered in media. Some examples are: Interview on amlansing.com, January 26, 2010, Tattoo-ID system featured in The State News, Lansing State Journal, Research Currents-Fall 2008, College of Engineering, MSU, www.morphotrak.com, MSU News, Freep.com, Chicagotribune.com, wwj.com, msutoday.com, spacewar.com, wtopnews.com, redorbit.com, medicalnewstoday.com, thirdfactor.com, forensicmag.com, ABC Channel 12, on Feb 4, 2010.

Key Publications

Representative publications on TattooID include;

- J-E. Lee, A. K. Jain, and R. Jin,"Scars, Marks and Tattoos (SMT): Soft Biometric for Suspect and Victim Identification", *Proc. Biometric Sym posium, Biometric Consortium Conference*, 2008.
- K. Jain, J.-E. Lee, R. Jin, N. Gregg, "Content Based Image Retrieval: An Application to Tattoo Images", *Proc. International Conference on Image Processing*, Nov., 2009.

Unconstrained, Non-Ideal Iris Recognition

Stephanie Schuckers, Clarkson University; Lawrence Hornak, Natalia Schmid, Arun Ross, West Virginia University and student team members
sschucke@clarkson.edu lawrence.hornak@mail.wvu.edu
natalia.schmid@mail.wvu.edu arun.ross@mail.wvu.edu

The advent of iris recognition required constrained presentation of the iris by users via confined head positioning and eye gaze. In 2004, a CITeR project began research considering iris classification and matching for unconstrained, non-ideal iris imagery. Outcomes of this original project include some of the first published work on non-ideal iris recognition and the first public datasets of off-angle iris images. This work became the foundation for three additional CITeR research projects spanning segmentation and recognition for off-angle images, non-ideal iris recognition segmentation and recognition, iris recognition from a distance, and measurement of quality in iris images. Recently, based on preliminary results from a CITeR project, a large DHS funded iris/face image collection was completed in early 2010 and included over 150 subjects, two visits, and iris images up to 25 feet. A unique aspect of this dataset is controlled image quality at acquisition for blur, illumination, occlusion, resolution, angle, and motion. This dataset will provide a quality metric baseline in IREX II, hosted by NIST, to be completed in summer 2010.

Outcomes

- 7 published journal papers and over 26 conference papers since 2004
- Public dataset of >1000 controlled off-angle iris images from >70 subjects (2006)
- 3 Public datasets releases between 2007-2010 of iris images as part of a multimodal set of iris/face/fingerprint/hand/voice/palm
- Public dataset of iris and face images (Quality—Face / Iris Research Ensemble (Q-FIRE) Dataset Overview, 2010)
    - Release: 3000 iris videos (~150 frames each) from 175 subjects, two visits
    - Used in NIST IREX II iris quality evaluation

Key Publications

- Abhyankar A, Hornak LA, Schuckers SACS, Off-angle iris recognition using bi-orthogonal wavelet network system, in Automatic Identification Advanced Technologies, 2005. Fourth IEEE Workshop on, Page(s):239 – 244, 17-18 Oct. 2005.
- S. A. C. Schuckers, N. A. Schmid, A. Abhyankar, V. Dorairaj, C. Boyce, L. A. Hornak, “On Techniques for Angle Compensation in Nonideal Iris Recognition,” IEEE Trans. on System, Man, and Cybernetics, Part B, vol. 37, no. 5, pp. 1176-1190, 2007.
- J. Zuo and N. A. Schmid, “Robust Iris Segmentation Algorithm for Non-Ideal Iris Imagery,” IEEE Trans. on SMCB 2009, in print [version from Sept. 26].

CITeR Affiliate Organizations

- Accenture
- Booz Allen Hamilton
- Center for Applied Social Research at University of Oklahoma
- Computer Science Corporation
- Defense Intelligence Agency
- Biometric Identity Management Office
- Department of Defense – Defense Academy for Credibility Assessment
- Department of Defense – Defense Research and Engineering
- Department of Defense – USSOCOM/SOALT
- Department of Homeland Security – Science & Technology
- Federal Aviation Administration (FAA) – Information Systems Security
- Federal Bureau of Investigation
- Forensitec/Nemesysco
- Laurea University of Applied Sciences, Finland
- Lockheed Martin
- MorphoTrak
- National Security Agency
- Northrop Grumman
- Office of the Director of National Intelligence
- Raytheon
- Sandia National Labs
- Science Applications International Corporation
- U.S. Army, Picatinny Arsenal – ARDEC
- West Virginia High Technology Consortium (WVHTC) Foundation

Center Site Directors

WVU

Larry Hornak, lawrence.hornak@mail.wvu.edu 304.293.9694
Bojan Cukic, bojan.cukic@mail.wvu.edu 304.293.9686

University of Arizona

Judee Burgoon, jburgoon@cmi.arizona.edu 520.621.5818
Jay Nunamaker, jnunamaker@cmi.arizona.edu

Clarkson *(pending site)*

Stephanie Schuckers, sschucke@clarkson.edu 315.268.6536

Program Development and Management

Larue Williams, larue.williams@mail.wvu.edu 304.293.8274