IEEE
BIOMETRICS
COUNCIL NEWSLETTER

The Rise of Wearable Devices

Wearable devices offer a promising alternative to conventional biometric data trackers. Dr. Emanuele Maiorano offers some insights about the potential of these devices in this issue's **Lecture Notes**, starting on page 44. The issue also offers a report on the Winter Biometrics School, including interviews with eight students who attended the event on grants from the International Association for Pattern Recognition and the IEEE Biometrics Council. Read all about it on pages 13 to 21.

GREETINGS FROM THE EIC

ANDREW TEOH BENG JIN
Yonsei University, Korea

Dear Readers of the Biometric Newsletter,

Welcome to the new issue!

In this issue's **News and Council Activities section**, we are excited to share calls for participation in the 21st International Summer School for Advanced Studies on Biometrics for Secure Authentication, scheduled in picturesque Alghero, Italy. Mark your calendars as the application deadline for this event is set for March 13, 2024. Seize the opportunity to immerse yourself in this enriching experience within biometrics.

Our **Special Feature** for this edition addresses the 8th Winter School on Biometrics (WSB2024), which was generously supported by IAPR TC4 and the IEEE Biometrics Council. WSB 2024, a training course to foster research in biometrics and related fields, unfolded successfully from January 21 to 25, 2024, in Shenzhen, China. In addition to coverage of the event, we bring you insightful interviews with the scholarship recipients of WSB2023. The remarks offer valuable perspectives on their overall experience with the course and their impressions of several of its notable events.

The **Spotlight Section** describes the EU program PriMa (Privacy Matters), funded by the European Union's Horizon 2020 research and innovation program through the Marie Skłodowska-Curie grant agreement. The article provides a comprehensive overview of the program's background and impacts. Other highlights include an insightful interview with Javier Galbally, Senior Capability Building Officer with eu-LISA, discussing his perspectives on transitioning from academia to industry, and his experience with European IT systems regulation. Additionally, we showcase an interview with emerging researcher Chouyou Fu, the recipient of the 2023 IEEE Biometrics Council Best Doctoral Dissertation Award,

shedding light on his noteworthy contributions to biometrics and multimodal LLMs. In our interview series with **Biometric Pioneers**, Professor Davide Maltoni shares his latest research projects and insights on emerging biometric security problems, particularly in presentation attack detection, deep fakes, and sample manipulations.

The **Lecture Notes** section provides a comprehensive exploration of wearable biometrics, offering an in-depth overview, summary, and insights into the challenges associated with this timely and emerging topic in the field. Our featured paper in **Notes from the Literature**, "Audio-Visual Fusion for Emotional Recognition in the Valence-Arousal Space Using Joint Cross-Attention," is also a noteworthy contribution to this edition.

This resource-rich edition caters to researchers by offering valuable tools and insights. Our **Database Digest** introduces the Face Recognition Challenge in the Era of Synthetic Data (FRCSyn) database, from an event at the Winter Conference on Applications of Computer Vision (WACV). In the **Source Code** section, we showcase MEGVII Technology's repository for "ID-unaware Deepfake Detection Mode," addressing the crucial generalization challenge in deepfake detection. The **COTS** section highlights Tobii's Advanced Solutions in Eye-Tracking and Multimodal Analysis.

Finally, I want to remind our readers that your suggestions for new content or notifications of news relevant to the community are always welcomed.

Warm regards,

Andrew Teoh

COUNCIL NEWS

CALL FOR PARTICIPANTS

21st International Summer School for Advanced Studies on Biometrics for Secure Authentication
BIOMETRICS: Trustful, Fair and Privacy-Friendly

Alghero, Italy – June 3 - 7 2024
http://biometrics.uniss.it

Contact: tista@uniss.it

Application deadline: March 15, 2024
Download the application at
http://biometrics.uniss.it

The IAPR/IEEE International Summer School for advanced studies on biometrics has been held each summer in Alghero, Italy since 2003. It provides an active and dynamic forum to follow the most recent developments in science and technology, and offers a cutting edge, intensive training course that is always up to date.

Over the last two decades automatic biometric recognition has reached a very high level of accuracy, even on very large and challenging datasets. However, other issues and concerns not directly related to recognition accuracy have arisen, including the **fairness**, **reliability** and **trustfulness** of current biometric systems.

This edition of the school will address these issues and try to answer some compelling questions, such as: How do we mitigate bias in biometric systems? How can we design privacy-preserving and "ethical" biometric devices? What can we learn from human perception? How can we better deploy current AI approaches? How do we cope with adversarial attacks in biometric recognition? What is the scalability and real potential for biometric systems? What is the potential impact of biometrics in forensic investigation and crime *prevention*?

In this 21st edition, the courses will focus on lessons learned, and on new and emerging issues, such as:

- **What is the impact of AI and advanced learning techniques in biometrics?**
- **How do we make "Deep Biometric" systems** *explainable?*
- **How can we exploit new biometric technologies in forensic and emerging applications?**
- **How can we develop fair, trustful and privacy-friendly biometric systems?**
- **Where are we going now?**

The courses will provide a clear and in-depth picture of the state-of-the-art in biometric verification/identification technology from both theoretical and scientific points of view, as well as in diverse application domains. Lectures will be presented by 18 outstanding experts in the field from both academia and industry.

Open sessions will be organised with questions and answers moderated by leading experts in the field.

To Apply:
Applications are open to students, instructors, researchers, professionals, and others willing to deepen their knowledge in the field. All participants in the school must attend in person. In exceptional cases of travel limitations, remote participation via videoconferencing may also be arranged.

Expected school fees will be on the order of 1,700 € (400 € in videoconference) for students and 2,300 € (800 € in videoconference) for others. Fees include full accommodation, and all courses and materials. A limited number of partial scholarships will be awarded to Ph.D. students, selected on the basis of their scientific background and on-going research work. The scholarship request form can be downloaded from the school web site at http://biometrics.uniss.it.

Send a completed application form, along with a short resume to
Prof. Massimo Tistarelli at biometricsummerschool@gmail.com

Key Dates for Summer School 2024:
- Submission of applications: **Accepted till March 15th, 2024**
- Registration: **April 15th, 2024**

LOCATION
The school will be hosted by Hotel Dei Pini (https://www.hoteldeipini.com/) immersed in the Capo Caccia bay, near Alghero, Sardinia. The location is considered one of the most beautiful resorts in the Mediterranean Sea. Hotel Dei Pini has a recently renovated conference centre that is fully equipped for scientific events. The school venue, as well as the surroundings, are a perfect environment for the program's activities.

The organisers and all lecturers are fully committed to making this year's school as successful, instructing and inspiring as in past years.
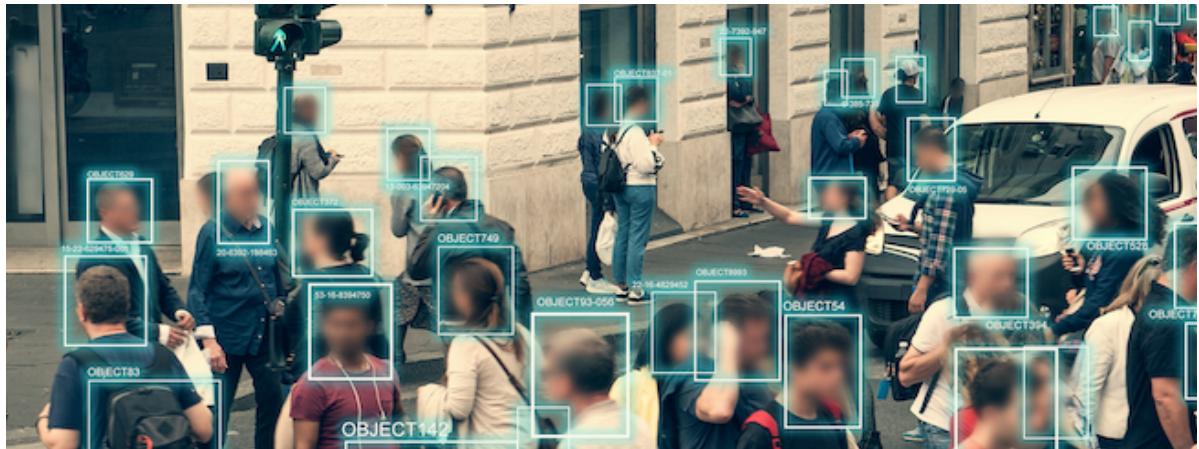
SCHOOL COMMITTEE

Massimo Tistarelli, Computer Vision Laboratory, University of Sassari, Italy
**Josef Bigun,** Department of Computer Science, Halmstad University, Sweden
Enrico Grosso, Computer Vision Laboratory, University of Sassari, Italy
Anil K. Jain, Biometrics Laboratory, Michigan State University, USA
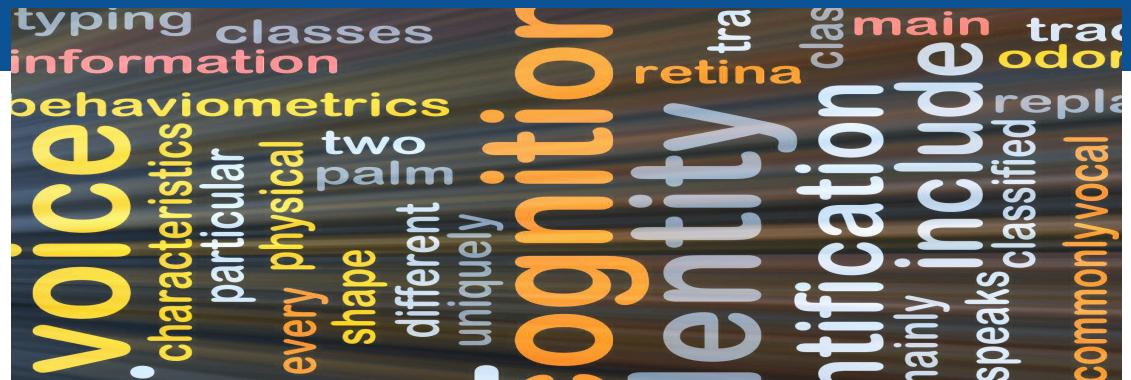
DISTINGUISHED LECTURERS FROM PAST SCHOOLS

Josef Bigun Halmstad University – Sweden	**David Meuwly** Netherlands Forensic Institute – NL
Thirimachos Bourlai West Virginia University – USA	**Emilio Mordini MD** Responsible Technologies – Italy
Vincent Bouatou Safran Morpho – France	**Mark Nixon** University of Southampton – UK
Kevin Bowyer University of Notre Dame – USA	**Alice O'Toole** University of Texas-Dallas– USA
Deepak Chandra Google Inc. – USA	**Maja Pantic** Imperial College – UK
Rama Chellappa University of Maryland – USA	**Johnathon Phillips** National Institute for Standards and Technology – USA
John Daugman University of Cambridge – UK	**Tomaso Poggio** MIT – USA
Farzin Deravi University of Kent – UK	**Nalini Ratha** IBM – USA

James Haxby Dartmouth University – USA	**Arun Ross** Michigan State University – USA
Anil K. Jain Michigan State University – USA	**Tieniu Tan** CASIA-NLPR – China
Joseph Kittler University of Surrey – UK	**Massimo Tistarelli** Università di Sassari – Italy
Davide Maltoni Università di Bologna – Italy	**Alessandro Verri** Università di Genova – Italy
John Mason Swansea University – UK	**James Wayman** University of San Josè – USA
Aldo Mattei Arma dei Carabinieri – Italy	**Lior Wolf** Tel Aviv University – Israel

IN THE NEWS…

By Emanuele Maiorana, Assistant Professor, Roma Tre University, Rome, Italy

Biometric recognition systems have now become an integral part of our daily lives, largely due to their use as authentication methods for mobile devices. As a result, interest in the functioning and implications of their use in everyday life is also growing. Numerous articles on this topic are now appearing in publications that are not strictly scientific in nature. The following is a selection of articles that appeared between October and November 2023 on some of the most popular English-language news websites, including *The Financial Times, Forbes, The Guardian, The New York Times,* and the *BBC*.

Google's AI-Powered Biometric Security Can't Compete With The iPhone 15 (October 17, 2023)
https://www.forbes.com/sites/jaymcgregor/2023/10/17/googles-new-pixel-8-security-cant-challenge-the-iphone-15/
A comparison of the capabilities of the new Google Pixel 8 secure version of Face Unlock against those of the already established iPhone 15.

ID R&D President Alexey Khitrov Talks Biometric Authentication, Accessibility, AI's Rise (October 20, 20223)
https://www.forbes.com/sites/stevenaquino/2023/10/20/id-rd-president-alexey-khitrov-talks-biometric-authentication-accessibility-ais-rise-in-recent-interview/
An interview with Alexey Khitrov, president of ID R&D. A Mitek company, ID R&D is a New York-based biometrics firm that, according to Khitrov, focuses its work specifically on "voice and face modalities," with the latter focused on liveness.

Why is Technology Best for Checking Bank Customer Identities? (October 23, 2023)
https://www.ft.com/content/2c5291ae-2f31-439d-8176-a669a88d41e0
The article discusses interest in biometric recognition for checking bank customer identities. Among the approaches still in development, behavioural biometrics, which profiles things like the angle at which users typically hold a device, or the speed at which they press its buttons or type, is mentioned as a promising alternative to current methods.

Readers reply: How Do We Know Every Fingerprint is Unique? (November 5, 2023)
https://www.theguardian.com/lifeandstyle/2023/nov/05/readers-reply-how-do-we-know-every-fingerprint-is-unique.
In a section where readers answer other Guardian readers' questions, this column solicited responses regarding fingerprint recognition, particularly affirming uniqueness.

MyGov to Use Face or Fingerprint Recognition Instead of Passwords in Bid to Fight Scams (November 9, 2023)
https://www.theguardian.com/australia-news/2023/nov/09/mygov-to-use-face-or-fingerprint-recognition-instead-of-passwords-in-bid-to-fight-scams
The article reports that the Australian government will introduce passkeys, like face or fingerprint recognition, for secure access to citizens' myGov accounts. This would make it much harder for scammers than existing systems based on usernames and passwords.

Is Amazon One the Future of Biometrics? (November 28, 2023)
https://www.forbes.com/sites/rogerdooley/2023/11/28/is-amazon-one-the-future-of-biometrics/
The article discusses the use of the Amazon One palm recognition technology, which is considered one of the most interesting applications of biometric identity verification. The author presents some of the advantages and disadvantages of this strategy.

Important Considerations Before Using Biometrics for Authentication (November 28, 2023)
https://www.forbes.com/sites/forbestechcouncil/2023/11/28/important-considerations-before-using-biometrics-for-authentication/
The article lays out several aspects that should be carefully evaluated before deploying and using biometric recognition systems.

Improving Identity Security with Touchless Fingerprint Biometrics (November 30, 2023)
https://www.forbes.com/sites/tonybradley/2023/11/30/improving-identity-security-with-touchless-fingerprint-biometrics/
The article focuses on touchless fingerprint biometrics, an innovation redefining identity security and making biometric verification more inclusive and accessible than ever before.

SPECIAL FEATURE

Spotlight on Winter School on Biometrics

By Prof. Shiqi Yu, Associate Professor of Computer Science and Engineering, Southern University of Science and Technology, Shenzhen, China

The 8th Winter School on Biometrics (WSB2024), a training course to promote research in biometrics and related fields, was successfully held from 21 to 25 January 2024 in Shenzhen, China. It was jointly organized by the Department of Computer Science of Hong Kong Baptist University, the Institute of Automation of the Chinese Academy of Sciences, and the Department of Computer Science and Engineering of Southern University of Science and Technology. Supported by the IAPR TC4 and the IEEE Biometrics Council, the school drew 73 participants, including 60 paid attendees and 13 volunteer students. Four of the attendees were from outside China (3 from India, and 1 from Vietnam). Eight other students attended via a grant after selection by the winter school directors.

The program included 14 lectures, given by leading researchers in the field of biometrics. Lecturers and their topics were as follows:

- Dr. Raffaele Cappelli, Associate Professor of Computer Science and Engineering, University of Bologna, Italy
  "Hands on Fingerprint Recognition with OpenCV and Python"

- Dr. Anil Jain, University Distinguished Professor and Douglas E. Zongker Endowed Professor, Michigan State University, USA
  "Introduction to Biometrics"
- Dr. Josef Kittler, Distinguished Professor, University of Surrey, UK
  "Self-Supervised Learning"
- Dr. Ajay Kumar, Distinguished Professor, The Hong Kong Polytechnic University, Hong Kong, China
  "Contactless Palmprint Recognition"
- Dr. Xiaoming Liu, Anil K. and Nandita Jain Endowed Professor, Michigan State University, USA
  "Biometric Recognition at a Distance"
- Dr. Brian Lovell, Professor of Electrical Engineering and Computer Science, The University of Queensland, Australia
  "Biometrics in Surveillance Videos"

- Dr. Chen Change Loy, Nanyang Technological University, Singapore
  "Harnessing Generative Priors for Visual Content Restoration"

- Dr. Anoop M Namboodiri, Professor, IIT Hyderabad, India
  "Large-scale Biometrics Recognition"

- Prof. Karthik Nandakumar, Associate Professor of Computer Vision, Mohamed bin Zayed University of Artificial Intelligence, UAE
  "Biometric Matching in Encrypted Domain"
- Dr. Mark Nixon, Emeritus Professor, University of Southampton, UK
  "Gait Biometrics, Forensics and Soft Biometrics"
- Dr. Vishal M. Patel, Associate Professor of Electrical and Computer Engineering, Johns Hopkins University, USA
  "Federated Learning for Biometrics"
- Dr. Arun Ross, Martin J. Vanderploeg Endowed Professor in the College of Engineering, Michigan State University, USA
  "AI and Biometrics: Privacy and Synthesis of Data"
- Dr. Tieniu Tan, Professor at the Institute of Automation, Chinese Academy of Sciences, China

"Biometrics: Progress, Problems and Prospects"

- Dr. Pong C Yuen, Hong Kong Baptist University, Hong Kong, China "Remote Photoplethysmography Based 3D Facial Mask Presentation Attack Detection"

All but three of the featured lecturers delivered their talks in person. The others presented online due to difficulties in traveling to the site. The topics covered included biometric identification by face, fingerprint, palmprint, or gait, soft biometrics, privacy in biometrics, trustworthy biometrics, multimodal biometrics, and large-scale applications. The lecturers presented the most up-to-date view of biometrics and shared their experiences with young students and researchers.

The hands-on session was organized by the OpenCV China Team and featured presentations by Jia Wu and Wanli Zhong on how to develop a real-time face recognition and human interaction system. Most participants finished research projects on face recognition and submitted their reports on-site. Of these projects,

three teams were honored for their excellent work.

Other activities held during the school included an open poster session, a mentoring session, and a social program that encouraged sharing and communication. Thirteen students presented In the poster session, while in the mentoring session, nine participant groups were lead by one of the conference speakers. Mentors guided the discussion on any topics of interest to the students.

Lastly, the social program included a cruise out to sea. Four professors, Drs. Nixon, Kittler, Loy, and Yu, joined the program and shared their time with students. The students enjoyed the trip and the communication with friends and professors.

MEASURING IMPACT: Conversations with 2004 recipients of Winter School Scholarships

by Thomas Swearingen, Graduate Research Assistant, Michigan State University, Lansing, Michigan, USA

The award grantees for Winter School 2024. Top row: Yunjie Xiang, Hai Yuan, Xiao Yang, Palak Verma. Bottom row: Amber Hyatt, Son Nguyen, Cairang Xiangxiu, Rishabh Shukla

Eight students were able to attend the 8th Winter School on Biometrics through grants from the International Association for Pattern Recognition and the IEEE Biometrics Council. We reached out to the grantees to get their feedback on the conference as a whole, and their impressions of several of its special events.

The grantees were:

Yunjie Xiang

Xiang received his B.S. degree in automation from Chuzhou University, Chuzhou, China, in 2019 and an M.S. degree in transportation engineering from FuJian University of Technology, Fuzhou, China, in 2022. He is currently working towards a Ph.D. degree in computational linguistics at the School of Information

Science and Technology, Tibet University, Lhasa, China. His research interests include Tibetan information processing and computer vision.

Hai Yuan
Yuan, from Jinzhou City, Liaoning Province in China, is currently pursuing a Ph.D. at China University of Mining and Technology in Xuzhou. His research focuses on image processing and biometric recognition.

Xiao Yang
Yang is a doctoral student with the School of Information and Control Engineering at China University of Mining and Technology in Xuzhou, China. Her research interests include computer vision and multi-modality biometric recognition.

Palak Verma
Verma is a Ph.D. student at IIT Jammu, and the recipient of a Prime Minister Research Fellowship. Her Ph.D. research focuses on "Biometric Clones using AI for Privacy in a Metaverse."

Amber Hyatt
Hyatt is a Ph.D. student at the Amar Nath and Shashi Khosla School of Information Technology at the Indian Institute of Technology (IIT) in Delhi. Her research focuses on biometric security, with a specific focus on template protection in biometrics and strategies to guard against deepfakes.

Son Nguyen
Nguyen is an MS student at Hanoi University of Industry in Hanoi, Vietnam, studying electronic engineering with a specific focus on information security. In 2020, he was awarded the gold medal at the Vovinam competition, and the university encouragement prize for scientific research.

Cairang Xiangxiu
Xiangxiu, from the holy land of Tibet, received a bachelor's degree from Qinghai University for Nationalities in 2020, a master's degree from Tibet University in 2023, and is currently a doctoral student studying software engineering at the School of Computer Science at Sichuan University in Chengdu, Sichuan, China. His current research, with his supervisor Qijun Zhao, focuses on document image restoration.

Rishabh Shukla
Shukla is a Ph.D. student and research scholar at IIT Jammu, Jammu and Kashmir, India. He recently presented a paper "Vikriti: A Novel Approach for Real Looking Fingerprint Data-Set Generation" at the 2024 *IEEE/CVF Winter Conference on Applications of Computer Vision.*

SWEARINGEN: *Can you share your overall experience as a scholarship grantee at the 8th Winter School on Biometrics? What were the highlights of the program for you?*

Yuan: The five-day schedule was filled with learning, exploration, and interaction opportunities. I was fortunate to attend lectures covering everything from basic theories to cutting-edge technological applications in biometrics, significantly broadening my knowledge and deepening my understanding of biometric technologies. Participation in the practical sessions allowed me to apply theoretical knowledge to real-world problem-solving, which enhanced my grasp of the subjects.

Another highlight was the poster presentation segment, where I had the chance to showcase my research projects and ideas. It provided a platform not only to display my work, but also to exchange feedback with experts and peers globally. It yielded invaluable advice and guidance from top experts in the field that has greatly assisted in refining my research direction and methodology.

Yang: The five days spent at the winter school were enriching and meaningful, during which I met many like-minded friends. It brought together top scholars from around the world who shared not only the history, current state, and future of biometric technology, but also touched upon current hot topics. Including these topical areas, such as applications of large models, data security, and privacy protection, gave me a more comprehensive understanding of biometric technology.

I believe the highlight of this program was the in-depth learning obtained during a hands-on session under the guidance of the OpenCV development team. I personally completed a facial recognition project during this time. This practical session not only deepened my understanding of theoretical knowledge, but also improved my hands-on ability, allowing me to encounter and solve some technical challenges during actual operation.

Verma: As a scholarship recipient my overall experience was incredibly rewarding and enriching. The program provided a comprehensive overview of various biometric topics, ranging from traditional methods of fingerprint and iris recognition using deep learning algorithms,

to cutting-edge techniques like remote photoplethysmography-based 3D facial mask presentation attack detection, and federated learning for preserving privacy. One of the highlights for me was the prospect of learning from internationally renowned experts in the field through lectures, mentoring, and hands-on sessions. These interactions not only deepened my understanding of biometrics, but also inspired me to explore new research directions and methodologies. Presenting my own research work during the poster session was a privilege and greatly enriched my participation.

Hyatt: My overall experience as a scholarship grantee was very good. The scholarship enabled me to attend and learn. Highlights of the program for me are the various lectures by experts in the field, which enabled me to get deeper insight into the subject.

Nguyen: The program introduced cutting-edge technologies in the field of biometrics, and I believe these will be a part of the future. Alongside these technologies, the organizers have prepared diligently to allow students to interact with leading professors.

Xiangxiu: Top experts in the field of biometric identification from different countries and regions offered in-depth explanations of the latest technologies in the industry. For young scholars and graduate students, this helped to consolidate basic knowledge of biometric identification and share the latest developments. The main courses of this winter camp are based on advanced biometric technology, and aims to share and exchange the latest scientific research

results. This provides students with opportunities to develop personal and professional relationships and lay the foundation for future career development.

> *"In short, this experience has benefited me greatly, not only improving my professional skills, but also allowing me to make many like-minded friends."-- Xiang*

Shukla: My time at WSB2024 as a scholarship recipient was amazing! The lectures from top experts were so good, especially one on synthetic data in biometrics. Learning about it made me see biometrics in a whole new light.

Xiang: As a recipient of an 8th Winter Biometric Recognition Winter Camp Scholarship, I was deeply honored to participate in it. The entire experience was very fulfilling and meaningful to me. I was able to learn together with outstanding researchers and scholars from around the world whose professional knowledge and unique insights have brought me a lot of inspiration. These excellent researchers shared the latest technologies, applications, and challenges in biometric recognition, and this in-depth communication has benefited me greatly. In addition, I also participated in experiments and research projects set up by the OpenCV team, and personally experienced the practical operation and

application of OpenCV. These practical experiences not only deepened my understanding of the principles and methods of OpenCV, but also honed my experimental skills and teamwork skills.

For me, the highlight of this project lies in its international perspective and cutting-edge research content. Researchers from different countries and cultural backgrounds exchange ideas, bringing us rich perspectives. At the same time, the cutting-edge technologies that the project focuses on have also shown us the enormous potential and development space in the field of biometric recognition in the future.

In short, this experience has benefited me greatly, not only improving my professional skills, but also allowing me to make many like-minded friends. I am deeply honored to have been a part of this project and look forward to further researching and exploring more mysteries in the field of biometric recognition

SWEARINGEN: *The winter school featured lectures from internationally renowned experts in various biometric fields. Can you tell us about a specific lecture or topic that left a lasting impression on you and how it has influenced your understanding or interest in biometrics?*

Yuan: While many lectures left a profound impression, Xiaoming Liu's talk on "Biometric Recognition at a Distance" was particularly memorable. Professor Liu explored the latest advancements and challenges in long-distance biometric recognition. He detailed the current state of remote recognition technology and how advanced algorithms and sensing

technologies can capture and identify human features. During the social program, I had the privilege of discussing topics such as a love for scientific research, finding life's purpose, and achieving self-fulfillment in research with Professor Anil Jain. With his profound academic background and rich life experience, Jain provided me with invaluable advice and insights. He emphasized the importance of continuous curiosity, encouraging me to pursue new knowledge and skills while also reminding me to balance research work with a personal life, and maintain ongoing passion and motivation.

Yang: The lecture by Professor Vishal M. Patel on Federated Learning for Biometrics left a deep impression on me. He discussed the motivation behind federated learning and started with the classic algorithm FedAvg to vividly explain the process. This method allows different users to collaborate in learning with the help of a server, while protecting private data and utilizing local data to train a global model. Finally, Professor Patel introduced the challenges faced by federated learning and its applications in face recognition, face

anti-spoofing, and liveness detection. This topic not only broadened my horizons but also sparked my interest in delving into personal privacy protection.

> *"I had the privilege of discussing topics such as a love for scientific research, finding life's purpose, and achieving self-fulfillment in research with Professor Anil Jain" —Yuan*

Verma: Among the numerous lectures delivered by professionals, one topic that left a lasting impression on me was the exploration of biometric matching in the encrypted domain as delivered by Professor Nandakumar. This topic introduced innovative possibilities for template protection using concepts like hashing, deep feature transformation methods, and biometric crypto systems. Such efforts can ensure the security and privacy of biometric data while maintaining high accuracy in matching. Learning about these approaches has significantly influenced and motivated me to further investigate the intersection of cryptography and biometric systems in my future research.

Hyatt: The lecture by Professor Mark Nixon was very interesting to me because he showed real-life examples, such as how biometrics enabled the police to catch a thief based on gait. I am currently working on fingerprints and this lecture developed my interest in working further on gait biometrics.

Nguyen: The most impressive lecture for me was "Introduction to Biometrics" by Dr. Anil Jain. Previously, I only used MATLAB for image sharpening, which presented many difficulties for me. After listening to his lecture, I gained more ideas for future projects that don't necessarily require MATLAB applications.

Xiangxiu: The most influential lecture for me was Professor Anil Jain's talk entitled "Introduction to Biometrics." First of all, Professor Jain introduced the concept of biometric identification and explained the history, development and application of the field based on practical applications. Then, Jain explained the working principles of biometric recognition systems, such as fingerprint recognition and face recognition. Finally, Jain summarized the development prospects and challenges in the field of biometrics.

Xiang: The lecture that left a deep impression on me was academician Tieniu Tan's presentation on "Biometrics: Progress, Problems and Prospects." Tan introduced innovative aspects of recent work on facial recognition, iris recognition, and privacy protection biometrics from the perspective of data acquisition, preprocessing, feature extraction, feature matching, and recognition result response. The focus was on the development of Tan's team in iris recognition, generative AI models, and GAN, as well as related work on graph representation and image interpretation. However, Tan makes clear that current biometric recognition technologies are facing challenges, such as the high demand for user cooperation, decreased open set recognition performance, unpredictable attacks, and interference from age factors. In response to these issues, Tan also elaborated on future directions, including individual centered biometrics, multimodal biometrics and adaptive fusion, and interpretable biometrics and service centralization.

I believe that as future researchers or practitioners, we should not only focus on innovation and applications of technology, but also pay attention to the ethics and social responsibility they entail. This speech not only enhanced my interest in biometric technology, but also reminded me to always maintain a focus on ethical and privacy issues in my future studies and work. I believe that only with full consideration of ethics and social responsibility can biometric technology truly benefit human society.

SWEARINGEN: *The hands-on session organized by OpenCV China Team focused on real-time face recognition and human interaction systems. How did this practical aspect enhance your learning, and did you face any challenges or interesting moments during the project work?*

Yuan: The practical session highlighted the transformation from theoretical knowledge to practical application. The hands-on course helped me gain a deep understanding of real-life applications in facial recognition and human-computer interaction systems. Despite encountering some challenges with programming and algorithm optimization during the project work, these experiences ultimately deepened my understanding and enhanced my practical skills.

Yang: During the practical session, I faced the challenge of optimizing algorithm performance in a facial recognition project. Through continuous trial and adjustment, and with the help of the OpenCV team, I successfully improved the accuracy and efficiency of the recognition algorithm. The process of collaborating with team members and solving problems brought me a great sense of achievement.

Verma: The hands-on session organized by the OpenCV China Team, which focused on real-time face recognition and human interaction systems, provided a practical application of the theoretical knowledge gained during the program. Witnessing other teams' demonstrations of identity recognition despite face coverings, along with integration with gesture recognition for website control, was particularly intriguing. It expanded my grasp of the potential applications of biometric technologies.

Hyatt: The hands-on session organized by OpenCV China Team was very interesting and enabled me to learn many new concepts of face biometrics and human interaction. The project taught me many new shortcuts using OpenCV that I did not previously know.

Nguyen: Two years ago, I used OpenCV for my scientific research project, incorporating the YOLO model. When participating in the program and revisiting OpenCV, I was able to quickly re-familiarize myself with it.

Xiangxiu: In this Hands-On project, we chose Project A, which involves building a 1:N face recognition system with camera stream input using OpenCV. For the network architecture, we employed the open-source YuNet and SFace from the professor's team for face detection and recognition tasks, respectively. Ultimately, we successfully implemented the task of detecting and recognizing multiple faces from a single camera.

Shukla: The hands-on session with the OpenCV China Team was a blast! Working on real-time face recognition was challenging yet exciting. Despite some bumps along the way, I managed to overcome them and achieve some good results.

Xiang: In the practical stage, we focused on the implementation of real-time facial recognition and human-computer interaction systems. The OpenCV China team helped us deeply understand the practical applications of these technologies. I learned how to use the OpenCV library for face detection, feature extraction, and recognition.

By writing code to implement these functions, I gained a deeper understanding of the principles and implementation process for facial recognition technologies. At the same time, I also encountered some challenges, such as how to maintain stable recognition rates under different lighting conditions, and how to handle occlusion and facial expression changes. Through continuous experimentation and optimization of algorithms, I gradually overcame these difficulties and was able to improve the accuracy of facial recognition.

Overall, this practical session has given me a deeper understanding of the implementation principles and application

scenarios of real-time facial recognition and human-computer interaction systems. By overcoming challenges and solving problems, I have not only improved my technical skills, but also developed the ability to work with others as a team and solve problems. These experiences will have a positive impact on my future learning and work.

SWEARINGEN: *The social program included a cruise with professors Mark Nixon, Josef Kittler, Chen Change Loy, and Shiqi Yu. How did this informal setting contribute to your interactions with the professors and fellow participants? Can you share any valuable insights or experiences gained during this social program?*

Yuan: The social program, especially the cruise activity, provided a rare opportunity for informal interactions with authoritative figures in the field. This interaction not only offered me valuable guidance, but also inspired me in my career development. Through this interaction, I learned a great deal about transforming academic research into practical applications, which is immensely important for my future studies and career development.

Yang: The boat trip provided me with a rare opportunity to interact with leading figures in the field in a relaxed setting. From them, I learned not only research skills but, more importantly, the proper attitude towards research and facing challenges. This sense of closeness and inspiration will have an immeasurable impact on my future research career.

Verma: The social program offered a relaxed and informal setting for networking and collaboration. Interacting with prominent investigators and fellow participants outside of formal sessions provided valuable insights and exposure, fostering a sense of camaraderie and a global network of biometrics-proficient individuals. The International Winter School on Biometrics has significantly contributed to my growth and development as a researcher. I am grateful to the IEEE Biometrics Council for the support that enabled me to attend this stimulating learning opportunity.

Hyatt: The social program was very interactive and helped me to get to know people from different places who are working on different biometrics projects. The Informal session with professors helped us to know them well and enjoy time together. It has also helped me to make friends.

Nguyen: It provided me with the opportunity to learn about various countries around the world, which I had previously only explored through the internet and books. The excursion also helped me gain confidence in communicating with professors, and I shared some interesting aspects about my beautiful country, Vietnam, with both the professors and fellow participants.

Xiangxiu: The 2024 Winter School on Biometrics not only allowed me to meet many like-minded colleagues, but also gave me a deep appreciation of the vastness and infinite possibilities of academia. During discussions, I learned a lot and expanded my understanding of the field of computer vision. At the same time, I also

shared my research results and received recognition and suggestions from my peers. On this international academic platform, I felt the pulse of world science and technology, and also saw my own shortcomings. This did not make me feel discouraged. On the contrary, it made me more determined to keep learning and making progress. I hope that I can meet every challenge and run toward greater goals like my parents.

Shukla: Getting to hang out with professors on a cruise was nice. In those casual settings, I got to chat with them and other participants, and I learned so much more than I ever could in a formal setting. It was an experience I'll cherish forever!

"On this international academic platform, I felt the pulse of world science and technology"
— Xiangxiu

Xiang: Taking a boat trip with outstanding scholars such as Mark Nixon, Joseph Kitler, Chen Changle, and Shiqi Yu did provide me with a rare informal communication environment. On such an occasion, the professors let go of the serious atmosphere in the classroom and communicated with us students in a more relaxed and down-to-earth way. On the cruise ship, we enjoyed the beautiful scenery while casually chatting about academic and life topics. This atmosphere made me more

relaxed so I could dare to ask professors questions and even share my own insights. And the professors were also willing to share their academic experiences and life insights with us, which has benefited me greatly.

In addition, the interaction with professors and other participants made me feel the charm of academic research. In our communications, I learned about how professors apply theoretical knowledge to practical research, as well as the thinking and coping strategies they employ when facing challenges. These valuable experiences will have guiding significance for my future academic path.

Lastly, this social activity made me realize the importance of teamwork from this social activity. On the cruise ship, we discussed academic issues together, and everyone actively expressed their own opinions and inspired others. This brainstorming process made me realize that only close cooperation among team members can achieve better research results.

SWEARINGEN: *What are your final thoughts on your time at the school?*

Yang: Overall, the 8th Winter School on Biometrics was a valuable learning and growth opportunity for me, deepening my understanding of the field of biometrics and laying a solid foundation for my future research direction and career development.

Verma: I would like to express my gratitude to the IEEE Biometric Council for awarding me a grant to participate in the Winter School on Biometrics.

Hyatt: Overall, the program was very helpful to me as I was able to see various lectures from different experts about the scope of biometrics in the future, and was given many open problems to work on. The hands-on session with Prof. Raffaele Cappelli helped me to better understand a paper of his I had read earlier. Also, Prof. Shiqi Yu has been very helpful at every stage of the journey.

I would like to attend more of such programs in the future as it helped me to understand some of the areas in my research where I was lacking. It enabled me to talk to experts in the field and get their assistance in my work. Lastly, I would like to add that the scholarship has really helped me a lot and should continue in future for other aspirants.

Nguyen: I would like to express my gratitude to the organizers and sponsors for providing us with such a meaningful program. I believe it will benefit us greatly on our research journey.

Xiangxiu: I would like to thank Teacher Yu and his team, Mr. Wang, Sister Dan, etc. for their careful care despite their busy schedules. I would also like to thank my tutor, Professor Zhao Qijun, for supporting and sponsoring my participation in this winter camp.

Xiang: Finally, I am very grateful for the valuable experience and insights that this social project has brought me. These experiences not only enriched my academic life, but also laid a solid foundation for my future academic research and career development. I believe that in the future, I will apply these valuable experiences to practical work, continuously pursue excellence, and make greater contributions to the academic community and society.

SPOTLIGHT ON EU PROGRAMS: PriMa-ITN—PRivacy Matters

By Raymond Veldhuis, Professor, University of Twente, Enschede, The Netherlands

The PriMa project ran January 1, 2020 to December 31, 2023 with funding from the European Union's Horizon 2020 research and innovation programme, under Marie Skłodowska-Curie grant agreement No. 860315. Detailed information about the project, including all publications, can be found at https://www.prima-itn.eu.

Background and Goals

Characterised by a ubiquity of sensors in IoT and mobile devices, CCTV cameras and other devices, a high degree of interconnectivity, cloud storage, and extensive processing power, the rapid digitalisation of society created increasing technology to capture personal information. Consequently, there is a growing challenge to maintain individual privacy. One factor contributing to this challenge is the growth of recognition technologies that not only identify individuals, but can also, by inference from biometric data, determine their individual emotional state, gender, health, age, and even their profession. Additionally, the rapid advancement of artificial intelligence has allowed for extensive data mining and aggregation, as well as linkage and inference of personal information. Hence, there is a real possibility that acceptable privacy may become unattainable unless technological and societal steps are taken to allow citizens to regain control of their personal information.

In response to these concerns, the overall objectives of the PriMa program were:

1. To train 14 creative, entrepreneurial, and innovative researchers as privacy protection experts.
2. To contribute to a full understanding of the multidisciplinary nature of privacy protection in a digitalised society.
3. To contribute to the development of solutions that address this important societal challenge.

The research addressed the following topics:

- Analysis of privacy risks,
- Methods for privacy protection, and
- Assessment of the impact of privacy protection.

These topics are discussed in depth below.

Analysis of Privacy Risks

A number of literature studies have been performed on privacy vulnerabilities in various domains (e.g. biometric data, mobile-sensor data, medical data, the Internet of Things, and E-learning). These studies examined both privacy leakage and deliberate attacks on systems. In addition, the problem has also been addressed from a legal perspective.

Along with the studies mentioned above, experiments were also run to identify and quantify privacy risks in realistic cases. Various systems were designed to mimic current and future privacy-sensitive data processing. These include a biometric system for continuous authentication based on data acquired through user interaction with mobile devices. As a result, new measures that quantify privacy leakage were proposed and will be evaluated.

Privacy Protection

Literature studies on privacy protection have been performed in the following domains:

- Facial privacy protection by identity obfuscation and by encryption of biometric data
- Privacy protection for keystroke dynamics;
- Privacy protection for E-learning, E-banking, and E-health.

Where necessary, these studies were supported by experiments. Researchers also investigated new privacy protection methods for the above domains. This research has resulted in:

1. A protocol for keystroke dynamics that can authenticate under encryption
2. New computationally efficient methods for face recognition under encryption
3. A new approach called GaitPrivacyON that addresses privacy protection for gait recognition
4. Another new approach that applies face morphing as a transformation function for biometric template protection
5. New and improved methods for changing the area around the eyes to obfuscate identity in facial images.

The value of these contributions lies in the fact that biometric data can be stored and processed without revealing the personal information present in this data. As a follow-up current research is developing

new concepts for detecting and mitigating leakage of personal data in software.

Impact Assessment of Privacy Protection
Here the focus was on the impact of privacy protection in virtual reality applications and in the combination of biometric recognition and blockchain technologies. In the latter domain the focus is on the legal aspects. Furthermore, in the virtual reality domain interpersonal trust between users and avatars is studied in various ways. For that purpose, a social virtual reality prototype was built with basic functionalities for integrating and evaluating privacy protection measures as well as conducting user and usability studies. Experiments were set up for the measurements of trustworthiness between users and avatars.
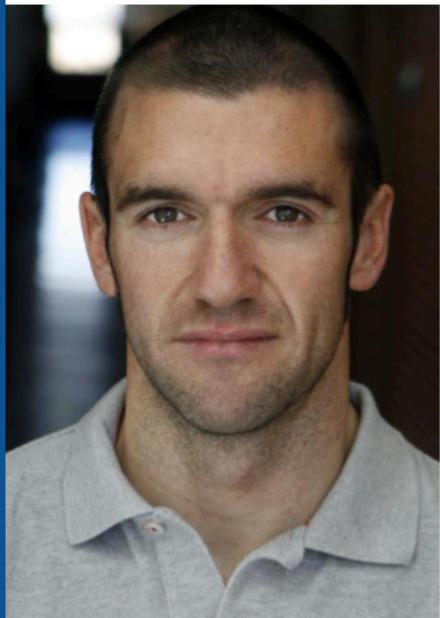
Figure 1: Participating institutions in PriMa

EXPERT PERSPECTIVES: Javier Galbally

Interview conducted by Dr. João Neves, Assistant Professor of Computer Science at the University of Beira Interior, Covilhã, Portugal

Javier Galbally, Senior Capability Building Officer with eu-LISA, received his M.Sc. degree in Electrical Engineering from the Universidad de Cantabria, Spain, in 2005, and his Ph.D. degree in Computer Science and Electrical Engineering from the Universidad Autónoma de Madrid, Spain, in 2009. He served as an Assistant Professor at that school until 2012, and the following year joined the European Commission at the DG Joint Research Centre. Galbally worked as a Scientific/Technical Officer at DG JRC for nine years before accepting his current appointment at the European Agency eu-LISA in May 2022. Galbally has chaired the EAB Research Projects Conference since 2017, and is the author of more than 100 publications, which have produced more than 7,000 citations. His research interests focus on the security and performance of biometric systems, and pattern and biometric recognition.

NEVES: You transitioned from academia to the European Commission. How did this transition impact your research work?

Galbally: While both academia and DG JRC belong to the research sphere, the way science is viewed in these two institutions differs somewhat. Of course, a similar scientific method is applied in both cases, as are the best scientific practices and principles for exploring a new problem. The main difference is the type of problems tackled.

In academia, you have, in theory, greater freedom on the research questions you investigate. I say "theoretical freedom" because, in practice, you are also bound by the resources (i.e., funding) available to carry out your research. But, provided that you have the funding, you can address any problem you find interesting.

On the other hand, the main mission of DG JRC is to give scientific support and evidence-based answers to EU institutions and Member States whenever they face a new open question in some specific domain (e.g., biometrics). This mission is especially important during the regulation cycle, when a new piece of legislation is proposed by the European Commission (EC), or when an existing piece of legislation is being reviewed. In practice

this means that your research work is tied to requests received on specific topics by other EU institutions (or Member States).

These differing realities between academia and DG JRC also lead to alternate paths in the search for funding.

> *"In academia applying for funding takes up much of a researcher's time. At DG JRC a budget is allocated and ensured at the beginning of the year. This means that researchers spend less time finding financial resources."*

While in academia applying for funding takes up much of a researcher's time, at DG JRC a budget is allocated and ensured at the beginning of the year as part of the EC. This means that researchers spend less time finding financial resources. Once a specific study is approved, the required funds are available, though, of course the principal investigator has to duly justify all expenses.

Another difference is that the scientific work in academia is very much focused on producing publications. We could say that scientists are "evaluated" in terms of their publication record, which includes total number of publications, the Impact Factor of the forums in which they publish, the "h" number, and the number of citations. While publishing in international, peer-reviewed journals and/or conferences is viewed positively at DG JRC, it is not the main goal. Instead, as stated above, the purpose of research is to give data-based answers to specific problems. As such, the work of researchers at DG JRC is less visible in the usual outlets, and that means its scientific impact or scientific curriculum can suffer somewhat when measured according to the usual criteria used in academia.

To sum up, we could say that, from a general point of view, more "cutting edge" research is carried out in academia, while the type of work carried out at DG JRC is "applied research," which has a clear practical application in the real world. This does not mean that academia does not perform any applied research or that no cutting edge studies are accomplished at DG JRC.

NEVES: What were your key contributions during your time at DG Joint Research Centre?

Galbally: Following the line of "applied research" to give evidence-based support to other European Commission DGs in the regulatory cycle, I was a major contributor to a study on "age and aging on fingerprints." This study was requested by DG HOME during a review of the regulation for the Visa Information System (VIS) that

manages requests by third country nationals (citizens of non-visa exempt countries) .to enter the Schengen area The purpose of the study was to determine the lowest threshold age to acquire fingerprints for issuing a visa. At that time, the age limit for fingerprinting travellers was 12 years of age. Based on our experiments, carried out on almost 500.000 fingerprints, it was determined that current recognition technology does not have a substantial accuracy drop above 6 years of age. On the other hand, below that age the accuracy of the technology does degrade significantly. The technical report produced was the basis for a proposal from the EC (DG HOME) to lower the required fingerprinting age for visas from 12 to 6 years. The proposal was finally approved by the European Parliament. To me, this is a clear example of the direct impact that research carried out at DG JRC has on the regulatory process, and on the real world. Such impact is very difficult to accomplish while working in academia. As a researcher at DG JRC you have a clearer sense of "applicability" and "contribution" to society.

You can learn more about the project described above in publications available at https://ieeexplore.ieee.org/document/8509614, and https://publications.jrc.ec.europa.eu/repository/handle/JRC112332

As I mentioned earlier, while applied research is the focus of DG JRC, this does not mean that no "exploratory research" is carried out. In fact, one of the projects that I have fond memories of was the development of the first-ever touchless full-3D fingerprint sensor. The prototype acquisition scanner was based on 3D laser sensing used at DG JRC to analyze nuclear waste containers. This collaborative effort between the biometrics and nuclear safety teams resulted in the "3D FLARE project," which showed that it is possible to capture 3D samples (point cloud files) of fingerprints in a consistently accurate manner.

For more about the FLARE project, go to https://ieeexplore.ieee.org/document/9160923.

NEVES: Considering your experience in writing technical reports for regulating large European IT systems, can you tell us how these systems are adopting the latest advances in biometrics?

Galbally: After working 9 years for DG JRC, and currently 2 years at the EU Agency eu-LISA, I can confirm that EU institutions working in the Justice and Home Affairs (JHA) domain make a conscious effort to stay up to date not only on the latest advancements in biometrics, but also in the IT field in general. To this end, EU Institutions consider research and innovation as key functions that contribute to their overall efficient operation. In general, one of the main goals of R&I departments in EU Institutions is to help the organization keep up to date with the evolution of technology.
Yet, four important factors can hinder and slow down integration of the most recent

findings in biometrics by large European IT systems. These factors are key to explaining why real-world systems managed by public institutions are usually one step behind in the adoption of the latest technological developments:

- **Operational readiness.** One of the priorities of large European IT Systems is availability. New biometric algorithms can only be integrated in the systems once they have been extensively tested and consistently proven not only deliver *high* performance, but also *reliable* performance. This means that new technology needs to go through a testing period of 1 to 2 years before its implementation in operational systems can be considered.
- **Size and scalability.** Some of the latest developments in technology are only applicable to small-scale systems. Speed and computational efficiency are two critical factors that come into play when considering systems with millions of entries and tens of millions of queries.
- **Procurement.** Transparency in the expenditure of public money is another key priority of EU institutions. As a result, the procurement process for any new piece of technology takes time, making it difficult to have the "latest version" of a given piece of IT equipment or algorithm.
- Regulation. Technology advances significantly faster than regulation.

Technology has to be implemented according to the necessary regulatory safeguards. This means that, in some cases, before being able to integrate certain technologies, there is a waiting period until new regulations are put in place.

With these caveats in mind, one of the priorities of eu-LISA, as the European Agency managing the large European IT systems, is integration of new biometric solutions to address the following key challenges of this technology:

- **Data quality:** To ensure interoperability among systems and to avoid potential vendor lock-in situations, eu-LISA is actively involved with ISO SC37 in standardization initiatives for biometric characteristics (especially face, fingerprints and finger-marks).
- **Vulnerability detection**: One of the priorities in operational systems is to make them as resistant as possible to potential attacks. In this regard, eu-LISA closely follows developments achieved by academia and research projects, such as iMARS in the areas of Presentation Attack Detection (PAD) and Morphing Attack Detection (MAD).
- **Algorithmic fairness:** Operational systems in the areas of law enforcement, and border and migration management process data of great demographic

variability, coming from citizens from all over the world. As such, one of the key features that large European IT Systems should comply with is equal treatment to all citizens, independently of their demographics (e.g., ethnicity, age, gender) to the largest extent possible. While we know that full equality is almost impossible to achieve, testing of any new biometric technology with regards to its potential demographic bias is a priority of EU institutions.

- **Encryption:** Data protection is another key feature with which large European IT systems must comply. In this regard, eu-LISA is currently monitoring developments in the area of Biometric Template Protection (BTP), especially the new algorithms based on Homomorphic Encryption. These systems may be operationally ready in the near future and can become an integral part of the next generation of systems.

NEVES: As an example, is EUROPOL already adopting state-of-the-art face recognition methods for forensic data analysis?

Galbally: Unfortunately, I cannot speak on EUROPOL's behalf, as I do not know their systems well enough.

NEVES: You have served as Chair of the EAB Research Projects Conference since 2017. What motivated you to take on this role, and how has this experience

influenced collaborative research and advancements in the field?

Galbally: First and foremost, at the time I had (and still have) a very good relationship with the organisers of the conference and, especially, with the "founder" of the event —and chair at the time—Professor Christoph Busch. When he decided to step down from his role and proposed it to me, I saw it as a motivating "next step" in my research career. I felt that it was a good time to jump from "speaker" to "organiser" of these types of events. One of my main motivations when I took over as chair was to contribute in my own small way to the biometric community. However, I have to add, from a more "selfish" point of view, I also saw it as an opportunity to "gain visibility" among my peers and to increase my professional network.

It has been a challenging process, but I am very happy that I took the opportunity that was offered to me as I have learned a lot on the way. Hopefully, participants at the EAB RPC over the last 7 years have found the event interesting and informative, and helped them in building their own

networks. And I also hope that they are understanding of the "inabilities" of the chair.

I truly believe that the EAB RPC is a very unique forum for discussion, networking, and learning within the ever-growing landscape of biometric-related events. It is not a "purely scientific" conference, but rather an event where all sides of the biometric world are presented, including:

1. Technical content developed in EU-funded research projects
2. Updates in biometrics presented by public institutions, such as the European Commission, EU Agencies in the JHA domain (e.g., Frontex, Europol, eu-LISA), or by US colleagues from the Department of Homeland Security (DHS) and NIST
3. The latest developments from industry.

NEVES: As a Senior Capability Building Officer at the European Agency eu-LISA since May 2022, could you share insights into your current responsibilities and how your expertise in biometrics contributes to the agency's objectives?

Galbally: My main responsibilities in the Agency are:

- Monitoring the latest developments in technology, with special focus on biometrics, in order to disseminate this knowledge in the agency, and identify possible areas where technology can improve the organization

- Supporting the Operations Department in projects related to the implementation of biometrics within the EU large scale IT systems managed by the Agency
- Strengthening the engagement of the Agency with our stakeholders, especially in academia and science
- Collaborating/coordinating possible Pilot Projects and/or Proof of Concept projects with academia and industry in the field of biometrics

Just as a concrete example of my activities, last year, we conducted a pilot project with the Swedish Agency for Migration to assess the quality of fingerprints being acquired in Swedish consulates all over the world for the issuing of visas. The main goal of the project was to evaluate the performance of the User Software Kit (USK) that the Agency distributes to member states, and to establish quality thresholds in order to determine if fingerprints in visa applications were of sufficient quality to be processed and used by the central system for recognition purposes. As a side-result of the protocol, we also reached some very interesting findings regarding the quality of individual fingers that we published in a scientific conference paper.
To read more about these results, go to https://www.eulisa.europa.eu/Publications/Reports/eu-LISA%20Paper%202023%20-%20Fingerprint%20Quality.pdf

As I mentioned in one of my previous replies, while still being related to research, all these tasks and duties must have, at the

end of the day, a practical application. I know this may sound like a very "corporate" reply, but it is nonetheless a fact that, where the rubber meets the road, my main goal is to contribute to the overall mission of the Agency. That is, to improve the management and operation of the EU large-scale IT systems entrusted to eu-LISA. These systems are key building blocks to maintaining the Schengen area as an area of security, freedom and justice.

NEVES: Considering your extensive experience in academia and technical regulation, do you think there is still a gap between research and industry? If so, what strategies do you believe can contribute to closing the gap?

Galbally: Indeed there is a gap between research and industry. However, I am not sure if this gap should be closed. Both academia and industry are contributing pieces to the overall technology development cycle, and both are equally important. Research should keep exploring the limits of technology to push its boundaries ever a bit further. While in search of profits industry should apply reliable academic results to solve real-world problems.
Both have different, but perfectly legitimate objectives. And both are needed to keep advancing what technology is able to accomplish.

> "I think that communication between academia, industry, and the public sector is key. However, I do not think that academia should become industry, or the other way around."
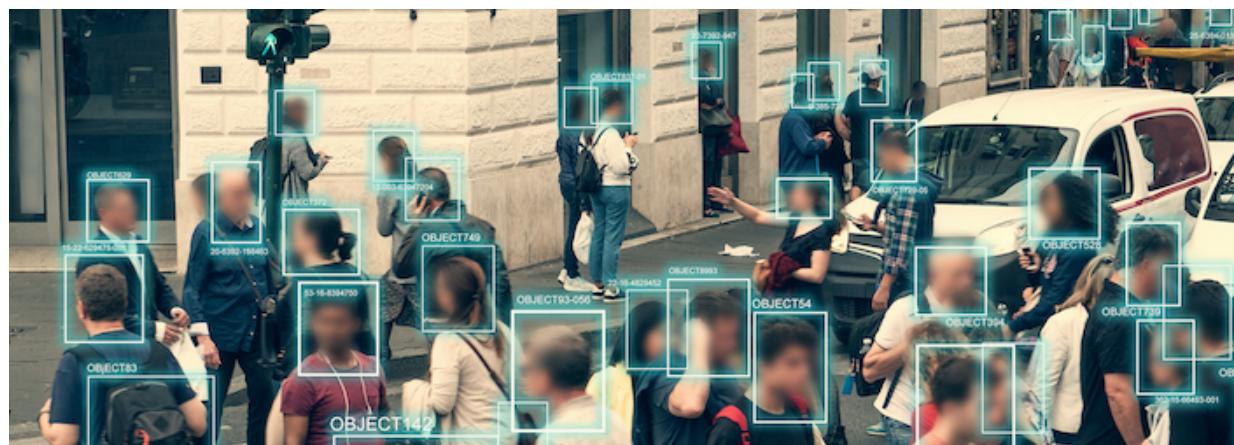
It is true that both "worlds" should not be fully independent. They should complement each other. It is absolutely necessary to establish communication channels between the two like the aforementioned EAB RPC. There should be fluent communication and exchange between industry and academia so that, from a high-level perspective, they jointly identify the priority problems of a given technology, and both work towards solving them. Academia looks for innovative, "geeky" new ways of addressing the challenges, even if many of these solutions may not be applicable to the real world. Meanwhile, industry identifies the best potential solutions that can be introduced to the market.
In summary, I think that communication between academia, industry, and the public sector is key. However, I do not think that academia should become industry, or the other way around.

NEVES: With the proliferation of AI media generation techniques, what do you foresee as the future of biometric recognition practices?

Galbally: It is always tricky to try to predict the future. I do not think that many people saw the boom of generative AI coming. However, if I had to guess, regarding biometrics:

- **Challenges:** Synthetically generated biometric samples will bring (or have already brought) an added layer of complexity to the protection of biometric systems. Potential threats carried out with this type of data include a vulnerability to morphing attacks that was disclosed just a few years ago. New detection and protection mechanisms will have to be developed.

- **Opportunities:** I do not think that everything is dark. Generative AI also opens a lot of doors to improve biometrics. For instance, it can help as a first step in the evaluation of algorithms and systems. Just as an example, demographic bias or the performance of quality measures could be estimated on synthetic data. It is clear that, at least for the foreseeable future, synthetic data should in no way "substitute" for real data in the evaluation of biometric technology. However, it can be of great help as a first step for the estimation of performance not only accuracy-wise, but also in terms of functions such as speed, computational efficiency, and processing time.

RESEARCHER ON THE RISE: *Chouyou Fu*

Interview conducted by Dr. Ruben Tolosana, *Assistant Professor of Biometrics and Data Pattern Analytics - BiDA Lab at the Universidad Autonoma de Madrid, Spain.*

Chaoyou Fu received his Ph.D. degree in pattern recognition and intelligent systems from the Institute of Automation of the Chinese Academy of Sciences in Beijing, China. Under the supervision of Professor Ran He, Fu has pursued research interests in biometrics and multimodal large language models. He now works on a unified solution for tasks such as biometrics through large models to better serve human life and security. To date, Fu has published a total of 18 papers in such publications as *IEEE Transactions on Pattern Analysis and Machine Intelligence* and *Transactions on Information Forensics and Security*. Representative works include "DVG-Face: Dual Variational Generation for Heterogeneous Face Recognition" and "MME: A Comprehensive Evaluation Benchmark for Multimodal Large Language Models." Fu's honors include the 2023 IEEE Biometrics Council Best Doctoral Dissertation Award.

TOLOSANA: You have worked on many different topics in the field of multimodality (vision+language) and biometrics. What is your advice for young PhD students on how to quickly get acquainted with, and contribute scientifically to, new research fields?

Fu: First, expand the breadth of your own research. For young PhD students, breadth of research is as important as depth. The latter is well understood, that is, to dig deeper into our own research direction and become an expert in the field. The former is easy to overlook because it is usually not directly related to our current research. If the breadth of the research is sufficient, on the one hand, it can bring a steady stream of inspiration to our main research direction, and on the other hand,

it can help us make a smoother transition when facing a new research direction.

The second is to find commonalities in the research. No matter what the research direction, there are always some common problems to be sorted out. For example, what are the main difficulties? What are the representative works? What training and testing data is needed? When I start a new investigative path, I usually do extensive research first and make a report to the advisor or my classmates in the form of a PowerPoint to help me deepen my understanding of the field.

Finally, we need to have some basic skills, such as the ability to read a paper, to quickly judge its quality, to find the most useful points and so on. There is also the

ability to write code, which allows us to "get our hands dirty" quicker. It is worth mentioning that social skills are also important, so we can quickly find friends in any new initiative who can help us adapt.

TOLOSANA: You have also published quite a bit in top conferences and journals during your Ph.D. studies, and you received the IEEE Biometrics Council Best Doctoral Dissertation Award in 2023. What are the strategies and key factors that have encouraged this level of productivity?

Fu: I always keep a constant stream of inspiration by reading papers extensively, which is probably the main reason I have been able to publish in some top conferences and journals. I maintain a habit of reading arXiv papers every day. I think it is the best channel to get the most cutting-edge research information. However, I caution that only senior students should read arXiv papers, because the quality can be uneven, and an ability to judge quality is required.

Second, every time I have a new idea, I quickly do experiments. Although most of these inspirations do not achieve the expected experimental effect, I still accumulate a lot of experience in the process, making the gap between inspiration and experimental implementation smaller. Even if only a small number of experiments have yielded positive results, they have been enough to inspire some high-quality papers.

In addition, I can quickly write papers by myself after the experiment has achieved certain results. With the help of my

advisor, my writing ability has been gradually improving. This relieves the pressure when I write papers, an effect which has been recognized by reviewers.

Finally, I usually collaborate with other friends, from whom I gain a lot of advice to improve my work.

TOLOSANA: What is the most valuable expertise you have gained during your Ph.D.? What would you change if you could return back?

Fu: The most valuable expertise I gained is how to learn. Especially in my first year of Ph.D., I clearly realized my shortcomings in paper retrieval, reading, writing, review, and rebuttal, as well as in coding ability. I fully understood that only by improving these skills would I become a qualified Ph.D., so I strengthened these abilities one by one. For example, in terms of paper reading and writing, I consulted with teachers and classmates who are very good at these practices. I would observe and imitate their reading habits step by step, and write down effective words and sentences in a notebook. In terms of paper review and rebuttal, I consulted my teachers to tap their rich experiences, and actively helped them do preliminary reviews of manuscripts. In terms of coding, I specifically looked for significant open-source projects, and volunteered to take on some coding tasks. After more than a year of comprehensive high-intensity training, I can clearly feel improvement in these abilities.

If I could return back, I would like to strengthen my ability at organization and

division of labor, which are needed to complete some of the larger and more complex projects in today's large models. Obviously in this day and age, it is very difficult to do much impactful work on one's own.

TOLOSANA: One of your current research topics is related to the use of Large Language Models (LLMs), such as GPT-4 from OpenAI and Gemini from Google. In your experience, can you tell us how LLMs are being exploited for biometrics in the industry?

Fu: At present, there is very little work on the combination of LLMs and biometrics. Here, I only offer some ideas in this direction. LLMs bring a tendency to solve all tasks through unified dialogue. From this perspective, traditional biometrics can be combined with LLMs to achieve some novel capacities. For example, given a picture, you can ask biometric-related questions, such as "Is there a basketball star in this picture?" and "Who looks younger in this picture?" In these tasks, we can use traditional biometric models and data to construct some question-answer pairs to train LLMs, or as auxiliary tools of LLMs. This combined system improves the biometric capabilities of LLMs, and is expected to provide a new paradigm for biometrics. That is, the task is done in an end-to-end question-and-answer manner, rather than through many single models and complex pipelines.

TOLOSANA: You are also an expert in face recognition and data generation. With the proliferation of AI media generation techniques, what problems in face recognition might be more solvable?

Fu: If the generated face is very normal, even if it is real, any help to the face recognition model will be limited. This is because today's face recognition models are already very powerful and can recognize these images easily, which means there will be little gain in recognition performance. However, if the generated faces are unconventional, such as the heterogeneous face images I studied, AI is expected to improve face recognition models. The heterogeneous face, like the portrait or near-infrared face, belongs to a relatively small data type, which is usually beyond the ability of current face recognition models. Therefore, generating a large number of unconventional face images as a training set is a good way to tackle such recognition problems.

TOLOSANA: If you had extra time and funds, which topic would be of your interest to you?

Fu: I would want to study brain science, because I still wonder why despite our models getting bigger and more intelligent, there is still a big gap from the level of human intelligence. This question has puzzled me for a long time, and I have yet to come up with a reliable answer. Studying brain science might give me some new ideas and inspiration.

Biometric Pioneers: *Davide Maltoni*

Interview conducted by Aparna Bharati, Assistant Professor of Biometrics and Data Pattern, Lehigh University, Bethlehem, PA

Davide Maltoni is a Full Professor in the Department of Computer Science and Engineering - DISI at the University of Bologna. His research interests are in pattern recognition, computer vision, machine learning, and computational neuroscience. Maltoni is co-director of the Biometric Systems Laboratory (BioLab), which is internationally known for its research and publications in the field. The BioLab team has proposed several original techniques for fingerprint feature extraction, matching and classification; for hand shape verification; for face location; and for performance evaluation of biometric systems. Maltoni is co-author of the *Handbook of Fingerprint Recognition,* which was published by Springer in 2022, and he holds three patents for fingerprint recognition products. He was elected as a Fellow of the International Association for Pattern Recognition in 2010.

BHARATI: Can you provide an overview of your research interests in the areas of pattern recognition, machine learning, computer vision, and computational neuroscience? How did these interests lead you to specialize in biometric systems?

Maltoni: Pattern recognition and computer vision have always been the main topics of my research activity. The interest in machine learning and neuro-inspired approaches is more recent, starting from around 2010. Biometrics was a perfect fit to apply the above techniques and, at the same time, to solve real problems. In fact, even if I like theory and elegant formal approaches, I get maximum satisfaction when the outcome of my research has practical applications.

BHARATI: As the co-founder and co-director of the Biometric Systems Laboratory (BioLab), could you share some insights into the laboratory's contributions and achievements in the field of biometrics, particularly in fingerprint recognition, face recognition, and hand recognition?

Maltoni: We did a lot of work on fingerprint recognition, including feature extraction, matching, classification and indexing. Our approach for direct gray-scale minutiae detection was able to work in real-time on 1997 PCs at a stage when existing techniques were much slower and less accurate. Minutiae Cylinder Code, introduced in 2010, is still a competitive fingerprint matching approach today. Our synthetic fingerprint generator (SfinGe) was adopted and used worldwide for testing/developing algorithms in large scale projects. We also worked on face detection

and recognition and, in 2014, introduced the Face Morphing attack.

BHARATI: Your involvement in organizing international competitions for fingerprint verification algorithms (FVC) is noteworthy. How have these competitions contributed to the advancement of fingerprint recognition technology, and what role do they play as benchmarks in the field?

Maltoni: Twenty-five years ago, independent evaluation of algorithms was not popular, and there was no way to really understand the accuracy of existing techniques, be they commercial or academic. FVC2000 was the first evaluation campaign—yes, we started before the National Institute for Standards and Technology—and, based on its success, has been followed by analogous events every two years. It was finally replaced by FvcOnGoing, which is still in use. FVC datasets have been used by thousands of researchers for the development and evaluation of their solutions.

BHARATI: In 2014, you demonstrated the feasibility of enrolling double-identity face biometrics in electronic documents to address morphing attacks. How has this research impacted the field of biometrics, and what are the challenges associated with securing facial biometrics against morphing attacks?

Maltoni: The impact is very relevant, and some real cases have been reported by police agencies in which fake electronic documents with morphed face images have been used to elude immigration controls. Detecting a good quality morphed image is quite complex and today's detectors are still

not mature enough and need to be improved.

BHARATI: Your role as the coordinator of various EU projects, such as BioSec, Fidelity, Ingress, State of the Art Morphing Detection (SOTAMD), and iMars, reflects substantial involvement in collaborative research. Could you share the story behind some of these collaborative efforts and the contributions of these projects to the field?

> **"Detecting a good quality morphed image is quite complex and today detectors are still not mature enough and need to be improved."**
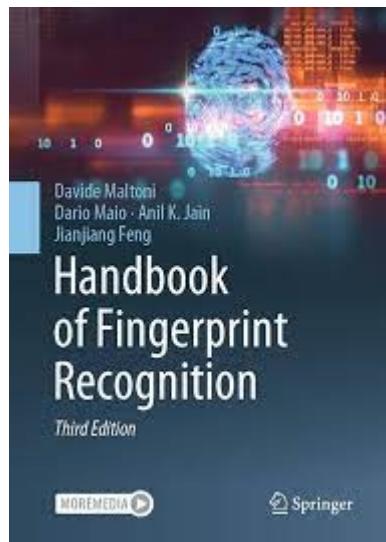
Maltoni: We always collaborated with other labs around the world. For example, FVC2000 was organized together with Anil K. Jain from Michigan State University. In the European landscape, together with other leading labs and companies, we were able to convince the European Commission to invest in the development of Biometrics. BioSec and Fidelity were focused on biometric security, while in SOTAMD and iMars, face morphing is the central topic.

BHARATI: Your book, *Handbook of Fingerprint Recognition*, has received significant honors, including the Professional and Scholarly Excellence award from the Association of American Publishers. How has the field of fingerprint recognition evolved since the publication of the first edition in

2003, and what motivated you to contribute to this area through a comprehensive handbook?

Maltoni: At that stage, in 2003, it was difficult to study all the literature and understand the pros and cons of existing techniques. Furthermore, many papers were not available online and it was very time consuming to collect information. Therefore, the first version of the handbook was an attempt to establish order in the field, and to provide a systematic framework in which to place all existing techniques, including historical white papers and technical reports by the FBI. The idea was to make things simpler for those approaching fingerprint recognition.

The book became popular and, after 6 years, we released a second edition. Writing a monographic book takes a lot of time and, in my mind, there would not have been a third edition. However, the advent of deep learning was a game changer for biometrics, and even though fingerprint recognition was less affected than other modalities, a book update was necessary. Therefore, a third (and last ;-)) edition was finally published in 2022.

BHARATI: Can you discuss any current or upcoming research projects or specific areas of interest that you find particularly exciting within the realm of biometric systems or related fields?

Maltoni: Today we have accurate biometric recognition approaches for most modalities, but their deployment in large scale projects requires solving security and privacy problems. Presentation Attack detection, deepfakes, and sample manipulations are fields where further research activity is needed, and where my lab is currently active.

BHARATI: With the rapid advancement of generative AI techniques, how do you see these models impacting the security, accuracy and reliability of fingerprint recognition systems in the future?

Maltoni: The impact is evident. The availability of powerful generative approaches, such as stable diffusion, allows for generating and manipulating biometric samples with unprecedented quality, and any designer of biometric systems cannot ignore this. Fortunately, AI also provides powerful techniques to fight against such security threats.

BHARATI: Considering the increasing use of mobile devices for biometric authentication, what are your thoughts on the security and usability trade-offs in implementing fingerprint recognition on smartphones and other portable devices?

Maltoni: Smartphones today are powerful enough to run most of the existing biometric algorithms. However, server side solutions

are sometimes preferred by vendors in order to collect user data, though hopefully only for training purposes. Of course, protecting the biometric data inside the device is central and I think that more independent auditing and post design inspection would be necessary to validate manufacturers' solutions.

BHARATI: With the growing interest in explainable AI and ethical considerations in technology, how do you approach ensuring transparency and ethical considerations in the development and deployment of biometric systems, especially in the context of data-driven learning-based algorithms?

Maltoni: I am a fan of explainable methods, and always try to open the "black box" and understand the decision process of an AI algorithm. This is not only for transparency and ethical considerations, but also for scientific curiosity and the possibility of improving algorithms based on the understanding of their limits.

LECTURE NOTES

By Emanuele Maiorana, Assistant Professor, Roma Tre University, Rome, Italy

Emanuele Maiorana is a tenure track Assistant Professor in the Department of Industrial, Electronic and Mechanical Engineering at Roma Tre University in Rome, Italy. His research interests include digital signal and image processing, with an emphasis on biometric recognition. Starting with the 2007 Lockheed Martin Best Paper Award for the Poster Track, Maiorana has received numerous honors, most recently the 2022 Best Paper Award at the IAPR International Conference on Pattern Recognition Applications and Methods. Maiorana has served as General Chair for the IAPR TC4 Workshop on Mobile and Wearable Biometrics at ICPR 2020 and the IEEE 9th International Workshop on Biometrics and Forensics in 2021, and will hold the same title for this year's IEEE 16th International Workshop on Information Forensics and Security. He has been an Associate Editor of the *IEEE Transactions on Information Forensics and Security* since 2020.

Advancements in biometric people recognition technologies have been remarkable, encompassing new developments not only in algorithmic development and application, but also in interaction paradigms between biometric systems and the individuals who provide the required physical or behavioral identifiers. Initially reliant on desktop solutions employing technologies like fingerprint, palmprint, or facial recognition, biometric systems primarily found application in scenarios such as forensic analysis and physical access control to restricted areas. However, with the evolving capabilities of smartphones over the past two decades, biometric authentication has become more accessible and widespread. This seamless integration with mobile devices not only democratized biometric authentication, but also brought it into the mainstream. Contemporary mobile devices commonly feature fingerprint sensors or facial recognition systems, providing users with convenient and highly secure methods to unlock their devices and access sensitive information with unparalleled security.

Biometric Potential for Wearable Devices

Considering the numerous technological innovations taking place nowadays, there are certainly many scenarios related to the possible future uses of biometric recognition technologies. Among these

scenarios, the next probable steps may revolve around wearable devices, often indicated as the next big thing in personal computing following the mobile technology revolution (Maiorana, 2022).[1]

Indeed, owing to their capability to track physical activity and health-related metrics, and coupled with potential integration into an Internet of Things (IoT) ecosystem for data exchange with other devices, wearable technology is experiencing a notable surge in popularity. Among wearable devices, earphones, wristbands, and smartwatches currently dominate the market, while headbands, chestbands, smart clothing, goggles, and headsets are also rapidly gaining traction among a broad user base.

The proliferation of these devices presents a significant opportunity to develop novel paradigms for biometric recognition systems. In turn, such developments could lead towards a more pervasive and integrated future. Indeed, numerous existing wearable devices inherently capture physical, behavioral, or cognitive traits. These capabilities could permit the extraction of distinctive features that can separate legitimate users from unauthorized attackers.

Wearable sensor systems can record physiological data that are typically difficult to capture from a distance. This makes them challenging to steal or replicate, and inherently facilitates liveness detection. Moreover, perhaps the most compelling capability of these devices is enabling continuous recognition without requiring users to specifically interact with the acquisition device. This is an important difference from traditional desktop or mobile recognition systems, and thus offers a convenient and user-friendly recognition process.

Continuous recognition using wearable devices

Many of the human characteristics wearable devices can record exhibit unique features even in the absence of specific activities, such as walking, talking, or gesturing. The majority of these traits are regulated by the autonomic nervous system (ANS), which is why their utilization for authentication purposes are often termed *cognitive biometrics* (Revett and de Magalhales, 2010).[2]

FROM THE HEART
Undoubtedly, the primary source of many of these traits lies in heart activity. The commonly associated signal is the electrocardiogram (ECG), which detects electrical changes resulting from cardiac muscle depolarization and repolarization during each heartbeat (Ye et al., 2011).[3] While ECG studies for biometric recognition have predominantly collected data utilizing medical equipment, numerous investigations have explored the feasibility of biometric recognition using wearable devices. These include chestbands (Lehmann and Buschek, 2020),[4] armbands, and electronic textiles (Pourbabaee et al., 2018).[5] The latter are fabrics embedded with electronics.

Another method of analyzing heart activity involves a photoplethysmogram (PPG), an

optical measurement of blood volume pulse variations due to the cardiac cycle (Yadav et al., 2021).[6] PPG is typically obtained by illuminating the skin, often on the wrist, with green, red, or infrared (IR) light. This modality holds significant promise for wearable biometric devices, as it is already integrated into many commercial products for monitoring fitness or health parameters (Retsinas et al., 2020).[7] Additionally, acoustic devices have been employed to gather heart-related information through phonocardiograms (PCGs). These devices can use either digital stethoscopes placed on the user's chest (Cheng et al., 2020),[8] or in-ear microphones tuned to capture sounds associated with the cardiac cycle (Cao et al., 2023).[9]

Apart from electrical, optical, and acoustic methods, inertial measurements have also been utilized to extract discriminative data from heart activity (Maiorana et al., 2023).[10] These methods detect vibrations caused by heart compressions, and produce seismocardiograms (SCGs) using accelerometers, or gyrocardiograms (GCGs) with gyroscopes.

BRAIN
Numerous studies have also been undertaken to extract distinctive insights from brain activity. Typically, collecting this data relies on non-invasive electrical measurements obtained through an electroencephalogram (EEG). As with heart activity, the majority of such investigations have utilized medical-grade acquisition devices. Yet, there have been attempts to use relatively affordable wearable sensors,

such as the single-electrode Neurosky MindSet or the Emotiv EPOC+ wireless headset (Arnau-Gonzalez et al., 2021).[11] Additionally, novel designs have been proposed to enhance EEG data collection, including the use of an in-ear sensor with dual EEG channels (Nakamura et al., 2018).[12]

BREATH, SKIN, AND SIGHT
Respiratory activity presents another avenue for biometric applications. These operations rely on chestbands equipped with pressure sensor gauge variations in rib cage cross-sectional areas. The resulting data reflects lung volume oscillations during breathing cycles (Raji et al., 2020).[13]

Traits associated with both cutaneous and subcutaneous tissues, which are collectible using wearable devices, have also been explored for biometric recognition purposes.

A notable skin-dependent cognitive trait, typically acquired using wristbands, is electrodermal activity (EDA). Also known as galvanic skin response (GSR), EDA measures the resistance of an electrical path along the skin surface over time (Piciucco et al., 2021).[14] It is a trait often considered for *affective computing* applications, as it depends on changes in eccrine sweat gland activity. As this activity is controlled by the sympathetic branch of the ANS—and therefore associated with the user's emotional state on a subconscious level—EDA is a reliable measure of physiological arousal and stress.

Other subcutaneous structures not directly dependent on the ANS have also been investigated for biometric purposes. For instance, the acoustic signals produced by earphones have been analyzed two different ways. Researchers have examined the spectra of otoacoustic emissions (OAE) produced by the cochlea (Liu et al., 2023),[15] or the frequency changes made by the human skull in response to sounds emitted and received by smart glasses frames (Schneegass et al., 2016).[16]

Even antenna sensitivity has been explored as a biometric trait. This can be done by measuring the return loss of wearable patches operating at 2.45 GHz, with the interaction depending on the subject's body tissues (Saadat et al., 2021).[17] Efforts have also been made to capture images of subcutaneous veins using wearable devices. However, the complexity of managing camera properties like focal length has limited progress in this area. So far, only one prototypical solution for capturing these images have been proposed (Akula et al., 2023).[18]

Lastly, the highly distinctive characteristics of the iris can nowadays be collected by wearable devices. While initial attempts to do so may have impaired vision significantly, advancements such as the Apple Vision Pro headset, coupled with the Optic ID application, now make this type of application a concrete possibility.

Aspects to be addressed

As a relatively new field of study, wearable biometrics presents several aspects that require thorough consideration before it can be widely used in real-world scenarios. One of the most crucial considerations is the stability of the distinctive properties extracted from the analyzed traits, particularly when dealing with cognitive characteristics. The long-term stability of these traits depends on various factors, including aging, personal habits like dietary choices, and even the placement of on-body sensors, which may vary significantly across different sessions. While longitudinal tests have been conducted at least once for most of the mentioned traits, time spans exceeding one week between acquisition sessions have been primarily explored only for ECG (Ye et al., 2011),[3] PPG (Retsinas et al., 2020),[7] and EEG (Arnau-Gonzalez et al., 2021).[11]

Furthermore, beyond assessing the stability of distinctive features, biometric traits collected for continuous recognition purposes should be checked for their ability to recognize a subject regardless of the ongoing activity. Typically, only a limited set of well-defined activities, such as sitting, standing, lying down, or walking, has been considered for such analyses. Conversely, recordings taken in uncontrolled environments, where subjects are not directed to perform specific activities, have been explored primarily for ECG (Lehmann and Buschek, 2020),[4] PPG (Yadav et al., 2021),[6] and EDA (Piciucco et al., 2021)[15] traits. Significant variations in recognition performance can be observed in such unsupervised scenarios, owing to potential discrepancies in physiological

characteristics used for enrollment and authentication.

Additionally, aside from the performed activity, several traits recorded by wearable devices may also be influenced by the subject's emotional state. This is demonstrated by wristbands collecting PPG and EDA datastate, warranting further investigation into this aspect.

Conversely, a capability that holds promise for developing efficient biometric systems using wearable devices lies in multimodality. As demonstrated by the success of wristbands collecting PPG and EDA data, it is indeed feasible to gather multiple physiological signals simultaneously using devices positioned on the head or wrist of an individual. The integration of various identifiers could significantly enhance the recognition performance of the developed systems (Ekiz et al., 2021).[21]

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NOTED IN THE LITERATURE

Audio-Visual Fusion for Emotional Recognition in the Valence-Arousal Space using Joint Cross-Attention

A summary of an article in the July 2023 issue of IEEE Transactions on Biometrics, Behavior, and Identity Science, prepared by its authors R.G. Praveen, P. Cardinal and E. Granger

INTRODUCTION

Automatic recognition and analysis of human emotions have drawn much attention over the past few decades. It has a wide range of applications in various fields, such as health care (anger, fatigue, depression and pain assessment), robotics (human-machine interaction), and driver assistance (driver condition assessment). Emotion recognition (ER) is a challenging problem since the expressions linked to human emotions are extremely diverse in nature across individuals and cultures. Recently, real-world applications have brought about a shift in affective computing research from laboratory-controlled environments to more realistic natural settings. This shift has further led to the analysis of a wide range of subtle, continuous emotional states elicited in real-world settings, such as pain intensity, and depression level estimations. Normally, continuous ER states are formulated as a dimensional problem in which complex human emotions can be represented in a dimensional space. Figure 1 illustrates the two-dimensional space representing emotional states, where valence and arousal are employed as dimensional axes. Valence reflects the wide range of emotions in the dimension of pleasantness, from being negative (sad) to positive (happy), whereas arousal spans the range of intensities from passive (sleepiness) to active (high excitement).

Human emotions can be conveyed through various modalities, such as the face, voice, text and physiology (electroencephalogram, electrocardiogram, etc.). Each modality typically carries different information, with vocal and facial modalities being the predominant contact-free channels in videos carrying complementary information. In this work, we investigated the prospect of efficiently leveraging the intra- and inter-modal A-V relationships captured in videos to improve capture performance beyond the capability of unimodal systems.
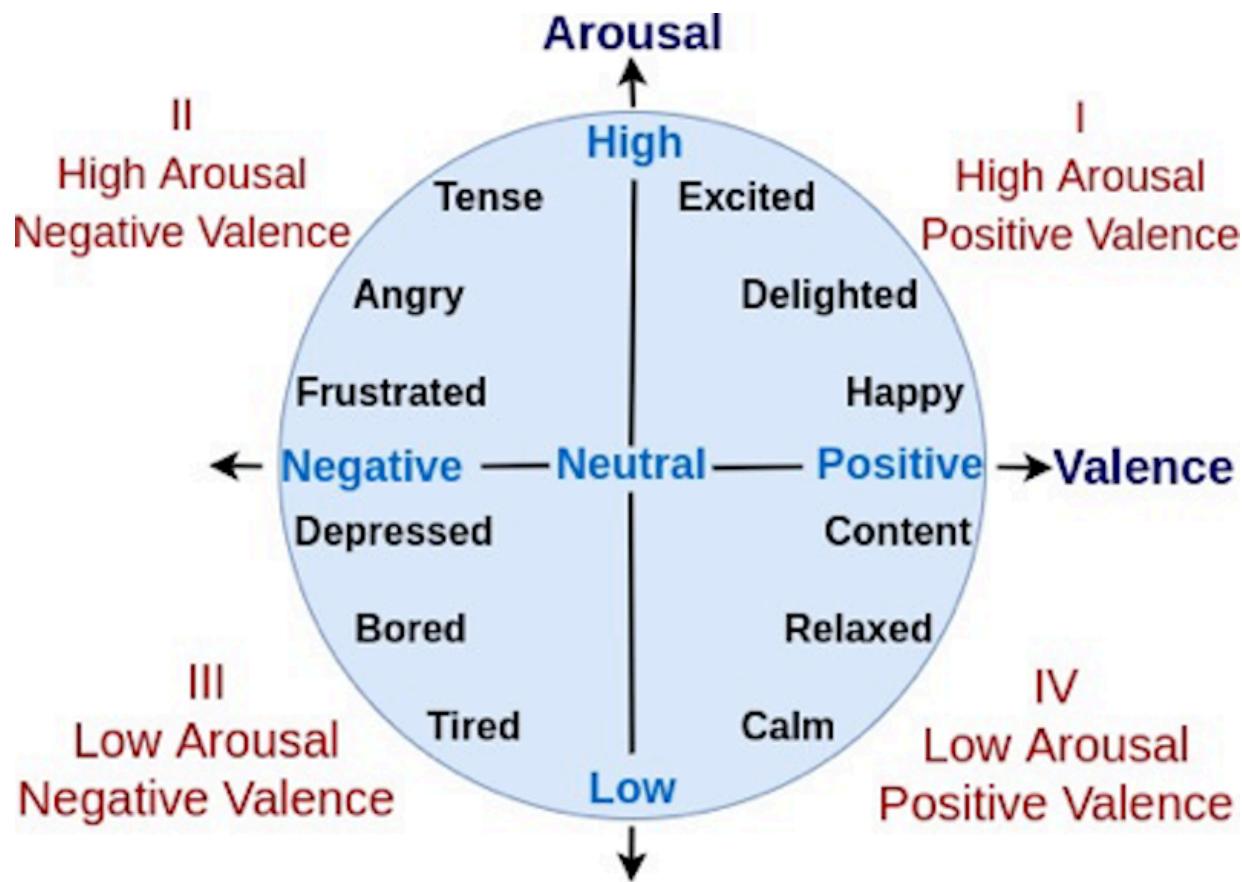
Figure 1: Valence-arousal space

PROPOSED METHOD

Given the set of video sequences, we extracted the audio and visual streams separately. The visual stream is preprocessed to obtain cropped and aligned images and the audio stream is processed to obtain spectrograms of the corresponding visual clips. The extracted materials were then fed to visual and audio backbones to extract the corresponding visual and audio

features, respectively, feeding the results to the joint cross-attentional model. Using this fusion model, we compute the attention weights for each modality based on the correlation across the joint feature representation (concatenated version) and
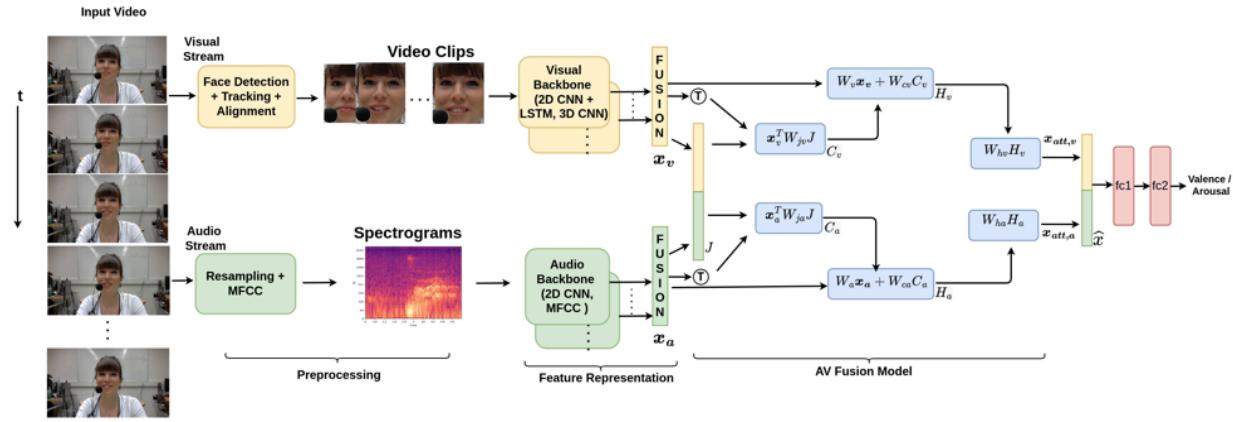
Figure 2. Joint Cross-Attention A-V Fusion model for dimensional emotion recognition

the individual modalities. Deploying the joint feature representation helps to leverage the temporal modeling of both intra- and inter-modal relationships for effective A-V fusion. A higher correlation measure shows that the corresponding features are highly related within the same modality, as well as with other modalities. These attention weights are used to modulate the corresponding audio and visual features, which are further concatenated and fed to the prediction layers for estimating valence and arousal.

RESULTS
For better understanding of the proposed approach, we provide in Figure 3 a visualization of the attention scores of the proposed approach, as well as vanilla Cross Attention (CA) for both modalities. We can observe that the proposed model focuses on visual modality when the person smiles, as the facial muscles around his nose and mouth significantly change over time. The vanilla CA model fails to focus on some of the important clips of visual modality. Similarly, the proposed model assigns high attention score for audio modality when the person exhibits significant modulation of vocal expressions.

In addition to the attention scores of A and V modalities, we also visualize the valence and arousal predictions over time for videos of the Affwild2 dataset. The proposed Joint Cross Attention (JCA) model is able to capture the contextual relationships between A and V modalities better than that of vanilla CA, which enhances performance. As shown in Fig. 4, we can observe that both the JCA and vanilla cross-attention models are able to track the ground truth for valence and arousal. Yet, when a fully frontal face is not available (due to pose

variations), the predictions of the proposed JCA model closely follow the ground truth better than that of vanilla CA, especially for valence.
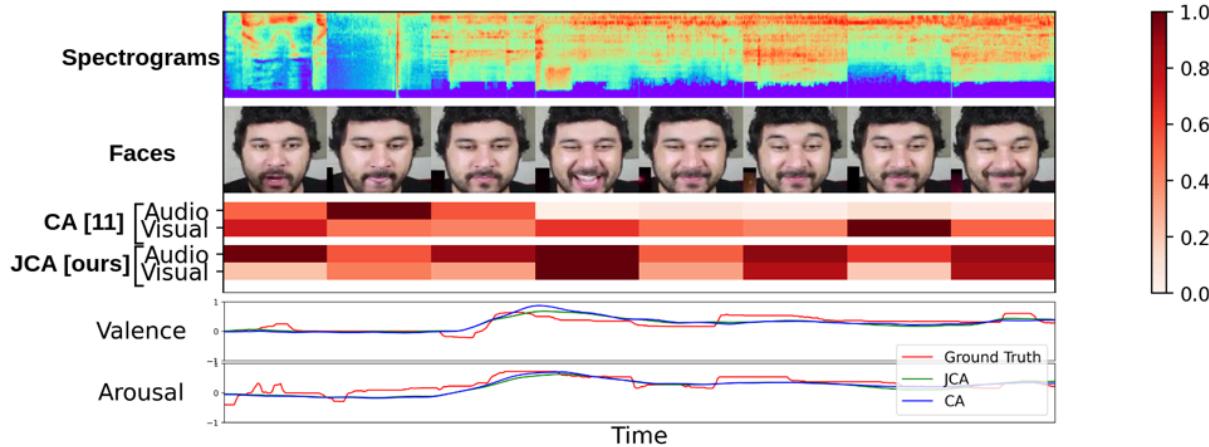
Figure 3: Visualization of the attention scores of our proposed approach

CONCLUSION

In this paper, a JCA fusion model is explored for video based dimensional ER. By jointly modeling the inter and inter-modal relationships, features of each modality attend to the other modality as well as itself, resulting in robust audio and visual feature representations. Results show that the proposed model is a cost-effective approach that can outperform the state-of-the-art. It encodes inter-modal relationships, while sustaining a high level of performance, even when audio segments are noisy and absent. Although the JCA fusion model has been proposed for dimensional emotion recognition, it can also be explored for other applications pertinent to audio visual fusion, such as identity verification, event localization, etc.

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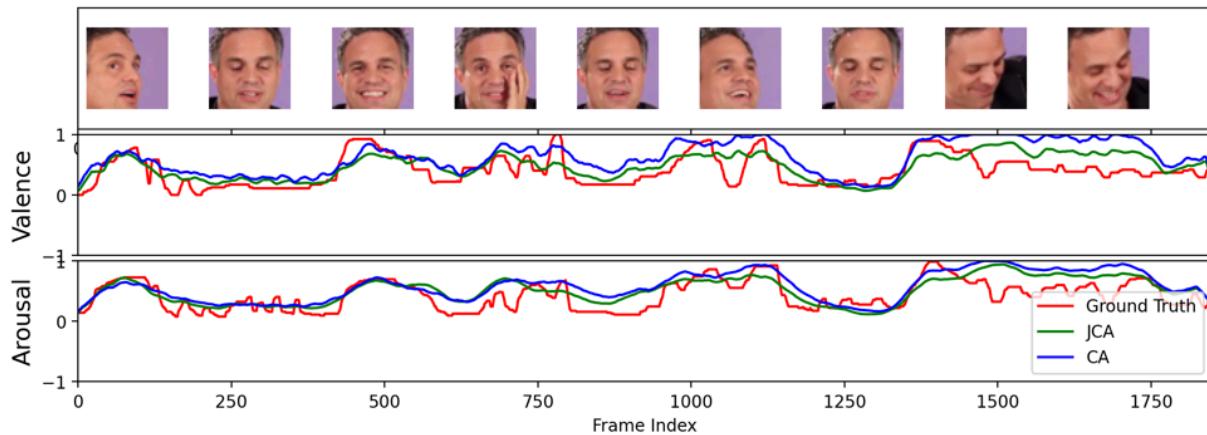
Figure 4: Visualization of the predictions of valence and arousal of our proposed approach

R.G. Praveen, P. Cardinal and E. Granger, "Audio-Visual Fusion for Emotion Recognition in the Valence–Arousal Space Using Joint Cross-Attention," in *IEEE Transactions on Biometrics, Behavior, and Identity Science*, vol. 5, no. 3, pp. 360-373, July 2023, doi: 10.1109/TBIOM.2022.3233083

DATABASE DIGEST

Face Recognition Challenge in the Era of Synthetic Data (FRCSyn)

By Emanuela Marasco, Assistant Professor, Information Sciences and Technology Department and Center for Secure Information Systems, George Mason University, Fairfax, VA, USA

FRCSyn is the first international challenge focused on exploring the use of synthetic data to address limitations in face recognition, such as data privacy, demographic biases, generalization to unseen scenarios, and performance in challenging situations like age disparities, pose variations, and occlusions. The challenge aims to address two main research questions:

1) Can synthetic data effectively replace real data for training FR systems, and what are the limitations of FR technology exclusively trained with synthetic data?

2) Can the utilization of synthetic data be beneficial in addressing and mitigating existing limitations within FR technology?

Organizers provide competition participants with two novel synthetic databases, DCFace and GANDiffFace, to address common challenges in FR, such as imbalanced demographic distributions, pose variation, expression diversity, illumination and occlusion. DCFace and GANDiffFace each contain 10K identities with 50 images per identity representing a diverse range of demographic groups, including variations in ethnicity, gender and age. GANDiffFace synthetic data was generated by combining GANs with diffusion models.

Real data is also provided, including:
● CASIA-WebFace containing ~494K facial images
● FFHQ with 70K high quality images
● BUPT-BalancedFace, created to address performance disparities across different ethnicity groups, and consisting of 24K identities with 45 images per identity
● AgeDB 570 IDx29, CFP-FP 500IDx14, and ROF 180 identities with 31 images per subject.

Figure 1: Examples of Synthetic Data

The first task in the challenge explores the use of synthetic data to address demographic biases in FR systems. The second task explores the application of synthetic data to enhance overall performance in FR under challenging conditions. The baseline is obtained by training only with CASIA-WebFace and FFHQ, while the competition is based on accomplishing two subtasks by training exclusively with synthetic databases, and with both real and synthetic data.

The paper is available for download at https://github.com/zws98/wacv_frcsyn.

SOURCE MATERIAL: P. Melzi, et al. "FRCSyn Challenge at WACV 2024: Face Recognition Challenge in the Era of Synthetic Data." *Proceedings of the IEEE/CVF Winter Conference on Applications of Computer Vision***, 2024.**

SOURCE CODE

Overcoming the Challenge of Generalisation in Deepfake Detection

By Chiara Galdi, Assistant Professor, EURECOM, Biot, France

Generalisation of artificial intelligence models refers to an algorithm's ability to perform well on new and unseen data beyond the specific examples on which it was trained. This attribute is fundamental to the usefulness of artificial intelligence models in real-world applications, as it ensures that the model can adapt to the variability and complexity of data it was not explicitly programmed to handle. The challenge is to balance the model's ability to learn from the training data without overfitting, thus maintaining sufficient flexibility to effectively apply the learned models to new situations.

The challenge of generalisation in deepfake detection—the identification of synthetic media in which a person's appearance has been altered or generated through artificial intelligence—stems from the detector's ability to work consistently across new identities and contexts. Many models struggle due to their dependence on specific features or biases learned during the training process. This problem underlines the importance of developing detection methods that generalise well across different datasets and real-world scenarios.

The *ID-unaware Deepfake Detection Model* addresses the challenge of generalising deepfake detection by building on the knowledge that binary classifiers are sensitive to identity information and tend to develop biases towards specific identities. This phenomenon, termed "Implicit Identity Leakage" was introduced in a presentation at the 2023 *IEEE/CVF Conference on Computer Vision and Pattern Recognition* in Vancouver, BC, Canada [1]. The official implementation of the model is now hosted on a GitHub repository by Renhe Ji (MEGVII Technology) [2]. To mitigate "Implicit Identity Leakage," the authors introduce a method that significantly reduces the influence of identity representation, thereby improving performance compared to existing strategies. This method is based on the observation that object detection modules focus on local areas of images, instead of the global representation. Thus, the model focuses on local artefacts, as local areas usually do not reflect the identity of images.
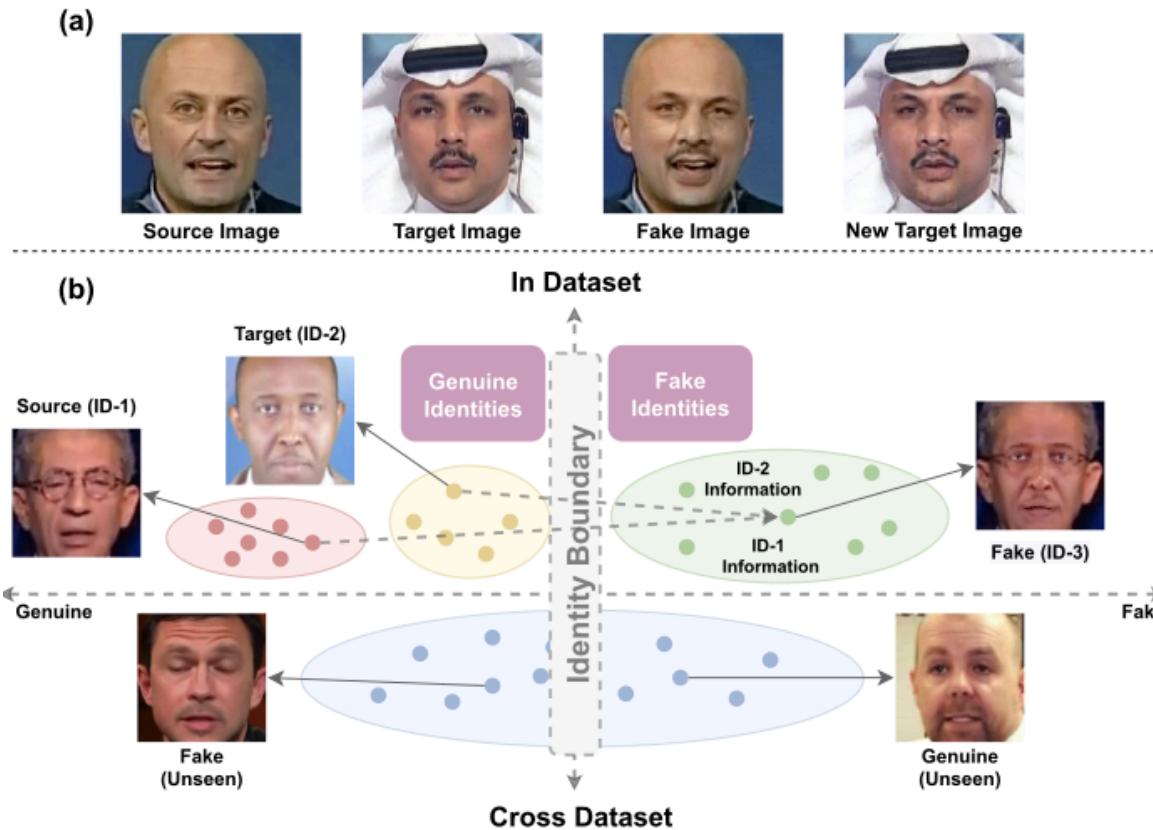
Figure 1. An illustration of the Implicit Identity Leakage phenomenon as presented in S. Dong et al. [1]

The repository includes code for training and testing the model, as well as pre-trained weights and detailed instructions for data preparation and evaluation.

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2) "Official implementation of ID-unaware Deepfake Detection Mode,"CADDM. https://github.com/megvii-research/CADDM

COMMERCIAL OFF-THE-SHELF SYSTEMS

Tobii's Advanced Solutions in Eye-Tracking and Multimodal Analysis

By Chiara Galdi, Assistant Professor, EURECOM, Biot, France

Eye-tracking technology captures and analyses where and how we look at visual objects, providing deep insights into human behaviour and cognitive processes. By monitoring eye movements, researchers can infer a person's concentration, attention and level of engagement. This technology has a variety of applications ranging from improving user experience by better understanding interactions with digital interfaces, to aiding in medical diagnostics, particularly in identifying cognitive disorders. Furthermore, in education, eye-tracking helps personalise learning experiences by understanding how students engage with study materials.

Eye movements, including micro-movements such as nystagmus, offer unique patterns that can be exploited for biometric recognition. These involuntary, rapid, oscillatory eye movements are unique to each individual, just like fingerprints.

Known for offering advanced eye-tracking and behavioural research solutions, Tobii [1] products enable comprehensive analysis through multimodal data collection. Multimodal biometrics refers to the integration and use of multiple biological or behavioural traits for identification or verification purposes. These solutions typically integrate eye-tracking with data from other biometric sources, an approach that increases security and accuracy by reducing the probability of false positives or negatives.

One of the company's products, Tobii Pro Lab [2], is useful for researchers and practitioners who wish to integrate eye tracking with EEG or other biometric data for comprehensive analysis. It is particularly helpful to those who wish to segment data based on gaze behaviour, discard non-targeted gaze data, or conduct fixation-related potential analysis. With the ability to record eye-tracking data in Tobii Pro Lab and synchronise it with partner software data, users can ensure accurate data fusion. The solution supports advanced analysis functions and offers an easy-to-use export format for seamless integration with external analysis tools.

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BIOMETRIC COMPENDIUM ALERT
February 2024

By Dr. Carmen Bisogni, Research Fellow, Biometric and Image Processing Laboratory, University of Salerno, Salerno, Italy, and Dr. David Freire-Obregón, Associate Professor, University of Las Palmas de Gran Canaria, Gran Canaria Island, Spain

Below is a list of the latest papers addressing topics in biometrics that have been accepted (via early access) or published in various IEEE Journals.

BIOMETRICS ENCRYPTION AND TEMPLATE SECURITY

1. L. Zhang, A. Li, S. Chen, W. Ren and K-K.R. Choo, "A Secure, Flexible, and PPG-Based Biometric Scheme for Healthy IoT Using Homomorphic Random Forest," in *IEEE Internet of Things Journal*, vol. 11, no. 1, pp. 612-622, 1 Jan.1, 2024. DOI: 10.1109/JIOT.2023.3285796

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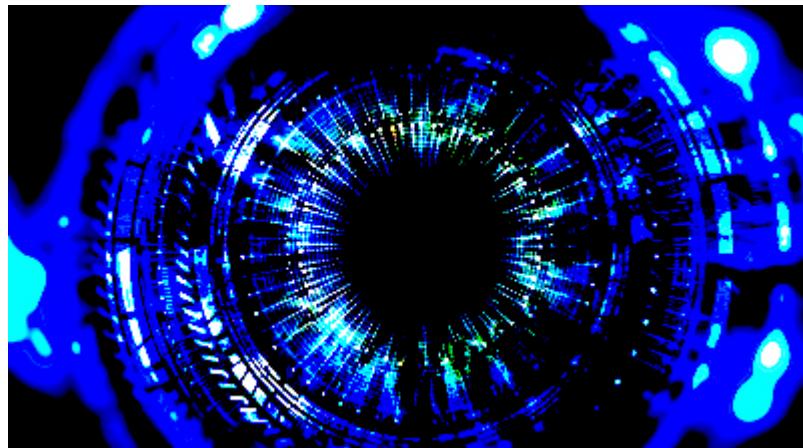
DATASETS AND OVERVIEW SURVEY

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IEEE TRANSACTIONS ON BIOMETRICS, BEHAVIOR AND IDENTITY SCIENCE

January 2024

Data and Algorithms for End-to-End Thermal Spectrum Face Verification
Thirimachos Bourlai; Jacob Rose; Suha Reddy Mokalla; Ananya Zabin; Lawrence Hornak; Christopher B. Nalty; Neehar Peri; Joshua Gleason; Carlos D. Castillo; Vishal M. Patel; Rama Chellappa
Publication Year: 2024, Page(s):1 - 14

Explaining Deep Face Algorithms Through Visualization: A Survey
Thrupthi Ann John; Vineeth N. Balasubramanian; C. V. Jawahar
Publication Year: 2024, Page(s):15 - 29

AFR-Net: Attention-Driven Fingerprint Recognition Network
Steven A. Grosz; Anil K. Jain
Publication Year: 2024, Page(s):30 - 42

Multimodal Person Verification With Generative Thermal Data Augmentation
Madina Abdrakhmanova; Timur Unaspekov; Huseyin Atakan Varol
Publication Year: 2024, Page(s):43 - 53

Considerations on the Evaluation of Biometric Quality Assessment Algorithms
Torsten Schlett; Christian Rathgeb; Juan Tapia; Christoph Busch
Publication Year: 2024, Page(s):54 - 67

2D-SNet: A Lightweight Network for Person Re-Identification on the Small Data Regime
Wei Li; Shitong Shao; Ziming Qiu; Zhihao Zhu; Aiguo Song
Publication Year: 2024,P age(s):68 - 78

Ethnicity and Biometric Uniqueness: Iris Pattern Individuality in a West African Database

John Daugman; Cathryn Downing; Oluwatobi Noah Akande; Oluwakemi Christiana Abikoye

Publication Year: 2024,Page(s):79 - 86

Cancelable Face Recognition Using Deep Steganography

Koichi Ito; Takashi Kozu; Hiroya Kawai; Goki Hanawa; Takafumi Aoki

Publication Year: 2024,Page(s):87 - 102

3-D Face Morphing Attacks: Generation, Vulnerability and Detection
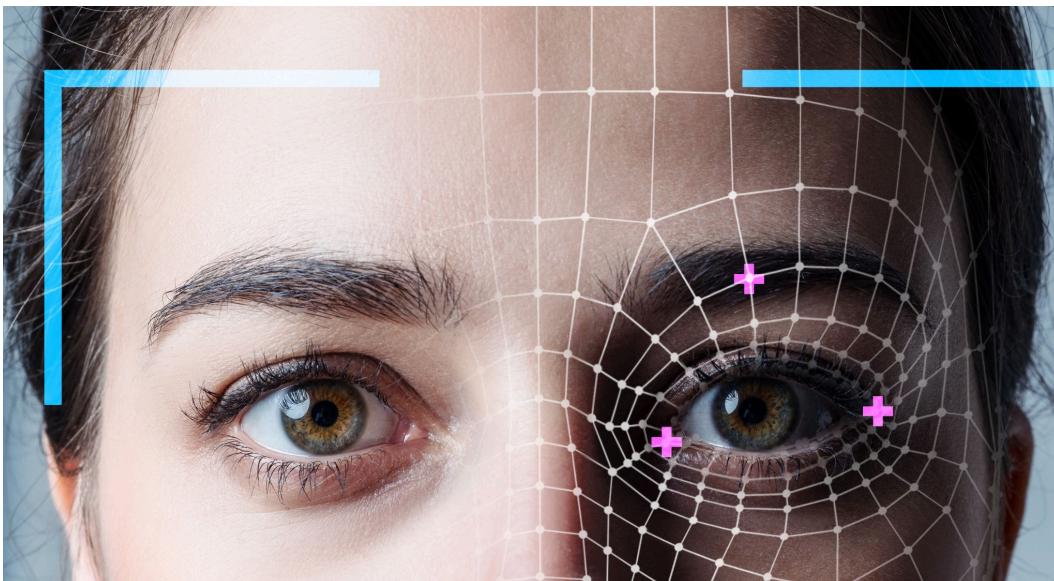
Jag Mohan Singh; Raghavendra Ramachandra

Publication Year: 2024,Page(s):103 - 117

Leveraging Diffusion for Strong and High Quality Face Morphing Attacks

Zander W. Blasingame; Chen Liu

Publication Year: 2024,Page(s):118 - 131

CATFace: Cross-Attribute-Guided Transformer With Self-Attention Distillation for Low-Quality Face Recognition

Niloufar Alipour Talemi; Hossein Kashiani; Nasser M. Nasrabadi

Publication Year: 2024,Page(s):132 - 146

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Call for Contributions

IJCB 2024 is intended to have a broad scope and invites papers that advance biometric technologies, sensor design, feature extraction and comparison algorithms, security and privacy, and social impact of biometrics technology. Topics of interest include, but are not limited to:

- Face, Iris, Fingerprint, Palmprint
- Periocular, Ear, Vein, Speech
- Behavioral and Gait Recognition
- Human Action Recognition
- Multi-modal and Multi-Spectral Biometrics
- Mobile-based Biometrics
- Biometrics at Altitude and Range
- Attribute Prediction via Biometric Modalities
- Template Protection and Cryptosystems
- Privacy, Demographic Bias, Fairness
- Biometrics Explainability and Interpretability
- Template Design, Selection and Update
- Datasets, Evaluation, Benchmarking
- Performance Modeling and Prediction
- Large Scale ID Management
- Presentation Attack Detection (e.g. Anti-spoofing), Morphing Attack Detection
- Biometric DeepFakes, Digital Data Forensics
- Biometric-related Law Enforcement and Forensics
- Biometrics in Healthcare, Banking, IoT
- Synthetic Data & Realities for Biometrics
- Ethical, Social and Legal Issues
- Biometrics for Social Good

Paper Submission

Submitted papers may not be accepted or under review elsewhere. Submissions may be up to eight pages, plus additional references, in IEEE conference format. Please visit the submission page for additional details on paper formatting. Accepted papers will be submitted for inclusion into IEEE Xplore Xplore's scope and quality requirements. Submission is through CMT - https://cmt3.research.microsoft.com/IJCB2024/.

Awards and TBIOM Special Issue

Several awards will be given out to the best papers from IJCB 2024, including (1) Best Paper award, (2) the Best Student Paper award, (3) Daily Best Poster awards.

The awards will consist of a commemorative plaque as well as award money. Additionally, the authors of the best-reviewed papers will be invited to submit an extended version of their paper to a special issue of the *IEEE Transactions on Biometrics, Behavior, and Identity Science* (IEEE-TBIOM).

Timeline
Paper submission deadline: **March 15, 2024**
Supplementary material: **March 22, 2024**
Special session proposal deadline: **April 24, 2024**
Review comments to authors: **April 30, 2024**
Rebuttal deadline: **May 7, 2024**
Decisions to authors: **May 17, 2024**
Camera-ready papers due: **June 30, 2024**
More details can be found at https://ijcb2024.ieee-biometrics.org/ .

CALL FOR CONTRIBUTIONS AND PARTICIPATION

18th IEEE International Conference on Automatic Face and Gesture Recognition
27-31 May 2024, Istanbul, Türkiye

https://fg2024.ieee-biometrics.org/

The 18th IEEE International Conference on Automatic Face and Gesture Recognition, which will be held 27-31 May 2024 in Istanbul, received 300 submissions for the main conference. The program includes keynotes by Mohamed Daoudi, Beatrice de Gelder, and Shiguang Shan, as well as an "Ask me Anything" session with Takeo Kanade. The call for papers is still out for the seven workshops organized at FG'24. These will be held on either May 27 or May 31, 2024, in the same venue as the FG 2024 main conference (the exact program will be

announced closer to the conference). Workshop papers will be published with the main conference proceedings.

IEEE BC will make **Diversity, Equity and Inclusion Grants** available to support the participation of researchers who self-identify as marginalised and/or underrepresented in the community (e.g., scholars who come from non-WEIRD – Western, Educated, Industrialized, Rich, Developed – societies, scholars from LGBTQ+ and underrepresented ethnic backgrounds) and who lack other funding opportunities to support their participation. Further information is available on the FG DEI website.

The FG'24 conference features three competitions:

1. The **Synthetic Data for Face Recognition Competition** invites teams to propose clever ways to use synthetic face recognition datasets (either existing or new datasets) to train face recognition models. The competition is split into two tasks, where the first task involves a predefined face recognition backbone and limits the dataset size to focus on the quality of synthesized face datasets, while the second task provides almost complete freedom on the model backbone, the dataset and the training. Website: https://www.idiap.ch/challenge/sdfr/
2. **REACT 2024 - The Second REACT Challenge** focuses on developing generative models that can automatically output multiple appropriate, diverse, realistic and synchronised facial reactions under both online and offline settings. The challenge encourages the participants to generate realistic images and video clips as results of their submission. Website: https://sites.google.com/cam.ac.uk/react2024/home
3. The **Brain Responses to Emotional Avatars Challenge** shares a special database collected from 40 subjects with an EEG device. The subjects are asked to show emotions they see on an avatar's face on the screen. The objective of this challenge is to conduct an analysis of EEG signals in order to accurately identify and classify different emotional states. Website: https://voxellab.pl/EmoNeuroDB/

The FG 2024 is also hosting a series of workshops on recent and new topics in face and gesture recognition, biometrics, applications and related emerging topics. Please refer to the workshop links below for the exact submission deadlines in March.

1. Fourth Workshop on Applied Multimodal Affect Recognition - https://cse.usf.edu/~tjneal/AMAR2024/

2. SkatingVerse: Segmentation and Assessment of Continuous Video in Figure Skating Competition and the 1st SkatingVerse Workshop & Challenge – https://skatingverse.github.io/

3. Second Workshop on Learning with Few or without Annotated Face, Body and Gesture Data – https://sites.google.com/view/lfa-fg2024/home

4. Advancements in Facial Expression Analysis and Synthesis: Past, Present, and Future – https://sites.google.com/view/afeas-24/home

5. Second Workshop on Privacy-aware and Acceptable Video-based Assistive Technologies – https://goodbrother.eu/conferences/privaal2024/

6. Synthetic Data for Face and Gesture Analysis – https://sites.google.com/view/sd-fga2024/

7. First International Workshop on Responsible Face Image Processing – https://responsiblefaceimageprocessing.github.io/fg2024/

UPCOMING CONFERENCES IN 2025

IJCB 2025 is planned for 8-11 September 2025 (tentative dates), in Osaka, Japan. The general chairs are Yasushi Yagi (Osaka University), Mark Nixon (University of Southampton), Hitoshi Imaoka (NEC), and Md Atiqur Rahman Ahad (University of East London). Program chairs are Vitomir Štruc (University of Ljubljana), Karthik Nandakumar (Mohamed Bin Zayed University of Artificial Intelligence), Xiangyu Zhu (Chinese Academy of Sciences), and Lale Akarun (Bogazici University).

FG 2025 will be held between 12-15 May 2025 (tentative dates), in Tampa/Clearwater, USA. The general chairs are Shaun Canavan (University of South Florida), Lijun Yin (Binghamton University), and Mohamed Daoudi (IMT Nord Europe), and the program chairs are Tempestt Neal (University of South Florida), Jeffrey Girard (University of Kansas), Shiguang Shan (Chinese Academy of Sciences), and Zakia Hammal (Carnegie Mellon University).

IBCN EDITORIAL REVIEW BOARD

Many thanks to those who contributed articles to this issue:

Dr. Fernando Alonso-Fernandez, who curated the article selected for this issue's ***Noted in the Literature*** section.

Dr. Aparna Bharati, who interviewed Dr. Davide Maltoni, Professor at the University of Bologna, Italy, for the ***Biometric Pioneers*** column.

Dr. Carmen Bisogni, and **Dr. David Freire-Obregón,** who compiled the items in the ***Biometric Alerts*** column.

Dr. Chiara Galdi, who selected and prepared both the ***Source Code*** and ***Commercial Off-the-Shelf Systems*** biometric products columns.

Dr. Emanuele Maiorana, who selected and compiled the items for our ***In the News*** section, and wrote the ***Lecture Notes*** article on the biometric potential for wearable devices.

Dr. Emanuela Marasco, who summarized a presentation by Melzi et al. for our ***Database Digest*** section.

Dr. João Neves, who interviewed Dr. Javier Galbally for our ***Expert Perspectives*** column.

Thomas Swearingen, who interviewed and compiled responses from grant recipients to the Winter School on Biometrics.

Dr. Ruben Tolosana, who interviewed recent Ph.D. graduate Chouyou Fu for the ***Researcher on the Rise*** section.

Dr. Raymond Veldhuis, Professor, University of Twente, Enschede, The Netherlands, who wrote the profile on the **Privacy Matters** program.

Dr. Shiqi Yu, Associate Professor of Computer Science and Engineering, Southern University of Science and Technology, Shenzhen, China, who authored the ***Special Feature*** article on the Winter School on Biometrics