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Forensic Imaging Techniques - an exploration of their potential as standalone tools and within a multimodal approach

Book of Abstracts

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PROGRAM

	5th November	6th November	7th November	8th November
8:00 – 9:00	Registration	Registration		
9:00 – 10:30	WG1 and WG2 meeting	09:00 – 09:10 Welcome 09:10 – 09:50 R. Heeren 09:50 – 10:10 A. Becue 10:10 – 10:30 C. Costa	09:00 – 09:30 E. Cyupers 09:30 – 09:50 J. Weerd 09:50 – 10:10 A. Udal 10:10 – 10:30 A. Meller	WG1 and WG2 networking
10:30 -11:00	Coffee break	Coffee break	Coffee break	
11:00-12:30	WG1 and WG2 meeting	11:00 – 11:30 M. Tistarelli 11:30 – 11:50 N. Passalis 11:50 – 12:10 H.K. Ekenel 12:10 – 12:30 B.A. Assanovich	11:00 – 11:30 F. Falchi 11:30 – 11:50 C. Vairo 11:50 – 12:10 A. Vadalazau 12:10 – 12:30 H.K. Ekenel	
12:30 – 14:00	Lunch	Lunch	Lunch	
14:00 – 15:30	MC Meeting	14:00 – 14:30 M. Bailey 14:30 – 14:50 M. Algarra 14:50 – 15:10 C. Villa 15:10 – 15:30 M. Ristova	14:00 – 14:20 M. Hain 14:20 – 14:40 M. Barac 14:40 – 15:00 J. Spigulis	
15:30-16:00	Coffee break	Coffee break	Guided tour + social dinner	
16:00 –18:00	MC Meeting	16:00 – 16:20 S. Francese 16:20 – 16:40 T. Fischer 16:40 – 17:00 B. Majaron 17:00 – 17:20 I. Safarik		

Monday - 5/11/2018

09:00 – 10:30 WG1 and WG2 meetings

10:30 – 11:00 Coffee break

11:00 – 12:30 WG1 and WG2 meetings

12:30 – 14:00 Lunch

14:00 – 15:30 MC Meeting

15:30 – 16:00 Coffee break

16:00 – 18:00 MC Meeting

Tuesday 6/11/2018

09:00 – 09:10 Welcome

09:10 – 9:50 Plenary talk: Ron Heeren - Resolving complexity with molecular imaging for forensic research

09:50 – 10:10 Andy Bécue - Investigation into the use of MALDI-MSI to monitor the variability of composition of fingermarks between donors and over time

10:10 – 10:30 Catia Costa - Imaging of fingerprints using secondary ion mass spectrometry (SIMS)

10:30 – 11:00 Coffee break

11:00 – 11:30 Invited talk: Massimo Tistarelli - Human Face Recognition: Potential, Challenges and Future Developments

11:30 – 11:50 Nikolaos Passalis - Fast Face Image Retrieval using Probabilistic Knowledge Transfer

11:50 – 12:10 Hazım Kemal Ekenel - Deep Face Embedding for Low Resolution Face Recognition

12:10 – 12:30 Boris A. Assanovich - Biometric Scheme Based on Non-Binary Turbo Codes

12:30 – 14:00 Lunch

14:00 – 14:30 Invited talk: Melanie Bailey - New approaches in microscale mass spectrometry: from fingerprints to organelles

14:30 – 14:50 Manuel Algarra -_Fingerprints Images based on Biocompatible Carbon Dots

14:50 – 15:10 Chiara Villa - Virtual 3D reconstruction of a controlled bus bombing

15:10 – 15:30 Mimoza Ristova SEM/EDX analysis of the dental cementum to establish one human's lifestyle for forensic applications (pilot study)

15:30 – 16:00 Coffee break

16:00 – 16:20 Simona Francese - Investigation of infinite focus microscopy for the determination of the association of blood with fingermarks

16:20 – 16:40 – Thomas Fischer - Specific identification of blood stains by means of multispectral classification techniques

16:40 – 17:00 – Boris Majaron - Toward objective assessment of bruise age by combining diffuse reflectance spectroscopy and photothermal radiometry

17:00 - 17:20 - Ivo Safarik - Magnetic textile solid phase extraction for the preconcentration of target analytes

Wednesday 7/11/2018

09:00 – 09:30 Invited talk: Eva Cyupers - Potential of imaging mass spectrometry in forensic toxicological services

09:30 – 09:50 Jaap van der Weerd- SHUTTLE: a European Toolkit for Trace analysis

09:50 – 10:10 Andres Udal - Multi-Modal Sensor Data Fusion in City Environment Monitoring Projects SMENETE and IMO

10:10 – 10:30 Amit Meller - Nanopores for ultra-sensitive sensing of minute DNA samples

10:30 – 11:00 Coffee break

11:00 – 11:30 Invited talk: Fabrizio Falchi - Attacking deep neural networks with adversarial images

11:30 – 11:50 Claudio Vairo - Facial-based Intrusion Detection System with Deep Learning in Embedded Devices

11:50 – 12:10 Artsemi Vadalazau - Special computer program to solving the problem of localization of poor informative fingerprints

12:10 – 12:30 Hazım Kemal Ekenel - A Comprehensive Analysis of Ear Biometry

12:30 – 14:00 Lunch

14:00 – 14:20 Miroslav Hain - Forensic study of paper documentation for contractual fraud revelation purposes

14:20 – 14:40 Marko Barac - Determination of deposition order of different ballpointpen inks, inkjet inks and laser toners – comparison of MeV SIMS and standard forensic techniques

14:40 – 15:00 Janis Spigulis - Snapshot triple spectral line imaging for counterfeit detection

17:00 Guided tour of old city + social dinner

Thursday 8/11/2018

9:00 – 12:00 WG1 and WG2 networking

Resolving complexity with molecular imaging for forensic research

R.M.A Heeren

M4I, Imaging Mass Spectrometry (IMS) Fac. Health, Medicine and Life Sciences

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Forensic research can greatly benefit from a comprehensive understanding of molecular patterns on surfaces. The astonishing complexity of biological systems has a direct effect on molecular evidence left behind at crime scenes. It becomes more and more evident that within this complexity lies the information needed to provide insight in the events leading up to a crime. The best way to capture disease complexity is to chart and connect multilevel molecular information from the spatial distribution of these molecular traces using mass spectrometry imaging and data science. Charting this territory through the generation of molecular maps from surfaces containing biological trace, hairs, fibers, to the study of pigments and binding media on paper and paint for falsification research has become reality. The forensic implementation of imaging mass spectrometry complemented with high throughput "omics" approaches has been one of the enabling technologies in this field. We now have new MS based chemical microscopes to target forensic trace analysis in various chemically complex surfaces. State-of-the-Art molecular imaging with mass spectrometry now enables high resolution forensic surface screening that provides direct insight into molecular origin and degradation of trace materials. The development and application of new MS based chemical microscopes, driven by biomedical tissue analysis in various diseases, can be directly translated to the forensics research practice and forensic pathology. There is a clear need to add analytical structural separation utilizing ion mobility of gas phase ion chemistry to improve and validate molecular identification. This lecture will discuss the innovations and interdisciplinary use of MS based imaging techniques (MALDI, SIMS and DESI) for the analysis of complex surfaces relevant to forensic research.

Human Face Recognition: Potential, Challenges and Future Developments

Massimo Tistarelli

University of Sassari, Italy

Keywords: Face recognition; Biometrics; Identification

Biometric recognition has attracted the attention of scientists, investors, government agencies as well as the media for the great potential in many application domains, including criminal investigations. Among the many developed techniques for biometric recognition, face analysis seems to be the among the most promising and interesting modalities. This lecture will focus on the current state of the art in face recognition technologies and its perspectives as a support to forensic analysis. The human visual system certainly provides a remarkable benchmark for face recognition, but also an inspiration for algorithmic design. The ability of the human visual system of analysing unknown faces, under different perspective and to extract different personal features, is an example of the amount of information which can be extracted from face images. This is not limited to the space or spectral domain, but heavily involves the time evolution of the visual signal. Nonetheless, there are still many open problems which need to be "faced" as well. This not only requires to devise new algorithms but to determine the real potential and limitations of existing techniques, also exploiting the time dimensionality to boost recognition performances. This lecture will review several past and current methods for face matching, based on diverse computational frameworks and image representations, both in 2D and 3D. Some new methods are described, tested with conventional and also new databases from real working environments.

This research work has been partially supported by a grant from the European Commission (H2020 MSCA RISE 690907 "IDENTITY") and by a grant of the Italian Ministry of Research (PRIN 2015).

New approaches in microscale mass spectrometry: from fingerprints to organelles

Melanie Bailey

University of Surrey, Guildford, United Kingdom

Keywords: fingerprints, gunshot residue, hair, paint

The University of Surrey houses the Surrey Ion Beam Centre, which is the UK's national facility for ion beam applications. We have (and are developing) tools that can image trace elements and molecules in samples at micron resolution, in air. We also have funding to develop multimodal (ion beam and mass spectrometry) imaging and sub-cellular analysis for biomedical applicaitons. We are using these more advanced techniques as well as more widely available ones (e.g. secondary ion mass spectrometry, paper spray mass spectrometry and liquid chromatography) to maximise the information that we can recover from small samples. In this talk we will show how these tools can be used to give new information about forensic samples – for example to develop drug testing from a fingerprint, to recover a greater number of fingermarks and to gain more information from evidence such as gunshot residue particles, hair and paint.

Potential of imaging mass spectrometry in forensic toxicological services

Eva Cuypers

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Keywords: Forensic Toxicology

Imaging mass spectrometry is a biochemical tool that possibly features the necessary sensitivity and specificity in forensic science. Moreover, it can provide spatial information on compound distribution in a wide range of matrices. Compared to other, standardly used equipment in forensic analysis, sample preparation is rather limited. Imaging results are easy to understand, also for a non-analytically trained audience such as a court jury. Although these strengths should make imaging mass spectrometry the method of choice in forensic (toxicological) analytical services, very few imaging techniques are currently used. This presentation will show the great potential of imaging mass spectrometry in hair, fingerprint and tissue analysis. On the other hand, it will also discuss the challenges this technique is still facing in order to be used and accepted in routine forensic toxicological services.

Attacking deep neural networks with adversarial images

Fabrizio Falchi

Laboratory of the Information Science and Technologies Institute of the Italian CNR, Pisa, Italy

Maliciously manipulated inputs for attacking machine learning methods and deep neural networks, in particular, are emerging as a relevant issue for the security of recent artificial intelligence technologies, especially in computer vision. Adversarial images are maliciously manipulated images, often indiscernible from authentic inputs by humans, specifically crafted to make a deep neural network to misbehave. In this talk, the fundamentals of adversarial machine learning are introduced and a review of recent relevant scientific works on the specific topic of adversarial images is given.

Investigation into the use of MALDI-MSI to monitor the variability of composition of fingermarks between donors and over time

Marie Gorka (1), Marc Augsburger (2), Aurélien Thomas (2), Andy Bécue (1)

1) ESC/UNIL, Lausanne, Switzerland
2) UTCF/CURML, Lausanne, Switzerland

Keywords: fingermark, composition, variability, MALDI

This contribution aims at presenting the collaborative project that has recently taken place between our two institutions (i.e., École des Sciences Criminelles – ESC/UNIL and Unit of Toxicology – UTCF/CURML) in the frame of a Master degree research.

In this project, Matrix-Assisted Laser Desorption/Ionization combined with Mass Spectrometry and Imaging capabilities (MALDI-MSI) was considered to investigate the variability of composition of fingermarks within a group of four individuals and over a limited deposition time-frame. The research was divided in two parts: (i) an intravariability study performed on a single donor who was asked to provide several eccrine, sebum-rich, and natural fingermarks, and (ii) an intervariability study conducted on four individuals who were asked to provide natural fingermarks. The sets of molecular masses extracted from the analysis of the collected fingermarks were then processed and clustered using statistical tools and chemometrics.

The intravariability study highlighted the possibility to differentiate fingermarks by their secretion type (i.e., eccrine, sebum-rich, or natural) based on the apparent similarity of composition between fingermarks of a same type. The analysis of fingermarks left by a given individual at different days also allowed emphasizing some consistency of composition. Finally, the intervariability study highlighted the possibility to cluster fingermarks provided by the four donors from the similarities of their respective molecular compositions.

This feasibility study aimed at supporting the use of MALDI-MSI as a multimodal tool to explore the evolution of composition with time, combined with a better understanding of the consistency of composition that may be observed for a given donor over a prolonged

time-frame. Further work is currently on-going on this topic. This approach could benefit the forensic community in different manners: (i) by bringing additional fundamental knowledge about fingermark composition and donorship characteristics [research purpose], (ii) by assessing if the overall chemical composition of fingermarks could be of a specific use in an investigative framework [investigation purpose].

This research is supported by the Swiss National Science Foundation (project #205121_182180).

Imaging of fingerprints using secondary ion mass spectrometry (SIMS)

Catia Costa (1), Roger P. Webb (1), Vladimir Palitsin (1), Mason Malloy (2), Melanie J. Bailey (2)

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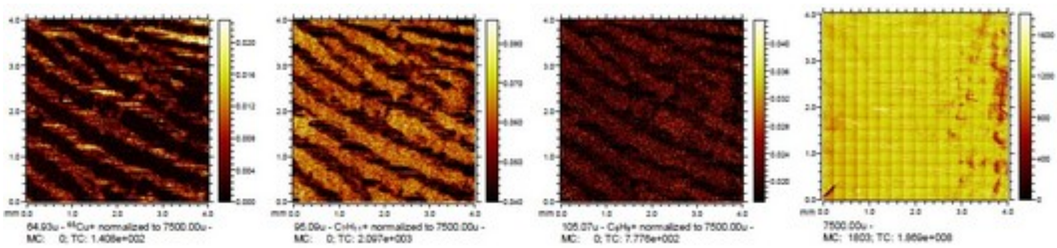
2) Dept. Chemistry, University of Surrey, United Kingdom

Keywords: TOF-SIMS, fingerprints, MeV-SIMS, ambient

The application of time of flight secondary ion mass spectrometry (TOF-SIMS) for fingerprint visualisation has been widely reported in the literature. Reports have looked into different aspects of fingerprint imaging, including the detection of exogenous contaminants, overlapping fingerprints and inks and partially recovered fingermarks. This work has led to the inclusion of the technique in the Home Office's Fingerprint Source Book as a Category C process [1]. Although it is not considered for routine use by Police Forces, TOF-SIMS has successfully developed latent fingerprints where other conventional processes have failed to do so [2]. To study this further, and in collaboration with the Defence Science and Technology Laboratory (Dstl), we have investigated the application of TOF-SIMS to enhance fingerprints in challenging substrates and in the presence of contaminants. We have looked at the imaging of fingerprint samples collected on brass, steel and ABS plastic substrates after (a) ambient ageing; (b) immersion in sea water; (c) powder contamination; (d) viscous contamination and (e) aqueous contamination. A sub-section of these samples were imaged using TOF-SIMS after development at the Home Office's Centre for Applied Science and Technology (CAST) to explore compatibility with existing development methods. Analysis using TOF-SIMS require high vacuum conditions, limiting the size of the sample that can be analysed in the vacuum chamber. To overcome issues like sample size, we have been developing an ambient pressure secondary ion mass spectrometry system using MeV heavy ions (AP-MeV-SIMS). AP-MeV-SIMS will allow the simultaneous collection of molecular and elemental information through the combination of mass spectrometry and conventional IBA techniques under full ambient conditions. The developmental stages of the technique focussed on the effect of different gases (nitrogen, helium, nitrous oxide and air), sample biasing and geometrical arrangements (environmental chamber, nozzles or cones). In the initial experiments we demonstrated the molecular imaging of a cocaine pellet in full ambient conditions. The peak assignment was further confirmed through the identification of a cocaine fragment, allowing for the differentiation between cocaine and ambient signals. The further development of such capability will allow for quick and non-destructive analysis and/or imaging for forensics, archaeology and cultural heritage applications.



Caption: Ion images of fingerprint collected from a male donor after viscous contamination on brass and aged for 1 week. Images show the 65Cu+ (left), hydrocarbon C7H11+ (middle) and hydrocarbon C8H9+ (right).

References:

1. Bleay, S., et al., Fingerprint Source Book. 2nd ed, ed. C.f.A.S.a.T. (CAST). 2017.

2. Bailey, M.J., et al., Enhanced imaging of developed fingerprints using mass spectrometry imaging. Analyst, 2013. 138(21): p. 6246-6250.

Fast Face Image Retrieval using Probabilistic Knowledge Transfer

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Aristotle University of Thessaloniki, Thessaloniki, Serres, Greece

Keywords: face image retrieval, deep learning, knowledge transfer

Even though a large amount of data are collected from Closed-circuit television (CCTV) systems in daily basis, discovering forensic evidence is such large database is especially hard for several reasons, including the need to filter and extract only the useful information in such large collections, as well as processing large amount of data in an efficient way. Machine Learning and Deep Learning methods can be exploited to this end, providing powerful analysis tools for effectively processing video footage and performing human identification and event detection, among other tasks. However, applying Deep Learning methods in large-scale setting comes with its own challenges, since most of the state-of-the-art Deep Learning methods are computationally expensive and require the use of supervised information for training, increasing both the cost and the human effort needed for their successful application. Therefore, existing Deep Learning methods must be carefully extended and adapted toward the needs of large-scale forensic applications [1]. In this work, we present a representation learning method that is capable of a) learning small and compact representations that can be effectively used for large-scale face image retrieval and b) incorporating information from different sources and modalities into the learning process. The proposed method works following the idea of neural network distillation [2], i.e., transferring the knowledge encoded in a large and complex neural network/model into a smaller and faster one. However, the method is applied in a representation learning fashion allowing for learning spaces of arbitrary dimensionality, while exploiting different information sources. To this end, the proposed method models the probability distribution induced by the larger model and learns a student model that matches this distribution [3], instead of matching the actual representation extracted from the models, which is not possible if the models extract representations of different dimensionality. This approach also allows for transferring the knowledge encoded in handcrafted feature extractors into a small and compact neural network that can be used for extracting small representations that can be used for efficiently querying large face image databases. Furthermore, supervised information can be incorporated into the learning process, when available, further increasing the performance of the models, without the risk of overfitting the representation. The effectiveness of the proposed approach is evaluated using a large scale face image dataset.

References:

1. Mena, Jesus. Machine learning forensics for law enforcement, security, and intelligence. Auerbach Publications (2016)
2. Hinton, Geoffrey, Oriol Vinyals, and Jeff Dean. "Distilling the knowledge in a neural network." NIPS Deep Learning Workshop (2014)
3. Passalis, Nikolaos, and Anastasios Tefas. "Learning Deep Representations with Probabilistic Knowledge Transfer." Proceedings of the European Conference on Computer Vision (2018)

Deep Face Embedding for Low Resolution Face Recognition

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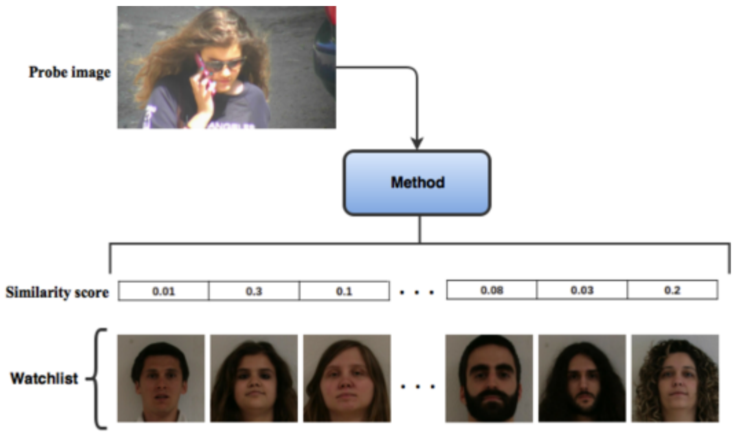
Keywords: Face Recognition, Deep Learning, Surveillance

In this work we have leveraged deep learning models trained on VGGFace2 database [1] for feature extraction in unconstrained Face Recognition under mismatched condition. We evaluated the robustness of the learned face embedding on International Challenge on Biometric Recognition in the Wild, ICB-RW2016 database [2]. There are 90 subjects in the database and each of the subjects have a frontal face image as gallery and five probe images captured from a surveillance camera. The task is to find the matches of probe faces in the gallery and report Rank-1, Rank-5 face Identification Rate and Area Under the Curve of Cumulative Match Curve (AUC of CMC). The faces in the probe and gallery sets are cropped using the ground truth bounding boxes and faces are aligned using corners of the eyes and bottom of the nose. The aligned faces are resized to 224 x 224 in order to be fed into deep learning models for feature extraction. Four deep learning models which are used for feature extraction are listed as follows: ResNet-50, SENet-50 models trained on VGGFace2 which are named as VF2-ResNet and VF2-SENet. Also, ResNet-50, SeNet-50 models trained on MS-Celeb-1M database and fine-tuned on VGGFace2 database which are named as VF2-ft-ResNet and VF2-ft-SENet. We removed the classification layer of the models and extracted 2048 dimensional face descriptors of the faces in ICB-RW 2016 database. Finally, a Nearest Neighbor classifier with correlation as the distance metric is used for finding the matches. A list of Rank-1 to Rank-G (G is the number of subjects) is created per experiment to calculated the AUC of CMC. All the models outperformed the highest reported result in [3]. Furthermore, we propose an ensemble model by concatenating features extracted from four models. Our ensemble model achieved 91.78% Rank-1, 98.00% Rank2, and 0.997 CMC. The results are reported in Table 1.

Table 1: Identification rates and CMC of using different models in feature extraction

Model	Rank-1 (%)	Rank-5 (%)	CMC
Ensemble Model	91.78	98.00	0.997
VF2-ft-SENet	85.33	98.22	0.995
VF2-SENet	85.11	97.11	0.994
VF2-ResNet	87.11	96.00	0.993
VF2-ft-ResNet	87.11	96.89	0.991
Ekenel et al. [3]	72.00	86.22	0.962



Caption: In the ICB-RW 2016 [2], probe/test image is compared to the watchlist/samples in the gallery set. The gallery images are collected under controlled, indoor studio settings. Probe images are acquired from outdoor surveillance cameras.

References:

1. Cao, Qiong, et al. "Vggface2: A dataset for recognising faces across pose and age." Automatic Face Gesture Recognition (FG 2018), 2018 13thIEEE International Conference on. IEEE, 2018.

2. J. Neves, and H.& Proença, "ICB-RW 2016: International Challenge on Biometric Recognition in the Wild", Biometrics (ICB), 2016 InternationalConference on (pp. 1-6). IEEE.

3. E. Ghaleb, G. Özbulak, H. Gao, H.K. Ekenel, “Deep Representation and Score Normalization for Face Recognition Under Mismatched Conditions”, IEEE Intelligent Systems, Vol. 33, No. 3, p. 43-46, May/June2018.

Biometric Scheme Based on Non-Binary Turbo Codes

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Keywords: Face recognition, HOG-data, biometric, non-binary turbo codes

Face recognition is one of the techniques that measures and matches the unique characteristics of human being for the purposes of identification or authentication and is often used for biometrics solutions. We have developed the FaceAnalyzer Platform (FAP) [1] based on OpenFace tool [2] to carry out the study of human characteristics and perform the analysis, recognition and verification of human biometric data, elements of his emotions by capturing images and video, features extraction and data processing. OpenFace [2] is one of the best toolkits performing facial landmark detection, head pose estimation, facial action unit recognition, and eye-gaze estimation with available source code for both running and training the models. The tool OpenFace [2] uses Conditional Local Neural Fields [3] (CLNF) to perform Facial Landmark detection and tracking. CLNF is an instance of a Constrained Local Model (CLM) that uses Point Distribution Model (PDM) which captures landmark shape variations and patch experts (PE) to capture local appearance variations of each landmark. To track landmarks in videos Baltrusaitis et all [2] initialize the CLNF model based on landmark detections in previous frame. If tracking has been failed model is reinitialized using the dlib face detector. The modified OpenFace tool allows to detect multiple faces in an image and track multiple faces in videos. Model is also able to extract head pose information by the use of a pseudo 3D representation of facial landmarks using orthographic camera projection. Proposed landmark detector can learn non-linear and spatial relationships between the input pixels and the landmark being aligned. At this stage, the model is being improved taking into account the reliabilities of each patch expert. To perform a study of human biometric characteristics, we exploited the person's face HOG-data (Fig. a) using the OpenFace tool. To neutralize the noisiness of the extracted characteristics, binary BCH-codes with (*n,k,d*) parameters have been used [1]. The application of BCH codes (511,58,91) and (511,28,111) allowed to achieve the results of face authentication with FRR at the level of

3%. Further it was suggested to use more powerful noise-resistant codes, non-binary turbo codes in biometric system design. One of the known approaches to creating such a system is to use a code-offset construction, which forms an auxiliary sketch (Secure Sketch) stored in the database. It is applied together with binary error correcting code (*n, k, d*) and represents the offset *D* that "shifts" the code vector *X* of the applied noise-resistant code, containing the user's password *S* by the biometric measurement value *B*, i.e. *D*=*B*-*X*. In the subsequent biometric measurement *B*', subtraction *D*-*B*'=*Y*, decoding *Y* and obtaining the password *S*', generally coinciding with *S*, is performed. In this paper, we propose the implementation of a fuzzy extractor based on the scheme of the so-called fuzzy commitment using non-binary turbo codes, where their effectiveness can be estimated by the Euclidian distance. The proposed scheme exploited the OpenFace tool [2] and has better biometric performance and implementation flexibility compared to [1] and has the ability to choose the type of non-binary code, arbitrary its block length and the distortion level due to data quantization to achieve the necessary confidentiality and data security. The proposed scheme includes two basic procedures: Enrollment and Authentication (see Fig. b). At the registration side, the *m*-ary Secret Password S_m enters the Non-Binary Encoder, where the encoding function X_m=F(S_m) add the redundant symbols for error correction, forming framed data blocks X_m that pass through the *m*-ary modulator and are subtracted from a block of biometric quantized data B_q formed at the output of a Quantizer D_m= B_q-X_m. The quantizing interval used takes into account the power of the noise-resistant error-correcting code used and the specified level of the user data security. The obtained data block D_m is written to the Data Base and stored together with hash $h(S_m)$ in it. At the authentication side, the subtraction B'_q-D_m=Y_m for a new data block B'_q is performed, resulting in a vector Y_m, that becomes an input to the Non-Binary Decoder. The decoding function S'_m =$F^{-1}(Y_m)$ is applied giving the user password S'_m as the output. Next, hash function $h(S'_m)$ is compared to $h(S_m)$. If they are equal, the user is successfully authenticated. In this paper we consider the use of non-binary turbo codes constructed from non-binary convolutional component codes concatenated via a random symbol interleaver mapped onto phase-shift keying (8-PSK) constellation. The polynomials used produced coding matrix g=[166;176] over the ring GF(8) for systematic 1/3-rate turbo code. Then 8-ary random secret key S_m of length 166 was turbo encoded with terminating zeroes into resulting matrix 3x172 of X_m and then modulated into a constellation 8-PSK. Each symbol of X_m was presented by I-Q complex numbers giving framed data matrix 3x344. To get the biometrical face features the Caltech Base has been used. Data from 511 real numbers, obtained after a special mask to get the most representative components of 4464-element HOG vectors have been used as biometric raw data [1]. The biometric quantized data B_q was calculated after quantization with interval q=0.19635, normalized and linearly mapped to the interval [0, 2pi) of angles presented then by two I-Q components. The data block was obtained and put to the Data Base together with hash $h(S_m)$ in it. At the authentication stage, the subtraction B'_q-D_m=Y_m- for a new quantized data B'_q, was performed and a vector Y_m, was decoded after 3 iterations by the modified BCJR algorithm giving the user password S'_m . Next, hash function $h(S'_m)$ with $h(S_m)$ was compared. Preliminary experimental estimates of FAR and FRR resulted in values FAR = 0%; FRR ~ 0.1%, which is several times better than the known results for turbo codes. The application of the proposed method allows to significantly improve the main performance indicators of biometric systems based on fuzzy extractors and to adjust the system parameters to the required length of the user's secret key and the necessary level of confidentiality.

References:

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2. T. Baltrusaitis, L.-P. Morency, and P. Robinson. OpenFace: An open source facial behavior analysis toolkit. WACV, 2016.-pp. 1-10.

3. T. Baltrusaitis, L.-P. Morency, and P. Robinson. Constrained local neural fields for robust facial landmark detection in the wild. ICCVW, 2013.-pp. 354-361.

Fingerprints Images based on Biocompatible Carbon Dots

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Keywords: Fingerprints, Carbon dots, Fluorescence

Simple, fast, and laboratory efficient fluorescent doped N- and P- carbon nanoparticles synthesis was developed for fingerprint imaging. Nanoparticles, with an average size of 6.5, and around 220 nm were obtained respectively. ATR, solid NMR, XPS and fluorescence spectroscopy revealed their surface functionalization. Fluorescence spectra, under MCR-ALS treatments, revealed in both cases the presence of three fluorophore groups corresponding to different structural motifs, which supported the previous chemical analysis.

The images obtained on different surfaces such as mobile telephone screen, magnetic band and metallic surface of a credit card, and a Euro banknote treated with the obtained nano-powders, allow us to record positive matches, confirming that the experimental results illustrate the effectiveness of the proposed method. The obtained results were validated by the scientific protocol of the Police Automated Fingerprint Identification System (AFIS) based on a biometric identification. The cytotoxicity of carbon nanoparticles was checked, and it was demonstrated that they are non-harmful.

Virtual 3D reconstruction of a controlled bus bombing

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2) Department of Radiology at Aarhus University Hospital, Aarhus, Denmark

Keywords: 3D reconstruction, CT scanning, Photogrammetry, Blast injuries, multimodalities

Accurate and precise forensic crime scene reconstructions are fundamental for determining the sequence of events occurred during a crime or an accident. Significant technological advances have involved many of the disciplines surrounding forensic investigations, including crime scene reconstruction. We will show how 3D technologies can be used to better understand the dynamic of a controlled bus bombing.

CT scanning, photogrammetry and modeling techniques have been used to virtually recreate the victims (the pigs) and the crime scene (the bus). Several 3D reconstructions of the scene before and after the explosion were re-created to better visualize the dynamic of the incident and the blast injuries. Three different "injury zones" could be identified based on the severity of the injuries of the pigs, as evaluated from autopsy and CT scanning. All the pigs suffered extensive blast injuries. The pigs closer to the detonation site underwent traumatic amputation and destruction due to a combination of blast injuries. Primary blast injuries and secondary injuries were found in all the other pigs. Fractures both due to tertiary or combined blast injuries were found in all the pigs except the one far from the detonation side.

In conclusion, 3D reconstructions give an illustrative and more comprehensive view of the entire scene (environment and victims). 3D visualizations can be used to better evaluate the lesions and thus to better understand the dynamic of the event.

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SEM/EDX analysis of the dental cementum to establish one human's lifestyle for forensic applications (pilot study)

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Keywords: forensic odontology, dental cementum, incremental lines, SEM/EDX, elemental analysis

In our previous work we have introduced an improved method for estimation of a chronological age of a human being by analyzing the incremental lines in a dental cementum, using Scanning Electron Microscopy (SEM) images of the longitudinal sections of the tooth roots. In the present study we have used the protocol for incremental line thickness estimation in order to analyze the elemental content evolution with the age of the individual. The protocol that allows accurate age estimation even if the SEM images reveal limited number of distinct incremental lines was used to analyze 29 samples from different female individuals. Herein we present the results of some of the most typical case studies. The SEM micrographs were subjected to image analysis with a calibrated thickness measuring tool in absolute units from the Adobe Photoshop. The calculated incremental line thickness was used to plot the cementum growth timeline in years of biological age, starting with the year at which the corresponding tooth erupts. The EDX tool was used to study the elemental content along the established timeline. Occurrence of some unusual elements other than those constituting the apatite and other regularly occurring elements in the dental root structure, could associate the individual to a certain lifestyle, relating her/him to a tradition, but also indicate an undesired exposure and implementation of uncommon (Ti, Zn) and/or toxic elements (Cd, Cu, Sr and other) in the cementum structure.

Investigation of infinite focus microscopy for the determination of the association of blood with fingermarks

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The determination of the type of deposition mechanism of blood within fingermarks at the scene of violent crimes is of great importance for the reconstruction of the bloodshed dynamics. However, to date, evaluation still relies on the subjective visual examination of experts. Practitioners encounter three types of scenarios in which blood may be found in fingermarks and they refer to the following three deposition mechanisms: *(i)* blood marks, originating from a bloodied fingertip; *(ii)* marks in blood, originating from a clean fingertip contacting a blood contaminated surface; *(iii)* coincidental deposition mechanisms, originating from a clean fingertip contacting a clean surface, leaving a latent fingermark, and subsequent contamination with blood. The authors hypothesised that, due to differences in distribution of blood in the furrows and on the ridges, the height of blood depositions on the ridges and furrows (and their relative proportions), will differ significantly across the three depositions mechanisms. A second hypothesis was made that the differences would be significant and consistent enough to exploit their measurement as a quantitative and objective way to differentiate the deposition mechanisms. Preliminary data on a different

chemical matrix using MALDI MSI were obtained concluding that this technique could not offer the answers to the research questions posed[1].

In recent years, infinite focus microscopy (IFM) has been developed, allowing for the computational generation of a 3D image of the topology of a sample via acquisition of images on multiple focal planes. On these bases, it was hypothesised that the application of this technique would allow the distinction of deposition mechanisms *(i)* to *(iii)*. Though IFM enabled the analysis of tape lifted samples with some success, for samples produced and analysed directly on the surface of deposition, the results show that the measurements from any scenario will be highly dependent on the original surface of deposition (both in terms of its nature and of the variable exposure to environment); as crime scenes exhibit a wide range of possible relevant surfaces of deposition, the technique showed to not have the desired wide appeal for inclusion into a standardised set of protocols within a routine crime scene work-flow[2].

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Specific identification of blood stains by means of multispectral classification techniques

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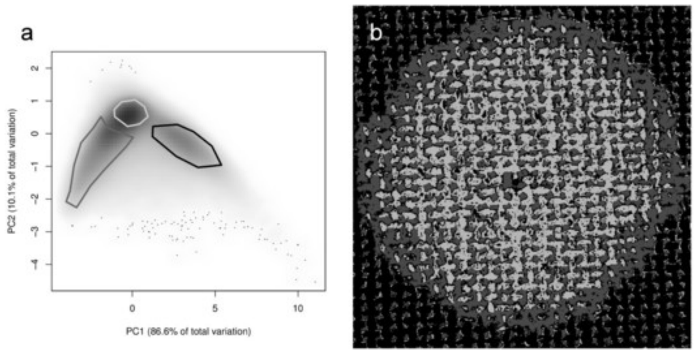
Keywords: multispectral classification, blood stains

It was the aim of this study to prove the hypothesis that colored organic coordination complexes possess specific multispectral reflectance properties, which facilitates their identification in images. Here we report on our results achieved with blood stains on fabric. The multispectral hypercubes were unfolded, followed by supervised classification of all pixels each containing multispectral information [1]. The classification techniques used were principal component ordination analysis (PCA), linear discriminant analysis (LDA) as well as decision tree machine learning (Random forest classification). Per-pixel classification results were then reallocated into the xy-dimensions of the original image, thus giving images of multispectral features. It was found that PCA classification gave most specific and reliable results, where principal components 1 and 2 explained more than 95% of the total variance, regardless of the organic complex investigated, and that the PCA model developed sensitively responded to blood age.



Caption: PCA classification results. a) ordination plot with spectral features highlighted, black polygon contains pixels classified as fabric, light grey as bright and dark grey as dark blood, b) classification image, same color codes

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This research was supported by the Brandenburg State Police and the Brandenburg State Institute of Forensic Medicine.

Toward objective assessment of bruise age by combining diffuse reflectance spectroscopy and photothermal radiometry

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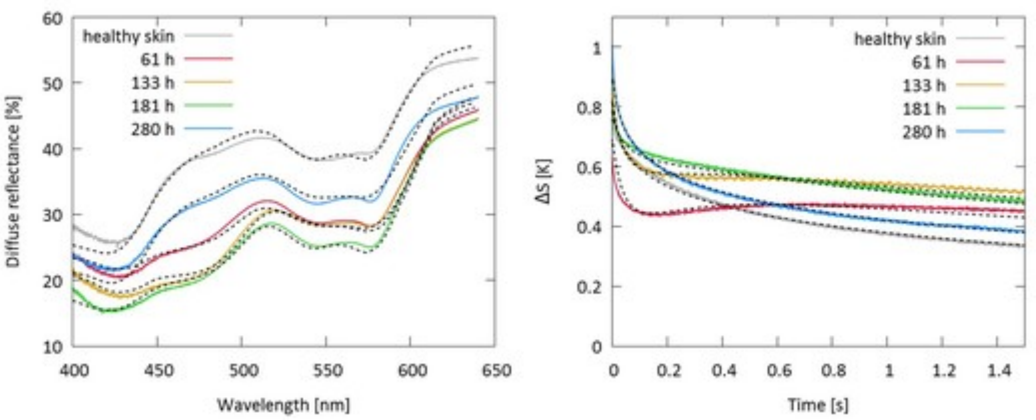
Keywords: Traumatic bruises, Age assessment, Hemodynamics, Diffuse reflectance spectroscopy, Photo-thermal radiometry

Assessment of bruise age in forensic investigations is based on specific discoloration of human skin due to inherent dynamical processes involving extravasated hemoglobin and products of its biochemical decomposition. However, the current protocol relies exclusively on visual inspection and subjective estimate from a highly trained expert in forensic medicine. Consequently, uncontrolled factors such as intensity and spectrum of ambient light, skin thickness and pigmentation of the injured site, depth of blood spillage, etc., contribute to limited accuracy of the assessed time of injury. Our group is aiming at development of a more accurate approach, utilizing two noninvasive optical techniques: Diffuse reflectance spectroscopy (DRS) and pulsed photothermal radiometry (PPTR).

The study has so far involved over 30 human volunteers, mostly with bruises incurred accidentally at a known time point, and a few with bruises induced under controlled circumstances. Diffuse reflectance spectra in visible spectral range (400–650 nm) are assessed from visually uniform lesion sites using an integrating sphere (Ocean Optics). PPTR measurements involve irradiation by a milisecond light pulse from a medical-grade laser (at 532 nm), and recording of the resulting transient change of mid-infrared emission using a fast infrared camera (FLIR SC7500). Parameters of an earlier proposed dynamical model of hemodynamics in a self-healing bruise [1] are assessed by objective fitting of the experimental data with predictions from a dedicated numerical simulation of light and heat transport in intact and bruised human skin. Namely, the stability of bruise analysis is aided by a prior quantitative analysis of a nearby (or contralateral) uninjured skin site [2].

Our interim results indicate a large individual variability of the blood spillage time (6–58 h) and Hb mass diffusivity (4–13 × 10^{-4} mm^2/h) [3]. The Hb decomposition rates also vary (10–55 h) and are gradually decreasing with time as the inflammatory response subsides. A plausible decrease of the Hb oxygen saturation level (from 40–100% to below 20%) is also indicated. A study of correlations between these specifics with anatomical location, age, gender, lifestyle, etc. is under way.

The presented methodology allows quantitative evaluation of hemodynamics in traumatic bruises. The assessed parameter values and trends improve our understanding of the involved processes and their individual differences, thus paving the way toward development of a technique for objective assessment of the bruise age.



Caption: Diffuse reflectance spectra (left) and PPTR signals acquired form an incidental bruise at differ-ent times post injury and an intact nearby site (see the legend). Dashed lines present the best-fitting model predictions.

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Magnetic textile solid phase extraction for the preconcentration of target analytes

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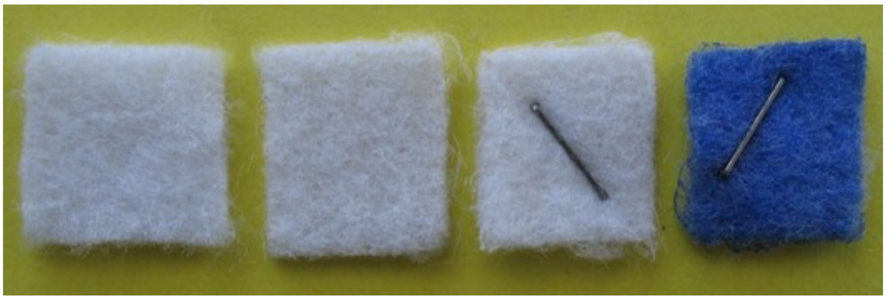
Keywords: Magnetic textile solid phase extraction, image analysis, HSB color space

Magnetic solid phase extraction (MSPE) is currently frequently used analytical procedure for the preconcentration, extraction and clean-up of both organic and inorganic compounds from variety of biological, clinical, forensic, food, environmental and other samples. Recently a new type of preconcentration procedure, based on the use of magnetically modified textile (Magnetic textile solid phase extraction; MTSPE) has been developed. This extremely simple procedure has already been used for the extraction of model dyes and fountain ink dye released from ink written documents into large volume of water. In the standard procedure, the analytes adsorbed on the textile squares (modified with an appropriate affinity ligand, see Fig. 1) are eluted and subsequently analyzed using a suitable analytical procedure, such as spectrophotometry or liquid chromatography. However, we have also developed a new analytical approach enabling elution-free assay of colored compounds by image analysis of the photos of dyed textile squares; freely available software was used for evalution. Using HSB color space, the value of saturation was directly proportional to the initial dye concentration of the analyzed solutions. Magnetic textile solid phase extraction can be easily adapted for the detection of large variety of analytes important in environmental technology, biochemistry, biotechnology and forensic science. Further optimization of this procedure can involve the type of textile used, its size and the type of affinity ligand bound.



Caption: Fig. 1. Pieces of native nonwoven textile, textile impregnated with chitosan, magnetically modified chitosan impregnated textile and magnetically modified chitosan impregnated textile treated with excess of blue ink (from left to right).

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SHUTTLE: a European Toolkit for Trace analysis

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Keywords: microscopy automation trace image processing

Microtraces are small pieces of evidence that have been transferred to someone or something. Microtraces include materials such as fibres, hairs, plant and animal traces, paint smears and glass splinters. Forensic experts examine such microtraces found on a person or an object and compare them to materials of known origin, such as the clothing of a suspect, or the glass from a broken window on a crime scene. The analysis and comparison of those particles might help in the investigation to get a better understanding in the chronology of a succession of actions or even identify a suspect.

Nowadays, initial microtrace analysis is based primarily on microscopy: microtraces are examined one-by-one, and the expert decides whether something is relevant enough to explore further. A selection of microtraces will be analysed further microscopically (e.g. by polarisation microscopy, micro-spectroscopy, etc.) or by other instrumentation. This process to analyse micro traces is time-consuming and subjective. Finding a way to automatize some part of the analysis process, will be a key to facilitate the work of the expert, and to reduce the subjectivity of the results.

Eight forensic laboratories from different countries in Europe have teamed up to develop a toolkit, which will improve the initial investigation of micro traces: the SHUTTLE project. This project has been financed by the H2020 program [1]. SHUTTLE stands for Scientific High-throughput and Unified Toolkit for Trace analysis by forensic Laboratories in Europe.

The core of the SHUTTLE toolkit will consist of an automated microscope that will acquire high quality images of recovered traces. The acquired images will be processed automatically and an overview of available traces will be reported. In first instance, we will focus on blood, skin cells, gunshot residues (especially NC), hairs, fibres, and saliva. Algorithms to classify additional traces or to classify traces more accurately can be developed by users and added as plug-ins to extend the range of traces that can be classified. The data will be stored in a computer database, thereby facilitating future data analysis, such as provenancing of traces and forensic comparisons.

The automation will allow a more efficient workflow, while the obtained results are more objective.Wide implementation of the SHUTTLE toolkit will homogenise the procedures for trace evidence examination in laboratories throughout Europe and hence facilitate better international collaboration and exchange of data. The project aims to standardize the sampling methods, to homogenize the initial analysis process and enhance the synergy between different criminal research laboratories in Europe.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 786913.

Multi-Modal Sensor Data Fusion in City Environment Monitoring Projects SMENETE and IMO

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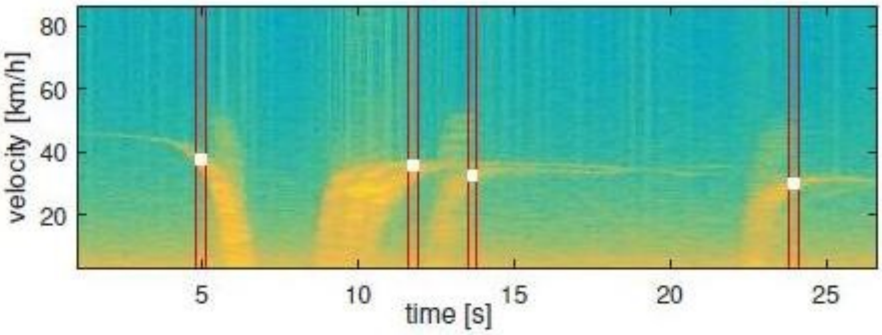
Keywords: wireless ad hoq network; heterogeneous sensor data; data fusion; data aggregation

Presentation describes the sensor information management solutions in on-going large ad-hoc wireless network projects in Tallinn and Estonia. Project goals are to test data fusion and network self-configuration algorithms in large (700 nodes) city wireless networks for collecting multi-modal information of different type including environment (8 sensors), traffic (3 sensors) and human mobility [1]. Discussion focuses on processing of information from 3 types of low-power traffic sensors: 1) Microwave (MW) radar-type Doppler sensors (see Fig.1) [2]; 2) Linear microphone arrays; 3) Passive InfraRed (PIR) sensors. Presentation discusses the sensor signal testing results, in-sensor (edge computing) algorithms and data fusion and aggregation (in-network / mist computing) algorithms and methodologies. Additionally, the metho-dologies of self-configuration and self-organization of network of wireless smart nodes are considered [3].



Caption: Fig. 1. Illustration of microwave sensor node capability to detect vehicles from 50-100 m distance via computing of spectrogram from time-domain signal and application of speed and driving direction detection algorithm [2].

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Nanopores for ultra-sensitive sensing of minute DNA samples

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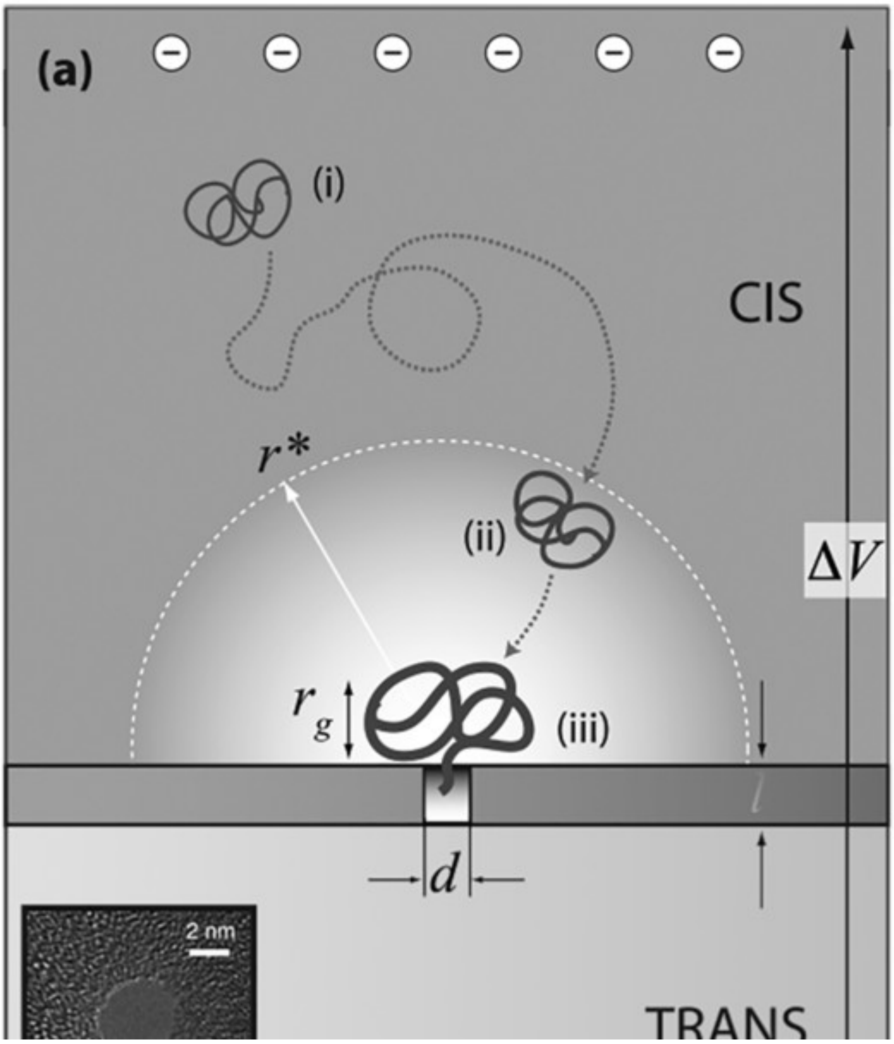
Nanopores (NPs) are single molecule biosensors, which utilize electrokinetic focusing and transport to detect and characterize unlabeled biomolecules. A nanopore sensor consists of a nanometer-sized pore (i.e., 1-10 nm in diameter) embedded or formed in an insulating membrane that separates two chambers containing an electrolyte solution. When an electrical bias is applied across the membrane, ions flow freely through the pore producing a constant open pore current. The flow of ions is partially impeded when a biomolecule diffuses through the pore or translocates from one side to the other under the influence of a driving force, thereby changing the ionic current. Due to their extremely simple sensing principle, nanopore sensors can be designed to produce compact, battery operated devices for portable sensing applications.

Controlling and tuning the capture rate and the translocation speed of biomolecules through the NP are crucial features to allow sensing of fine biomolecular features and extremely small concentrations of DNA molecules, within the experimental bandwidth limitations. In the first part of my lecture I will discuss two physical methods to: (i) enhance the *capture rate of DNA* molecules into solid-state using salt gradients to enable sensitive sensing down to a few attomoles, and (ii) slowing down the *translocation speed* of DNA and proteins through NPs using a novel optoelectronic effect that can be switched on or off in a fraction of a millisecond. In the second part of my lecture I will discuss biomedical applications utilizing NPs: (i) Genotyping DNA using a barcoding method utilizing sequence-specific peptide-nucleic acids (PNA) probes; (ii) discrimination among DNA strands at extremely low dilutions. I will finally discuss a solid-state hard microfluidic nanopore biosensor, which permits multi-layer fluidics and on-chip bioassay chamber.



Caption: Single DNA sensing using Solid-state Nanopores

Facial-based Intrusion Detection System with Deep Learning in Embedded Devices

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Keywords: Intrusion detection, Facial recognition, Deep learning, Convolutional Neural Network, Embedded devices

With the advent of deep learning based methods [1], facial recognition algorithms have become more effective and efficient. However, these algorithms have usually the disadvantage of requiring the use of dedicated hardware devices, such as graphical processing units (GPUs), which pose restrictions on their usage on embedded devices with limited computational power. We propose an approach that allows building an intrusion detection system, based on face recognition, running on embedded devices. It relies on deep learning techniques and does not exploit the GPUs. Face recognition is performed using a knn classifier on features extracted from a 50-layers Residual Network (ResNet-50) [2] trained on the VGGFace2 dataset [3]. In our experiment, we determined the optimal confidence threshold that allows distinguishing legitimate users from intruders. In order to validate the proposed system, we created a ground truth composed of 15,393 images of faces and 44 identities, captured by two smart cameras placed in two different offices, in a test period of six months. We show that the obtained results are good both from the efficiency and effectiveness perspective.

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Special computer program to solving the problem of localization of poor informative fingerprints

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Keywords: Palmoscopy computer program algorithm

Among the objectives of any fingerprint examination process of determination of the particular finger and (or) particular part of the specific (right or left) hand is the most frequent. This task has particular importance in cases of less informative traces of the palmar surface examination. Fragmentary traces of small area may be even impossible to orient correctly. For the comprehensive examination in relation to the only one person expert has to compare trace in question with 38 areas of the hand (14 phalanges of the fingers and 5 palmar areas on each arm). Moreover, expert has to make a comparison on each of the 38 areas sequentially rotating the fingerprint. Accordingly, increase of the number of identifiable persons results in to increase of the total number of comparisons. The localization of one fingerprint on the base of dactylograms of two identifiable persons requires comparison of 76 hand areas, of 3 persons — 114 areas, of 4 persons — 152 areas, etc. The complex of the particular signs must be examined in the process of such comparisons, and on the base of analysis of their collocation in ridge pattern sequential comparisons with the similar complexes of the particular signs must be performed in the examined trace(s) on each areas. The development team has developed the program for comparing fingerprints using the algorithm based on the localization of each particular sign in relation to the “events” surrounding it in nearby papillary lines. The algorithm uses the beginning and end, merging and branching of the papillary line as "event". This approach doesn't depend on the orientation of the fingerprint. Thus, each sign is characterized by a set of "events" and all "events" comprise identification complex which is sufficient for the determination of the hand area. Experiments has demonstrated the effectiveness of the algorithm even if only 5 particular signs are present in the fingerprint. The algorithm significantly reduces the number of refusals to conduct the examination on the base of poor informativeness of the fingerprints. This simplifies the sampling planning for the poroscopy and edgeoscopy.

A Comprehensive Analysis of Ear Biometry

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Keywords: deep learning, ear recognition, age and gender

In this study, we present an analysis of person identification, age and gender classification from ear images. For age and gender classification, we have utilized both geometric-based representation and appearance-based representation. For geometric features, we have manually identified 8 landmarks on the ear. Afterwards, we have calculated the distances between these landmarks to obtain 14 different geometric features. We have also benefited from random forest to obtain feature importance and select the most relevant features according to these importances. Besides, we have used rectangle area of the ear and polygon area of the ear as additional features. In total, we have 16 different geometric features to use for age and gender classification. For appearance-based representation and classification, which has been used for recognition, age and gender classification, we have employed 3 different well-known convolutional neural network models, which are AlexNet, VGG-16, and GoogLeNet. These models have been fine-tuned on a large-scale ear dataset, which was generated from the Multi-PIE face dataset, therefore, we named it as Multi-PIE ear dataset [1]. With this way, we have performed domain adaptation, which is a two-stage fine-tuning. First, we have fine-tuned the pretrained ImageNet model on the Multi-PIE ear dataset [1], which contains around 17000 ear images. Then, this fine-tuned model has been employed on the target datasets used for age and gender classification [2], and person recognition, i.e. UERC dataset [3], which was collected under uncontrolled conditions for ear recognition. According to the experimental results on the UERC dataset [3] and age/gender dataset, the domain adaptation has been significantly improved the recognition performance and age and gender classification accuracies. Besides, we have performed data augmentation to obtain more data. We have also benefited from combination of different deep CNN models to reduce the error rate further. In addition, we have examined effect of alignment. For this, we have aligned all ear images to one side but this did not affect the performance in a better way. Moreover, we have analyzed the effect of ear image quality, such as the illumination level of the image and aspect ratio of the image, on the performance for all tasks. According to the experimental results, appearance-based representation have provided better performance than geometric-based representation for both age and gender classification tasks. We have obtained 94% accuracy for gender classification task, whereas we have achieved 52% accuracy for age classification task. For ear recognition, we have achieved 67.53% accuracy. These results indicate that ear images have useful information for age & gender classification and ear recognition. However, age classification must be investigated more deeply in the future work.

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Forensic study of paper documentation for contractual fraud revelation purposes

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Keywords: electron scanning microscopy, spectroscopy, FTIR

Distinguishing of originality between paper types as well as printers, chemical compositions of ink, and printing dyes is necessary to detect alterations, obliterations, erasures, and page substitutions in case of fraudulent documents in the forensic science.

The study is focused on the proving originality of the proposed documents. The examined document consists of three sheets of paper with one-sided printed text and signatures of the involved parties. The SEM, FTIR, Elrepho Spectrophotometer, UV light with various wavelengths was used for investigation the document and to obtain chemical and physical evidence of the sheets originality or fraudulency. It was revealed by SEM that three pages were not produced using the same printer, however it was proven that laser printer was used to print the pages. Spectrophotometer pointed to optical properties such as brightness, whiteness, colorization, optical variability of surface as well as light scattering coefficient. This method revealed differences in the sheets of papers, especially the brightness D65, CIE whiteness, light scattering coefficient, basis weight and optical variability of surface were different in the case of second sheet from three-page document. Finally, chemical analysis by FTIR confirmed that the paper, printing ink and pens used in documentation are not identical, too. From obtained results we can assume that the integrity of document has been violated and second sheet from the three-page investigated document was substituted.

Determination of deposition order of different ballpoint pen inks, inkjet inks and laser toners – comparison of MeV SIMS and standard forensic techniques

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Keywords: MeV TOF-SIMS, PCA, toners, ballpoint pen, intersection lines of different writing tools

In the present work, possibility to determine deposition order for several different combinations of laser toners, inkjet inks and blue ballpoint pen inks using Time-of-flight Secondary Ion Mass Spectrometry using MeV ions (MeV TOF-SIMS) technique were explored. MeV TOF-SIMS attached to the heavy ion microprobe can be used for identification and 2D imaging of broad range of organic molecules by measuring time-of-flight of secondary molecular ions sputtered from the sample surface. As an excitation, instead of primary ions with keV energies that are used in keV TOF SIMS setups, fast and heavy primary ions with MeV energies produced in accelerators are employed.

Technique yields rich spectral information about chemical composition of a sample and excellent surface sensitivity, therefore having a valuable role in forensic tasks such as examination of forged documents. Principal Component Analysis (PCA) analysis of 2D images of intersections as well as several regions of interest of pure inks and toners (ballpoint pens, laser printers and inkjet printers) and their intersections has been performed. Dataset was obtained in positive mode with 5 MeV Si^{4+} primary ions from 6 MV Tandem Van de Graaff accelerator at Ruđer Bošković Institute.

Obtained results were compared with the polarization microscopy, video spectral comparator and microRaman spectroscopy, techniques that are usually used to determine deposition order of intersecting lines of different writing tools in the Forensic Science Center Ivan Vučetić. Results obtained by MeV SIMS and those techniques were compared and discussed.

Snapshot triple spectral line imaging for counterfeit detection

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We present recent results related to application of our originally developed multi-spectral-line imaging technology for validity analysis of the documents and banknotes. For document analysis in frame of the RRS, results obtained by smartphone *Nexus5* with add-on three laser wavelength illuminator for snapshot acquisition of three spectral line images (448nm, 532nm, 659nm) [1] were compared with those obtained by *Nexus5* with add-on three LED illuminator for sequential acquisition of three spectral band images (centered at 460nm, 535nm and 663nm) [2] and multispectral camera *Nuance EX* (51 spectral band, 450-950 nm) with additional ring-shaped halogen light source [3].

As for the banknote analysis, new series of comparative measurements of 58 authentic and counterfeit (provided by Bank of Latvia) 20 EUR and 50 EUR banknotes were taken. Details of the examined banknotes are provided in the table below.

Banknotes	**Authentic**	**Counterfeit**			
		Jet-printed	Offset-printed	Copied	Other
EUR 20 (new version)	7	2	-	2	3
EUR 20 (old version)	2	-	10	-	3
EUR 50 (new version)	15	1	-	-	2

EUR 50 (old version)	3	-	1	-	7
In total:	**58**				

Results of the measurements confirmed exceptionally high spectral resolution of the proposed imaging methodology which allowed reliable detection of counterfeit elements both in documents and in banknotes.

References:

1. J.Spigulis et al., J.Biomed.Opt., 22(9), 091508 (2017) [
2. I.Kuzmina et al., J.Biomed.Opt., 20(9), 090503 (2015)
3. I.Kuzmina et al., J. Biomed. Opt., 16(6), 060502 (2011)