Title: Aiding Forensic Investigations using Machine Learning

H. Sharifzadeh, S. Pour, X. Francis, A. Keivanmarz, R. Fleming, I. Ardekani, A. Newton

Abstract: Advances in machine learning find rapid adoption in many fields ranging from communications, signal processing, and the automotive industry to healthcare, law, and forensics. In this talk, I briefly focus on a couple of research projects revolving around machine learning and forensic investigations: a) A biometric tool based on vein pattern recognition for CSAI investigations, b) Prediction and reconstruction of wear patterns on footwear outsoles. These research projects mainly rely on cutting-edge machine learning algorithms applied to forensics area for helping law enforcement agencies identify criminals/victims:

A) A Biometric Tool Based on Vein Pattern Recognition for CSAI Investigations

In 2018, global technology companies reported over 45 million online photos and videos of children being sexually abused [1]. Child sexual abuse imagery (CSAI) is identified as one of the fastest growing crime industries [2] and is tied to other crime areas including human trafficking and underage prostitution [3]. Providing effective technology to identify perpetrators and victims in CSAI is a priority for law enforcement agencies and is backed by international organisations and governments [4,5,6].

Even though DNA, face, fingerprint, and palmprint are amongst the most common biometric traits employed in well-established identification systems, these traits are not applicable to CSAI cases, where perpetrators usually cover their faces and only non-facial skin is partially observable. Lack of such effective identification technology along with the universality of a mass communication medium such as the Internet has enabled the rapid growth of this industry and the number of child victims in sex trafficking and CSAI [7]. Developing an investigative tool to aid in the identification of perpetrators and victims of CSAI crimes may help to put a significant dent in the industry.

To overcome the limitations of current identification techniques, vein pattern as a new investigative tool has been recently introduced to the forensic community and early research with promising results has explored the possibility of visualising vein pattern from normal digital images (photographs and videos) [8,9,10]. Vein pattern recognition is not novel and has been used as a biometric trait for authentication purposes [11,12,13]; such techniques use a near infra-red (NIR) image which requires special camera for capturing NIR pictures, whereas our recently introduced solutions are able to take a normally captured image and analyse this with our novel algorithms based on machine learning and digital image processing techniques. This will allow us to identify criminals in CSAI with only a small portion of their skin captured from the videos and photos they are featuring in, and from this we will be able to detect their individual vein pattern- as unique to an individual as their fingerprint or DNA.

In the first part of the talk, we will briefly discuss our recently developed method for uncovering vein patterns from digital images. Within a machine learning framework, we describe feature extraction, image enhancement, and training/testing phases for this purpose; furthermore, our experimental results on some random internet images and different body limbs are presented. The results show the efficiency of our method.

B) Prediction and Reconstruction of Wear Patterns on Footwear Outsoles

Footwear evidence is often the most abundant form of evidence at a crime scene and in some cases, can prove to be as specific as a fingerprint [14]. Shoeprints' ability to uniquely identify an individual is of interest as they can provide valuable evidence in criminal investigations, not only for identifying suspects, but also helping forensic investigators link different crimes as well as reconstruction of crime scene and suspect number determination [15,16].

To assist in the evaluation and identification of shoeprints, databases containing reference shoeprints of the most common outsoles in production are maintained by law enforcement agencies [17,18]. Computational methods to aid forensic scientists in the analysis of shoeprints have revolved around the development of automatic algorithms to identify shoeprints in a photograph taken from the crime scene; and to find a match from such databases using shoeprint recognition software [19,20].

While these computational methods and databases exist, these forensic tools are limited in their ability to correctly match crime scene shoeprint evidence to the perpetrator's shoes due to the impact of wear and tear over time and the resulting distortion on the shoeprint. The wear pattern is usually influenced by biomechanics such as the weight and gait of the wearer, environmental stressors, and additional factors like the material of construction. In such situations, it falls on the forensic scientist to evaluate the outsole and determine if it matches the scene print while considering the formation of additional wear features. This task involves the careful analysis of the outsole and requires intimate knowledge of the breadth of factors that influence wear patterns.

Built upon on our recent work on wear pattern analysis [21,22], we use a unique dataset that has been specifically collected to study the pattern of wear that has formed over time on the outsole. Within a computational machine learning framework, we present a deep learning model that, for the first time, can automatically predict the wear pattern over time and is able to reconstruct the outsole back to its original state at a given time.

References

[1] M. Keller, D. Gabriel, "The Internet Is Overrun With Images of Child Sexual Abuse," The New York Times, https://www.nytimes.com/interactive/2019/09/28/us/child-sex-abuse.html [online; accessed November 2022]

[2] J. Eggestein, K. Knapp, Kenneth, "Fighting Child Pornography: A Review of Legal and Technological Developments," Journal of Digital Forensics, Security and Law: vol. 9 (4), Article 3, 2014

[3] S. Chawla. Global report on trafficking in persons. Technical report, United Nations Office on Drugs and Crime, 2012

[4] New Zealand Wellbeing Budget 2019, https://www.treasury.govt.nz/publications/wellbeing-budget/wellbeing-budget-2019 [online; accessed November 2022]

[5] Canada National Strategy To Combat Human Trafficking 2019-2024, https://www.publicsafety.gc.ca/cnt/rsrcs/pblctns/2019-ntnl-strtgy-hmnn-trffc/index-en.aspx [online; accessed November 2022]

[6] UK backs project to end modern day slavery for girls and women. https://www.gov.uk/government/news/work-in-freedom/ [online; accessed January 2020]

[7] N. Pereda, G. Guilera, M. Forns, J. Gomez-Benito, "The international epidemiology of child sexual abuse: a continuation of finkelhor," Child Abuse & Neglect, vol. 33(6):331–342, 2009

[8] H. Sharifzadeh, H. Zhang, and A. Kong, "Vein Pattern Visualization Through Multiple Mapping Models and Local Parameter Estimation for Forensic Investigation," 22nd IEEE International Conference on Pattern Recognition (ICPR), Stockholm, Sweden, 2014

[9] S. Pour, H. Sharifzadeh, I. Ardekani, X. Francis, "Vein Pattern Visualisation and Feature Extraction Using Sparse Auto-encoder for Forensic Purposes," 16th IEEE International Conference on Advanced Video and Signal-based Surveillance (AVSS), Taipei, Taiwan, 2019

[10] S. Pour, H. Sharifzadeh, I. Ardekani, X. Francis, "An Adaptive Method for Vein Recognition Enhancement Using Deep Learning," 19th IEEE International Symposium on Signal Processing and Information Technology (ISSPIT), Dubai, UAE, 2019

[11] Y. Taka, Y. Kato, K. Shimizu, “Transillumination imaging of physiological functions by NIR light,” World Congress on Medical Physics and Biomedical Engineering, Chicago, USA, 2000

[12] X. Wang, K. Sushita, K. Shimizu, “Evaluation of personal identification system by Transillumination imaging of a finger,” IEEE EMBS Asian-Pacific Conference on Biomedical Engineering (APBME), Kyoto, Japan, 2003

[13] Fujitsu Develops Technology for World's First Contactless Palm Vein Pattern Biometric Authentication System, Fujitsu Laboratories Japan, 2003, http://www.fujitsu.com/global/news/pr/archives/month/2003/20030331-05.html [online; accessed November 2022]

[14] W. Bodziak, “Forensic Footwear Evidence (Practical Aspects of Criminal and Forensic Investigations),” CRC Press, Florida, 2016

[15] T. Napier, “Scene linking using footwear mark databases,” Science & Justice, vol. 42(1), pp.39–43, Jan. 2002

[16] W. Bodziak, “Footwear Impression Evidence: Detection, Recovery and Examination,” 2nd Edition, CRC Press, Florida, 2000

[17] Z. Geradts, J. Keijzer, “The image-database REBEZO for shoeprints with developments on automatic classification of shoe outsole designs,” Forensic Science International, vol. 82(1), pp. 21–31, 1996

[18] A. Bouridane, “Shoemark Recognition for Forensic Science: An Emerging Technology,” Imaging for Forensics and Security: From Theory to Practice, pp.143–164. Springer, Boston, 2009

[19] P. de Chazal, J. Flynn, R. Reilly, "Automated processing of shoeprint images based on the Fourier transform for use in forensic science," IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 27(3), pp. 341-350, 2005

[20] S. Alizadeh, C. Kose, “Automatic retrieval of shoeprint images using blocked sparse representation,” Forensic Science International, vol. 27, pp. 103–114, 2017

[21] X. Francis, H. Sharifzadeh, A. Newton, N. Baghaei, S. Pour, “Learning Wear Patterns on Footwear Outsoles Using Convolutional Neural Networks,”18th IEEE International Conference on Trust, Security and Privacy in Computing and Communication (TrustCom), 2019

[22] X. Francis, H. Sharifzadeh, A. Newton, N. Baghaei, S. Pour, “Feature Enhancement and Denoising of a Forensic Shoeprint Dataset for Tracking Wear-And-Tear,”19th IEEE International Symposium on Signal Processing and Information Technology (ISSPIT), Dubai, 2019

Short Bio: Dr Hamid Sharifzadeh received his PhD from Nanyang Technological University (NTU) in Singapore in 2011. After completing his studies, he undertook two postdoctoral fellowships at NTU, focusing on speech and image processing, before joining Unitec Institute of Technology in Auckland, New Zealand in 2014 where he is currently an Associate Professor. His research interests lie in digital signal processing and machine learning. He has published over 50 papers in international journals and conferences, and he is a Senior Member of IEEE (SrMIEEE) and a Member of IET (MIET).