Forensic Sci Rev 30:21–32; 2018

Forensic Face Recognition as a Means to Determine Strength of Evidence: A Survey

C. G. Zeinstra[1*], D. Meuwly[1,2], A. C. C. Ruifrok[2]
R. N. J. Veldhuis[1], L. J. Spreeuwers[1]

[1] Faculty of Electrical Engineering
Mathematics and Computer Science
University of Twente
Enschede
The Netherlands

[2] Netherlands Forensic Institute
The Hague
The Netherlands

TABLE OF CONTENTS

INTRODUCTION 22
I. OPERATIONAL LEVEL OF FORENSIC FACE RECOGNITION 23
A. Analysis and Comparison 23
B. Evaluation and Verification 24
II. TACTICAL AND STRATEGIC LEVELS OF FORENSIC FACE RECOGNITION 25
A. Recommendations and Working Groups 25
B. Levels of Expertise, Training, and Proficiency Tests 25
III. CRITICISM OF FORENSIC FACE RECOGNITION 25
IV. FORENSIC FACE RECOGNITION RESEARCH DIRECTIONS 26
A. Human Aspect of the Forensic Face Recognition Examiner 26
B. Expert Aspect of the Forensic Face Recognition Examiner 26
C. Anthropometry 27
D. Automatic Forensic Face Recognition Systems 27
E. Forensic Face Recognition Datasets 28
F. Computational Forensic Approaches 28
CONCLUSION AND FUTURE DIRECTIONS 29
REFERENCES 29
ABOUT THE AUTHORS 31

* Corresponding author: Dr. Chris G. Zeinstra, University of Twente, P. O. Box 217, 7500 AE Enschede, The Netherlands; +31 (0)53 489 2842 (voice); c.g.zeinstra@utwente.nl.

1042-7201/30-1/Jan. 2018/21–32/$18.00 •

Forensic Face Recognition as a Means to Determine Strength of Evidence: A Survey

REFERENCE: Zeinstra CG, Meuwly D, Ruifrok ACC, Veldhuis RNJ, Spreeuwers LJ: Forensic face recognition as a means to determine strength of evidence: A survey; *Forensic Sci Rev* 30:21; 2018.

ABSTRACT: This paper surveys the literature on forensic face recognition (FFR), with a particular focus on the strength of evidence as used in a court of law. FFR is the use of biometric face recognition for several applications in forensic science. It includes scenarios of ID verification and open-set identification, investigation and intelligence, and evaluation of the strength of evidence. We present FFR from operational, tactical, and strategic perspectives. We discuss criticism of FFR and we provide an overview of research efforts from multiple perspectives that relate to the domain of FFR. Finally, we sketch possible future directions for FFR.

KEYWORDS: Facial biometrics, FISWG, forensic face recognition (FFR) approaches, forensics.

INTRODUCTION

In this survey paper, we present different aspects of forensic face recognition (FFR), with a particular emphasis on strength of evidence. The aim of this paper is to convey the breadth of FFR, with its many aspects and connections to related domains.

FFR is the use of biometric face recognition for several applications in forensic science. Biometric face recognition uses the face modality as a means to discriminate between human beings; forensic science is the application of science and technology to law enforcement.

In general, FFR includes scenarios of ID verification (1:1) and open-set identification (1:N+1), investigation and intelligence (M:N+1), and evaluation of the strength of evidence as described in Meuwly and Veldhuis [42]. There are two image types involved in FFR. The trace image often captures a crime scene and is most often taken under uncontrolled conditions. The reference image is a photograph of a suspect and is taken under controlled conditions. Concrete FFR use cases are given in Zeinstra et al. [73].

A use case in which FFR is frequently employed is to investigate criminal activities that are carried out in places monitored by surveillance cameras, like shops or gas stations. Extracted stills from closed-circuit television (CCTV) recordings that contain the face of the perpetrator are used as trace images. Another example is the withdrawal of money using a stolen debit card. In this case, trace images are recorded by a small camera inside an automated teller machine (ATM) and they typically exhibit perspective image distortion. These use cases are examples of investigation (M:N+1) or, in the case of a concrete suspect, examples in which the strength of evidence against that suspect is evaluated. Another example is when an immigration officer might be convinced that a given identity document is genuine, but that it does not correspond to the person who is presenting it. If the immigration officer forbids the person to enter, the subsequent investigation is an example of evaluation of strength of evidence in which the passport photograph serves as a trace image.

A survey by Jain et al. discusses additional open-set investigation (M:N+1) use cases: (a) mug shot search that is robust to facial aging, (b) matching forensic (composite) sketches to face photograph databases, and (c) retrieval using facial scars and marks [33]. Case (b) is an example in which trace images consists of a representation (sketch) by an image, instead of a captured image.

A final, very noteworthy but rather extreme, example of an FFR use case (M:N+1) is the "super recognizers" [57] at the London (UK) Metropolitan Police. Super recognizers are claimed to be able to identify persons from CCTV footage, based on an exceptional memory for discriminating facial features in previously seen low-quality images. Super recognizers were used for example during the London riots of 2011 [76].

FFR has its modern genesis in the Bertillonage system [4]. Bertillonage systematically uses facial and body features to describe criminal individuals. It features anthropometric measurements, as well as categorizations of facial features; for example, it recognizes 16 different ear shape types. Also, highly discriminating features like facial marks can be described. **Figure 1** depicts some examples.

Bertillon particularly advocates for a mugshot from face and profile, enhancing that the profile contains information that is in the same time more distinctive and less subject to intra variability (ear, upper profile), that has been forgotten in the modern mugshot process. Finn gives a historical account of Bertillonage; in particular the use and acceptance of photography ("the criminal image") as a means to represent information and evidence [26]. Bertillonage as such has been superseded as a means to individualize persons by fingerprinting (and DNA profiling in the last 25 years) [16].

males; *Forensic Sci Int* 177:168; 2008.
57. Russell R, Duchaine B, Nakayama K: Super-recognizers: People with extraordinary face recognition ability; *Psychon Bull Rev* 16:252; 2009.
58. Saks MJ, Koehler JJ: The coming paradigm shift in forensic identification science; *Science* 309:892; 2005.
59. Sinha P, Balas B, Ostrovsky Y, Russell R: Face recognition by humans: Nineteen results all computer vision researchers should know about; *Proc IEEE* 94:1948; 2006.
60. Sklar A: Fonctions de répartition à n dimensions et leurs marges; *Publications de l'Institut de Statistique de l'Université de Paris*; 1959.
61. Spaun NA: Facial comparisons by subject matter experts: Their role in biometrics and their training; *Proceedings — 3rd International Conference on Biometrics*; Alghero, Italy; p 161; June 2009.
62. Spaun NA: Forensic biometrics from images and video at the Federal Bureau of Investigation; *Proceedings — First IEEE International Conference on Biometrics: Theory, Applications, and Systems*; Washington, DC; p 1; September 2007.
63. Srinivas N, Flynn PJ, Vorder Bruegge RW: Human identification using automatic and semi-automatically detected facial marks; *J Forensic Sci* 61:117; 2016.
64. Taigman Y, Yang M, Ranzato M, Wolf L: DeepFace: Closing the gap to human-level performance in face verification; *Proceedings — 2014 IEEE Conference on Computer Vision and Pattern Recognition*; Columbus, OH; p 1701; June 2014.
65. Tome P, Fierrez J, Vera-Rodriguez R, Ramos D: Identification using face regions: Application and assessment in forensic scenarios; *Forensic Sci Int* 233:75; 2013.
66. Tome P, Vera-Rodriguez R, Fierrez J, Ortega-Garcia J: Facial soft biometric features for forensic face recognition; *Forensic Sci Int* 257:271; 2015.
67. Turk M, Pentland A: Eigenfaces for recognition; *J Cogn Neurosci* 3:71; 1991.
68. University of Twente: ForenFace; *http://scs.ewi.utwente.nl/downloads/show,ForenFace/* (Accessed November 21, 2017).
69. Vera-Rodriguez R, Tome P, Fierrez J, Expsito N, Vega FJ: Analysis of the variability of facial landmarks in a forensic scenario; *Proceedings — 1st International Workshop on Biometrics and Forensics*; Lisbon, Portugal; p 1; April 2013.
70. White D, Phillips PJ, Hahn CA, Hill M, O'Toole AJ: Perceptual expertise in forensic facial image comparison; *Proc R Soc B* 282:20151292; 2015; *https://www.cogsci.msu.edu/DSS/2015-2016/OToole/OToole_2015_Perceptual.pdf* (Accessed December 14, 2017).
71. Wong Y, Chen S, Mau S, Sanderson C, Lovell BC: Patchbased probabilistic image quality assessment for face selection and improved video-based face recognition; *Proceedings — IEEE Biometrics Workshop, Computer Vision and Pattern Recognition Workshops*; University of Colorado: Boulder, CO; p 81; June 2011.
72. Zeinstra CG, Veldhuis RNJ, Spreeuwers LJ: Beyond the eye of the beholder: On a forensic descriptor of the eye region; *Proceedings — 23rd European Signal Processing Conference (EUSIPSO)*; EURASIP: Nice, France; p 779; September 2015.
73. Zeinstra CG, Veldhuis RNJ, Spreeuwers LJ: Discriminating power of FISWG characteristic descriptors under different forensic use cases; *Proceedings — 15th International Conference of the Biometrics Special Interest Group;* Fraunhofer Institute: Darmstadt, Germany; p 171; September 2016.
74. Zeinstra CG, Veldhuis RNJ, Spreeuwers LJ: Examining the examiners: An online eyebrow verification experiment inspired by FISWG; *Proceedings — 3rd International Workshop on Biometrics and Forensics*; University of Gjøvik: Gjøvik, Norway; p 1; March 2015.
75. Zeinstra CG, Veldhuis RNJ, Spreeuwers LJ: Towards the automation of forensic facial individualisation: Comparing forensic to non-forensic eyebrow features; *Proceedings — 35th WIC Symposium on Information Theory in the Benelux*; Eindhoven, Netherlands; p 73; May 2014.
76. Zolfagharifard E: Are you a super recognizer? *http://www.dailymail.co.uk/sciencetech/article-3125173* (Accessed November 21, 2017).

ABOUT THE AUTHORS

C. G. Zeinstra; D. Meuwly
A. C. C. Ruifrok
R. N. J. Veldhuis; L. J. Spreeuwers

Chris G. Zeinstra studied mathematics (M.Sc.) at the University of Groningen (Groningen, The Netherlands), and took a special one-year course in computer science (Hons.) at the University of Leiden (Leiden, The Netherlands), between 1990 and 1998. He started his career as a software engineer at Royal Dutch Mail and as a technical project manager at Ericsson ETM (Rijen, The Netherlands). He joined the Hanze University of Applied Sciences (Groningen, The Netherlands) as a lecturer in computer science in 2002. In 2017 he obtained his Ph.D. for his work on forensic face recognition, a joint project between the University of Twente (Enschede, The Netherlands) and the Netherlands Forensic Institute. In this project he applied biometric techniques on features that have a forensic meaning, in particular FISWG characteristic descriptors. His Ph.D. work supervisors were Raymond Veldhuis and Luuk Spreeuwers.

Didier Meuwly received a classical education (Latin/Philosophy) and he was educated as a criminalist and criminologist (1993). He obtained his Ph.D. (2000) at the School of Forensic Science (IPS) of the University of Lausanne (Lausanne, Switzerland). Currently he shares his time between the Netherlands Forensic Institute (NFI) of the Ministry of Security and Justice of the Netherlands, where he is a principal scientist, and the University of Twente, where he holds the chair of the Forensic Biometrics Department.

Dr. Meuwly specializes in the automation and validation of the probabilistic evaluation of forensic evidence, and more particularly of biometric traces. He was previously the leader of a project about the probabilistic evaluation of fingermark evidence and of the fingerprint section within the NFI. From 2002 to 2004, he worked as a senior forensic scientist within the R&D department of the Forensic Science Service (UK-FSS), at the time an executive agency of the British Home Office. From 1999 to 2002 he was a leader of the biometric research group of the IPS. He is a founding member of two working groups of the European Network of Forensic Science Institutes (ENFSI): the Forensic Speech and Audio Analysis Working Group (FSAAWG) in 1997 and the European Fingerprint Working Group (EFPWG) in 2000. He is still active within the EFWPG. Dr. Meuwly is also a member of the editorial board and a guest editor of *Forensic Science International* (FSI).

Arnout C. C. Ruifrok received his M.Sc. in biology from the University of Groningen in 1982. In 1987 he received his Ph.D. from the same university for his work on the evaluation of the effects of heat-treatment (hyperthermia) on the cellular plasma membrane. In 2002 he joined the Netherlands Forensic Institute, where he is a team leader in the area of image analysis, biometrics speech, and audio. His main responsibilities are research on the possibilities of use of biometric features in forensic identification, forensic applications of biometric systems, and facial comparison.

From 1987 to 1992 Dr. Ruifrok was involved with research projects concerning the effects of heat and radiation on tumor and normal tissues in animal model systems at the Daniel den Hoed Hospital (Rotterdam, The Netherlands) and the Radboud University (Nijmegen, The Netherlands). In 1992 he moved to the US to work on mathematical models of radiation response of tissues at the M. D. Anderson Cancer Center (Houston, TX), Department of Biomathematics, where he became involved in image analysis and pattern recognition. From 1999 to 2002 he joined the M. D. Anderson Department of Pathology, working on automated recognition and classification of cancer cells and in situ hybridization signals. Dr. Ruifrok is active in the Facial Identification Scientific Working Group.

Raymond N. J. Veldhuis graduated from the University of Twente in 1981. In 1988 he received a Ph.D. degree from Nijmegen University (Nijmegen, The Netherlands), with a thesis entitled “Adaptive Restoration of Lost Samples in Discrete-Time Signals and Digital Images”. Dr. Veldhuis is now a full professor in biometric pattern recognition at the University of Twente, where he is leading a research team in this field. The main research topics are face recognition (2D and 3D), fingerprint recognition, vascular pattern recognition, multibiometric fusion, and biometric template protection. The research is both applied and fundamental.

Dr. Veldhuis was a researcher at Philips Research Laboratories (Eindhoven, The Netherlands) working in various areas of digital signal processing (1982–1992) and in the field of speech processing (1992–2001).

Luuk J. Spreeuwers studied electrical engineering at the University of Twente, from 1982 to 1988. In 1992 he received his Ph.D. from the University of Twente with a thesis entitled “Image Filtering with Neural Networks — Applications and Performance”. Subsequently he worked as a postdoc at the University of Twente and at the Hungarian Academy of Sciences (Budapest, Hungary). Currently Dr. Spreeuwers investigates 2D and 3D face recognition in Dr. Veldhuis's group at the University of Twente. Dr. Spreeuwers's current main interests are model-based image processing, pattern recognition, and biometrics.

Dr. Spreeuwers was senior researcher (1997–1999) in the area of image processing in Mindmaker Ltd. (Budapest, Hungary). During 1999–2005, Dr. Spreeuwers worked on 3-D modeling and segmentation at the University Medical Center (Utrecht, The Netherlands).

Dr. Spreeuwers's main interests are model-based image processing, pattern recognition, and biometrics. He holds world records in 3D face recognition on the standard verification and identification benchmarks using FRGCv2 data (99.3% @FAR=0.1% and 99.4% rank 1).