Forensic Handwriting Examination at IGS Conferences: A Review by Numbers

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Abstract. We review the number of contributions to the advancements in handwriting analysis for forensic applications that were presented at the biennial conferences of the International Graphonomics Society through its 20 editions. We introduce a taxonomy for the systematic analysis of the literature, propose a way to evaluate the overall interest and relevance of the topic in the context of the conference editions, as well as the interest and relevance of each category of the taxonomy. We discuss past and current trends emerging from the quantitative analysis and outline some future possible developments.

Keywords: Forensic Handwriting Examination · Graphonomics

1 Introduction

The biennial conferences of the International Graphonomics Society have been the most relevant scientific events organized to fulfill the Society's mission of promoting the advancement of research in the field of graphonomics. The term graphonomics was introduced during the first conference to denote the scientific and technological effort for unveiling relationships between the planning and generation of handwriting and drawing movements, the resulting spatial traces of writing and drawing instruments (either conventional or electronic), and the dynamic features of these traces. Thus, it highlights the multidisciplinary and interdisciplinary nature of the entire research field, which encompasses motor control, experimental psychology, neuroscience, pattern recognition and artificial intelligence. The cross-fertilization between such diverse disciplines aims at understanding how handwriting is learned and executed, to which extent the handwriting characteristics vary under the influence of the neural, psychological, and biomechanical conditions of the writer, and to which extent the handwriting behavior can be explained in terms of patterns appearing in a given set of quantitative features derived from handwriting statistical and/or computational models.

Forensic handwriting examination (hereinafter referred as FHE) pertains to the analysis of handwriting for evaluating to which extent the specimen under investigation can be attributed to a given writer or to a writer among a set of them, by comparing the questioned samples to the genuine ones. It is therefore not surprising that forensic handwriting examination has deeply rooted in graphonomics, its goal being that of finding

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the characteristics of handwriting to evaluate and defining a measure of the similarity between two handwritten samples.

In this context, we survey the works that have been presented at the 20 biennial conferences over 40 years, from 1982 to 2022. The purpose is to identify the dimensions of forensic handwriting examination that have been addressed, how they have developed during this time-lapse, and to which extent they reflect the general trends in the field as observed from a broad perspective.

For sake of space, in this short paper, we will not discuss the major contributions of each paper, but rather how the number of papers falling in each of the categories varied over the years, with the aim of detecting their quantitative trends. For the same reason, the reference section includes only the proceedings and other publications that follow from the conferences. These goals will be pursued in a future extended version of the survey.

The remaining of the paper is organized as it follows. In Sect. 2 we will present the rationale behind the taxonomy we have adopted to present the literature, while in Sect. 3 we will outline the trends that we have observed, and suggest possible reasons related to changes in the field due to new methodological paradigms and/or technological developments. In Sect. 4 we briefly highlight what could be the future trends and the concluding section attempts to highlight some open issues and challenges that remain to be addressed.

2 A Taxonomy of Forensic Handwriting Examination Literature

In order to dissect how the different aspects of handwriting have contributed to the interest and the relevance of the topic, we have grouped the works on FHE that were presented at the IGS conferences into six categories:

- Methodologies
- Signature Verification
- Writer verification/identification
- Disguising writer identification
- Tools
- Case report

The *Methodologies (MET)* category includes papers that present either theories or experimental works aimed at finding the handwriting characteristics that reflect at the best the handwriting of a subject or a group of subjects and how they should be compared. The papers in this category look at handwriting generation and execution by adopting a motor control perspective to formulate hypotheses about the sources of the variability exhibited by the samples produced by different subjects or by the same subjects in different occasions, and by designing experiments rooted in the framework of experimental psychology for supporting the hypotheses or to unveil quantitative relation between the considered aspects of handwriting. Some of the papers included in this category, moreover, addressed the more general problem of defining the operative procedure forensic experts should follow during handwriting examination, from document collection to

final opinion formulation, in order to make the whole process easy to reproduce by different experts, while leaving the forensic expert to exert their expertise in putting the data into context and formulating the final answers to the specific questions for whom the examination has been requested.

Signatures are among the oldest and certainly the longest-lived means of authorship identification. Originally produced by ink and paper, the development of digitizing tablets capable of acquiring the temporal information of the trajectory has been deployed and used to collect signatures, opening new challenges to forensic experts, due to the intertwining of the handwriting execution and its digital representation and storage. As signatures are among the most automated handwriting movements, and because they are not meant to convey a message to the reader, but rather to link the writer to a graphical representation of its name, they raise specific issues and offer peculiar characteristics to be exploited, and then we have introduced the *Signature Verification (SV)* category.

The papers included in the *Writer identification/verification (WI/WV)* category describe the efforts to the general problem of assessing an individual identity through the analysis of the handwriting production. As such, they include mostly experimental studies adopting feature sets derived from the findings of investigations on handwriting learning and execution or exploiting properties of the digital representation of handwriting execution, and then processing them by some kind of statistical analysis, often implemented by a computer model of the probability distribution function, to achieve the final goal.

Disguising writer identification (Disguising) aims at detecting handwriting produced by a subject that intentionally modifies its handwriting behavior for eventually denying the authorship of a handwritten sample. It differs from the previous category because in writer identification/verification forensic experts aim to detect differences and weight their relevance with respect to similarity, in the latter they look for similarities and weight their relevance with respect to differences.

Papers belonging to the *Tools* category somehow complement those belonging to the previous ones, as they presented tools that have been developed for evaluating handwriting characteristics and put the obtained values in a statistical framework to have a quantitative profile of the handwriting, and eventually to evaluate the similarities/differences among samples.

The *Case Report (CR)* category, eventually, includes paper that describe the forensic examination of "extra-ordinary" cases, i.e. cases that deviate from the ordinary casework either for the relevance of the case itself (as it happens when new findings are reported to clarify previously disputed or questionable conclusion) or because they adventure in unexplored territories (as in case of the handwritings produced by subject with personality or motor disorders), so opening new technology-driven avenues or addressing challenging issues beyond the current state of the art and best practices.

3 FHE by Numbers

A preliminary analysis of the proceedings [1], as well as of the journal special issues and the books containing extended versions of selected papers presented at the various editions [2], allowed us to extract 164 papers that explicitly refer to FHE out of 907

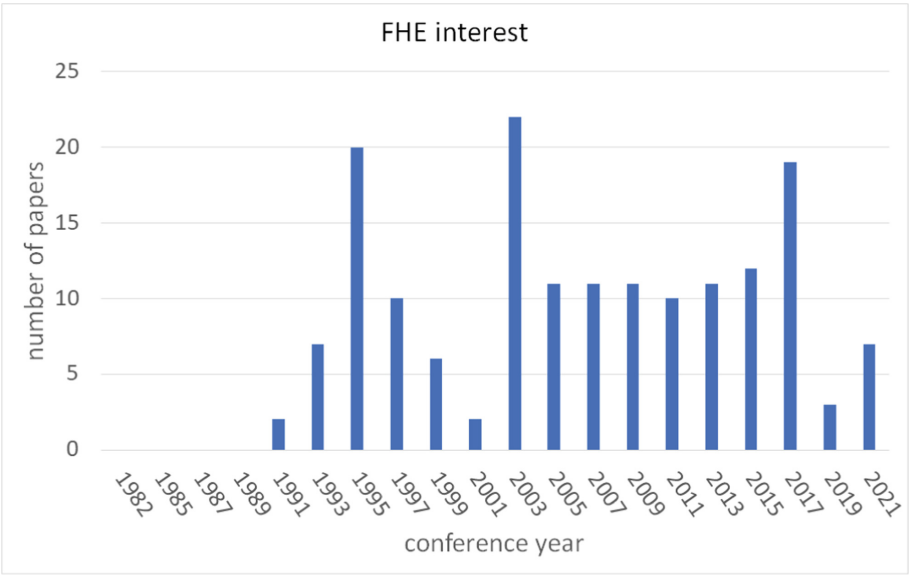

Fig. 1. The interest in FHE at IGS conferences, measured as the number of papers addressing the general topic of FHE at each edition of the IGS conference.

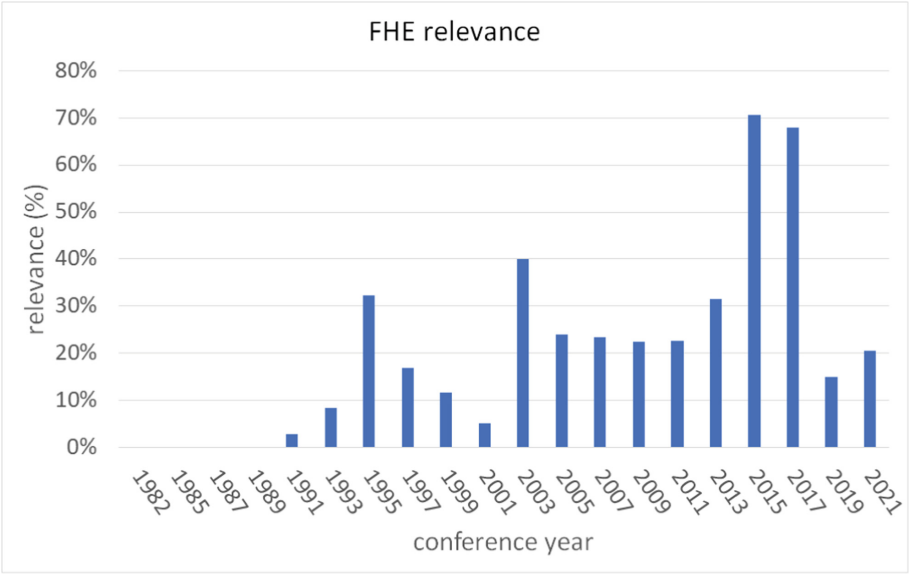

Fig. 2. The relevance of FHE at IGS conferences, measured as the percentage of papers addressing the general topic of FHE with respect to the total number of papers presented at each edition of the IGS conference.

papers presented at the conferences. Figure 1 shows the interest in the topic, expressed by the number of FHE papers presented at the different editions of the conference, while Fig. 2 shows the relevance of the topic within the conferences, defined as the percentage of FHE papers with respect to the total number of papers presented at each conference.

The histogram in Fig. 1 shows that starting from the 5th edition of the conference, FHE has been one of the topics addressed in every following conference, with a mean relevance of 18.1%. It also shows that the conference editions with the higher number of FHE papers have been the 7th, 11th and 18th editions with 20, 22 and 19 papers, respectively.

The 7th and 11th editions of the conference were organized in conjunction with the annual symposium of the Association of the Forensic Document Examiners and that had the effect of a significant increase of FHE papers with respect to the previous editions. The interest in forensic handwriting examination at IGS conferences surged again at the 11th edition and it remains stable until the 17th and 18th editions, when it accounts for roughly 70% of the total number of papers. The lasting interest in FHE since 2003 may reflect the reaction of forensic experts and scientists to several rulings of the US Supreme Court that questioned forensic document examination expertise as scientific expertise: Daubert et al. v. Merrell Dow Pharmaceuticals, U.S. v. Starzecpyzel cases, General Electric Co., et al. v. Joiner et al., Kumho Tire Co., Ltd., et al. v. Carmichael et al. and United States v. Paul ruled out in November 1993, April 1995, December 1997, March 1999 and May 1999, respectively.

The 18th edition of the conference, which was held in Italy, exhibited a renovated interest in FHE as an effect of the implementation of European directives about the legal effect of electronic signature and the following diffusion of commercial solutions for signing over a tablet in public offices. Many papers were submitted by Italian associations of forensic experts that in the years just before the conference had started a reconsideration and transformation of the procedures for handwritten document examination adopted by their affiliates.

In the last two editions, however, the interest decreases again, possibly because of the rather narrow focus of the 19th edition and the effects of the pandemics on the overall participation for the 20th edition.

To decide what category reflects to the best the content of the papers we have used author statements, experimental results evaluation and, as a last resort for a few cases, our judgement. So, while there maybe papers that could have been ascribed to a different category, we believe that the trends we have observed, as it will be described next, will not be affected by our choices.

After including each paper in its category, we have computed the interest and relevance of each category we have adopted. Figures 3 and 4 show the interest and relevance of each category with respect to the total number of FHE papers.

The histogram in Fig. 3 shows that each of the MET and SV categories accounts for more than 30% of the total number of FHE papers, and that together with the *WI/WV* category they include almost 85% of all the FHE papers presented at the 20 editions of the IGS conference. This is, at the same time, a piece of good and bad news. On the good side, the large number of papers addressing the methodological issues show that IGS conferences have been a primary place for the exchange of ideas between forensic

experts and scientists coming from the diverse disciplines envisaged by graphonomics to either get support for (or critics on) the foundations and best practice in FHE, or to offer other disciplines challenging issues. On the bad side, they show that disguising writer identification has been only marginally addressed at the conferences. This reflects a general trend in the field. A search on Scopus for the keyword "disguised handwriting" in title, abstract and keyword showed 49 documents, while a similar search for the keyword "writer identification/verification" returned 635 documents.

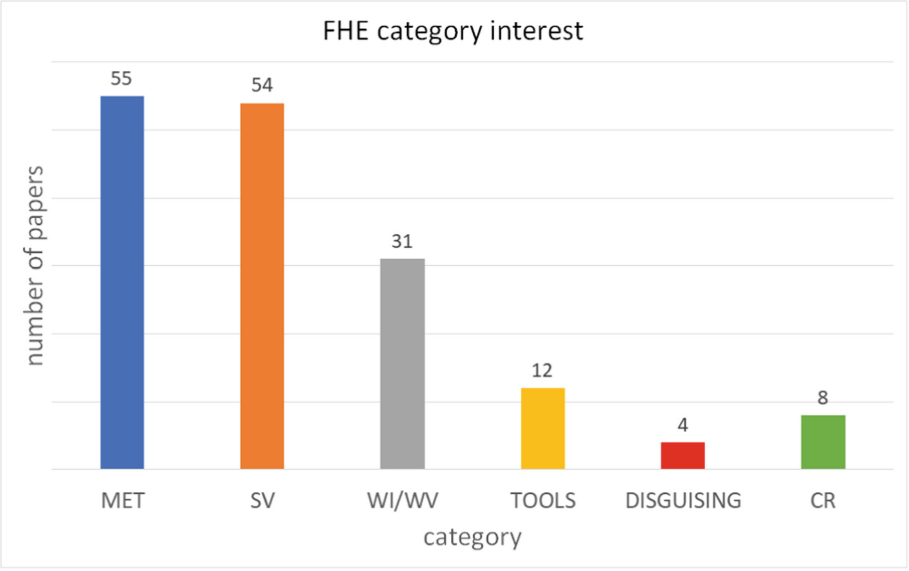

Fig. 3. The interest in FHE categories, measured as the number of papers included in each category presented at all the editions of the IGS conference.

The histogram in Fig. 4 shows that the distribution of the papers included in the MET category resembles very closely that of Fig. 3: roughly speaking, papers addressing methodological issues covers between 25% and 35% of the total number of FHE papers presented at each conference, confirming the observations we made by looking at the interest in the category. It also shows that the relevance of the SV increased a lot at the 11th edition and remained almost constant for the following seven editions. The large increment at the 11th edition was driven by two main factors: the widespread use of tablets, which raised new issues for FHE, and the availability of public datasets of genuine and forged signatures, which make it possible a fair comparison between competing approaches (and forensic experts as well) on a common ground. Eventually, the relevance of the TOOLS category reached its maximum at the 6th and 7th editions, but it has almost disappeared afterward. The main reasons for that could have been the establishment of the International Workshop on Frontiers in Handwriting Recognition, which was deemed more appropriate for presenting handwriting analysis tools by their designer since most of them were computer scientists, and the availability of powerful and versatile tools, such as MovAlyzeR and CEDAR-FOX.

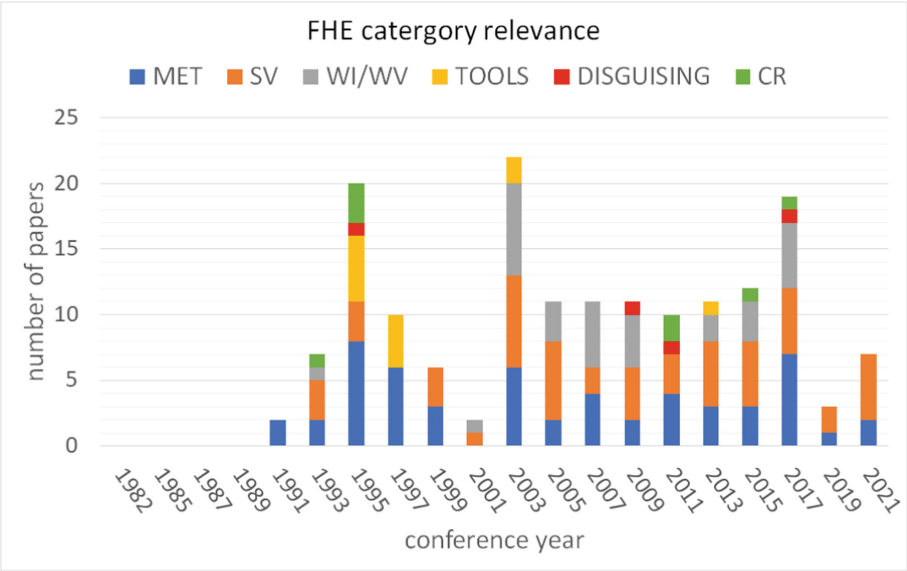

Fig. 4. The relevance of FHE categories, measured as the number of papers included in each category presented at each edition of the IGS conference.

4 Future Trends

In the last years, researchers that regularly attend IGS conferences are mainly interested in investigating how ageing and neurodegenerative disorders affect the planning and generation of handwriting. It is reasonable to expect that at the next IGS conferences FHE papers will focus on methods and experimental works aimed at considering the ageing of the neuromuscular system and the onset of neurodegenerative disorders during the assessment of authorship of a handwritten document.

Moreover, it is worth noting that the transition from handwriting on paper to handwriting on a tablet is still ongoing and both modalities will coexist still for many years. Therefore, we expect that at the next IGS conferences some papers will be focused on device interoperability, i.e. comparing online handwriting samples coming from different tablet devices, and mixed tool investigations, i.e. comparing handwriting samples written on a sheet of paper and on a screen.

5 Conclusions

We presented a quantitative review of the papers addressing the topic of forensic handwriting examination presented at the 20 editions of IGS conferences. At a glance, they show that forensic handwriting examination is a topic that has been addressed since the 5th edition and in each of the following ones. We have also discussed the factors that may have been the main causes of the "waves" of increasing/decreasing interest in the topic.

Our analysis at category level has shown that methodological issues have been addressed at each conference, and that they account for roughly one-third of the total number of papers related to FHE. It has also shown that signature verification and writer identification/verification have been the most addressed topics, while disguising writer identification has been the subject of the smallest number of papers. This seems to reflect the state of the art in FHE literature and one of the possible reasons for that is a lack of datasets that could be used to develop and test new proposals to address the subject. We believe that it is time for the IGS to call for a joint effort from forensic experts, experimental psychologists and computer scientists to collect and made publicly available such a data set.

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