Surveys and projects in handwriting analysis

State of the art in handwriting analysis software

Proposals for research in handwriting analysis

Contemporary topics, actors and resources in graphonomics

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Aim of the study

Our interest in handwriting stems from the wealth of information that it can provide about the social and cultural life of individuals and communities, as well as the neurocognitive and physiological mechanisms of the human body. The description of the physical aspects of the written word, it's production and perception is a central basic research that feeds the discussion of handwriting at higher level. Software development for handwriting analysis (HWA) is particularly beneficial since it requests formalization of methods, fosters objectivity and replicability, and enables automation of data processing. The aim of this study is to repertorize and evaluate such software as a first step in producing research tools for yet unexplored areas of HWA.

We look for commercial or public domain software able to measure any physical characteristic of handwriting, such as slant, cursivity, character sequence and other temporal aspects, density, regularity, etc. The extracted data has to be available for further processing and interpretation, software that analyze given aspects but don't display the measurements, being not useful for our goals (ex.: a signature verification software not expliciting the kinds of HWA it performs). We prefer software that is not script specific (ex.: not restricted to features particular to the Latin script). Since physical aspects rather than semantic are our primary concern, optical character recognition software will not be documented here.

A spin-off result of our research was the mapping of the aspects characterizing handwriting and the various scientific fields relating to handwriting analysis. Such an overview did not exist despite the breath of the research and the cultural status that handwriting enjoys.

The study was conducted by searching the Internet, compiling printed material and interviewing per email and telephone specialists in HWA. While we tried our best, we are aware that insider knowledge might reveal software that we were unable to locate.

Research fields and software

While there are many professions and interests centred around handwriting, a few have actively pursued the development of HWA software. These are: biometrics, forensic studies, graphology, paleography, kinetics and computer sciences. In the following we will discuss the particular goals of each of them, the handwriting aspects they consider and the software developed.

Biometrics

Biometrics is the umbrella term applied to all means of identification of individuals with the main purpose of security. Handwriting biometry represents today about 5% of the total biometrics market. Rather than a lack of usefulness for biometrical measures, this low figure should be considered as characterizing the underdevelopment of the HWA field and it's potential for untapped applications. Relying virtually entirely on computerized processing, biometrics are the primary place to look for HWA software.

The principal goal of handwriting biometrics is verification of identity claims (ex.: signatures) and identification of individuals (ex.: blackmail letters). Other applications are monitoring of health (ex.: stroke recovery monitoring through HWA) and the pursuit of scientific knowledge about constants and changes in human behaviour (ex.: gender and age as reflected in handwriting). The biggest domain for handwriting biometrics is authentication of financial transactions based on signature verification.

Given that HWA is not the goal of handwriting biometry but only a necessarily step, biometrical software cannot be used for HWA purposes without prior modification. Our survey concluded that handwriting biometrics software is not suitable for off-the-shelf use in HWA. However, there are a number of useful points that were learned about the contribution of biometry to HWA and the niches left empty in the current biometrical research.

Handwriting biometry differs from other HWA fields by the importance given to dynamic aspects of handwriting: sequence of character construction, duration of stroke length, speed and acceleration patterns of pen-tip movement, pressure by fingers on the writing instrument and by the instrument on the writing surface and even sound patterns of the moving pen-tip.

While some fields like paleography barely have showed an interest in handwriting dynamics because the documents they analyze are only the visible trace of hand motions, handwriting biometry deals overwhelmingly with the production of handwriting in the present and thus is able to record dynamic aspects. Processing of static handwriting has proved to be difficult, as show the problems of designing reliable handwriting OCR software, but the use of dynamic aspects has improved the reliability of HWA software to the point where signature verification is performed mainly on such aspects. E-commerce over the Internet and Pen computing are other social and technological factors that spurred the developments in dynamic analysis of handwriting.

Handwriting biometrics have a number of salient characteristics. They work primarily on constrained data as opposed to free data (ex.: verification of writer identity is done on the basis of his fixed signature rather than any text the writer might write); what matters is to identify individuals, not group appurtenance (ex.: age groups, gender or national writing styles); mostly life HWA is performed, not in the absence of the writer (i.e. dynamic aspects preferred over static). Thus HWA of free writing, group identification and static data are areas where handwriting biometry can expand. An untapped market is that of culture: cultural history (ex.: Art history), cultural industry (ex.: expertise of art objects), cultural conservation (public and private libraries and collections of art).

During our research we experienced difficulty in accessing detailed technical information about handwriting biometrical software. Most companies don't publish such data which is considered trade secret. We were however able to identify the limitations of current handwriting biometric software and their strong points, based on which we proposed new research axes and markets of development.

Forensic Studies

Handwriting is used in police investigations, by security agencies and detectives, and by lawyers in court as evidence material. Part of the questioned document specialization area, forensic HWA has together with handwriting divination and magic the longest history among all HWA fields. The institutionalized world where it gyrated and the critical aspect of it's expertise, has made forensic HWA to a well structured social body, having worldwide it's own societies, conferences and journals (a dozen only for North America).

A central contribution of forensic studies to HWA is to provide organized lists of aspects of handwriting that can be analyzed. By doing so they provide an overview over the object HWA specialist will work on. There are no other handwriting related field that can yield over a hundred investigation aspects.

HWA has however a long record of mistrusted forensic knowledge and many countries don't accept it as legal evidence. The reason is because many of the methods of describing the various aspects of handwriting are not formalized and their measurement accuracy unknown. Although we witness the increasing use of sophisticated tools such as multispectral cameras and image processing software, forensic HWA methods are designed primary for visual inspection and the observed aspects described in vague terms. The weight of tradition as well as the fear of loosing the expertise they incarnate, have created reluctance among many forensic experts against the mechanization of their trade.

Among other factors that limit forensic HWA is a low level of categorization effort. In the literature one might encounter seemingly endless lists of letter forms, given without an indication on how they relate to each other. Being absorbed by the study of writer idiosyncrasies makes it difficult to envision the handwriting phenomenon as a whole. Forensic HWA are still national, designed for specific writing systems, with unified methods still having a long way to go.

Surprisingly for the needs of forensic science the HWA software used in the field are disappointingly rudimentary. Less sophisticated than Photoshop, they are mere digital rulers for metric measurements and layered transparencies for visual comparison of handwriting (the Fish and Script systems used by the German police bureau, it's Dutch counterpart and the US Secret Service; the Wanda software in use in Germany and the French product ForenPix – see Bibliography for references). Only one software takes advantages of techniques developed in the field of artificial intelligence and pattern recognition, although only as a proof of concept: Wanda offers an computer aided search of letter shape prototypes in an on-line database. Another type of software that is advertised for HWA are in fact computerized check-lists, with the possibility of pooling the data in software for statistical analysis (ForenPix).

There is however a solid layer of document pre-processing in all mentioned software, mainly for the segmentation of the writing from the background, both at hardware and software level (using the physical proprieties of the ink and paper, and applying image processing).

Graphology

Whatever the scientific validity of reading one's psychology from the person's handwriting is, graphology should have the potential to develop methods for describing handwriting and software for HWA. This endeavour should be even more evident if the number of graphologist, their organization degree and publications are considered, as well as their social impact through the many companies that employ them. Graphology software tools however are electronic check-lists of a limited number of handwriting characteristics that are used to visualize psychological aspects of writers by means of bar graphs. Thus graphological HWA is reduced in these software to minimal visual inspection.

Paleography

Paleography is a scholarly research field dedicated to the HWA of pre-modern handwritings. It's principal aims are the dating, localization and writer or tradition identification, and the inference of socio-cultural aspects based on the analysis of handwriting. While this venerable profession has shown a substantive disinterest in modern technology, it has produced some of the few sophisticated ready-to-use HWA software. Also, it's cousin branch in Humanities, linguistics, was the initiator of the first encyclopaedia of graphonomics.

Because writer classification is central to paleography, it is not surprising that there are none less than three software available for this task. All of them are based on comparisons of instances of the same character. Entrap measures variations on entropy and was originally developed for HWA of Arabic script. A recent Israeli software based on previous work conducted on Hebrew writing in France during the 1970's and 1980's, uses geometrical aspects of the convex hull bounding the characters, while it's predecessors incorporated also the Fourier transform as mean of identification. An Italian software relies on the so-called tangent distance and statistical analysis to classify Latin letters. Noteworthy all three have been successful over a fair amount of benchmarking material. Therefore it is rather curious how little known these software are in the wider community interested in HWA and that besides their developers themselves. Mention should be made here also of the British Cuneiform Digital Forensic Project that is developing an web-based virtual 3D database of cuneiform tablets, which will eventually produce also tools for cuneiform HWA.

One critique that could be made regarding the present methods of paleographic HWA software is that they consider written characters to have a fairly stable morphology. Graphical context, as well as psycho-motor performance introduce variation in one's handwriting even during the production of a limited document. Consistency between characters and of the page texture they engender is not measured, thus the question of personal and group style is left out.

Kinetics

The study of psychomotor aspects of handwriting has given to HWA models of handwriting production as well as software and hardware tools for it's analysis. While the capture of the dynamics and pressure of pen-tip movement have been made ubiquitous by pen-computing (digitizing tablets, PDAs, pen computers sensitive screens), two products are particularly relevant to HWA. Steamed on over two decades of research in Dutch universities, the commercial Neuroscript software gives powerful recording, processing and analysis capabilities at research level standards. BiSP or Biometric smart pen is a German product, conceived also in an university, primarily intended for biometric authentification. It stands aside by being able to capture and process data from numerous sources: 3D pen-tip trajectory, 3D pen inclination, finger pressure on the pen and pen pressure on the writing surface, and sound pattern of the moving pen-tip.

It is the field of kinetics that was critical in setting the first public standards for description of dynamic aspects of handwriting and collected databases of on-line handwriting samples.

Computer Sciences

Computer scientist have developed a great number of methods for HWA and there exist a number of comprehensive surveys of the literature. However, the developed software was intended only for research purposes, so that it cannot be used as-is for HWA applications if access to it is granted.

Among the most significant theoretical contributions made to HWA are models of handwriting and it's individual uniqueness. Handwriting models resulted from the conjunction of interests in human kinematics, computer science and statistics, involving participants form the medical research, robotics and artificial intelligence fields. The models were helpful in retrieving kinematic data from static handwritten documents and the development of handwriting synthesis methods. Remarkably, much of the synthesis effort is taking place in Asian countries, where besides the complexities of the Chinese script, handwriting still enjoys an important cultural status. The digital simulation of brush movements is also a field where Asian research is particularly strong. As for the mathematical ability to prove that handwriting can be an individual biometric characteristic, it was an achievement grounded in a long involvement with OCR and the search for diversified applications of HWA, particularly in forensic studies.

Computer scientist have also the merit of organizing the HWA field: they succeeded in joining the forces of many individual researchers and laboratories, created the International Graphonomics Society, the first publications, conferences and joint research projects.

Conclusion

Despite the great need for HWA software and the amount of scientific research into HWA, there are currently extremely few off-the-shelf software that can be used. Furthermore, there are a number of application fields and interest groups that poorly exported or connected to mainstream research (ex.: the field of group identification and aesthetic perception of handwriting and the profession of art historians and art experts).

Resources

Biometrics

— aSign from XMS (Sweden)
`http://www.anotes.com/anoto/offerings_asign.html`

— BiSP (Germany)
`http://www.bisp-regensburg.de/`

— Softpro products (Germany)
`http://www.signplus.com/en/`

— Cyber-SIGN (USA)
`http://www.cybersign.com/`

Forensic Studies

— Comparison of Wanda, Fish and Shape software
Van Erp M., L.G. Vuurpijl, K. Franke & L.R.B. Schomaker (2003) — The WANDA Measurement Tool for Forensic Document Examination, *Proceedings of the 11th International Graphonomics Society Conference (2-5 November 2003, Scottsdale, AZ, USA)*, Tempe (AZ, USA), Neuroscript, 282–85.
`http://pentel.ipk.fhg.de/publications/vanerp03.pdf`

Franke Katrin, L.R.B. Schomaker, L.G. Vuurpijl & S. Giesler (2003) — A common ground for computer-based forensic writer identification, *Forensic science international*, 136 (supp): 84.
`www.ai.rug.nl/~lambert/papers/enfhex_wanda.pdf`

— Writing/background separation in forensic software
Franke Katrin & Mario Köppen (2001) — A computer-based system to support forensic studies on handwritten documents, *International Journal on Document Analysis and Recognition*, 3 (4): 218–31.
`http://unipen.nici.kun.nl/wandaML/WANDA/proper/proper_white.pdf`

— Wanda XML document description specifications
`http://lexx.ipk.fhg.de/wanda/frame.html`

— Unipen file format for dynamic handwriting description
`http://unipen.nici.kun.nl/`

— W3C XML specifications for digital ink
`http://www.w3.org/TR/InkML/`

— ForenPix from Fovea (France)
`http://www.foveafrance.com/Doc/ForenSystem/Fxsoft.pdf`
`http://www.foveafrance.com/Doc/ForenSystem/Fx_en.pdf`

— Multispectral camera from Fovea

http://www.foveafrance.com/Doc/ForenSystem/Fs_en.pdf

http://www.foveafrance.com/Doc/ForenSystem/Fsim_en.pdf

— Fovea products

http://www.foveafrance.com/Page1en.htm

http://www.foveafrance.com/Doc/ForenSystem/Presgen.pdf

Paleography

— Entrap software (Institute of Oriental Studies, St. Petersburg, Russia)

Rezvan Efim A. & N. S. Kondybaev (1996) — New tool for analysis ofhandwritten script, *Manuscripta Orientalia*, 2 (3): 43–53.

Rezvan Efim A. & N. S. Kondybaev (1999) — The Entrap software: test results, *Manuscripta Orientalia*, 5 (2): 59–64.

http://orient.thesa.ru/

— HWA software for Hebrew historic documents

Yosef I.B., K. Kedem, I. Dinstein, M. Beit-Arie, E. Engel (2004) — Classification of Hebrew calligraphic handwriting styles: preliminary results, *Proceedings of the 1st International Workshop on Document Image Analysis for Libraries (23-24 January 2004, Palo Alto, CA, USA)*, Washington (DC, USA), IEEE Computer Society, 299-305.

http://www.ee.bgu.ac.il/~dinstein/Publications/ClassificationHebrewCalligraphicStylesDIAL2004.pdf

Likforman-Sulem L., H. Maitre & C. Sirat (1991) — An Expert Vision System for Analysis of Hebrew Characters and Authentication of Manuscripts, *Pattern Recognition*, 24 (2): 121–37.

— Writer identification through tangent distance analysis (Istituto per la Ricerca Scientifica e Tecnologica, Trento, Italy)

Aiolli F., M. Simi, D. Sona, A. Sperduti, A. Starita & G. Zaccagnini (1999) - SPI: A System for Paleographic Inspections, Workshop on Intelligenza Artificiale per i Beni Ambientali, *Notiziario AI*IA*, 4: 34-8.

http://sra.itc.it/people/sona/PAPERS/aiolli99spi.pdf

— XML description standards for manuscripts

TEI Medieval Manuscripts Description Work Group

http://www.merrilee.org/tei-mss/

MASTER: Manuscript Access through Standards for Electronic Records

http://www.cta.dmu.ac.uk/projects/master/index.html

Digital Scriptorium

http://sunsite.berkeley.edu/Scriptorium/

Electronic Access to Medieval Manuscripts (Hill Monastic Libraray, Collegeville, MN, USA)
http://www.hmml.org/

Kinetics

— Neuroscript software for motor analysis (Tempe, AZ, USA)
http://www.neuroscript.net/

— Biometrical smart pen (University of Applied Sciences, Regensburg, D)
http://www.bisp-regensburg.de/

— References to off-line databases of handwriting samples (Chinese, Greek, Latin and Korean scripts)
Kavallieratou E., N. Liolios, E. Koutsogeorgos, N. Fakotakis, G.Kokkinakis (2001) – The GRUHD database of Modern Greek Unconstrained Handwriting, *Proceedings of the 6th International Conference on Document Analysis and Recognition (10-13 September 2001, Seattle, WA, USA)* Washington (DC, USA), IEEE Computer Society, 561–65.
http://slt.wcl.ee.upatras.gr/papers/kavallieratou5.pdf

— Unipen database of dynamic recordings
http://unipen.nici.kun.nl/

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Scope

The survey of available software for handwriting analysis (HWA) concluded the quasi-absence of sophisticated of-the-shelf HWA tools. We will make here a number of proposals for research axes that are currently underdeveloped or unexplored, yet crucial to HWA in particular and to the study of writing – graphonomics – in general. We explain the importance of the field for today's society and outline a research plan. Our proposals aim at a research and development project with modular extension capability of 2 to 6 years.

Importance of handwriting analysis today

For each of past, present and future aspects of our society there are particular reasons to be interested in handwriting. They all need to be addressed at a fundamental research level and by development of commercial applications.

Identity — Part of the humankind's memory about itself and the world our species inhabit is preserved only in written documents. Not only that these documents are getting each day less numerous due to various sources of destruction, and that therefore we should create ways of preservation, but also need to have the means of accessing them in order to make them an active component of our cultural identity. HWA can do both: facilitate storage and restoration, and prepare the interpretation of written material.

Regulation — There are many areas where HWA is used as a piece of evidence to ascertain a writer's identity: banking, e-commerce, police investigations, lawsuits, art objects trade. However sensitive they might be, especially in the context of present days, there is still much research to be done and applications to be written in order to objectify and automate the HWA process.

Communication — There are about 13 million individuals only among the population of USA with vision impairments, and the figures are expected to rise with ever longer life expectancies. One of the major destabilizing factors stated is their difficulty in accessing written material. Software for digital processing of type- and handwriting for increasing legibility would an enormous help for easier communication and better life quality.

Artistic & historical — As soon as the theoretical understanding of handwriting production and perception will be enough advanced to produce powerful handwriting processing software, there will be a new artistic field that we can expect to see emerge: synthetic handwriting, based on historical documents or pure invention. In fact, in Asia there are a growing number of virtual writing brush simulators reported in the technical literature and some writing robot prototypes, although intended as educational aid tools. We can also suspect that the availability of digital tools to manipulate the visual characteristics of writing will profoundly affect the history of writing, as hypertext did for the meanings carried by writing, more than a decade ago. Most probably it is the plasticity of digital writing that will be used: shapes can be individualized, visual identities modified hidden, appropriated and multiplied, and for the first time in history somebody can invent a true three dimensional and time dynamic script, because there are tools to allow us to represent writing that way.

Conjuncture — Additionally, it should not be overlooked that today is a favourable time for conducting research in handwriting. The biometrics industry is booming, pen computing is pressuring the development of handwriting OCR and there is an ever growing number of people enrolling in calligraphy associations, type designers contests and flooding world class exhibitions on exotic or futuristic calligraphy art.

Critical research axes

We identified a number of areas of handwriting research that are not explored or underexplored and that are critical to further developments in the field. They belong to the analysis and the manipulation of handwriting.

Analysis

While HWA has concentrated on the authentication and identification of individuals, it has left widely untouched the study of groups of writers that share common handwriting feature (country styles learned in schools, age groups, gender, medical conditions...). Together with group identification, HWA will benefit from designing techniques that apply to scripts independently from their system (Latin, Hebrew, Arabic, Chinese, Hindi...) and clarifying what aspects have to be treated independently. While it was so hard to bring the disparate fields of HWA into a common International Graphonomics Society, it should not split again in cultural turfs: general theories of handwriting should exist and considered as particular areas of kinetics and communication.

Morphological aspects — Most description elements routinely used in typography to describe the written stroke are not addressed in the researches done by the computer science community. These are thickness, contrast and chromatism of the stroke, and at the character and line level: character stretch, cursivity, connectivity degree, stroke length, line and page greyness and weight.

To give an example how uneven morphological aspects are treated across handwriting research fields, let us consider the intercharacter spacing (called kerning). We will find a long involvement of typography with the problem of kerning being not the mathematically uniform spacing of characters, but one that looks even to the human eye (which is called optical kerning). Now, while typography has succeeded in designing software for automatic optical kerning, nor the computer science, nor psychology has come forward with tools to measure and explain the phenomenon of optical kerning. The conclusion is that only through integration of disparate scientific and practical interests can the understanding of handwriting evolve.

Structural aspects — A serif is an example of a structural element of handwriting. Because it is easy to spot it visually in a document, structural elements are much used in forensic investigations. Computer scientist could design tools easy user input of structural elements and their automated search in documents. A prerequisite is however the existence of databases of handwriting samples. The collection of such samples is traditionally associated with historians – the paleographers –, who use them to date and localize old documents. Handwriting databases spanning over a wide range of time periods, cultures, social classes and ages, are necessary to understand the dynamics of handwriting evolution: why the present is as it is and how to prepare for changes in the near future.

Contextual allographs — Majuscules and minuscules are examples of structural allographs – graphic symbols with the same meaning, but radically different aspect. Morphological allographs are instances of the same character, where structure is preserved, although morphed by the natural process of human kinetics and physical variability in the writing implements (thirteen <a>'s in a row look each slightly different from the others). While finally we have today the theoretic basis of classifying allographs and identify writers based on allographs, both structural and morphological, there is one important aspect that is not addressed by computer science and largely undeveloped in forensic studies: the context and pattern of allographic choice.

There are numerous graphical reasons that can determine a writer to choose one allograph over the others, from simple end of lines where elongations are easier to produce, to the local environment of bi- and trigraphs, and aesthetic considerents such as writing one character per page in a particularly striking way. There are also neurokinetic determinants: mood, processing tiredness at writing, interruptions... Contextual aspects are so many, so interdependent and difficult to attribute to specific causes, that they are little studied. A more practical reason is that historically, both computer sciences and forensic sciences – where the bulk of automation in HWA is done -, have dealt with short text such as signatures, mail addresses or letters. For a solid knowledge of allographic behaviour of writers however, one has to operate on extended writing samples, as long as handwritten books – the traditional realm of paleographers. Contextual and pattern allography should be explored whatever the difficulties are because they represent the very writing behaviour of an individual – a very deep signature that is hard to fake due to it's complexity.

Quality — An increasing number of technical studies deal with the written text as it were the texture of a surface. While their principal goal is to provide means for differentiating between writers and help OCR software classify text according to the script it is written in, visual texture analysis has important implications for art history and the cognitive sciences that are neglected. Regularity and structural tension are the principal characteristics of good handwriting in most calligraphic traditions – they act as measures of quality. A possible implication of this is the cognitive function of calligraphic education to act as a training object for recognizing those real-world objects that display the characteristics of high quality writing. The production of calligraphy is equally interesting, since it has to investigate why the pleasure that might be experienced during body movement is the constant companion of qualitative handwriting. A handwriting quality measurement tool would also have applications in clinical medicine, where it could serve for testing and monitoring conditions, and be used as a rehabilitation therapy. Handwriting quality is the research hotspot of graphonomics with the widest ramifications into scientific fields.

Manipulation

Historically, the development of computational graphonomics was spurred by the OCR, and later by biometrics industry. Both domains produce analysis of handwriting, without generating a modified version thereof that could be re-presented to the onlooker. This fringe domain is however what handwriting legibility improvement, restoration and synthesis are doing.

Legibility improvement — The only method today that helps people with low vision read is through optical or digital magnification of the text – there is no software available for improving the legibility of handwritten messages. From the separation of text from the background, to the manipulation of handwriting at text block, line, character and stroke level, there are more than a dozen aspects that can make writing more legible: justifying, spacing and aligning lines, spacing words and characters, aligning them, making shapes morphologically consistent, opening loops, deslanting, simplifying and restoring shapes, dehashing, straightening, thickening and untexturing strokes. The aging world population is increasingly in need of devices to help it use handwritten communication in an efficient way.

Restoration — Together with the scholarly interest in the reading of historically important palimpsests such as Greek texts from the Antiquity reused in Medieval times, catastrophic flood and fires having afflicted libraries in the last century stirred the development of reading techniques for damaged documents, like multispectral analysis. Today it is the turn of digital processing to step in the restoration process, bringing with it the possibility of reconstructing the bits of writing for which there is no more any physical presence to be retrieved by the traditional means. In particular, it can use the still existing handwriting to identify it's characteristics and fill in the gaps: allographs and contexts can be identified, stroke sequences retrieved and the dynamics of the pen-tip reconstructed so that interrupted strokes can be continued.

Synthesis — Since the characteristics of a handwriting can be extracted, they can also be used to generate artificial writing. While handwriting synthesis is a branch of digital simulation, it relies on the findings of the analysis of handwriting. An important scientific contribution of this field is the need for understanding the kinetic and neurocognitive aspects of handwriting production and producing computational models to simulate them. The applications range from hands-free writing through digital secretaries that learned one's handwriting, to generating texts in the writing style of any given individual.

Conclusion

The strategic goal of our project is the establishment of interdisciplinary workgroups in the field of graphonomics. We focus on connecting art historians and art experts to computer scientists and neurophysiologist.

We can summarize the scientific goals that a 2 to 6 year long project on handwriting can have as group identification through morphological, structural, contextual and qualitative analysis and restoration, legibility improvement and synthesis by handwriting manipulation. The scientific infrastructure needed is multi-script databases of handwriting samples and general theories of handwriting production, perception and analysis, with an increased interdisciplinary approach as organizational cornerstone.

Contemporary topics, actors and resources in graphonomics

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Graphonomics is the study of the visual form of writing, as opposed to the meaning it conveys. This contribution provides an overview of the studied aspects, with emphasis on the physical characteristics of writing, and the principal areas contributing to graphonomic research. The collection of resources is focusing on the availability of off-the-shelf software for handwriting analysis.

The aim of this document is to serve as an introductory map to the field and stir interdisciplinary awareness among specialists. It is particularly aimed at art historians, art experts and neuropsychologists. From their collaboration with computer scientists and forensic experts we expect to see some very exciting future developments in graphonomics: how the ways in which writing is affected and perceived by the biological body interacts with the functions of writing in human cultures.

Aspects of writing studied in graphonomics

Graphonomics studies informational, physical, biological and cultural aspects of writing. The various solutions for encoding information in writing and their proprieties represent the informational aspects. By physical aspects we understand the spatio-temporal characteristics of writing, as well as its technology: materials, tools, processes. Physiology, neurology and psychology deal with the biological basis of writing production, perception and cognition; while the cultural ecosystem encompasses social relations, economic factors, artistic and literary creations, religious customs and popular practices. Graphonomics is approaching writing cross-culturally, cross-temporally and cross-technologically.

Writing study fields

Form	Graphonomics...
Meaning	Semantics, Philology, Philosophy...

Writing aspects

Informationa	encoding	
Physical	objectual	spatial
		temporal
		force
		sonor
		odor
	technologic	instruments
		inks
		supports
		accessories
Biological	physiological	
	neurological	
	psychological	
Cultural	social	
	economic	
	artistic	
	literary	
	customary	
	religious	
	technological	
	other	

Spatial aspects of writing		
Structure	character	stroke length (per character & script)
		holes
		openings directions
		curvature
		shape complexity
	text	gray
		patterns (per script & language)
Form	stroke	width
		contrast
		chromatism
		endings
		grayscale variation
		texture
		color
		tremor
		hashing
		3D shape
	character	size
		stretch xy
		optical slant
		shear
	line	stroke length (per word / script / language)
		connectivity
		character spacing
		word spacing
		baseline shape
		number of portant lines
		cursivity
	text-block	justification
		line spacing
		block shape
		weight
Context		
Quality	regularity	
	tension	
	degradation	
	individuality	

Temporal aspects of writing
Stroke movement direction
Character construction sequence of strokes
Corrections
Speed
Acceleration
Rhythm
Tremor

Actors and interest

Academia, economy, government, culture and arts are the main social areas contributing to graphonomics. In the pursuit of knowledge, scientists and humanists use writing as a medium of authorship identification (dating archival documents…), understanding biological and cognitive processes (human kinematics, neural basis of aesthetics…) and reproducing artificially human activity (machine reading, computer synthesized handwriting…). Investments of private and public companies come predominantly from the finance sector and research and development technology companies. They are directed towards the automation of authentication and communication processes based on writing (signature recognition, optical character reading…). Although being regrettable, the practice of graphologic psychological profiling during recruitment is also an area where private companies are active. The police forces, intelligence agencies and the legal system seek in graphonomics tools to establish authorship (authoring blackmail letters, monitoring correspondence, questioning potentially forged documents…). The quantification, conservation and popularization of the symbolic and monetary value embodied in calligraphies or inscribed objects of art is at the core of the art market and public and private art collections. As for the artists, writing is the creative material necessary for their personal transformation and the social influence they exert.

Actors and their interest in graphonomics

scientists (*) humanists (**)	Academia	Knowledge	authentication understanding biological and cultural phenomena simulation
finance technology companies graphology	Economy	Automation	authentication communication
police intelligence judiciary	Government	Authorship	authentication
art market private art collections public art collections	Culture	Value	authentication conservation popularization
artists	Arts	Creation	

(*) COMPUTER SCIENCES – computer sciences, OCR, artificial intelligence, pattern recognition, image processing, data bases, data mining; mathematics – statistics, information theory; medicine – kinematics, psychology, neurosciences, cognitive sciences, … (**) SUPPORT – codicology, paleography, epigraphy, papyrology, numismatics,diplomatics, ceramology, textile studies, arms studies, painting, tattoo; TECHNIQUE – calligraphy, typography (manual, mechanic, digital), xylography, lithography; CULTURE – Latin, Cyrillic, Hebrew, Arabic, Inidc, Chinese, Japanese, Korean, Egyptology, Assyriology, Sud-Arabic, Maya culture…; FIELD – art history, history, linguistics, anthropology, sociology, communication theory, literature, philology, philosophy, museology, bibliotheconomy

Resources

Biometrics

Software – Writer identification digital pens:

— aSign from XMS (Sweden)
http://www.anotes.com/anoto/offerings_asign.html

— BiSP (Germany)
http://www.bisp-regensburg.de/

— Softpro products (Germany)
http://www.signplus.com/en/

— Cyber-SIGN (USA)
http://www.cybersign.com/

Publications

Ashbourn Julian (2004) — *Practical Biometrics: From Aspiration to Implementation*, Springer Verlag, Berlin (D), 159 p.

Maltoni Davide & Anil K. Jain (Eds.) (2004) — *Biometric Authentication (ECCV 2004 International Workshop, BioAW 2004, Prague, Czech Republic, May 15, 2004, Proceedings)*, Springer Verlag, Berlin (D), 343 p.

Nanavati Samir, Michael Thieme & Raj Nanavati (2002) — *Biometrics: Identity Verification in a Networked World*, Hoboken (NJ, USA), John Wiley & Sons, 320 p.

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— Biometrics
http://www.jstor.org/journals/0006341X.html

— Biometric Digest
http://www.biometricinfodirectory.com/

— Biometric Technology Today
http://www.compseconline.com/publications/prodbio.htm

— Biometrics Market Intelligence Newsletter
http://www.biometricsmi.com/

Organizations

— International Biometric Society
http://www.tibs.org

— International Association for Biometrics
http://www.afb.org.uk/

On-line resources

http://www.biometricgroup.com/

http://www.eubiometricforum.com/

http://www.biometricinfodirectory.com/

http://findbiometrics.com/

Software

— Comparison of Wanda, Fish and Shape software
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`www.ai.rug.nl/~lambert/papers/enfhex_wanda.pdf`

— Writing/background separation in forensic software
Franke Katrin & Mario Köppen (2001) — A computer-based system to support forensic studies on handwritten documents, *International Journal on Document Analysis and Recognition*, 3 (4): 218–31.
`http://unipen.nici.kun.nl/wandaML/WANDA/proper/proper_white.pdf`

— Wanda XML document description specifications
`http://lexx.ipk.fhg.de/wanda/frame.html`

— Unipen file format for dynamic handwriting description
`http://unipen.nici.kun.nl/`

— W3C XML specifications for digital ink
`http://www.w3.org/TR/InkML/`

— ForenPix from Fovea (France)
`http://www.foveafrance.com/Doc/ForenSystem/Fxsoft.pdf`
`http://www.foveafrance.com/Doc/ForenSystem/Fx_en.pdf`

— Multispectral camera from Fovea
`http://www.foveafrance.com/Doc/ForenSystem/Fs_en.pdf`
`http://www.foveafrance.com/Doc/ForenSystem/Fsim_en.pdf`

— Fovea products
`http://www.foveafrance.com/Page1en.htm`
`http://www.foveafrance.com/Doc/ForenSystem/Presgen.pdf`

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Morris Ron N. (2000) — *Forensic Handwriting Identification: Fundamental Concepts and Principles*, San Diego (CA, USA), Academic Press, August 2000, 238 p.

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Periodicals

— International Journal of Forensic Document Examiners
http://static.highbeam.com/i/internationaljournalofforensicdocumentexaminers/

— Journal of Forensic Document Examination
http://www.afde.org/journal.html

— Journal of the American Society of Questioned Document Examiners
http://www.asqde.org/journal_e_journal.htm

— Proceedings of International Workshops on Frontiers in Handwriting Recognition
http://koigakubo.hitachi.co.jp/~IWFHR9/

Organizations

— International Association for Identification

`http://www.theiai.org/`

— American Society of Questioned Document Examiners

`http://www.asqde.org/`

— The Association of Forensic Document Examiners

`http://www.afde.org/`

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Rezvan Efim A. & N. S. Kondybaev (1996) — New tool for analysis ofhandwritten script, *Manuscripta Orientalia*, 2 (3): 43–53.

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— handwriting analysis software for Hebrew historic documents

Yosef I.B., K. Kedem, I. Dinstein, M. Beit-Arie, E. Engel (2004) — Classification of Hebrew calligraphic handwriting styles: preliminary results, *Proceedings of the 1st International Workshop on Document Image Analysis for Libraries (23-24 January 2004, Palo Alto, CA, USA)*, Washington (DC, USA), IEEE Computer Society, 299-305.
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— Writer identification through tangent distance analysis (Istituto per la Ricerca Scientifica e Tecnologica, Trento, Italy)

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`http://sra.itc.it/people/sona/PAPERS/aiolli99spi.pdf`

— XML description standards for manuscripts

TEI Medieval Manuscripts Description Work Group
`http://www.merrilee.org/tei-mss/`

MASTER: Manuscript Access through Standards for Electronic Records
`http://www.cta.dmu.ac.uk/projects/master/index.html`

Digital Scriptorium
`http://sunsite.berkeley.edu/Scriptorium/`

Electronic Access to Medieval Manuscripts (Hill Monastic Libraray, Collegeville, MN, USA)
`http://www.hmml.org/`

Publications

Günther Hartmut (1994, 6) (Ed.) — *Writing and its use*, Berlin, de Gruyter, 2 vol.
`http://www.amazon.de/ > writing and its use`

Daniels Peter T. & William Bright (1996) — *The World's Writing Systems*, Oxford (UK), Oxford University Press, 919 p.
`http://www.amazon.com/ > the world's writing systems`

Periodicals

— Gazette du livre médiéval
`http://www.oeaw.ac.at/ksbm/glm/glm.htm`

— Manuscripta orientalia
`http://orient.thesa.ru/`

Organizations

— International paleographic association
`http://www.irht.cnrs.fr/cipl/apices.htm`

On-line resources

— Ductus, an on-line course in paleography (University of Melbourne, Australia)
`http://www.medieval.unimelb.edu.au/ductus/`

Kinetics

Software

— Neuroscript software for motor analysis (Tempe, AZ, USA)
`http://www.neuroscript.net/`

— Biometrical smart pen (University of Applied Sciences, Regensburg, D)
`http://www.bisp-regensburg.de/`

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Kavallieratou E., N. Liolios, E. Koutsogeorgos, N. Fakotakis, G.Kokkinakis (2001) – The GRUHD database of Modern Greek Unconstrained Handwriting, *Proceedings of the 6th International Conference on Document Analysis and Recognition (10-13 September 2001, Seattle, WA, USA)* Washington (DC, USA), IEEE Computer Society, 561–65.
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`http://www.laboratorium.dist.unige.it/~piero/Papers/encyclopedia.pdf`

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`http://link.springer.de/search.htm > Plamondon`

Periodicals

— Journal of Motor Behavior

http://www.ProQuest.com

— Somatosensory and motor research

http://www.ingentaselect.com

— Motor Control

http://www.sciencedirect.com/Organizations

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— Surveys of HANDWRITING ANALYSIS

PLAMONDON R. & S.N. Srihari (2000) — Online and off-line handwriting recognition: a comprehensive survey, *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 22 (1): 63–84.
`http://csdl.computer.org/comp/trans/tp/2000/01/i0063abs.htm`

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BUNKE Horst (2003) — Recognition of Cursive Roman Handwriting: Past, Present and Future, *Proceedings of the 7th International Conference on Document Analysis and Recognition (3-6 August 2003, Edinburgh, Scotland)*, Washington (DC, USA), IEEE Computer Society, 1: 448-61.
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`http://www.elsevier.com/locate/patcog`

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— Handwriting synthesis

Wang Jue, Chenyu Wu, Ying-Qing Xu, Heung-Yeung Shum & Liang Ji (2002) — Learning-based Cursive Handwriting Synthesis, *Proceedings of the 8th International Workshop on Frontiers in Handwriting Recognition, (6-8 August 2002, Ontario, Canada)*, Washington (DC, USA), IEEE Computer Society, 157–62.
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— Synthetic textures

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additional resources
http://www.cs.berkeley.edu/~efros/research/synthesis.html
http://www.cns.nyu.edu/~lcv/texture/

— Virtual brushes

Chu N.S.H. & Tai Chiew-Lan(2004) — Real-Time Painting with an Expressive Virtual Chinese Brush, *Computer Graphics and Applications*, 24 (5): 76–85.
http://csdl.computer.org/comp/mags/cg/2004/05/g5076abs.htm

— Legibility improvement

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http://ieeexplore.ieee.org/xpl/abs_free.jsp?arNumber=721341

Organizations, Work groups

— International Graphonomics Society
http://www.cedar.buffalo.edu/igs/

— Nijmegen Institute for Cognition and Information (NICI), Nijmegen, The Netherlands
http://hwr.nici.kun.nl/

— Center of excellence for document analysis and recognition (CEDAR), The State University of New York, Buffalo, NY, USA
http://www.cedar.buffalo.edu/

— Laboratoire Scribens génie électrique, École Polytechnique de Montréal, Montréal, Canada
http://www.scribens.polymtl.ca/

— Center for Pattern Recognition and Machine Intelligence (CENPARMI), Montréal, Canada
http://www.cenparmi.concordia.ca/

Periodicals, Conferences

— Bulletin of the International Graphonomics Society
http://www.cedar.buffalo.edu/igs/BIGS_Volumes.html

— Conference of the International Graphonomics Society (IGS)
http://www.igs2005.unicas.it/

— International Workshop on Frontiers in Handwriting Recognition (IWFHR)
http://koigakubo.hitachi.co.jp/~IWFHR9/

— International Conference on Document Analysis and Recognition (ICDAR)
http://www.csc.liv.ac.uk/~prima/ICDAR2003/

— International Journal on Document Analysis and Recognition (IJDAR)
http://www.springeronline.com/sgw/cda/frontpage/0,11855,5-147-70-1122349-0,00.html