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GRAPHONOMICS FOR E-CITIZENS: E-HEALTH, E-SOCIETY, E-EDUCATION

Edited by
Claudio De Stefano and Angelo Marcelli

18-21 June 2017 – Gaeta, Italy

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IGS 2017

	Monday, 19	Tuesday, 20	Wednesday, 21
8:40-9:00	*Opening*		
9:00-9:20		**Forensic Handwriting Examination**	**Pattern Recognition for Forensic Applications**
9:20-9:40	**Handwriting Education**		
9:40-10:00			
10:00-10:20			
10:20-11:00	*Coffee Break*	*Coffee Break*	*Coffee Break*
11:00-12:00	**Keynote Speech** Prof. M. Schieber	**Keynote Speech** Prof. H. Harralson	**Keynote Speech** Prof. O. Tucha
12:00-13:00	**Poster & Exhibition Forensic Applications**	**Poster & Exhibition Cultural Heritage and Education**	**Poster & Exhibition Handwriting Analysis and Neuroscience**
13:00-14:20	*Lunch*	*Lunch*	*Lunch*
14:20-14:40	**Special Session on Sensory and Motor Brain-Machine -Interfaces**		**Special Session on Palaeography**
14:40-15:00		**Handwriting and Motor Control**	
15:00-15:20			
15:20-15:40			
15:40-16:00			
16:00-16:20		*Coffee Break*	*Coffee Break*
16:20-16:40	*Coffee Break*		
16:40-17:00	**Handwriting Analysis**	**Handwriting and Neuro Diseases**	**Handwriting Education**
17:00-17:20			
17:20-17:40			
17:40-18:00			
18:00-18:30			*Awards & Closing*

Monday, 19

ORAL SESSION 1:
HANDWRITING EDUCATION
(Chair: A. Accardo)

Objective Measurement of Handwriting Learning Outcomes at Elementary Schools Suggests Instruction Improvements

Hans-Leo Teulings and Bouwien Smits-Engelsman

Teachers evaluated neatness and legibility in 1179 handwriting samples in The Netherlands. We developed software to automatically identify each letter and estimate several feature per letter or letter pair. Results showed that poor neatness or legibility were associated with excessive mean or variability (standard deviation or SD) per handwriting sample. Critical features of poor handwriting are: Mean body letter height >3.7 mm (SD >0.55 mm), SD of distance to the rule line >0.35 mm, mean distance between the letters >1.3 mm (SD >0.5 mm), mean word space >6 mm (SD >1.5 mm), mean heights relative to the body height of ascender and descender loop letters <1.8 and for stick letters <1.5, letter connectedness <70%, and slant more >10 degrees forward (SD >6 degrees). Subsequently we verified the handwriting features in 324 children in the final year of elementary school. They showed significantly higher variability than required for neat and legible handwriting with respect to 4 key features: 65% of the children showed excessive variability of ascender slant, 51% showed excessive variability of letter body height, 43% showed excessive variability of word space, and 34% showed excessive variability of distance from the rule line. To reduce variability of these 4 and other handwriting features during the final years of elementary school, initial handwriting instruction should focus more on slow, fluent, and accurate movement execution and teachers should monitor especially those 4 handwriting features.

Executive Functions, Coordination and Developmental Functional Abilities as Predictors of Writing Capabilities among Adolescents

Liat Hen Herbst and Sara Rosenblum

Objective: (1) To compare writing capabilities, executive functions (EF), attention, coordination and developmental and functional

abilities of adolescents with dysgraphia to those of controls (2) To predict writing capabilities of adolescents with and without dysgraphia. Method: Participants included 80 adolescents, aged 13-18, 40 with dysgraphia, and 40 matched controls. Adolescents copied a paragraph and wrote an essay on paper affixed to a digitizer supplying objective handwriting process measures (Computerized Penmanship Evaluation Tool–ComPET). The essays' content quality was evaluated by the Six Trait Method. Furthermore, participants completed the Behavior Rating Inventory of Executive Function – Self-Report (BRIEF-SR), and performed tasks from the WebNeuro (EF), the Adult ADHD Self-Report Scales (ASRS-v.1.1) (attention) and the Adult Developmental Coordination Disorder Checklist (ADC) (Coordination). Parents completed developmental and functional questionnaires (Developmental History and Child Evaluation Checklist (CHECK)). Results: Significant group differences were found for the handwriting process (ComPET) and written content capabilities (Six Trait), executive control domains (BRIEF-SR & WebNeuro), attention (ASRS), and coordination (ADC). 43% of the variability of mean stroke duration and 63% of the variability of the written content quality were predicted by EF, attention, coordination and developmental and functional measures. Conclusion: Results strongly show significant differences in handwriting and writing performance between adolescents with and without dysgraphia. Variability in handwriting and writing can be predicted by executive control domains, attention, coordination and developmental functional abilities.

Relationships Between Handwriting Timing, Executive Functions and Daily Functioning among Adolescents with Neuro-developmental Disabilities
Yael Fogel, Sara Rosenblum and Naomi Josman

Objective: To examine the relationships between handwriting features, executive functions (EF) and daily functioning among adolescents with neuro-developmental disabilities (NDD). Method: Participants included 81 adolescents aged 10-19, 41 characterized with difficulties in daily functions and EF deficits according to parents' reports based on questionnaires about participants' daily function (CHECK) and EF deficits (BRIEF). Participants copied a written paragraph onto a sheet of paper affixed to a digitizer supplying

objective measures of the handwriting process, and further completed a computerized EF assessment (WebNeuro). Results: As expected, significant differences were found between the groups in daily functions and EF according to parents' reports. Compared to controls, adolescents with NDD required significantly more on-paper and in-air time per stroke while copying, and EF as measured by the computerized assessment were significantly more deficient. Significant correlations were found between the handwriting temporal process measures and both EF and daily functions. It was also found that EF domains and daily functions, predicted 30% of the variance of the 'in-air' and 25% of the variance in the 'on paper' handwriting time Conclusion: Study results strongly recommend that handwriting standardized evaluation contributes to better insight of daily performance amongst adolescents with NDD, emphasizing EF as an underlying mechanism of this disabilities.

KEYNOTE SPEECH
(Chair: A. Marcelli)

Control of the Hand and Arm: Distributed, but Serial Rather than Parallel Processing
Mark H. Schieber

We typically have the impression that we move one finger at a time during actions such as typing or playing a musical instrument. Careful inspection shows, however, that in virtually all such performances multiple fingers move simultaneously. This concurrent motion of multiple fingers reflects the underlying structure of the hand and the neuromuscular system that controls it. For example, the soft tissues of the hand produce some degree of coupling between adjacent digits, as do the interconnections between certain tendons. In addition, certain muscles have motor units that exert tension on the tendons to adjacent digits. These various forms of biomechanical coupling require active stabilization of other fingers while a particular finger moves. Furthermore, many single corticospinal neurons act on multiple muscles which in turn act on different digits. And finally, within the primary motor cortex—which is essential for dexterous, individuated finger movements—neurons active during the movement of any given finger are widely distributed and extensively intermixed with the neurons active during movement of any other

finger. Hence the entire system controlling the hand is active even when we think we are moving only a single finger. Similarly, in reaching out to grasp and manipulate an object (e.g. picking up your pen to write), we tend to think that the grasping motion of the hand is proceeding in parallel with the reaching movement of the arm, i.e. the hand and the arm are moving at the same time, but under separate control for different purposes. Recently, however, we have found that joint rotations, muscle activity, and neuron activity in the motor cortex, all proceed in two sequential phases. The first phase projects the entire upper extremity—arm and hand—toward the target's location; the second phase shapes the entire extremity to grasp and manipulate the object. Thus while reaching and grasping both involve the arm and the hand, projection of the extremity toward the target location is set in motion first, and thereafter the entire extremity is shaped to grasp and manipulate. These findings from reach-to-grasp movements are consistent with casual observation of handwriting, in which the arm moves to shift the hand to a fresh area of the paper, and thereafter the simultaneous motion of multiple digits moves the pen to form letters.

POSTER & EXHIBITION 1:
FORENSIC APPLICATIONS
(Chair: R. Senatore)

Uyghur Handwritten Signature Recognition Based on BP Neural Network
Ahat Yimin, Mahpirat Mamat, Hornisa Mamat, Alimjan Aysa and Kurban Ubul

Handwritten signature recognition is extensively studied in the past 30 years, but there are a few reports about Uyghur handwritten signature recognition. Bp neural network based recognition scheme is proposed for Uyghur handwritten signature recognition in this paper. Uyghur handwritten signature images were pre-processed firstly. Then, texture features, shape features and Hu invariant moment features were extracted respectively. Finally, the BP neural network based classification method used for signature recognition. A total of 1000 signature samples from 50 signers (20sample/person) were selected from in our Uyghur signature database for the experiment, and 95% of maximum recognition rate was obtained during the experiment. In order to further verify the effectiveness of the proposed

method in this paper, same amount of signatures were selected from GPDS signature database and comparative experiments were conducted. The experimental results show the efficiency of the proposed method.

Overview and New Trends in Dynamic Signature Verification
Donato Impedovo and Giuseppe Pirlo

This paper presents an overview of the field of dynamic signature verification. Through the paper, the different phases of the signature verification process are presented and some of the most valuable results are discussed. Finally, some of the challenges of the field of dynamic signature processing are focused and promising directions for further research are highlighted.

Feature Evaluation for Handwritng: A Ranking-Based Approach
Francesco Fontanella, Claudio De Stefano and Alessandra Scotto di Freca

Feature selection is generally considered a very important step in any pattern recognition process. Its aim is that of reducing the computational cost of the classification task, trying to increase, or not to reduce, the performance of the whole recognition system. In the framework of handwriting recognition, the large variability exhibited by the samples produced by different writers makes even more complex the selection of appropriate feature sets, and has led to the development of a wide research activity, which has produced many interesting results published in the literature. Nonetheless, this problem is very far to be solved in the general case, since the above results present limitations at different levels. The main drawbacks include the complexity, the dependence on the adopted classifiers and the difficulty in evaluating the interactions among features. In this study, we have tried to overcome some of the above drawbacks by adopting a feature ranking based technique: we have considered different univariate measures to produce a feature ranking and we have proposed a greedy search approach for choosing the feature subset able to maximize the classification results. In our work we have chosen one of the most widely used feature set in handwriting recognition, while the experimental results have been obtained by using three real word datasets of handwritten characters.

Evaluation of the Distance Between Averaged Handwritten Shape and Fonts by Earth Mover's Distance
Yoshinori Akao and Yoshiyasu Higashikawa

In forensic handwriting examination, we sometimes set standard font as reference character shape for pointing out the feature of handwritten shape. Empirically, we use textbook style font as the reference since we refer the font in learning how to write in elementary school. However the appropriateness was not proved numerically. Therefore in this study, we evaluated the difference of averaged handwritten shape and fonts numerically by using Earth Mover's distance (EMD). Average character shape of 60 participants was obtained by kernel density estimation. EMD value was obtained for nine types of fonts were evaluated concerning 500 Chinese characters, 46 Japanese hiragana characters, and 10 numerals. The result showed that EMD value was smallest in textbook style font concerning Chinese and Japanese hiragana characters. EMD value of the fonts designed based on handwritten shape was smaller than others based on printing typeface. The difference was statistically significant. Concerning numerals, the difference was not statistically significant.

User Adaptation for Multi-Classifier Signature Verification Based on the Kinematic Theory
Angelika Garz, Florian Schütz, Alessandro Villa, Réjean Plamondon and Andreas Fischer

Muscular movements of humans, such as signatures performed with a digital stylus, can be analyzed by the kinematic theory of rapid human movements. This paper introduces a user adaption method for signature verification based on neuromuscular analysis and dynamic time warping. Using only pen-tip trajectory information, the verification system considers two complementary perspectives: the former extracts and compares the neuromuscular strokes a signature is composed of, whereas the latter directly analyzes the observed handwriting signal. We compute a fixed user-dependent offset for each user and demonstrate on several benchmark datasets that the proposed user adaption method further improves the already very reliable multi-classifier system.

Looking at the Ink Distribution for Assessing Writing Modalities in Forensic Handwriting Examination
Sergio Frontini, Giuseppe Giordano, Francesco Dellavalle, Antonio Parziale and Angelo Marcelli

We present the motivations and the results of an investigation aimed at establishing to which extent bumps observed in the ink trace do not correspond necessarily to hesitation of the writing movements but can be observed in fluent handwriting as well. We will show by experiments that this latter case occurs very often and provide an explanation in term of the characteristics of the neuromuscular system involved in writing. Those observations provide also the ground for the features of the ink that discriminate between fluent and hesitant writing movements. We eventually discuss the implications on the practice of forensic handwriting examination.

SPECIAL SESSION 1:
SENSORY AND MOTOR BRAIN-MACHINE-INTERFACES FOR GRASPING AND MANIPULATION: FROM BASIC TO CLINICAL APPLICATIONS
(Chairs: J. L. Contreras-Vidal, S. Soekadar)

Biological and Bionic Hands: Natural Neural Coding and Artificial Perception
Sliman Bensmaia

Our ability to manipulate objects dexterously relies fundamentally on sensory signals originating from the hand. To restore motor function with upper-limb neuroprostheses requires that somatosensory feedback be provided to the tetraplegic patient or amputee. Given the complexity of state-of-the-art prosthetic limbs, and thus the huge state-space they can traverse, it is desirable to minimize the need of the patient to learn associations between events impinging upon the limb and arbitrary sensations. With this in mind, we seek to develop approaches to intuitively convey sensory information that is critical for object manipulation – information about contact location, pressure, and timing – through intracortical microstimulation (ICMS) of primary somatosensory cortex (S1). To this end, we first explore how this information is naturally encoded in the cortex of (intact) non-human primates

(Rhesus macaques). In stimulation experiments, we then show that we can elicit percepts that are projected to a specific localized patch of skin by stimulating neurons with corresponding receptive fields. Similarly, information about contact pressure is conveyed by invoking the natural neural code for pressure, which entails not only increasing the activation of local neurons but also recruiting adjacent neurons to signal an increase in pressure. In a real-time application, we demonstrate that animals can perform a pressure discrimination task equally well whether mechanical stimuli are delivered to their native fingers or to a prosthetic one. We anticipate that the proposed biomimetic feedback will considerably increase the dexterity and embodiment of upper-limb neuroprostheses and will constitute an important step in restoring touch to individuals who have lost it.

Neural Decoding of Hand Movements from Scalp Electroencephalography: A Review
José L Contreras-Vidal, Andrew Paek, Harshavardhan Agashe, Trent Bradberry and José Azorin

Recent studies suggest that signals from scalp electroencephalography (EEG) contain information about motor intent and hand kinematics that can be used for designing a non-invasive brain-machine interface (BMI) to external devices such as computer cursors and hand neuroprostheses. In this paper, we review potential pitfalls of EEG BMIs, address incorrect statements in the literature and summarize recent developments on neural decoding of hand kinematics from EEG and demonstrate the feasibility of using EEG-based hand neuroprostheses for restoring grasping in upper limb amputees as well as discuss some potential pitfalls within this domain.

Restoration of Finger Movements in Everyday Life Environments Using Brain-Machine Interfaces
Surjo Soekadar, Marius Nann and Matthias Witkowski

Finger paralysis following stroke or high cervical spinal cord injury (SCI) is among the leading causes of persisting disability worldwide. Currently, there is no standardized or accepted treatment for affected patients. The development of brain-machine interfaces (BMIs)

provides two new strategies to overcome finger paralysis: First, assistive BMIs can establish continuous brain control of robotic devices, exoskeletons or functional electric stimulation (FES) restoring finger movements, e.g. to eat and drink independently. Second, rehabilitative BMIs could trigger neurological recovery based on rewiring of existing or unmasking of remaining cortico-spinal pathways. A major challenge in rehabilitative BMIs is, however, that training has to be performed repeatedly and motor skills learned in the laboratory need to generalize to the patients' everyday life. Because of the required infrastructure and personnel, costs and efforts for such BMI-based treatment are high. Here we propose and discuss the combination of both strategies by using a wireless and wearable hybrid brain/neural hand exoskeleton restoring finger movements in everyday life. Besides having an immediate impact on the patients' autonomy, such approach would foster fast and broad adoption of a promising new rehabilitation approach for finger paralysis after stroke or SCI for which currently no other treatment exists.

Post-Stroke Hemiplegia Therapeutic Pipeline: Neural Reconditioning Through Brain-Robotics Interaction
Junichi Ushiba

The 2010s is the marked decade of neural rehabilitation for impaired central nervous system. Especially, Brain-Machine Interface (BMI) has raised as a novel neural reconditioning tool, and has been tested its clinical feasibility. Visual stimuli, neuromuscular electrical stimulation, and exoskeleton robotics actuated by user's volitional brain activity provide an electromechanically boosted neural sensorimotor signals, resulting in substantial functional reorganization in the brain. A number of therapeutic concepts combined with BMI have been proposed so far, but clinically feasible therapeutic pipeline has yet to be discussed. This paper proposes BMI-based combination therapies with impairment stage management. Task-oriented exercise of finger movement with BMI promoted functional recovery over minimally clinical important difference (MCID) in Fugl-Meyer assessment. Afterward, the patients transferred an alternative finger exercise with electromyogram controlled neuromuscular electrical stimulation. The mean outcome finally reached 2-3 times larger than MCID. Another study tested a feasibility of BMI-based exoskeleton

robot for shoulder flexion exercise. A daily 1-hour BMI exercise for shoulder flexion promoted functional recovery over MCID in a week. Since basic upper limb movement can be decomposed into shoulder flexion and posture stabilization, horizontal reaching, and finger grasping, combination therapy of finger and shoulder training might be clinically relevant for post-stroke patients with severe hemiplegia.

Quantitative Evaluation of Handwriting and Upper Limb Kinematics by Means of Optoelectronic Systems: State of the Art and Application to Subjects with Parkinson's Disease

Manuela Galli, Andrea Ancillao, Veronica Cimolin, Giorgio Albertini, Caterina Vicidomini, Lanfranco Iodice and Maria Francesca De Pandis

This paper provides a literature review about modern and advanced methods for the recording and analysis of handwriting/drawing in clinical contexts. Handwriting analysis represents a powerful clinical tool for the evaluation and follow-up of people with neurological diseases. Most of the clinical test is commonly administered by the "pen and sheet" method and the score is assigned by a trained operator on the basis of qualitative observation. The idea behind this paper is to record the drawing/writing gesture in order to study the motor strategy adopted by the subject and assign some quantitative scores to the drawing performance on the basis of actual measurements. In previous work we designed a novel protocol to capture handwriting by means of optoelectronic systems. This method overcame the limitations that were observed for graphic tablets and allowed a detailed analysis of the handwritten track, in terms of dimension of drawings, proportions, speed, smoothness, touches, as well as the posture and overall motor strategy adopted by the subject. Testing on the protocol proved an accuracy in track reconstruction of ~0.6 mm. The protocol was successfully applied to children with Down Syndrome that were evaluated by means of the Denver Developmental Screening Test, that is a graphical test which requires the subject to copy by hand some geometrical shapes. The results showed that children with Down Syndrome drew faster but with less accuracy. In ongoing work, we applied the drawing analysis protocol to study drawings and handwriting of subjects with Parkinson's Disease, in order to: (i) characterize and classify their drawings, (ii) identify the drawing features that may be useful for diagnostic purposes and (iii) correlate the quality of drawings to the severity of pathology.

ORAL SESSION 2:
HANDWRITING ANALYSIS
(Chair: E. Will)

Reliability of the Handwriting Sign Evaluation
Marie Anne Nauer and Yury Chernov

This paper presents the results of two studies of reliability of the evaluation of handwritings done with 81 subjects. The first one covers the analysis of three writing patterns (normal, fast or stressed and slow or thorough) on a graphics tablet. The second one involves the manual evaluation of the on-paper handwritings of the same subjects done by six experts. The major results are that although the patterns differ from each other the relation between the subjects remains the same; the manual evaluation demonstrated a very good agreement among experts and a high correlation with the variables on the graphics tablet. These results encourage assuming that manual procedure of the handwriting sign evaluation is objective and reliable.

The International Campaign for Cursive Handwriting
Claudio Garibaldi and Heidi Harralson

While handwriting instruction time in class rooms has been reduced, and cursive has been eliminated in some schools, research has established the importance of handwriting instruction in reading, writing, spelling, and composition in school-age children. Fluent, practiced, and over-learned handwriting skill is associated with better academic performance. This paper will summarize why cursive handwriting is important in the education of school children. There are campaigns in Italy and North America that focus on the return of cursive handwriting to the curricula of grade school children. The activity and progress made by these campaigns is summarized and encouraged in other countries.

Correlations Between 1° Type Fracture of the Radial Head and Handwriting Features Analyzed with Biometrics: A Case Report
Sabrina Belluco, Milena Pugnaloni and Guido Castellari

The functionality of the osteomuscular apparatus of the arm influences the movements of the wrist and of the fingers.

Consequentially, any type of injury and fractures of the arm may influence the handwriting performance. When the handwriting is analyzed in forensic field, because it is a disownment object of study, the expert should to be able to bring back any graphic variations to the temporary clinical condition of the person and contextualize all of these variations on time to time. It is necessary because the modifications brought to the handwriting performance, caused by traumas or sicknesses, can compromise the result of the verification. In this research we have analyzed the handwriting of a right handed woman who had undergone the 1° type radialhead fracture of the right arm. This study was possible because a few days before the accident, the lady had givenher handwriting sample to another research group. We followed the rehabilitative run and other handwriting samples were taken on different times. Therefore,it was possible to compare the post-trauma data with those taken before the accident. Weverified if the fracture of the radial head has somehow influenced the handwriting performance, if yes in which measure, and if the handwriting variations have been recovered as the motor functionality.

Measuring Handwriting Stability Versus Context Variations
Ana Rita Matias, Hans-Leo Teulings, Luis Silva and Filipe Melo

Objectivity of assessment of handwriting stability can be achieved by quantifying spatial features from optical scans of handwriting samples. Thirty children of ages 8 to 9 from a public school in Portugal copied a text derived from the BHK test for 5 minutes, which was retested immediately. We estimated the BHK letter formation score. Optical scans of the papers were processed by the LetterAlyzeR™ software to estimate horizontal and vertical sizes of each vowel letter: /a/, /e/, /i/, /o/, and /u/ and to calculate the ratio height by width. Results indicated that the letter features showed the same systematic size patterns across the text suggesting that stability of handwriting was already present in 8 to 9 year olds. We interpreted this result as evidence that handwriting has already stabilized at 8 to 9 year olds. This in turn suggests that children should learn their eventual handwriting forms instead of first teaching simplified block letter forms.

Tuesday, 20

ORAL SESSION 3:
FORENSIC HANDWRITING EXAMINATION
(Chair: P. Fisher)

From Complexity to Transparency in Forensic Science: A Review of the Work and Legacy of Dr. Bryan Found
Heidi Harralson and Emily Will

Dr. Bryan Found (1962-2016) made a substantial and profound impact on the application of scientific methods and theory in forensic disciplines. A review of his contributions to forensic handwriting examination is summarized including his published work on modular theory, complexity in handwriting, application of motor control theories to forensic handwriting examination, proficiency testing and examiner expertise, cognitive forensics, and transparency in forensic reporting.

Effect of Visual Feedback on the Static and Kinematic Characteristics of Signatures
Michael Pertsinakis and Hans-Leo Teulings

Signatures executed with and without visual feedback were collected in 40 adult volunteers. While producing the signatures the pen movements were recorded using an electronic inking pen on paper that overlaid a pen tablet. The recorded writing movements were stored and analyzed using handwriting movement analysis software. Initially, peer reviewed forensic comparison showed no differences in the design and the pictorial aspects, regardless of the complexity of the signatures. This suggests that the absence of visual feedback should not limit trained FDEs in their ability to achieve an opinion. The analysis of the pen dynamics confirms the forensic findings and shows that visual feedback significantly affects the duration and average absolute velocity of the signature movements - signatures are executed slower without visual feedback than with visual feedback. Furthermore, duration was significantly reduced as a function of educational level of the writer, while subjects react the same manner to the loss of visual feedback regardless the factors of gender and handedness. These findings suggest that in adults, signature execution is governed by open loop motor control not significantly

influenced by visual feedback while the speed of motor program execution is slowed when visual feedback is suppressed.

Dissimulation in Biometric Signatures
Maria Grazia de Corti, Grazia Reali and Laura Battistini

The deployment of Graphometric signature solutions integrated with documental management systems are increasingly becoming commonplace everywhere. The purpose is to capture a customer's signatures without printing on paper and to allow the secure transfer and storing of electronic documents while preventing forgery and/or disguise. With particular regard to the latter, the following questions arise: how can a FDE specialized in biometric signature verification detect that a disclaimed signature is actually a disguise? What are the handwriting parameters most affected by the disguise attempt and how is disguise reflected in the biometric data provided by the forensic software application? Spontaneous and disguised signatures have been collected and the biometric data analyzed with an approved forensic tool. Focusing on duration, pen pressure and in-air strokes, the study explores the similarities and the differences between genuine and disguised signatures. Lesser pressure, longer duration and an overall increase in frequency of in-air strokes if compared with the genuine signatures were found to be significant characteristics for writer identification. Significantly, all these features point to the forcing of the natural movement due to the disguise attempt, however fluid the disguised trace might visually appear.

Alfred Binet, Jules Courtier and Biometry. The Speed of Handwriting Movements from "Edison pen" to Biometry
Milena Pugnaloni, Chantal Sala, Roberto Federiconi and Manuela Vezzadini

Alfred Binet and Jules Courtier in 1894 discovered a "new method of observation: an electric pen, sold under the name Edison Pen, (that) provides some interesting data on the speed of grafic movements. It is formed of a needle driven by electricity, that execute about eleven thousand times per minute of small back and forth movements of 1 millimeter in length" Pointing the needle on a sheet of paper, the needle pierced the sheet according to the speed: the more hand was fast more the holes were far from each other". Using

the “Edison Pen” Binet e Courtier formulate some graphical rules that are still applied in handwriting expertise. They established that “In any regular line, the movement is slower at the beginning and at the end more than at its center. The movement, at first slow, accelerates, then reaches a uniform velocity, and then the velocity decreases little time before the end. These changes in speed are observed in all kinds of lines, whatever their direction”. In 2017 our “new method of observation” is biometry; in this study we want to apply the experiments of Binet et Courtier to confirm if the speed is indeed distributed according to those parameters and what are the elements that affect on it, as acceleration rate and in-air strokes.

KEYNOTE SPEECH
(Chair: C. De Stefano)

Handwriting in the Digital Age
Heidi Harralson

The media has extensively reported that handwriting is dead, but have the media’s reports been accurate? In a rush to embrace the latest digital tablet or iPhone, have we neglected that handwriting may be more important than those who promote technology want to admit? Media’s reports and other critics of handwriting misrepresented the cultural shift in handwriting as we embraced technology. Handwriting did not die and it is not exclusive of technology, but it has changed. We are seeing an increasing number of handwriting samples and signatures that do not exhibit the complexity or graphic maturity that allows for an effective forensic examination of handwriting characteristics. Many in the younger generation do not know how to write or read cursive handwriting while keyboarding and texting have replaced many handwritten activities. Our signatures are impacted by technology and we have lost the graphic stylization and complexity of formal, cursive handwriting in electronic tablet formats. Some young adults do not know how to sign their signature raising the question as to how the signature and its importance is shifting culturally. We will examine the effects of digital technology on handwriting, the decline and return of cursive handwriting, and review the challenges associated with analyzing and interpreting handwriting samples with limited graphic maturity and complexity. We will review methods in the analysis of

electronic signatures in forensic handwriting identification. In spite of the complications created by digital technology associated with handwriting, there are several positive benefits of electronic handwriting samples that are captured using sophisticated software systems at a high resolution. The capture of handwriting electronically has opened up research avenues that were not previously possible as computerized methods quantify temporal handwriting features. The method in which signatures are captured varies considerably in real-world applications necessitating the development of standards in the forensic analysis of electronic signatures. Analysis of electronic signatures requires the assessment of different variables that influence handwriting that are not applicable to wet ink or conventional signatures. We will review the special challenges associated with the forensic analysis of electronic signatures in addition to how technology and advances in research are changing the way handwriting is analyzed.

POSTER & EXHIBITION 2:
CULTURAL HERITAGE AND EDUCATION
(Chair: A. Parziale)

Automatic Page Segmentation
from Historical Handwritten Documents
Arpita Chakraborty, Michael Blumenstein and Umapada Pal

We propose a fast, generic and robust method to segment the historical handwritten double page document images while preserving text content with zero tolerance. The key idea is to locate the transitional space between two textual contents in the double page document images. For this task, 1D discrete Wavelet transform is applied and then the transitional space is analyzed to detect the optimal split point for each gray-scale document image. The proposed method is evaluated on three diverse and degraded handwritten historical datasets: State Library of Queensland (SLQ), Queensland State Archives (QSA) and the Prosecution Project. Experimental results show that the proposed method achieves higher accuracy in minimum time-span comparing with other existing method.

Keyword Spotting in Historical Documents Based on Handwriting Graphs and Hausdorff Edit Distance
Mohammad Reza Ameri, Michael Stauffer, Kaspar Riesen, Tien D. Bui and Andreas Fischer

Keyword spotting facilitates the indexation and organization of scanned historical manuscripts. In order to represent the structure and the shape of handwritten words, several graph-based approaches have been proposed recently with a view to template-based keyword spotting. Yet the high time complexity for graph matching, typically cubic-time or worse, imposes computational limits for processing large volumes of scanned documents. In this paper, we propose a novel quadratic-time method for graph-based keyword spotting using the Hausdorff edit distance. In an experimental evaluation on the George Washington benchmark dataset, we demonstrate that graph matching based on Hausdorff edit distance is a promising alternative to the standard sequence matching approach based on dynamic time warping, both in terms of accuracy and runtime.

Does Exercise in Children with Learning Disabilities Improve Cursive?
Graziella Pettinati, Heidi Harralson and Hans-Leo Teulings

Cursive handwriting can be problematic for children with learning disabilities. We tested a group of children with learning disabilities 3 times at intervals of several months during which they performed specific, simple handwriting exercises at home. The children showed improved handwriting legibility. The movements of the inking pen were recorded using a tablet and handwriting capture software. Results of the dynamic movement analysis showed that the children did not approach adult handwriting: they did not write faster, nor smaller, nor smoother, nor with reduced pen pressure. We interpret this as indication that the children learned to pay more attention to letter formation. As a result their handwriting became more legible. The children found the exercises and computerized handwriting tests engaging and were motivated after viewing their improvements.

Preliminary Study of t0, a Sigma-Lognormal Parameter Extracted from Young Children's Controlled Scribbles
Remi Celine, Jimmy Nagau, Jean Vaillant and Réjean Plamondon

This work deals with the interest of using the sigma-lognormal model for the analysis of children graphomotricity. The sigma-lognormal paradigm defines a complex movement as an optimal sequential combination of elementary lognormal movements more or less superimposed which are sequentially triggered by the central nervous system. Assuming the validity of this postulate in the case of children's controlled scribbles, this preliminary work investigates the distribution of the values of the parameter t0 with regard to the lognormal strokes that contribute to the reconstruction of scribbling movements. We consider two types of controlled scribble: the spontaneous and the curvilinear ones. Our exploratory approach shows that, globally and regardless of the scribble type, the values of t0 are mainly concentrated at the beginning of the onset phase of the previous elementary movement, that is at the beginning of the ascending period of its associated lognormal. Moreover, there is a localization prevalence of the t0 values on the contiguous previous elementary movement.

ORAL SESSION 4:
HANDWRITING AND MOTOR CONTROL
(Chair: H.-L. Teulings)

Computer Aided Design of Handwriting Trajectories with the Kinematic Theory of Rapid Human Movements
Daniel Berio, Frederic Fol Leymarie and Réjean Plamondon

We present the Sigma Lognormal model as a potential tool for curve generation in computer graphics related applications. We discuss its extension and parameterisations for the interactive definition of handwriting, drawing and calligraphic trajectories. This results in an efficient trajectory synthesis method, that has a user interface similar to the ones commonly used with Bézier curves or splines, but with the added benefit of capturing the kinematics of human drawing or writing movements. Such kinematics produced by the model can then be exploited to generate realistic stroke animations or to facilitate expressive rendering methods.

Do Synthetic Generated Signatures Reflect the Subject Motor Programs? A Pilot Study
Antonio Parziale, Moises Diaz, Miguel A. Ferrer and Angelo Marcelli

Handwritten signature is a biometric trait used for verifying a person's identity. Automatic signature verification systems typically require a lot of specimens in order to model the signing habit of a subject but, in a real scenario, few signature samples are available. To overcome this problem, methods for creating human-like duplicated signatures using one real signature per subject and based on sigma lognormal decomposition have been proposed in literature. In this paper, we evaluate if duplicated signatures show the same amount of variability observed in real signatures by detecting and analysing signature stability regions. In particular, we investigate if real and duplicated signatures could be the instances of a similar motor program. Experimental results on a standard dataset show that in some cases duplication methods introduce a variability that is greater than the writer's variability to such an extent to generate motor programs that do not belong to the writer's repertoire. Results suggest that a connection exists between trajectory plan and motor plan parameters, which cannot be modified independently one from the other in order to generate synthetic signatures that reflect the writer's motor program repertoire.

Characteristics of Bidirectional Unimanual and Bimanual Drawing Movements
Saira Talwar, Zhujun Pan, Rejean Plamondon and Arend Van Gemmert

The purpose of this study was to compare the kinematic properties of movements being generated unimanually and bimanually. Rapid line drawing strokes were assessed using classic kinematic variables in addition to Sigma-Lognormal model parameters to obtain a comprehensive understanding of movement characteristics. Sixteen right-handed participants were instructed to conduct 120 rapid drawing actions with the dominant hand, non-dominant hand, and both hands together. Classic kinematic variables included reaction time (RT), movement time (MT), time-to-peak velocity (PT), peak velocity (PV), and the

distance covered of the drawing (DS). The Sigma-Lognormal model was used to interpret agonist and antagonist synergies through their amplitudes (D1 and D2), emission of commands (t01 and t02), log-time delays (μ1 and μ2), and log-response time delays (Ã1 and Ã2). A 2x2 repeated measures ANOVA was applied to all dependent variables with manual condition and hand used as independent factors. MT, RT, PT, and PV showed significant differences between the two manual conditions. The Sigma-Lognormal model analysis showed significant manual condition differences for nlog, t01, μ2, D2 and D1 + D2. The finding with regard to the classic kinematic measures suggest that hand movements produced in a bimanual task result in an overall delayed, slower and less efficient movement as compared to hand movements of unimanual tasks. Parameters of the Sigma-Lognormal model revealed that the prolonged preparation duration during the bimanual task occurred on both CNS and neuromuscular levels.

An Exploratory Study into On-line Feedback and Movement Plane Orientation

Arend Van Gemmert, Shelby Montgomery, Jasmine Abdalla and Christopher Aiken

The purpose of this study was to compare different configurations of on-line feedback and movement plane orientations. Two graphic tasks (aiming and handwriting) were used to determine whether the orientation of the surface on which graphic tasks are performed affect pen-movements. Furthermore, the feedback configuration was varied by presenting feedback in the same plane as the movement or presenting feedback in a separate plane than the plane of the movements. The results suggest that in contrast to spatial characteristics, dynamic variables are affected by the separation of feedback and movements. Furthermore, the findings for the task resembling handwriting suggest that spatial characteristics are affected by the orientation of the writing surface. Some explanations for the found pattern of results are suggested and the possible implications of the findings for our understanding of handwriting production as determined by previous research is discussed.

ORAL SESSION 5:
HANDWRITING AND NEURO DISEASES
(Chair: A. Van Gemmert)

Alzheimer's Disease and Handwriting - What do we know so far?
Carina Fernandes and José Manuel Lopes Lima

Alzheimer´s disease (AD) is a progressive and irreversible neurodegenerative disease, involving the impairment of several cognitive functions. To determine how AD affects the handwriting of signatures, samples from three groups were analyzed: DA1 (17 individuals with probable AD; MMSE 20.12 ± 2.00); DA2 (17 individuals with probable AD; MMSE 11.06 ± 3.93) and a control group (30 healthy matched individuals; MMSE 28.07 ± 1.60). General features (Chi-Square Tests Linear-by-Linear Association, p<0,050) and constructional features (Fischer's Exact Test, p<0,050) were analyzed. In general features, differences were found in legibility, tremor and line quality, spacing between words, shape and direction of the baseline. Motor features such as velocity, level of connection and pressure didn't reveal significant differences. In constructional features, repetitions (e.g. letters M, d, e, n, and t), omissions (e.g. letters M, i, n, r and t) and substitutions (e.g. letters M, S, and d) were observed. The presence of additional writing, unrelated to the signatures, was also detected. These results reflect the overall cognitive deterioration associated with Alzheimer's disease, particularly of the temporal (memory functions) and parietal (visual-spatial capabilities) lobes.

Kinematic Analysis of Handwriting in Parkinson Disease
Flavia Costa and Agostino Accardo

Tremor is considered one of the most common disturbances of movement especially in Parkinson's disease (PD). To date there is not a unique methodology, test or parameter for the measurement of tremor. The objective of this study was to identify a set of tests and of kinematic parameters differentiating the writing of a PD subject from a normal, exploiting the tremor. To this aim, the writing movements of 22 PD patients and of 17 control subjects were analyzed. Each subject was asked to perform three tests: five

horizontal straight lines (HSL), Archimedes' Spiral (AS) and overlapping circles (C). The results showed that significant differences between subjects with Parkinson's disease and controls are recognizable, in all tests, especially in AS and C tests, requiring greater attention and coordination to perform a fast movement within a delimited space. Furthermore, some kinematic parameters measuring curvilinear velocity (on the whole trace as well as within a stroke) and trace fragmentation (stroke length and duration and #stroke/cm) were capable of differentiating significantly the two groups. In conclusion, kinematic analysis can be successfully used in the study of tremors and combined with suitable curvilinear tests can differentiate PD patients from normal subjects.

Do Handwriting Difficulties of Parkinson's Patients Depend on their Impaired Ability to Retain the Motor Plan? A Pilot Study
Rosa Senatore and Angelo Marcelli

Patients affected by Parkinson's disease (PD) show deficits in learning novel motor behaviors and executing previously acquired ones. We investigated whether the two phenomena are related, evaluating the hypothesis that PD patients have difficulties in executing fine movements (such as handwriting) acquired before the onset of the disease since they perform the task as they are executing it for the first time. We asked healthy subjects to write a sequence of 'l' on a digitizer tablet by drawing the loop of the letter in counterclockwise fashion (as they are used to do) and clockwise fashion (i.e. using a novel motor plan). We compared the kinematic features of the handwriting samples produced by healthy subjects to those measured in handwriting samples of the letter 'l' produced by PD patients. We focused the analysis on the ink trace segmentation points, which represent the starting/ending points of the elementary handwriting movements. Our results suggests that deficit observed in PD patients in executing both novel tasks (reduced learning performance compared to controls) and previously acquired task (disrupted kinematic features compared to controls) are due to the same underlying deficit, i.e. impaired ability of PD patients to retain the motor plan associated to the task.

Handwriting Analysis and e-Health: a Brief Overview

Claudio De Stefano, Francesco Fontanella, Donato Impedovo, Giuseppe Pirlo and Alessandra Scotto di Freca

This paper provides a brief overview on the use of handwriting analysis for early diagnosis, monitoring and tracking of neuromuscular degenerative diseases. In particular, we taken into account Alzheimer disease, Parkinson Disease and Multiple Sclerosis. Finally we also report the main issues still open.

Wednesday, 21

ORAL SESSION 6:
PATTERN RECOGNITION FOR FORENSIC APPLICATIONS
(Chair: G. Pirlo)

Dimensional Parameters of Handwriting:
An Analytical Study of the Height of Graphemes
Vincenzo Fiorentino, Andrea Chiuri, Claudio Ciampini, Sabino D'Agnelli, Gianmarco Dentici, Vito Matranga and Emanuele Paniz

This paper is devoted to a statistical analysis of some dimensional parameters which are usually considered in forensic handwriting analysis. We have taken into account absolute and relative dimensions under different writing conditions. In particular, in this report we have considered the height of lowercase (M) and uppercase (U) letters, as well as their specific ratio (M/U). A bayesian framework based on the computation of the likelihood ratio LR has been adopted. Our results agree with the general assumption that gives more importance to the relative values rather than to the absolute ones.

Combining FHE Features with Machine Decision Making for Automatic Writer Iidentification
Antonio Parziale, Rosa Senatore, Angelo Marcelli, Anna Paola Rizzo, Cristiano Molinari, Andrea Giuseppe Cappuzzo and Fabio Fontana

We present a method for writer identification that combines Forensic Handwriting Examination best practices with Pattern Recognition methodologies. The method is based upon a statistical characterization of the variability exhibited by a set of features that are meant to capture the distinctive aspects of document layout and handwriting. The features are quantitatively evaluated using a tool based on a model of handwriting generation and execution. The experimentation has been conducted on a database of handwritten documents produced by some writers using different writing modalities (spontaneous and copying). The experimental results confirm that the proposed method captures the distinctive

aspects of handwriting and it is able to characterize the intra-writer and inter-writer variabilities and therefore to identify the writer of a questioned document in most cases.

Assessment of Finger-based On-Line Signature Verification
Ruben Tolosana, Ruben Vera-Rodriguez, Javier Ortega-Garcia and Julian Fierrez

The high acceptance of the society towards the use of smartphones and tablets on a daily basis has raised the interest of many sectors on the use of finger patterns as a way of authentication. In this paper we carry out an assessment on the use of the finger as the writing tool for handwritten signature verification. The new e-BioSign database is considered in the experimental work. This database is comprised of 5 devices in total, three Wacom devices and two Samsung general purpose tablets. For these two Samsung tablets data is collected using a pen stylus but also the finger to study the performance of signature verification in a mobile scenario. A signature baseline evaluation based on Dynamic Time Warping (DTW) is carried out for the case of using the finger as the writing tool. Good results are achieved for the case of random forgeries (less than 1.0% EER), but the performance is significantly degraded for skilled forgeries compared to the case of using the pen stylus as the writing tool.

Offline Signature Verification Based on Bipartite Approximation of Graph Edit Distance
Paul Maergner, Kaspar Riesen, Rolf Ingold and Andreas Fischer

Handwritten signatures can easily be conceived as graphs, which represent parts of the signature with nodes and their relations with edges. Although this powerful representation formalism has been introduced and advocated early for signature verification, only few current systems are relying on it. This might be due to the high computational complexity involved in graph matching. In this paper, we introduce a novel approach to graph-based signature verification using an approximation of graph edit distance, which can cope with any type of labeled graphs and can be efficiently computed in cubic time regarding the graph size. We present first experiments based on keypoint graphs as a proof of concept and outline our future lines of research.

KEYNOTE SPEECH
(Chair : R. Plamondon)

Handwriting in Children with Attention Deficit Hyperactivity Disorder – A Story About Devils, Dreamers, Crippled Legs and an "Aha!" Experience
Oliver Tucha

It has been shown that children with attention deficit hyperactivity disorder (ADHD) suffer from handwriting difficulties. This lecture will present the results of a series of studies on children diagnosed with ADHD concerning (I) their attention impairments and handwriting difficulties, (II) the effects of stimulant drug treatment on various attentional functions of children with ADHD, (III) the stimulant-induced alterations of both qualitative and quantitative (i.e. kinematic) features of handwriting, (IV) the interaction between handwriting fluency and conscious control of handwriting, and (V) possible approaches to the treatment of handwriting difficulties in children with ADHD. This presentation will also tell how studies on handwriting challenged our understanding and practice of treatment of ADHD in childhood.

POSTER & EXHIBITION 3:
HANDWRITING ANALYSIS AND NEUROSCIENCE
(Chair: A. Scotto di Freca)

Evidence of Neurological Symptoms in the Handwriting of Wolfgang Amadeus Mozart
Martin Jarvis, Hans-Leo Teulings and Heidi Harralson

There have been reports among some clinicians and researchers that Mozart may have suffered from Tourette's syndrome. The basis of these reports seems to rest on the scatological phrases appearing in his historical letters. In our study, several of Mozart's letters were examined for specific motor movements associated with Tourette's syndrome. The results show limited support for the theory that Mozart suffered from Tourette's syndrome. We found other anomalies in Mozart's writing, such as the reversal of parts of his name along with exaggerated letter features which could point towards an autistic disorder.

The Frequency of Occurence of Handwriting Features in Online Male and Female Handwriting
Erika Bencsik and Erika Griechisch

In several criminal cases it is necessary to narrow the focus of the investigation, the demographic scope of suspects. For this task, in the case of handwritten anonymous letters, the investigating authority may delegate of a forensic handwriting expert. One of the professional question is that the expert can give any evidence of the gender of the writer. In this paper we attempt to examine whether there is significant difference in the male and female handwriting based on the characteristics applied in forensic examination. This study analyses online handwriting samples, thus we can also evaluate dynamical, time-dependent feature as well.

Influence of Gender on Handwriting of Young Subjects
Federica Mammoli, Cecilia Pescarollo, Valentina Piccoli and Agostino Accardo

Different studies concerning gender differences in motor performance of handwriting movements have been carried out in an age range up to 17 years. In this paper we investigated the influence of gender on handwriting in a sample of young subjects (21-28 years old) in order to examine the possible differences in handwriting process due to gender in this specific age range. The relationship between gender and some kinematic aspects of handwriting was studied by analyzing the script of 84 (42 females and 42 males) university students, randomly recruited at University of Trieste that performed a copying task acquired by a digital tablet and analyzed by a suitable proprietary software. Significant differences between genders were observed in the number of strokes/s and strokes/cm, in the stroke length and duration as well as in the horizontal peak velocity of strokes and pen lift duration. The differences support the hypothesis that females, in this specific age range, write in a less fragmented way, with higher velocity and shorter motor planning time that male peers. In conclusion, although the limited number of candidates, the study confirms that many kinematic parameters can be profitably used to quantify objectively differences between genders in handwriting process.

A Computational Model-Based Analysis of Cerebellar Plasticity in Motor Learning
Danilo Romano, Angelo Marcelli and Rosa Senatore

The Cerebellum is involved in many cognitive and motor functions. This work focuses on the inspection of the role of the Cerebellum during motor learning. The investigation is led through simulation of a computational model representing the types and the connections of the different cerebellar neural structures. We inspect the role and the function of the main actor in cerebellar learning: the synaptic plasticity mechanism. The presence of different plasticity sites has been reported in the Cerebellum and this work aims at analysing the role of the two mechanisms of synaptic plasticity: Long-Term Depression (LTD) and Long Term Potentiation (LTP). We want to inspect their relevance in every site and the contribution of the site itself during motor learning. We have investigated the role of the Cerebellum in three different tasks: learning motor behaviours, acquiring conditioned responses and adapting the natural vestibulo-ocular reflex (VOR). We have also simulated lesion-based scenario where we caused artificial lesions at granule cells, the input processing units for all the analysed tasks. Our work remarks some results reported in literature and also leads to some new considerations about the role of some plasticity sites.

Modification in Handwriting Size Changes the Velocity of Execution: Literature and Experimental Results
Nicolò Di Toma, Mirka Mantoan and Stefania Rendina

In Forensic Handwriting Examination, it is important to know the principles that control the graphomotor movements in order to provide judgement on questioned handwriting. Over the years, many principles about handwriting movement have been formulated and adopted in courts, but not always scientifically proven. Now, thanks to hardware tablets and adequate software it is possible to establish objectively the relationship between various features of handwriting; this allows us to know how a feature changes if one or more features are modified. Our study investigates the relationship between size and velocity of handwriting. We investigated whether a change in the size follows a modification of the velocity, precisely when the subject himself varies the size of his handwriting. Preliminary

research has been conducted on existing Italian and international literature. The relationship between the size and velocity has also been tested by conducting an experiment on 20 participants. Subjects were asked to write on a digitizer tablet based on three conditions: (1) write a sentence with their usual handwriting, (2) write the same sentence using a smaller letter size, and (3) using a bigger letter size. Results show that a size modification in handwriting changes the velocity of strokes execution, confirming that handwriting size and velocity are related. Research supports the knowledge of handwriting movements principles, thus enabling advancements of forensic science in Italy.

SPECIAL SESSION 2:
DIGITAL PALAEOGRAPHY AND CODICOLOGY
(Chair: M. Maniaci)

Digital Palaeography and Codicology: What's Going On?
Marilena Maniaci

Over recent decades, digital palaeography – being indeed a diverse array of techniques and research practices very dissimilar in assumptions and purposes – has emerged as a new trend in manuscript studies, in a position of sharp discontinuity with the traditional principles and methods of the discipline. The presentation offers an overview of the main challenges, potentials and open issues concerning the application of digital techniques to Medieval handwriting and book history, from the early emergence of the so-called "statistical" or "quantitative codicology" in the *nineteenth-seventies* to the most recent developments, proposing the use of computer image analysis not as an aid in the creation of historically-based taxonomies, but as a source for patterns and classifications produced automatically.

Text Recognition for Medieval Documents.
A Gentle Introduction to the Service Platform "Transkribus"
Hubert Alisade

The service platform "Transkribus" (http://transkribus.eu) aims to support humanities scholars, archives/libraries but also public users with standard services for recognising, searching and enhancing

historical documents. Especially the possibility to train Handwritten Text Recognition (HTR) engines to recognize also historical scripts and documents makes Transkribus a unique instrument for researchers. The presentation will demonstrate the platform, explain the options and constraints of the technology, and also provide results achieved on medieval documents.

Automatic Algorithms for Medieval Manuscript Analysis
Ruggero Pintus, Ying Yang, Holly Rushmeier and Enrico Gobbetti

Massive digital acquisition and preservation of deteriorating historical and artistic documents is of particular importance due to their value and fragile condition. The study and browsing of such digital libraries is invaluable for scholars in the Cultural Heritage field, but requires automatic tools for analyzing and indexing these datasets. We will describe a set of completely automatic solutions to estimate per-page text leading, to extract text lines, blocks and other layout elements, and to perform query-by-example word-spotting on medieval manuscripts. Those techniques have been evaluated on a huge heterogeneous corpus of illuminated medieval manuscripts of different writing styles, languages, image resolutions, amount of illumination and ornamentation, and levels of conservation, with various problematic issues such as holes, spots, ink bleed-through, ornamentation, and background noise. We also present a quantitative analysis to better assess the quality of the proposed algorithms. By not requiring any human intervention to produce a large amount of annotated training data, the developed methods provide Computer Vision researchers and Cultural Heritage practitioners with a compact and efficient system for document analysis. This work was partially supported by a Yale University and CRS4 research agreement, as well as by the Scan4Reco project funded by European Union's Horizon 2020 Framework Programme for Research and Innovation under grant agreement no 665091.

Visualisation and Dynamic Analysis of Medieval Writing Processes in the Context of Neurological Diseases and Disorders
Stephen Smith, Márjory Da Costa-Abreu, Deborah Thorpe

Differentiating the signs of neurological conditions in historical handwriting is challenging, since only static writing samples survive.

We have lost information about the dynamic features of writing (e.g. the speed of writing; accelerations and decelerations; and the pressure applied to the quill), which would be useful for the diagnosis of the condition. In this paper, we examine how technology developed to quantify and re-animate medieval-style writing process in real-time, combined with the analysis of static samples of the writing of a medieval scribe with a tremor condition, can help to gain more insight into medieval neurological diseases and disorders.

Improving Handwriting Binarization on Historical Documents
Manuel Bouillon, Rolf Ingold and Marcus Liwicki

This paper presents an improvement of handwriting binarization techniques on colored historical documents. We introduce a novel preprocessing step into the usual document image analysis (DIA) workflow. Before binarization, we propose a Greyification step to enhance the input image with the help of a new grayscale conversion algorithm, namely the Greyifier algorithm. This new algorithm uses luminance and color information to improve the contrast between the foreground and the background. Especially on documents with non-black ink and moreover with diverse colors, e.g. illuminations in historical manuscripts, we expect an increased performance. This modification of the usual workflow of historical document analysis eases the binarization task as well as other following tasks like layout analysis, line segmentation, OCR, etc. We demonstrate the effects of our novel preprocessing technique on a set of challenging historical documents, which we also make publicly available for research purpose. This improvement is illustrated in this paper on the binarization task, where the results of four different binarization methods are successfully improved.

ORAL SESSION 7:
HANDWRITING EDUCATION

(Chair: S. Rosenblum)

IntuiScript, a New Digital Notebook for Learning Writing in Elementary Schools: 1st Observations

Nathalie Girard, Damien Simonnet, Eric Anquetil and Mickaël Renault

IntuiScript is an innovative project that aims for designing a digital notebook dedicated to handwriting learning at primary schools. One of the main goals is to provide children real-time feedback to make them more autonomous. These feedbacks are produced by automatically analysing their drawing, and this online analysis makes possible an adaptation of the pedagogical scenario to each child according to his own difficulties. The IntruiScript project complies with a user-centered design approach, based on iterative campaigns of development and test with more than 1000 children from three to seven years old, in 40 pilot-classes, and implying also teachers and pdagogical experts. First short-term test campaigns have been done allowing to evaluate the pedagogical relevance of educational scenarios proposed and have generated an anonymous database of 27.000 handwritten characters, with their descriptions (gesture, drawing time, completion rate ...). This paper presents the approach to analyse the children writings and to give them feedbacks. The first observations extracted from the in-class experiments and the database collected are also presented.

Development of Graphomotor Skills in School-Age Children

Pierluigi D'Antrassi, Margherita Rustia and Agostino Accardo

Graphomotor skills development can be studied in different way; recently the use of digital tablets allowed a more accurate system for examining kinematic characteristics of writing movement. Although the importance of study of pre-writing skills is known, in the literature the investigations are limited to the first years of primary school. The aim of this study is the evaluation of the evolution of graphomotor skills with schooling. In order to achieve this goal, the drawing of sequence of simple shapes as well as of continuous shapes produced by 257 children from 1st to 8th

grade were acquired by using a digital tablet and a series of kinematic parameters (like horizontal, vertical and curvilinear velocities, number of strokes/cm, pen lift duration, etc.) was extracted from the handwriting. Results showed dependence of the performance on the specific test used (small improvements corresponding to greater complexity) with a general increase in velocity and reduction in stroke number per cm, caused by a less fragmentation of trace and greater automation of the movement with schooling. The kinematic analysis of pre-writing patterns allows an early estimation of preschool drawing abilities and the monitoring of handwriting skills evolution with schooling.

Impact of Handwriting Training on Fluency, Spelling and Text Quality in Primary School Children

Peter Falmann, Sibylle Hurschler Lichtsteiner and Werner Wicki

Results of recent studies indicate that the quality of texts composed by children and adolescents is influenced by their transcription skills acquired so far. An increased automaticity of handwriting and spelling skills is considered to affect higher order writing activities like composing by setting free cognitive resources of the working memory devoted to transcription. This study aimed at investigating the impact of combined handwriting /spelling training on fluency, spelling and text quality among normally developing 3rd graders (N = 175). In addition to the handwriting/spelling training group (n = 78) the sample included two other intervention groups, a (mere) handwriting training group (n = 34) and a (mere) spelling training group (n = 36), as well as a reading fluency training control group (n = 27). Data were collected in pre-, post-, and follow-up measurements including group-administered tests (spelling, visuo-motor integration, copy task, and composing) and individually administered tests and tasks (visuo-spatial working memory and several handwriting tasks on the digitizing tablet and CSWin software). Preliminary results indicate no long lasting significant differential effects of the respective trainings regarding the fluency of handwriting. Further analysis on the effects on text quality and on other variables are still being carried out.

Effects of Physical Education with EDUballs on First-Grade Schoolchildren's Writing Skills and Handwriting Kinematics

Sara Wawrzyniak, Hans-Leo Teulings, Marcin Korbecki, Ireneusz Cichy and Andrzej Rokita

The aim of this study was to investigate whether handwriting skills improve in first-grade children who participated in physical education (PE) with EDUballs compared to children who followed standard physical education program. The EDUball program combines PE with language and mathematics exercises. In addition, the study aimed at determining whether handwriting assessment correlates with dynamic handwriting parameters. The study involved 84 first-grade elementary school children. The results showed that children participating in PE with EDUballs achieved significantly higher writing scores and lower pen pressure compared to the control group who participated in the standard PE. The findings of this study demonstrated that using EDUballs in physical education improves children's handwriting performances and is a promising, new way of teaching in elementary schools.