IGS 2021

The 20th Conference of the International Graphonomics Society

Intertwining Graphonomics with Human Movements

June 6-9, 2022
Museo Elder
Las Palmas de Gran Canaria

ABSTRACTS
of the
20th Conference of the
International Graphonomics Society

Intertwining Graphonomics with Human Movements

Edited by
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and Miguel A. Ferrer

June 6-9, 2022
Las Palmas de Gran Canaria, Spain

Contents

Program 1
Committee 3
Abstracts 7
Who is coming 29

Program

Start	Tuesday, 7	Wednesday, 8	Thursday, 9
9h10	**Opening & Keynote 1** (Advance in the Kinematic Theory). Chairman: Claudio De Stefano	**Keynote 2** (Robotics). Chairman: Jan Mucha	**Keynote 3** (Movements in Quadrupeds Animals). Chairman: Moises Diaz
9h50		**Oral Session 3** (Handwriting learning and development) on page 14	**Special Session I** (Handwriting for Neurodegenerative Disorders) on page 22
10h10	**Oral Session 1** (Historical documents) on page 7		
11h10	Coffee Break	Coffee Break	Coffee Break
11h40	**Posters Session** on page 8	**Oral Session 4** (Handwriting learning and development) on page 17	**Special session II** on page 24
13h00	Lunch	Lunch	Lunch
14h40	**Oral Session 2** (Forensic handwriting examination) on page 12	**Oral Session 5** (Motor control) on page 19	**Special Session III & Panel discussion** on page 27
15h30	Coffee Break	Coffee Break	Coffee Break
16h00	**Panel discussion**	**Oral Session 6 & Panel discussion** on page 21	**Closing & Awards**
19:30	Gala Dinner		

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ABSTRACTS

Tuesday, 7

ORAL SESSION 1 (Historical documents). Chairman: Antonio Parziale

Transcript Alignment for Historical Handwritten Documents: The MiM Algorithm

Giuseppe De Gregorio, Ilaria Citro, Angelo Marcelli

Libraries contain a large number of handwritten documents of historical and cultural interest, and a digital image and digital transcription are available for some of these old documents. The ability to trace back to the portion of the image that contains the handwritten text starting from the transcription can be essential to the study of the document by scholars in humanities, as well as to the development of modern technologies that greatly facilitate the search, indexing, and transcription of ancient documents. We propose a method to perform the transcription alignment automatically. The method analyzes images of handwritten text lines together with the corresponding transcription and performs the alignment analyzing the line from left to right and from right to left alternatively, in such a way to make the method language-independent. Experiments on the Bentham Collection dataset have shown that the method can correctly align more than 70% of the text. We also show that, by using a GUI we have designed for the purpose, our method reduces the time to achieve error-free alignment by more than 47% compared to the time required for manual alignment.

Improving handwriting recognition for historical documents using synthetic text lines

Martin Spoto, Beat Wolf, Andreas Fischer, Anna Scius-Bertrand

Automatic handwriting recognition for historical documents is a key element for making our cultural heritage available to researchers and the general public. However, current approaches based on machine learning require a considerable amount of annotated learning samples to read ancient scripts and languages. Producing such ground truth is a laborious and time-consuming task that often requires human experts. In this paper, to cope with a limited amount of learning samples, we explore the impact of using synthetic text line images to support the training of handwriting recognition systems. For generating text lines,

we consider lineGen, a recent GAN-based approach, and for handwriting recognition, we consider HTR-Flor, a state-of-the-art recognition system. Different meta-learning strategies are explored that schedule the addition of synthetic text line images to the existing real samples. In an experimental evaluation on the well-known Bentham dataset as well as the newly introduced Bullinger dataset, we demonstrate a significant improvement of the recognition performance when combining real and synthetic samples.

Writer Retrieval and Writer Identification in Greek Papyri
Vincent Christlein, Isabelle Marthot-Santaniello, Martin Mayr, Anguelos Nicolaou, Mathias Seuret
The analysis of digitized historical manuscripts is typically addressed by paleographic experts. Writer identification refers to the classification of known writers while writer retrieval seeks to find the writer by means of image similarity in a dataset of images. While automatic writer identification/retrieval methods already provide promising results for many historical document types, papyri data is very challenging due to the fiber structures and severe artifacts. Thus, an important step for an improved writer identification is the preprocessing and feature sampling process. We investigate several methods and show that a good binarization is key to an improved writer identification in papyri writings. We focus mainly on writer retrieval using unsupervised feature methods based on traditional or self-supervised-based methods. It is, however, also comparable to the state of the art supervised deep learning-based method in the case of writer classification/re-identification.

POSTER SESSION. Chairman: Miguel A. Ferrer

Impact of Writing Order Recovery in Automatic Signature Verification
Moises Diaz, Gioele Crispo, Antonio Parziale, Angelo Marcelli, Miguel A. Ferrer
In signature verification, spatio-temporal features offer better performance than the ones extracted from static images. However, estimating spatio-temporal or spatial sequences in static images would be advantageous for recognizers. This paper studies recovered trajectories from skeleton-based images and their impact in automatic signature veri-

fication. To this aim, we propose to use a publicly available system for writing order recovery trajectory in offline signatures. Firstly, 8-connected recovered trajectories are generated from our system. Then, we evaluate their impact on the performance of baseline signature verification systems to the original trajectories. Our observations on three databases suggest that verifiers based on distributions are more suitable than those that requiring the exact order of the signatures for the off-2-on challenge.

Spiral based Run-Length Features for Offline Signature Verification

Walid Bouamra, Moises Diaz, Miguel A. Ferrer, Brahim Nini

Automatic signature verification is one of the main modes to verify the identity of the individuals. Among the strategies to describe the signature in the verifiers, run-length features have attracted the attention of many researchers. This work aims to upgrade the classical run-length distribution as an additional representation for off-line signatures. Specifically, we add a fifth direction to the four classical directions of run-length features. Such fifth direction runs the signature in a spiral way providing an outside to inside view of the signature. This paper evaluates the performance of the new run-length direction combined with the classical ones. For classification purposes, we used a one-class support vector machine. Additionally, we study how to combine the new direction with the previous four original ones at both feature and score levels. Our results validate the use of this novel direction in run-length features in our own experiments and external inter-national competition in signature verification.

Automatic Age Detection from Handwritten Documents

Najla Alqawasmeh, Muna Khayyat, Ching Y. Suen

Age detection from handwritten documents is a crucial research area in many disciplines such as forensic analysis and medical diagnosis. Furthermore, this task is challenging due to the high similarity and overlap between individuals' handwriting. The performance of the document recognition and analysis systems depends on the extracted features from handwritten documents, which can be a challenging task as this depends on extracting the most relevant information from row text. In this paper, a set of age-related features suggested by a graphologist, to detect the age of the writers, have been proposed. These features include irregularity in slant, irregularity in pen pressure, irregularity in

text lines, and the percentage of black and white pixels. Support Vector Machines (SVM) classifier has been used to train, validate and test the proposed approach on two different datasets: our data set FSHS and Khatt dataset. The proposed method has achieved a classification rate of 71% when applied to the FSHS dataset. Meanwhile, our method outperformed state-of-art methods when applied to the Khatt dataset with a classification rate of 65.2%. Currently, these are the best rates in this field.

Measuring the Big Five Factors from Handwriting using Ensemble Learning Model AvgMlSC

Afnan Garoot, Ching Suen

The Big Five Factors Model (BFFM) is the most widely accepted personality theory used by psychologists today. The theory states that personality can be described with five core factors which are Conscientiousness, Agreeableness, Emotional Stability, Openness to Experience, and Extraversion. In this work, we measure the five factors using handwriting analysis instead of answering a long questionnaire of personality test. Handwriting analysis is a study that merely needs a writing sample to assess personality traits of the writer. It started manually by interpreting the extracted features such as size of writing, slant, and space between words into personality traits based on graphological rules. In this work, we proposed an automated BFFM system called Averaging of SMOTE multi-label SVM-CNN (AvgMlSC). AvgMlSC constructs synthetic samples to handle imbalanced data using Synthetic Minority Oversampling Technique (SMOTE). It averages two learning-based classifiers i.e. Multi-label Support Vector Machine and Multi-label Convolutional Neural Network based on offline handwriting recognition to produce one optimal predictive model. The model was trained using 1066 handwriting samples written in English, French, Chinese, Arabic, and Spanish. The results reveal that our proposed model outperformed the overall performance of five traditional models i.e. Logistic Regression (LR), Naïve Bayes (NB), K-Neighbors (KN), Support Vector Machine (SVM), and Convolutional Neural Network (CNN) with 93% predictive accuracy, 0.94 AUC, and 90% F-Score.

Recognition of Graphological Wartegg Hand-drawings

Yunqi Xu, Yee Ching Suen

Wartegg Test is a drawing completion task designed to reflect the personal characteristics of the testers. A complete Wartegg Test has eight

4cm x 4 cm boxes with a printed hint in each of them. The tester will be required to use pencil to draw eight pictures in the boxes after they saw these printed hints. In recent years the trend of utilizing high-speed hardware and deep learning based model for object detection makes it possible to recognize hand-drawn objects from images. However, recognizing them is not an easy task, like other hand-drawn images, the Wartegg images are abstract and diverse. Also, Wartegg Test images are multi-object images, the number of objects in one image, their distribution and size are all unpredictable. These factors make the recognition task on Wartegg Test images more difficult. In this paper, we present a complete framework including PCC (Pearson's Correlation Coefficient) to extract lines and curves, SLIC for the selection of feature key points, DBSCAN for object cluster, and finally YoloV3-SPP model for detecting shapes and objects. Our system produced an accuracy of 87.9% for one object detection and 75% for multi-object detection which surpass the previous results by a wide margin.

Easing Automatic Neurorehabilitation via Classification and Smoothness Analysis
Asma Bensalah, Alicia Fornés, Cristina Carmona Duarte, Josep Lladós
Assessing the quality of movements for post-stroke patients during the rehabilitation phase is vital given that there is no standard stroke rehabilitation plan for all the patients. In fact, it depends basically on the patient's functional independence and its progress along the rehabilitation sessions. To tackle this challenge and make neurorehabilitation more agile, we propose an automatic assessment pipeline that starts by recognising patients' movements by means of a shallow deep learning architecture, then measuring the movement quality using jerk measure and related measures. A particularity of this work is that the dataset used is clinically relevant, since it represents movements inspired from Fugl-Meyer a well common upper-limb clinical stroke assessment scale for stroke patients. We show that it is possible to detect the contrast between healthy and patients movements in terms of smoothness, besides achieving conclusions about the patients' progress during the rehabilitation sessions that correspond to the clinicians' findings about each case.

Motor Movement Data Collection from Older People with Tablets and Digital Pen-based Input Devices
Gergely Hanczár, Erika Griechisch, Ákos Molnár, Gábor Tóth

Our study's aim is two-fold. Firstly, to assess the technical capabilities of digital tablets with digital pen inputs to establish their suitability as data collection equipment for use in screening for Mild Cognitive Impairment (MCI). Secondly, to test such equipments' usability in clinical settings by test subjects who are over 65 years of age and would be the typical participants in such screening tests. Before we started to analyze the fine motor movement of older people in order to diagnose the motor movement-based symptoms of Alzheimer's disease and MCI, we had to gain experience in data collection in this age group. Our goal was to check the quality of the data collected with different devices from older people. First, data was collected using our standard measurement protocol and also we collected real-life handwritten signatures. The collected "in vitro" and "in vivo" data were analyzed. In the second part of the research, we asked older people to solve different writing and drawing tasks on certain digital devices that are able to collect data about their hand motor movement. We found that every device had pros and cons. Overall, the data we collected with them were good quality and provided a good basis for further research. We have also established that the use of such tablet devices to collect data did not pose any usability challenges for participants.

ORAL SESSION 2 (Forensic handwriting examination).Chairman: Angelo Marcelli

Numeric Approach in Handwriting Comparison
Marie Anne Nauer
In forensic handwriting examination, the examinator is repeatedly confronted with very similar handwritings. In case of counterfeiting, such imitation is mostly executed as similarly as possible to the model. However, there are writers who by nature have a very similar style to their "model" or can put themselves in the person's shoes exceptionally well. In forensics, this often results in wrong judgements. This circumstance is to be countered by means of a more specific approach than usual. In consequence, in all these cases where highly similar handwritings occur we have to use comparison methods as e.g. systematic scales of quantified on the basis of a highly differentiated quality analysis, followed by a systematic numerical approach. Some appropriate instruments have proven to be very useful and convenient in this context so as to

achieve scientifically based assessments. In the following, some related methods will be presented for discussion.

Implementing Human-Robot Interaction to Mimic Human Writing

Tomasz Kordziukiewicz, Anastasiya Kreidzich, Moises Diaz, Kanstantsin Miatliuk

The paper presents an approach to implementing human-robot interaction via computer to perform writing process by UR3 robot mimicking human writing. To this aim, online human signing standards were generated first. Next, the human-robot communication technologies were tested and the novel author's method of interaction with robot via computer was proposed to perform robot writing. After that, robot writing task was performed using human signing standards mimicking human writing and robot signatures were acquired as a result. Finally, conclusive remarks were presented.

Signature down-sampling for finger input online signature verification

Mohammad Saleem, Bence Kovari

Online signatures are widely accepted and used for authentication purposes. They are acquired using special devices with different sampling frequencies. A stylus or finger can be used as an input method. This paper studied the minimum sampling frequency required to achieve the best accuracy in online signature verification systems. Three different dynamic time warping-based verifiers were applied on the finger input signatures set of the DeepSignDB database. The results show that we can achieve a highly accurate online signature verification system for finger input signatures using lower sampling frequency, reducing time and computation costs.

Forensic Handwriting Examination at IGS conferences: A review by numbers

Angelo Marcelli, Antonio Parziale

We review the number of contributions to the advancements in handwriting analysis for forensic applications that were presented at the biennial conferences of the International Graphonomics Society through its 20 editions. We introduce a taxonomy for the systematic analysis of the literature, propose a way to evaluate the overall interest and rel-

evance of the topic in the context of the conference editions, as well as the interest and relevance of each category of the taxonomy. We discuss past and current trends emerging from the quantitative analysis and outline some future possible developments.

Wednesday, 8

ORAL SESSION 3 (Handwriting learning and development).Chairman: Cristina Carmona

Copy of geometric figures in children from 4 to 6 years old: a kinematic analysis

Ana Rita Matias, Filipe Melo, Beatriz Costa, Hans-Leo Teulings, Gabriela Almeida

The acquisition and development of prerequisites for writing, in preschool age, is essential, as are figures copy. Objective: To study the relationship between different kinematic variables (process) in children between 4 and 6 years old. Methodology: A cross-sectional observational study was carried out, with a descriptive and correlational research. 110 children participated in the study, 42 children aged 4 years, 44 aged 5 years, and 24 aged 6 years. Results: Process variables vary according to age and figures, but in some situations in a heterogeneous way. Conclusion: The analysis of the process of copy figures provides more detailed information about the handwriting readiness of each child. Its relevance in preschool age is significant, as it can lead to a preventive action, whether diagnostic or intervention. It is important, that in the future children with graphomotor difficulties could be included in the sample to help us to define their graphomotor characteristics.

Handwriting Performance, Motor Coordination and Quality of Life Among Adolescents with Dysgraphia

Liat Hen-Herbst, Sara Rosenblum

Objectives: To (1) compare handwriting process measures, motor-coordination performance, and quality of life (QOL) between adolescents with dysgraphia and matched controls, as well as the correlations between those domains among individuals with dysgraphia; Further

to (2) examine the contribution of handwriting process measures and motor-coordination performance to the prediction of the physical domain of QOL among adolescents with dysgraphia.
Method: Participants included 80 adolescents (13–18 yr), 40 with dysgraphia and 40 matched controls. Adolescents copied a paragraph on paper affixed to a digitizer supplying objective handwriting process measures (Computerized Penmanship Evaluation Tool [ComPET]) and completed the Adult Developmental Coordination Disorder Checklist (ADC motor performance) and World Health Organization Quality of Life Questionnaire brief version (WHOQOL-BREF).
Results: Significant group differences were found for the handwriting process (ComPET), motor-coordination performance (ADC), and self-perceived QOL (WHOQOL-BREF). Significant correlations were found between handwriting process measures and motor-coordination ability (ADC-C) and physical QOL. 38% of variability in the adolescent's QOL physical domain was predicted by pen stroke height, duration and current feelings about participants' motor-coordination performance as reflected by others.
Conclusion: Results show strongly significant differences in handwriting and motor-coordination performance between adolescents with and without dysgraphia, as in aspects of QOL. Variability in physical QOL can be predicted by handwriting capabilities and motor-coordination performance.

Enhanced Physiological Tremor in Normal Ageing: Kinematic and Spectral Analysis of Elderly Handwriting

Serena Starita, Monica Guerra, Lorenzo Pascazio, Agostino Accardo

Tremor is a motor phenomenon that occurs in both neurological disorders and normal people. Enhanced physiological tremor can manifest in healthy elderly, as a consequence of age-related normal neurodegeneration, along with an overall decline of motor performance as slowing, decreased coordina-tion, and balance difficulties. Handwriting is a complex neuromotor skill in-volving fine motor control as well as high-level cognitive processes and its analysis represents a method to investigate motor impairments of the upper limb that occur during the execution of voluntary movements. In this preliminary study, we aimed at characterizing handwriting-related kinetic tremor in the elderly by using a digitizing tablet. 11 healthy elderly (over 70 years old) subjects and 17 healthy younger subjects were enrolled in the trial. Participants were asked to perform an accurate drawing task - Ar-chimedes' Spi-

ral, and three fast drawing tasks - overlapped continuous cir-cles and diagonal ascending/ descending lines). Data analysis consisted of integrating classical kinematic analysis with spectral analysis. Results of kine-matic analysis show the elderly handwriting is overall slower and more fragmented in spiral and diagonal lines tasks but not in overlapped circles compared to younger subjects. The spectral analysis of velocity and accelera-tion drawing profiles reveals a significant presence of enhanced physiological tremor in the elderly but only in the accurate spiral task. We assess that, be-side the Archimedes' spiral already used in previous research works, fast di-agonal lines tasks can be employed for kinematic characterization of elderly handwriting but not for tremor identification. The spiral remains the only handwriting exercise able to reveal the presence of age-related enhanced physiological tremor. We conclude that the nature of the handwriting task influences the emergence of involuntary movement and the strength at which motor im-pairments arise.

Modifying visual feedback facilitate learning to write?

Jean-François Connan, Marianne Jover, Alexandrine Saint Cast, Jérémy Danna

The purpose of handwriting is to produce a legible trace quickly and fluently. Learning to write therefore rely on the efficient integration of visual and proprioceptive feedback, with a transition from a control based on the written trace in writing beginners to a progressive switch to a control based mainly on writing movements in expert writers. The aim of this study was to test the effect of a partial deletion of the written trace, as well as the effect of added visual information on handwriting kinematics in a learning task. Twenty-four adults learned to write with their non-dominant hand six new pseudoletters on a touch screen digital tablet. The participants trained to trace three pseudoletters with modified visual FB conditions and the other three without any visual modification (control condition). Results revealed that, on the short-term, the pseudoletters learned with modified visual feedback were traced faster and more fluently than those learned in the control condition, without spatial accuracy reduction. This method seems to be efficient, at least in proficient adults, and is currently being tested with children with dysgraphia.

ORAL SESSION 4 (Handwriting learning and development). Chairman: Sara Rosenblum

Comparison between two Sigma-Lognormal extractors with primary schools students handwriting

Nadir Faci, Cristina Carmona-Duarte, Moises Diaz, Miguel A. Ferrer, Réjean Plamondon

In this study, we examine the differences between two Sigma-Lognormal extractors. Script Studio is used to extract the Sigma-Lognormal parameters based on the velocity, and iDeLog is used for extracting the parameters based on both the velocity and the trajectory. The iDeLog software is tested with and without smoothing the data. Handwriting data are used to compare both types of extractor. They consist of triangles drawn on a Wacom Cintiq 13HD by healthy children aged between six and thirteen years old. Global-ly, Script Studio Extract the data with the best SNR for the trajectory (SNRt) and the velocity (SNRv). Moreover, it used slightly more lognor-mals for the reconstruction than iDeLog with smoothing, and nearly half of the number of lognormals used in iDeLog without smoothing. Finally, iDeLog without smoothing has a better reconstruction of the velocity and the trajectory than iDeLog with smoothing.

Effects of a graphomotor intervention on the Graphic Skills of children: an analysis with the Sigma-Lognormal model

Ana Rita do Amaral Matias, Filipe Melo, Helena Coradinho, Orlando Fernandes, Guillaume de Broin, Réjean Plamondon

One of the most discussed issues in handwriting is the question of when young children are (or not) ready to begin handwriting instruction. Several studies highlight the importance of early detection of graphomotor difficulties to better assist and remediate them in the first years of formal school. Also, it is necessary to understand how children control handwriting movements and its learning strategies. Using the Sigma Lognormal approach, in this study we aim to study the effects of a graphomotor intervention program, in the Graphic Skills according to lognormal parame-ters. Sixty-three children attending the last year of pre-school (25 EG; 30 CG) performed the first nine figures of Beery-Buktenica Developmental Test of Visual-Motor Integration (6th edition) (Beery VMI) on a digitizing tablet. To address the issue related with handwriting, forty-seven second graders (20 EG; 21 CG)

performed The Concise Assessment method for Children's Handwriting (BHK), in same conditions above mentioned. A follow-up assessment has been performed six months after the end of graphomotor intervention program. All participants benefited from 16 sessions (twice a week) of a graphomotor intervention program, divided in small groups (6-8 children/group). Each session lasted for 30 minutes. In general children who benefited from a graphomotor intervention showed better fine movement quality improved with better motor control quality and higher movement fluidi-ty. The maintenance of results after six months was more consistent in preschoolers, be-cause the second-year students are still in a process of handwriting automation.

Copilotrace: a platform to process graphomotor tasks for education and graphonomics research

Celine Remi, Jimmy Nagau

Recent works highlight that a graphomotor analysis of the pupil's movements throughout his schooling for a maximum of writing and production situations could contribute to improving the support of the learning of handwriting well beyond the first years of school. However, to our knowledge, there is no tool to date that could constitute a shared and mobilizable help for all teachers from kindergarten to high school for such process. The Web-platform Copi-lotrace was thought to try to answer this problem. After a review and a dis-cussion of the uses of digital technology to assist teacher's practices of eval-uation and monitoring of students' graphomotor skills, the architecture, and main functionalities of Copilotrace, which are centered on the contextualized acquisition and analysis of graphomotor tasks, are presented. Then, the main contributions of the use of Copilotrace, that were validated thanks to some research actions initiated in Guadeloupe within the framework of the eMag-Ma project, are detailed.

The Mental Effort Allocated in Handwriting Production among Adolescents with Executive Function Deficits

Yael Fogel, Sara Rosenblum

This study aimed to compare handwriting-product and -process measures between adolescents with executive function deficits (EFD) and controls and predict group membership. In a secondary analysis with 81 adolescents aged 10–18 years (41 characterized with daily function difficulties and EFD by parent-reported Behavioral Rating Inventory of Executive Function), participants copied 2 paragraphs onto a pa-

per affixed to a digitizer for objective handwriting-process measures. Their written products were scored according to the Handwriting Legibility Scale, which assesses global legibility, overall effort to read the script, layout on-page, letter formation, and text alterations. Significant group differences were found in Tasks 1 and 2 (effort, layout) and temporal-process measure (in-air, on-paper time), and Task 2 global legibility, letter formation, and pen-pressure components. Significant within-group differences were found for Tasks 1 and 2 velocity, in-air time, stroke weight, and height measures while the EFD group showed significant within-group differences for global legibility and Task 1 tilt. The discriminant-function analyses identified that product and process measures correctly classified 75% of the groups. Results suggest handwriting production is important to understanding deeper handwriting-product and -process measures. Combining handwriting-product and -process measures may reflect the mental-effort process, emphasizing the complexity of handwriting as a routine daily performance among adolescents with EFD.

ORAL SESSION 5 (Motor control). Chairman: Andreas Fischer

iDeLog3D: Sigma-Lognormal Analysis of 3DHuman Movements
Miguel A. Ferrer, Moises Diaz, Cristina Carmona-Duarte, Jose Juan Quintana, Réjean Plamondon
This paper proposes a 3D representation of human kinematics with the Kinematic Theory of Rapid Human Movements and its associated Sigma-Lognormal model. Based on the lognormality principle, a human movement is decomposed as a vector sum of temporally overlapped simple movements called strokes, described as two virtual target points linked by an arc of circumference and with the movement velocity having a lognormal shape. The paper extends the former 2D theory to the third dimension by linking the 3D virtual target points with planar circumferences covered with lognormal velocity profiles and reconstructing the 3D kinematics of the whole movement with temporally overlapping consecutive planes. Parameter optimization is accomplished jointly in the temporal and spatial domains. Moreover, the lognormal parameters used are numerically estimated, potentially providing a set of possible solutions that provide insights into the physical and biological mean-

ings of the Sigma-Lognormal model parameters. We show that the 3D model, called iDeLog3D, achieves competitive results in analyzing the kinematics of multiple human movements recorded by various sensors at different sampling rates. The iDeLog3D are available to the scientific community following license agreements

Should we look at curvature or velocity to extract a Motor Program?

Antonio Parziale, Angelo Marcelli

Experimental studies led by Lashley and Raibert in the early phase of human movement science highlighted the phenomenon of motor equivalence, according to which complex movements are represented in the brain abstractly, in a way that is independent of the effector used for the execution of the movement. This abstract representation is known as motor program and it defines the temporal sequence of target points the effector has to move towards to accomplish the desired movement. We present and compare two algorithms for the extraction of motor programs from handwriting samples. One algorithm considers that log-normal velocity profiles are an invariant characteristic of reaching movements and it identifies the position of the target points by analysing the velocity profile of samples. The other algorithm seeks target points by identifying the trajectory points corresponding to maximum curvature variations because experimental studies have shown that the activity of the primary motor cortex encodes the direction of the movement. We have compared the performance of the two algorithms in terms of the number of identified strokes when handwriting samples were drawn by 32 subjects with their dominant and non-dominant hands. The results have shown that the two algorithms show a similar performance over 55% of samples but the extraction of motor programs by analysing the curvature variations is more robust to noise and unmodeled motor variability.

Effects of Biscriptuality on Graphomotor Coordination Dynamics

Gaëlle Alhaddad, Jérémy Danna, Céleste Younes-Harb, Jean-Luc Velay, Marieke Longcamp

Biscriptuality is the ability to write in two different writing systems. The aim of this study was to examine the effects of biscriptuality on graphomotor coordination dynamics in right-handed adults. Thirty-four French monoscriptuals and 34 French-Arabic biscriptual partici-

pants traced series of loops in two writing directions, and in two senses of rotation. We found that biscriptuals displayed a general advantage over monoscriptuals in terms of spontaneous tracing frequency, while both groups displayed a preference for the left-to-right direction. This finding provides novel evidence on the effect of script writing expertise on graphomotor patterns by showing that biscriptuality could be an asset.

ORAL SESSION 6 (Motor control). Chairman: Ana Rita

The RPM3D project: 3D Kinematics for Remote Patient Monitoring

Alicia Fornés, Asma Bensalah, Cristina Carmona-Duarte, Jialuo Chen, Miguel Ferrer, Andreas Fischer, Josep Llados, Cristina Martín, Eloy Opisso, Réjean Plamondon, Anna Scius-Bertrand, Josep Maria Tormos

This project explores the feasibility of remote patient monitoring based on the analysis of 3D movements captured with smartwatches. We base our analysis on the Kinematic Theory of Rapid Human Movement. We have validated our research in a real case scenario for stroke rehabilitation at the Guttmann Institute 5 (neurorehabilitation hospital), showing promising results. Our work could have a great impact in remote healthcare applications, improving the medical efficiency and reducing the healthcare costs. Future steps include more clinical validation, developing multi-modal analysis architectures (analysing data from sensors, images, audio, etc.), and exploring the application of our technology to monitor other neurodegenerative diseases.

Age Reduces Motor Asymmetry in Graphic Task

Deborah Watson, Zhujun Pan, Qun Fang, Arend Van Gemmert, Chris Aiken

The purpose of the present study was to compare motor asymmetry between older and younger adults performing a graphic task. Thirty-four right-handed older and 38 younger adult participants drew continuous cursive "l" loops on a digitizer tablet using their right and left hand, respectively, aimed to assess age-related hand asymmetry differ-

ence in the performance of movements. We focused on mean velocity, peak velocity, stroke size, and the ratio of the duration to decelerate to the duration of the overall movement time (RDP). A 2-way mixed design ANOVA with age-group as the between factor (young and old), and hand (left and right) as the within factor. The results showed a significant age by hand interaction for mean velocity (p = .012) and peak velocity (p ¡ .001) supporting decreased asymmetry when aging after young adulthood. Further analysis revealed reductions in motor asymmetry across the lifespan is mediated by a greater decline in the dominant (right) hand compared to non-dominant (left) hand.

Thursday, 9

SPECIAL SESSION I (Handwriting for Neurodegenerative Disorders). Chairman: Claudio De Stefano

Early dementia identification: on the use of random handwriting strokes

Vincenzo Gattulli, Donato Impedovo, Giuseppe Pirlo, Gianfranco Semeraro

Timely diagnosis plays a crucial role for the treatment of neuro-degenerative diseases. In particular, Dementia Identification in early stages is important to help patients to live in a better way and to help clinicians to find a pathway of treatments to slow the effects. To the aim, a wide set of different handwriting tasks is here considered, and Shallow and Deep Learning method-ologies are compared. Furthermore, Random Hybrid Stroke (RHS) are adopted to represent the handwriting time series. This solution outperforms the classical Deep Learning methodology and it is compared to a state-of-art shallow learn-ing approach. Finally, a decision-level fusion for the results is adopted.

Prodromal Diagnosis of Lewy Body Diseases Based on the Assessment of Graphomotor and Handwriting Difficulties

Zoltán Galáž, Jiří Mekyska, Ján Mucha, Vojtěch Zvončák, Zdeněk Smékal, Marcos Faundez-Zanuy, Luboš Brabenec, Ivona Morávková, Irena Rektorová

To this date, studies focusing on the prodromal diagnosis of Lewy body diseases (LBDs) based on quantitative analysis of graphomotor and handwriting difficulties are missing. In this work, we enrolled 18 subjects diagnosed with possible or probable mild cognitive impairment with Lewy bodies (MCI-LB), 7 subjects having more than 50% probability of developing Parkinson's disease (PD), 21 subjects with both possible/probable MCI-LB and probability of PD ¿ 50%, and 37 age- and gender-matched healthy controls (HC). Each participant performed three tasks: Archimedean spiral drawing (to quantify graphomotor difficulties), sentence writing task (to quantify handwriting difficulties), and pentagon copying test (to quantify cognitive decline). Next, we parameterized the acquired data by various temporal, kinematic, dynamic, spatial, and task-specific features. And finally, we trained classification models for each task separately as well as a model for their combination to estimate the predictive power of the features for the identification of LBDs. Using this approach we were able to identify prodromal LBDs with 74% accuracy and showed the promising potential of computerized objective and non-invasive diagnosis of LBDs based on the assessment of graphomotor and handwriting difficulties.

Generation of synthetic drawing samples to diagnose Parkinson's disease

Gennaro Gemito, Angelo Marcelli, Antonio Parziale

The current state-of-the-art artificial intelligence tools for automatic diagnosis of Parkinson's disease from handwriting exhibit impressive performance but they require a lot of training samples from both healthy subjects and patients. Publicly available datasets include very few samples drawn by a small number of individuals and that represents a limit to the use of deep learning architectures. In this paper, we evaluate if synthetic handwriting could be used to train a convolutional neural network that recognizes the handwriting of Parkinson's disease patients. In the experimentation, we synthetically generated dynamic signals of spirals and meanders through the use of a Recurrent Neural Network. The performance of the system was evaluated on the NewHandPD dataset. The results showed that the use of synthetic samples increased the recognition accuracy of a convolutional neural network.

Signature Execution in Alzheimer's disease: an analysis of motor features

Carina Fernandes, Gemma Montalvo, Michael Pertsinakis, Joana Guimarães

The analysis of signatures attributed to individuals with Alzheimer's disease (AD) poses special challenges to Forensic Handwriting Examiners (FHEs) and research on the subject has been scarce. The aim of the study was to assess how AD impacts motor features in signature execution through kinematic analysis. The study included 10 individuals with mild AD, 10 individuals with moderate AD and 10 healthy controls matched by age, education and gender. Eight hybrid signatures were collected from each participant using a digitizer and Neuro-Script's MovAlyzeR® software. The study revealed no statistically significant in-tergroup differences regarding average absolute velocity, absolute jerk, normal-ized jerk and average pen pressure in the text-based signatures that were pro-duced. Findings suggest that, in text-based signatures, motor features are relative-ly preserved in the initial and moderate stages of Alzheimer's disease and, there-fore, FHEs should not expect significant changes in such features for this signa-ture type. These results also support the hypothesis that motor programs respon-sible for the creation/execution of text-based signatures are not significantly im-paired in the initial and moderate stages of the illness, due to the automation and lower cognitive demands of well-trained signatures.

SPECIAL SESSION II (Handwriting for Neurodegenerative Disorders).Chairman: Antonio Parziale

Ensemble of convolutional neural networks for Parkinson's disease diagnosis from offline handwriting

Matej Gazda, Máté Hireš, Peter Drotár

This paper proposes the ensemble of deep convolutional neural networks for diagnosing Parkinson's disease from offline handwriting. The advantage of the offline approach lies in the fact that handwriting acquisition can be performed without any specialized equipment by using only a smartphone camera. The convolutional neural networks ensemble relies on pre-trained networks where the diversity is achieved through the multiple-fine-tuning of individual networks. The experi-

mental results on two handwriting datasets showed that the proposed approach currently provides the highest classification accuracy compared to other strategies for diagnosing Parkinson's disease based on offline handwriting.

Classification of Patients with Parkinson's Disease Using Free Handwriting Features Collected through a Smart Ink Pen

Simone Toffoli, Francesca Lunardini, Monica Parati, atteo Gallotta, Manuel Muletti, Chiara Belloni, Maria Elisabetta Dell'Anna, Simona Ferrante

Systems for the monitoring of Parkinson's disease (PD) patients, able to complement clinical assessment, are needed. These solutions should be objective, based on technology that captures physical characteristics of the pathology, and capable of providing frequent measures conducted both on-site and remotely. Since one of the most typical clinical hallmarks of PD is handwriting deterioration, we devised an innovative smart ink pen for quantitative and reliable handwriting monitoring, without altering the natural writing conditions. 30 PD patients and 30 age-matched controls performed two unconstrained writing tasks (free text and grocery list) with the smart ink pen. A series of 47 writing and tremor indicators were computed and used to classify patients from age-matched controls. Catboost and Logistic Regression classifiers were used, and the SHAP model explanation technique was applied to explore the contribution of the features in the classification. Very good performance were obtained through the Catboost classifier when combining features extracted from both tasks (Accuracy: 93%, Precision: 96%, Recall: 90%; F1: 93%; AUC: 98.9%). We achieved a classification performance in line with previous work, with the advantages of acquiring writing data through an ink pen writing on common paper, and proposing an unconstrained protocol mimicking daily-life writing.

Spectral Analysis of Handwriting Kinetic Tremor in Elderly Parkinsonian Patients

Serena Starita, Katerina Iscra, Monica Guerra, Lorenzo Pascazio, Agostino Accardo

Tremor is one of the motor impairments of Parkinson's disease (PD) and manifests as different types, i.e. rest, kinetic and postural. To date, kinetic tremor is barely examined and there is no agreed methodology to test and analyse it. In this study, we aimed at characterizing handwriting-related kinetic tremor in PD during Archimedes' Spiral

(AS) and overlapped Circles (C) drawing activity using a digitizing tablet. To achieve this, we integrated classical kinematic analysis with spectral analysis to establish a set of parameters able to discriminate PD patients from healthy controls. 15 PD patients and 11 elderly healthy control subjects were enrolled in the trial. The results reveal that there are significant differences between PD patients and control subjects, especially at the level of spectral features. PD tremor produces higher Spectral Power (SP) and a clear peak in the band of involuntary movements, while SP of enhanced physiological tremor in controls is lower and randomly distributed over the frequencies. We conclude that spectral analysis and features extracted from the band of involuntary movements can be used to characterize parkinsonian handwriting kinetic tremor. The findings support the theory that the kinetic tremor in PD patients can be distinguished from involuntary movement in the elderly caused by physiological age-related deterioration of the neuromuscular system's functional capacity.

Exploration of Various Fractional Order Derivatives in Parkinson's Disease Dysgraphia Analysis

Jan Mucha, Zoltán Galáž, Jiri Mekyska, Marcos Faundez-Zanuy, Vojtech Zvoncak, Zdenek Smekal, Lubos Brabenec, Irena Rektorova

Parkinson's disease (PD) is a common neurodegenerative disorder with a prevalence rate estimated to 2.0 % for people aged over 65 years. Cardinal motor symptoms of PD such as rigidity and bradykinesia affect the muscles involved in the handwriting process resulting in handwriting abnormalities called PD dysgraphia. Nowadays, online handwritten signal (signal with temporal information) acquired by the digitizing tablets is the most advanced approach of graphomotor difficulties analysis. Although the basic kinematic features were proved to effectively quantify the symptoms of PD dysgraphia, a recent research identified that the theory of fractional calculus can be used to improve the graphomotor difficulties analysis. Therefore, in this study, we follow up on our previous research, and we aim to explore the utilization of various approaches of fractional order derivative (FD) in the analysis of PD dysgraphia. For this purpose, we used the repetitive loops task from the Parkinson's disease handwriting database (PaHaW). Handwritten signals were parametrized by the kinematic features employing three FD approximations: Grunwald-Letnikov's, Riemann–Liouville's, and Caputo's. Results of the correlation analysis revealed a significant relationship between the clinical state and the handwriting features

based on the velocity. The extracted features by Caputo's FD approximation outperformed the rest of the analyzed FD approaches. This was also confirmed by the results of the classification analysis, where the best model trained by Caputo's handwriting features resulted in a balanced accuracy of 79.73 % with a sensitivity of 83.78 % and a specificity of 75.68 %.

SPECIAL SESSION III (Handwriting for Neurodegenerative Disorders).Chairman: Angelo Marcelli

Lognormal features for early Diagnosis of Alzheimer's Disease through handwriting analysis

Nicole Dalia Cilia, Tiziana D'Alessandro, Cristina Carmona-Duarte, Claudio De Stefano, Moises Diaz, Miguel Ferrer, and Francesco Fontanella

Alzheimer's disease causes most of dementia cases. Although currently there is no cure for this disease, predicting the cognitive decline of people at the first stage of the disease allows clinicians to alleviate its burden. Clinicians evaluate individuals' cognitive decline by using neuropsychological tests consisting of different sections, each devoted to testing a specific set of cognitive skills.

WHO IS COMING

Kanstantsin Miatluk
Moises Diaz
Agostino Accardo
Jan Mucha
Zolta Galaz
Najla Alqawasmeh
Yunqui Xu
Deborah Watson
Angelo Marcelli
Giuseppe De Gregorio
Cristina Carmona Duarte
Miguel Ángel Ferrer
Gianfranco Semeraro
Asma Bensalah
Isabelle Marhot Santani
Gaelle Alhaddad
Claudio De Stefano
Nagau Jimmy
Yael Fogel
Marie Anne Nauer
Liat Hen-Herbst
Serena Starita
Jeremy Danna
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Réjean Plamondon
Antonio Parziale
José Juan Quintana
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Gergely Hanczar
Carina Fernandes
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Mathias Seuret
Andreas Fischer
Anna Scius-Bertrand
Peter Drotar
Ana Rita Matias
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Mohammad Saleem
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