# Lognormality: an open window on neuromotor control

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**Abstract.** This special session presents the works carried out at the Scribens laboratory and its affiliated laboratories. It summarises the 17 talks presented at the ACFAS 2023 conference, describing the key elements of the theory, some gesture analysis algorithms that have emerged from it, and then provides an overview of its various applications, particularly in the fields of biomedical engineering, human-machine interaction.

## 1. Introduction

The Kinematic Theory of human movement can describe, using a fundamental equation called the "lognormal function", the speed of an end-effector. Various software Packages have been developed to reverse-engineer movements by reconstructing them, and this reconstruction provides central parameters that represent the state of the brain, and peripheral parameters that describe the properties of the neuromuscular systems that produced the movement. Over the years, the theory has been tested and validated in numerous experiments, and successfully used to describe the essential properties of the velocity profiles of the fingers, wrist, trunk, head and eyes, etc. This led to postulate the Lognormality Principle, which states that the lognormal impulse response of a neuromuscular system emerges from a convergent process driven by the central limit theorem. This optimal overall characteristic reflects the behaviour of individuals who have perfect control over their movements. The production of complex movements is achieved by the temporal superposition and summation of lognormal velocity vectors, with the aim of minimising their number in a given task, to produce efficient, fluid gestures, optimising the energy required to generate them. As a corollary, motor control learning in children can be interpreted as a migration towards lognormality. Then, for most of their lives, normal adults take advantage of their lognormality to control their movements. Finally, as ageing and health problems increase, there is a progressive deviation from lognormality.

This manuscript presents the works carried out at the Scribens laboratory and its affiliated laboratories. It summarises the 17 talks presented at the ACFAS 2023 conference, describing the key elements of the theory, some gesture analysis algorithms that have emerged from it, and then provides an overview of various applications, particularly in the fields of biomedical engineering, human-machine interaction. Throughout this paper we will look back on these studies, as well as forward, and will therefore cover past, current and future work. In addition to specialists in signal processing, neuropsychology, neuroscience, education, kinesiology, paediatrics, students who have completed internships or studies at the Scribens laboratory and student entrepreneurs who plan to use lognormality as a metric in their product have participated to this overview.

More specifically, this paper covers the main topics of the program. The name of the presenter is given after the title while the name of all the authors of each study are listed in the acknowledgements.

## 2. The Lognormality Principle : theory and overview of applications. Presented by Réjean Plamondon

## 3. Aging

### 3.1 Remote monitoring of stroke patients via 3D kinematics and artificial intelligence:Presented by Asma Bensalah

**3.2 Kinematic signature in people with Parkinson's and psoriatic arthritis: potential of the sigma-lognormal approach: Presented by Karina Lebel**

**3.3 Contribution of lognormality in the identification of kinematic biomarkers in the identification and early differential diagnosis of Parkinson's disease: Presented by Romeo Salameh, Guillaume Seguin De Broin**

## 4. Performance

**4.1 Deep reinforcement learning for ECG modelling using lognormals: Presented by Christian O'Reilly**

**4..2 Kinematic theory, muscle fatigue and optimality: contribution to the biomechanics of the upper limb: Presented by Mickael Begon**

**4.3 Objective analysis of surgical performance thanks to a simulator augmented by artificial vision: Presented by Olivier Desbiens, Aymeric Guy**

**4.4 Kinematic reconstruction of static calligraphic traces from curvilinear features: Frédéric Fol Leymarie**

## 5. Techniques

**5.1 Separation Algorithm and Evaluation Applied to the Delta-Lognormal Model: Presented by Simon-Pierre Boyoguéno Bidias**

**5.2 Analysis of three-dimensional movements with the sigma-lognormal model: Presented by Andreas Fischer**

**5.3 Comparison of symbolic and connectionist algorithms to correlate the age of healthy children with Sigma-Lognormal neuromotor parameters: Presented by Zigeng Zhang**

## 6. Childhood

**6.1 Interest of kinematic theory and its lognormal models in assessing graphomotor skills in kindergarten and first grade students: Presented by Denis Alamargot, Marie-France Morin**

**6.2 The use of the Lognormality Principle for the characterization and analysis of graphomotor behaviours involving young learners in a school context : Presented by Céline Rémi**

**6.3 Lognormality in children with mild traumatic brain injury: a pilot study : Presented by Nadir Faci**

**6.4 Kinematic analyses of rapid pencil strokes produced by children with ADHD: Presented by Raphaëlle Fortin**

**6.5 Identification of children born prematurely at risk of developmental difficulties at preschool age: usefulness of the pencil stroke test :Presented by Marie-Noëlle Simard**

**6.6 Exploring the Benefits of Virtual Reality Lognormality Analysis for Diagnosing ADHD in Children : Presented by Caroline Bazinet**

## 7. Conclusion

## 8. Acknowledgements

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This Section provides detailed formatting instructions and can also be used as a template.

**General.** The format of the final submission for IGS2023 is similar to those of the previous IGS formats. It should contain maximally 4 pages of single-spaced lines, printed on A4 paper in a single column of 16 cm wide and 24 cm high. The text should be in 10-point normal Times font. The lines are justified.

**Title, Authors, Affiliation.** The title should be centered in 14-point bold Times font with initial capitals of all main words. Author's name(s), affiliations and email should be centered using 10-point Times font. Use the first name, middle initial and capitalize the last name (e.g., Angelo MARCELLI). The author's affiliation should be italicized. The author(s) should be preceded by a blank line.

**Abstract.** Summarize in less than 200 words the objective, methods, results, and a clear conclusion. The abstract should be in 9-point normal Times font. The left and right margins are set back 1 cm resulting in line lengths of 14 cm. The abstract should be preceded and followed by a blank line.

**Text.** Section headings starting at **1. Introduction** should be in 11 point bold font on a separate line. The sections should be numbered using a hierarchic, decimal numbering. New paragraphs, except the first one of a section, should indent 1 cm. The section heading should be preceded by a blank line.

**Figures and Tables.** Figures and Tables should be numbered consecutively (Figure 1., Figure 2., ...) and appear close to their reference in the text. All figures and diagrams should be black and white images suitable for photocopying. Figure captions and table headings should be in a normal 9-point Arial font, centered with respect to the figure/table. The word Figure and Table, with its numbers, should be bolded. A blank line should be between the text and the figure, table heading, or figure caption. Figure caption should be located below the figure, table heading above the table.

**Formulas.** Formulas are numbered with a sequence number between brackets on the same line, flushed to the right. The position of the formula is manually centered by inserting spaces between formula and sequence number. Formulas may used various, generally available 10-point fonts. A blank line should between text and formula.

**References.** The last (unnumbered) section is the list of references using APA style (http://www.library.ubc.ca/pubs/apastyle.pdf) in 9-point normal Times font with hanging indents of 1 cm. Citations should be inserted in the text, preferably at the end of the sentence, by using first author name and year of publication between brackets. For instance the first two papers of the reference list provided below would be cited as (Tappert & al., 1990; Simon, 1992).

**Footnotes.** Footnotes should use 9-point normal Times font and be placed at the bottom of the pages where they appear if possible.

## References

Tappert, C.C., Suen, C.Y. & Wakahara, T. (1990). The State of the Art in On-line Handwriting Recognition. *IEEE Trans. on PAMI, 12(8),* 787-808.

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