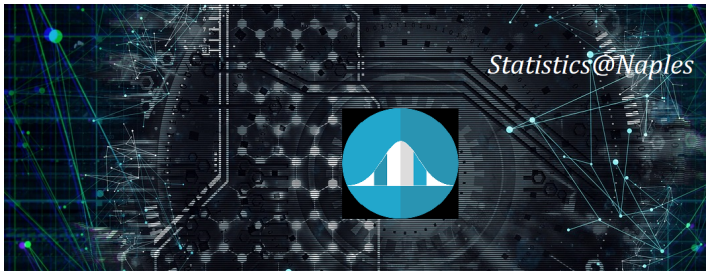

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Bayesian MANOVA for the combined evaluation of handwriting evidence

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Forensic science is a broad field that uses scientific principles and technical methods to help with the evaluation of evidence in legal proceedings of criminal, civil, or administrative nature. Forensic scientists examine recovered traces that can be given by glass fragments, fingerprints, body fluids, textile fibers, digital device data and handwriting. The handwriting examination is a well-known field of analysis. Consider a case involving a handwritten document of unknown origin. Handwritten features extracted from this questioned document will be compared to those extracted from a document written by a person that is suspected of being at the origin of the anonymous document. The propositions of interest are the following:

H_p: the suspect is the author of the manuscript;

H_d: the suspect is not the author of the manuscript.

Handwriting individualization is still largely dependent on the experience of the document examiner, though studies have been conducted with the aim of supporting handwriting examiners to reduce the degree of subjectivity of their expertise. Marquis et al. (2005) proposed to increase the degree of objectivity of handwriting analyses by implementing elements of Fourier analysis in order to describe the contour shape of loops of characters. Specifically, the characters that contain loops can be described by means of Fourier descriptors, which can be used to characterize the shape complexity and other geometric attributes. The analyses conducted showed that these features have a good discriminating power. With the aim of implementing the use of these handwriting features for handwriting identification, Bozza et al. (2008) proposed a Bayesian probabilistic approach by modeling the data with multivariate Normalinverse-Wishart distribution (NIW). The value of the evidence is subsequently assessed by means of the Bayes factor, which can be interpreted as a measure of the strength of support provided by the evidence in favor of the hypothesis H_p against the hypothesis H_d. This approach was accomplished to take into account the correlation between variables, the variability between-writers and within-writer variability. However, the above model is implemented separately for each different type of handwritten character. This can be problematic because it can lead to a different conclusion depending on the type of character that is retained.

In this research, it is proposed the implementation of a Bayesian Multivariate Analysis of Variance (MANOVA) via using the loop characters as predictors. The indicator of the loop character is transformed into a dummy variable (corner-point representation), so that it is possible to model variables describing the handwriting characters jointly taking into account the variability between characters, the variability between-writers for every character and within-writer variability. The Bayesian MANOVA is compared with the two-level random effect model (NIW) proposed by Bozza et al. (2008), that is implemented by modelling all characters jointly or separately. Three different methods for estimating the marginal likelihoods are used; the Generalized Harmonic Mean, the Laplace-Metropolis and the Bridge Sampling. Finally, the performances of the NIW and MANOVA models are compared with those of an alternative one, where a conjugate approach is chosen. This does not allow to model the within and between variation separately, but the marginals can be obtained analytically.

Firstly, we estimate the Bayes factor of the two data models for each writer to determine which model is more compatible with the data. Secondly, there have been selected handwriting features originating from the same writer or from different writers to evaluate the rate of false negatives (that is cases where the BF is smaller than one for characters originating from the same source) and false positives (that is cases where the BF is greater than one for characters originating from different sources). Finally, the sensitivity of models is

examined in two critical aspects: the misleading background information and the choice of degrees of freedom for the Wishart-inverse distribution that is used to model the handwriting variability. With reference to the misleading background information, the prior distributions were elicited by selecting writers characterized by either small or marked differences.

Keywords : 1. Handwriting Evidence 2. Fourier Analysis 3. Multivariate Bayesian Modelling 4. Bayes Factor 5. Sensitivity

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