Individual Motor Signatures: from human perception to biometric applications

Alexandre Coste
EuroMov Digital Health in Motion,
Univ. Montpellier, IMT Mines Alès,
Montpellier, France
alexandre.coste1@umontpellier.fr

I. Introduction

Like for faces and voices, humans seem particularly adept at reading human movement to retrieve significant social information about people such as their emotional states [1] or their identity [2,3]. A few decades ago, this remarkable ability inspired some researchers to design biometric systems able to automatically identify/authenticate persons from their behavioral attributes such as gait and gesture [e.g. see 4 for a recent review]. Behavioral traits, such as gait and gesture, have indeed numerous advantages. Firstly, they provide robust and continuous visual signals, even in distant or challenging viewing conditions. Secondly, they are non-intrusive biometric cues, which do not require any cooperation from individuals. Finally, with the growing number of CCTV cameras and the fact that criminals do not necessarily think of disguising their motor behaviour unlike the face, behavioral cues seem particularly relevant for forensic applications. Yet, despite considerable advances in recent years in computer vision and pattern recognition, movement-based cues are still not valued enough due to their lack of distinctivness and temporal stability. Within this context, our research work aims mainly at determining whether body movements can be considered as potential reliable cues for persons recognition and if it is the case, to what extent and to what conditions. For this purpose, we take a computational modelling approach, strongly rooted on Psychology to the study of the "individual motor signatures" (*IMS*) — i.e. idiosyncratic kinematic characteristics — their extraction, and their contribution to identity recognition. I summarize here our main findings and give some interesting perspectives.

II. Main results

We developed a method [5] for extracting identity information embedded in complex biological signals (Fig. 1). This allowed us to unravel the information used by human observers to recognize people from biological motion [6].

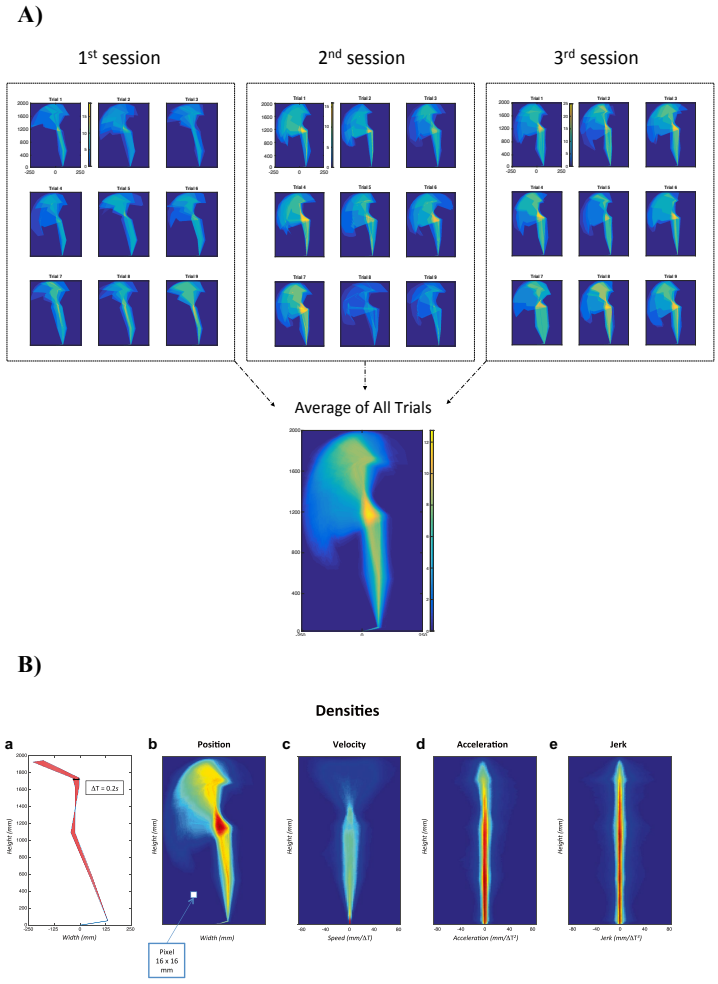

Fig. 1. A) Using a postural improvisation task over three different weeks (nine trials of 30s per session), we evidenced a person-specific motion signature — a sort of kinematic fingerprint — characterized both by its temporal invariance (i.e. small intra-individual variation) and its distinctiveness (i.e. large inter-individual variation). B) Method for extracting the individual motor signatures. Several kinematic variables (position; velocity; acceleration; jerk) were combined to quantify the similarity/dissimilarity between movement patterns. a) Silhouette between two successive positions, with a temporal granularity of ΔT = 0.2 s and a spatial granularity of 16 mm2 pixel. From b) to e) Mean densities of position, velocity, acceleration and jerk, respectively. Colour gradient indicates the frequency of appearance of body segments within each pixel (occurrence), the

red coloured pixels being the most visited places in space by the participant, while those in blue were the least visited.

We found that identity perception ability varies substantially across individuals, some individuals being close to the best performance and some others at chance level. Specifically, we found that recognition is essentially based on salient motion properties (kinematic position and jerk characteristics) that are both stable over time and distinctive between individuals, which we refer to as "individual motor signatures". Moreover, we found that the perceptual representations of postural signatures are veridical in the sense that closely reflects the physical postural trajectories (see Fig. 2) and that the similarities between people's actions were notoriously error prone and led to many misidentifications

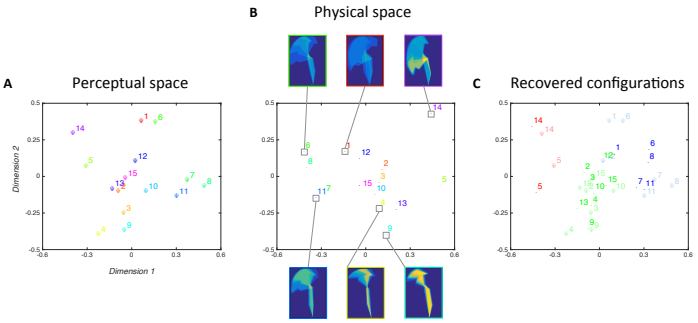

Fig. 2. A) Visual perceptual space constructed by the first two dimensions of multidimentional scaling (MDS) and based on judgments of kinematic similarity. Phi symbols (Ψ) indicate the position of the participants' postural signatures into the psychological space. B) Physical space constructed by the first two dimensions of MDS and based on the physical trajectory distance. Dots indicate the position of the participants' postural signatures into the physical space. Densities of position for representative trials are also shown. C) Resulting MDS map for perceptual and physical distances after Procrustes alignment. The three distinct groups of participants obtained by hierarchical clustering are represented in three different colours (opaque colours for the perceptual space and default colours for the physical space)

It is important to note that the similarity issue between individuals is not specific to humans but is also problematic from an algorithmic point of view. Indeed, biometric systems compute the similarity between the input biometric signature (i.e., features set extracted from data) and the signatures previously stored in the database. If the similarity measure exceeds a threshold, then a "match" or an "accept" is declared, if not, then a "non-match" or a "reject" occurs. However, when the biometric signatures of two individuals are very similar, errors often occur (false accept or false reject). Our latest work therefore aims to improve recognition rates in both humans and machines by identifying the conditions in which humans and machines excel/fail. In particular, we currently examine the impact of different sources of intra-individual variations such as inter-trials variability, social influence and intentions on identification performance. Our first results indicate that some individuals have a quite specific way of moving which is preserved over time (trials), while others tend to change their movement between trials. Interestingly, this inter-trials variability seems to be associated with two of the five personality traits: openness to experience and conscientiousness. In addition, we noticed that individuals in dyadic interaction express a form of behavioral plasticity. That is to say, the mere co-presence elicits at least six different behavioral reactions, ranging from no adaption to a partial or total loss of a participant's individual preferences towards the partner's signature (i.e. unilateral adaptation) or both partners (i.e. bilateral adaptation) to a new (social) common signature. This finding is of great signifiance since many of our daily actions are not carried out in isolation, but are influenced by the social context and, in particular, by the actions performed by others.

III. Moving Forward

Automatic person identification and suspicious behavior detection are of growing interest for many modern civil and military applications. In a laboratory setting, we have validated the existence of individual motor signatures and shown that they can be used for identification / authentication purposes [5]. Next practical step will be to validate these laboratory findings in real life cases and extend them to the detection of suspicious behavior. One of the main challenges is to extract the 2D/3D pose of a person (skeleton) with great precision and to deduce a motor signatures from video surveillance system (CCTV cameras). Ideally, this should be done in real time. To date, most research has focused on facial recognition. However, facial recognition is limited with poor-quality videos or when individuals hide their faces. In addition to that, facial cues (e.g., facial expressions) convey little information about people's intentions, making the detection of suspicious behavior a challenging task. Body movements, on the other hand, provide relevant information about the actions produced (i.e., content) as well as people's identity (i.e., movement style or IMS). They are also visually more robust than facial features, as they remain accessible even when people are seen from the back. For these reasons, we strongly believe that investigating the motor signatures is a promising research avenue, with interesting consequences for many applications, especially in the security field.

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