Quantifying the Inherent Chaos of Human Movement Variability

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Movement variability is defined as the variations that occur in motor performance across multiple repetitions of a task and such behaviour is an inherent feature within and between each persons' movement [4]. In the previous three decades, research on measurement and understanding of movement variability with methodologies of nonlinear dynamics has been well established in areas such as biomechanics, sport science, psychology, cognitive science, neuroscience and robotics [1, 2]. To quantify movement variability, we therefore consider a methodology from nonlinear dynamics called uniform reconstructed state space where essentially dynamics of an unknown system can be reconstructed using one dimensional time series. As pointed out by Bradley et al. [3] uniform reconstructed state space, if done right, can guarantee to be topologically identical to the true dynamics and determine dynamics invariants such as fractal dimension, Kolmogorov-Sinai entropy or Lyaponov exponents. These algorithms, however, require time series measured with costly sensors that provide well sampled data with little noise. Such requirement is generally a common problem when doing precise characterisation of time series using dynamic invariants, to which Bradley et al. [3] proposed additional tools, for practitioners, of nonlinear time series analysis such as surrogate data, permutation entropy, recurrence plots and network characteristics for time series. For this study, we are interested in the use of uniform reconstructed state space and the analysis of recurrence plots so as to understand the quantification of movement variability. Particularly, we are interested in the analysis of data collected through cheap wearable inertial sensors and its effects on the reconstructed state space and the recurrence plots for different lengths and preprocessing techniques (like smoothing and normalisation) of the time series. So, here we show the characterisation of human movement variability in the context of human-humanoid imitation activities. Specifically, we explore the reconstruction of state spaces and its recurrence plots for 20 participants performing repetitions of simple vertical and horizontal arm movements in normal and faster velocity. We also explore the differences between wearable inertial sensors attached to the person and to the humanoid robot and between different axes of inertial sensors. With that in mind, our contribution to knowledge is in regard to the reliability of data from cheap wearable inertial sensors to analyse human movement in the context of human-humanoid imitation activities using methodologies of nonlinear dynamics. Such understanding and measurement of movement variability using cheap wearable inertial sensors lead us to have a more intuitive selection of parameters to reconstruct the state spaces and to create meaningful interpretations of the recurrence plots. Additionally, having a better understanding of nonlinear dynamics tools with the use of cheap inertial sensors is important for the development of better diagnostic tools for various pathologies which can be applied in areas of rehabilitation, entertainment or sport science [4].

References

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