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ėMOTION: Analysis of Emotion and Movement Variability in the Context of Human-Robot Interaction

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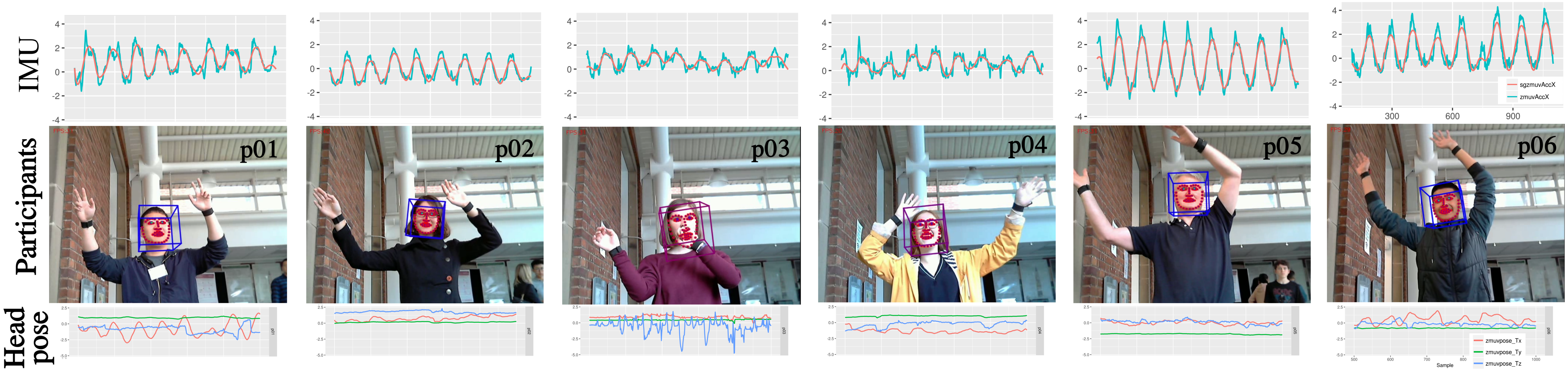
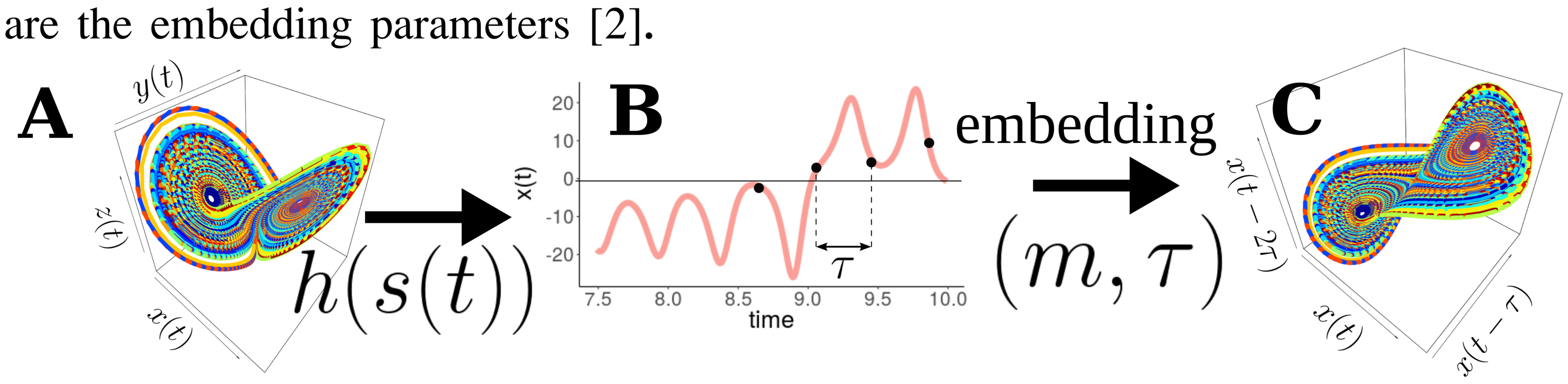


1. INTRODUCTION

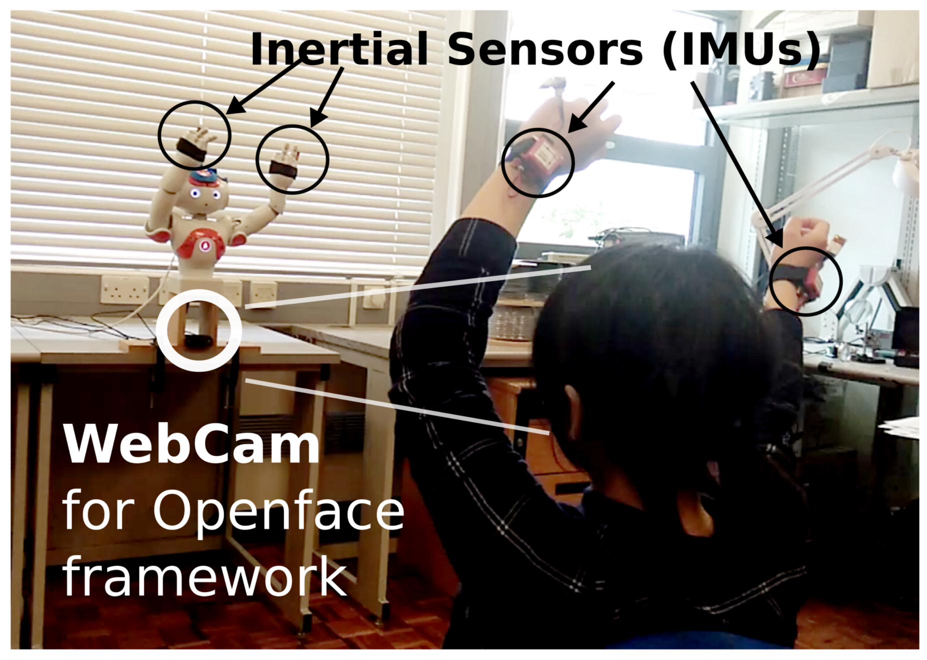
Movement variability is an inherent feature within and between persons [1]. Research on measuring and understanding movement variability using nonlinear dynamics has been well established in the previous three decades in areas such as biomechanics, sport science, neuroscience and robotics to name but a few. With that in mind, we hypothesise that the subtle variations of both time-varying facial expressions and simple body movements can be quantified in a similar fashion as with the methodologies of movement variability.

2. UNIFORM TIME-DELAY EMBEDDING [UTDE]

The purpose of time-delay embedding theorem is to reconstruct an unknown M-dimensional state space from a 1-dimensional measurement function $x(t) = h(s(t))$. The theorem is based on m delayed copies of $x(t)$ uniformly separated by τ, and it is defined as a matrix $X(t) = \{x(t), x(t-\tau), x(t-2\tau), ..., x(t-(m-1)\tau)\}$ where (m, τ) are the embedding parameters [2].



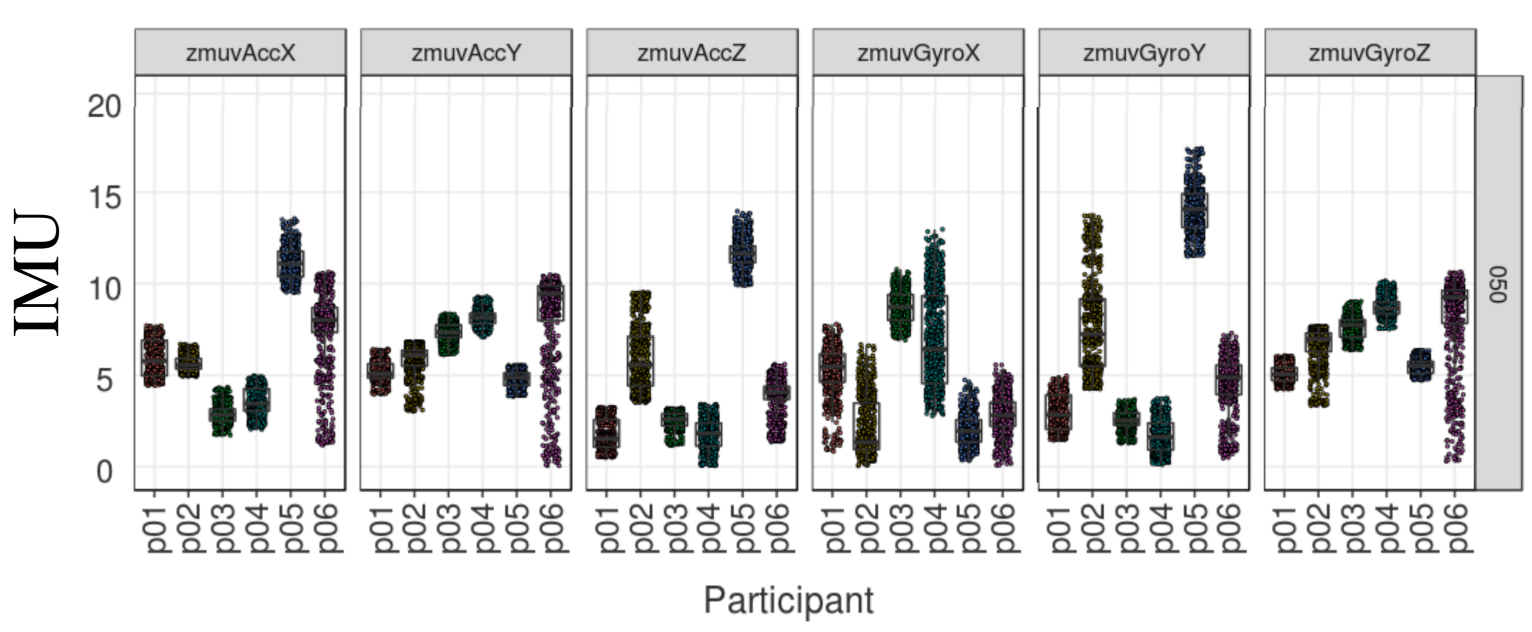
3. HUMAN-ROBOT IMITATION



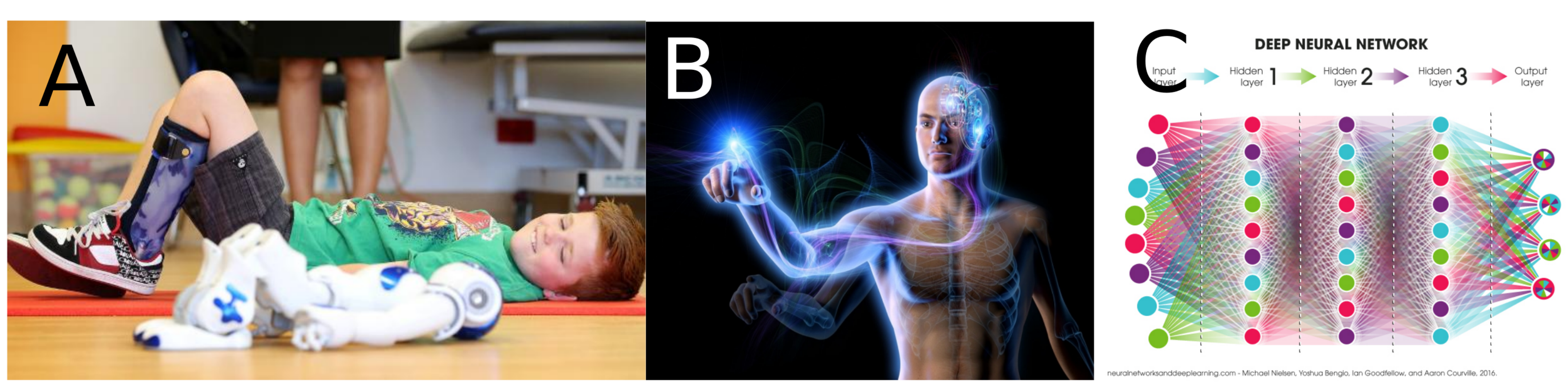
In a face-to-face human-robot imitation activity, six healthy participants followed what the robot does (repetitions of simple upper arms movements). Time series were then collected using IMUS and the Openface framework [3].

4. METHOD AND RESULTS

After applying the UTDE theorem ($m = 100$, $\tau = 4$) to the data from the sensors, the following errors plots show the variability of movement between both participants and sensors.



5. APPLICATIONS



(A) Rehabilitation, (B) Neuroscience or (C) Artificial Intelligence to mention a few.

6. CONCLUSIONS AND FUTURE WORK

We not only presented visual differences of movement variability for arms and head pose between six participants, but also we quantified such movement variability using the time-delay embedding theorem. With that in mind, we conclude that the time-varying facial expressions can also be quantified using nonlinear dynamics. Some of the areas where this work can make a potential impact are: rehabilitation, neuroscience or AI to mention a few. In future experiments, we intend to investigate deep learning techniques for automatic classification of the movement variability.

6. REFERENCES

[1] **K. M. Newell and D. M. Corcos.** 1993. *Variability and Motor Control.* Human Kinetics Publishers.
[2] **L. C. Uzal, G. L. Grinblat and P. F. Verdes.** 2011. *Optimal Reconstruction of dynamical systems: A noise amplification approach.* Physical Review E - Statistical Nonlinear and Soft Matter Physics 84, 1 (2011).
[3] **T. Baltrusaitis, P. Robinson, and LP Morency.** 2016. *OpenFace: an open source facial behavior analysis toolkit.* In IEEE Winter Conference on Applications of Computer Vision.
[4] **M. P. Xochicale.** 2018. Emotion and movement variability: a pilot study (emmov-pilotstudy). http://github.com/mxochicale/emmov-pilotstudy