Project Offer for Student Projects

Project Type [MSc Thesis, GR]

Project Title: Transformer-based Explainable AI for Biomechanical Prediction Analysis: Optimized Kinematics and Kinetics Prediction

Research Domain(s): Machine Learning, Explainable AI

Project Director: Prof. Daniel Roth

Project Advisors: Daniel Homm

Project Abstract

This project aims to analyze the contribution of different input features to biomechanical prediction models based on wearable sensor data. The focus lies on applying and evaluating explainable AI (XAI) techniques to a transformer-based architecture. By integrating post-hoc interpretability methods with a state-of-the-art transformer model, the project seeks to systematically quantify how individual sensor features affect the prediction of lower-body kinematics and kinetics. The overall objective is to derive insights for sensor reduction, model optimization, and improved interpretability in human motion analysis.

Background & Motivation

Accurate motion tracking is essential for biomedical modeling, clinical diagnostics, and performance monitoring. While marker-based motion capture systems remain the gold standard in terms of precision, their usage is limited by high costs, controlled laboratory settings, and complex preparation procedures. Wearable sensors offer a practical and scalable alternative, enabling movement analysis in real-world environments.

Inertial Measurement Units (IMUs) are widely used in modern wearable devices. Recent research demonstrates that combining IMU and electromyography (EMG) data provides strong predictive power for estimating joint kinematics and kinetics. However, achieving state-of-the-art accuracy typically requires extensive feature sets, which may limit model efficiency, interpretability, and usability.

This project addresses these limitations by applying XAI methods to a transformer model to better understand feature relevance. Insights from this work can guide feature selection, reduce computational cost, and support future applications.

Key research includes:

- Training and evaluation of a transformer model
- Investigating XAI strategies for transformer models
- Applying these to a recently developed transformer architecture
- Evaluating the outcomes and provide suggestions for future changes

Recommended background (motivation in learning)

- Python, including libraries such as NumPy, Pandas, PyTorch, and TensorFlow
- Explainable AI methods (mostly post-hoc methods such as Shap adaptations, ...)
- Interest in optimization, explainability and development of machine learning models
- Interest in motion analysis

Please send your transcript of records, CV and motivation to: Daniel Homm (Daniel.homm@tum.de) with CC to hex-thesis.ortho@mh.tum.de

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Literature

[1] Daryakenari, F. H., & Farizeh, T. (2025). A novel transformer-based method for full lower-limb joint angles and moments prediction in gait using sEMG and IMU data. doi:10.48550/ARXIV.2506.04577

[2] Chotikunnan, P., Khotakham, W., Chotikunnan, R., Roongprasert, K., Pititheeraphab, Y., Puttasakul, T., ... Thongpance, N. (2025). Enhanced angle estimation using optimized artificial neural networks with temporal averaging in IMU-based motion tracking. *Journal of Robotics and Control (JRC)*, *6*(2), 1069–1082. doi:10.18196/jrc.v6i2.26345

[3] Xiang, L., Gao, Z., Yu, P., Fernandez, J., Gu, Y., Wang, R., & Gutierrez-Farewik, E. M. (2025). Explainable artificial intelligence for gait analysis: advances, pitfalls, and challenges - a systematic review. *Frontiers in Bioengineering and Biotechnology*, *13*(1671344). doi:10.3389/fbioe.2025.1671344

[4] Kalasampath, K., Spoorthi, K. N., Sajeev, S., Kuppa, S. S., Ajay, K., & Maruthamuthu, A. (2025). A literature review on applications of explainable artificial intelligence (XAI). *IEEE Access: Practical Innovations, Open Solutions*, *13*, 41111–41140. doi:10.1109/access.2025.3546681

[5] Cheng, Q., Xing, J., Xue, C., & Yang, X. (2025). Unifying prediction and explanation in time-series transformers via Shapley-based pretraining. doi:10.48550/ARXIV.2501.15070