Machine learning for estimating hand position

Approach based on forearm EMG and measured hand position

Graduate

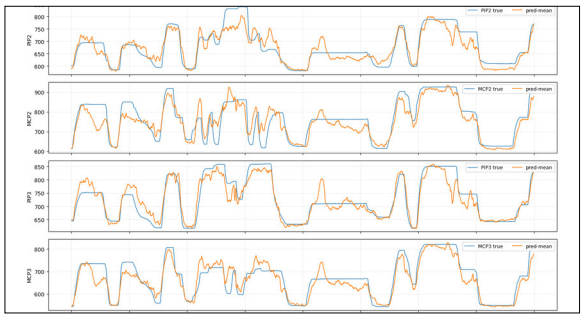
Philipp Heim

Objective: This work investigates the feasibility of independently mapping multiple degrees of freedom of the fingers from EMG signals. To this end, EMG signals are simultaneously recorded on the forearm and the angles of the finger joints are recorded using a specially developed glove. The measurements are taken at the metacarpophalangeal joint and the first interphalangeal joint of the index and middle fingers. The additional information from the finger joints allows training data to be used to train a neural network more reliably to continuously map the four degrees of freedom.

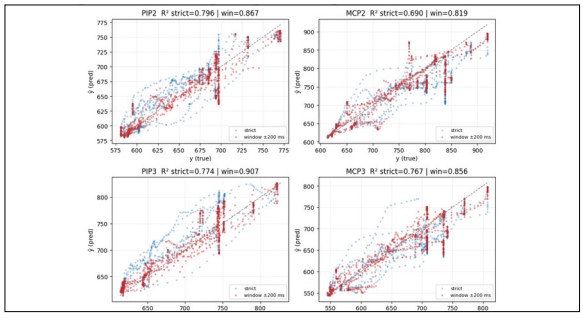
Approach: Four EMG channels are recorded. Two different variants of electrode placement are tested: Variant 1 selects positions based on visually estimated contrast in live EMG, while variant 2 is based on the flexors and extensors of the fingers in the forearm. Features are generated from the raw EMG signals: frequency analysis in eight bands with mean, variance, and standard deviation per band. The neural network has two causal encoder branches. One branch first processes the extracted features, while the other branch then processes the four raw EMG channels at 1000 Hz. Both representations are merged and mapped to the target channels. Training is carried out in phases with selective freezing of individual parts in order to first learn a stable spectral basis, then add high-frequency details, and finally finetune the fusion of the two paths.

Result: The evaluation is performed using time series comparisons and scatter plots. A time tolerance of ±200 ms ensures that the correct amplitude is detected even if the prediction is slightly delayed. Variant 1 of the electrode placement proves to be unsuitable. Variant 2, on the other hand, shows good agreement and stable correlations. With a tolerance of ±200 ms, the coefficient of determination increases to $R^2 = 0.856 \ldots 0.907$. Residual errors include slight overshoot on fast transients, drifting at constant angles, and crosstalk when one joint is at rest and another is moving quickly.

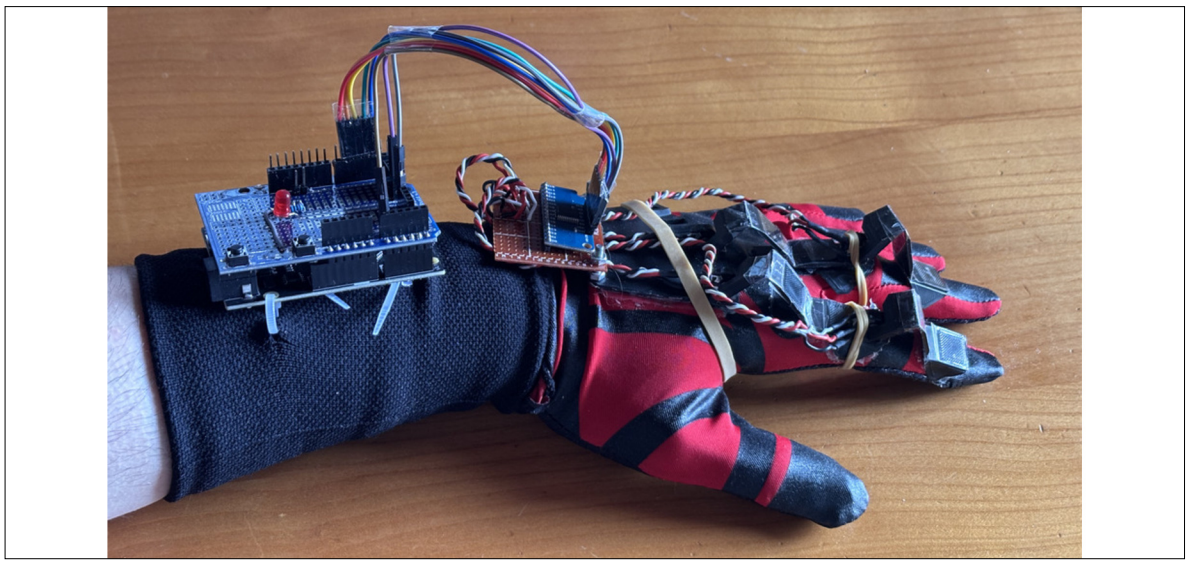
Angle comparison of measured and predicted values over time
Own presentment



Scatter plot of predicted angles versus measured angles
Own presentment



Glove for measuring finger joint angles
Own presentment



Advisor
Prof. Adrian Weitnauer

Co-Examiner
Prof. Dr. Christoph Würsch

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