
EMG based input and control system for lower limb prostheses

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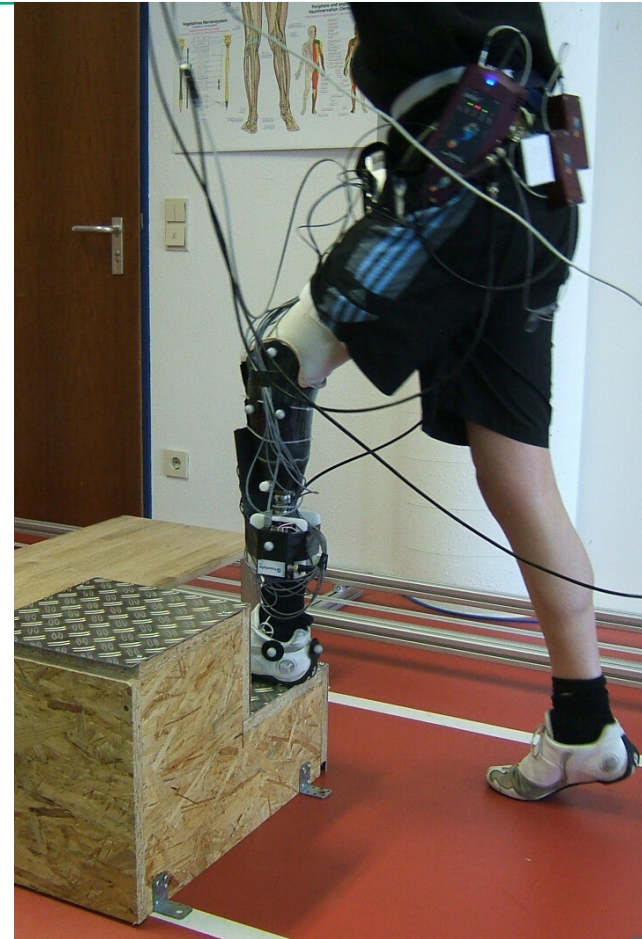
Motion systems, Fraunhofer IPA

Outline

- Intention & introduction
- Sensor concept
- Signal processing system
- Generation of virtual sensors
- Motion state estimation
- Feature extraction and classification for pattern recognition
- Results of the overall system
- Performed processing analyzes & Outlook

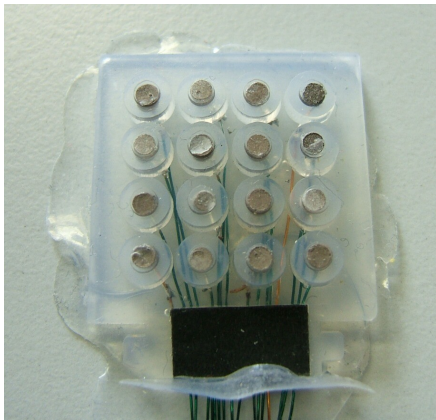
Intention & Introduction

- Development of voluntary control input system
- For lower limb prostheses
- Used in active prosthesis
- For actions like ankle lifting
- Based on surface electromyography (EMG)
- Sensor system integrated in prosthesis socket
- Real-time signal processing
- Usable in dynamic motions (walking) and static (standing)
- Reduced efforts for learning & parametrization



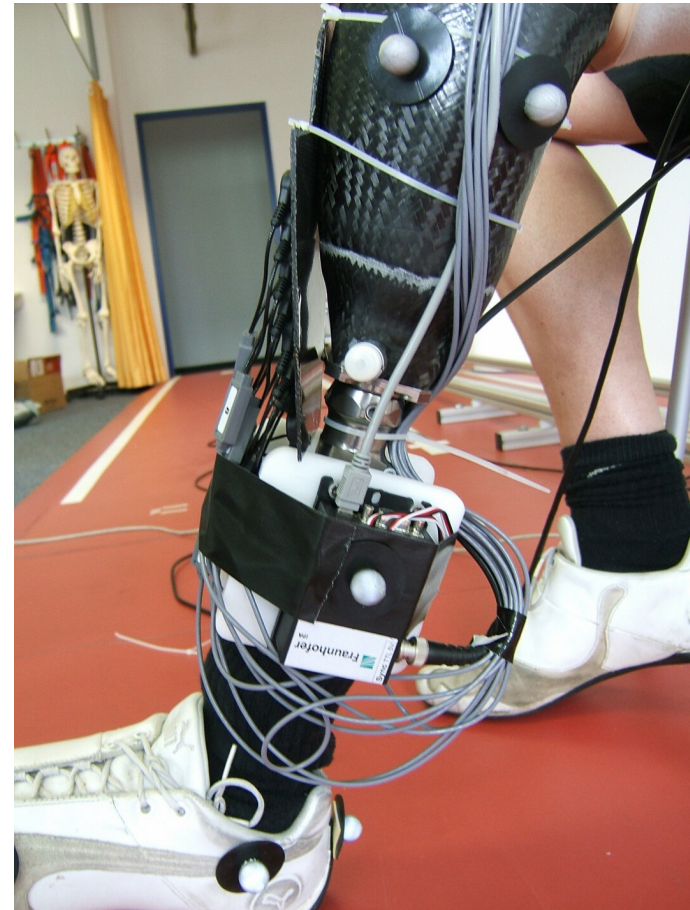
Sensor concept (I)

- 4x4 EMG array on skin surface
- 4x4 pressure sensor array under EMG array
- Different type of electrodes and carrier technology evaluated

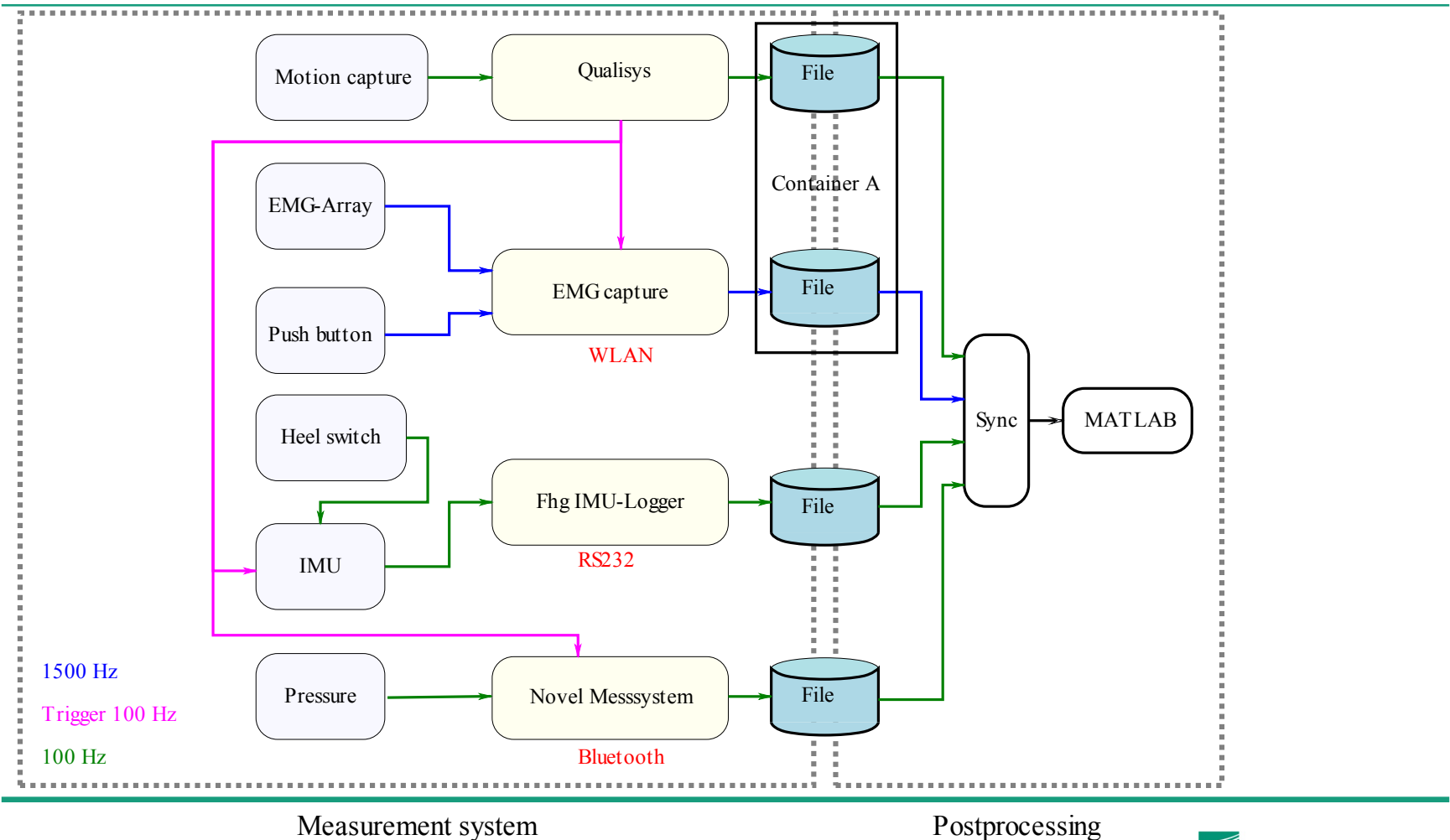


Sensor concept (II)

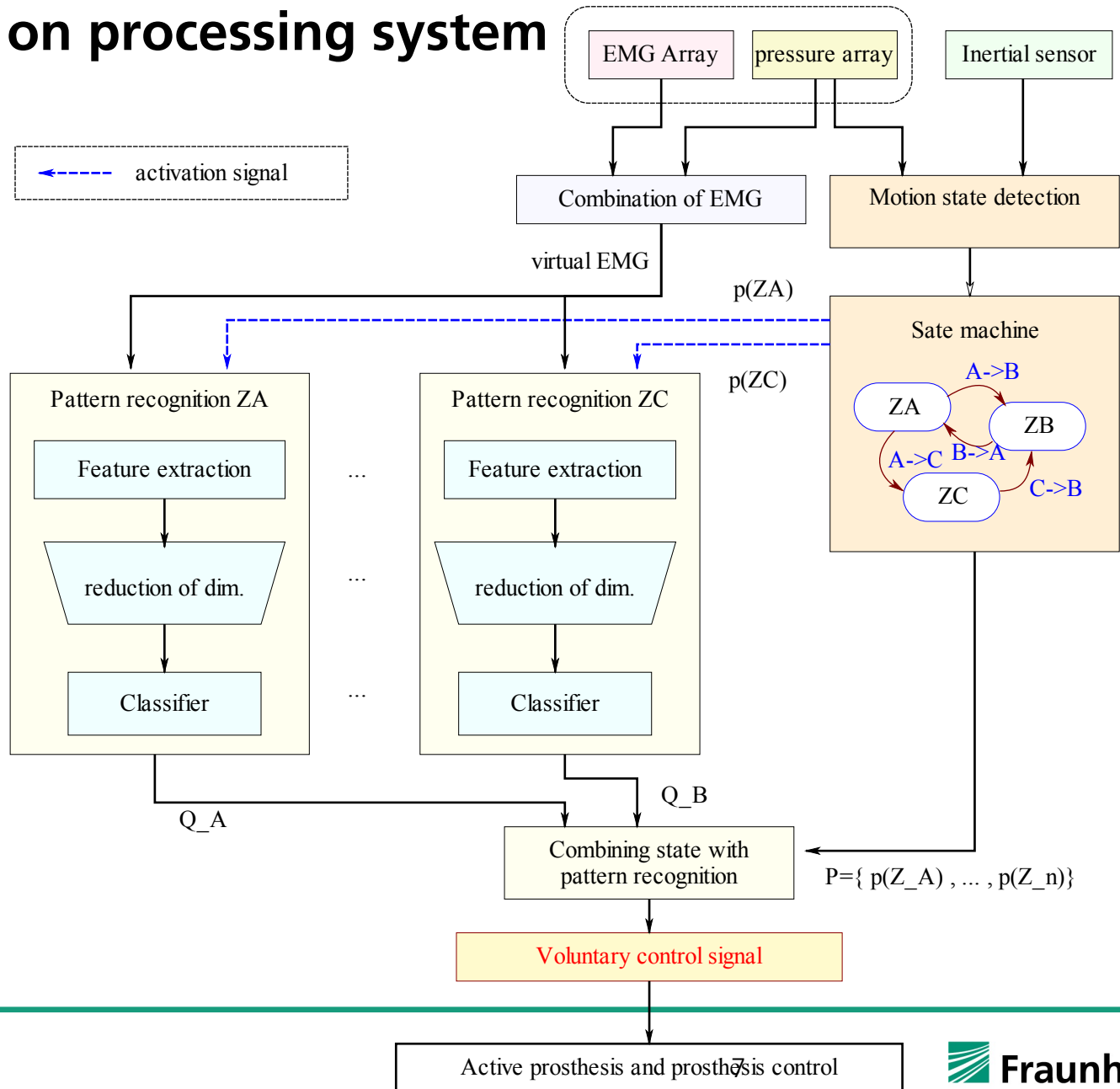
- Inertial measurement unit (IMU) attached to prosthesis
- Discrete pressure sensors under foot (heel and toe)



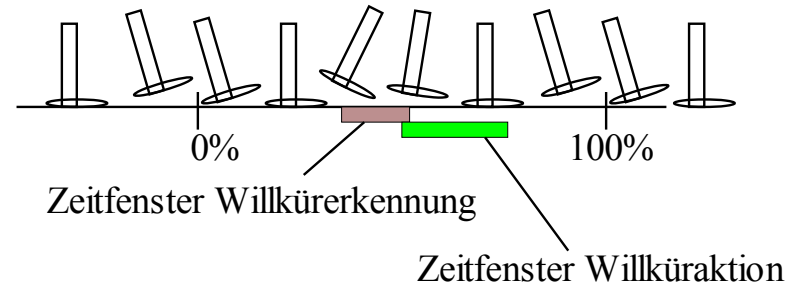
Sensor concept (III)



Overview on processing system

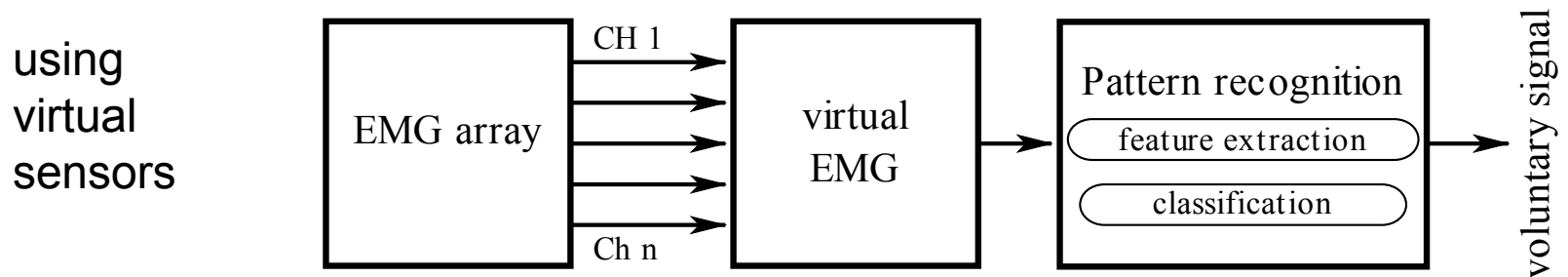
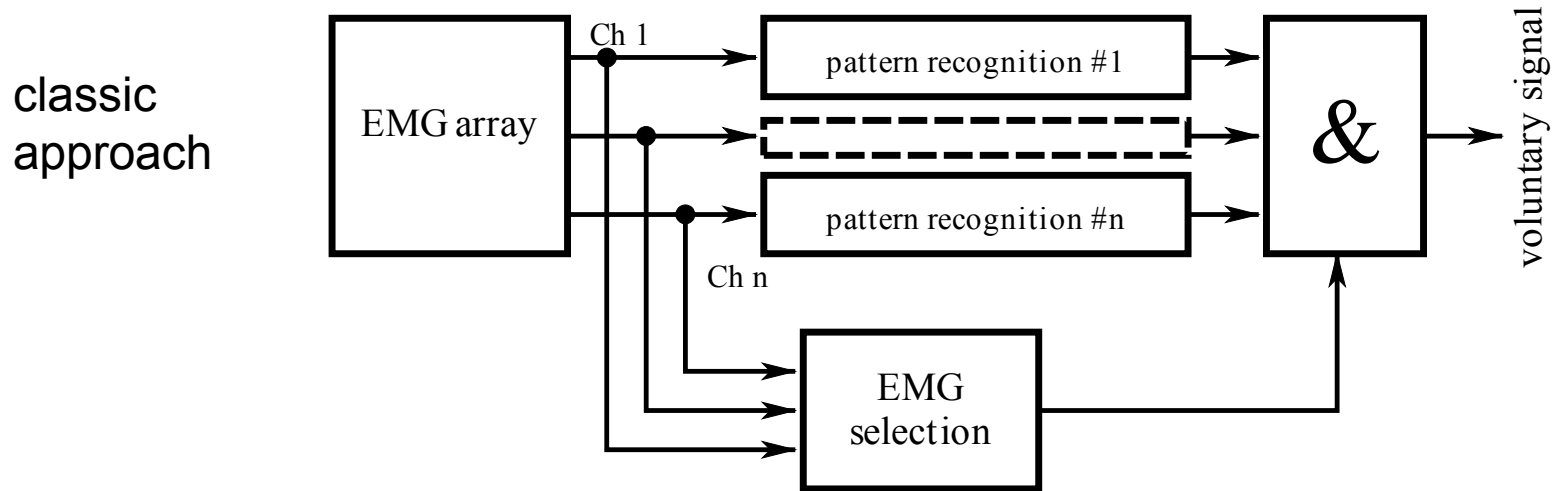


Requirements and constraints



- Real-time processing in human motion
 - Limitation of signal processing (no look ahead)
 - Small decision horizon (time window to give reliable result)
 - Usage of other sources for decision logik → robustness
 - State estimators where possible
 - Preferable methods inducing only small latency
- Minimization of processing demands → mobile embedded device
- Modularization of functionality for disabling of unused function blocks

Concept of „virtual EMG“ (I)



Concept of „virtual EMG“ (II)

■ Methods of comparison:

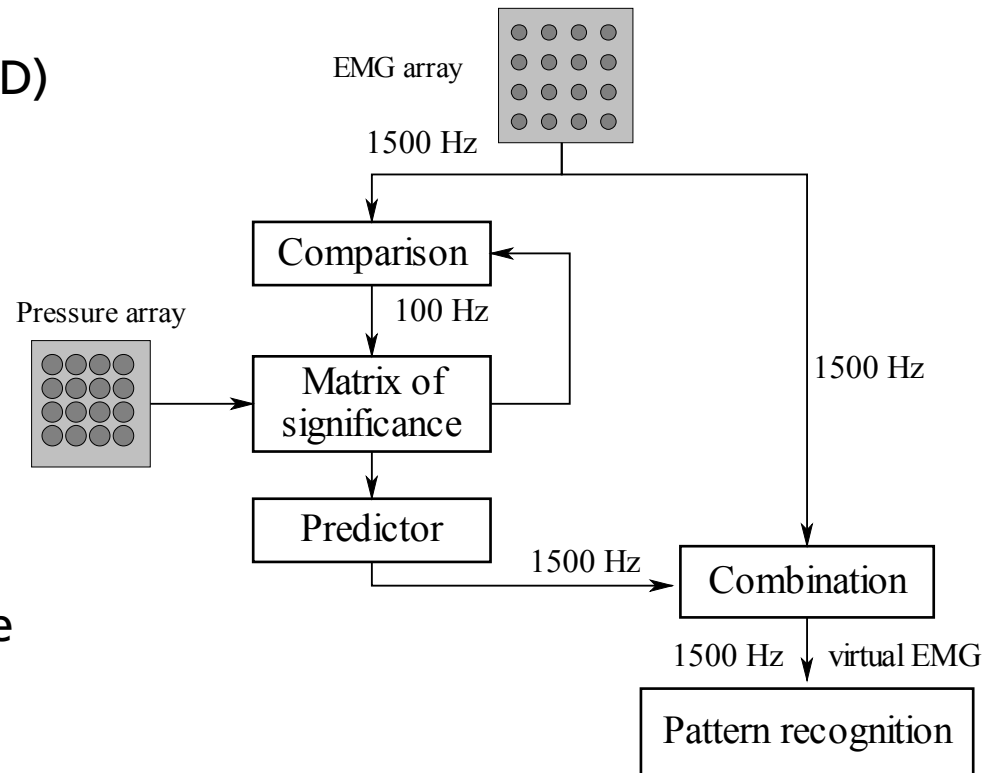
- Energy of Difference (EoD)
- covariance
- cross correlation

■ Matrix of significance

- combination of comparison coefficients

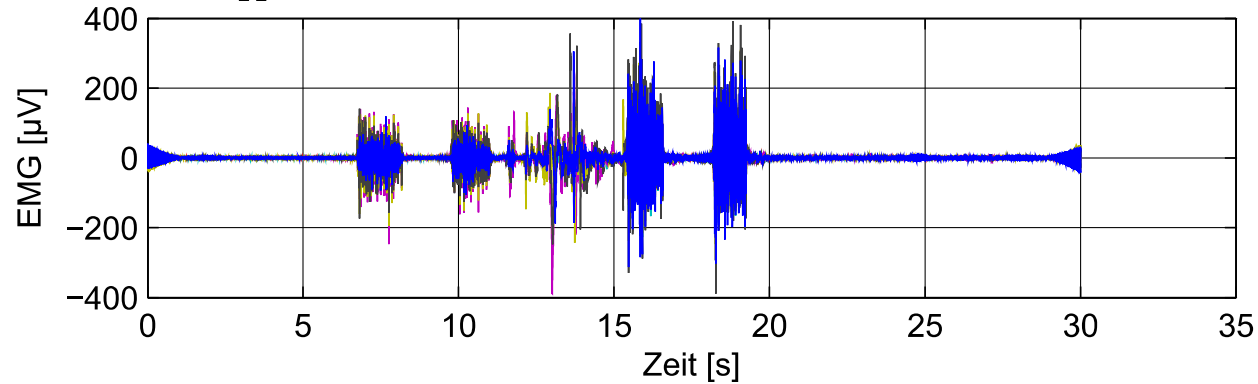
■ Usage of predictor:

- Prediction of significance matrix
- Interpolation
- Frequency adaptation

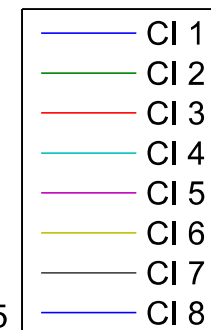
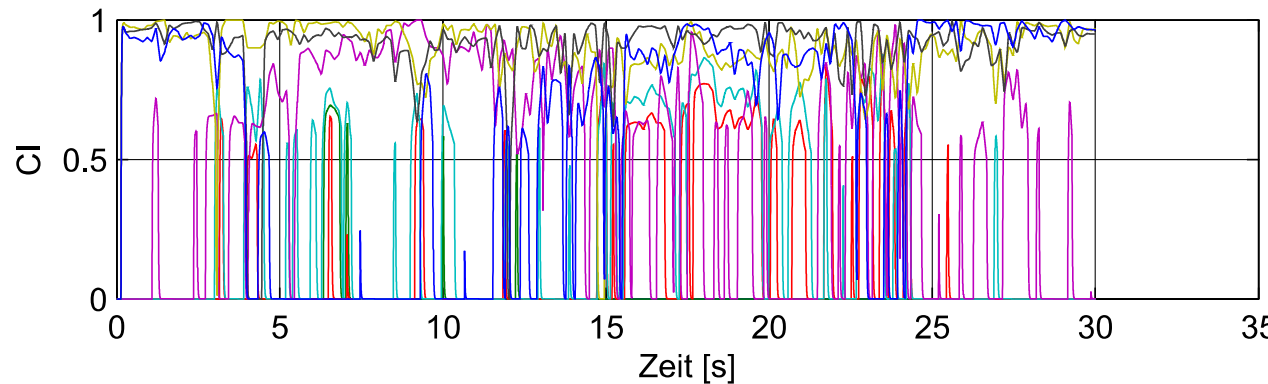
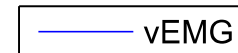
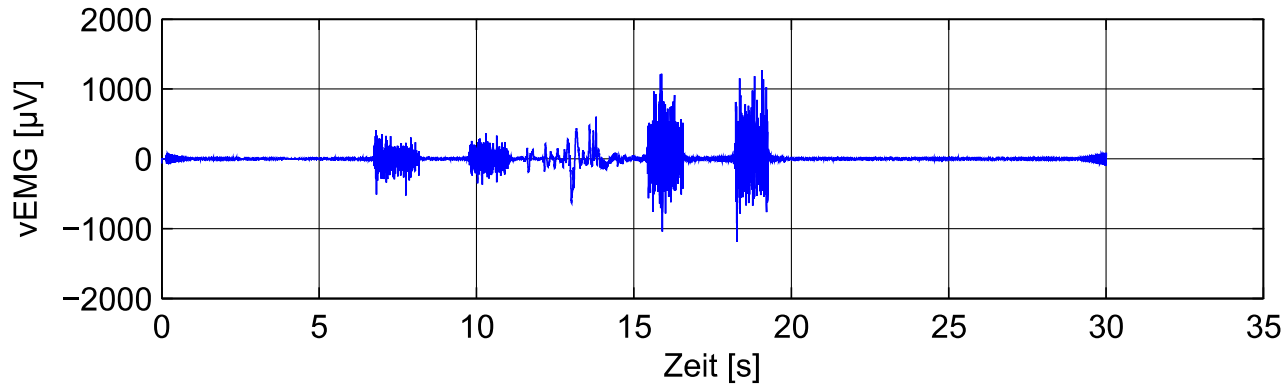


Results „vEMG“

EMG-Signal

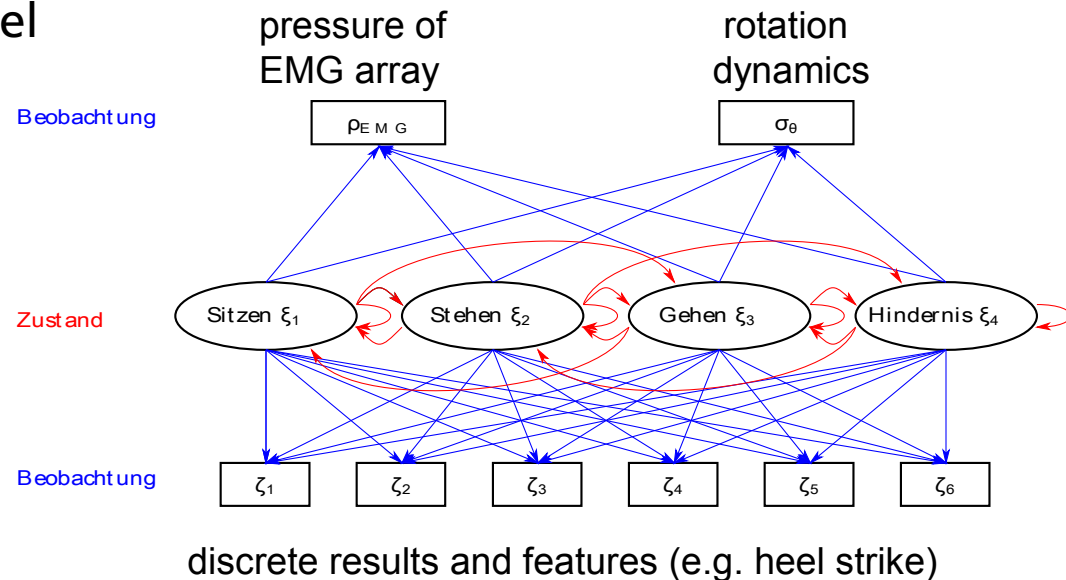
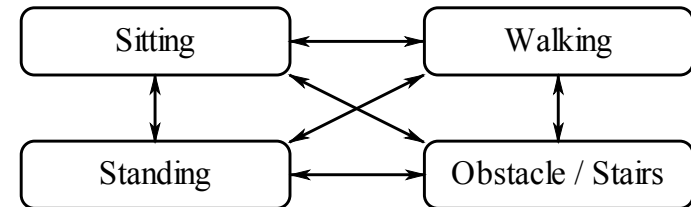


virtuelles EMG



Motion state detection

- Motion state transition
- Feature extraction
- State estimation using
 - Hidden Markov Model
 - Fuzzy systems
 - mod. Kalman filter
- Estimation of
 - Gait phase [%]
 - Gait cycle length

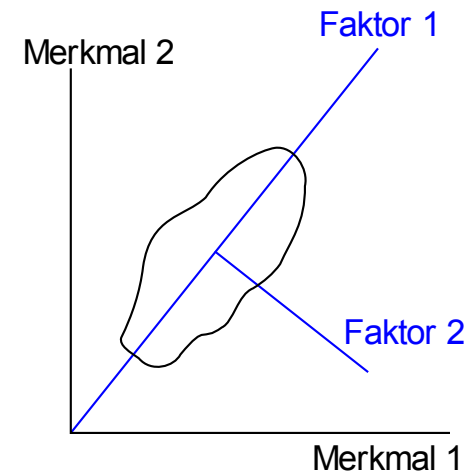


Concept of feature space reduction

EMG pattern recognition

- Based on vEMG a feature vector \mathbf{y} is generated
 - Time domain
 - Frequency domain
 - AR coefficients
 - Wavelet coefficients (discrete WT)
- Reduction of feature space dimension necessary
- used method: Principal Component Analysis:

$$\begin{bmatrix} z_1 \\ \vdots \\ z_9 \end{bmatrix} = \mathbf{M}_{PCA} \begin{bmatrix} y_1 \\ \vdots \\ y_{500} \end{bmatrix}$$



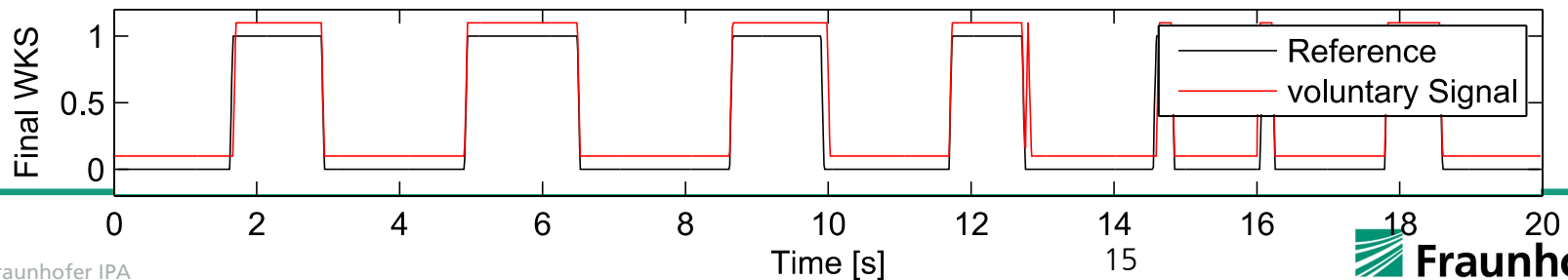
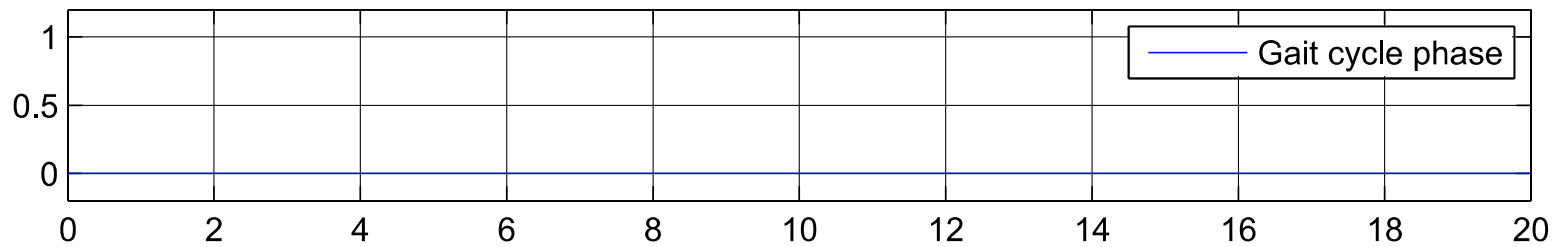
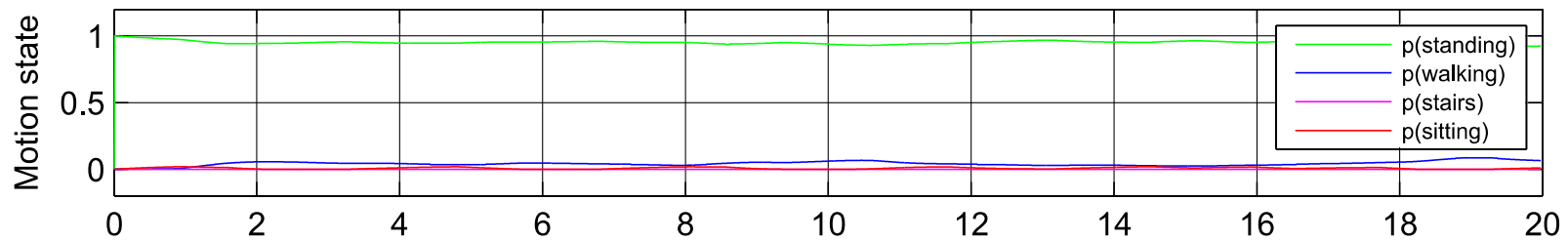
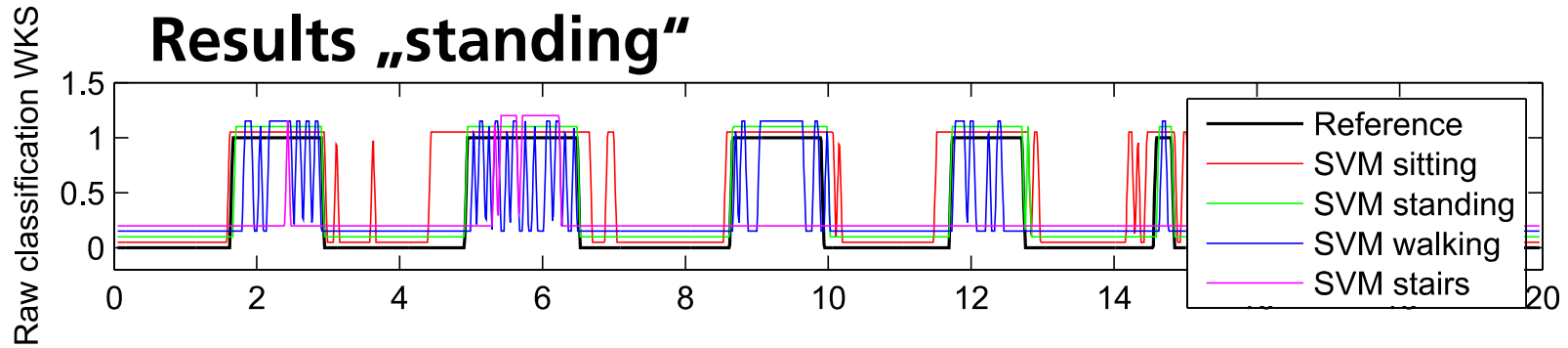
Pattern recognition of vEMG

- Methods investigated:
 - Linear Discriminant Analysis (LDA) --> Reduction of dimensionality and classifier in one
 - Support Vector Machine (SVM) --> only classifier, needs PCA
- Background of SVM: transformation of unsolvable problems in higher dimensional spaces → linear discrimination of nonlinear areas
- Pattern recognition must decide for each detected motion state whether control signal is present and plausible
- Requires training of SVM for each motion state

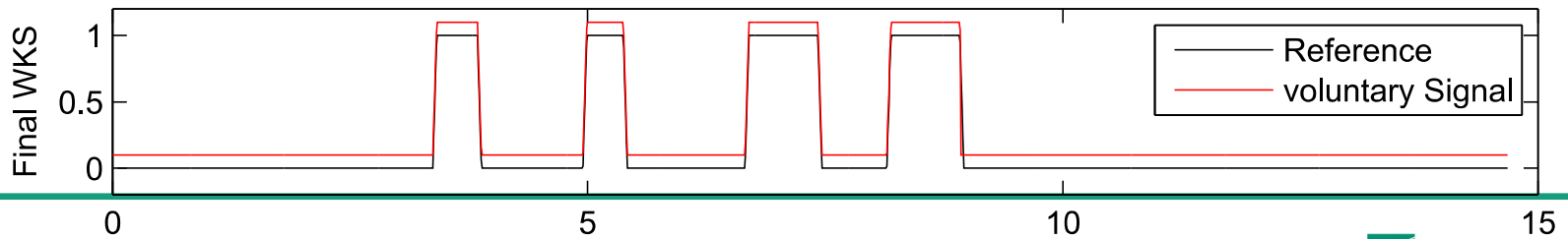
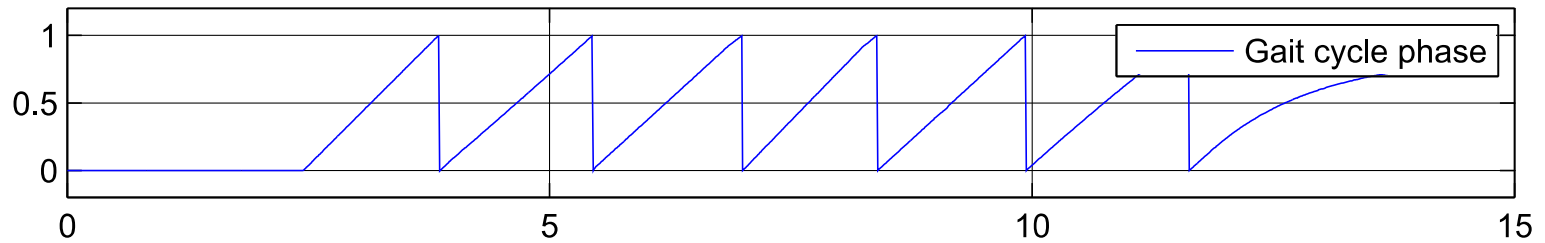
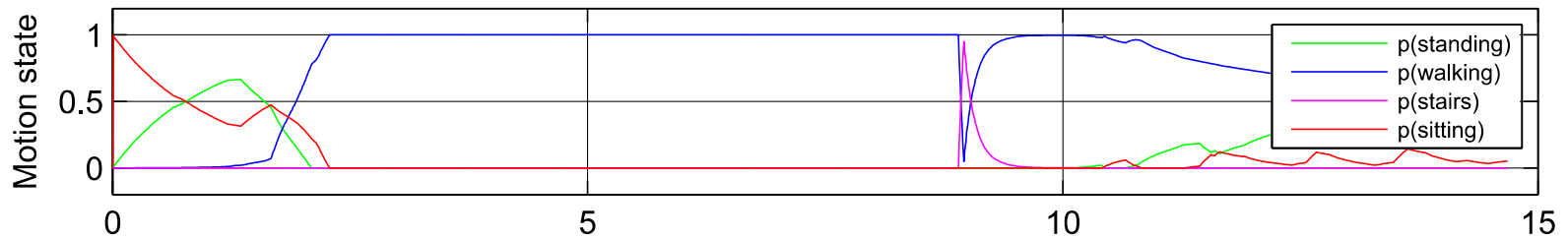
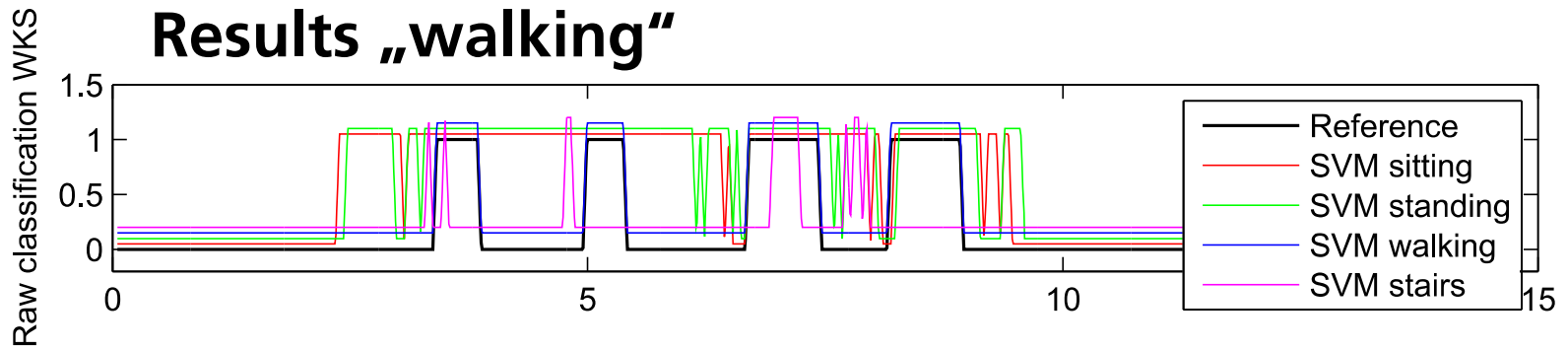
Goal:

- Derive SVM parameters for motion states which were not measured

Results „standing“



Results „walking“



Performed analyses & Outlook

- Generalization of
 - Feature extraction
 - Dimension reduction (PCA) by comparison of eigenvectors
- Required dimension of reduced feature vector per motion state
- Determination of generalized SVM parameter set for classification
- Result of classification applied to data sets of different motion types

Current research work & Outlook

- Supervised training of SVM classifier (no brute force)
- ROC-curve like termination of SVM training (not best performance, but most common features found)
- Automatic comparison of SVM parameter sets from different patients

Thank you for your attention !

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