Automatic identification of inertial sensors on the human body segments

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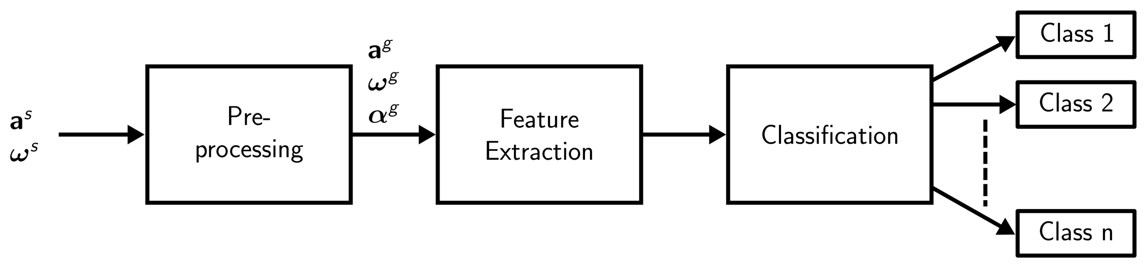
Introduction

A major drawback of current inertial sensor motion capture systems is the large set-up time. By using wireless inertial sensors and automatic identification of their positions on the human body, this set-up time can be reduced. A new method to automatically identify body segments to which inertial sensors are attached during walking, is presented according the following scheme.



Pre-processing

Measurements of walking data were recorded from 31 walking trials of 10 healthy subjects with an Xsens MVN motion capture suit using full body configuration (17 inertial sensors).

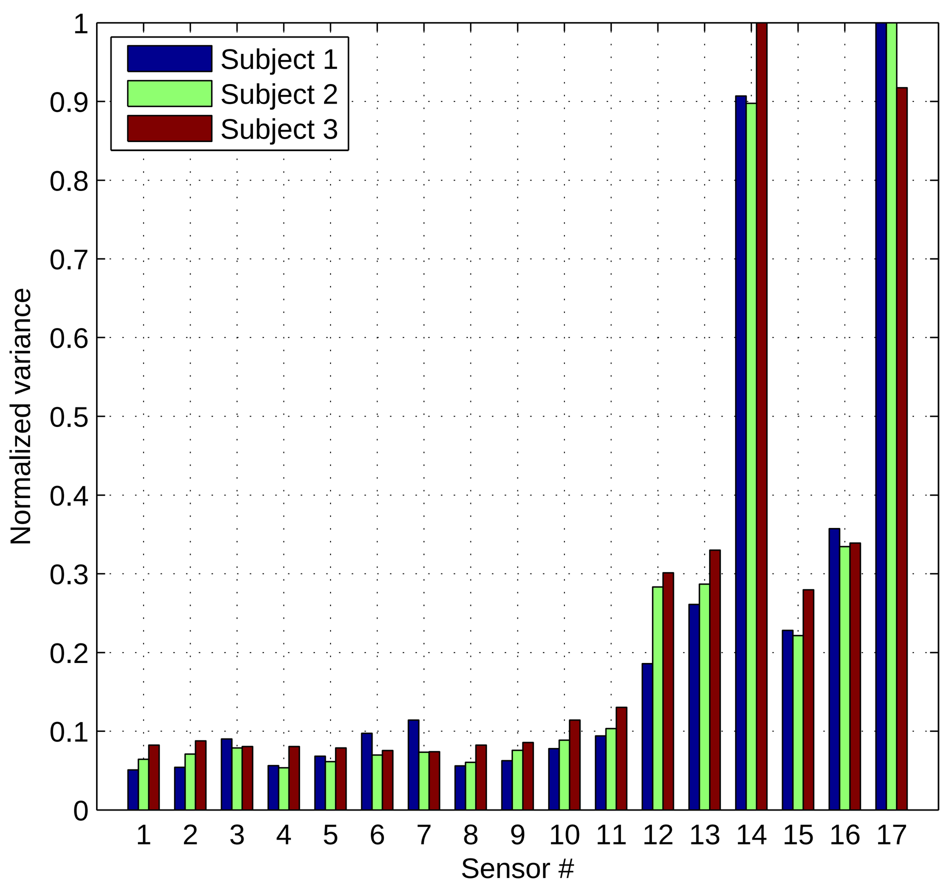
Accelerations ($\mathbf{a}$) and angular velocities ($\boldsymbol{\omega}$) were expressed in global coordinates with x-axis aligned with walking direction, y-axis pointing left and z-axis pointing up.

From 3D angular velocities, 3D angular acceleration were calculated ($\boldsymbol{\alpha} = d\boldsymbol{\omega}/dt$).

Feature extraction

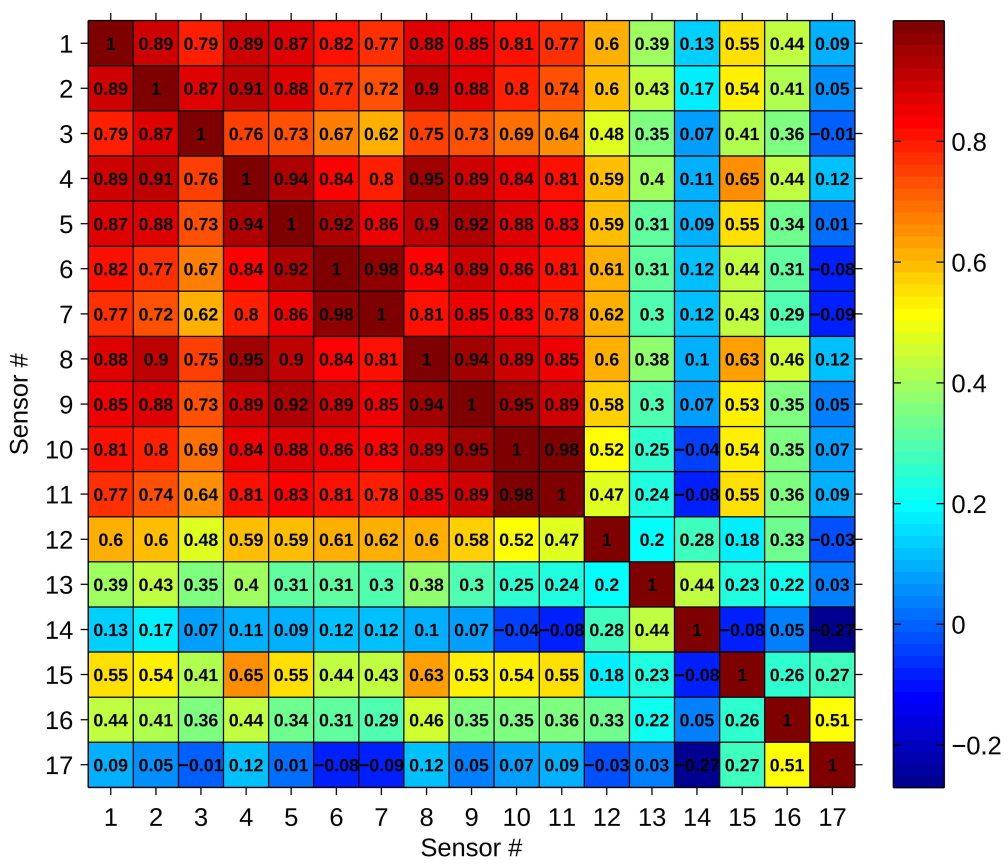
Features were extracted from magnitudes and x, y and z- components of $\mathbf{a}$, $\boldsymbol{\omega}$ and $\boldsymbol{\alpha}$. Fifty seven features were extracted and ranked (mean (12), variance (12), correlation coefficients (24) and inter-axis correlation coefficients(9)).

Example of variance of magnitude of acceleration (Var$\{||\mathbf{a}||\}$):



#	Segment
1	Pelvis
2	Sternum
3	Head
4	Right shoulder
5	Right upper arm
6	Right forearm
7	Right hand
8	Left shoulder
9	Left upper arm
10	Left forearm
11	Left hand
12	Right upper leg
13	Right lower leg
14	Right foot
15	Left upper leg
16	Left lower leg
17	Left foot

From correlation coefficient matrices sum and maximum are used as features:



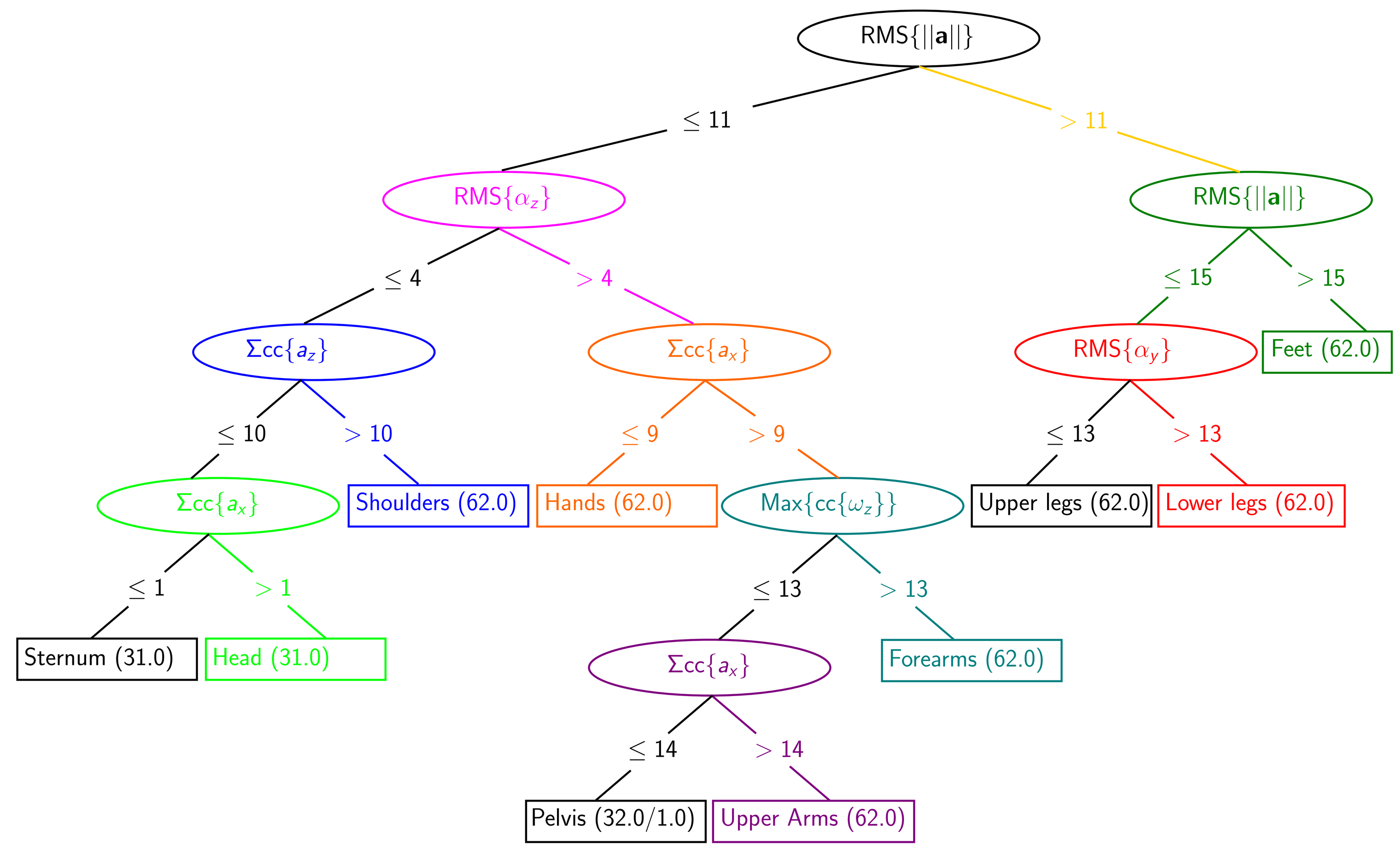
$\sum cc\{\|\|\mathbf{a}\|\|\}$	Max$\{cc\{\|\|\mathbf{a}\|\|\}\}$
10.54	0.89
10.56	0.91
8.92	0.87
10.94	0.95
10.62	0.94
10.19	0.98
9.78	0.98
11.00	0.95
10.67	0.95
10.26	0.98
9.81	0.98
7.25	0.62
4.78	0.44
1.75	0.44
6.76	0.65
5.48	0.51
1.41	0.51

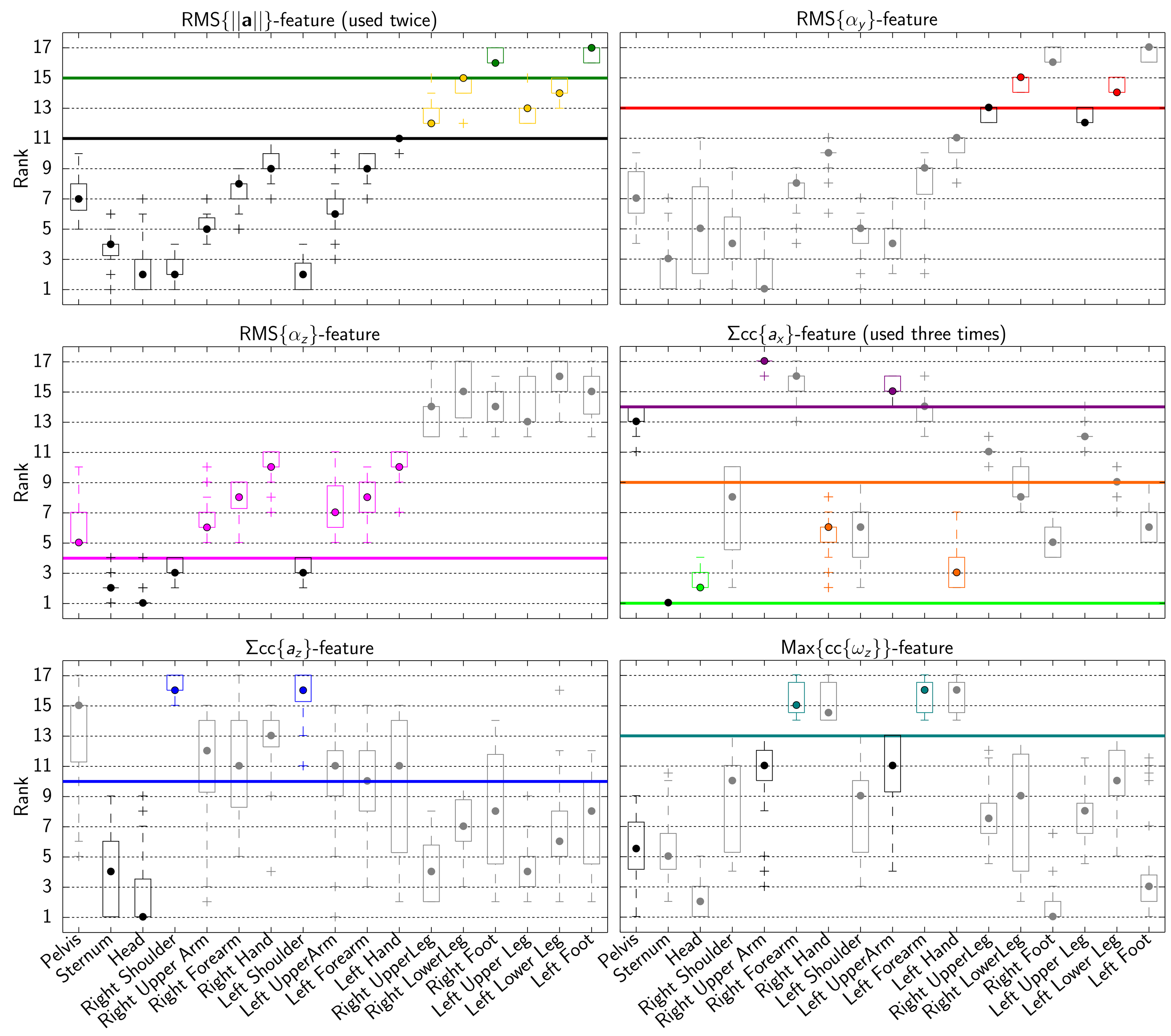
Classification

Classification is split into three steps. First the segments are identified without distinguishing left and right. In the second step inter-axis correlation coefficients are used to distinguish left from right segments. In the third step left and right upper arms are identified using correlation with forearms.

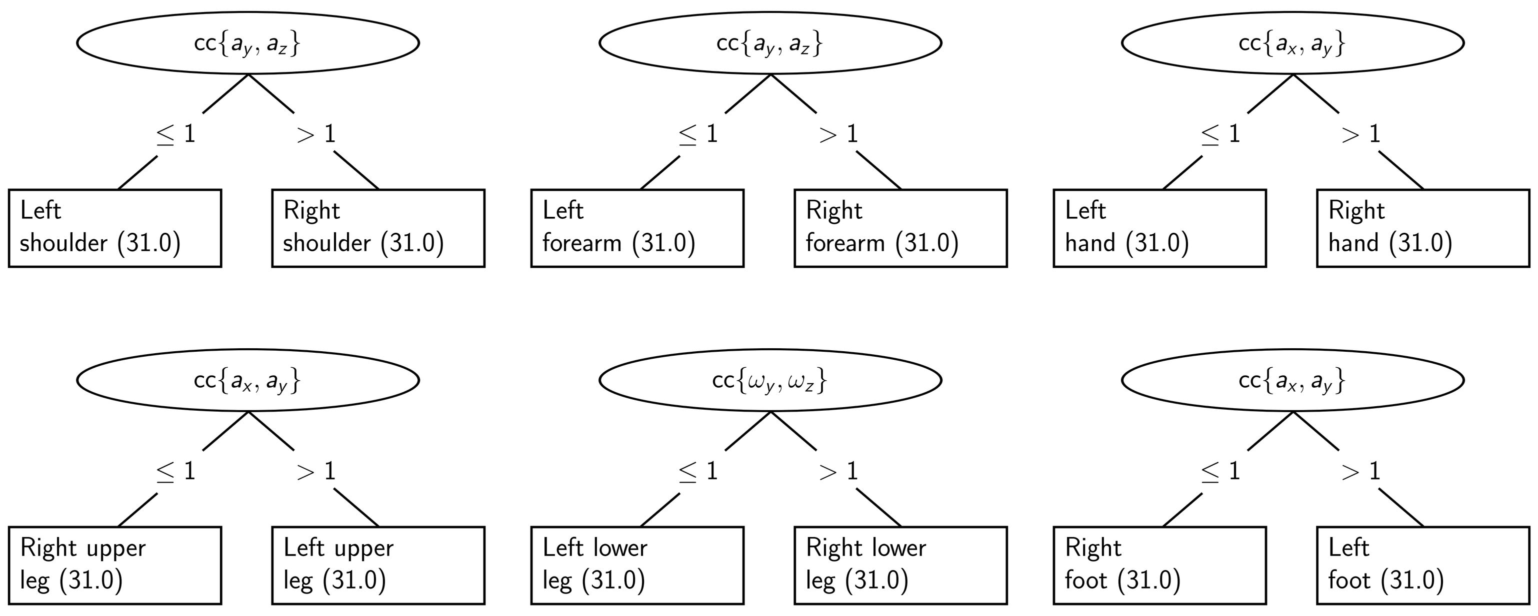
A C4.5 based decision tree classifier (feature with highest information gain makes split) was constructed with Weka (Waikato Environment for Knowledge Analysis) using 10-fold cross-validation, giving a generalized indication of error for independent datasets.

Results





A total of 525 of 527 sensors were correctly classified (99.62 %). For the second step the inter-axis correlation coefficients were used, resulting in 100 % correct identification.



Overall, nine different features were needed for the identification. For identification of the left and right upper arm the correlation with the forearm was needed.

Conclusions and future work

An accurate (99.62 %) method for automatic identification of inertial sensors is presented. However, the sensor configuration has to be known beforehand because of the ranking (physical information is lost).

Subjects have to be walking, other daily-life activities (or even arbitrary movements) will be investigated next.

Acknowledgment

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