PIECEWISE LINEAR DYNAMICAL MODEL FOR HUMAN ACTIONS CLUSTERING FROM INERTIAL BODY SENSORS WITH CONSIDERATIONS OF HUMAN FACTORS

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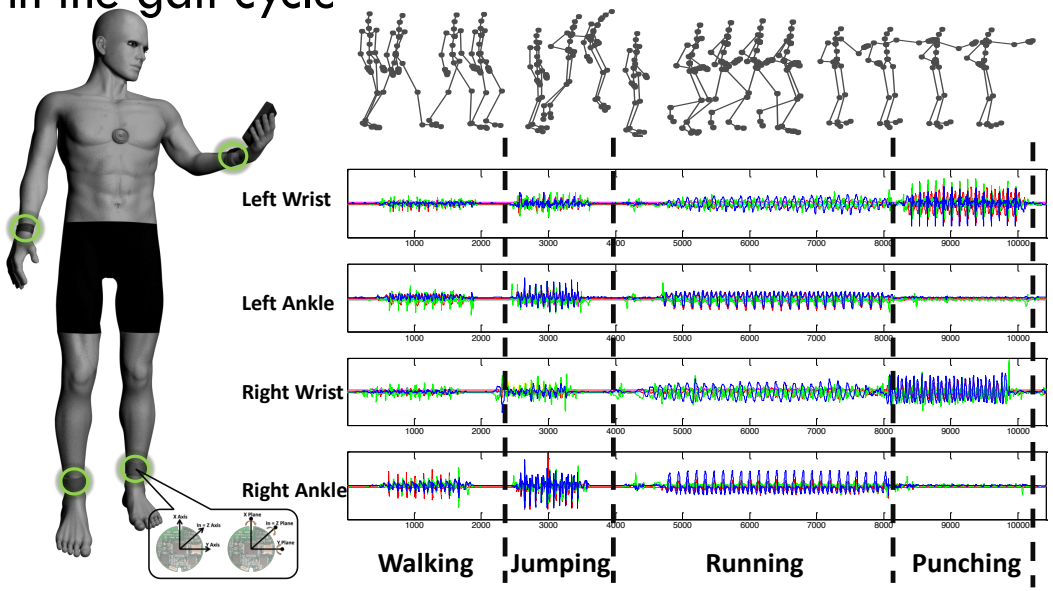
Motivation

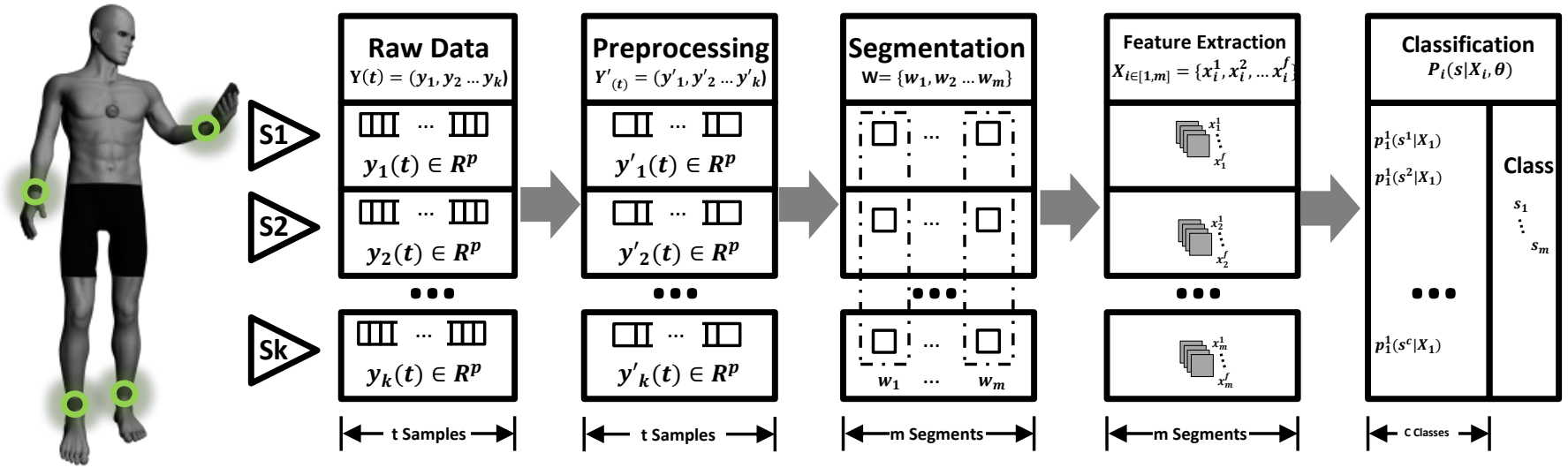
- Dividing motion data into discrete segments is useful
  - Training
  - Diagnosis
- Segmentation can be at different granularities
  - Walking vs. not-walking
  - Where in the gait cycle



Problems

- Typical BSN Processing Pipeline

Assumes repeatability of signals



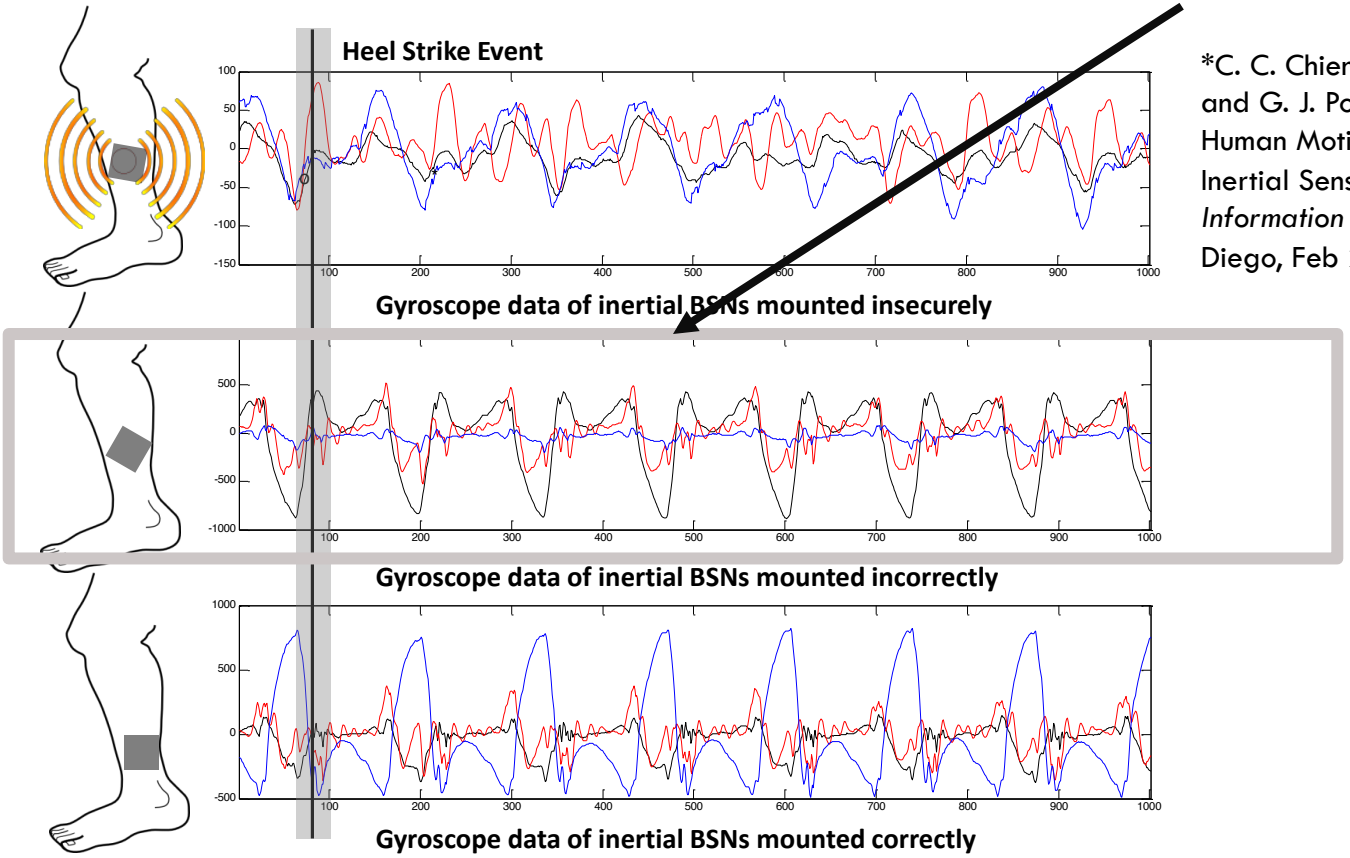
Credit: A. Bulling, U. Blanke, and B. Schiele, "A Tutorial on Human Activity Recognition Using Body-Worn Inertial Sensors", *ACM Computing Surveys (CSUR)*, vol. 46, no. 3, pp. 33, 2014.

Problems

- ‘Human Factors’

Physical placement affects signal

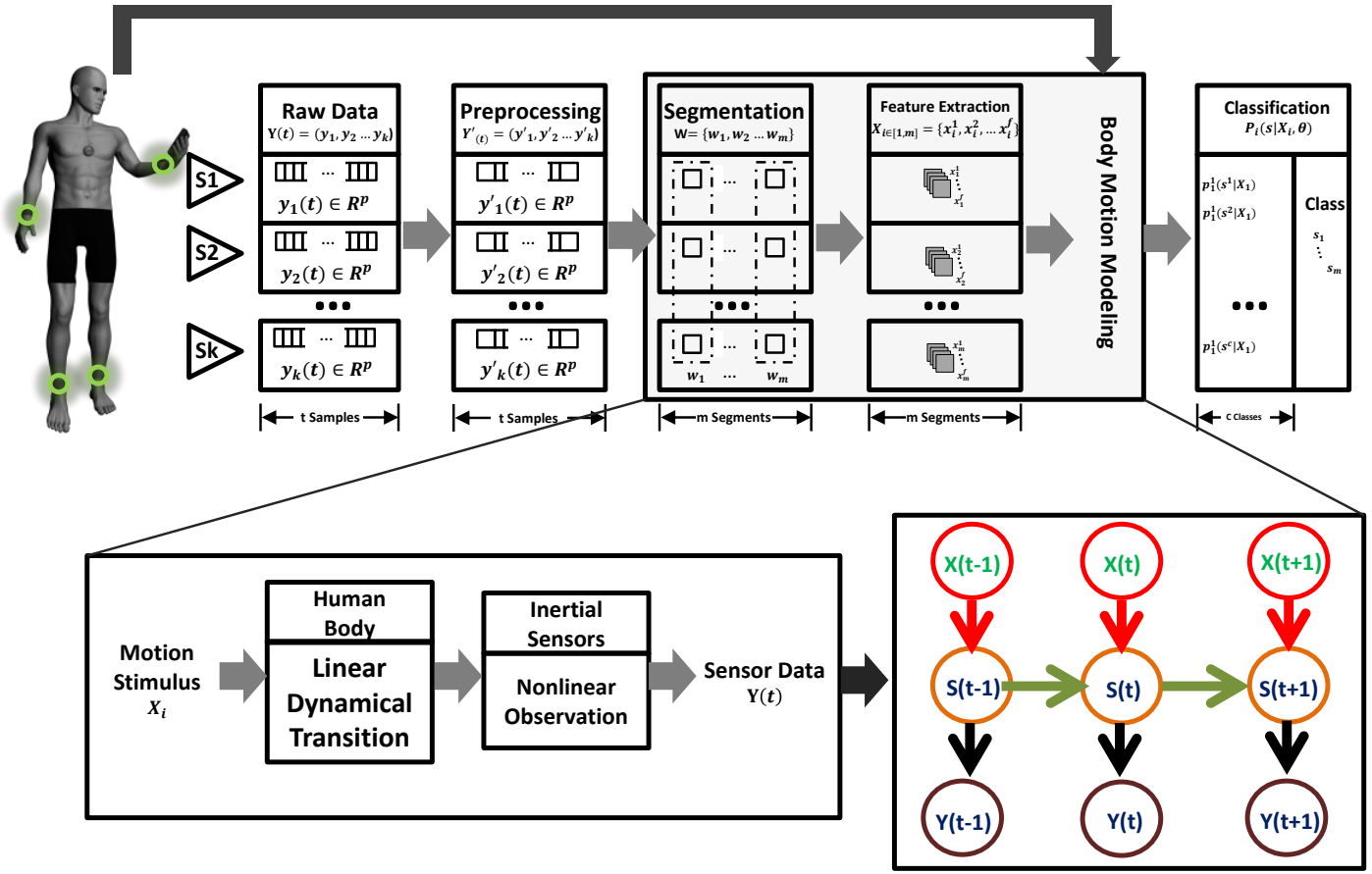
Chien et al. (2013)*: Model-based estimation



*C. C. Chien, J.Y. Xu, H-I Chang, X. Wu and G. J. Pottie, “Model Construction for Human Motion Classification using Inertial Sensors”, *IEEE Workshop on Information Theory and Applications*, San Diego, Feb 2013

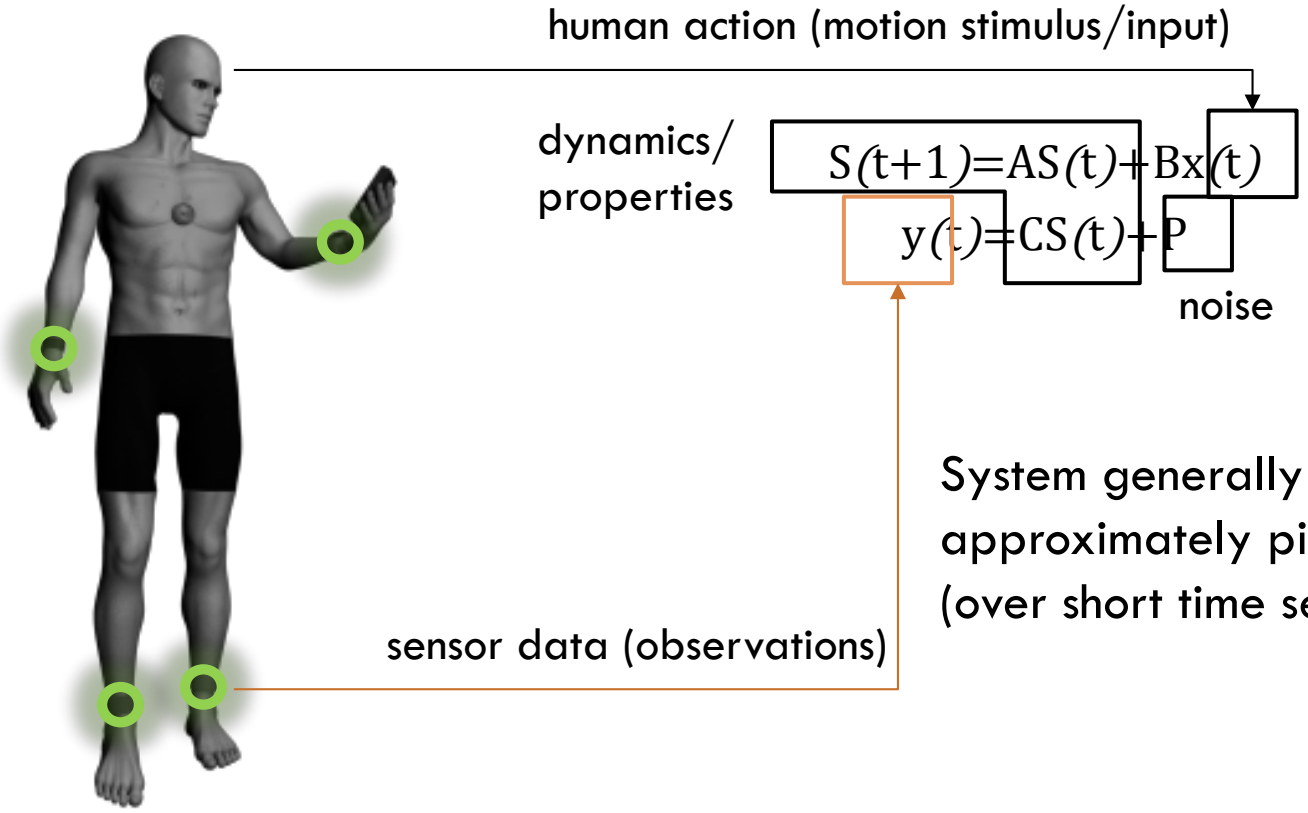
Addressing Problems

- Our Approach



Our Approach

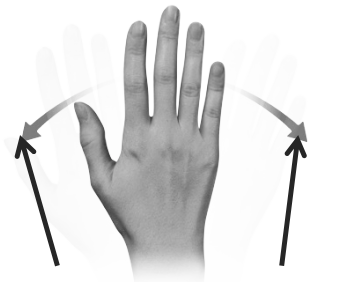
- Basic Approach:
  Piecewise Linear Dynamical Modeling



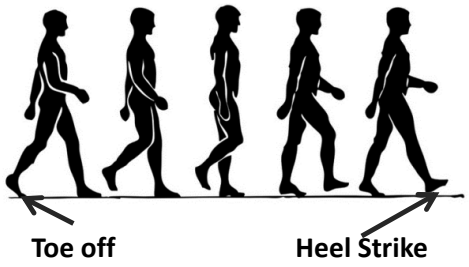
System generally non-linear, but approximately piecewise linear (over short time segments)

Our Approach

- Identifying Motion Stimulus

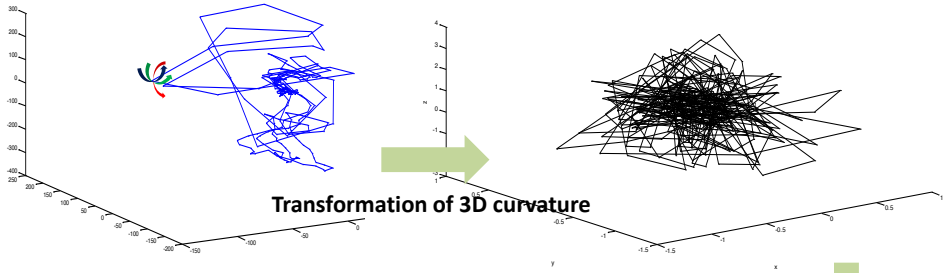


(a)



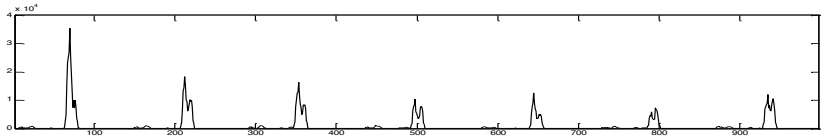
(b)

$$\text{Cur}\downarrow\text{gyro} = \nabla\downarrow 3\ (\nabla\downarrow 1\ (\nabla\downarrow 1\ (y(t, g(1)), y(t, g(2)), y(t, g(3)))))$$



(a) (b)

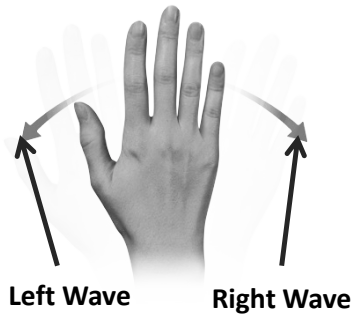
Scalar time-series curvature



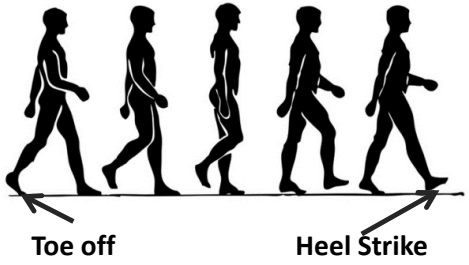
(c)

Our Approach

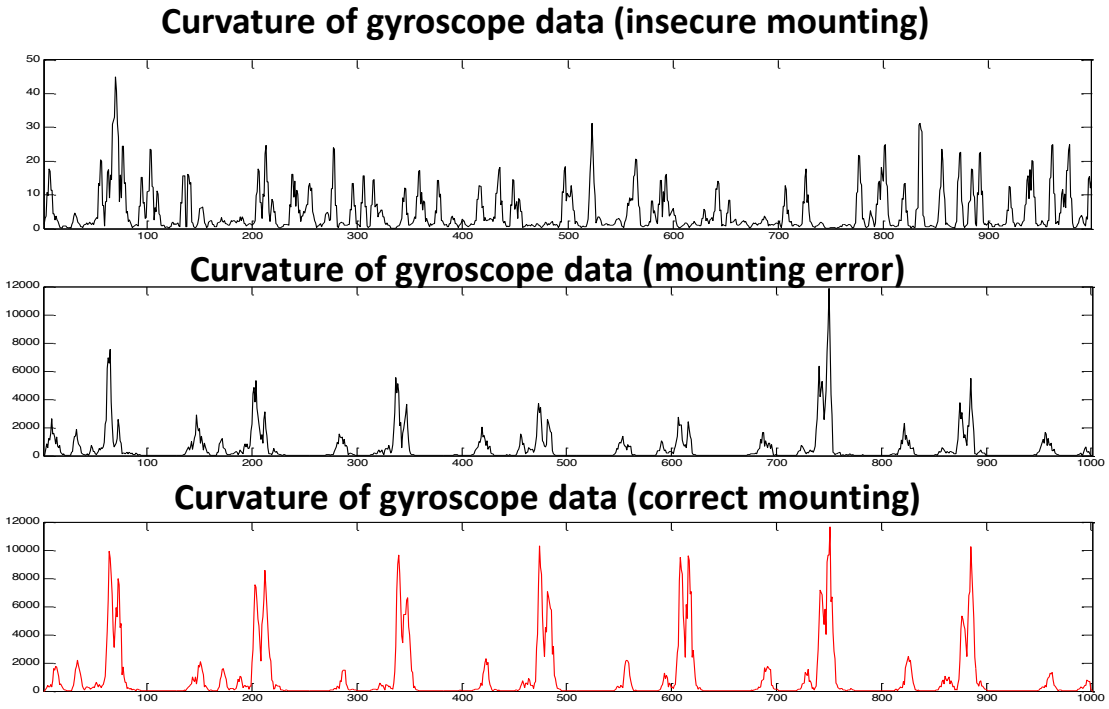
- Identifying Motion Stimulus



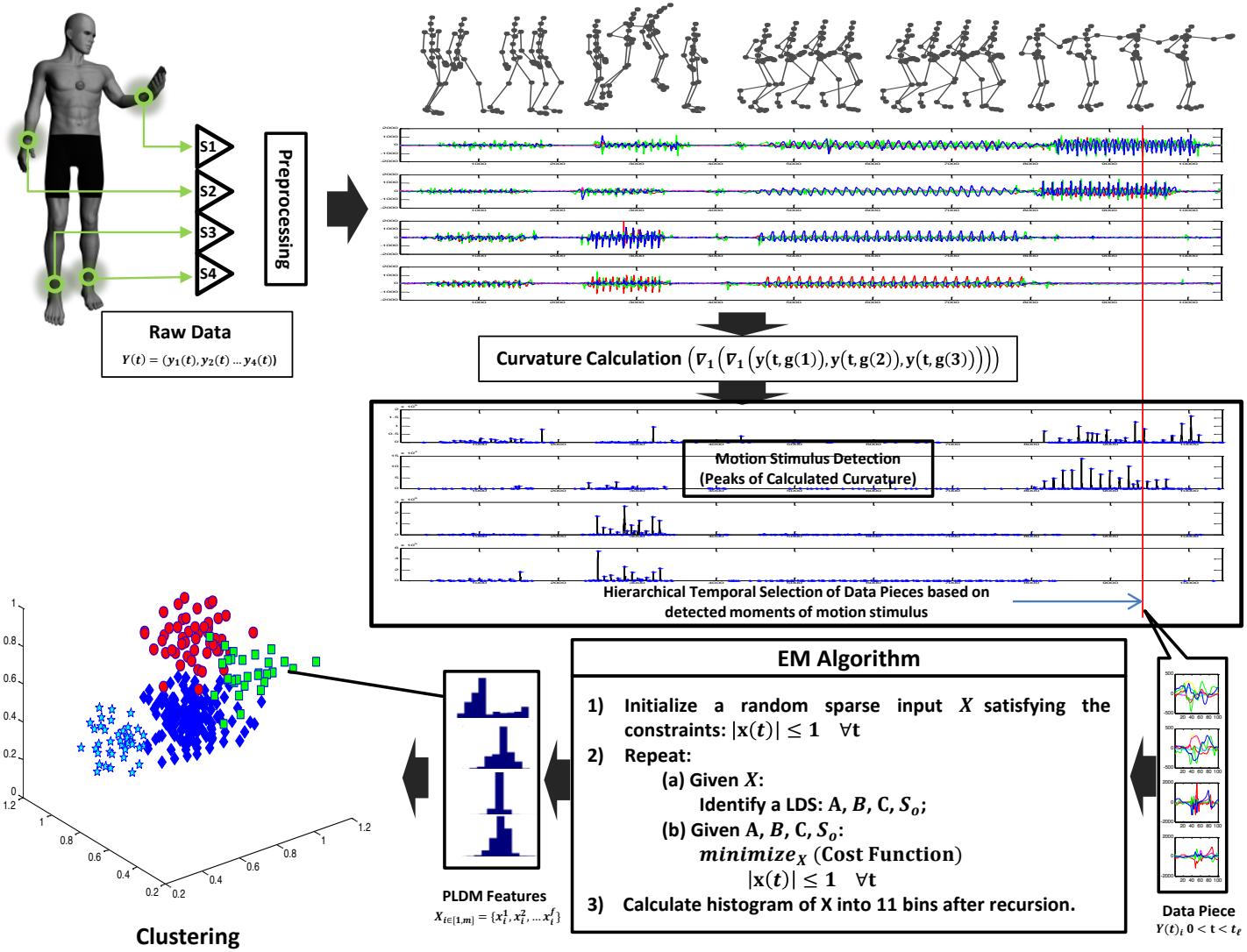
(a)



(b)

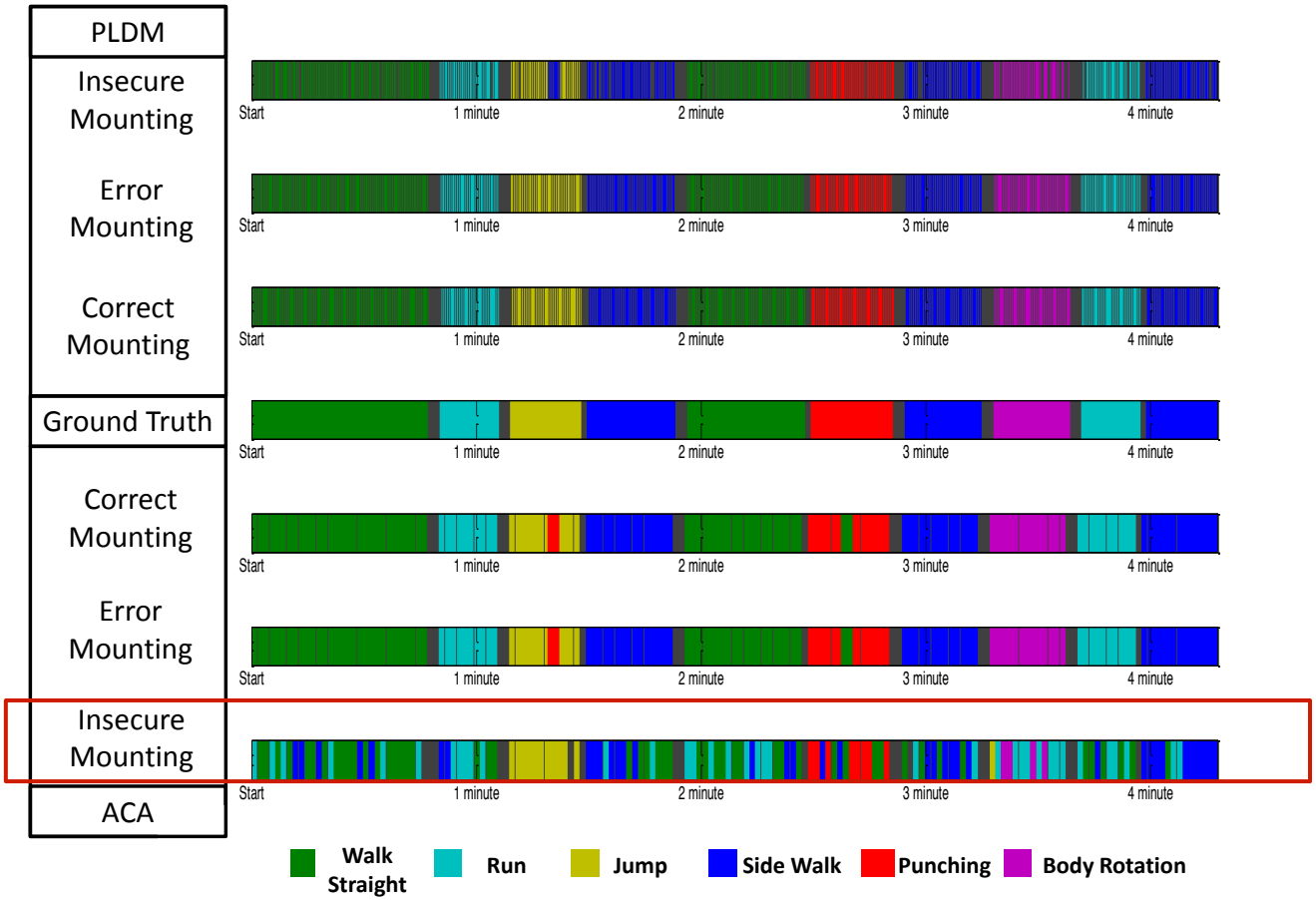


Overall Algorithm



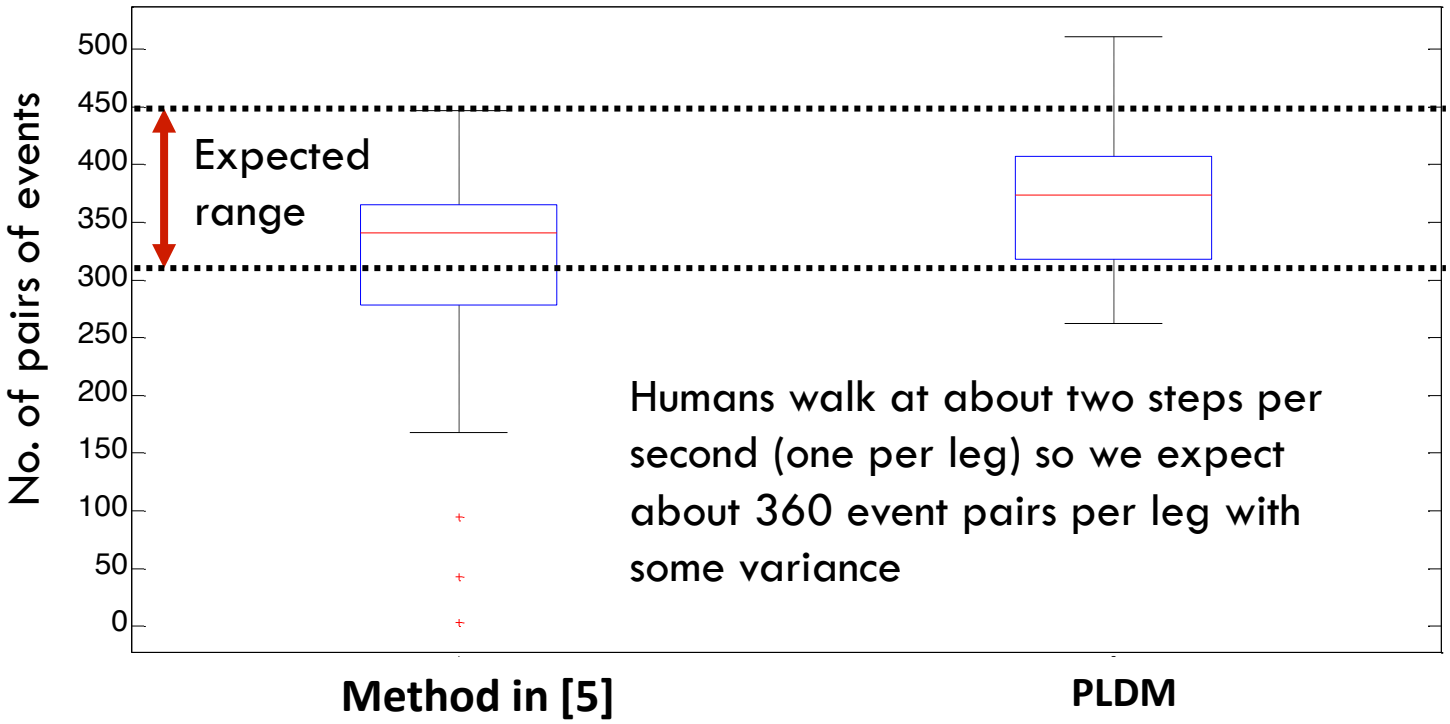
What does this buy us?

- Coarse-grain segmentation



What does this buy us?

- Fine-grained segmentation
  - Heel-strike and toe off detection



[5] S. Chen, C. L. Cunningham, J. Lach, and B. C. Bennett, "Extracting Spatio-Temporal Information from Inertial Body Sensor Networks for Gait Speed Estimation", *IEEE International Conference of Body Sensor Networks (BSN)*, pp. 71-76, 2011.

Recap

- Segmentation is important for BSNs
- Human factors can be a problem
- Linear dynamical systems modeling can help for
  - Fine grained
  - Coarse grained

Future Work

- Reduce Computation Complexity
- Optimize clustering process
- Other Applications
  - Surgery education data analysis
  - Head impact identification (in sports)
  - …