Diagnosing Rare Diseases by Movement Primitive-Based Classification of Kinematic Gait Data

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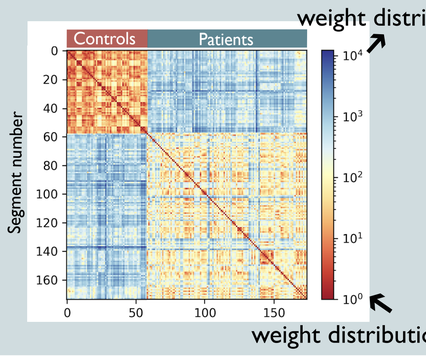
Background: many rare diseases involve motor symptoms

- E.g. Stiff Person Syndrome, Legg–Calvé–Perthes disease (LCPD)
- Limited exploration of using movement data for diagnosis
- **Goal:** Develop innovative diagnostic tool:
  - Based on biological motor control theory
    ➔ Movement Primitives (MPs) (Clever et al. 2016)
  - Standard classification algorithms

Hypotheses:

H1. Individual data are best discribed with a similar number of movement primitives



H2. Weight distribution for selected DoF (Degrees of Freedom) differentiates patients from controls

Ideal heatmap for hypothesis 2

Conclusions and outlook

- 42 DoF can be reduced to 8 MPs to recapitulate the gait data
- Weights for relevant DoF can differentiate visually between patients and controls
- Weight distributions will be used for classification

Methods: Weights and Temporal Movement Primitives Extraction

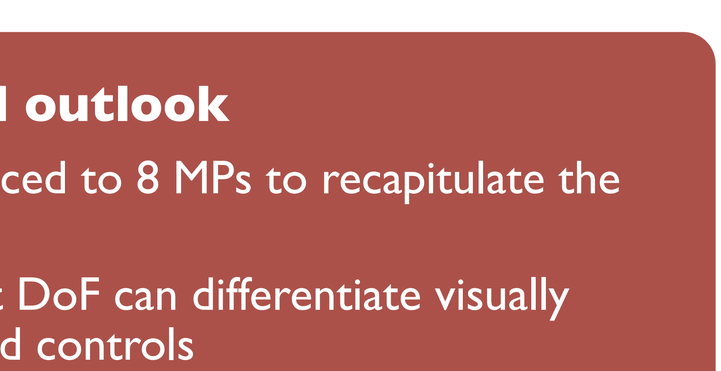
- **Data Source:** Motion capture gait data with 42 DoF time series of joint angles from LCPD patients (41) and contolls (14) (Stief et al. 2016)
- **Algorithm:** MP algorithm for data reduction based on Gaussian Process (Clever et al. 2016, 2017)

H1. Find the best number of MPs:

42 DoF ➔ ? MPs

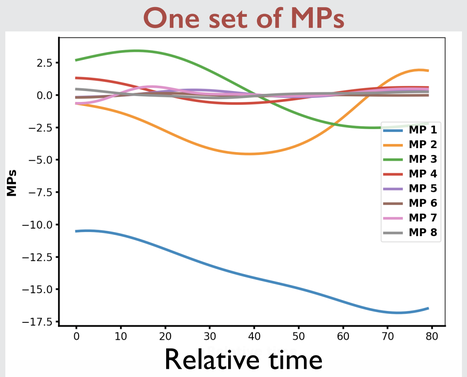
- **Criteria:**
  - Varience Accounted For (VAF)
  - Evidence Lower Bound (ELBO)

➔ Examined 4 - 10 MPs (All 55 individuals)



H2. Weight differences between patients and controls of different DoF

One set of MPs

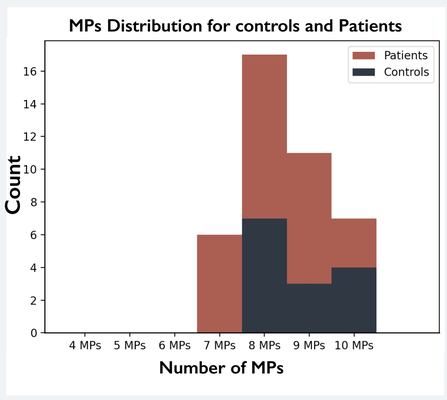


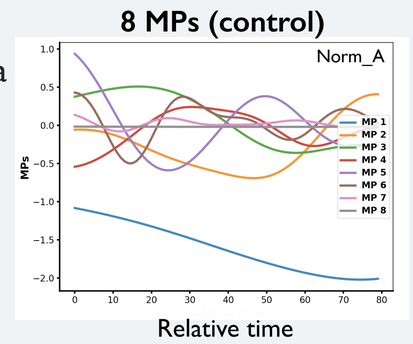
One set of MPs for patients and controls together

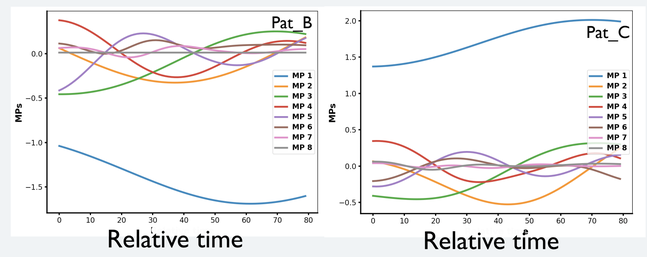
- Different weight distributions for each DoF for every step cycle of every indiviual
- Kullback-Leibler divergence as the measurements between weight distributions

Result 1: 42 DoF ➔ **8** MPs

- 8 MPs are enough to describe the 42 DoF data
- Differences and similarities in the 8 MPs between individuals





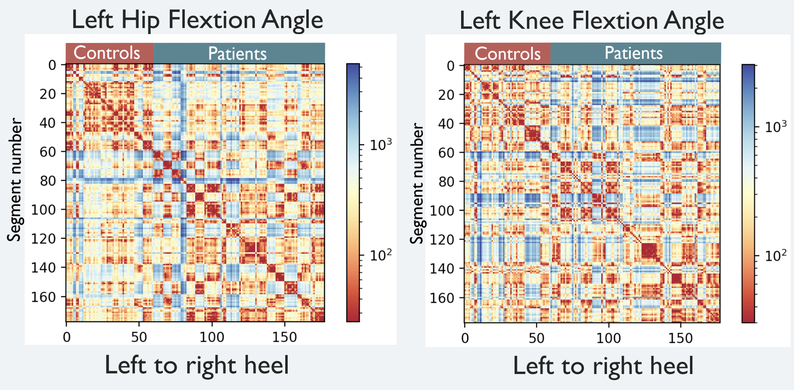


Result 2: Weight differences between control group and patients

- Most interesting DoF according to previous research (Stief et al. 2016)

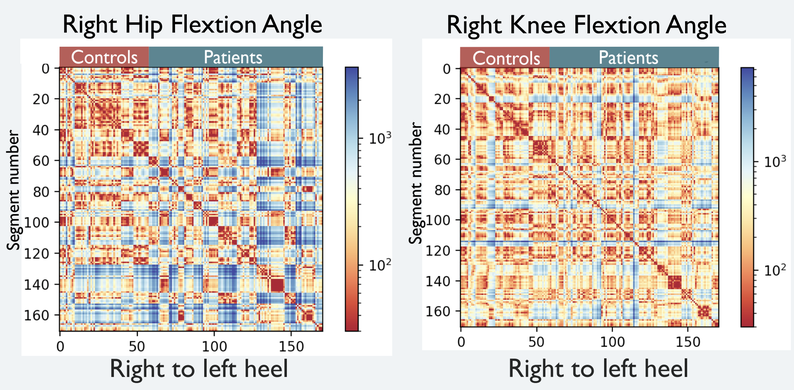
Affected side

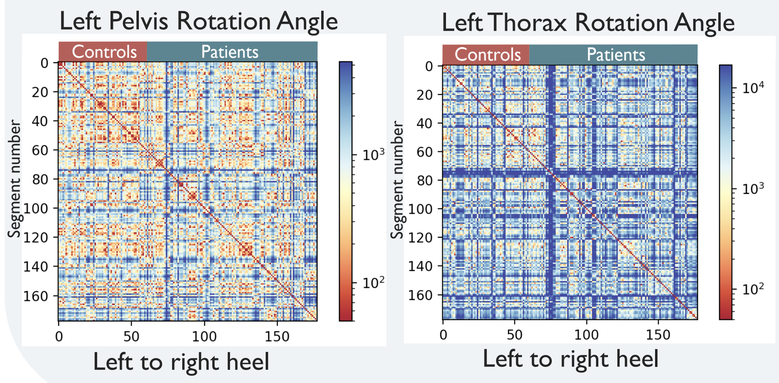
Expected similarities within vs. differences across groups



Unaffected side

More distal differences less pronounced





Less noticeable effects despite the expectation

Discussion: Weight distributions for classification

- **For classification:** DoF, mean/covariance of the weight distribution
- **Representation of data:** Does coordinate system matter? (e.g. Euler angles, Quaternions)
- Classification based on data from other devices (e.g. Smart phones)
- Extend to other rare diseases

Clever, et al. (2016) in "Robotics and Autonomous Systems," 83, 287–298.
Clever, et al. (2017) in "IEEE Robotics and Automation Letters," 2 (2), 977-984.
Stief, et al. (2016) in "Gait Posture," 47, 51–56.

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Cardinal Mechanisms of Perception