

Functional data analysis of running data by 3D-motion capture

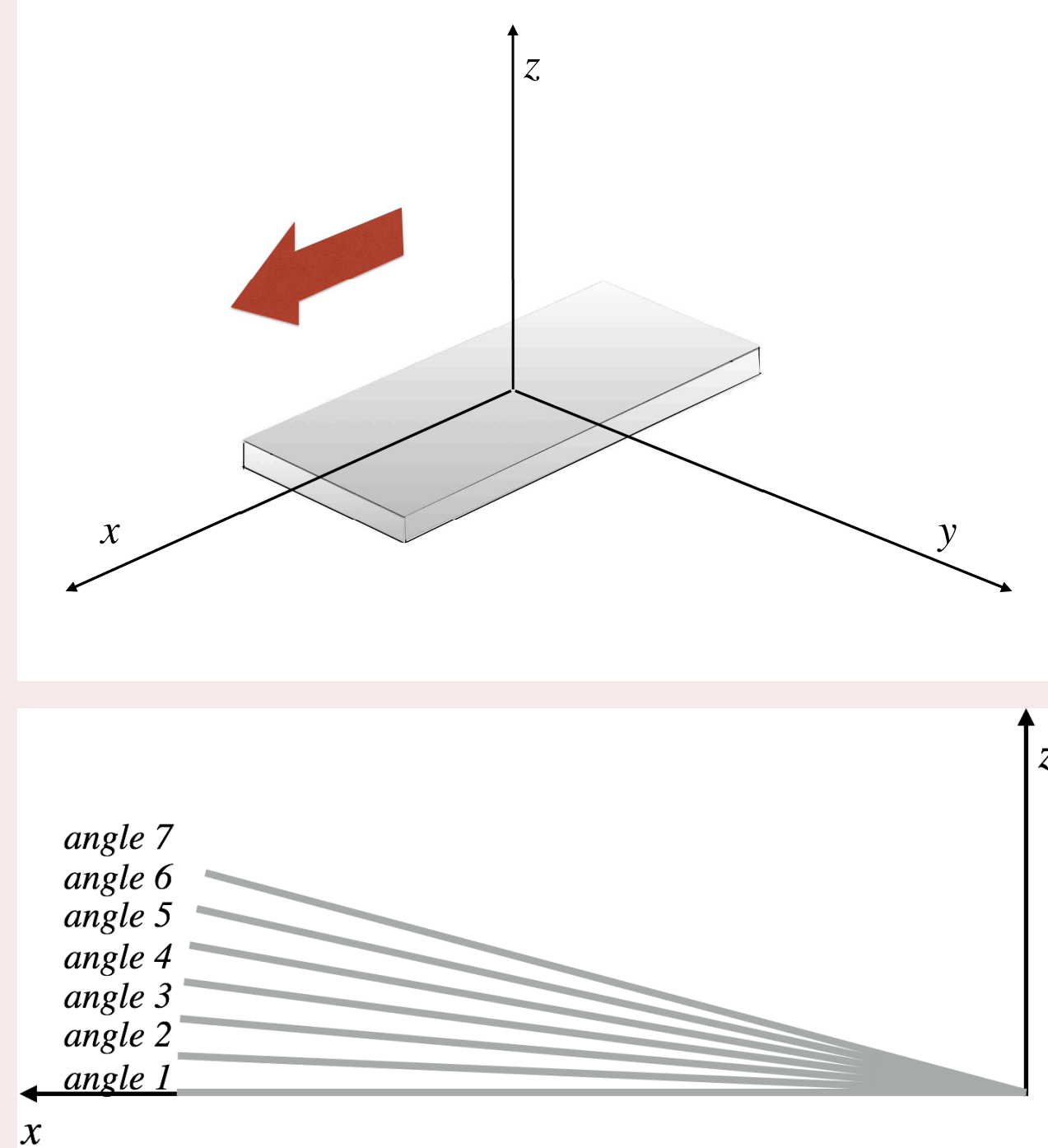
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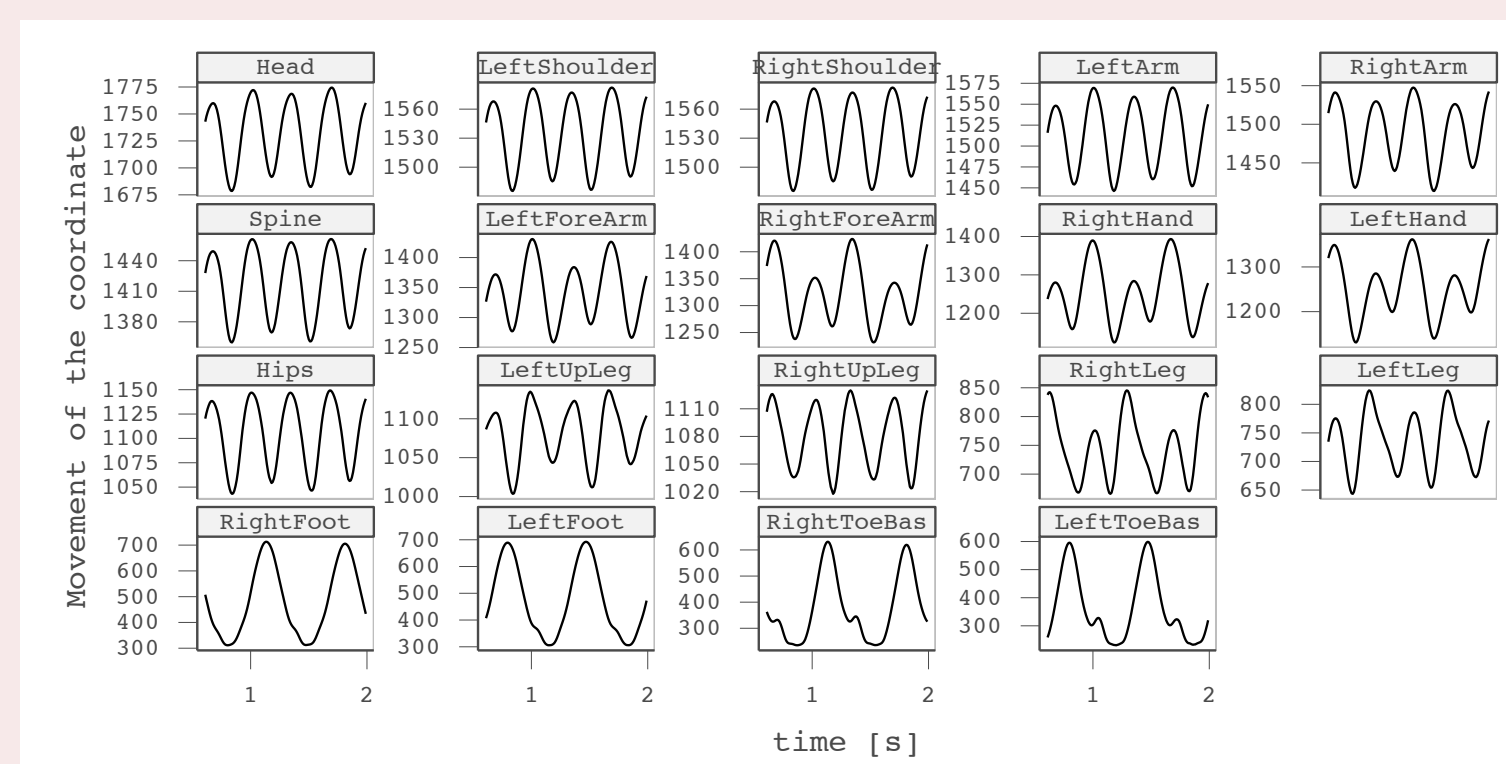
Background

- Running is very popular for their health
 - More than 20,000 runners have been taking part in Boston and Tokyo marathon recent years
 - However, running is sometimes very dangerous and may result in death
- 3D running models obtained by the 3D motion capture system
 - The data set is created by projecting 3D locations of 19 markers to the 3D human skeleton models
 - The measurements are arranged on the timeline and multivariate time-series
- We propose/analyze:
 - we use function data modeling for the observed data of joints locations when the subject runs on the treadmill under the 3D motion capture system
 - The 3D modeling is a basically approximations of trajectories of joints locations owing to functions



Data

- There are 3 runners and 6 or 7 angles of inclination
- about 18,000 frame (1 frame = 0.01 [s])
- The data size of a runner is



$$6_{angle} \times 18,000_{frame} \times 19_{parts} \times 3_{axis} = 6,156,000 \text{ data}$$

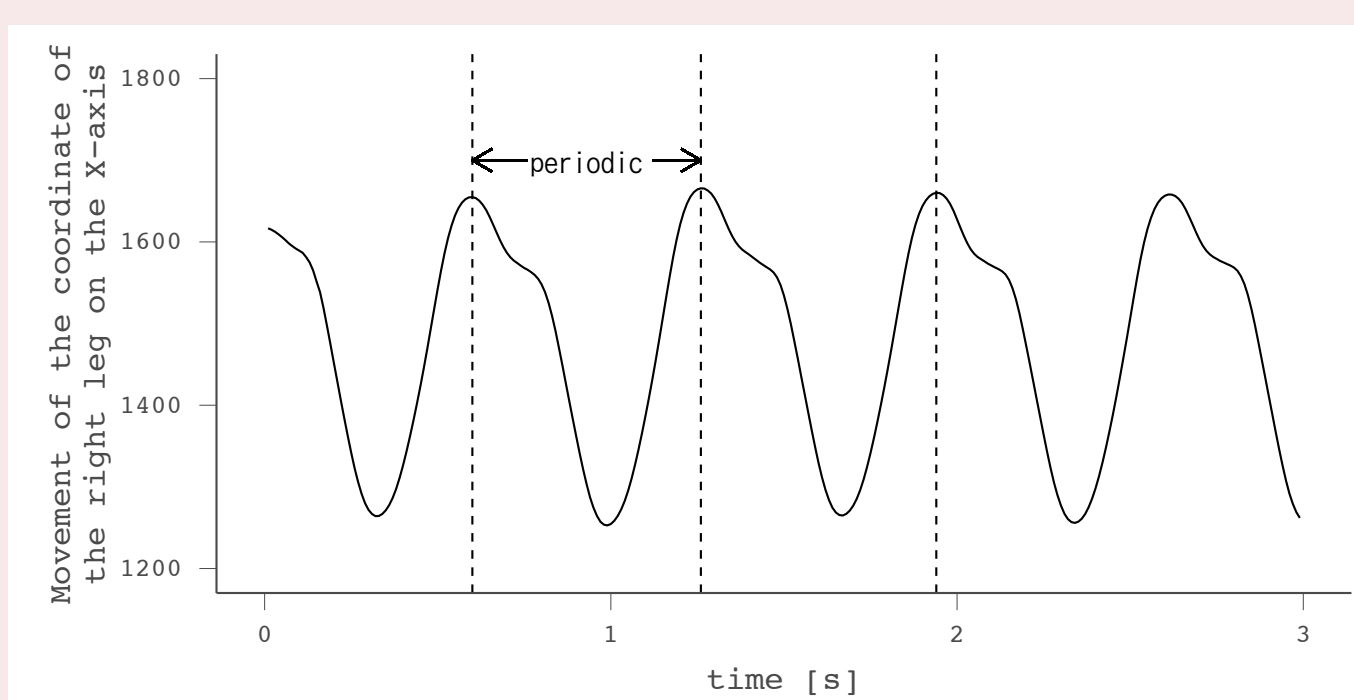
Procedure for Functional Data Analysis

- We use *Functional Data Analysis*. Procedure is

- 1 Data Registration
- 2 Data Representation
- 3 Graphing Functional Data

1. Data Registration

- We observed 3D-motion capture data as time-series
 - To analyze using functional data analysis, it is useful to change to the periodical data
 - However, running pace is kept changing so the periodic interval is not unique



- 1 For screening the data for outliers

$$\frac{|y_i - \text{med}(y)|}{\text{MAD}(y)} < 3$$

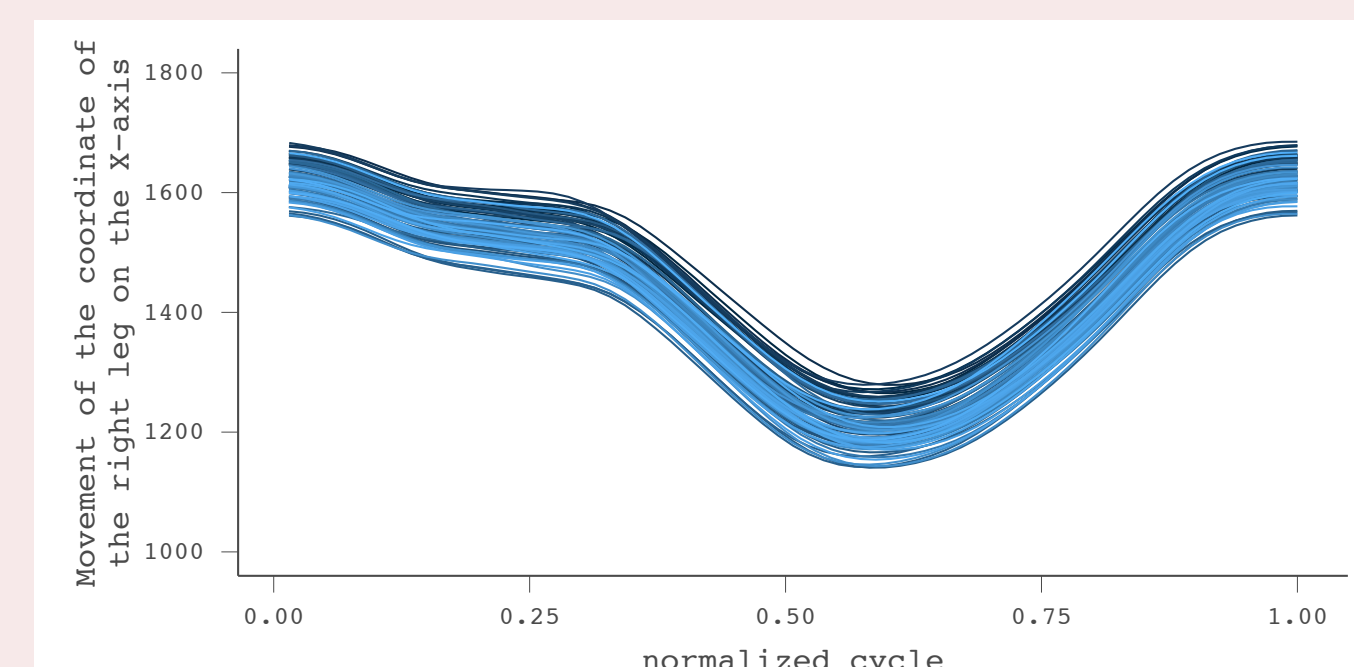
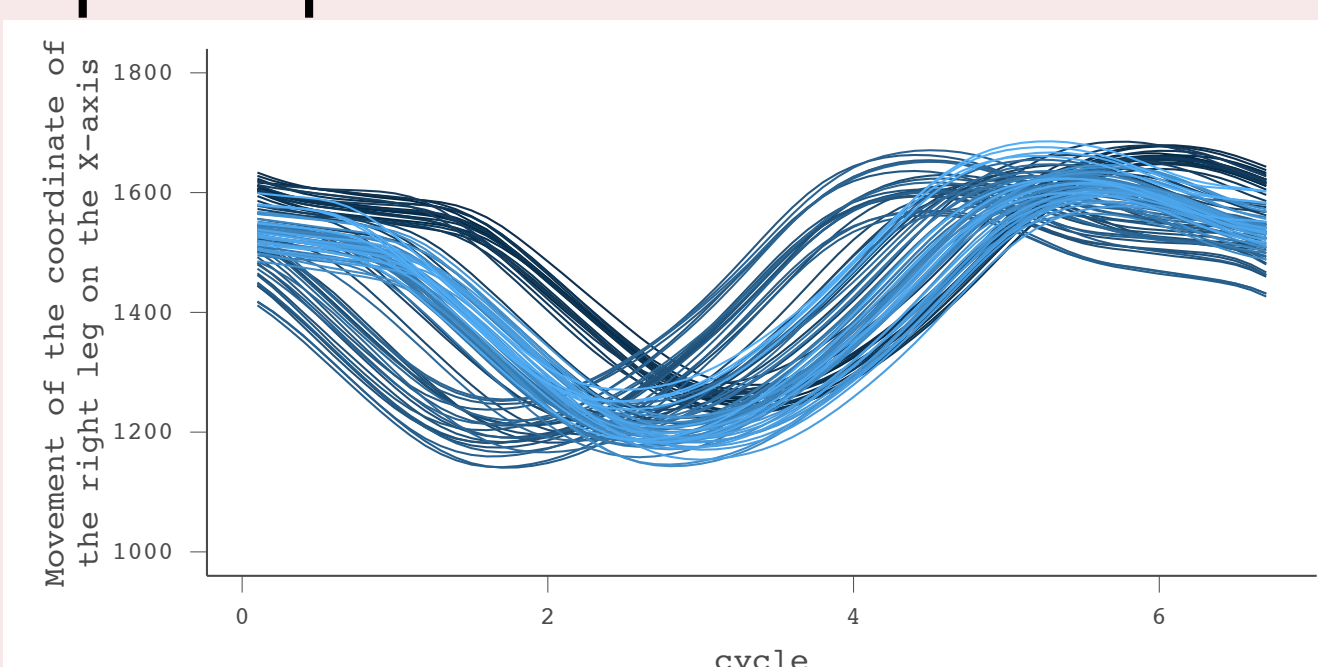
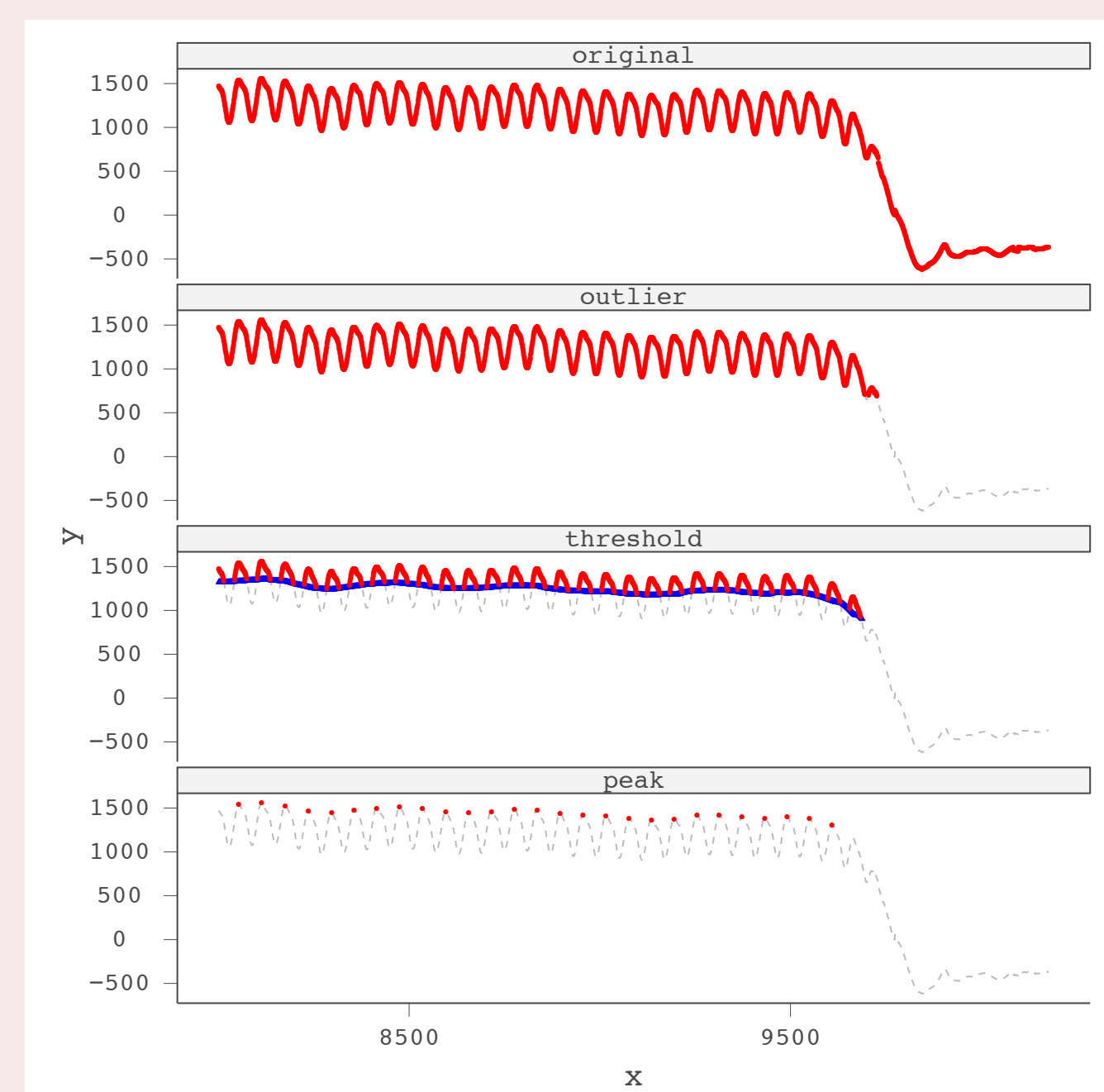
- The median absolute deviation (MAD) [1] given by

$$\text{MAD} = b \text{ med}|y_i - \text{med}(y)|$$

- 2 Calculating a moving average as the threshold

$$y_i > m_i(n), \quad m_i(n) = \frac{1}{n} \sum_{k=i}^{i+n-1} y_k$$

- 3 Searching the maximum value in the group of consecutive numbers as peak points



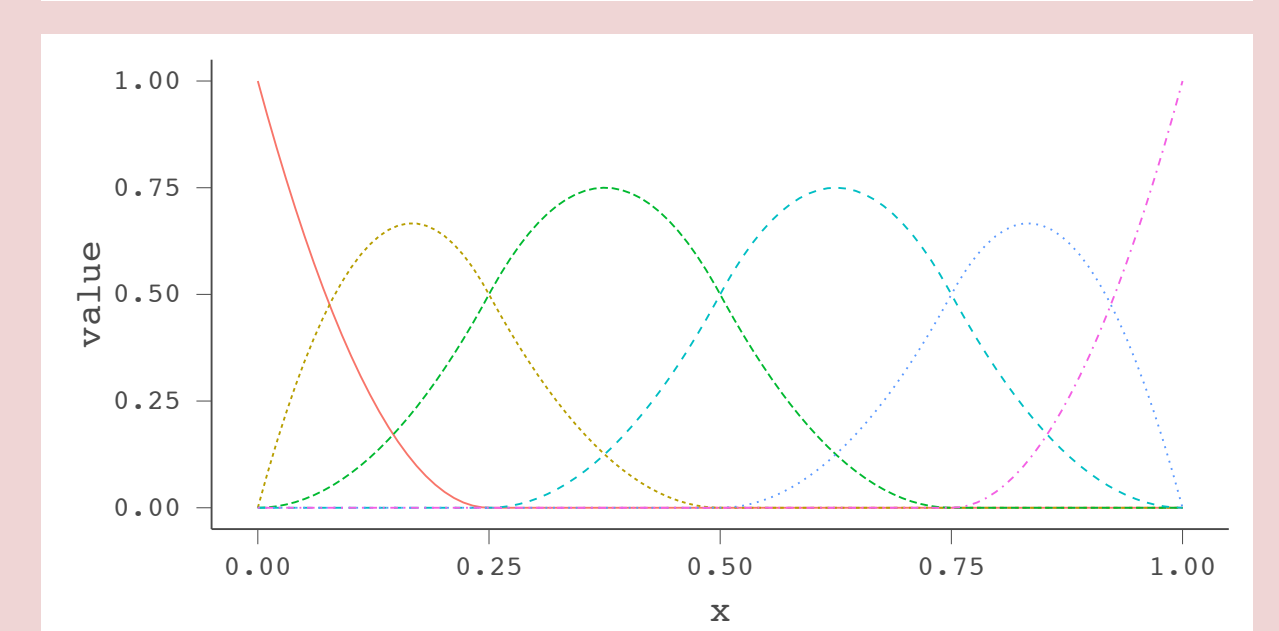
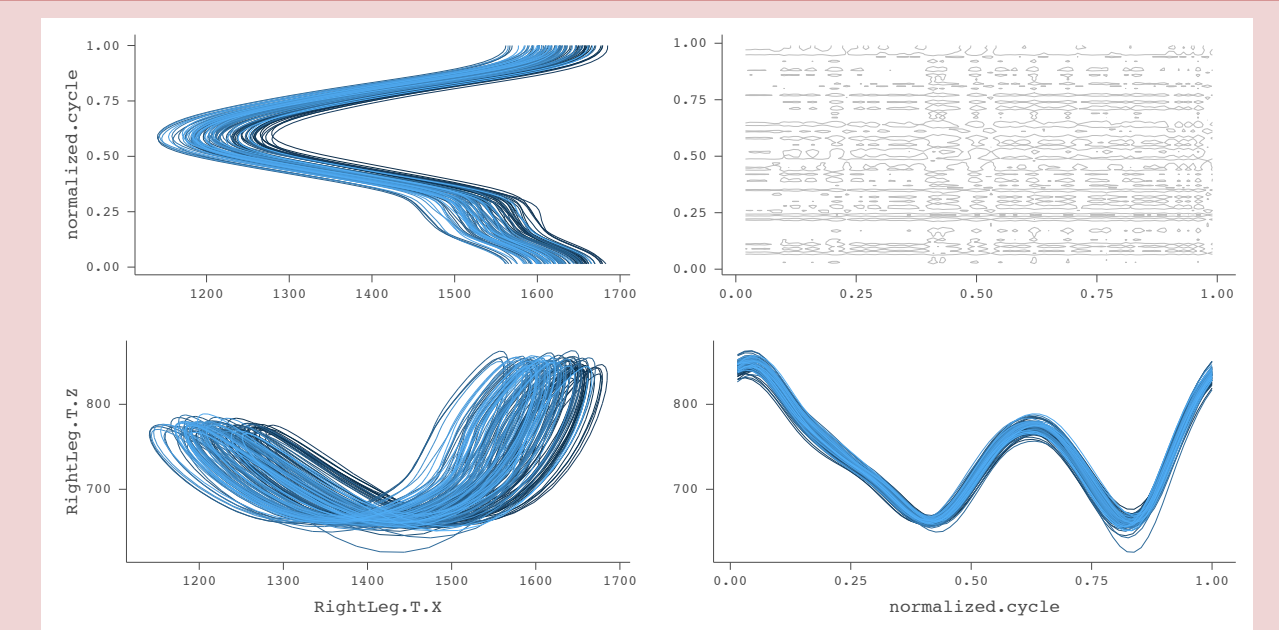
2. Data Representation

basis function

- Basis Expansions

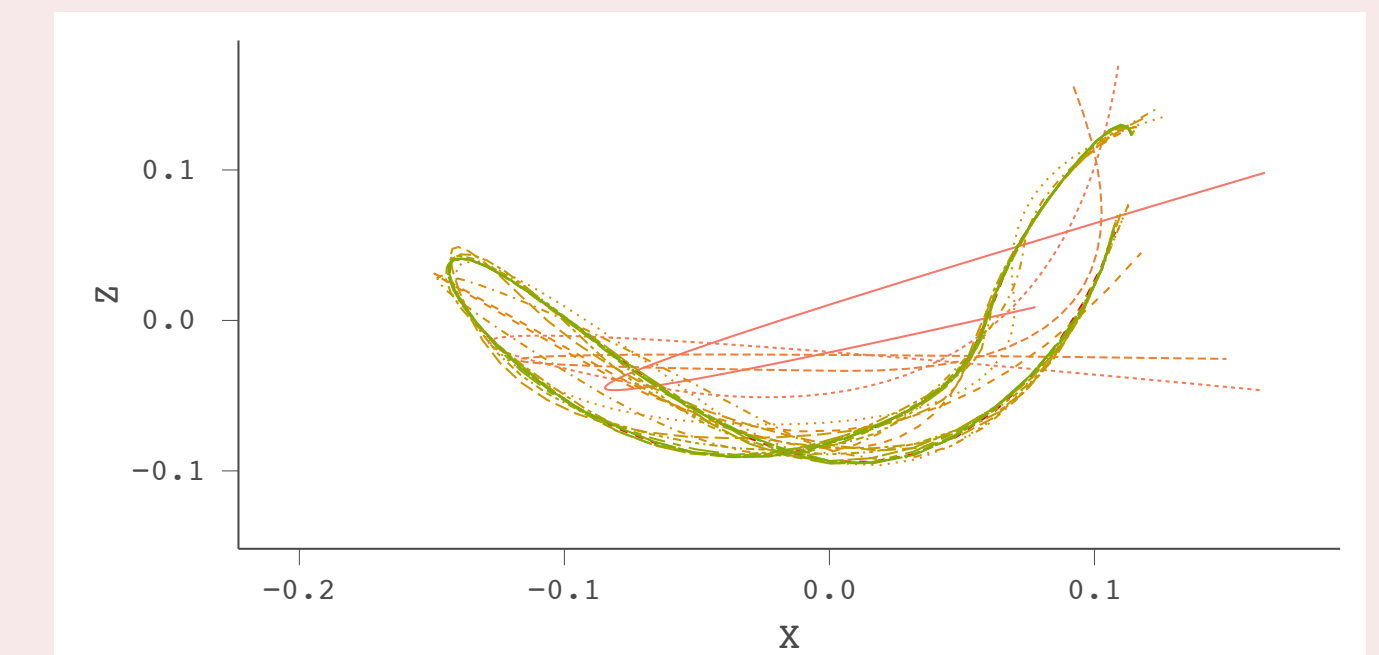
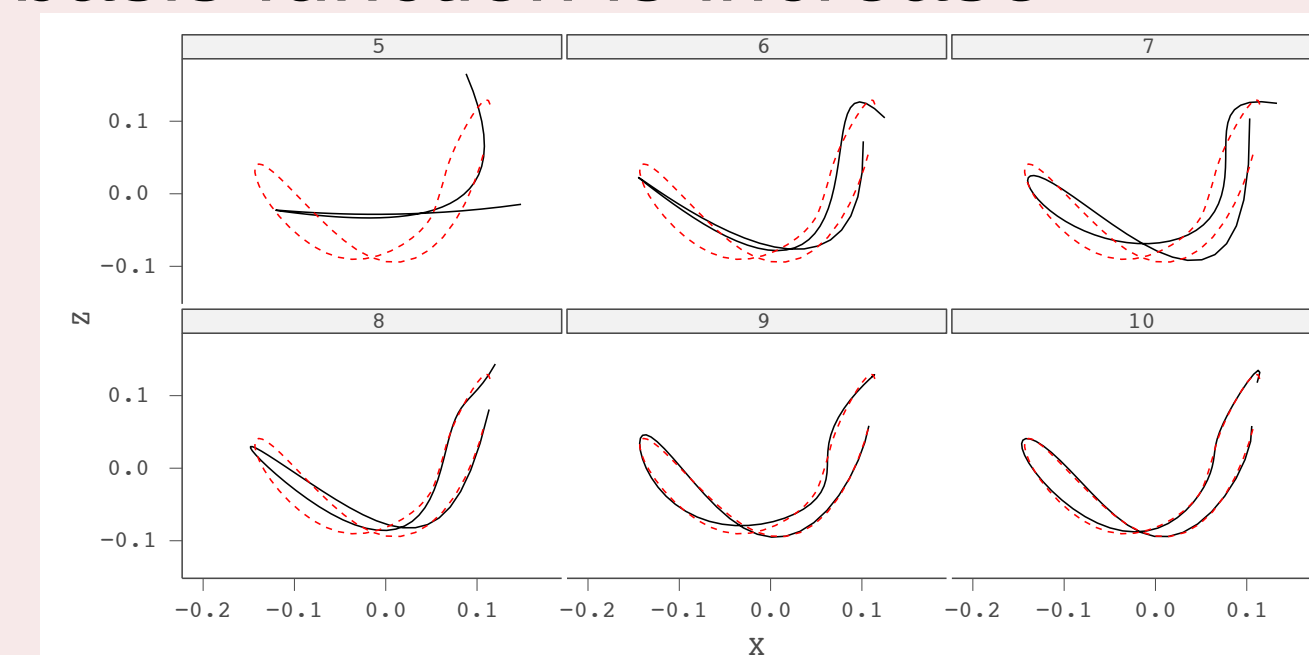
$$y_i = x(t_i) + \epsilon_i, \\ x(t) = \sum_{j=1}^K c_j \phi_j(t)$$

- Splines bases
 - Splines are polynomial segments joined end-to-end
 - Segments are constrained to be smooth at the joins
 - The points at which the segments join are called knots
 - System defined by
 - The order n (order = degree+1) of the polynomial
 - the location of the *knots*
 - B-splines are particularly useful means of incorporating the constraints



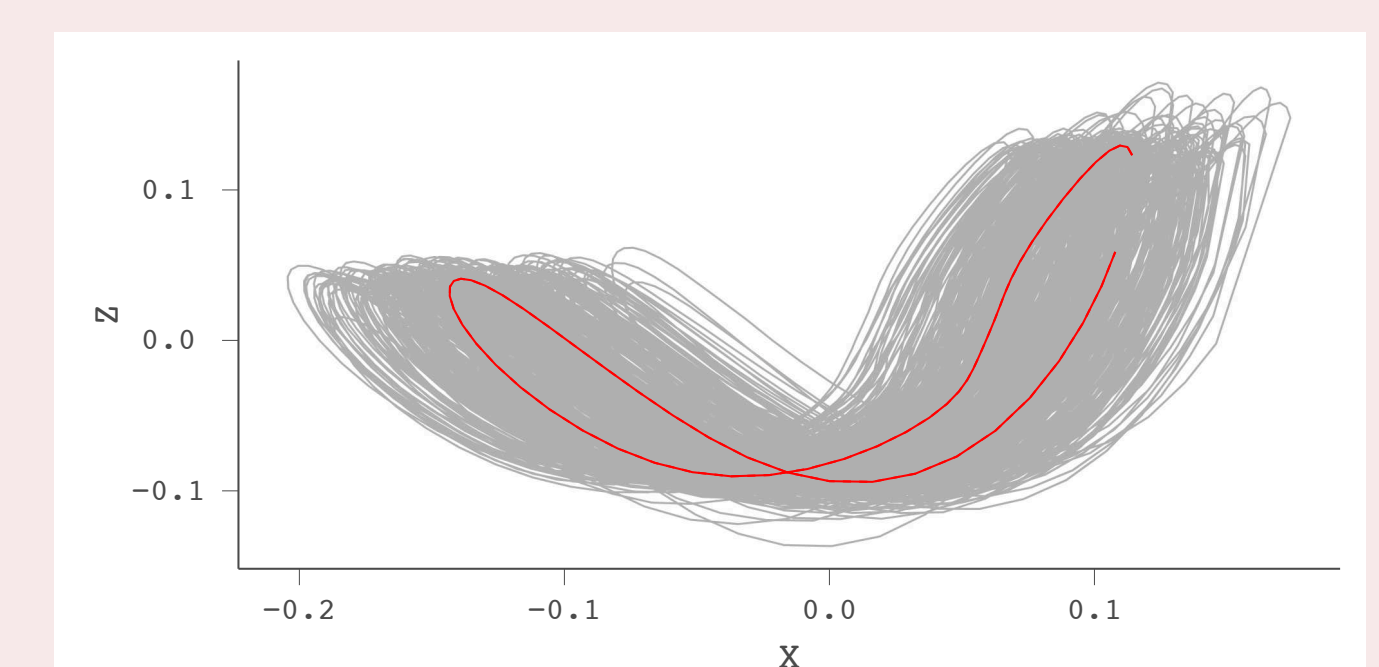
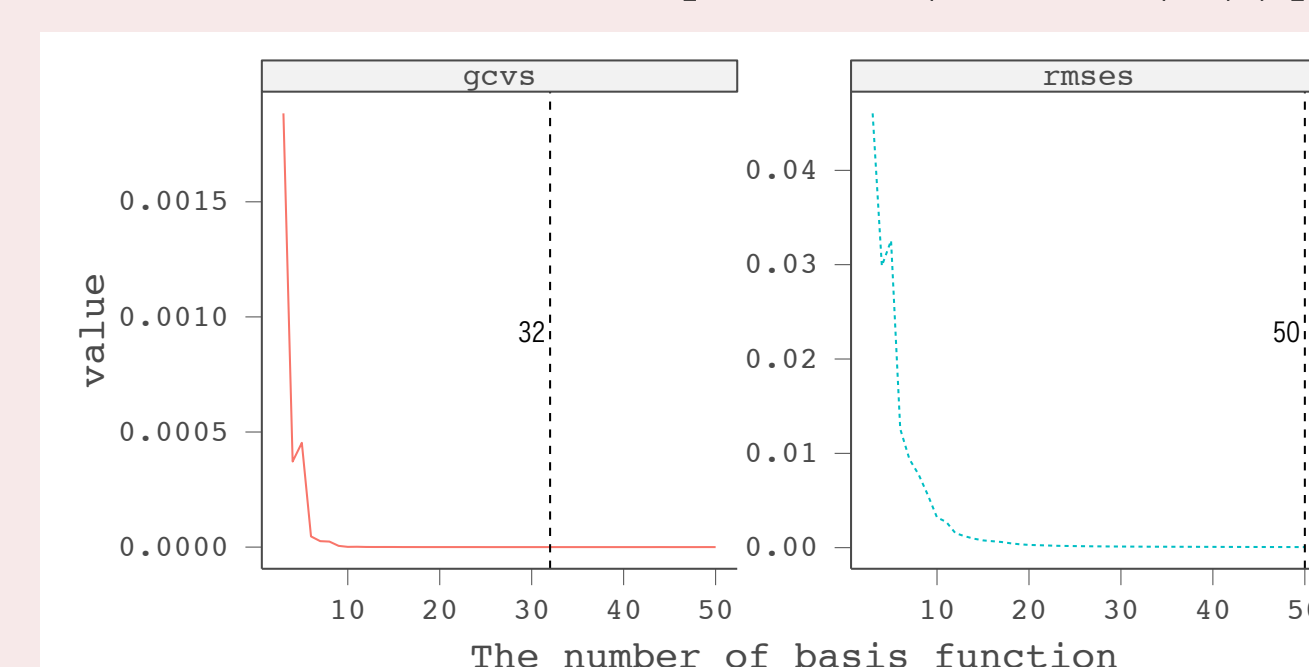
$$\text{knots} = [t_0, t_1, \dots, t_{m-1}], \\ \phi_{j,0}(t) = \begin{cases} 1 & \text{if } t \in [t_j, t_{j+1}), \\ 0 & \text{if } t \notin [t_j, t_{j+1}) \end{cases} \\ \phi_{j,n}(t) = \frac{t - t_j}{t_{j+n} - t_j} \phi_{j,n-1}(t) + \frac{t_{j+n+1} - t}{t_{j+n+1} - t_{j+1}} \phi_{j+1,n-1}(t)$$

- An illustration of basis expansions for B-splines then the number of basis function is increase



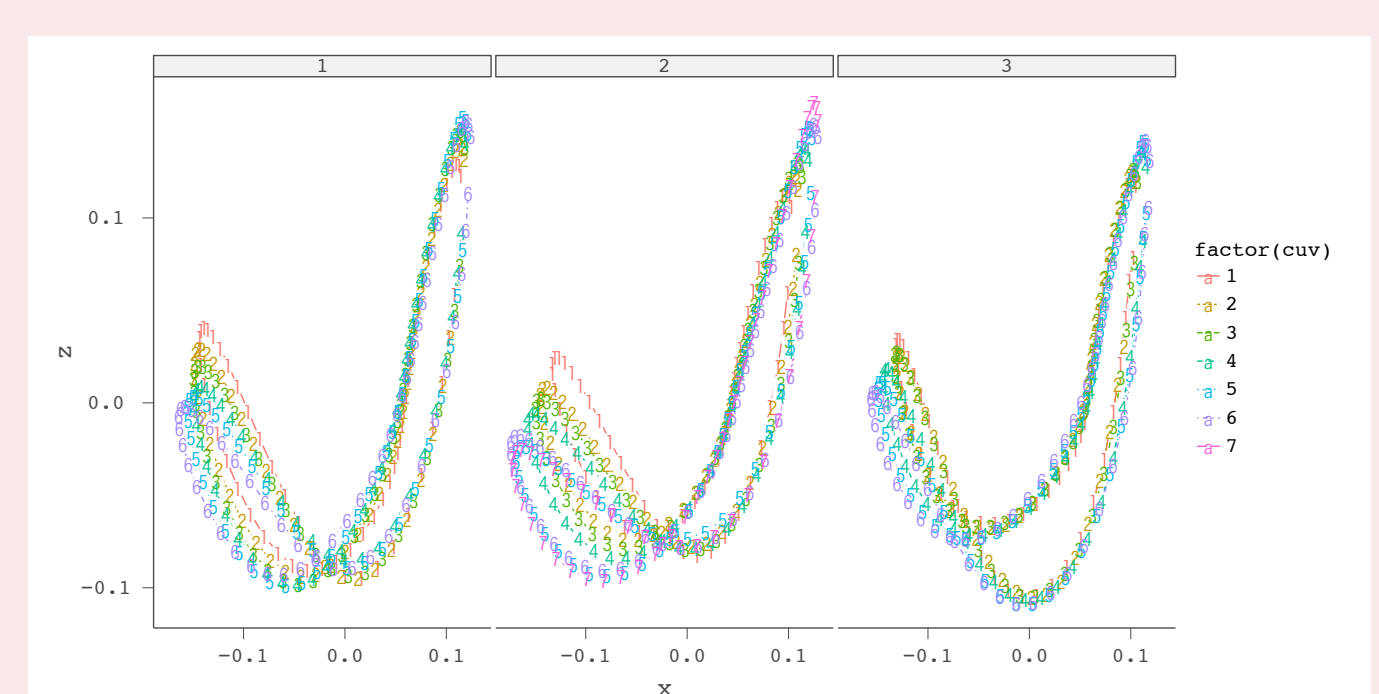
- Choosing smooth parameters using cross validation
 - There are a number of data-driven methods for choosing smoothing parameters
 - Generalized cross validation (GCV) tends to smooth more RMSE

$$\text{GCV}(\lambda) = \frac{\sum (y_i - x_\lambda(t_i))^2}{[\text{trace}(\mathbf{I} - \mathbf{S}(\lambda))]^2}, \quad \text{RMSE} = \sqrt{\frac{1}{N} \sum (y_i - x(t_i))^2}$$



3. Graphing Functional Data

- The mean of smoothing function for each angles of inclination by 3 people on X - Z axis
 - On X axis,
 - the stride of person 2 tends to be long as the gradient of road is increased
 - the stride of person 3 is in the trend that does not change to comparatively
 - On Z axis,
 - the kicking motion of person 2 tends to be lower as the gradient of road is increased
 - its motion of person 3 is in the trend that does not change to comparatively



The trajectory of the right leg

Conclusions

- In this poster, we discuss about trajectory changing when some loads are applied to subjects and also investigate statistical interactions of human joints in the body
- Using Functional Data Analysis
 - By using MAD, we exclude the outlier and detective the peak interval on moving data
 - From the continuous time-series data, we can create the periodic curve
 - By the functional data analysis, we can get the feature of running form

Reference

- [1] Hampel, F. R. (1974), "The Influence Curve and its Role in Robust Estimation," Journal of the American Statistical Association, 69, 383-393.
- [2] Ramsay, J. O. and B. W. Silverman (2005). Functional Data Analysis, Second Edition. New York: Springer.