Detection and segmentation of locomotor cycle in mice movement using processed data from marker-based 3D motion capture on voluntary treadmill running

FACULTY OF INFORMATION ENGINEERING, INFORMATICS AND STATISTICS

SAPIENZA
UNIVERSITÀ DI ROMA

MASTER COURSE IN COMPUTER SCIENCE

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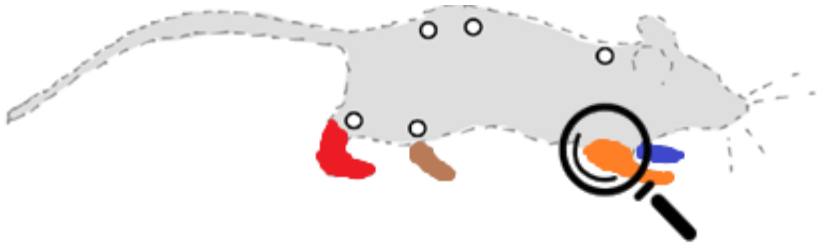
Exploring Information Hidden in Movement

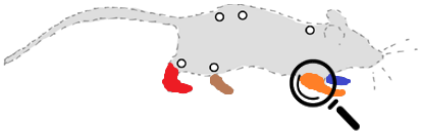
What does the whole body do when a mouse takes a step?

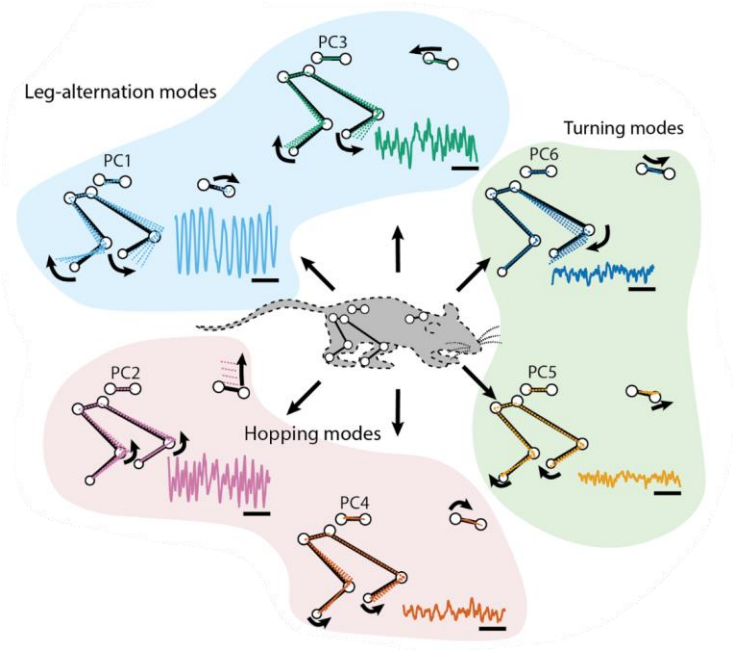


Exploring Information Hidden in Movement

What are the components of movement?

What does the whole body do when a mouse takes a step?



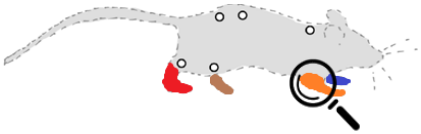


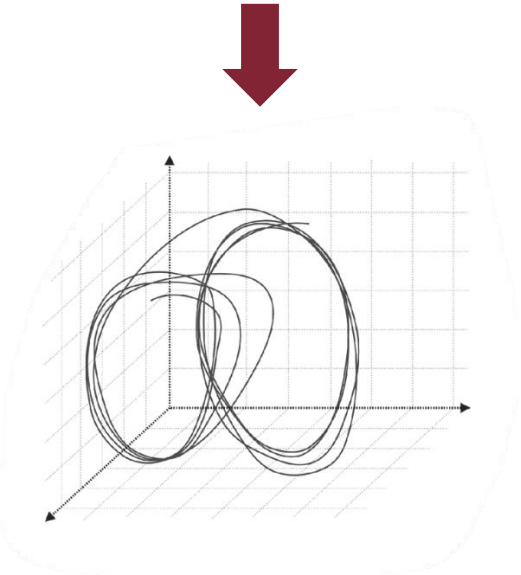
Exploring Information Hidden in Movement

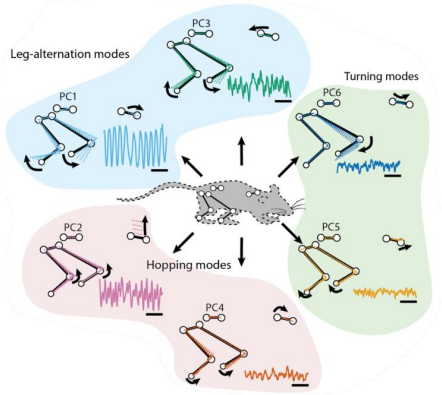
What is the structure of a gait?

What does the whole body do when a mouse takes a step?

What are the components of movement?







Data Science Approach

1. Data Collection

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3D Motion Capture

2. Data Processing

↓

Labeling and Gap-filling

3. Data Analysis

Movement Decomposition	Unitary Movements
PCA	RQA and Delay Embedding
↓	↓
What are the components of movement?	*What is the structure of a gait?*

4. Data Visualization → *What does the whole body do when a mouse takes a step?*

Neuronal Rhythms in Movement Unit

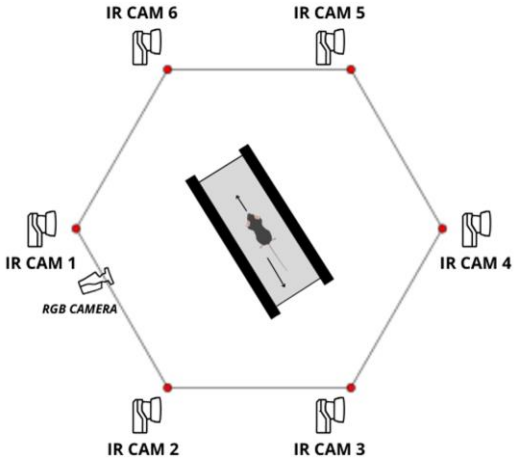
Research Internship at Okinawa Institute of Science and Technology

My contribution to the research:

- Data Processing
- Delay Embedding Threshold Criterion
- Data Visualization

Data Collection

High-Quality 3D Marker-based Motion Capture

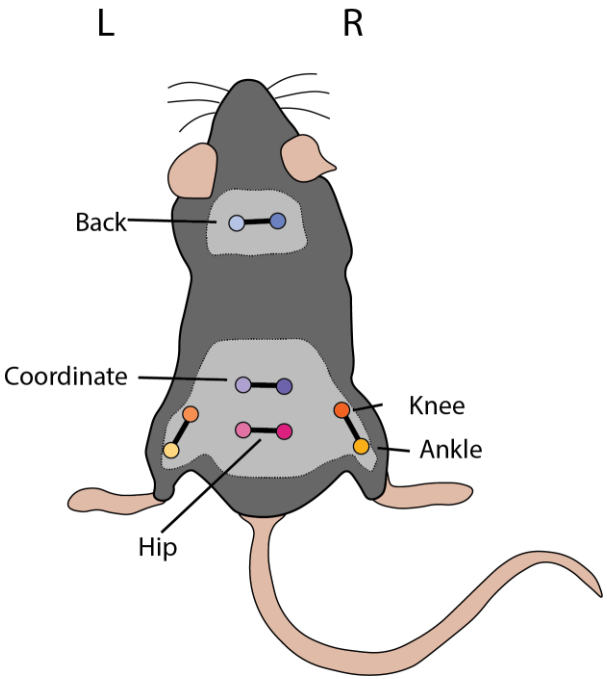


3D Motion Capture environment setup

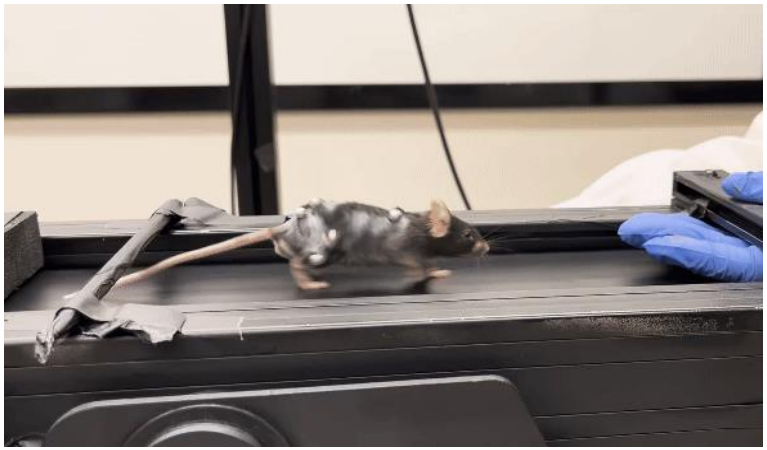
Qualisys Track Manager calibration process

Data Collection

High-Quality 3D Marker-based Motion Capture



10 markers skin implantation setup

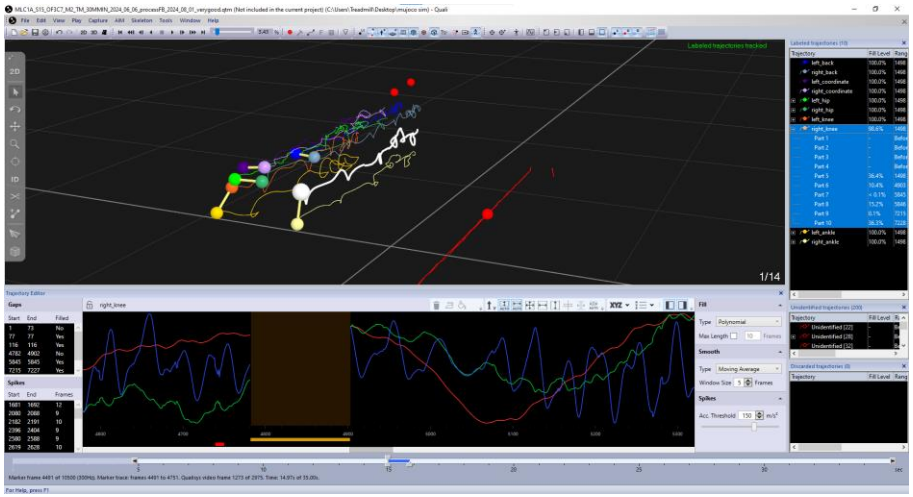


Mouse running on treadmill at $30\,m/min$

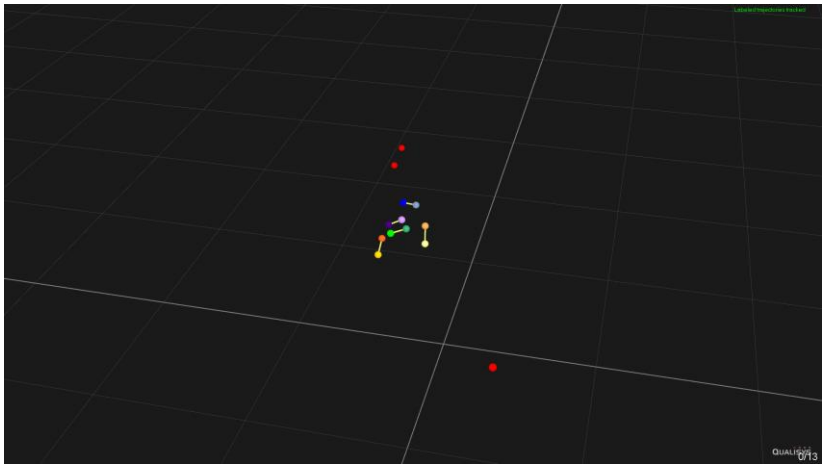
Mouse running on treadmill at $30\,m/min$ *slowed to 25% speed*

Data Processing

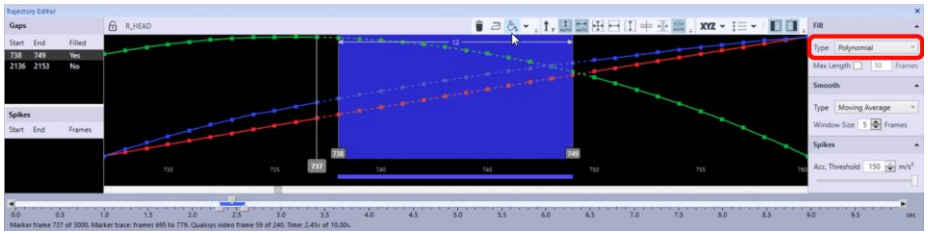
Labeling and Gap-filling



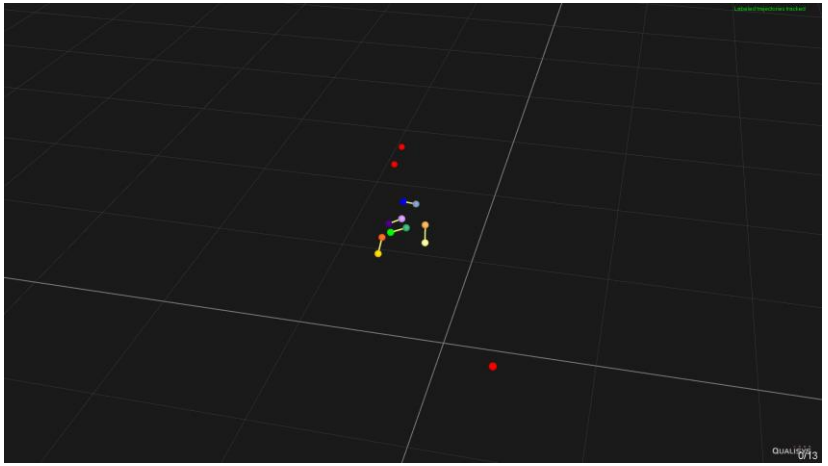
Manual labeling and gap-filling editor on Qualisys Track Manager



Labeled and gap-filled running animation at $30\ m/min$



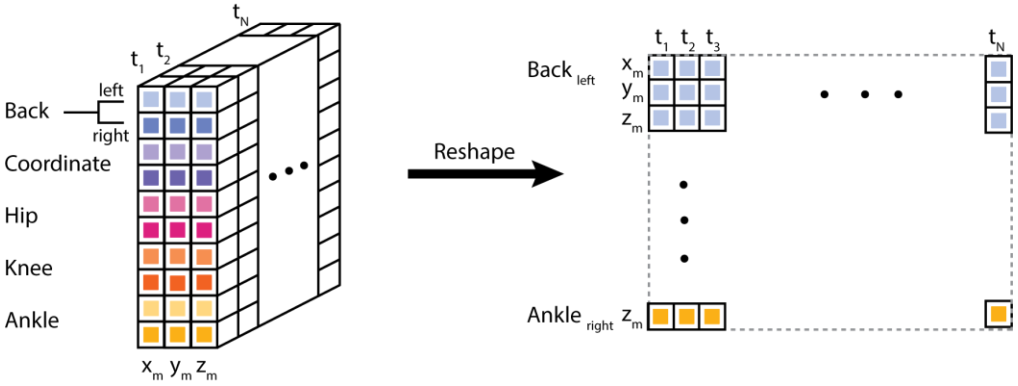
Gap-filling with polynomial interpolation



Running animation at $30\ m/min$ *slowed to 25% speed*

Data Processing

Reshape and Egocentric Tranform

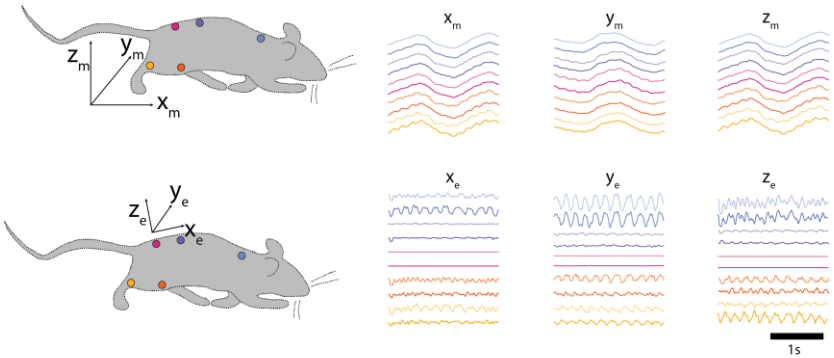


$$(\mathbf{10}, \mathbf{3}, \boldsymbol{T}) \rightarrow (\mathbf{30}, \boldsymbol{T})$$

Where:

- T is the total number of frames

- Highlight how different parts of the move relatively to each other
- Remove translation and rotation

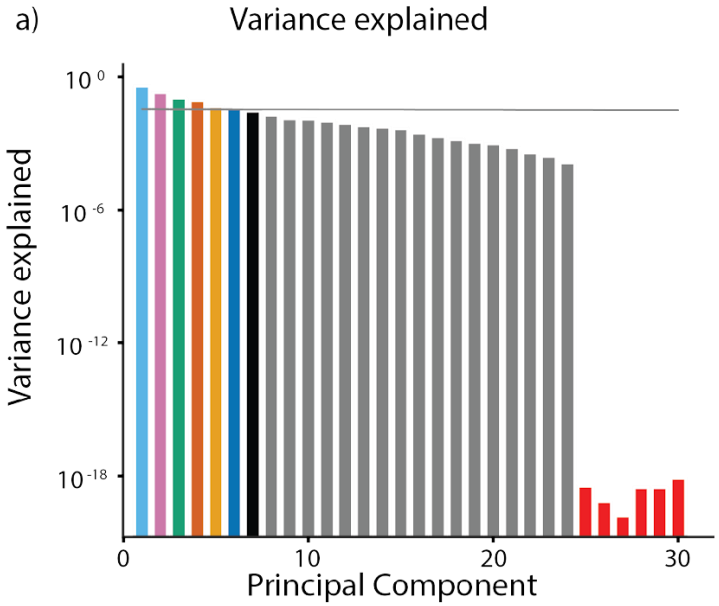


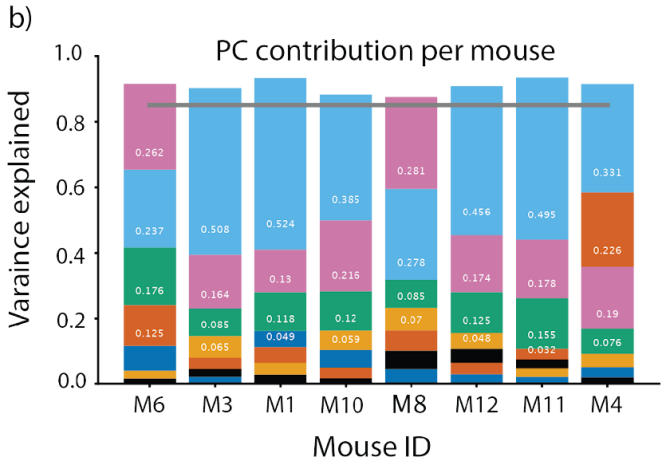
Data Analysis: Movement Decomposition

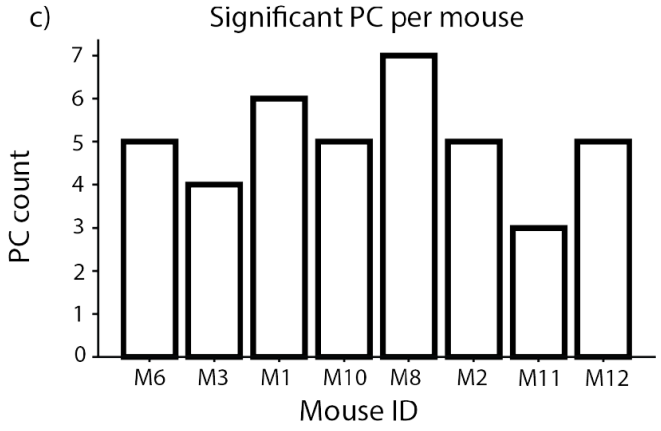
Principal Component Analysis

PCA data pre-processing:

- Mean Subtraction
- Dataset Shuffle
- Parallel Analysis
- No Standardization





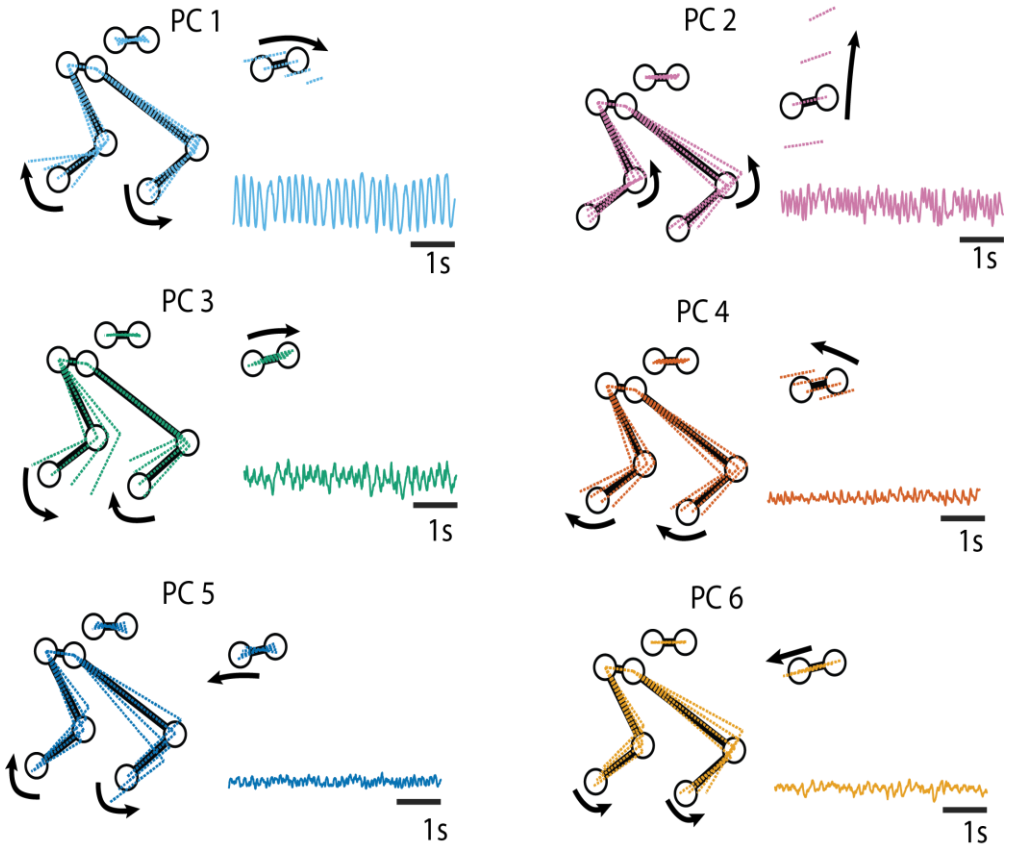


Data Analysis: Movement Decomposition

Modes of Deformation

Project data on a Principal Component to observe the variation along a specific direction

Study the **deformation** of the mean body configuration and compare the movement with traditionally defined gaits



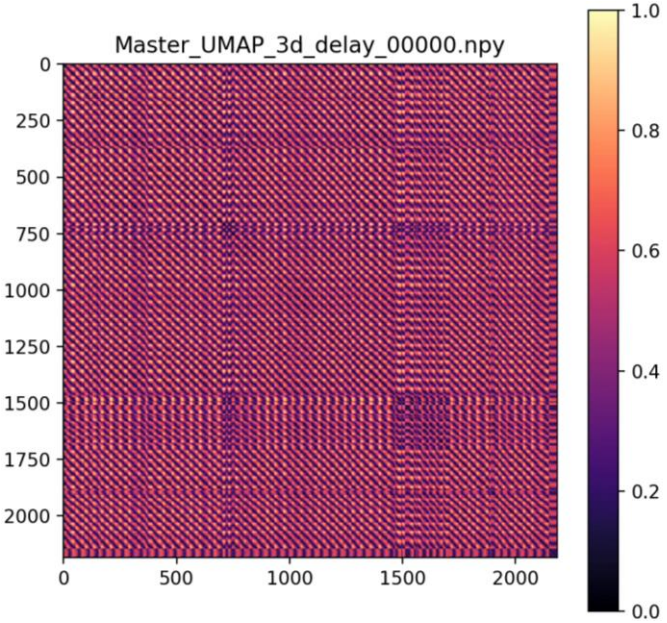
Data Analysis: Unitary Movements

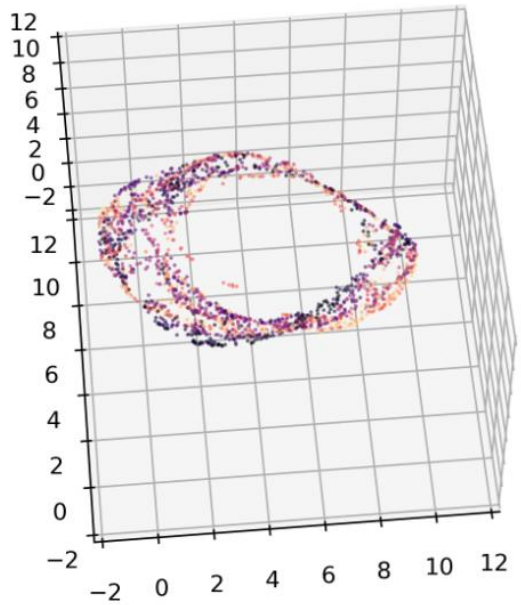
Recurrence Quantification Analysis

Reduce dimensionality with UMAP: $(30, T) \rightarrow (3, T)$

Compute matrix of distances and obtain **recurrence plot**

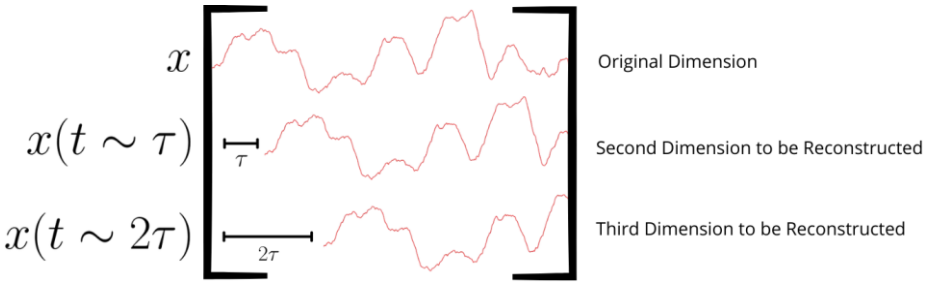
Visualize 3-dimensional time series on X, Y and Z axes



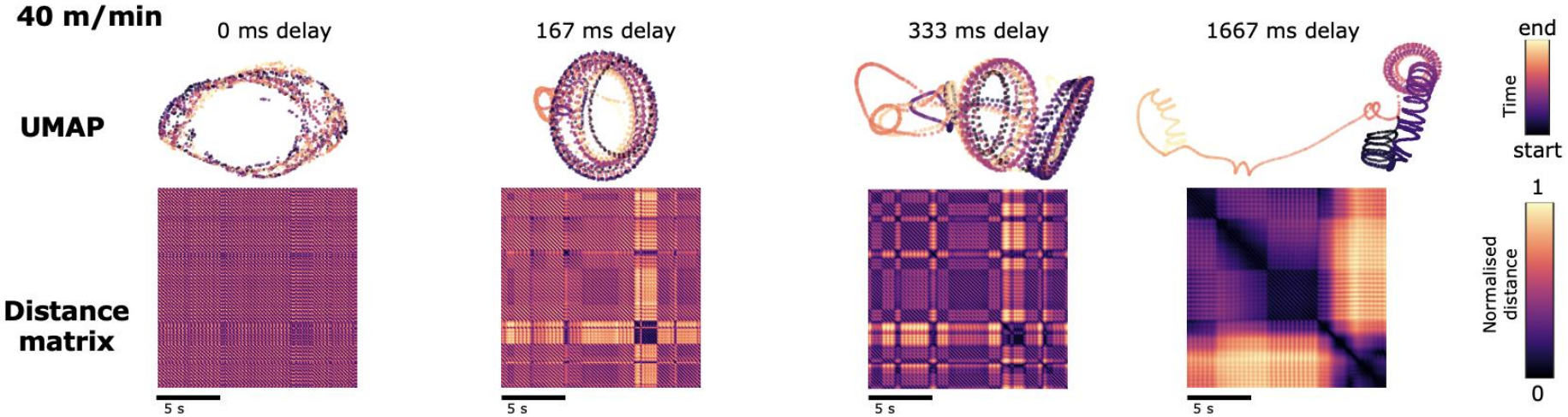


Data Analysis: Unitary Movements

Delay Embedding

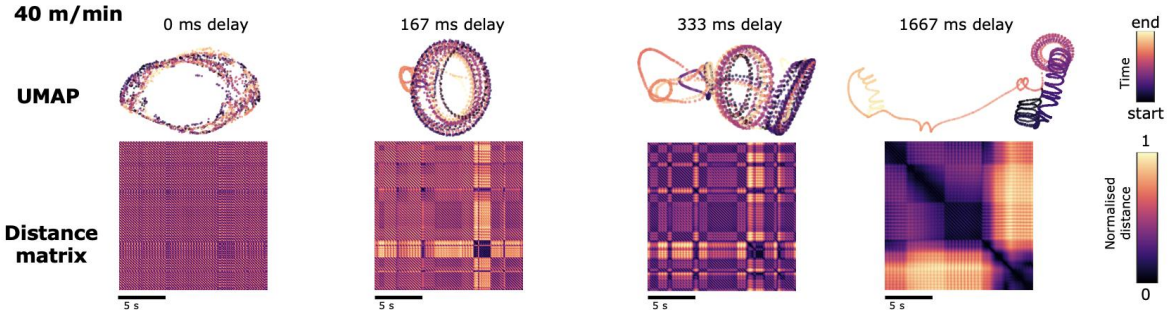


$$\tau = 1 \text{ frame} = \frac{1}{300}\, ms$$



Data Analysis: Unitary Movements

Overembedding Handling

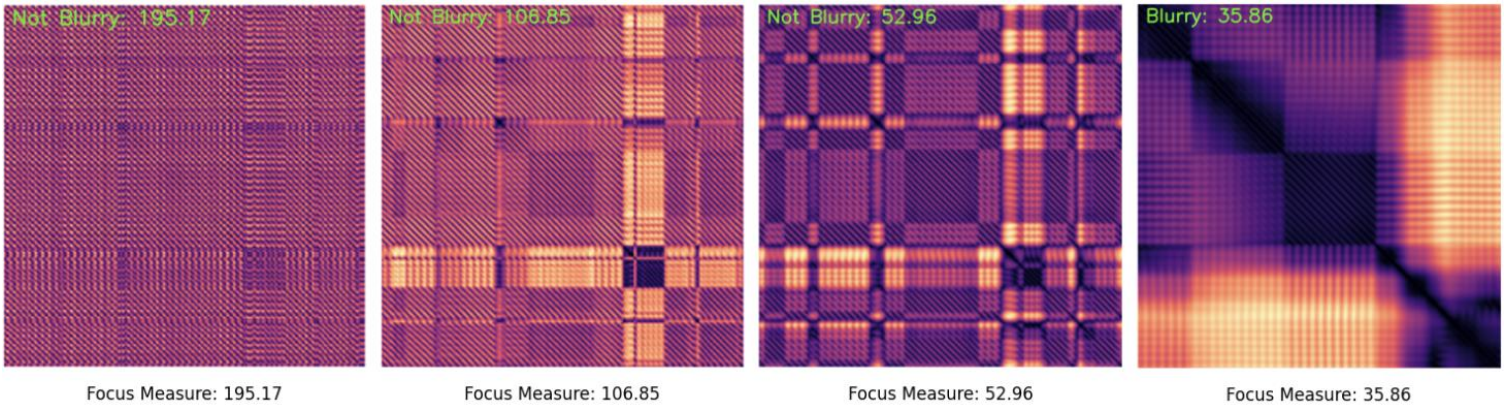


Focus Measure

=

Variance of the Laplacian Operator on an Image

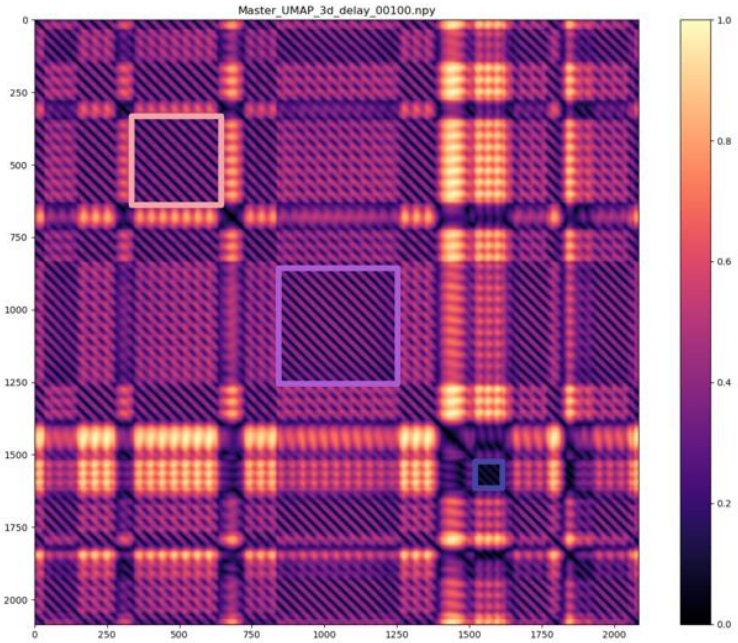
Quantify the **unfolding** of the underlying attractor obtained from the delay embedding



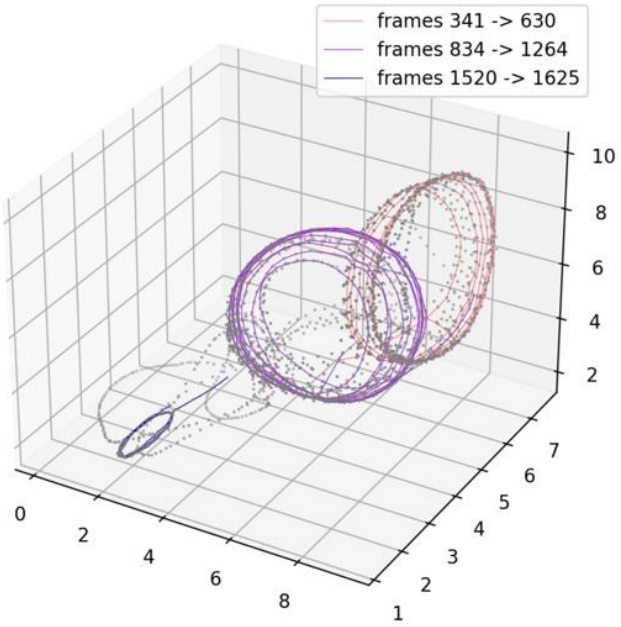
Data Analysis: Unitary Movements

Unitary Movements and Segmentation

Unitary Movement = coordination pattern + unit of locomotion

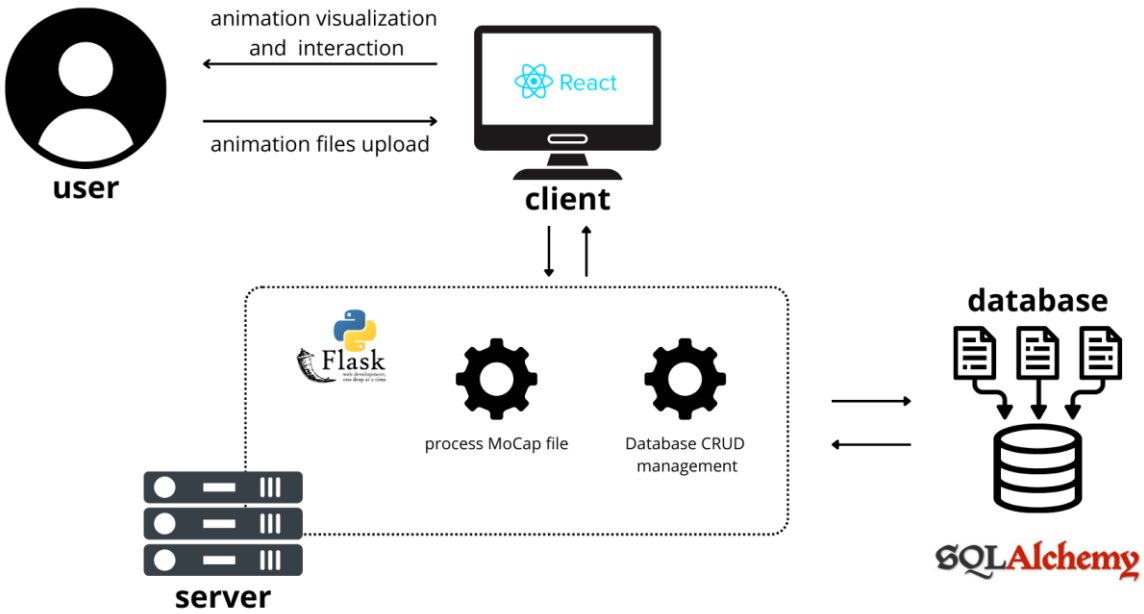


Plots obtained from a correct $333ms$ delay



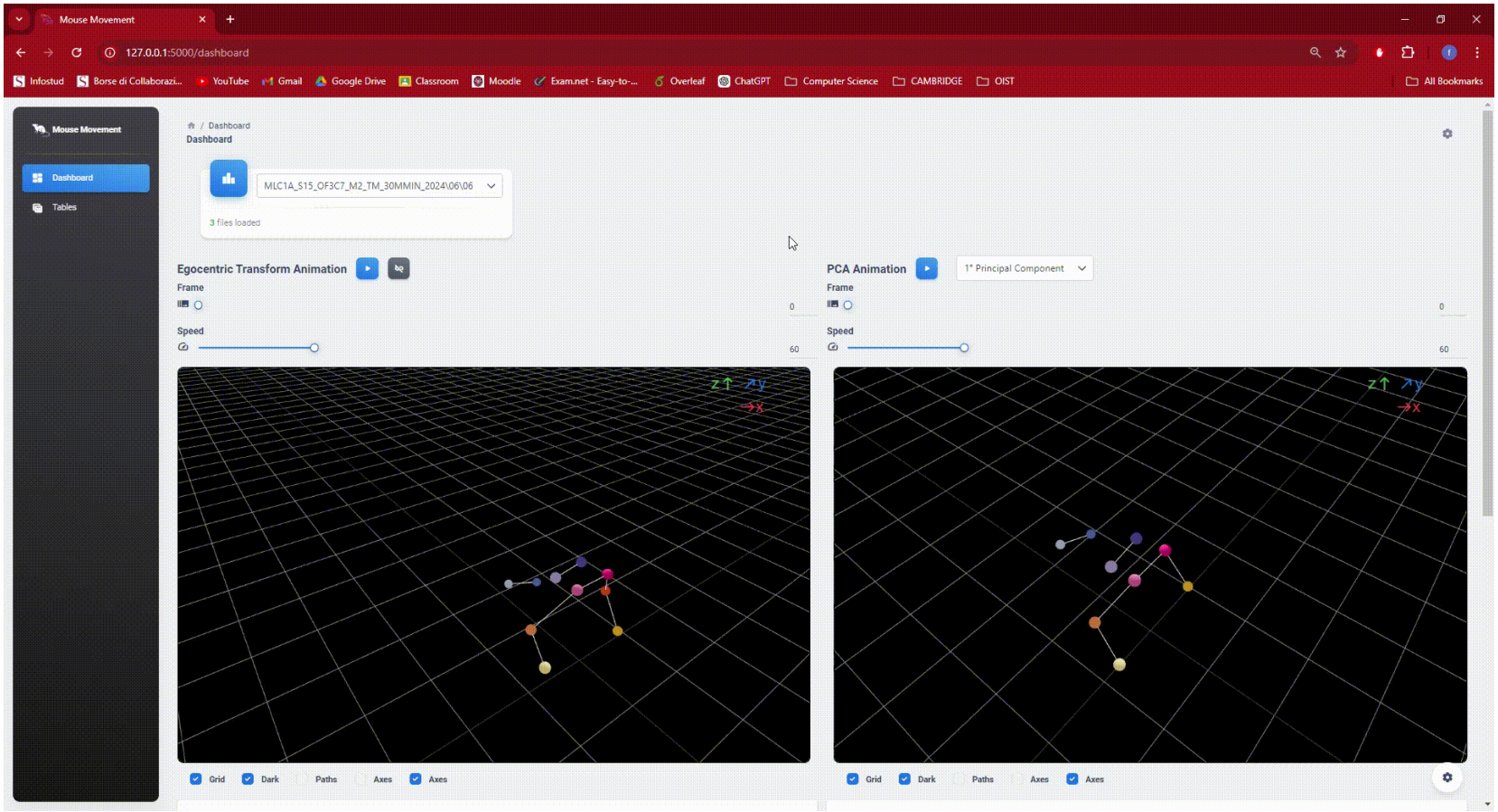
Data Visualization

Mouse Movement: A Web Application for 3D and 2D Visualization and Interaction



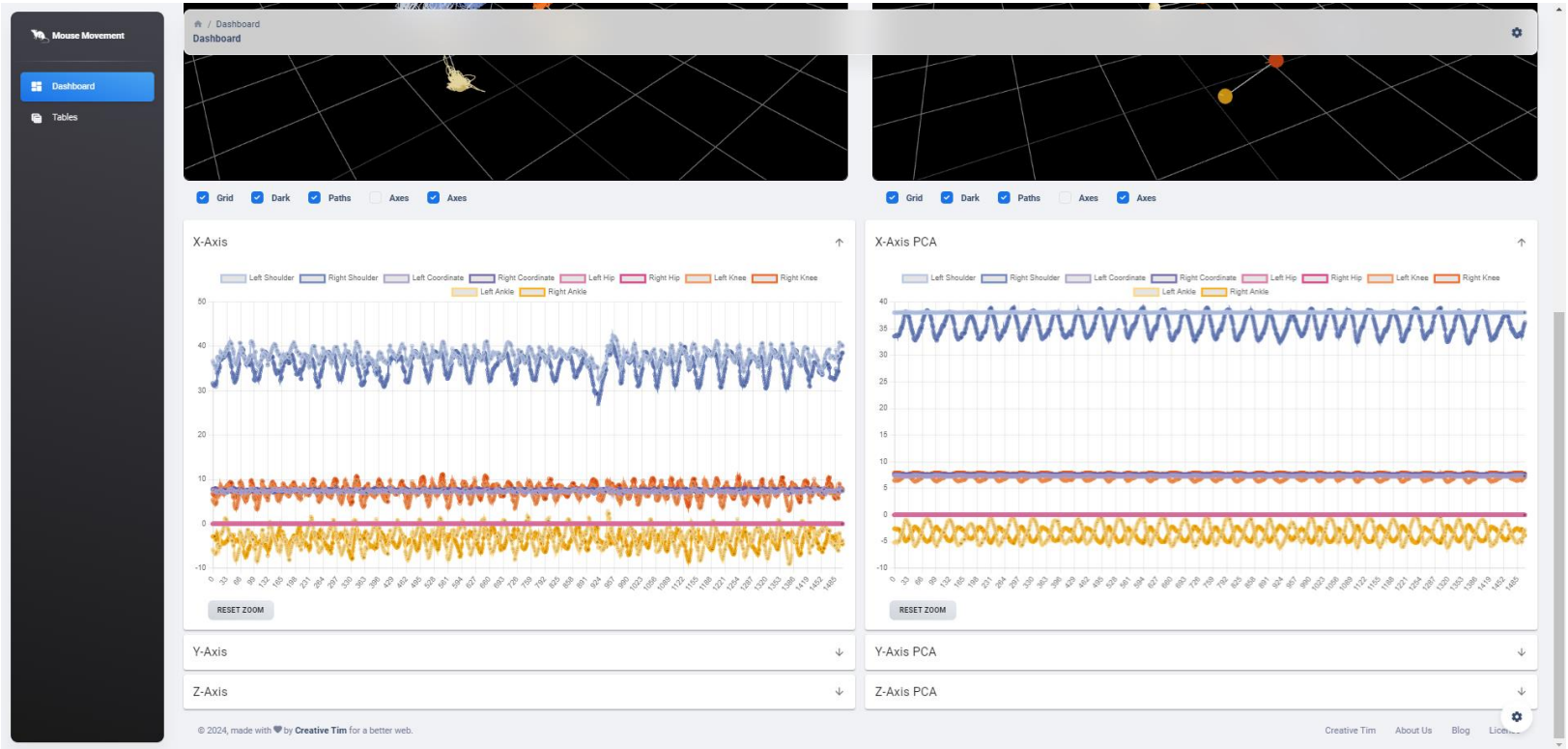
Data Visualization

Mouse Movement: 3D Visualization and Interaction



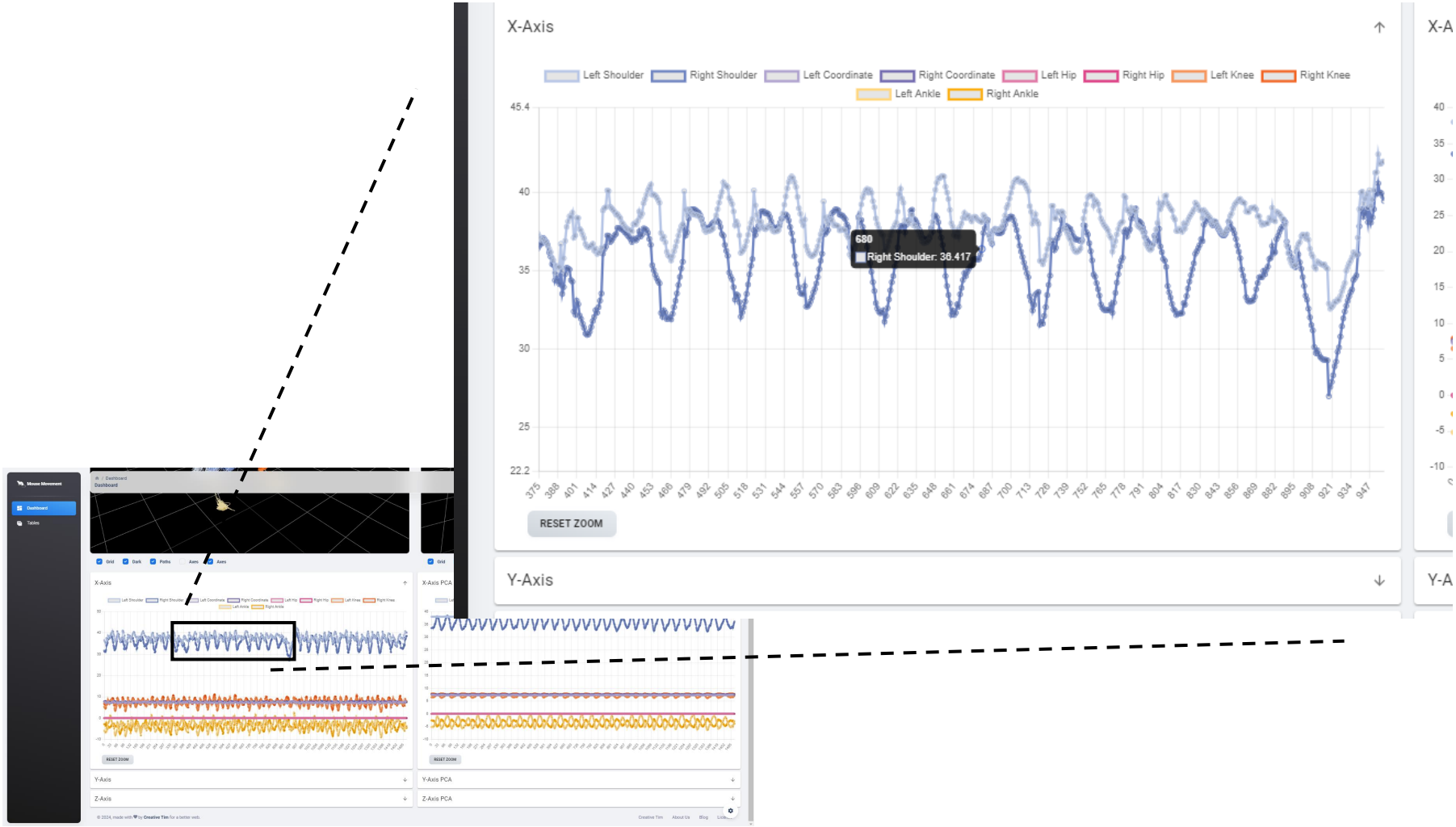
Data Visualization

Mouse Movement: 2D Visualization and Interaction



Data Visualization

Mouse Movement: 2D Visualization and Interaction



Thank you for your attention!