Movemento : An app to visualise and analyse complex gait cycle datasets

written

by

Kabita Bhusal (Matriculation no.: 8119930), kabita.bhusal@sport.uni-giessen.de

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1 Introduction

Gait analysis is essential for understanding human movement, with applications in medical diagnosis and sports performance optimization. However, many existing systems require advanced technical skills, limiting their accessibility. This project aims to create a user-friendly platform for gait data analysis through a graphical user interface (GUI). The tool allows users to load, preprocess, and analyze gait data, focusing on features like maximum knee angle and swing phase duration. Key functionalities include gait event detection and graphical representation of gait cycles, enabling comparisons across individuals or conditions. This tool provides an accessible solution for healthcare professionals, sports scientists, and researchers to analyze gait patterns effectively.

2 Methodology

The methodology for this project begins with the analysis of a pre-existing dataset, provided in a zip file, containing knee joint angle measurements during multiple gait cycles. This dataset includes data for three different conditions, each comprising 20 subjects with 30 steps recorded per subject. The knee joint angles were captured at a sampling rate of 250 Hz, ensuring a high level of detail for each gait cycle. This data serves as the foundation for developing and testing the gait analysis tool, allowing for in-depth analysis of various gait features across different conditions.

2.1 Data Preprocessing

The knee angle data was first imported into MATLAB using the ‘uigetfile‘ function. Initial data cleaning involved converting all negative values to positive using the ‘abs‘ function to ensure consistency in analysis and improve visual representation. To reduce noise and smooth the signal, a moving average was applied to the data using MATLAB’s ‘movmean‘ function, with a window size of 20. This approach preserved the natural frequency of the gait cycle while removing minor fluctuations.

Next, temporal normalization was performed to equalize the length of all gait cycles, allowing for meaningful comparisons across subjects and conditions. The ‘interp1‘ function was employed to interpolate knee angle values based on a normalized time vector, ensuring uniform time scales for each cycle. Additionally, synchronization was done by aligning all maximum knee angles to enhance visual analysis and pattern recognition.

Event detection was carried out based on specific percentage points within the gait cycle, allowing for the identification of key moments like stance phase and swing phase. Figures 1 and 2 illustrate the differences between the raw and preprocessed knee angle data for one subject.

2.2 Data Analysis

Two features, maximum knee angle and swing phase duration, were selected for statistical analysis to assess differences across conditions. A t-test was conducted to compare these features between two specific conditions, and ANOVA was performed to analyze differences across three conditions.

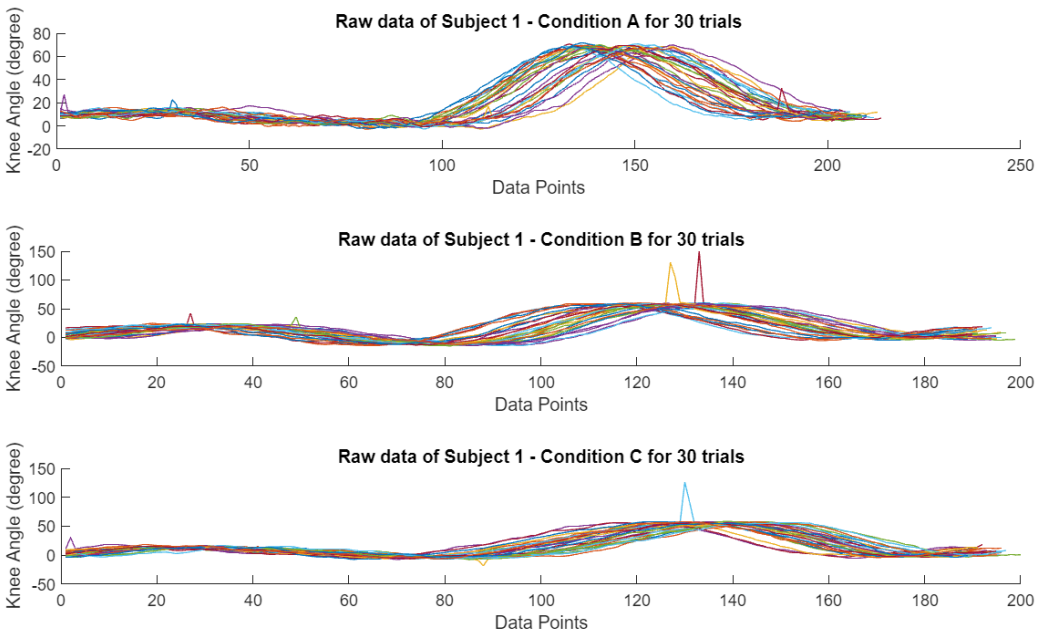
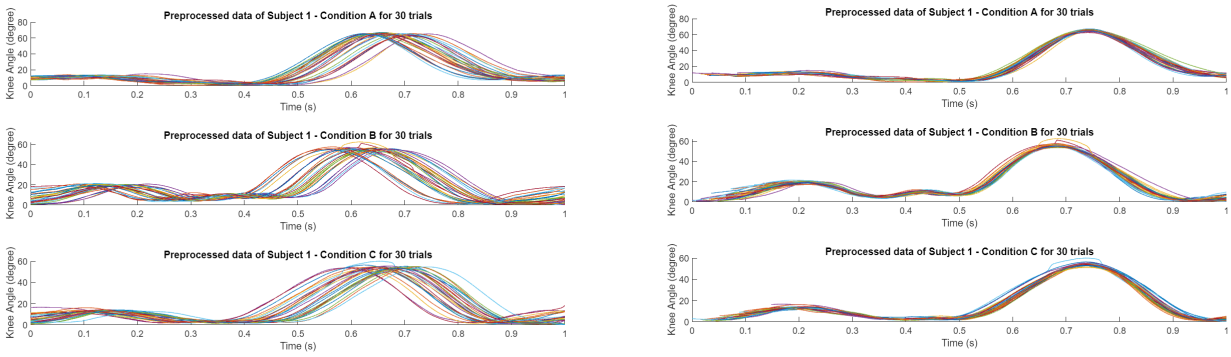


Figure 1: Raw Data



(a) (b)

Figure 2: Preprocessed Data

2.3 Developement of GUI

A graphical user interface (GUI) was developed in MATLAB to provide a user-friendly platform for visualizing and analyzing knee angle data. The GUI offered several key functionalities:

Data Loading: Users could easily upload the dataset using a "Load Data" dialogue box.

Signal Plotting: The GUI allowed users to plot both raw and preprocessed knee angle data over time or frames to visually inspect gait cycles.

Preprocessing Options: A button enabled users to apply or remove various preprocessing steps to the data.

Gait Cycle Events Identification: An automated function detected key gait cycle events and highlighted them on the graph for clear visualization.

Statistical Analysis: The GUI displayed important metrics, such as maximum mean knee angle, standard deviation, and swing phase duration for each gait cycle.

3 Implementation

Important Note: Run only the app.m file while ensuring all other files remain in the current folder of MATLAB to open the application.

3.1 Software Architecture

The system is divided into several key components, which are organized in a modular way to ensure a clear separation of responsibilities and efficient interaction between them. These components are:

Loading page:

The Loading Page serves as the initial interface for users to upload the knee angle data file. This page is specifically designed to accept data exclusively in **zip file** format, ensuring compatibility with the system's processing requirements. Upon selecting and successfully loading the appropriate zip file, the system transitions seamlessly to the Display Page, where users can begin visualizing and analyzing the loaded data.

Display page:

The Display Page is a central interface that facilitates various data analysis tasks through three main tabs, each dedicated to specific functionalities:

1. **Raw Data Tab:** This tab presents the unprocessed knee angle data and includes three sub-tabs:
    - **Subject-Wise:** Displays the raw knee angle data for individual subjects, allowing for detailed examination.
    - **Subject-Wise Mean of 3 Conditions:** Shows the average knee angle data for each subject across three different conditions, providing insights into overall performance.
    - **Condition-Wise Mean:** Plots the average knee angle data across all subjects for each condition, enabling comparisons between different conditions.
2. **Preprocessing Data Tab:** This tab offers tools for various data preprocessing options. Similar to the Raw Data Tab, it also contains three sub-tabs for subject-wise and condition-wise visualization, ensuring consistency in analysis.

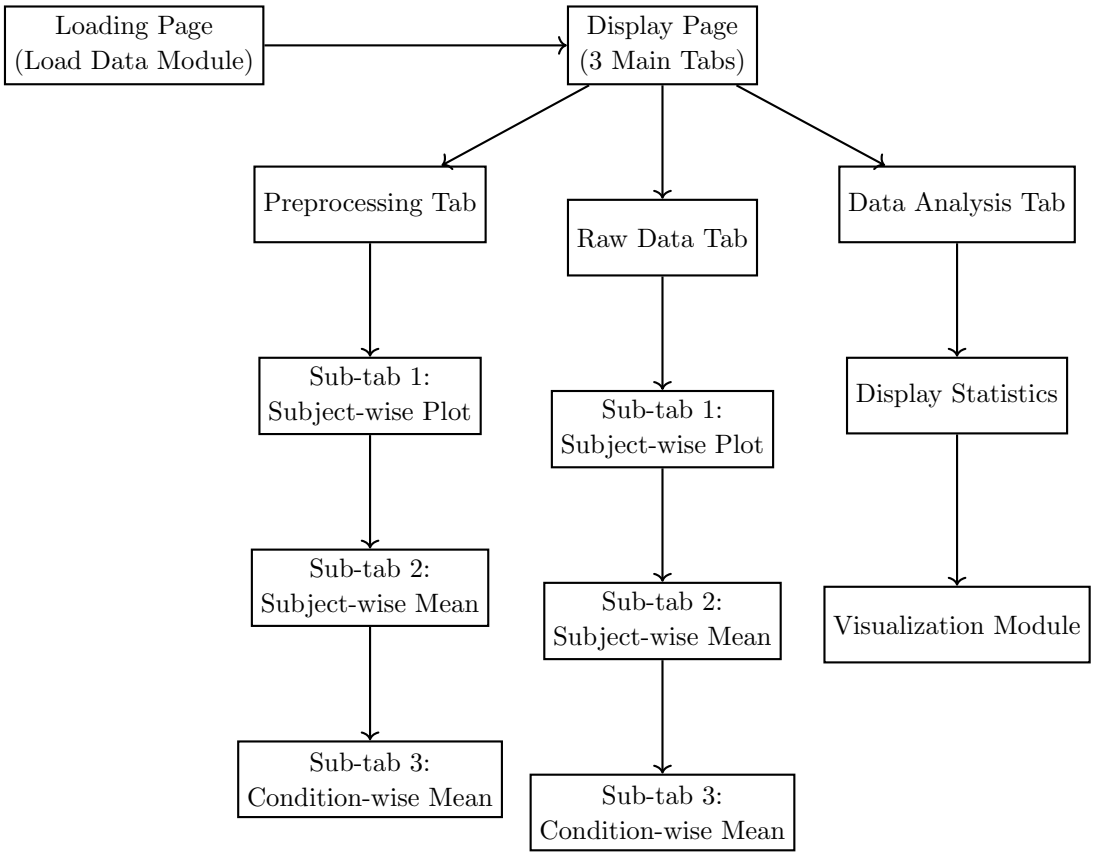
3. **Data Analysis Tab:** This tab includes tools for detecting gait cycles and analyzing processed data. It features a comparative chart box for conducting T-tests and ANOVA on maximum knee angle and stride phase duration across the mean of the three different conditions, facilitating comprehensive statistical analysis.

Core Functional Module:

- Data Input Module: Responsible for loading and reading the knee angle data from the zip file.
- Preprocessing Module: Handles signal processing tasks, such as applying filters to clean and smooth the raw data.
- Analysis Module: Detects gait cycles, and calculates key gait metrics like the standard deviation and maximum knee angle.
- Visualization Module: Generates and manages plots for visualizing the raw, filtered, and analyzed data. This module is responsible for creating both subject-wise and condition-wise plots across different stages of analysis

3.2 High-Level Flow Diagram:

This flow diagram illustrates how the different components of the system interact with each other, based on user input and data flow.



3.3 Componenet Interaction and Workflow

- **User Interaction:**

  1. The user starts by interacting with the Loading Page, where they load the knee angle data file.
  2. Once the data is loaded, the user is directed to the Display Page, which contains three main tabs: Raw Data, Preprocessing Data, and Data Analysis. Each of the Raw Data and Preprocessing Data tabs contains three sub-tabs for more detailed views.
  3. In the Raw Data Tab, the user can view the unprocessed data in three different sub-tabs: by subject, by subject means across conditions, and by condition-wise means across all subjects.
  4. In the Preprocessing Data Tab, the user can apply filters and view the preprocessed data in a similar subject/condition structure as in the Raw Data Tab.
  5. In the Data Analysis Tab, the user can detect gait cycles, compute statistical parameters such as maximum mean knee angle, stride phase duration and visualize the results in the GUI.

- **Modular Interaction:**

1. The Data Input Module loads the data, which is passed to both the Preprocessing Module and Analysis Module.
2. The Preprocessing Module processes the raw data and sends the filtered data to the Visualization Module for plotting.
3. The Analysis Module detects gait cycles and computes statistics, displaying the results in the Data Analysis Tab.
4. The Visualization Module manages all the graphical outputs, including subject-wise plots, condition-wise means, and overall statistics.

4 Result

The analysis revealed that the mean maximum knee angle varied significantly across different conditions, particularly when different loads were applied. This indicates that the load had a notable impact on the knee joint's movement. Additionally, the variance in maximum knee angle also differed between conditions, suggesting that load variations influenced the consistency of knee angle across trials. However, no significant difference was observed in the swing phase duration, indicating that the swing phase remained consistent regardless of the load applied. These findings suggest that while load affects knee angle mechanics, it does not alter the swing phase duration.

In the app's analysis section, all results were presented with feature selection options for maximum knee angle and swing phase duration. A comparative box chart diagram was included, displaying all values for enhanced visualization and analysis.