

Kinematic Event Detection

Assessing Different Kinematic Methods of Structuring Gait

This tutorial is based on a research project presented at the Ontario Biomechanics Conference (OBC) 2025 titled “**Assessing Different Kinematic Methods of Structuring Gait**”.

The goal of this tutorial is to help users replicate the research process and understand how to structure gait cycles without relying on kinetic data (e.g. from force plates or instrumented treadmills). Instead, we will use kinematic data and implement several established event detection algorithms using Visual3D.

This tutorial is intended for users who either do not have access to lab-grade kinetic instrumentation, or see this equipment as unideal for their environment- in the case of a field-based or markerless system.

Objectives

- Introduce and implement kinematic-based gait event detection methods from peer-reviewed literature.
- Provide a step-by-step approach to structuring gait cycles in Visual3D.
- Compare the derived cycles to kinetic-based baseline cycle.
- Use downloadable data, Visual3D pipelines, and batch scripting workflows in order to simulate the process of this investigation.

Background and Rationale

Traditionally, gait cycle events such as Heel Strike (HS) and Toe Off (TO) are defined using force thresholds derived from ground reaction force (GRF) data. This method is reliable but dependent on lab based equipment.

Kinematic methods detect HS and TO using joint angles, segment velocities, or spatial relationships between anatomical markers. Although these methods are not perfect, they are crucial for field-based studies, clinical gait analysis, and wearable-only workflows.

In our project, we evaluated the following kinematic event detection methods:

- Zeni et al. (2018) Method 1 and 2
 - DeAsha et al. (2012)
 - Hreljac & Marshall (2000)
 - O'Connor et al. (2007)
- **Max Knee Angle Method** - Local maximum events for knee reaching peak flexion.
- **Hip Surpasses Heel** - event placed when leading hip joint center overtakes opposite foot.

Each method identifies gait events based on unique kinematic patterns, such as:

- Local minima/maxima in foot marker trajectories.
- Peak knee flexion or extension.
- Spatial relationship between foot and hip joint centers.

Dataset Description

This tutorial uses the [Fukuchi et al. \(2018\)](#) walking dataset.

- Journal Article: [A public dataset of overground and treadmill walking kinematics and kinetics in healthy individuals.](#)
- **Participants:** 42 healthy adults (24 younger, 18 older)
- **Trials:** 5-8 treadmill walking trials per participant, increasing speed per trial.
- Data collected includes marker trajectories and kinetic data from an instrumented treadmill.

Important Notes:

- Only left-side gait events were analyzed.
- Data was pre-processed to extract joint angles, segment positions and other features required for each algorithm. This will be included in the sample data.

Downloads

The ZIP File for this tutorial can be downloaded [here](#). This provides files for the different steps of the workflow process of the research.

Compute Kinematic Parameters

Before applying the kinematic event methods, compute the joint angles and positions required. This typically includes the **Compute_Joint_Angle** and **Compute_Segment_Position**.

The base pipeline with all preprocessing steps. This will be used before applying any method-specific event logic.

Step 1: Set up your environment

Organize the workspace by participant. Make sure each trial has:

- A working biomechanical model.
- Joint angle outputs.

Step 2: Apply Kinetic Baseline Events

Use **Automatic_Gait_Event** command in Visual3D to generate Left Onset (LON) Kinetic events. These will serve as the gold-standard baseline.

```
Automatic_Gait_Events
! /FRAME_WINDOW=8
! /USE_TPR=TRUE
! /TPR_EVENT_INSTANCE=1
;
```

These events use vertical ground reaction force thresholds to identify HS/TO.

Results Summary

The project found that:

- Zeni's method 1 (HS foot vertical position), method 2 (TO foot vertical position), and peak knee angle method produced the most reliable cycles compared to the kinetic baseline.
- Some methods introduced variability as speed increased.
- Kinematic methods are viable alternatives in environments without force plates, provided method-specific biases are considered.

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Last update: **2025/05/28 19:14**

