Implementation Plan for "AddBiomechanics Dataset: Capturing the Physics of Human Motion at Scale"

Zitian Wang

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1. Background and Methods

The paper introduces the AddBiomechanics dataset, a large-scale repository of synchronized motion-capture, force-plate, and medical imaging data from hundreds of human subjects performing various activities of daily living (walking, running, jumping). The dataset includes:

- 3D marker trajectories (200+ markers, 120 Hz)
- Ground reaction forces (3D, 1000 Hz)
- Synchronized MRI scans of musculoskeletal anatomy

The authors demonstrate how inverse dynamics driven by motion data can estimate joint torques and muscle activations, and they validate these estimates against EMG measurements.

2. Implementation Plan

2.1 Reproducible Results

We will reproduce the published walking trial on a treadmill at 1.25 m/s: joint angle trajectories and computed knee joint torque profiles. Targets: match peak knee extension torque (1.2 Nm/kg) within 10% and reproduce waveform shape (correlation > 0.95).

2.2 Data & Parameter Settings

- Subjects: select 10 healthy adults (balanced gender, age 20–40).
- Trials: treadmill walking at 1.25 m/s, 60 s duration.
- Marker data: low-pass filter at 6 Hz (Butterworth, 4th order).
- Force data: low-pass filter at 20 Hz.
- Inverse dynamics:
  - Segment inertial parameters from anthropometric tables (Dempster).
  - Joint centers estimated from marker clusters.
- EMG comparison: normalize EMG amplitude to

2.3 Model Extensions and New Problems

- **Particle-based muscle modeling**: integrate SPH muscle fibers into kinematic chain to predict stress distributions.
- **Real-time feedback**: implement a particle-fluid hybrid to simulate blood flow and heat dissipation under dynamic loading.
- **Pathological analysis**: compare joint kinetics for subjects with gait impairments, to identify biomarkers of early osteoarthritis.
- **Data augmentation**: use generative particle models to synthesize new motion patterns for machine-learning applications.

This plan leverages the multimodal AddBiomechanics dataset to validate and extend particle-based musculoskeletal simulations at scale.