Gait Analytics as an Indicator of Health

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Problem Statement

This project originated with the request for a non-invasive system to prevent falls of clients at elder drop-in centers in Singapore.

This application gave the opportunity to aim toward two relatively novel contributions:

1. **Prevent** falls before they happen. Most gait systems only **detect** falls.
2. Analyze over time, using **gait trend analytics**. Most gait systems perform **one-time** analysis.
**Architecture**

**System**

The system has 3 modules:

1. **Event Detection** – Detect person walking across camera view by motion “tripwires”.

2. **Pose Estimation** – “Skeletal features” are extracted using the OpenPose tool.

3. **Trend Analytics** – Gait features are examined over time. A non-zero trend of gait features may indicate a health change.
Module 3 – Gait Trend Analytics

Trend Measurement and Alerting

Although we use standard statistical tests, our contribution is using gait trend analysis to **prevent** rather than just detect.

\[ t\text{-score}: t_0 \sim \text{slope} / \sigma, \quad Z\text{-test}: z(n) = \left| s_n - E(s) \right| / \sigma \]
Experiments

We really want to measure if falls are prevented. We do every experiment except that:

- Experiment 1 – Most consistent feature
- Experiment 2 – Trend for healthy population
- Experiment 3 – Outliers for healthy population
- Experiment 4 – Analytically-added trend
- Experiment 5 – Physically-added trend
- Experiment 6 – “Nudge”-added trend

Experiment Parameters:

- 3937 gait events, 50 labeled persons, two 3-month periods, 5 to 318 events per person
- 30 fps video capture, OpenPose confidence threshold > 0.2
- Chose OpenPose above-threshold frame closest to middle of walk to measure features
Experiments

Experiment 4 – Analytically-added trend.

Added 3, 5, and 10 degrees to angle features, and reduced speed by 10%, all in total, over the course of 1 month to healthy population data (3937 gait samples, 50 people).

“null hypothesis”

+ 3°

+ 5°

+ 10°

Observation – Above n=50 gait events for +3°, and n=30 for +5° and +10°, all trends are significant at 95% confidence

Conclusion – System measures trending back-angle feature with easily measured statistical significance.
Experiments

Experiment 6 – “Nudge”-added trend.

In our “null hypothesis test”, some samples contradicted this hypothesis. These people were purposefully attempting to improve their gait. This gave us an idea for a “nudge experiment.

Feedback:

- 3400 events, 35 people, 3 months.
- People walk with 2-4° “better” (more upright) gait when given positive feedback.
Other Applications

- **Elder Care**
  - Degenerative disease monitoring - e.g., Parkinson’s
  - Physiotherapy, Health Club – measure progress or general gait/posture health
  - Exercise Assist – next Peloton (network exercise bike) feature?
  - Worker Safety – continuous, noninvasive health monitoring for worker safety, quantitative measure of “don’t operate heavy machinery if …”
  - Workplace Safety – monitor all workers to maintain and design safer workplaces