Balance Estimation of Human Exercise using Kinect

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Rehabilitation and exercise programs for the elderly can be greatly improved with real-time feedback on exercise execution. The Kinect camera offers a low-cost sensor for developing such applications. In this project, we investigated the use of pose information detected by the Kinect camera to estimate force dynamics of the human body. Particularly, the torques that gravity forces apply to body segments with respect to ground contact points. The chief application of this research is to evaluate balance to prevent injuries and counterproductive movements. The results showed that this model was not able to properly evaluate balance due to noise in the Kinect data. Filtering methods would need to be researched and implemented in order to compensate for noise.

MOTIVATION

- Proper analysis of human exercise usually requires high-end and expensive equipment.
- Data gathered in a lab setting poses issues for patients with limited mobility.
- Goal is to analyze and provide feedback on exercise data using only video and cost-effective sensors.

[2]

TORQUES DETERMINE BALANCE

Assumptions made for Torque Model

- Arms and legs move in unison allowing for a two-dimensional model.
- Only heel and ball of foot used as contact points.
- Positive torque is towards front of person and negative towards back.
- Positive torque about ball of foot and negative torque about heel creates imbalance.

Limitations

- Noise in Kinect reduced by using anthropometric tables to estimate segment lengths.
- Mass and center of mass positions estimated using anthropometric tables.
- Kinect data recorded values for subjects who were balanced throughout the exercise.
- Analysis was done only for the shallow squat.
- The same Kinect data was used for all subjects since all were healthy and had no disabilities.

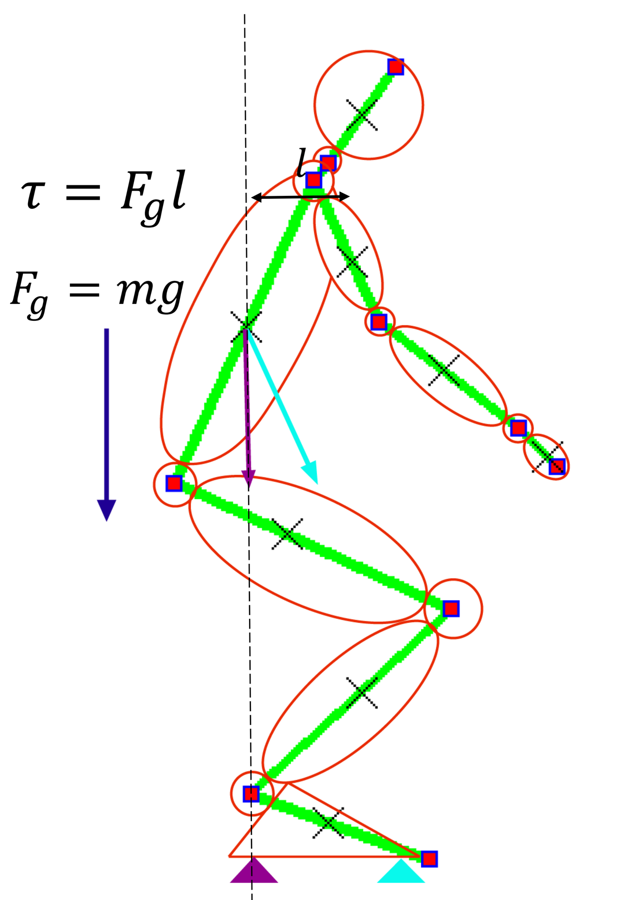

Figure 3. **Representation of torque applied to body segment center of mass with respect to contact points.**

Segment	Mass (%)	CM Position (%)	Radii of gyration Sagittal (%)	Radii of gyration Trans. (%)	Radii of gyration Long. (%)	Rel. Principal Moments Sagittal (%)	Rel. Principal Moments Trans. (%)	Rel. Principal Moments Long. (%)
Head + Neck	6.94	50.02	30.3	31.5	26.1	1.24	1.34	0.92
Head	6.94	59.76	36.2	37.6	31.2	1.24	1.34	0.92
Trunk	43.46	51.38	32.8	30.6	16.9	56.14	48.86	14.90

[1] Figure 4. **Sample of anthropometric table used to estimate center of mass positions and segment mass.**

Application of Torque Model

- The skeletal model was reconstructed using the calculated segment lengths and joint orientations.
- Center of mass positions are calculated for the two-dimensional skeletal model.
- Gravitational force acts on center of mass of body segments.
- Sum of torques on all body segments represents the overall torque acting on the body.
- Moment arm formula used to determine torque.

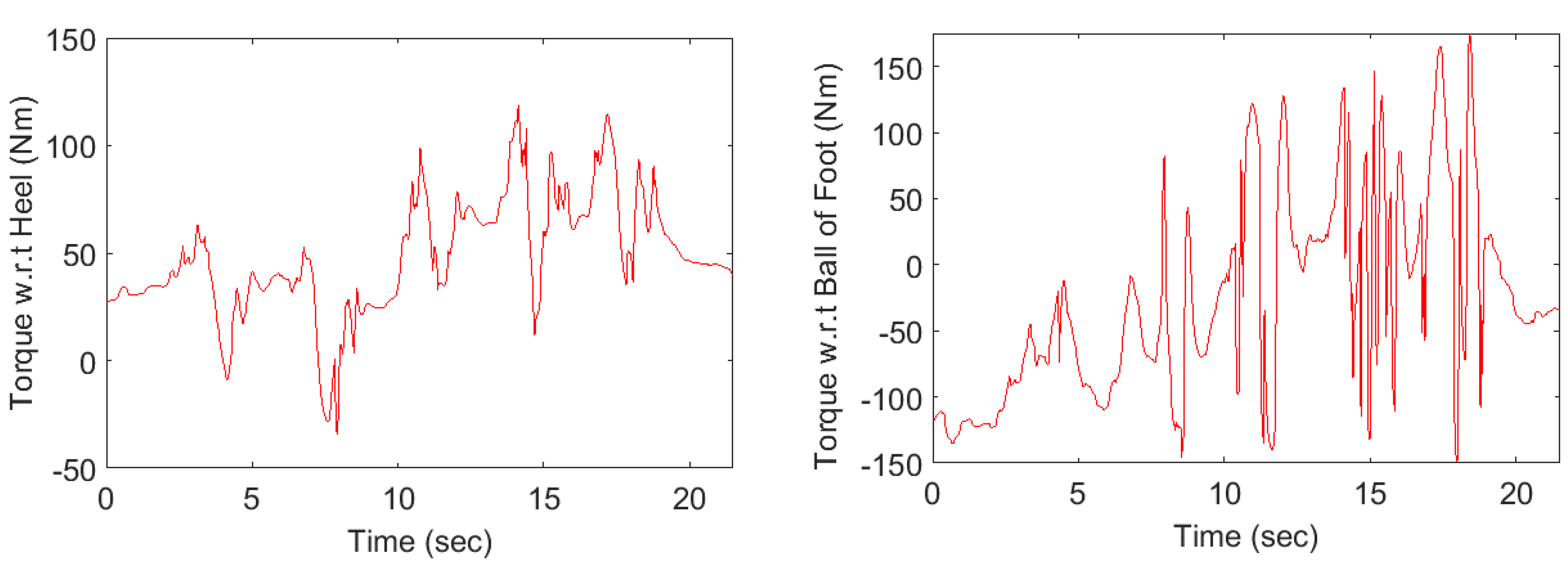

Figure 4. **Torques measured by model.** *The torques measured by the model indicate that subjects were off-balance throughout a portion of the exercise. This contradicts our assumption that subjects were balanced during the entire exercise measured by the Kinect.*

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OVERVIEW

Process

- Extract pose information using Kinect
- Determine segment lengths
- Estimate mass of segments
- Build two-dimensional model of skeleton
- Estimate center of mass positions
- Calculate torques acting on the body
- Sum torques to determine state of balance
- Perform analysis on seven subjects

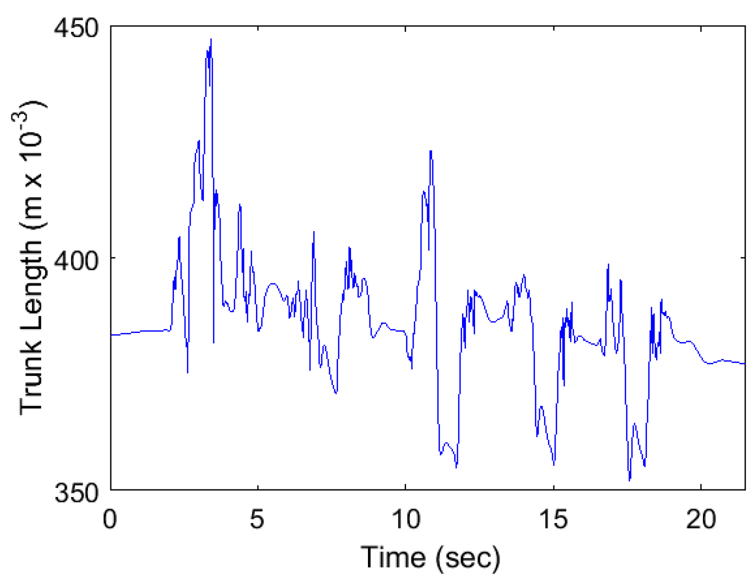

Figure 1. **Noise in Kinect data causes variations in segment length.** *Above is a graph of trunk length, all other segments have similar noise.*

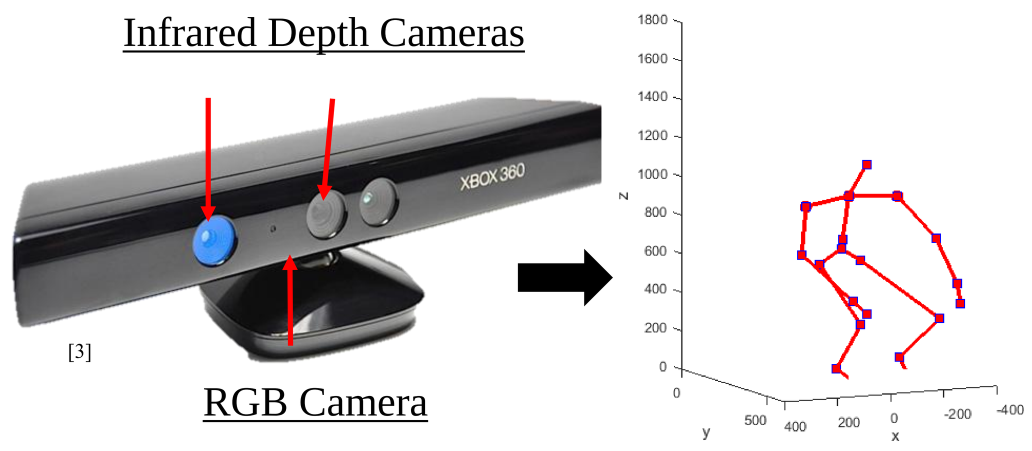

Figure 2. **Kinect data used to build skeletal model for analysis.**

Kinect Noise

- Kinect data tends to be noisy and must be compensated in some way (Figure 1).
- In this research, segment lengths changed significantly throughout the exercise.

RESULTS

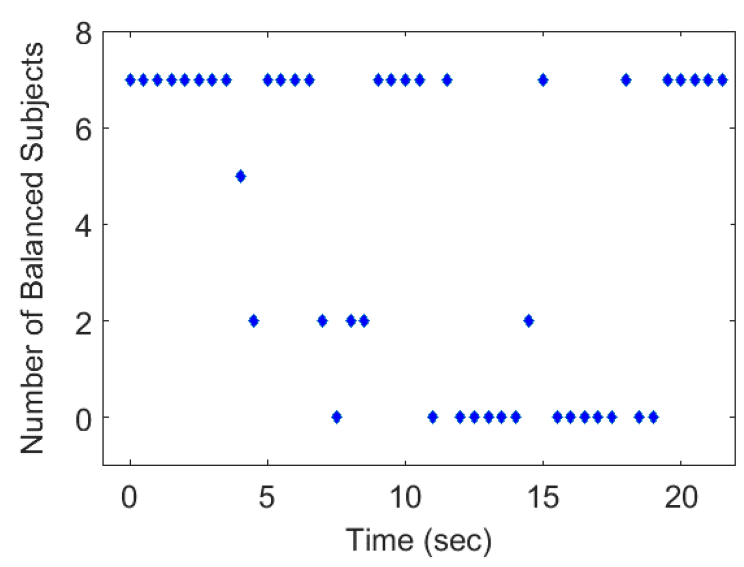

Figure 5. **Number of subjects balanced throughout exercise.** *Although graph above shows measurement for every fifteen frames, it is indicative of overall results.*

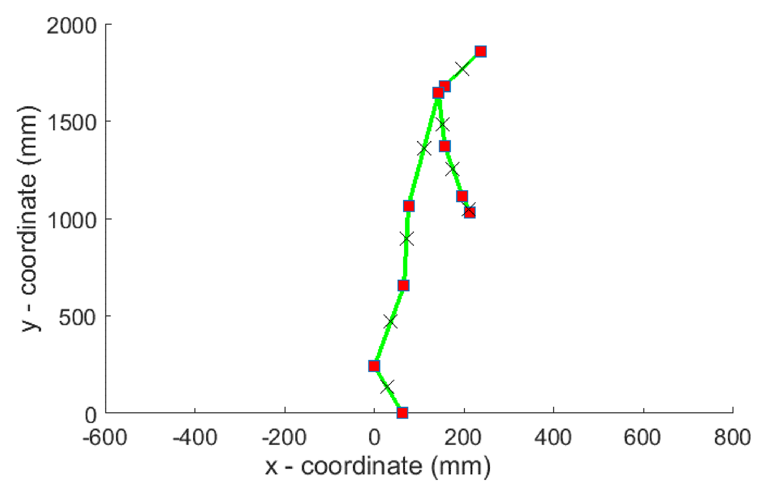

Figure 6. **Kinect frame that consistently produced off-balance results.** *Frame 500 and neighboring frames caused discrepancies in overall data.*

Error in balance model

- The height and weight of seven subjects was used in the analysis.
- Since this model assumed that subjects were always balanced, the results show some degree of error.
- The data suggests that the error was caused by noise in the Kinect data since subjects were consistently off-balance in the same frames (Figure 6).

Future Improvements

- Improve quality of Kinect data using noise filtering methods.
- Extend model to the three dimensional space.
- Extract segment length from individualized Kinect data.

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