

Estimation of Forces Acting on Human Joints via the Kinect Camera



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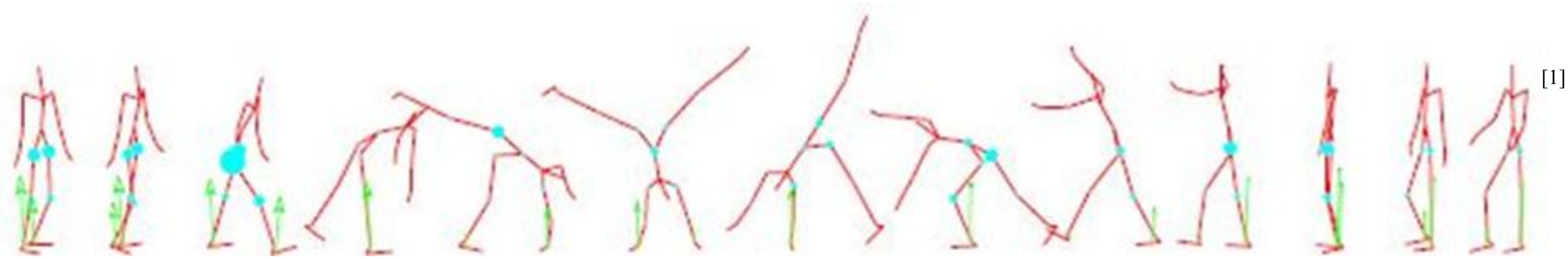


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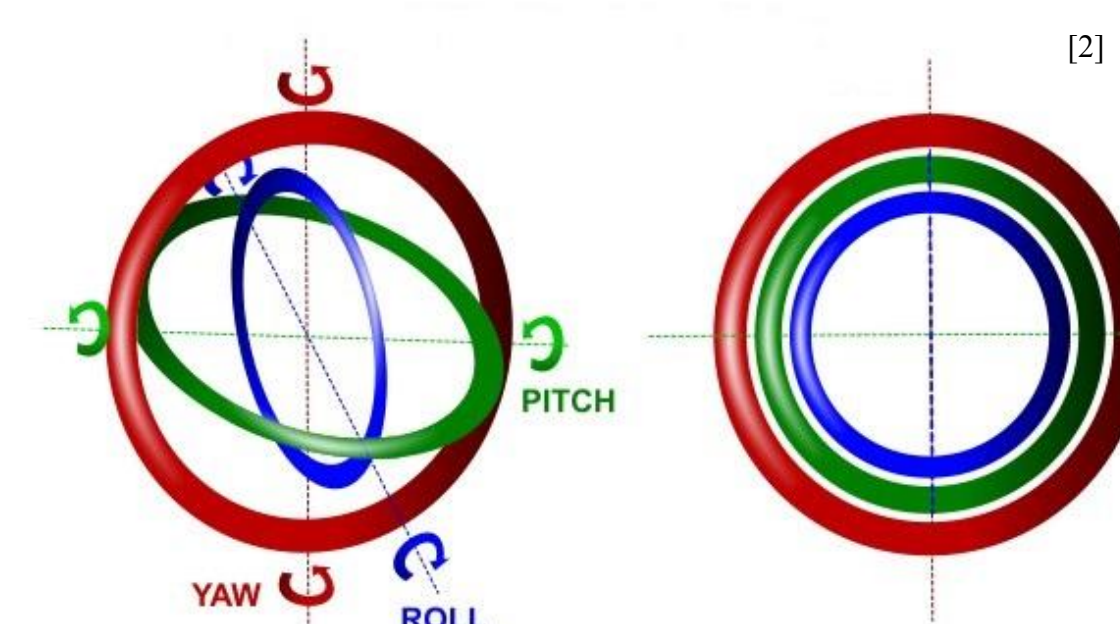
Abstract: The Microsoft Kinect camera has been studied extensively in recent years for its ability to capture human motion. This study explored the use of the Kinect camera to evaluate the forces acting on a person's joints while exercising. The motion trajectories recorded with the Kinect camera, in conjunction with a set of anthropometric parameters are applied to a dynamic model to calculate the forces affecting the human's joints. Since these forces are created, dampened, or counteracted by the muscles, the analysis of these data can be used to quantify muscular performance and provide recommendations for appropriate exercises.

Motivation

- The elderly and disabled tend to experience reduced mobility that makes it difficult to see a doctor regularly for advice and treatment.
- The Kinect camera's ability to capture human motion has been studied thoroughly for its availability and ease-of-use in-home.
- One of the key aspects of a person's overall health is their muscular strength, or, their ability to apply force to the joints of their body.
- We seek to determine the forces about the joints of an exercising person using the Kinect camera.



Key Concepts

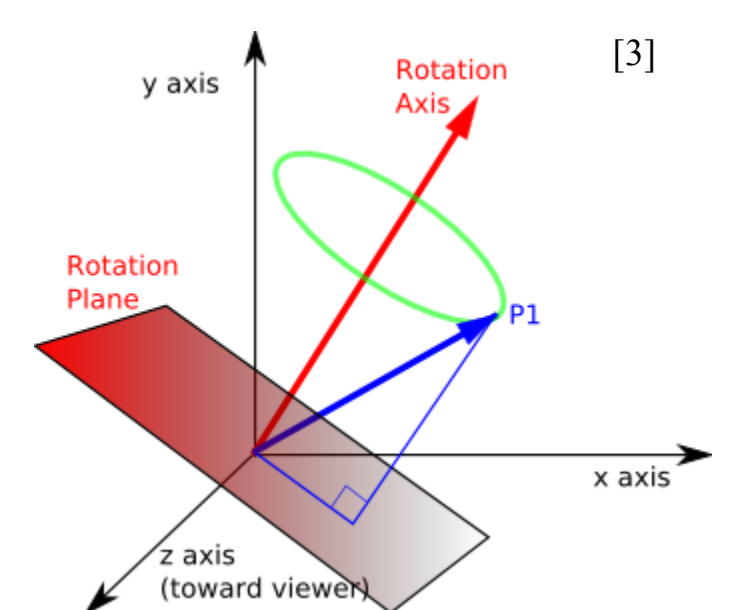


Euler Angles

- Euler Angles are a set of three angles specified about three axes to fully describe the relative orientation of a body.
- Euler Angles are a convenient way to calculate angular velocity and acceleration for use in the dynamic model.
- Euler Angles are susceptible to "gimbal lock," causing the temporary loss of a degree of freedom and mathematical difficulties.

Unit Quaternions

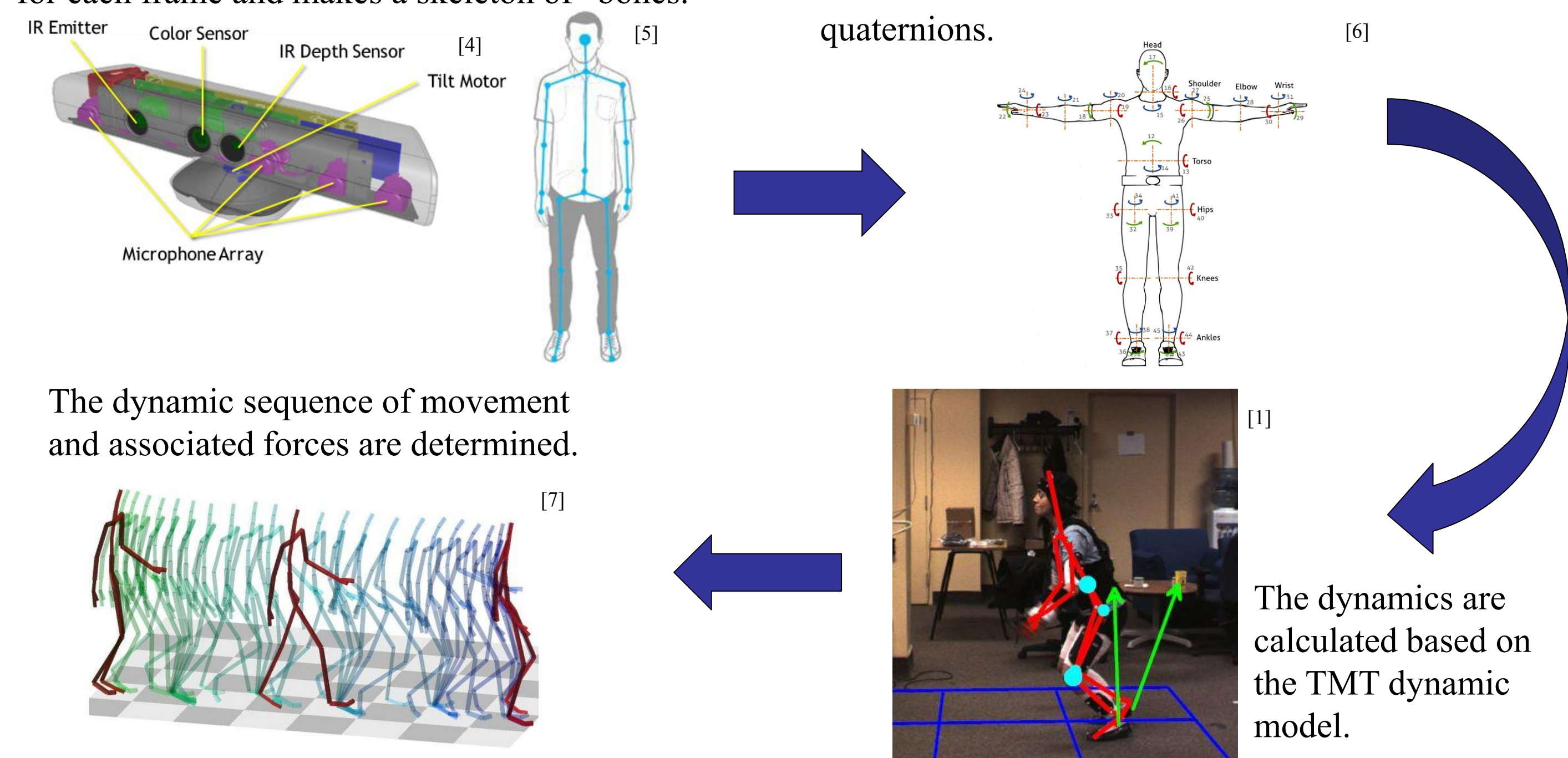
- Unit quaternions are a more convenient way to express a bodies orientation using a single rotation about an axis.
- Unit quaternions consist of four components:
 - x, y, z – the vector representing the axis of rotation
 - ω – the angle rotated about the x-y-z axis
- Unit quaternions must satisfy the equation: $\omega^2 + x^2 + y^2 + z^2 = 1$



Methods

The Kinect camera collects data of 3D joint locations for each frame and makes a skeleton of "bones."

Euler Angles and "bone" orientations are calculated and used to derive unit quaternions.

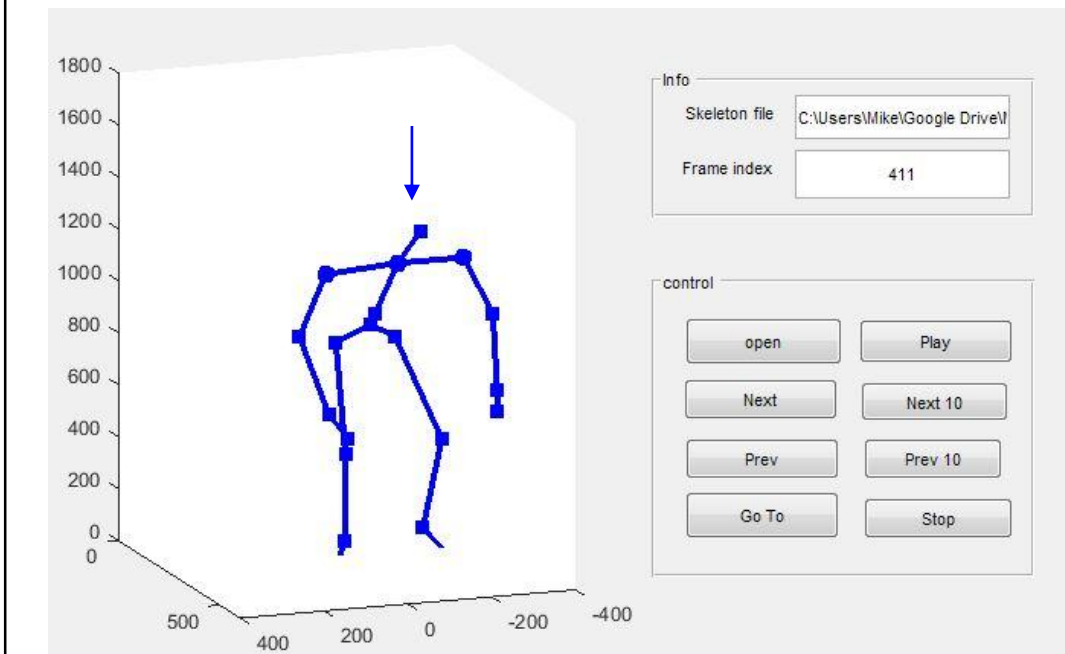
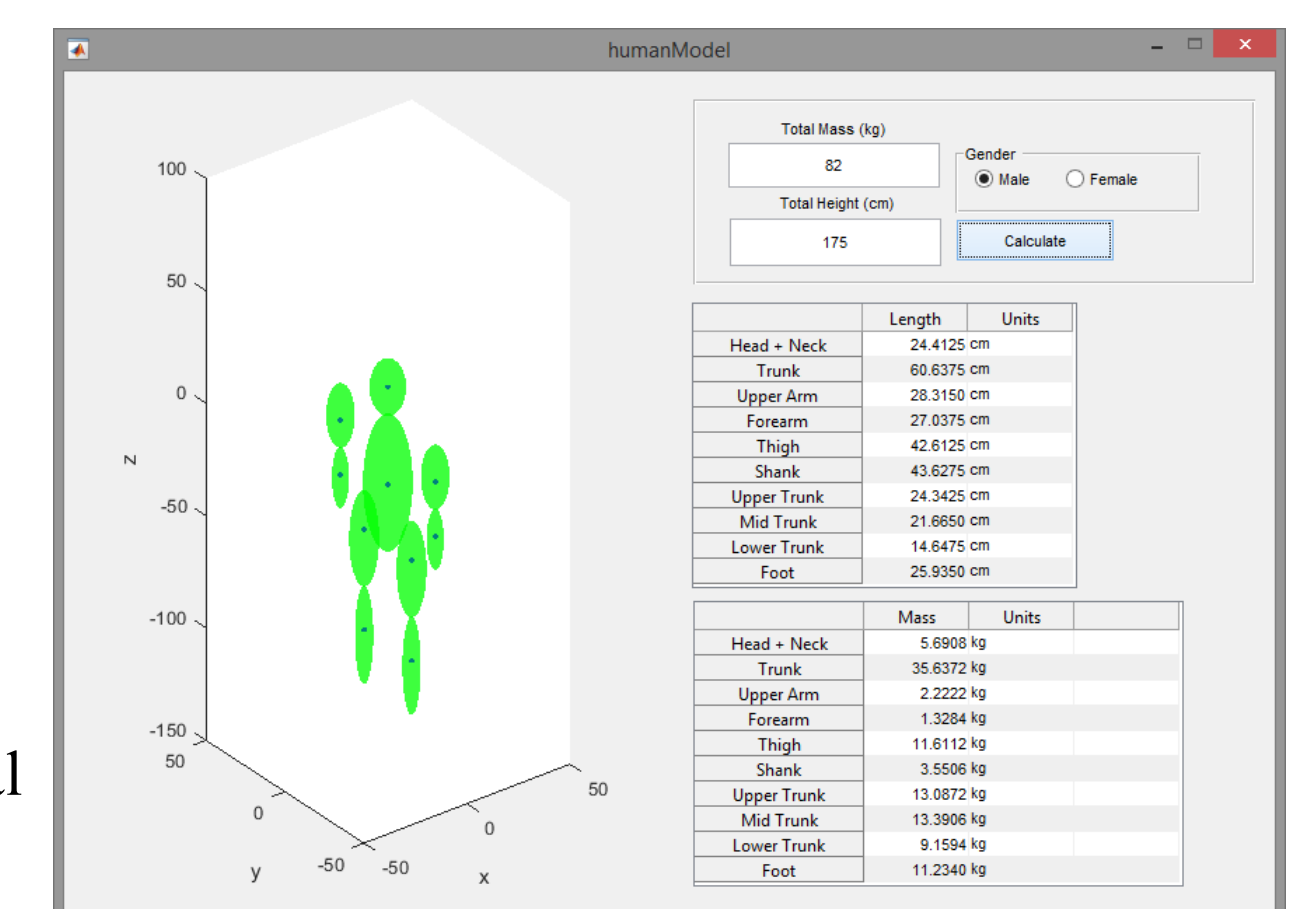


The Dynamic Model

The TMT method

The TMT method provides a general approach for determining the equations of motion of a constrained system in terms of generalized coordinates.

- A constrained system is a system of rigid bodies whose individual motion is affected by the overall motion of the system or its surroundings.
- Accounting for these constraints provided a more realistic model of the system's overall motion.
- Generalized coordinates are defined as any set of coordinates that fully describe the state of a complex physical system.
- Through the use of these concepts, the human body and its motion can be reconstructed.



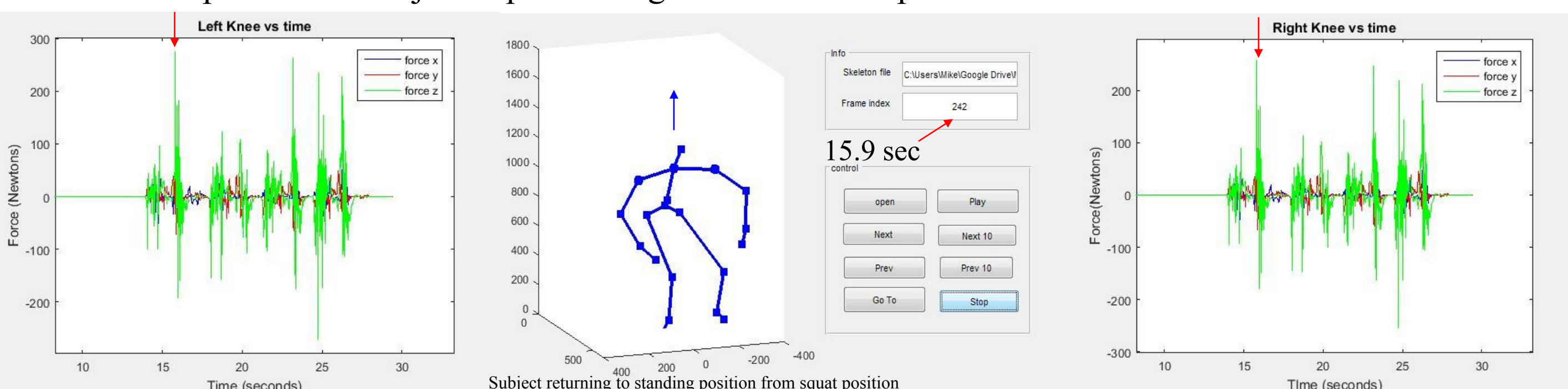
Subject experiences linear forces as he accelerates toward squat position.

Body Parameters and Calculated Forces

- The dynamics of a person can vary widely depending on a number of factors.
- To compensate for this, we have built a model that determines a person's body parameters based on three factors.
 - Height
 - Weight
 - Gender
- The forces calculated here reflect the linear forces acting on a joint that affect an overall acceleration of the body.

Results

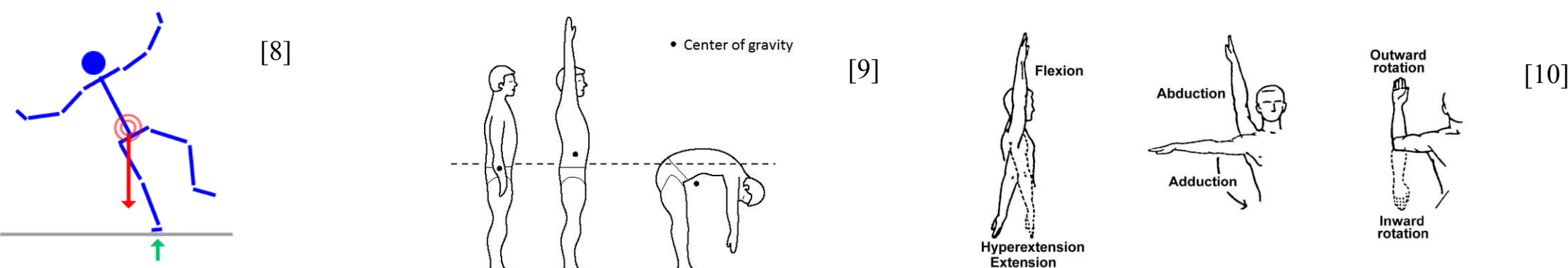
- The estimated forces clearly reflect the motion of the exercising person.
 - Forces peak when subject is performing most strenuous portion of exercise.



- The choice of a symmetric exercise (shallow squats) allows for the direct comparison of the forces between symmetric joints (knees).

Future Work

- This data may be smoothed through the use of a quaternion filter to better represent observed motion.
- This model forms a basis for the study of other aspects of human health via the Kinect camera
 - The person's ability to stay balanced while exercising
 - The person's ability to exert muscular strength for an extended period of time
 - The range of motion that the person can express in the course of exercise



- A model can be created that will evaluate the person's overall health based on these data and recommend proper exercises to address areas of physical weakness.

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Teleimmersion Lab

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