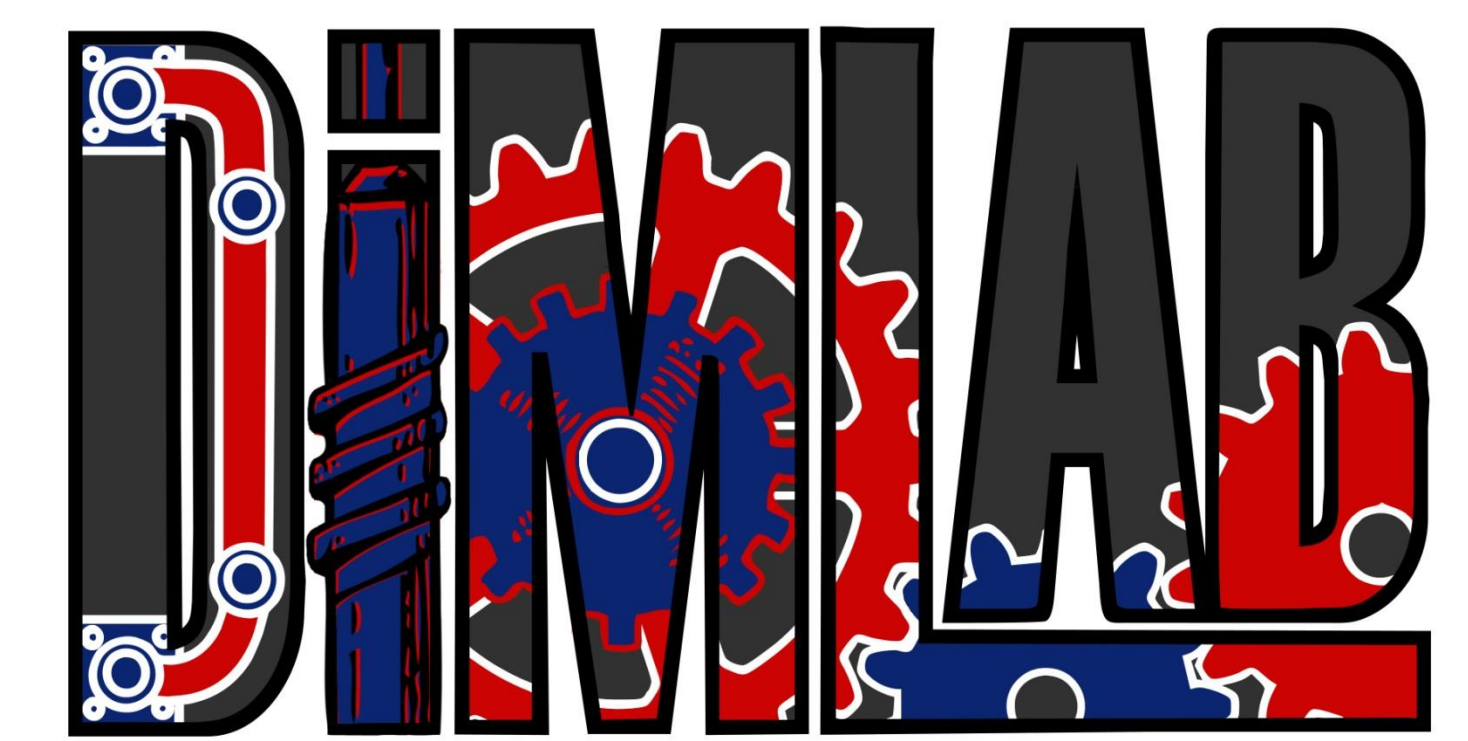


# RAPIDLY LOCATING AND ACCURATELY TRACKING THE CENTER OF MASS USING STATICALLY EQUIVALENT SERIAL CHAINS

Ali Almandeel

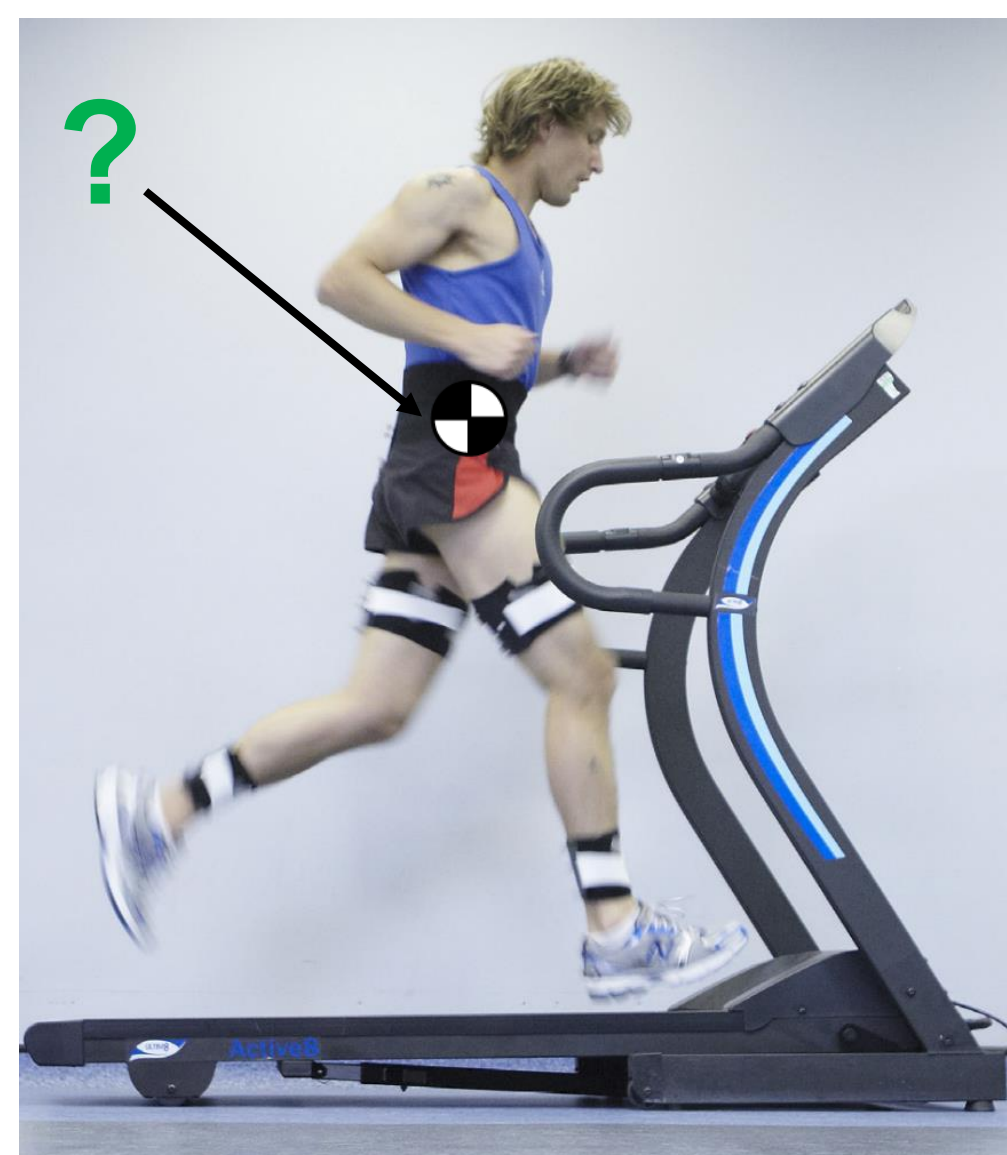
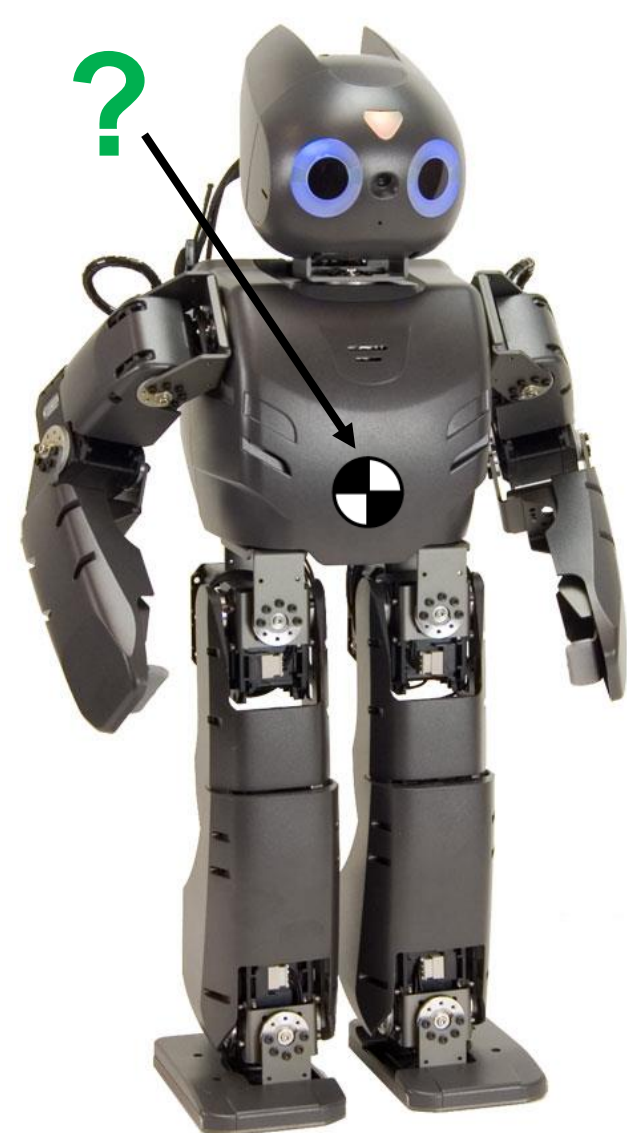
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## Introduction/Motivation

Identifying the center of mass location (CoM) provides a significant aid in controlling the balance of humanoid robots. For human beings, the stability of motion is highly influenced by their ability to control their CoM and center of pressure (CoP). Additionally, computing the CoM can prove critical to assessing rehabilitation and in elite sports training.

This research presents an estimation technique that uses the statically equivalent serial chain (SESC). A SESC is a representation of any multilink branched chain, like a human or humanoid, whose end-effector locates the CoM.

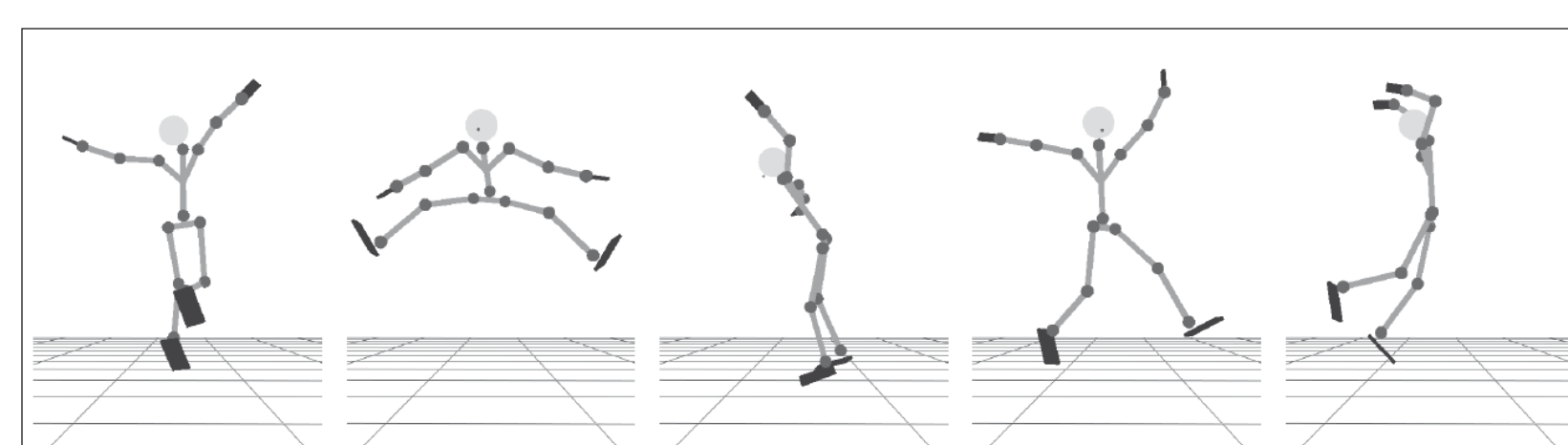


## Common Methods

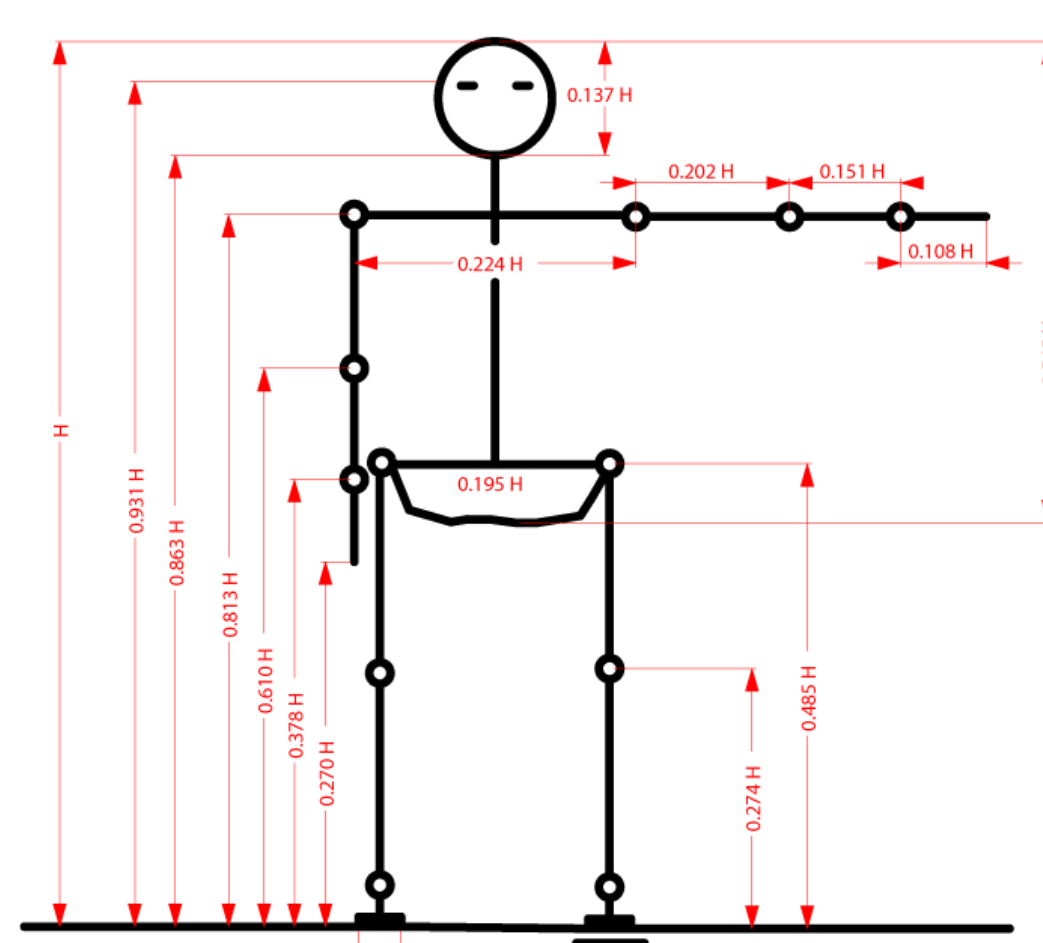
Anthropometric tables but their accuracy is readily questioned.  
Low-Pass Filter & Second Integral utilize force plate continuously.  
Floating-base dynamics require jumping motion in order to excite the body dynamics.



Schepers, H. Martin, et al. "Ambulatory estimation of center of mass displacement during walking." *Biomedical Engineering, IEEE Transactions on* 56.4 (2009): 1189-1195.



Ayusawa, Ko, Gentiane Venture, and Yoshihiko Nakamura. "Identifiability and identification of inertial parameters using the underactuated base-link dynamics for legged multibody systems." *The International Journal of Robotics Research* 33.3 (2014): 446-468.



Winter, David A. *Biomechanics and motor control of human movement*. John Wiley & Sons, 2009.

## Method

### Node-Based Statically Equivalent Serial Chain

Force Plate

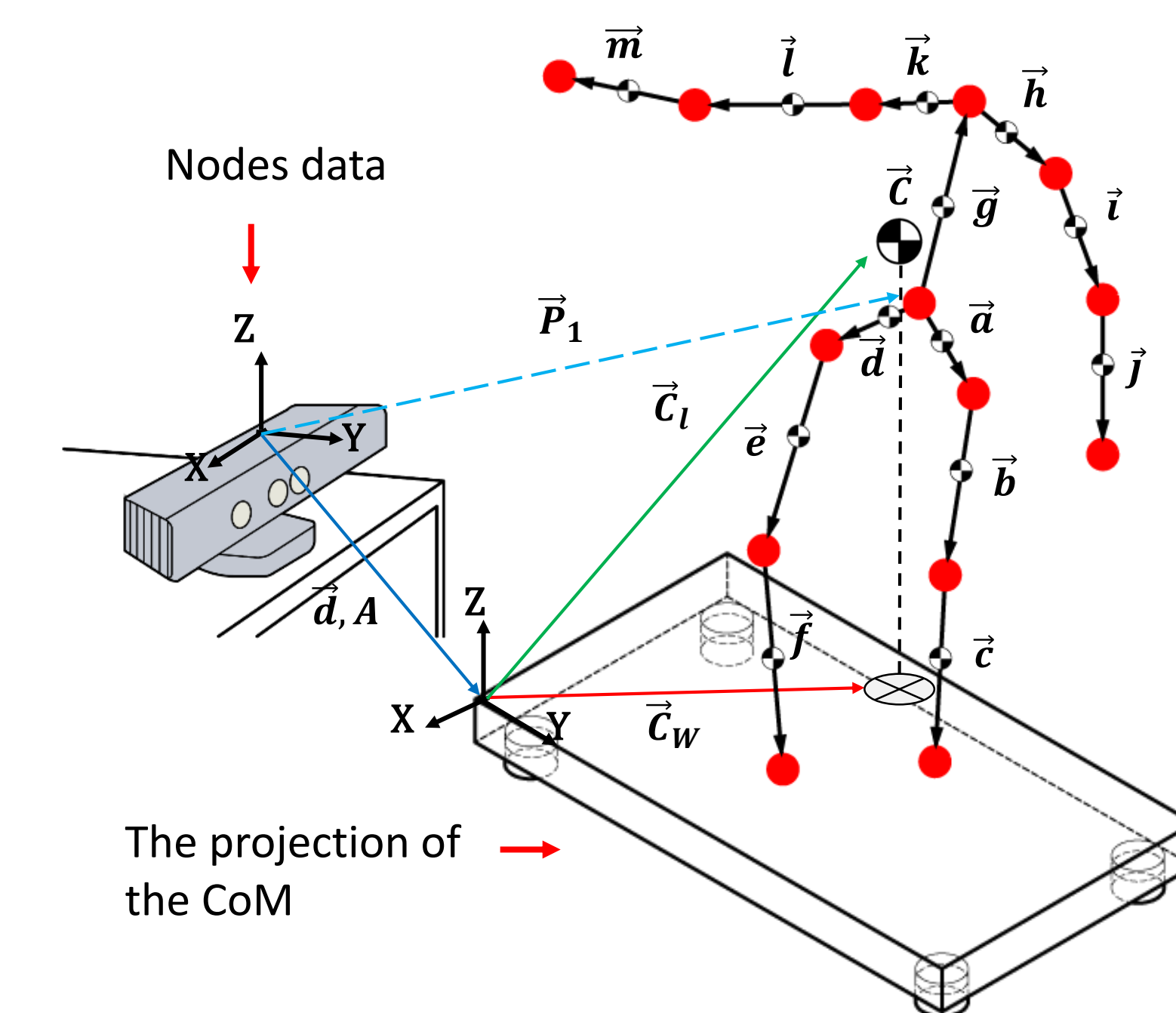
MoCap

SESC

$$\vec{C} = \vec{P}_1 + [\vec{a} \quad \dots \quad \vec{m}] \begin{Bmatrix} s_1 \\ \vdots \\ s_{13} \end{Bmatrix}$$

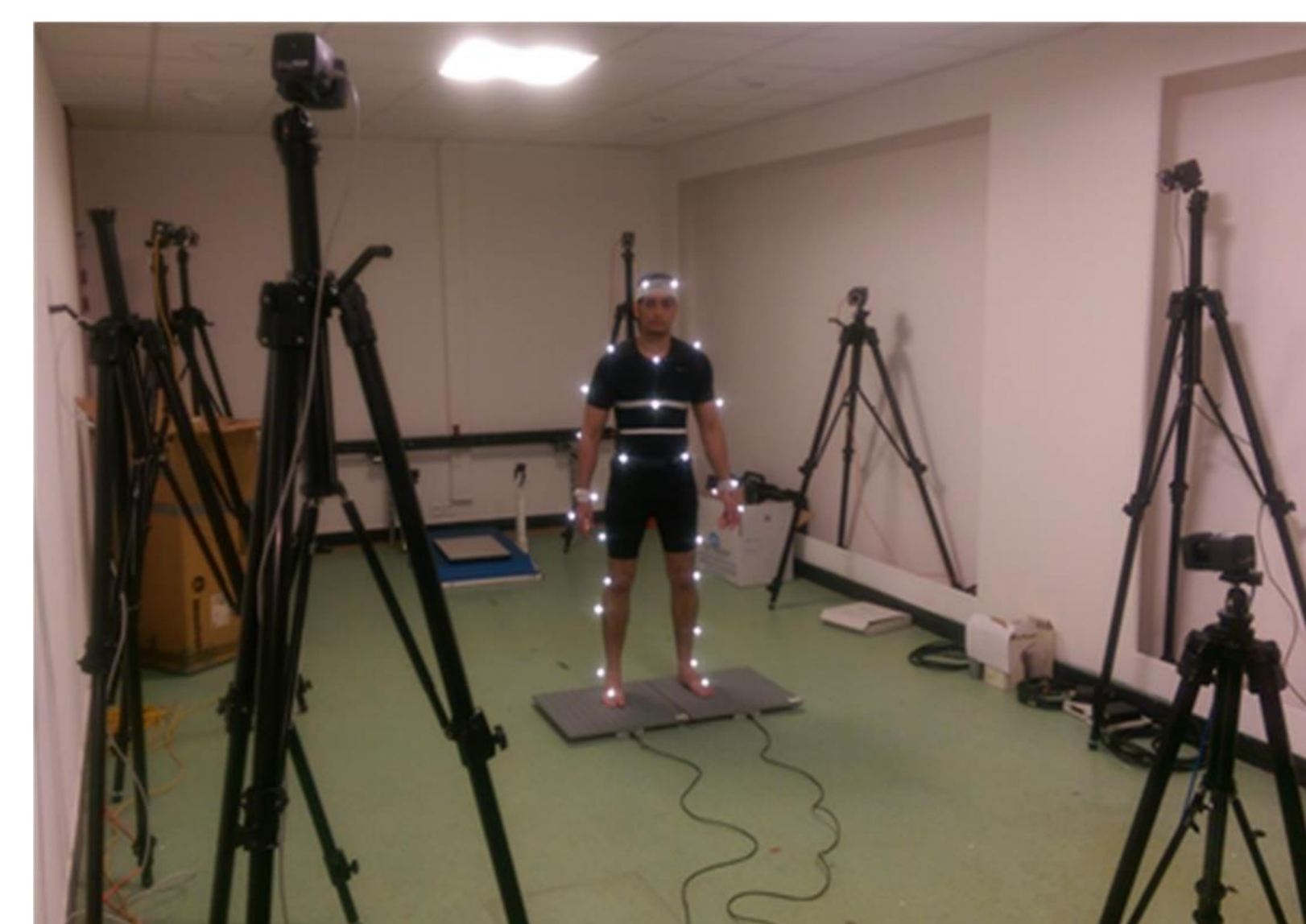
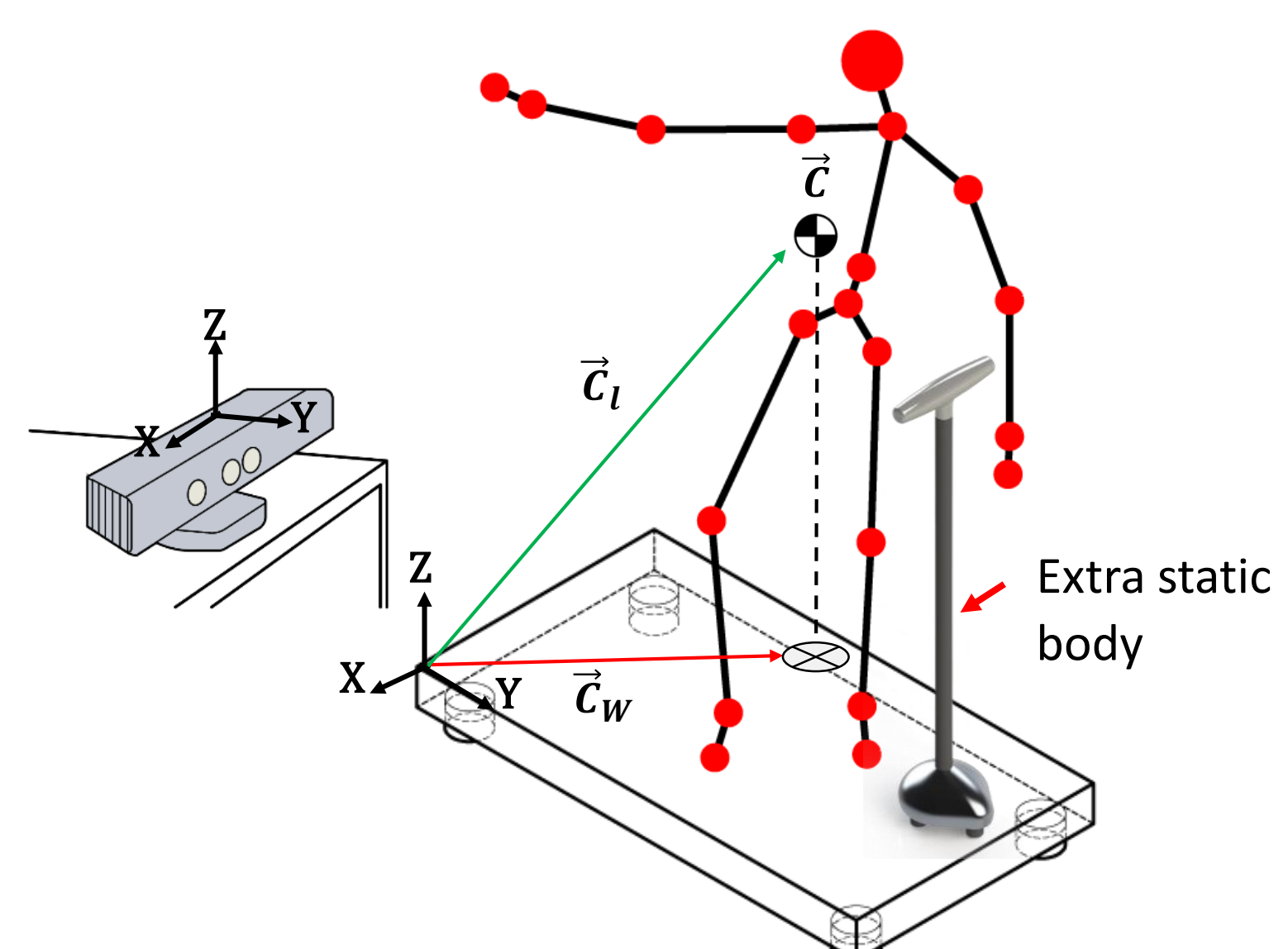
## SESC Construction

Depends on the node positions from a motion capture system (MoCap), like the Microsoft Kinect.  
During an experimental phase SESC also depends on the total mass and CoP from a force plate, like the Wii Balance Board.



## Extra Static Body SESC Modeling

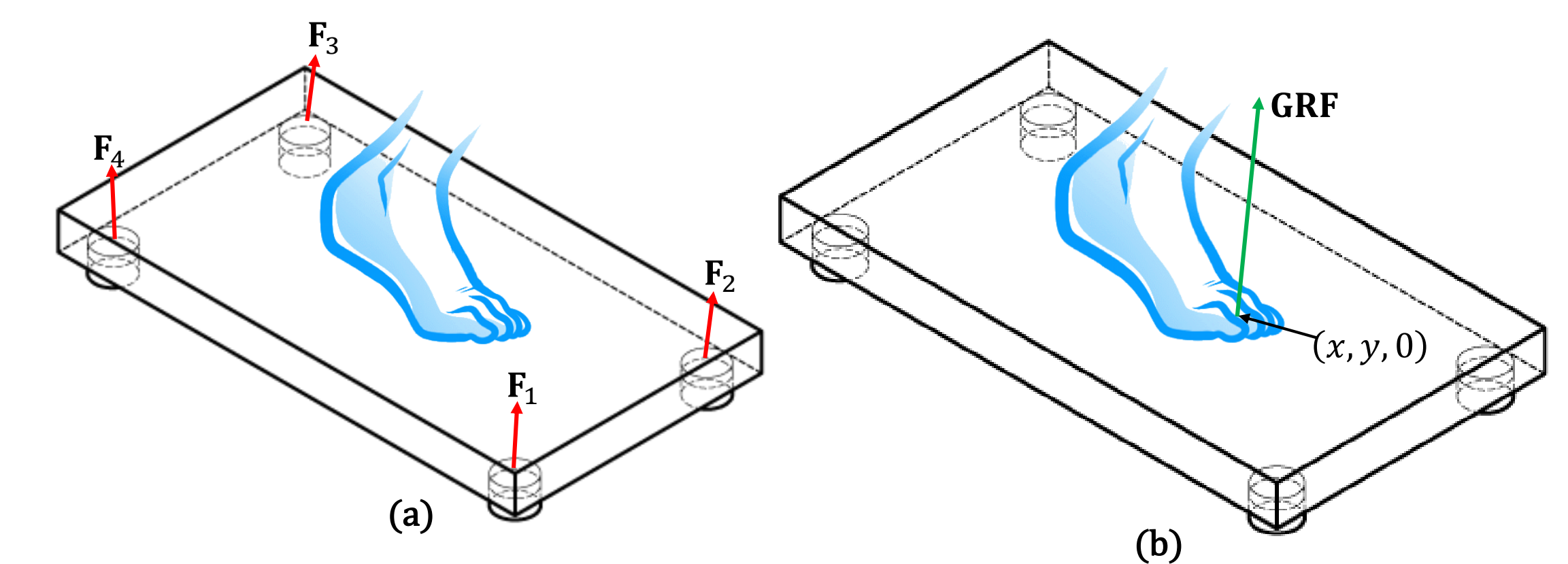
Including wheelchairs or walkers (static bodies) in the modeling process to provide support.



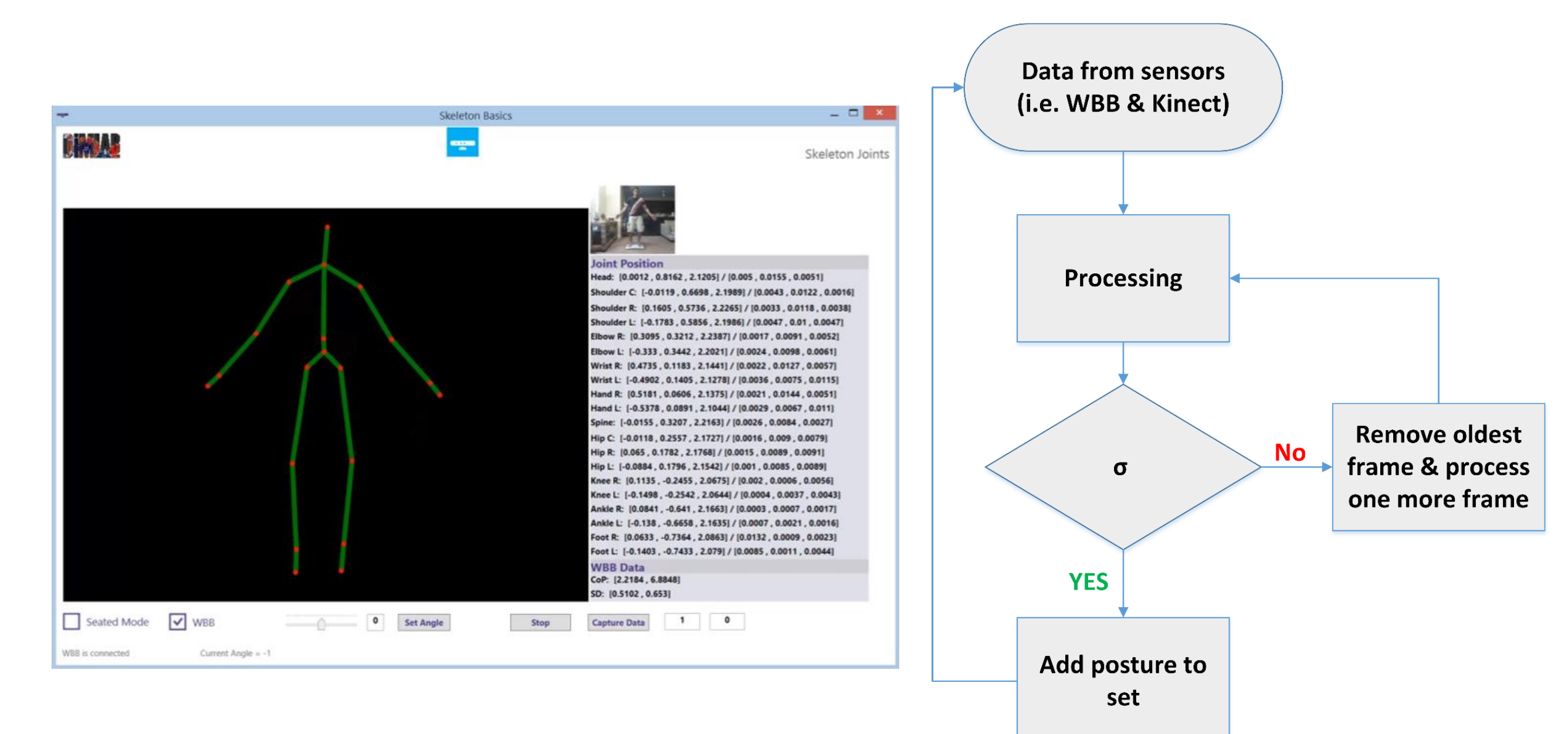
## COP Versus COM

Center of pressure is the point location of the vertical ground reaction force vector.

Center of pressure and projection of the center of mass are the same for a static posture.



## Capturing Static Poses



## Conclusion

The utility of the presented method as compared to other common methods is that the CoP, and hence, the force plate, is no longer needed after the SESC is constructed.

After constructing SESC the CoM can be estimated in real time by just using the MoCap.

Calculating the CoM can prove critical to assessing rehabilitation success in pathology detection and in the mastery of sport skills.