2023 대한재활의학회 춘계학술대회

계측화된 동작분석의 발전
Instrumented Motion Analysis

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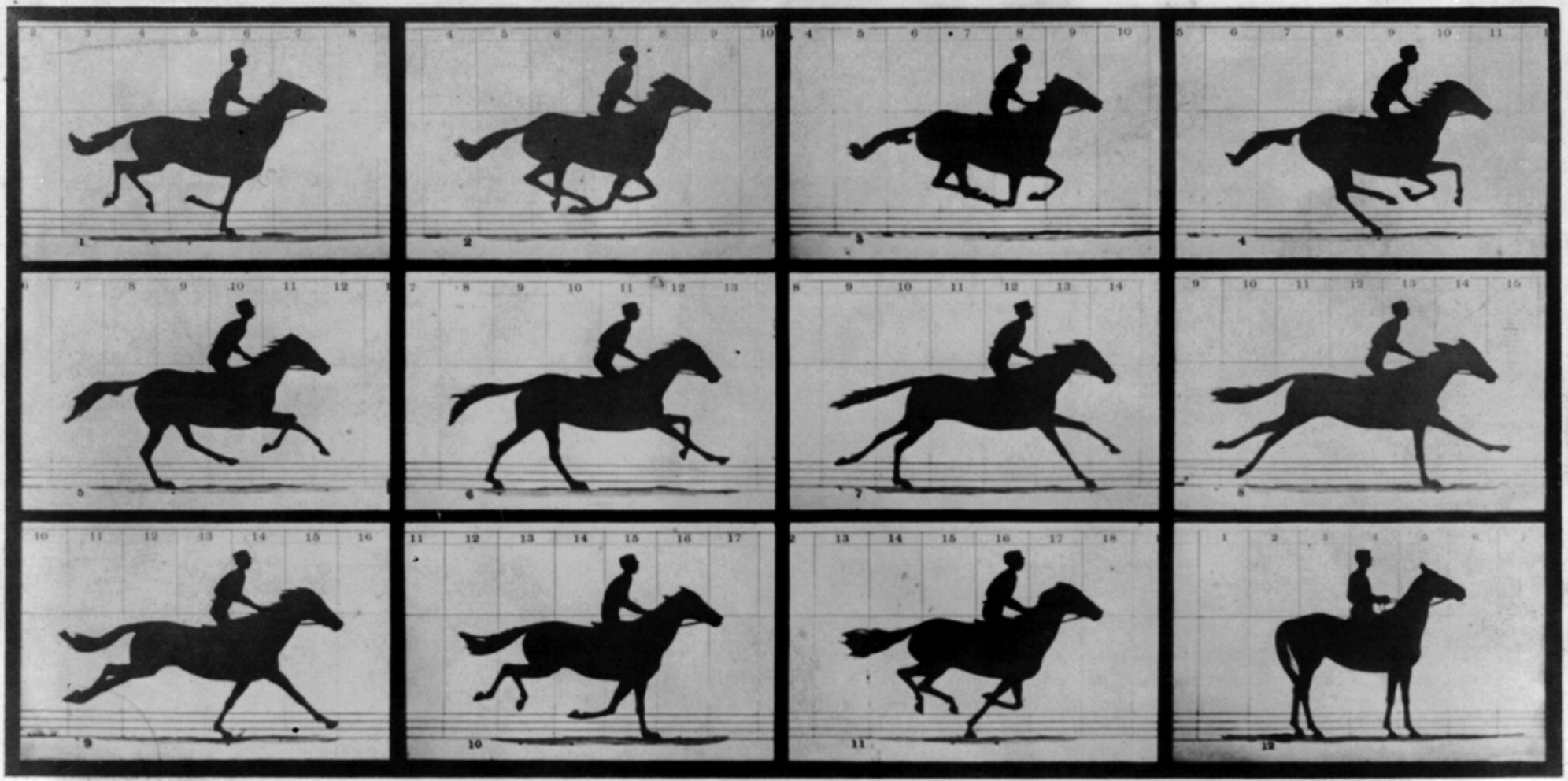
Eadweard Muybridge

- Photographer born at Apr 9, 1830
- Sallie Gardner at a Gallop (http://www.youtube.com/watch?v=PqfCmQtrTcE)
  - commissioned by Leland Stanford
  - whether a galloping horse ever lifts all 4 feet completely off the ground
  - Stanford's farm (Stockfarm) in Palo Alto on June 19, 1878
  - 24 cameras (27 inches apart): 58 km/h → 0.04 sec → 25fps



MORSE'S Gallery, 417 Montgomery St., San Francisco.

THE HORSE IN MOTION.

Illustrated by

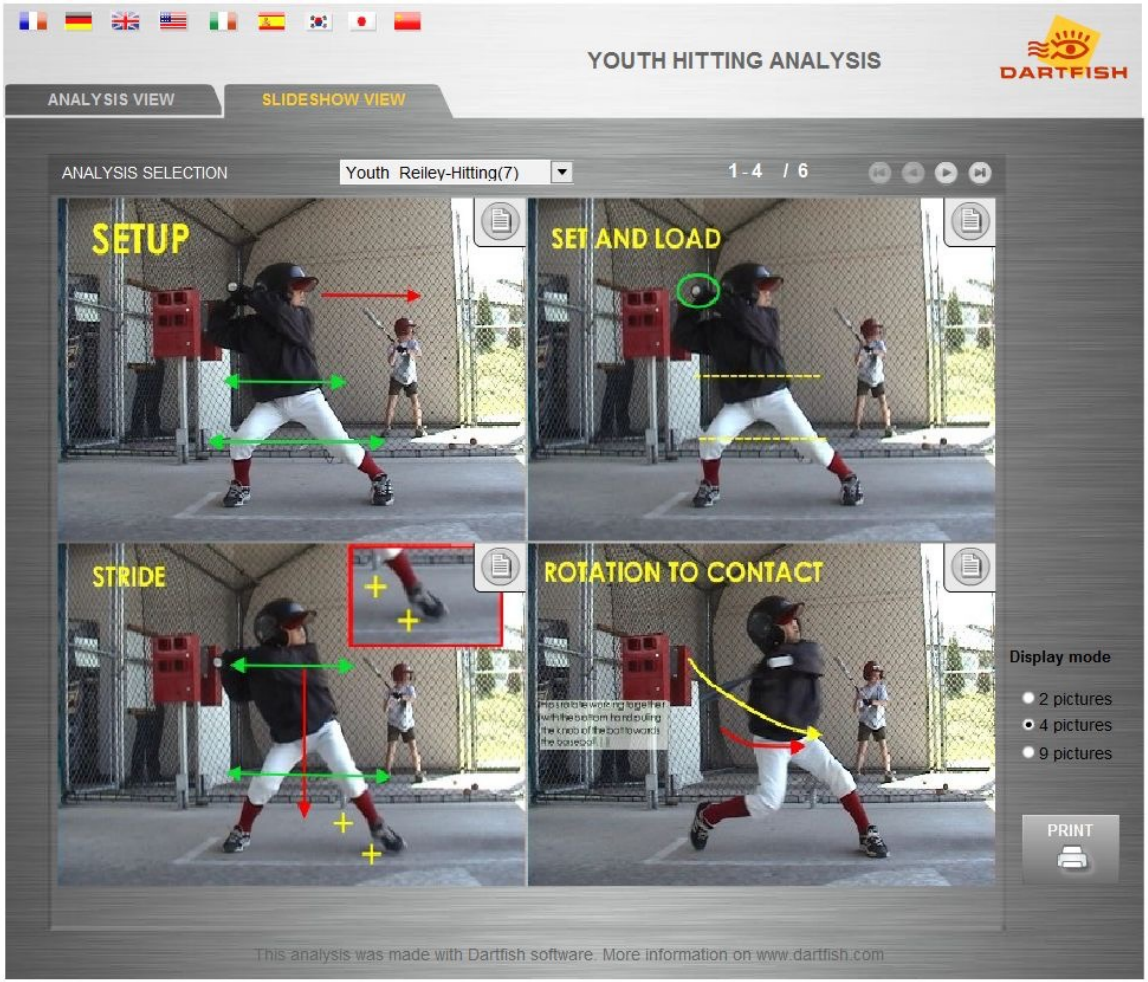
MUYBRIDGE.

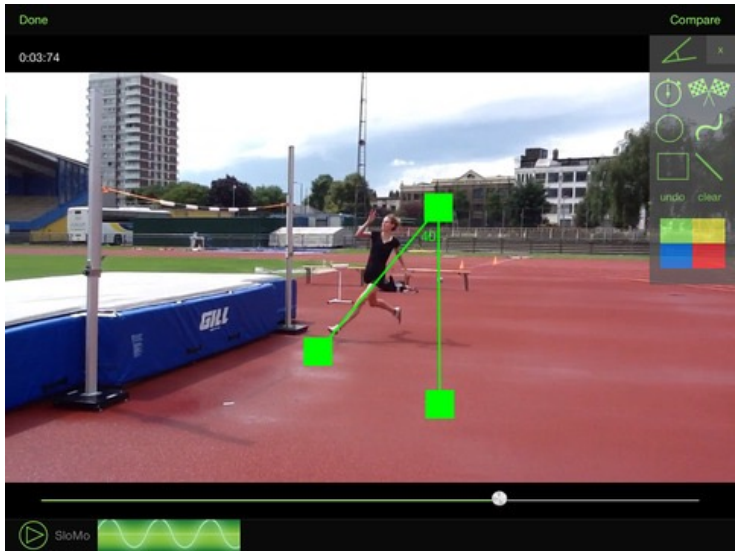
AUTOMATIC ELECTRO-PHOTOGRAPH.

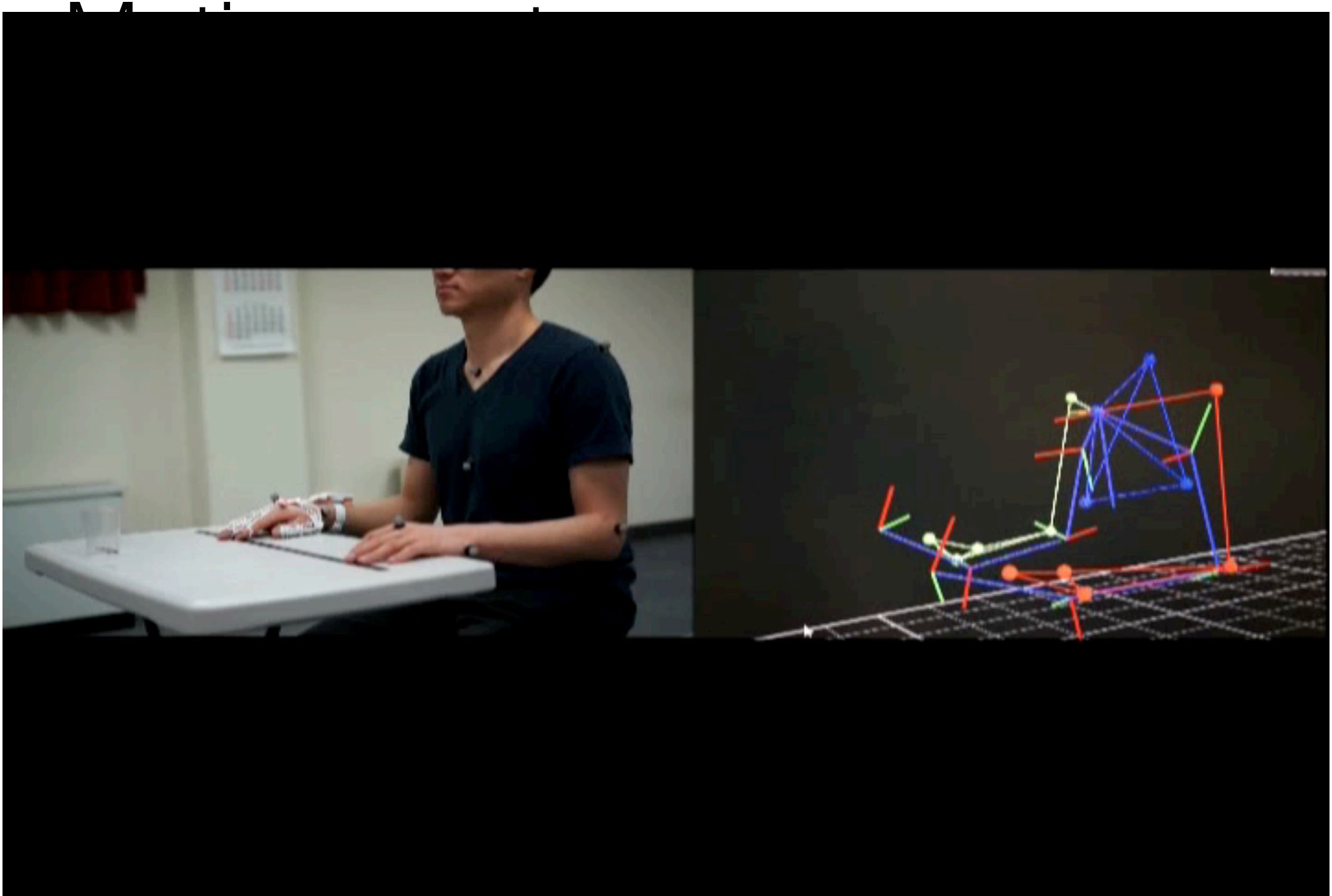
"SALLIE GARDNER," owned by LELAND STANFORD; running at a 1.40 gait over the Palo Alto track, 19th June, 1878.

The negatives of these photographs were made at intervals of twenty-seven inches of distance, and about the twenty-fifth part of a second of time; they illustrate consecutive positions assumed in each twenty-seven inches of progress during a single stride of the mare. The vertical lines were twenty-seven inches apart; the horizontal lines represent elevations of four inches each. The exposure of each negative was less than the two-thousandth part of a second.

Motion capture - pictures

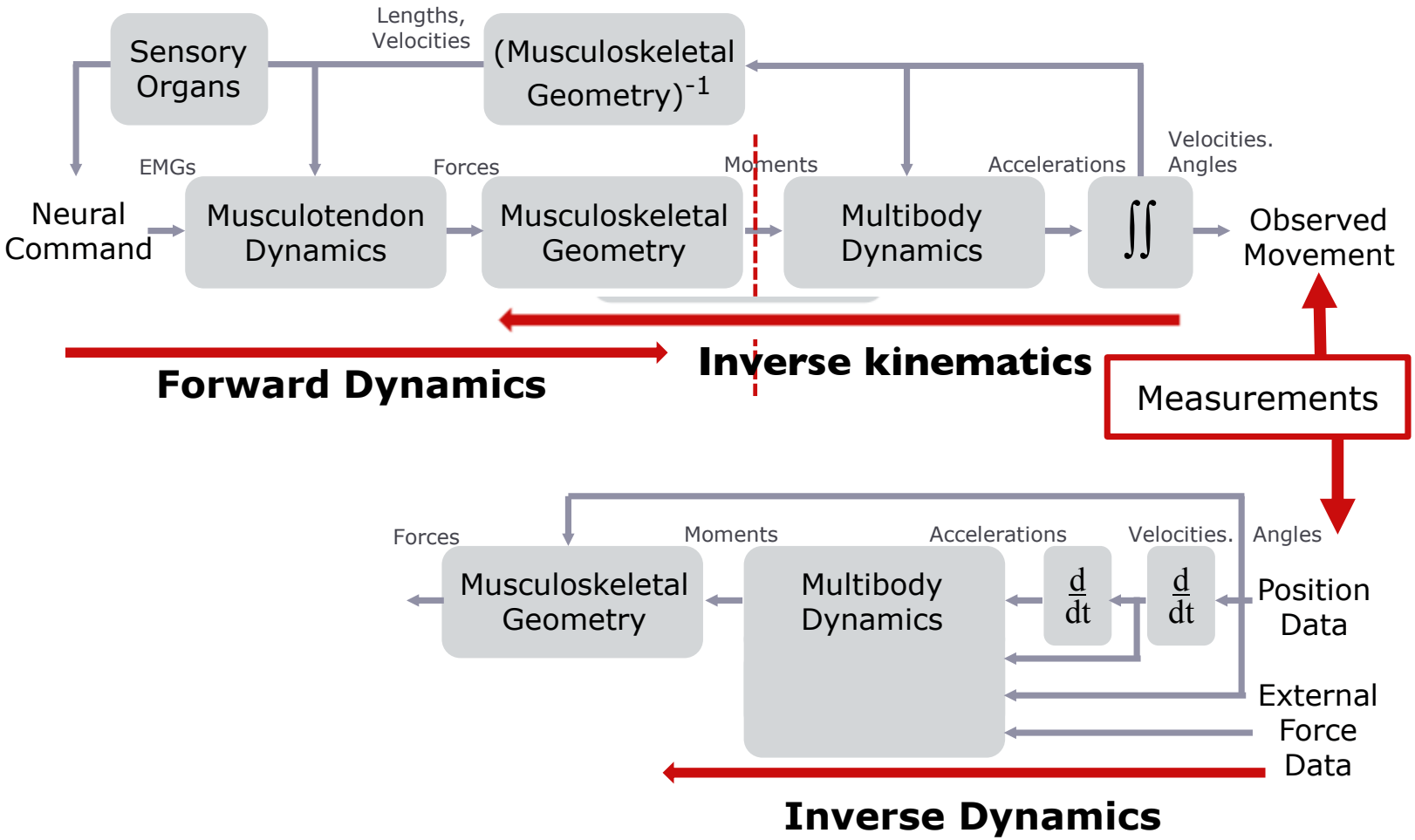






Marker-based Motion Analysis

Motion Analysis ?



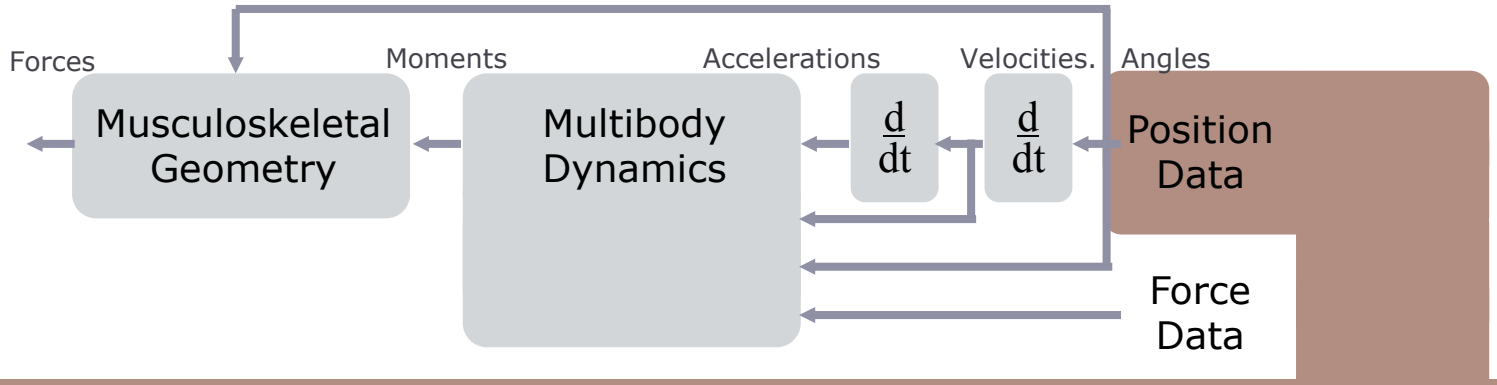
Computerized Motion Analysis

- Motion capture
- Kinematics : position, velocity and acceleration of body segments without consideration of causes
- Kinetics : relationship between motion and its causes, namely forces and torques
- EMG activity

Motion capture and Kinematics

- How can we determine the location of marker in space? -
- How can we measure the joint angle? -

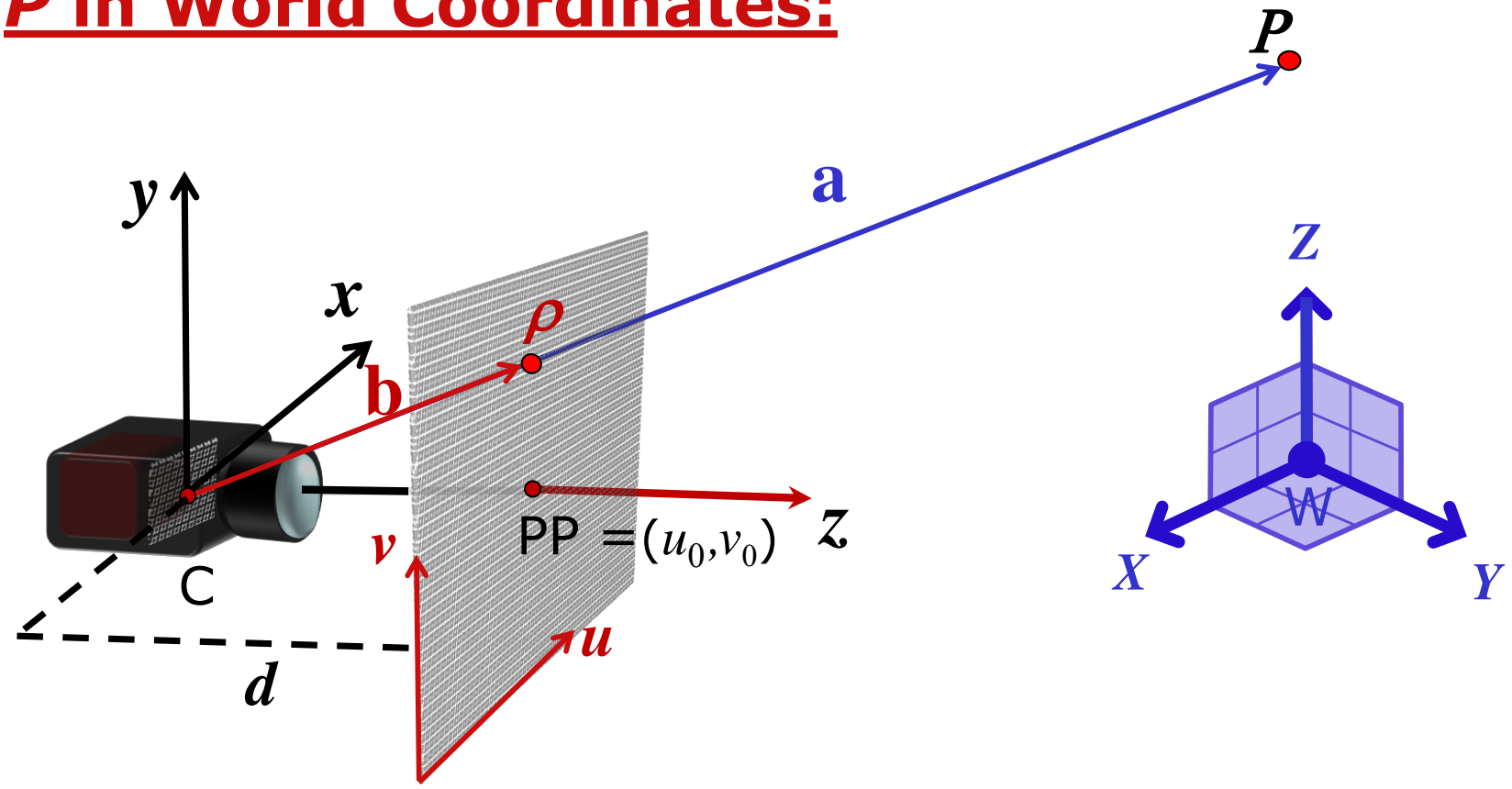
Motion capture system



Optical System

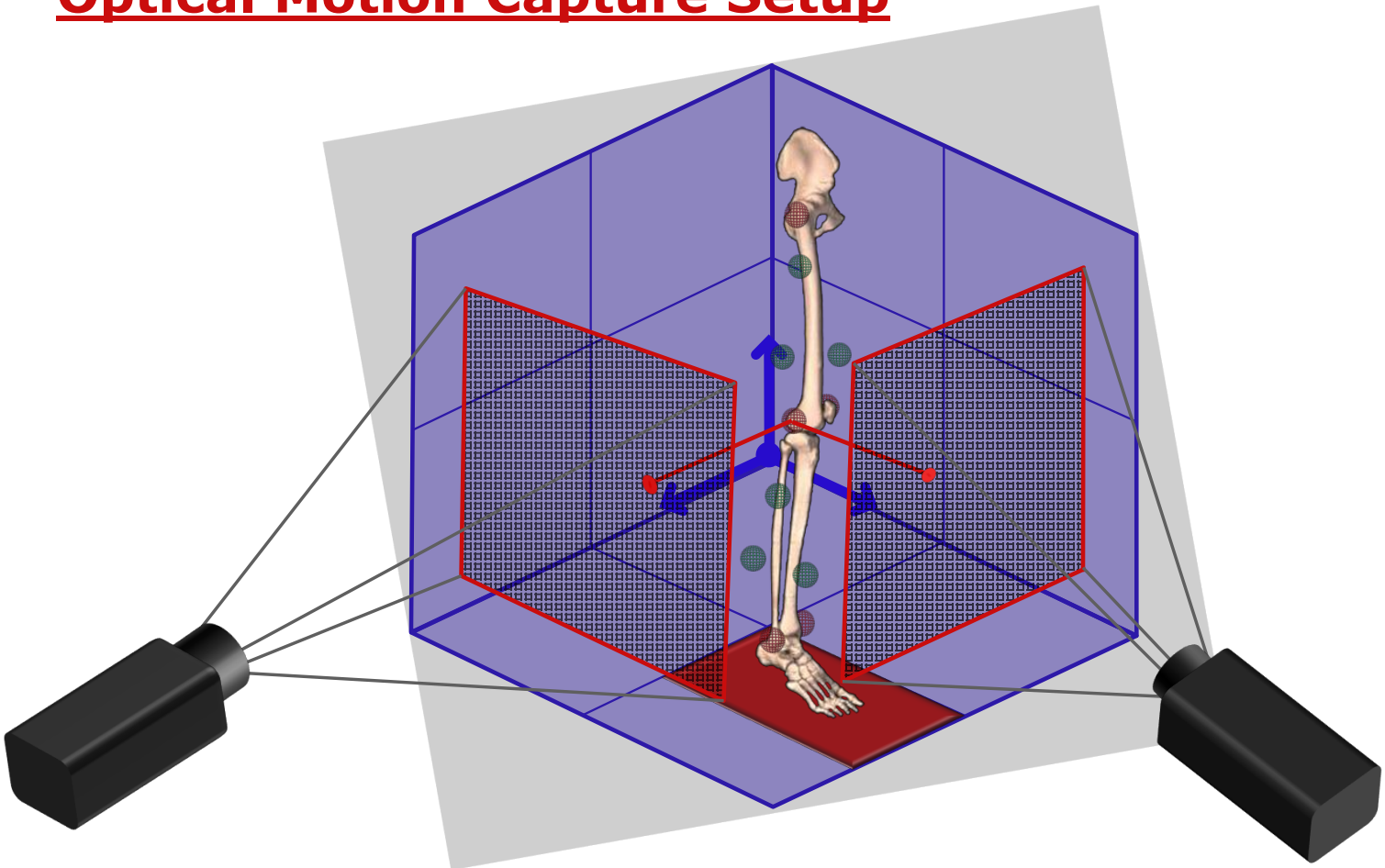
Motion capture technique (1)

P in World Coordinates:



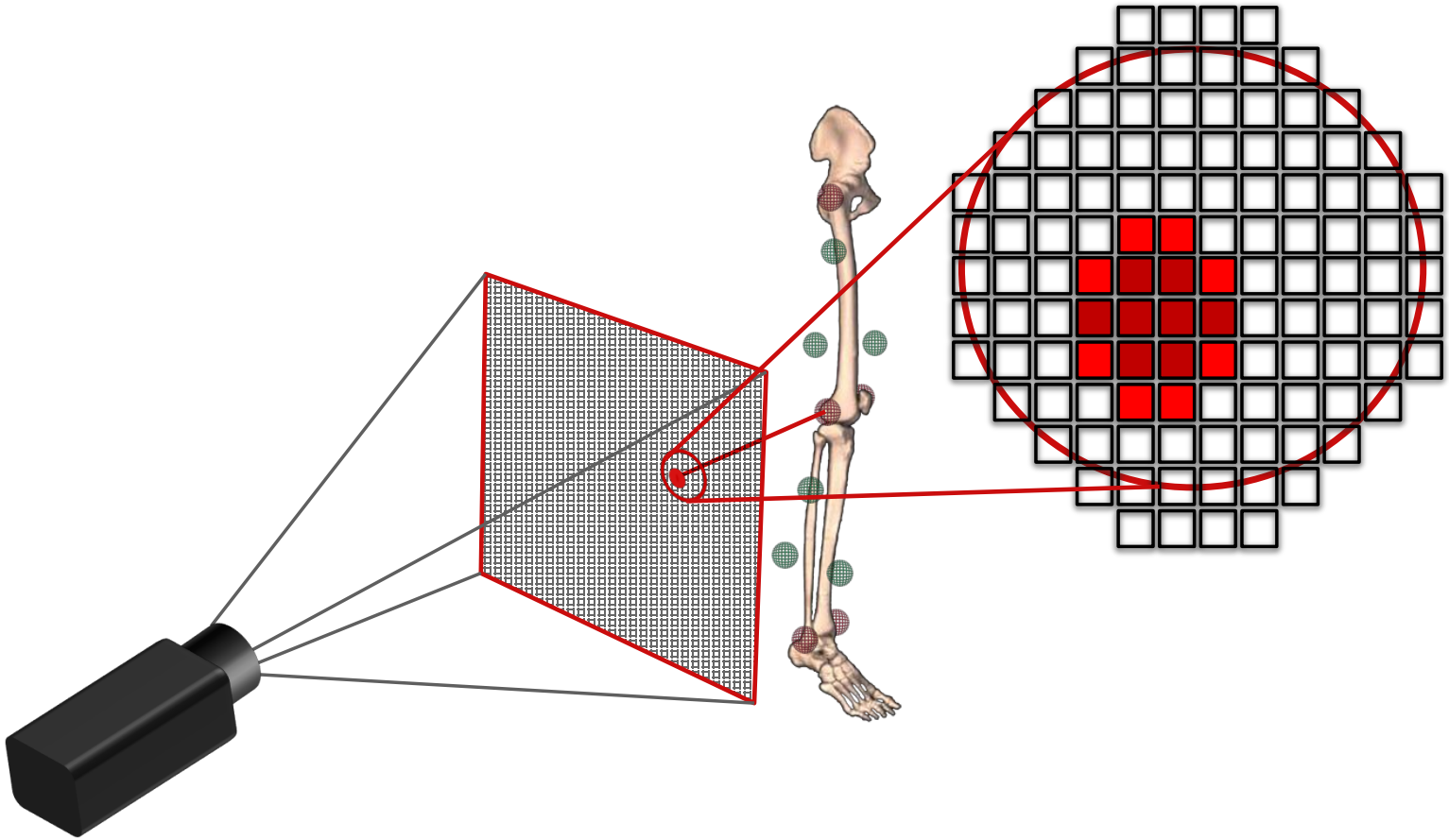
Motion capture technique (2)

Optical Motion Capture Setup



Motion capture technique (3)

Image Sensor Plane

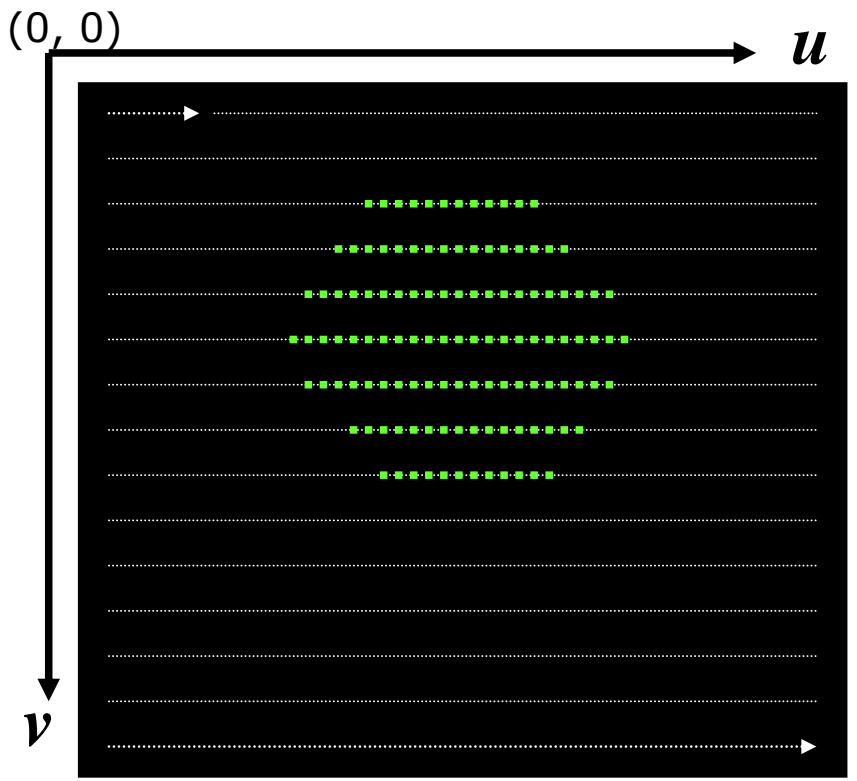


Capable of Detecting Many Markers at the Same Time

Motion capture technique (4)

Image Plane

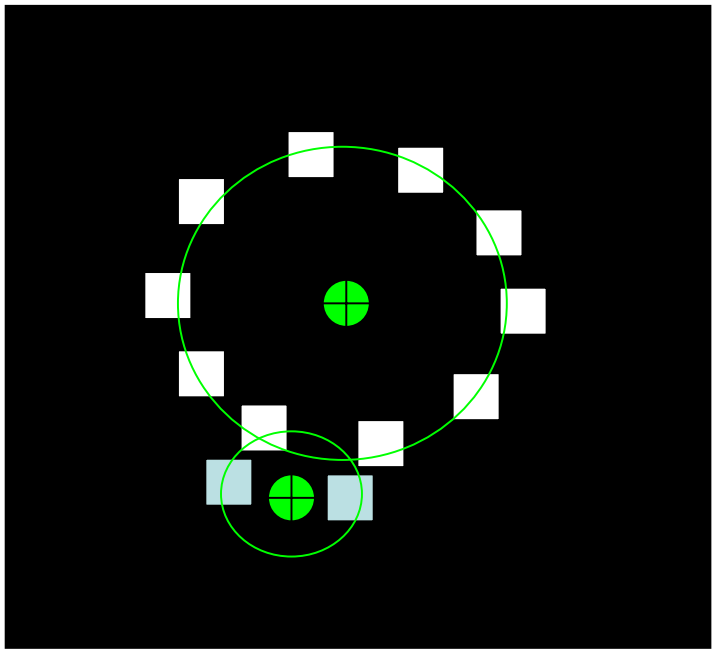
- Photosensitive detector array
- Resolution
  - **spatial** (pixels)
    - u horizontal
    - v vertical
  - **temporal**
    - scan rate



Motion capture technique (5)

Image Plane: Spatial Resolution

- More pixels are better!
- How many is reasonable?
  - Size of object
  - closeness of camera, related to field

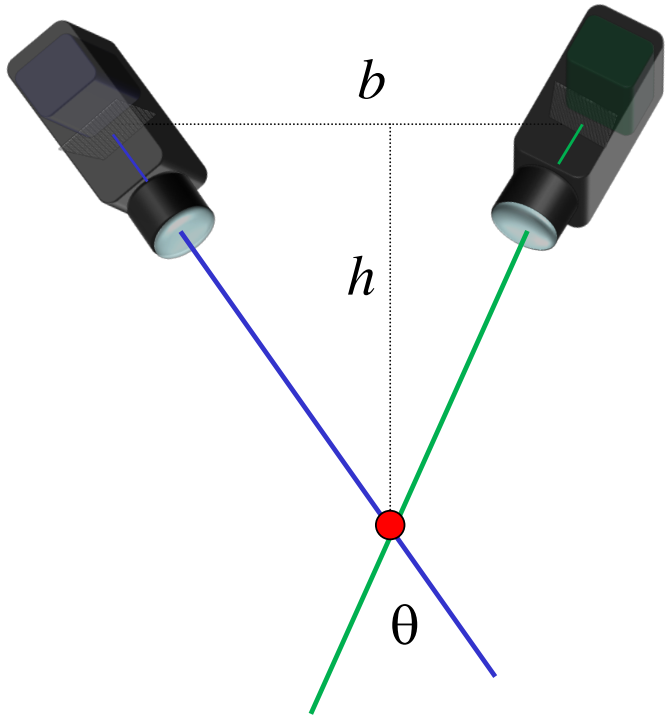


Spatial resolution

Motion capture technique (9)

Camera Placement

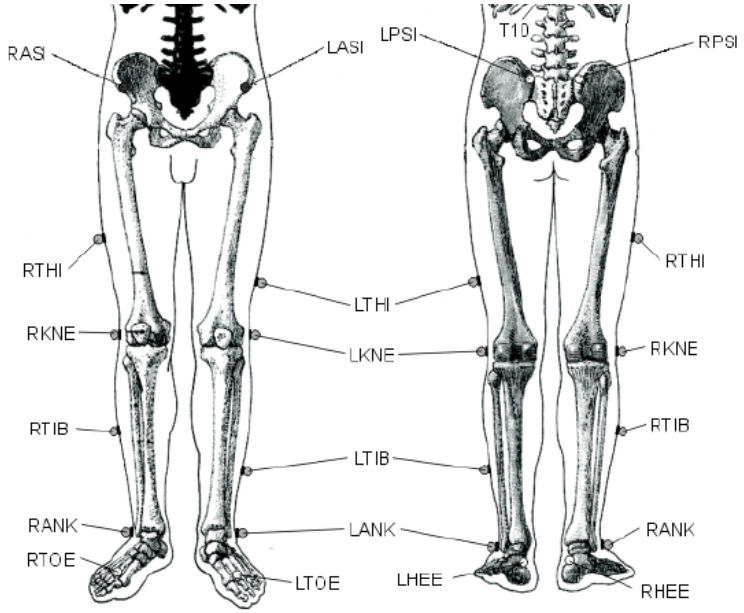
- If image planes are parallel, insufficient depth information
- Accuracy related to separation angle, θ
- Best when $\theta = 90^\circ$
  - do not fall below 60°
- base / length $\geq$ 0.3 - 0.4



$\theta > 60^\circ$

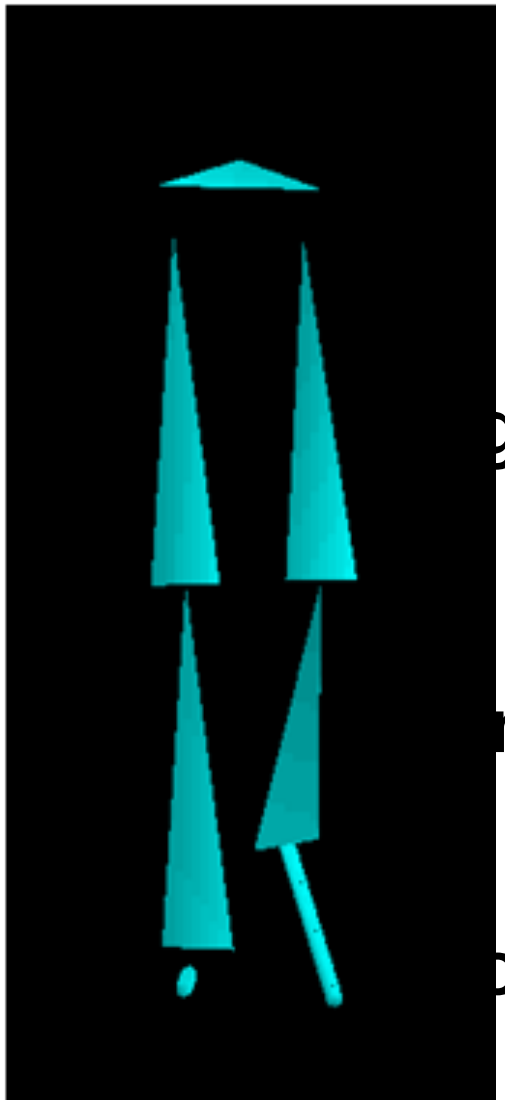
$b / h > 0.3$

Marker to Skeletal Model



Plug in gait model (marker set) in Vicon system

Plug-in-gait model



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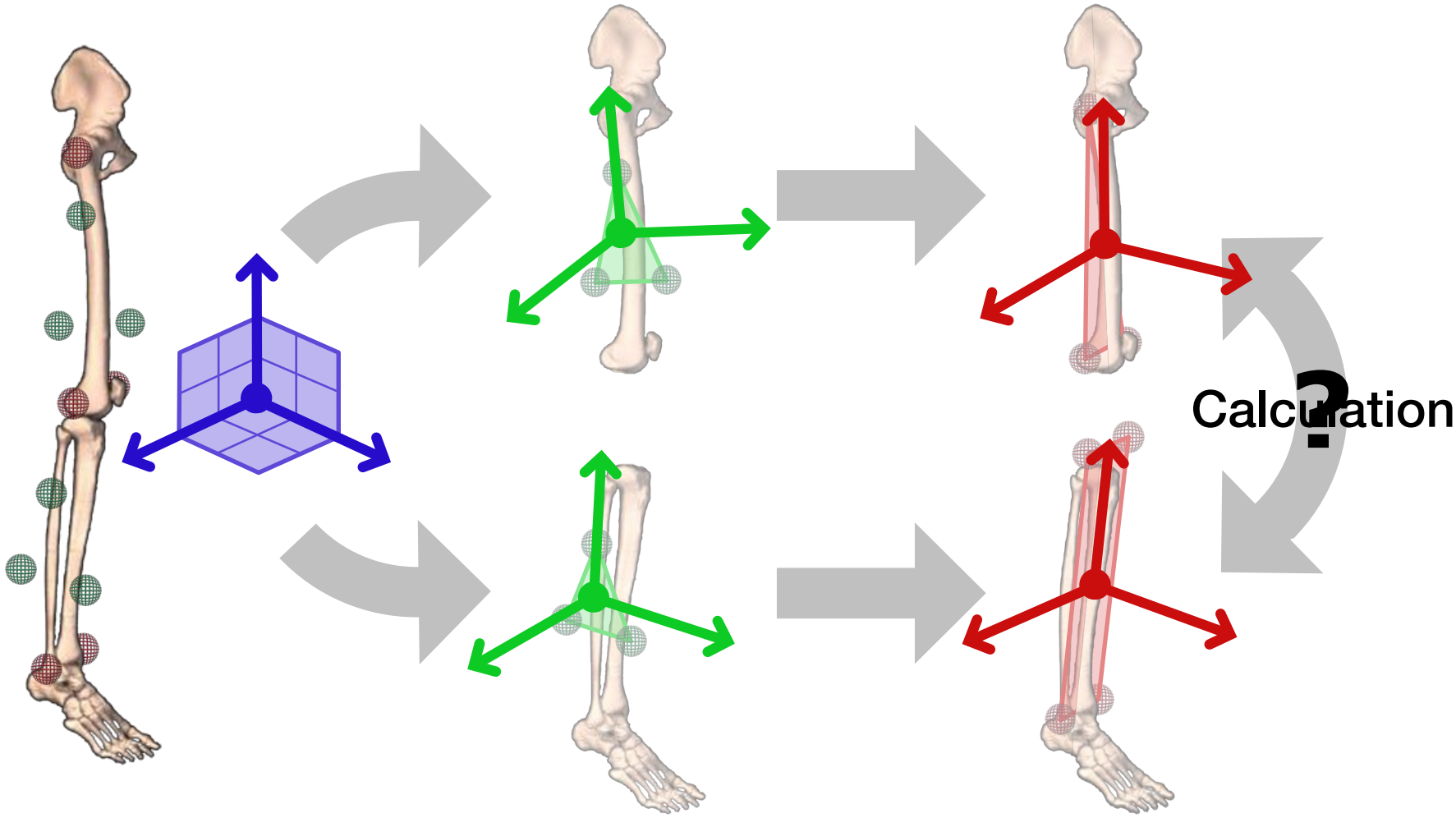
Complex **Simple**

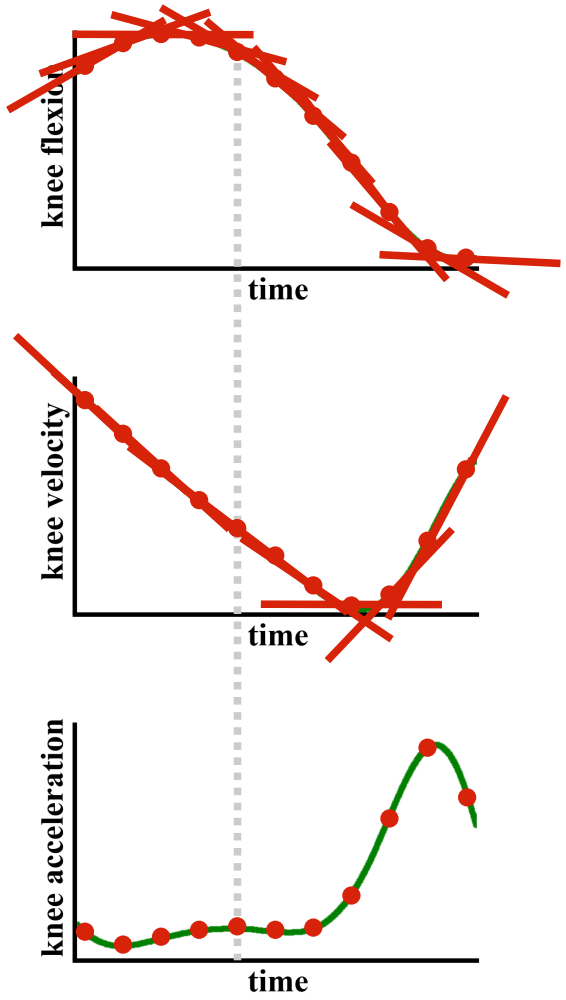
Measure Angle between coordinate frames using transformation matrix



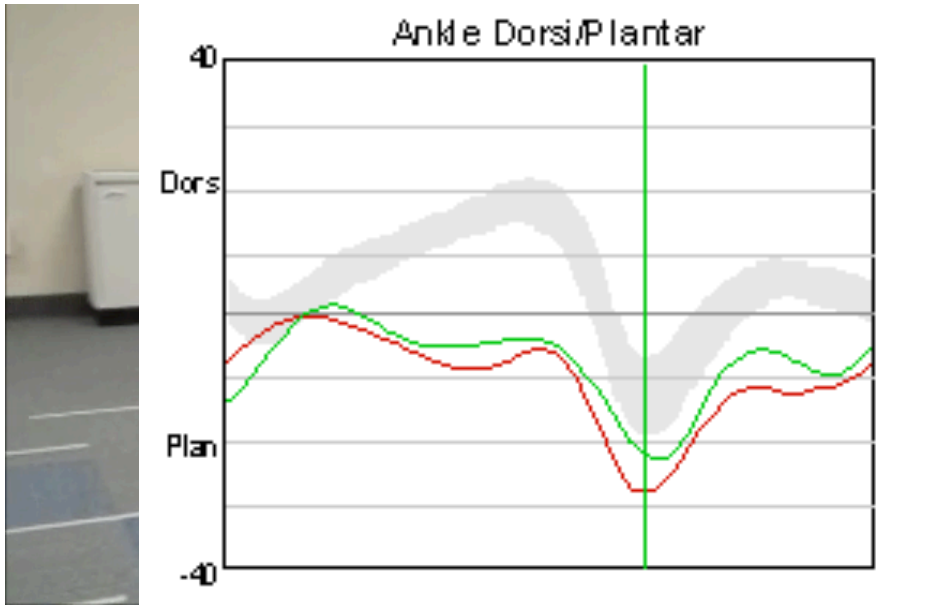
from Scott's presentation

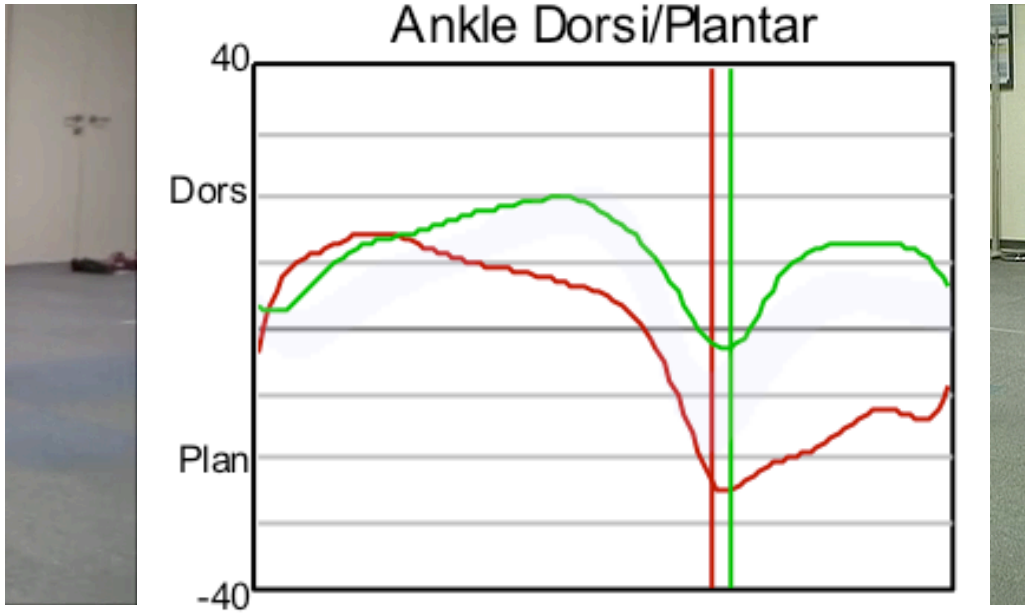
(Inverse) Kinematics

- Linear
  - Position (p)
  - Velocity (v)
  - Acceleration (a)
- Joint
  - Orientation (θ)
  - Angular velocity (ω)
  - Angular acceleration (α)



Equinus gait ?

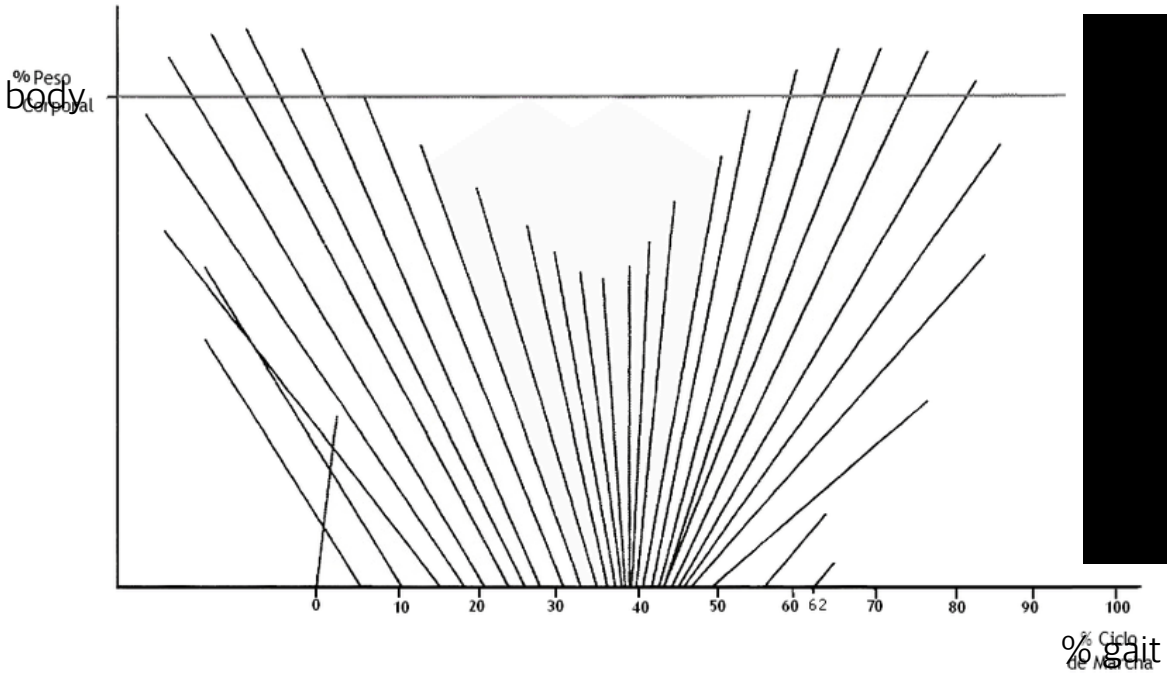


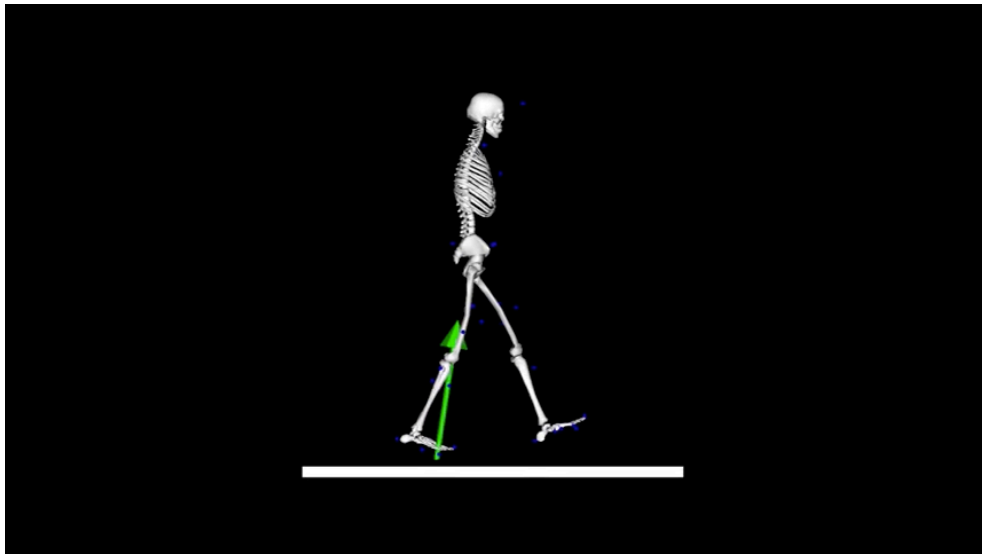


Inverse dynamics (Kinetics)

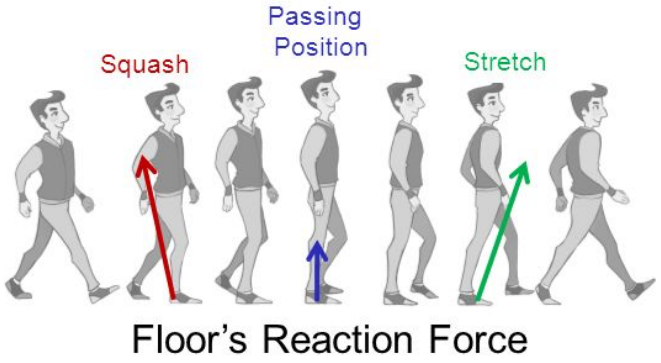
- How can we measure the joint moment(torque)? -

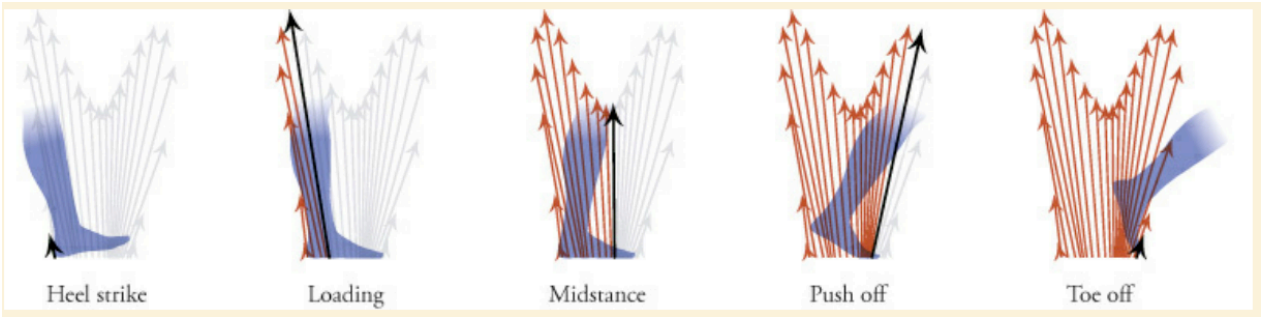
Ground reaction force

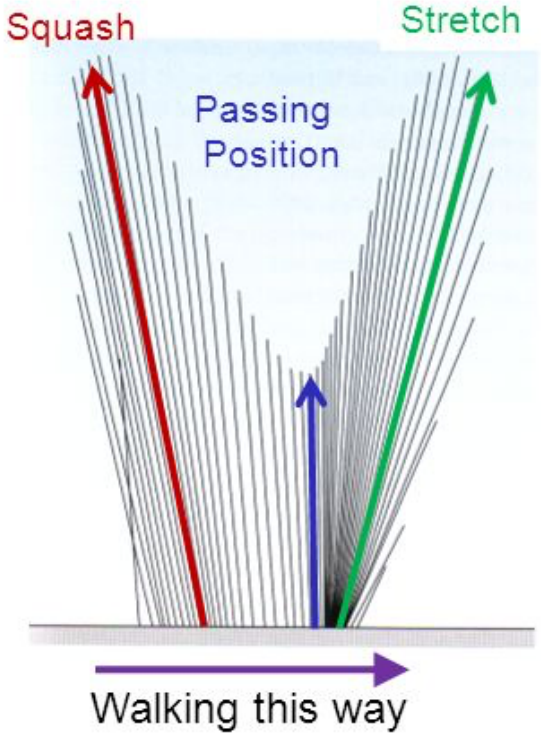


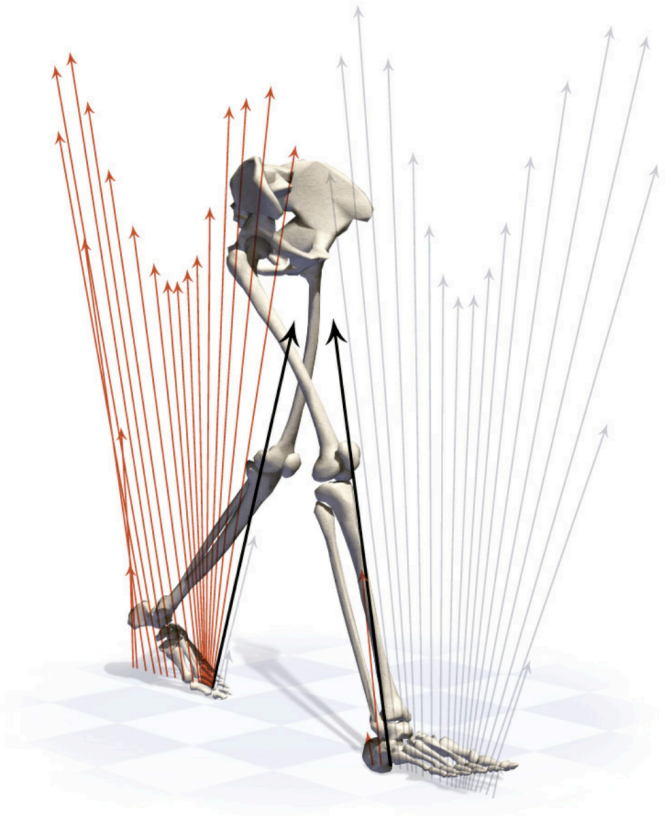


Ground reaction force





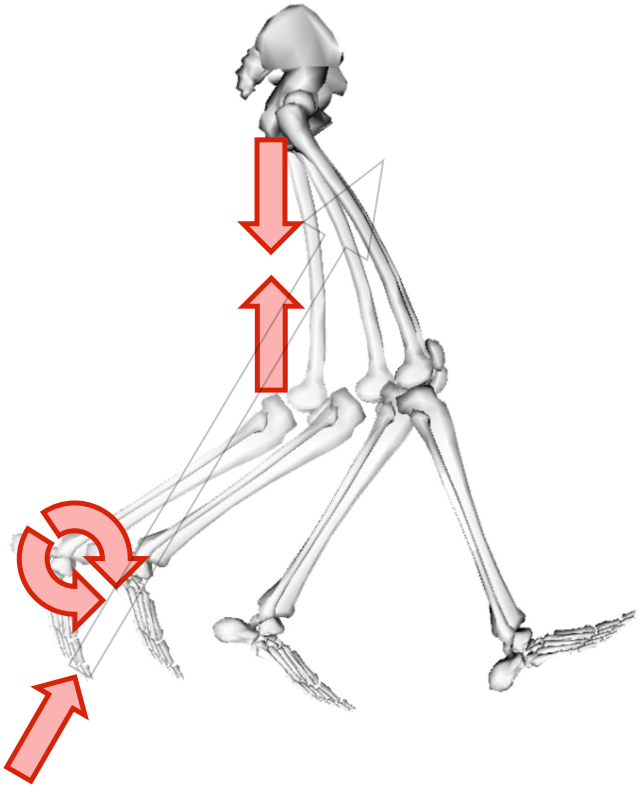




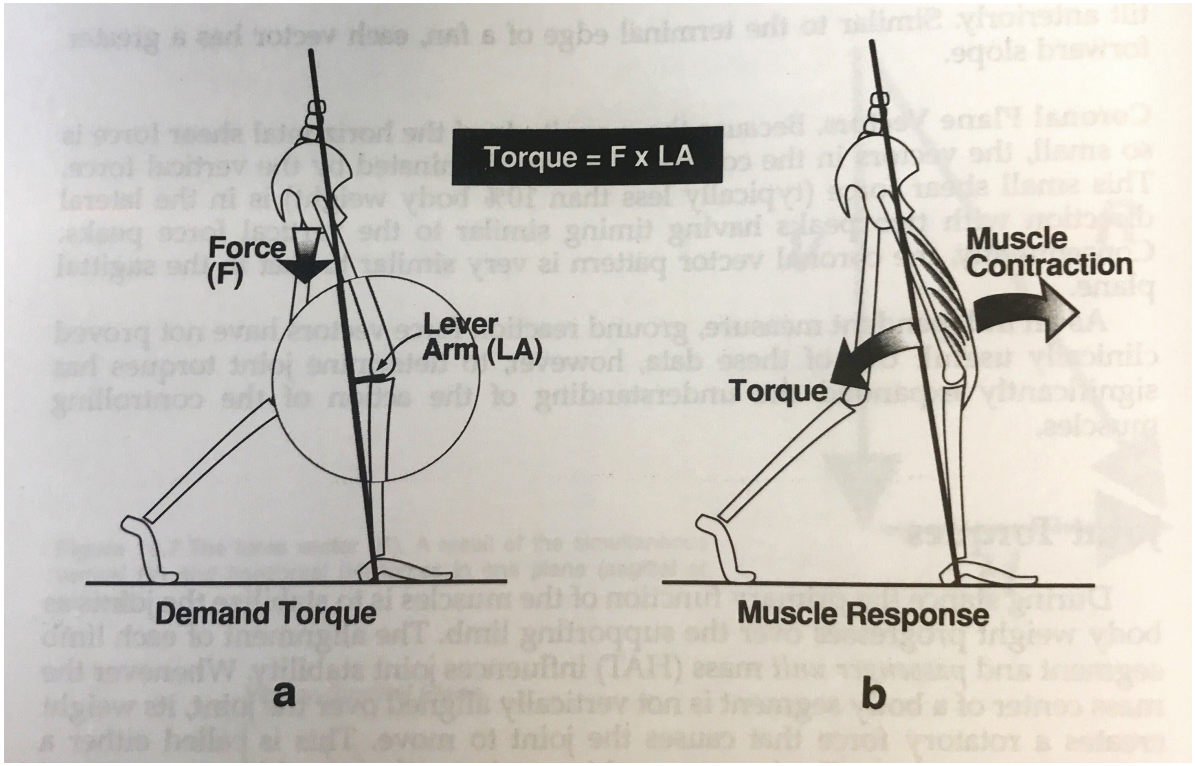
Inverse Kinetics

- Kinetics
  - Forces and torques cause the model to accelerate
- Force
  - Applied to points (e.g., ground reactions) or between points (e.g., muscles)
- Torque **(moment)**
  - Applied to a coordinate (e.g., joint torque)

- force x moment arm



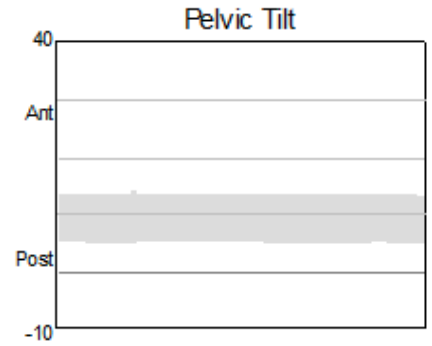
Inverse Kinetics

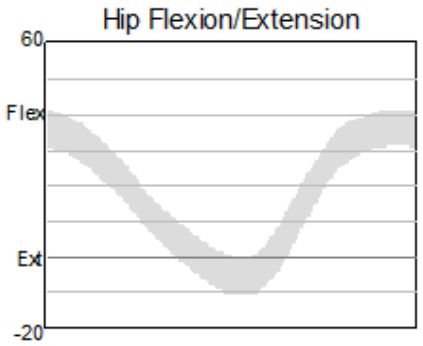


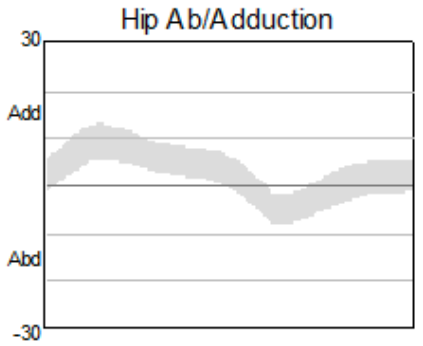
Motion = External torque (by GRF) + Internal torque (by body)

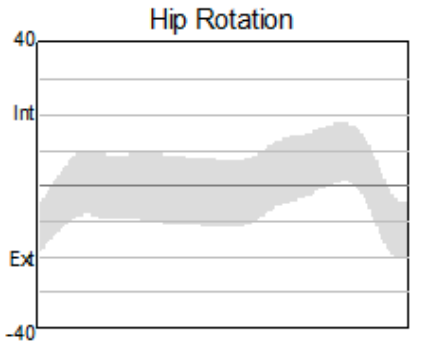
Internal torque (by body) = Motion – External torque (by GRF)

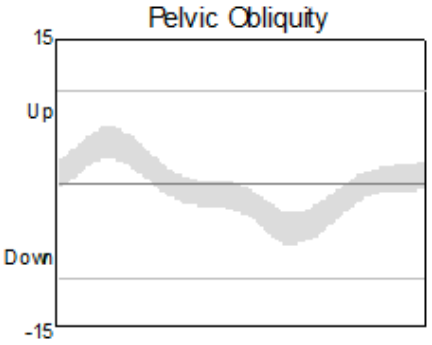
Normal gait analysis

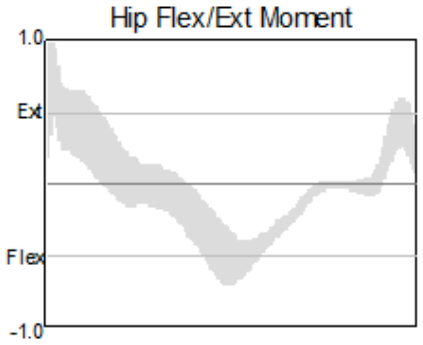


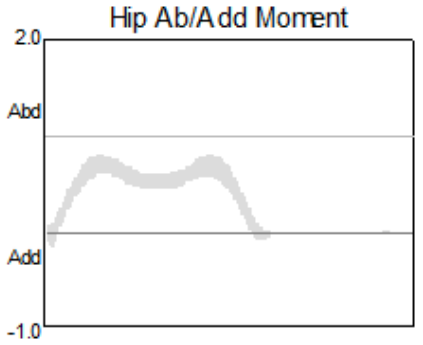


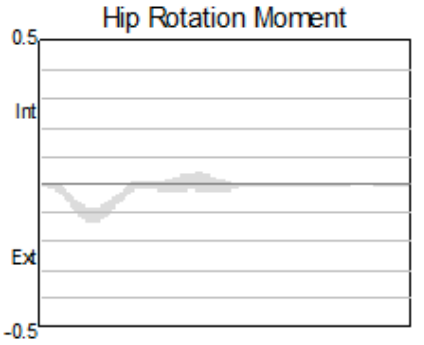


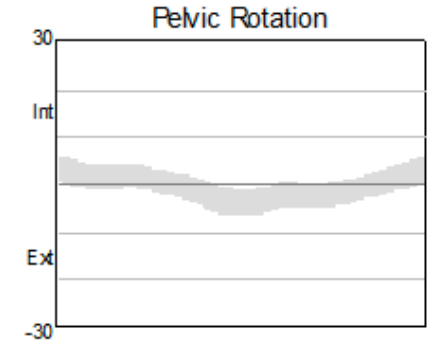


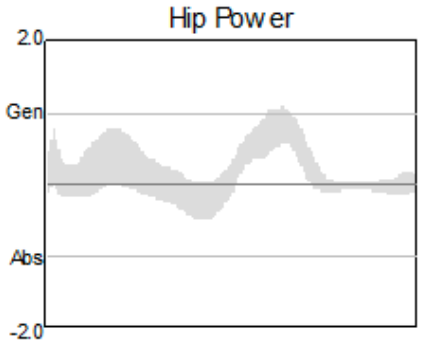




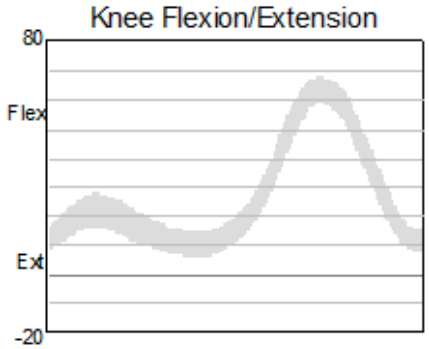


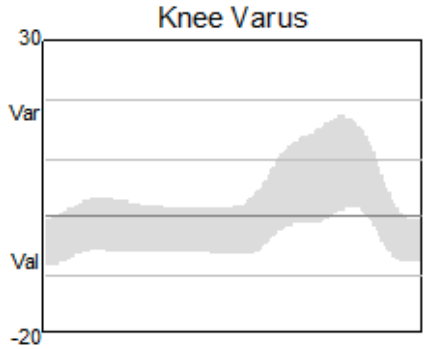


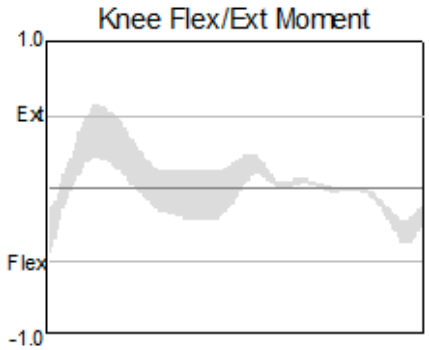


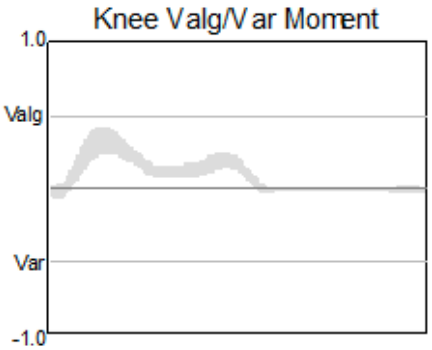


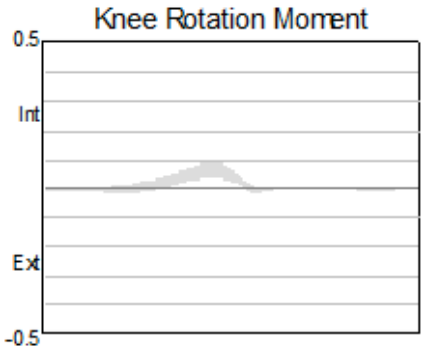
Normal gait analysis

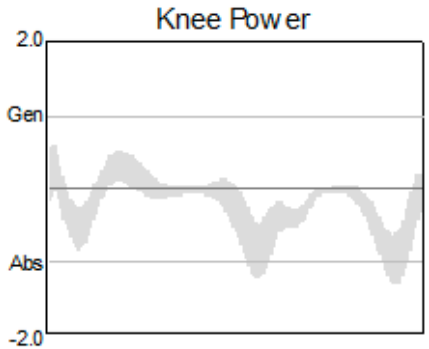












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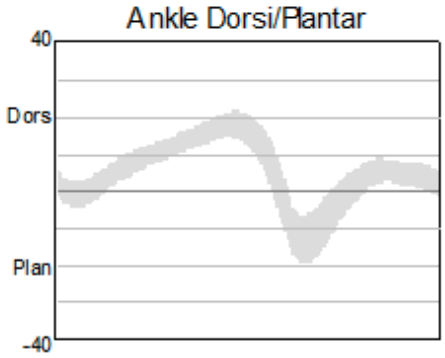

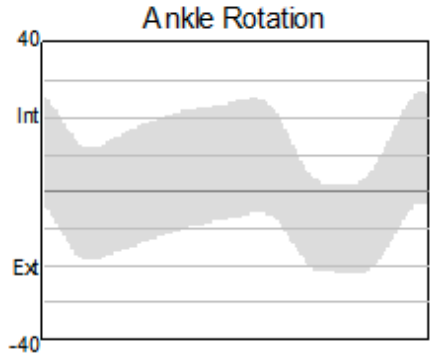

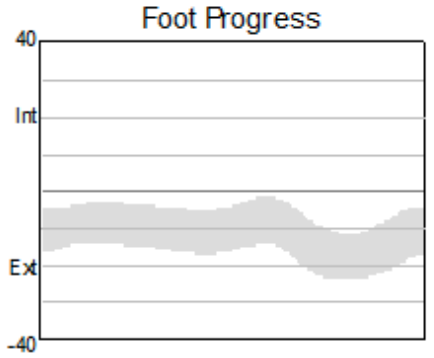

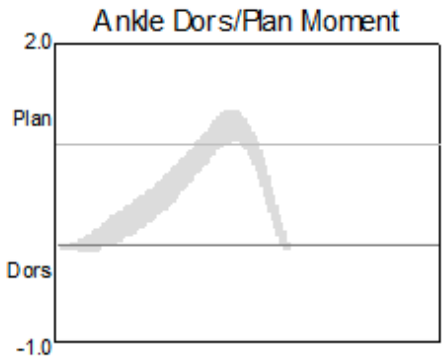

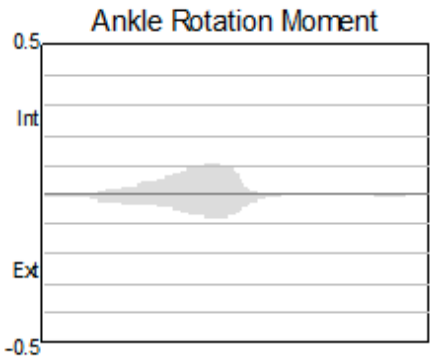

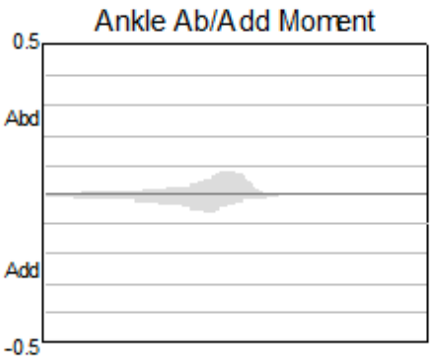

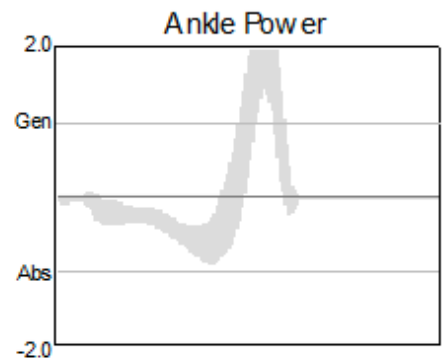

“Thank you for listening.”

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