Goals:

* Kinematics
* anthropometry
* Kinetics

} gait cycle

Movement Analysis

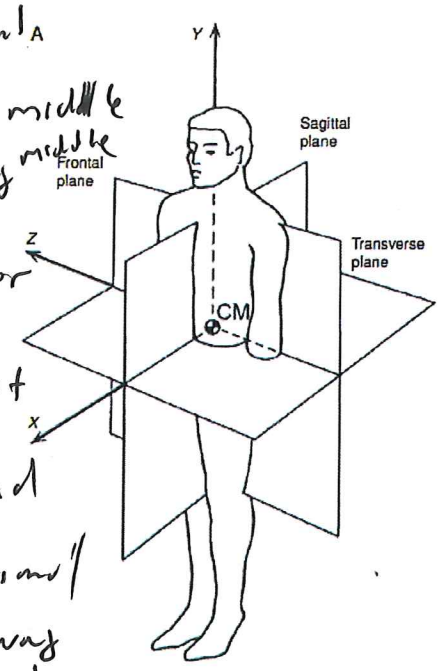
Anatomical Terms

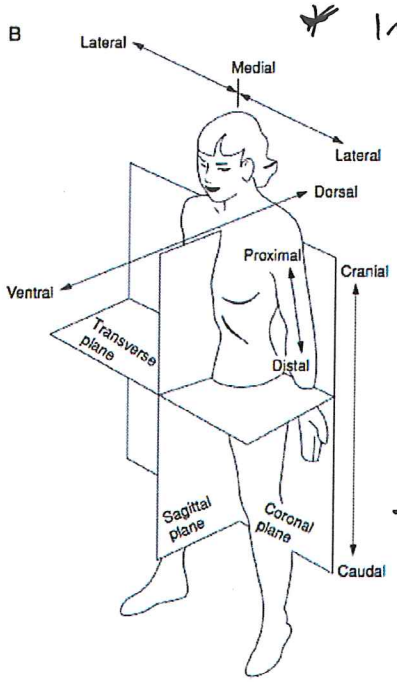
* medial - lateral

medial - near middle
lateral - away middle

* Anterior - posterior
- Anterior - in front of
Posterior - behind

* Distal Proximal
* distal away from trunk
* proximal towards trunk



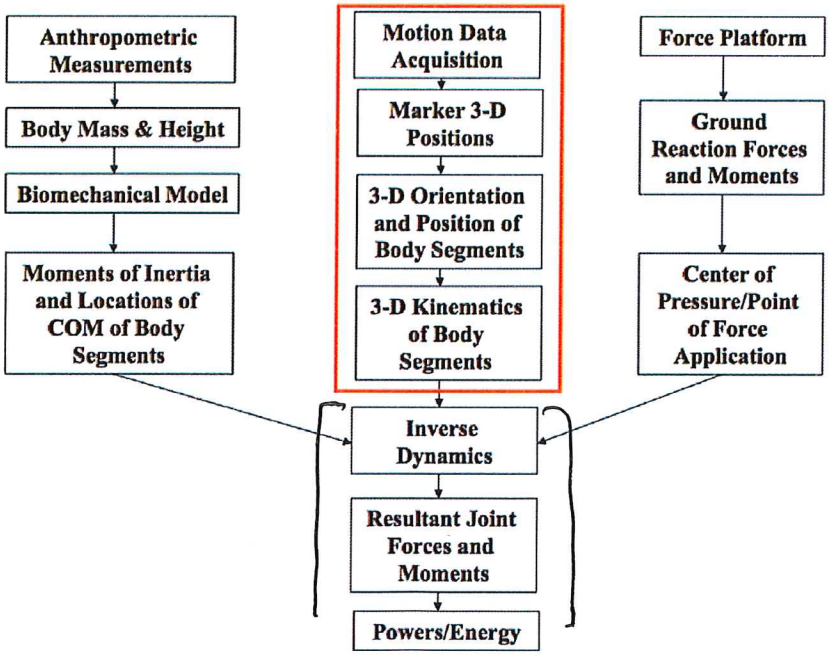


* Superior - Inferior
* Superior - above
* Inferior - below

* Cranial - Caudal
↳ ~~torso~~ towards head

Caudal: toward feet

Overview of Human Movement Analysis

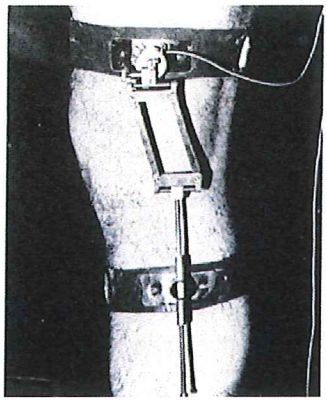


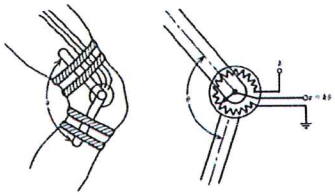
Motion Capture Techniques

* Goniometers
  * electrical potentiometer

Advantages:
- inexpensive, easy

Disadvantages:
- relative motion
- put a lot on, encumber motion.





* IMU (acc. + gyroscope)

Advantages:
- relative inexpensive

Disadvantages:
- noisy

* Retro-reflective markers
  * strobe of IR
    - reflect light back from markers
  * usually 6–12 cameras
  * specialized software
  * mature tech.

Advantages: relatively accurate. (1–2mm)

Disadv.: expensive
Skin motion artifacts

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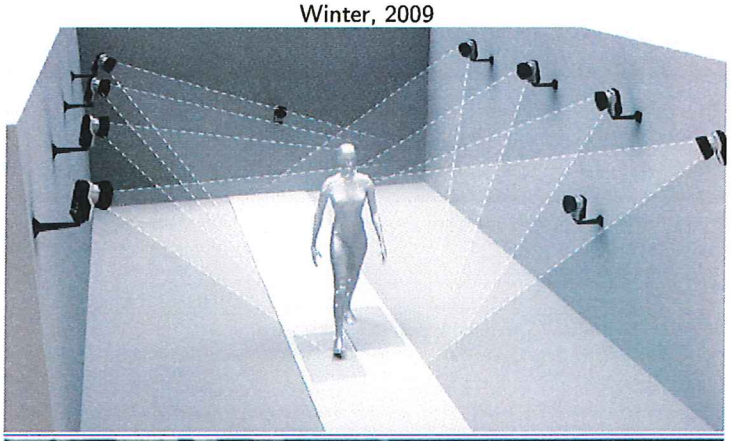
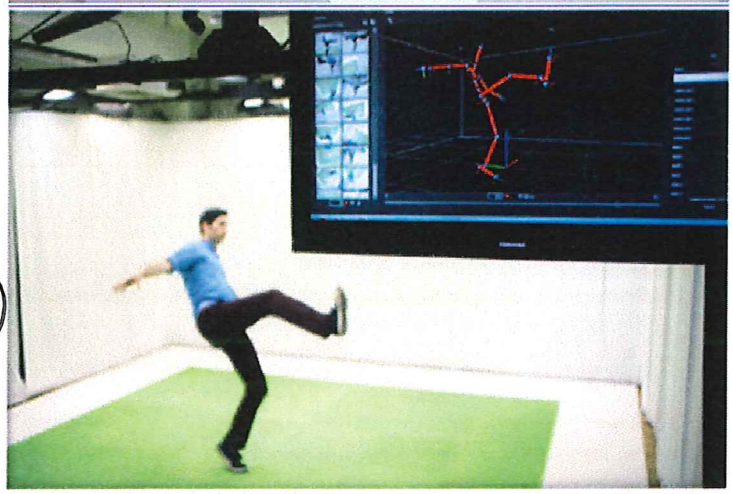
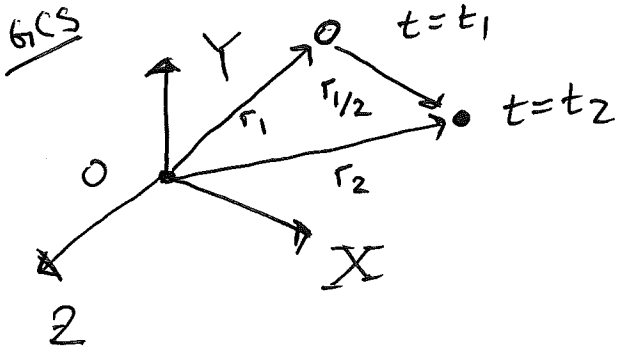


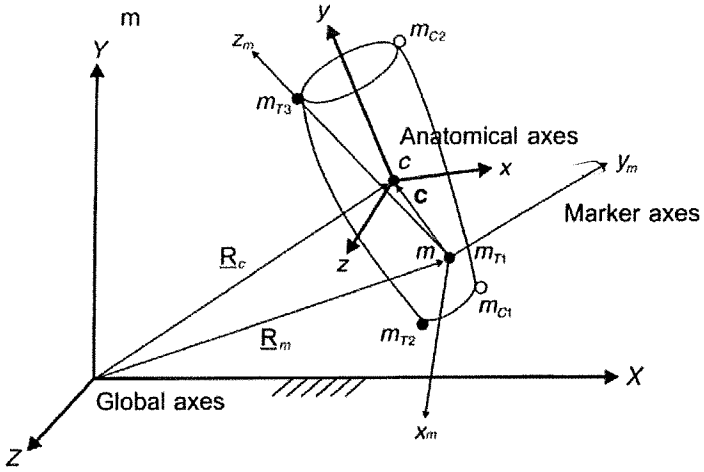


Kinematics Definition

Study of motion w/o regard to force.

Kinematics of a Rigid Body Segments





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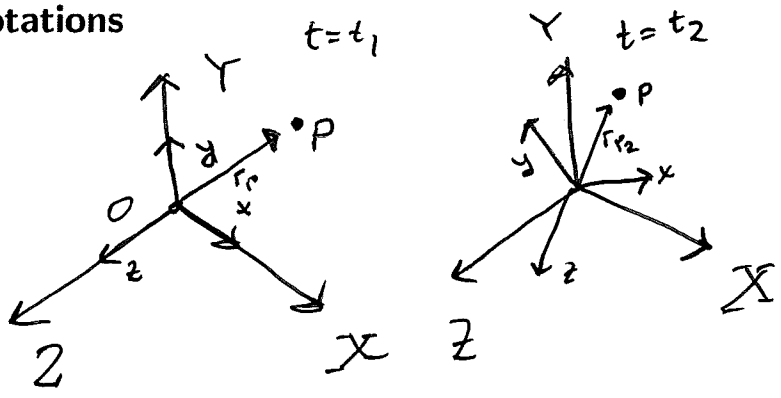
$r_1 = x\hat{i} + y\hat{j} + z\hat{k}$ Position vectors

$r_2 = \begin{bmatrix} x \\ y \\ z \end{bmatrix}$

$r_{1/2} = r_2 - r_1$ ← displacement

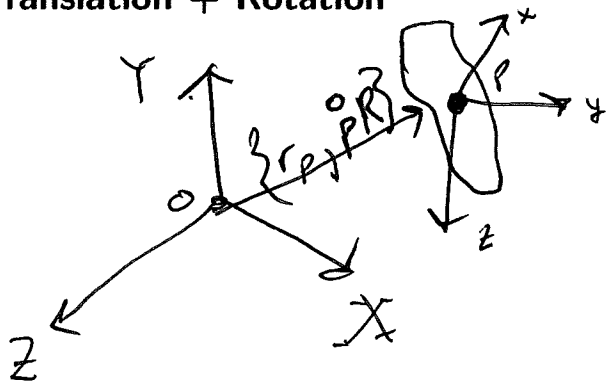
Translations

Rotations

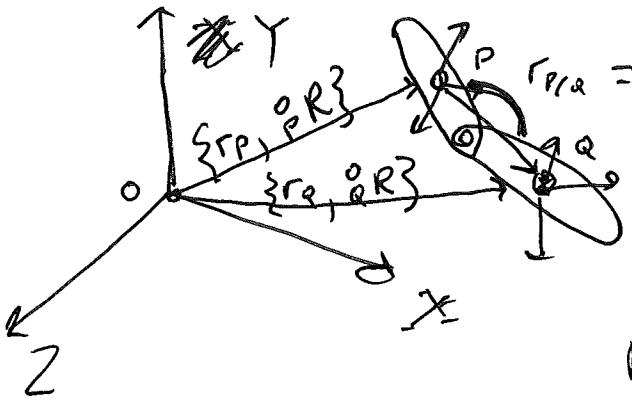


$r_{P_2} = R\, r_P$ ← rotation matrix

Translation + Rotation



Determining Joint Kinematics (Angles)



$${}^P_Q R = \{{}^0_P R\}^{-1} ({}^0_Q R)$$

$$= {}^P_O R \; {}^O_Q R$$

$$= {}^P_Q R$$

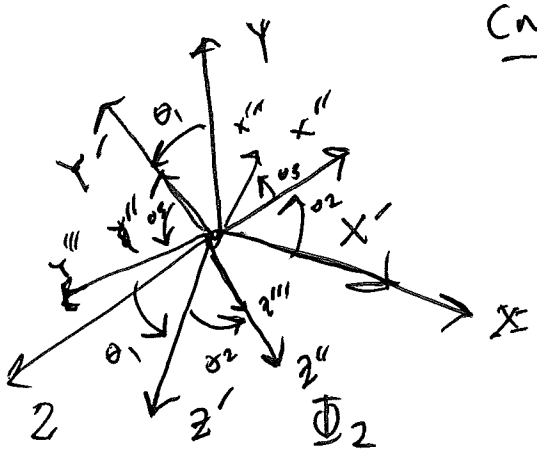
$$R^{-1} = R^T$$

$$({}^0_Q R)^{-1} = {}^Q_0 R = {}^0_Q R^T$$

Rotational Matrices

Cardan – x – y – z

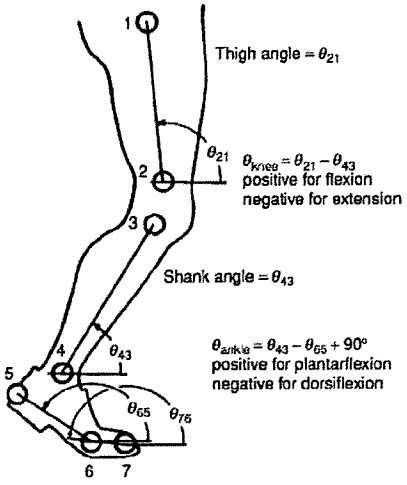
$\theta_1 \quad \theta_2 \quad \theta_3$



$$\begin{bmatrix} x \\ y \\ z \end{bmatrix}' = \underbrace{\begin{bmatrix} 1 & 0 & 0 \\ 0 & C_1 & S_1 \\ 0 & -S_1 & C_1 \end{bmatrix}}_{\Phi_1} \begin{bmatrix} x \\ y \\ z \end{bmatrix}$$

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix}'' = \begin{bmatrix} C_2 & 0 & -S_2 \\ 0 & 1 & 0 \\ S_2 & 0 & C_2 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix}'$$

~~Saggital Plane Angles~~



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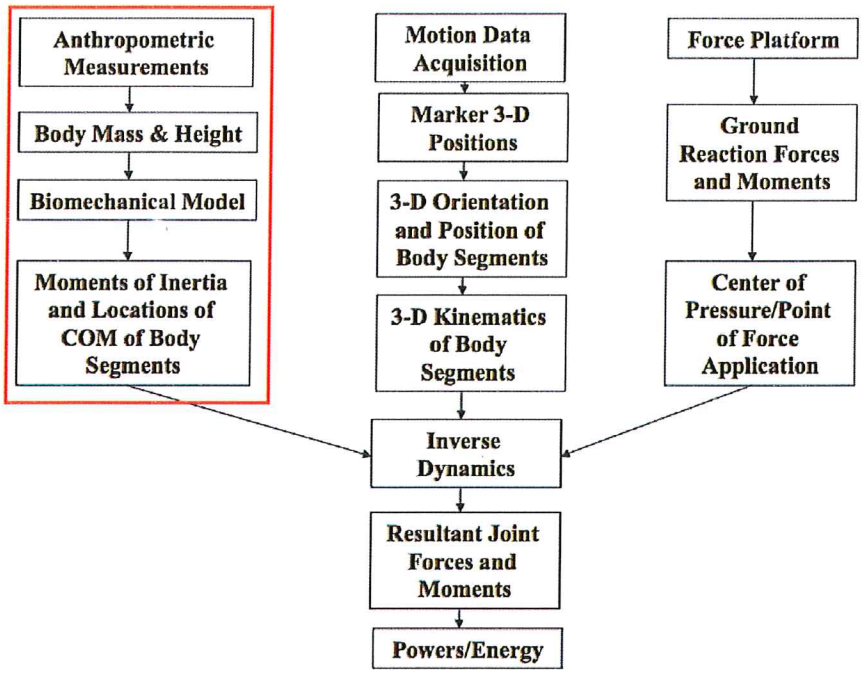
$$\begin{bmatrix} x \\ y \\ z \end{bmatrix}''' = \begin{bmatrix} C_3 & S_3 & 0 \\ -S_3 & C_3 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix}''$$

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix}''' = \Phi_3 \left(\Phi_2 \left(\Phi_1 \begin{bmatrix} x \\ y \\ z \end{bmatrix} \right) \right) \quad R$$

Overview of Human Movement Analysis

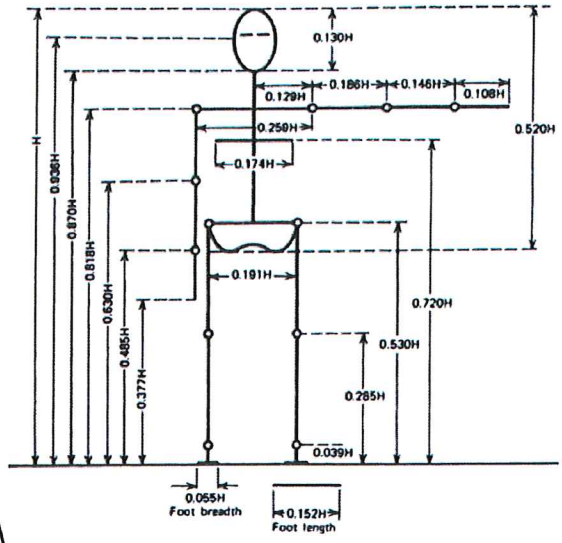


Ledoux

Anthropometry Definition

* measurement of human individuals

Segment Dimensions



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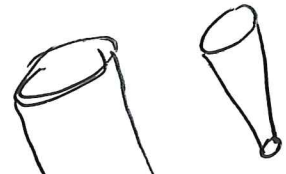
* mass & Inertia

Moment of Inertia



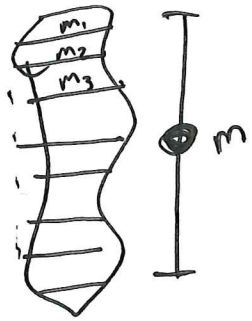
Inertia?

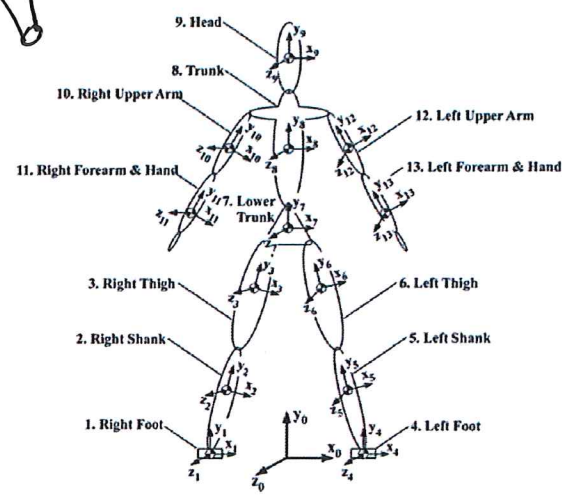
↳ resistance to movement

$I_o = \int r^2 dx$

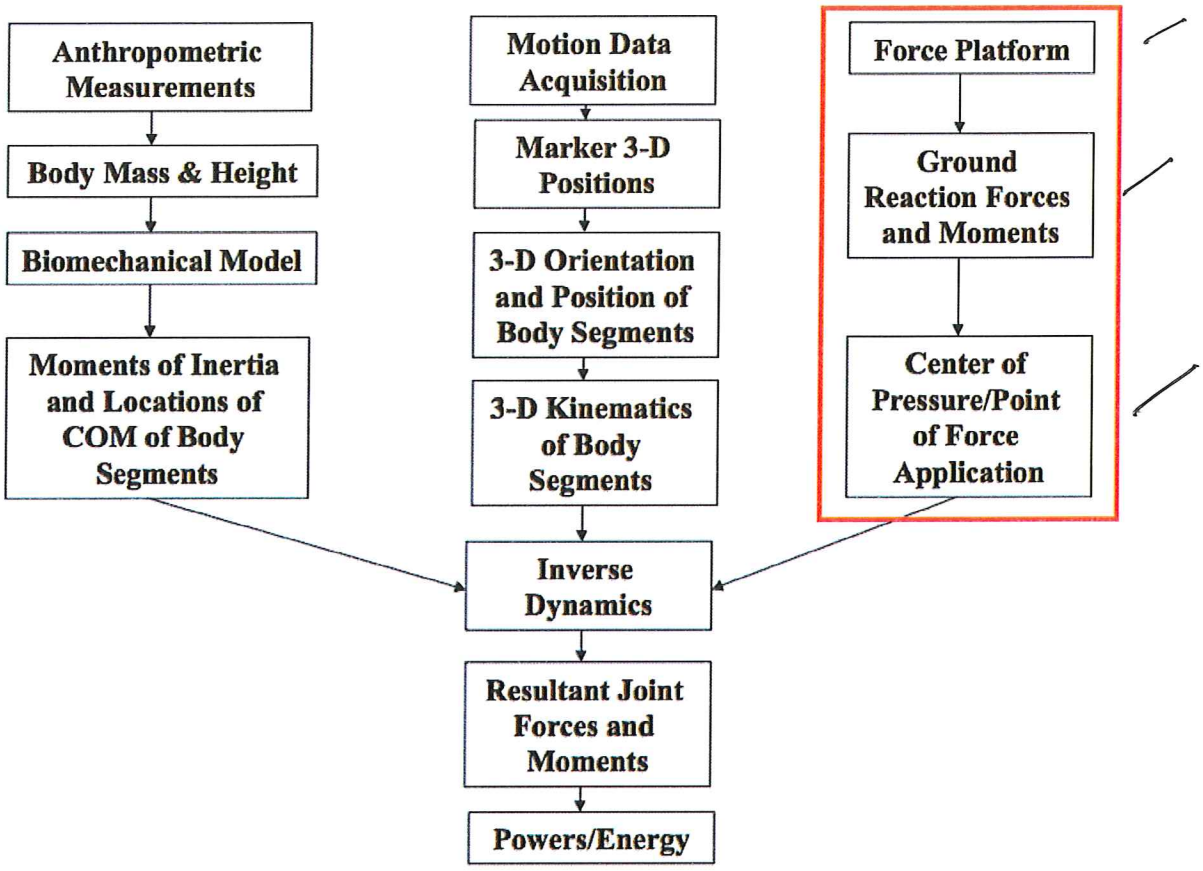
$I = \sum_i^n m_i x_i^2$

$I = \int x^2 dm$





Overview of Human Movement Analysis



Ledoux

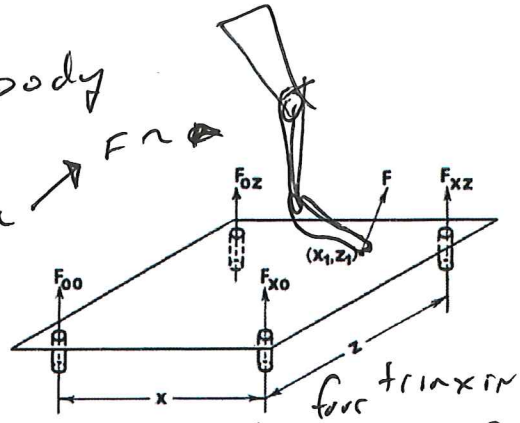
Kinetics Definition

study of forces on a body

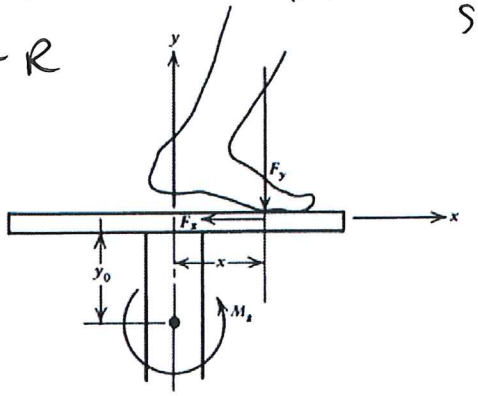
Types of Force Plates

two types sensors: * piezoelectric → FnR

* strain gage based → FnR



four triaxial sensors @ corners



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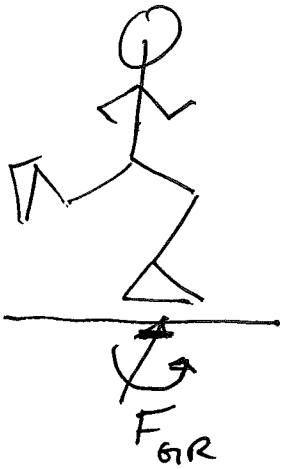
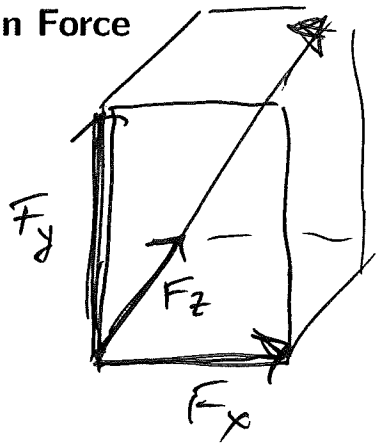
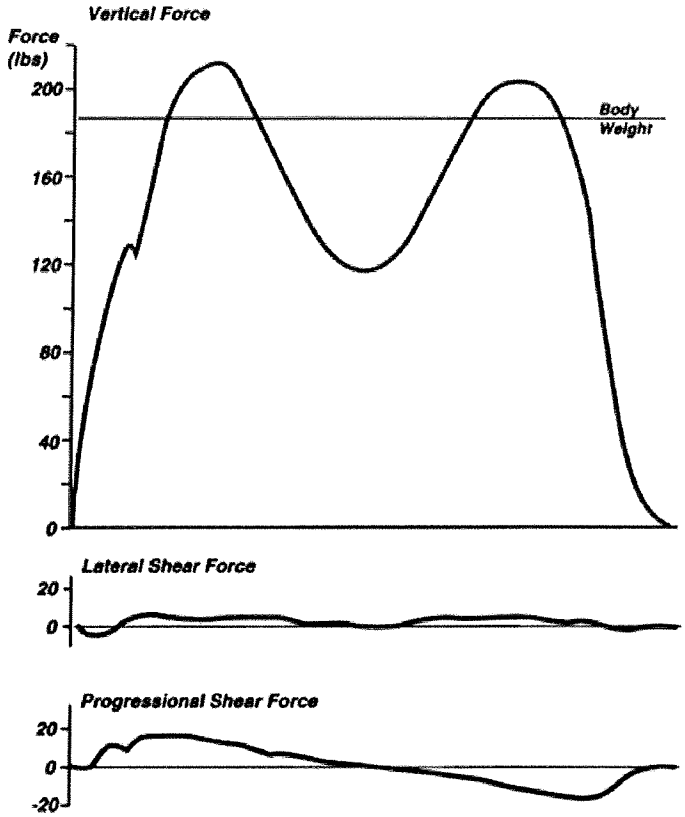
Ground Reaction Force



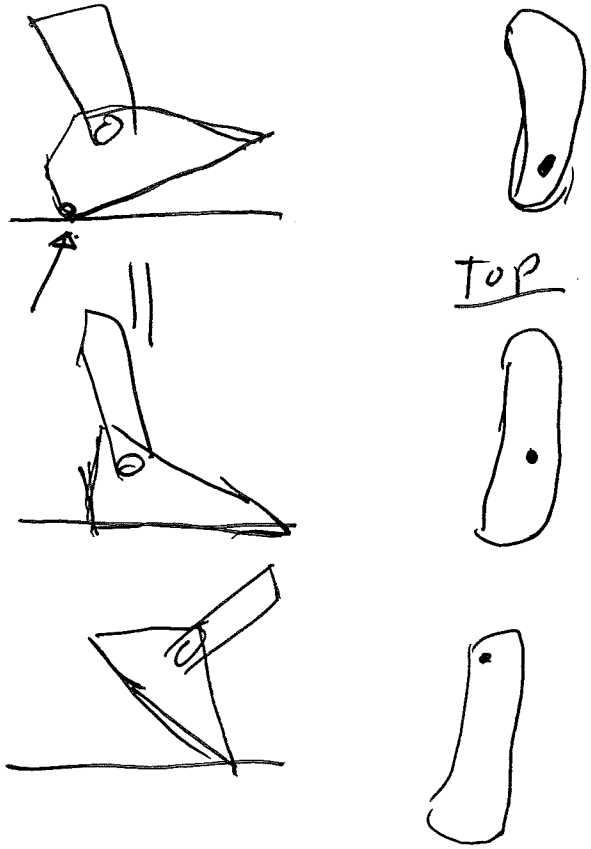


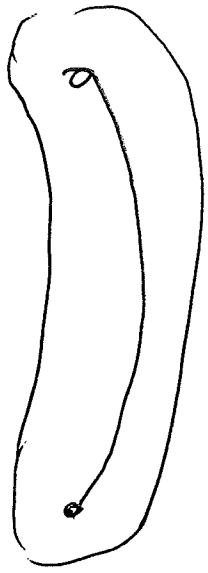


$$F_y = \sum_{N=i}^{N} m_i((a_{y_i}) + g)$$

Ledoux

Center of Pressure

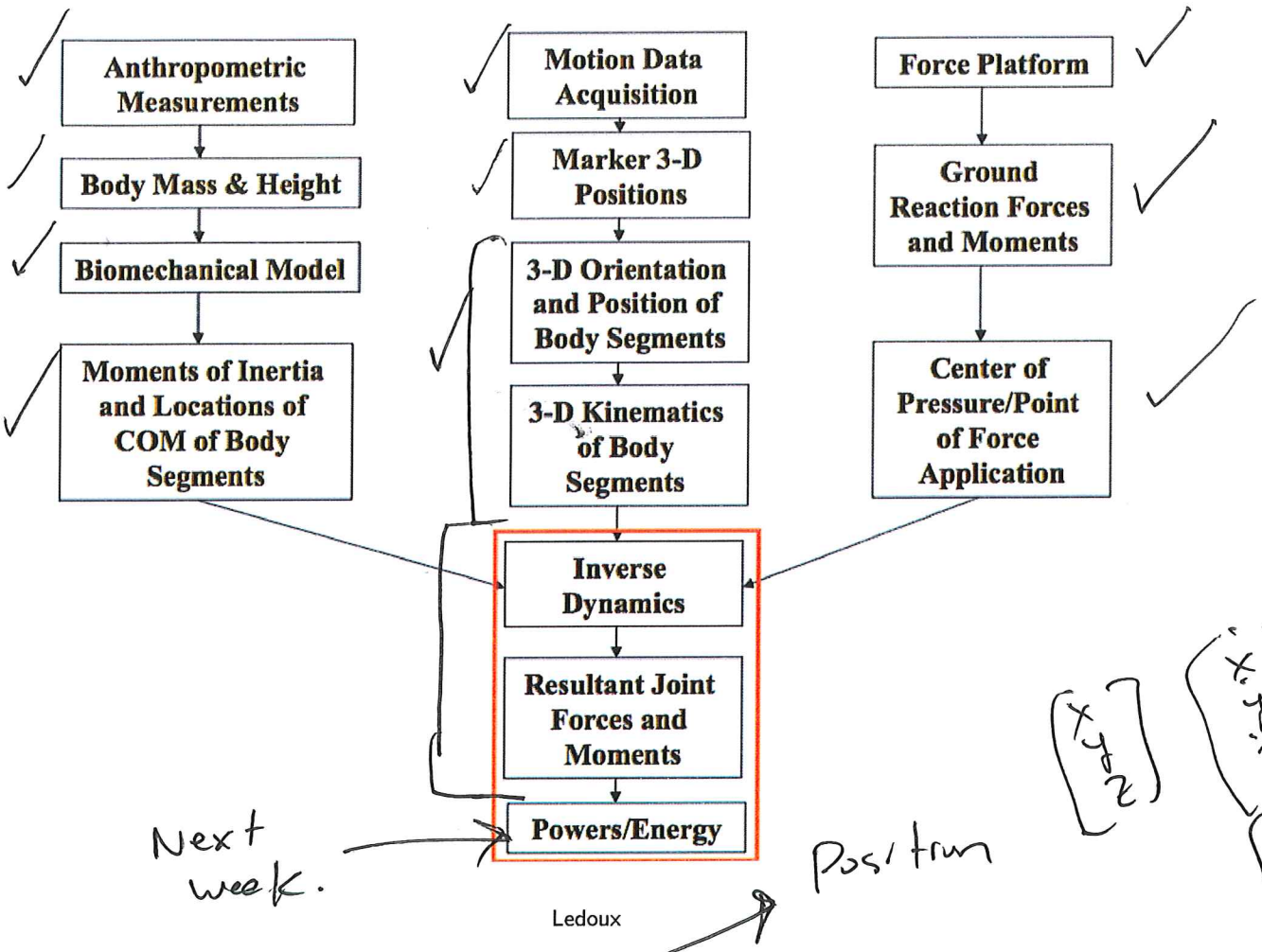




COP Progression

alot of clinical applications

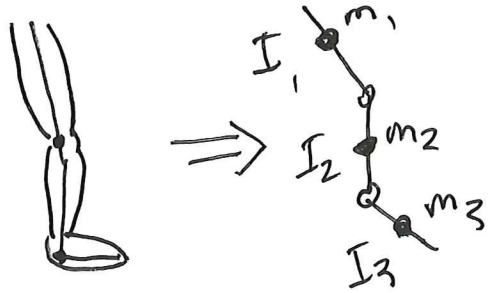
Overview of Human Movement Analysis



Inverse Dynamics Definition

Given the (Kinematics / Kinetic) → solve for joint forces

Link Segment Model



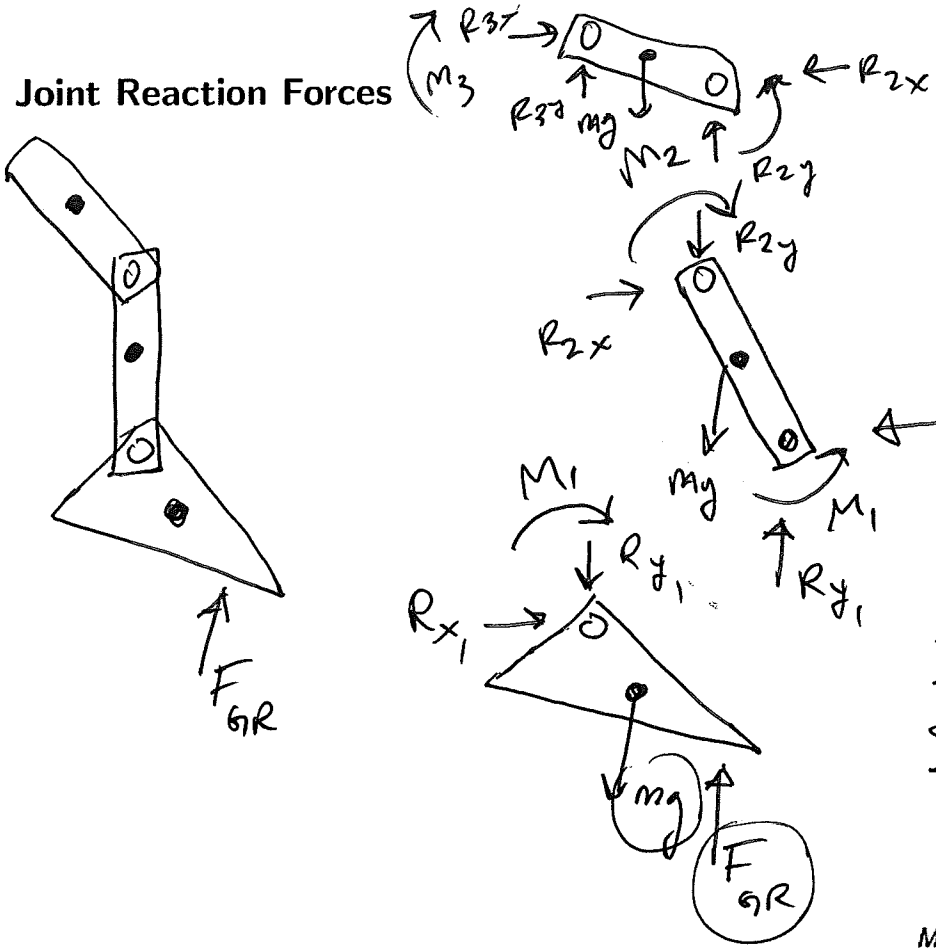
Assumptions

1. each segment has fixed mass @ COM
2. COM remains fixed
3. Joints are modeled as hinges
4. Moment of Inertia stays constant
5. Length of segment is fixed

Forces involved

1. Gravity (mg)
2. GRF + External forces
3. muscle forces

Joint Reaction Forces



$$\sum M = I\alpha$$

$$\sum F_y = m a_y$$

$$\sum F_x = m a_x$$

3D Example

$$\sum F_x = m a_x$$

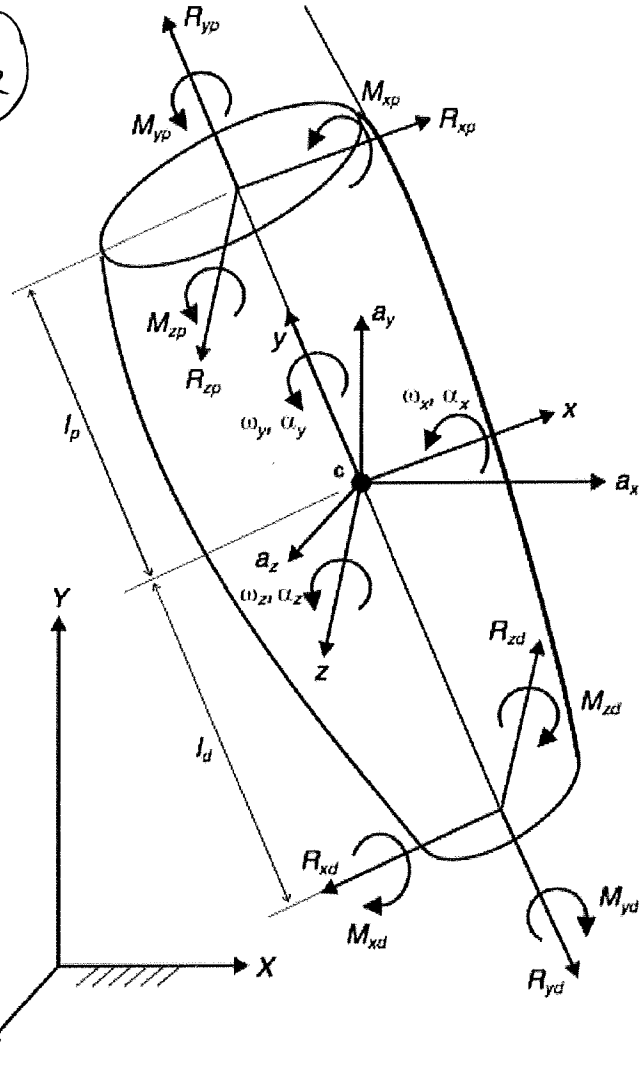
$$\sum F_y = m a_y$$

$$\sum F_z = m a_z$$

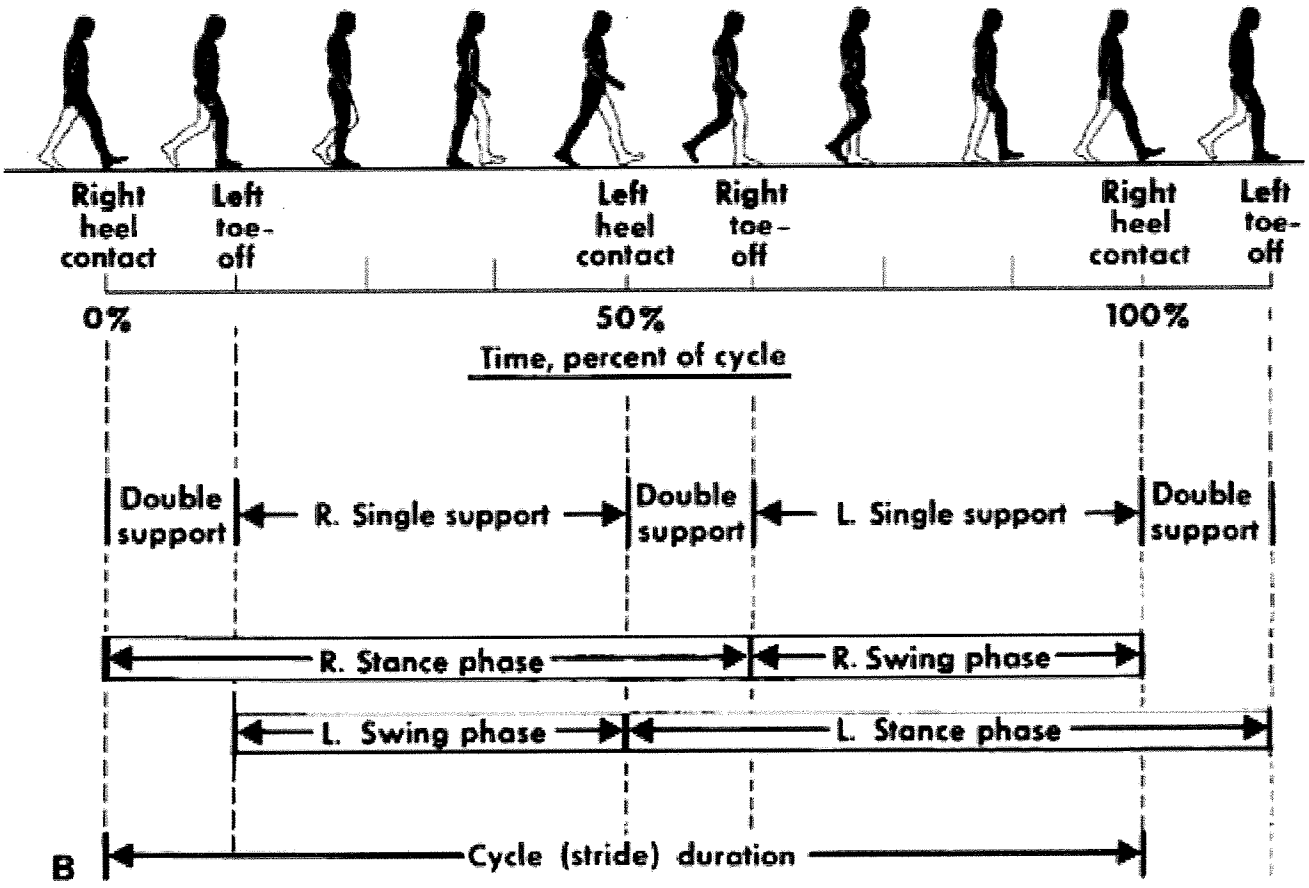
Euler Equations

$$\sum M_x = I_x \alpha_x + (I_z - I_y)\omega_y \omega_z$$

Captures interaction of angular velocity z in other axis.



The Gait Cycle



Time Dimensions of Walking Cycle

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Observation

Phases

* intral contact (heel strike)
* Loading response (weight transvers)
* Mid stance (alignment & balance of BW.)
* Termind Stance (heel rises) & adding power
* Toe off (
* swing.

For walking the same distance compared w/ running (70% less energy