What are the determinants of gait?
What is motion capture?
How are segment angles and joint angles calculated?
Standard gait cycle definition

Heel strike 60% Stance phase Toe off 40% Swing phase Heel strike

First double support Single limb stance Second double support

Note distinctions of % gait cycle

Vaughan et al.
Ground reaction forces during walking

Subject body weight = 681 N

Contact force plate with right foot

Stance phase
Determinants of gait

1. Pelvic rotation
2. Pelvic tilt
3. Knee flexion during stance
4. Plantarflexion during heel strike and heel off
5. Plantarflexion during heel off
6. Lateral displacement of pelvis
7. Ankle inversion-eversion-inversion during stance
8. Lateral flexion of trunk
9. Anterior-posterior flexion of trunk

Change in potential energy \( \sim 70 \text{ J} \)

Normal gait

Energy \( \sim 35 \text{ J} \)
Pelvic rotation (transverse plane)
Pelvic rotation (cont)
Pelvic tilt
Knee flexion

--- With no knee flexion
–––– With knee flexion
+ Plantarflexion
Put it together... sagittal plane
• During stance, the pelvis shifts laterally towards the stance phase limb

• This moves the COG closer to the stance leg, making it easier for the stance-side hip abductors to raise the swing leg and control pelvic tilt

• This results in horizontal (transverse plane) oscillation of the COG with an amplitude of ~5cm, and frequency one-half that of vertical (sagittal plane) movement (~1 Hz vs. 2 Hz)
Abductor lurch

- Exaggerated lateral shift due to loss of hip abductors (gluteus medius, gluteus minimus) on stance side
- Pelvic tilt is opposite to “Trendelengburg gait”
- Apes have Abductor lurch
Kinematic measurements

Figure 2 - Range of motion measurement of hip medial rotation

http://www.biomedsearch.com/attachments/00/19/18/75/19187538/1749-799X-4-3-3.jpg
On June 15, 1878, a clear and sunny day in Palo Alto, California, amid a gathering of art and sports journalists, Eadweard Muybridge photographed the first successful serial images of fast motion.

The subject of these photographs was the trotting horse, Abe Edgington, harnessed to a sulky. The horse was owned by railroad builder and former governor, Leland Stanford. Proven was Stanford's theory that during a horse's running stride, there is a moment of suspension where no hooves are touching the ground.

What had begun as a topic of irresolvable debate among artists and horse enthusiasts now launched a new era in photography.

http://www.cmp.ucr.edu/collections/permanent/object_genres/photographers/muybridge/default.html
Motion Capture

Passive systems

Active systems

http://www.vicon.com/

http://www2.brooklyn.liu.edu/bbut04/adamcenter/Instrumented%20Analysis%20Website/index.html


+ We don’t just study people….
Joint kinematics

- Joint center locations from kinematic data
- Compute joint angle rotations

Knee flexion during stall

<table>
<thead>
<tr>
<th>Knee angle (deg)</th>
<th>Time (s)</th>
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<tbody>
<tr>
<td></td>
<td>0</td>
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<tr>
<td></td>
<td>0.2</td>
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<td>0.4</td>
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<tr>
<td></td>
<td>1.8</td>
</tr>
<tr>
<td></td>
<td>2</td>
</tr>
</tbody>
</table>

- Landing Phase (S to F): Increasing flexion
- I1 to I2: Increasing flexion and extension
Locating the instant center. 

**A.** Two easily identifiable points on the femur are designated on a roentgenogram of a knee flexed 80°. 

**B.** This roentgenogram is compared with a roentgenogram of the knee flexed 90°, on which the same two points have been indicated. The images of the tibiae are superimposed, and lines are drawn connecting each set of points. The perpendicular bisectors of these two lines are then drawn. The point at which these perpendicular bisectors intersect is the instant center of the tibiofemoral joint for the motion between 80 and 90° of flexion. **Courtesy of Ian Goldie, M.D. University of Gothenburg, Gothenburg, Sweden.**
Instant centers of the knee: joint center moves during motion (not constant location)

Semicircular instant center pathway for the tibiofemoral joint in a 19-year-old man with a normal knee.

Abnormal instant center pathway for a 35-year-old man with a bucket-handle derangement. The instant center jumps at full extension of the knee. Adapted from Frankel, V.H., Burstein, A.H., & Brooks, D.B. (1971). Biomechanics of internal derangement of the knee. Pathomechanics as determined...
Segment angles: Absolute angle (relative to global coordinates, for example, +x axis) based on joint centers
Let’s work an example

\[ \phi_{\text{segment}} = \tan^{-1} \left( \frac{\Delta z}{\Delta x} \right) \]

\[ = \tan^{-1} \left( \frac{pz - dz}{px - dx} \right) \]

where \( p \): proximal, \( d \): distal

<table>
<thead>
<tr>
<th>Joint center</th>
<th>X coord (m)</th>
<th>Z coord (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoulder</td>
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<td>1.75</td>
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<tr>
<td>Hip</td>
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<td>1</td>
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<tr>
<td>Knee</td>
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<td>0.95</td>
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<tr>
<td>Ankle</td>
<td>2.4</td>
<td>0.5</td>
</tr>
<tr>
<td>Toe</td>
<td>2.7</td>
<td>0.5</td>
</tr>
</tbody>
</table>
**Joint angles:** Relative angle (relative to segment angles)
Angular velocities, accelerations
Wednesday

- Exam (covers through IRB)
  - Multiple choice
  - Open answer