Computer Animation and Visualisation

Lecture 3.

Motion capture and physically-based animation of characters

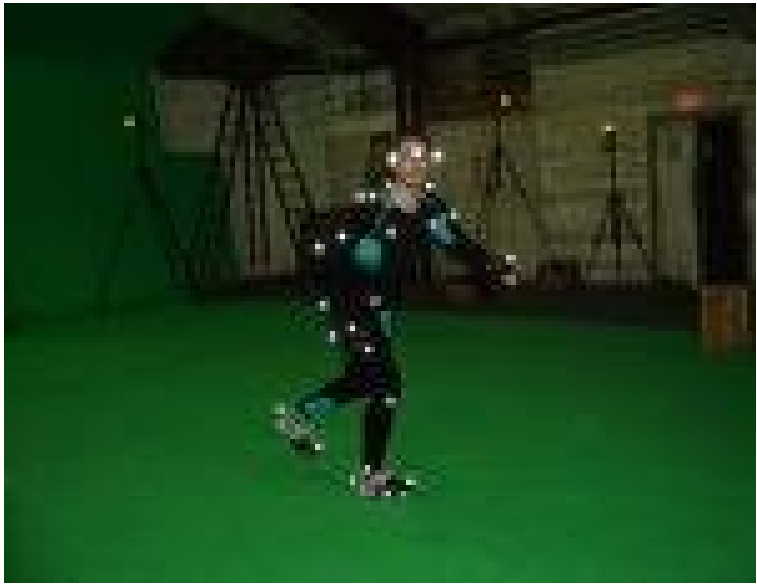
Character Animation

- There are three methods
  - Create them manually
  - Use real human / animal motions
  - Use physically based simulation



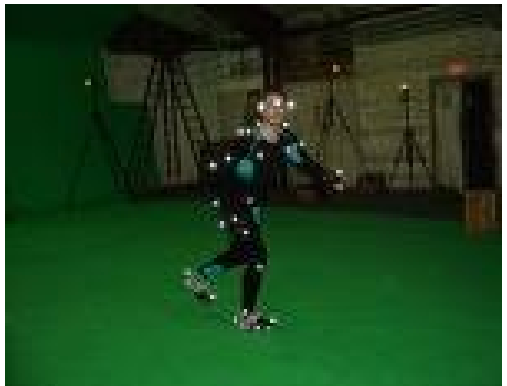
Using Real Human (Animal) Motion

- Real human (animal) motion is realistic
- Sometimes much faster and cheaper than manually producing the data



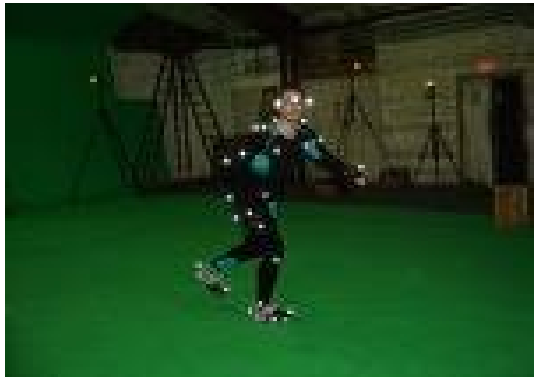
Capturing human motion

- We use the motion capture device (Mocap)
- There are three types of Mocaps
  - Optical
  - Magnetic
  - Mechanical
  - Inertial trackers



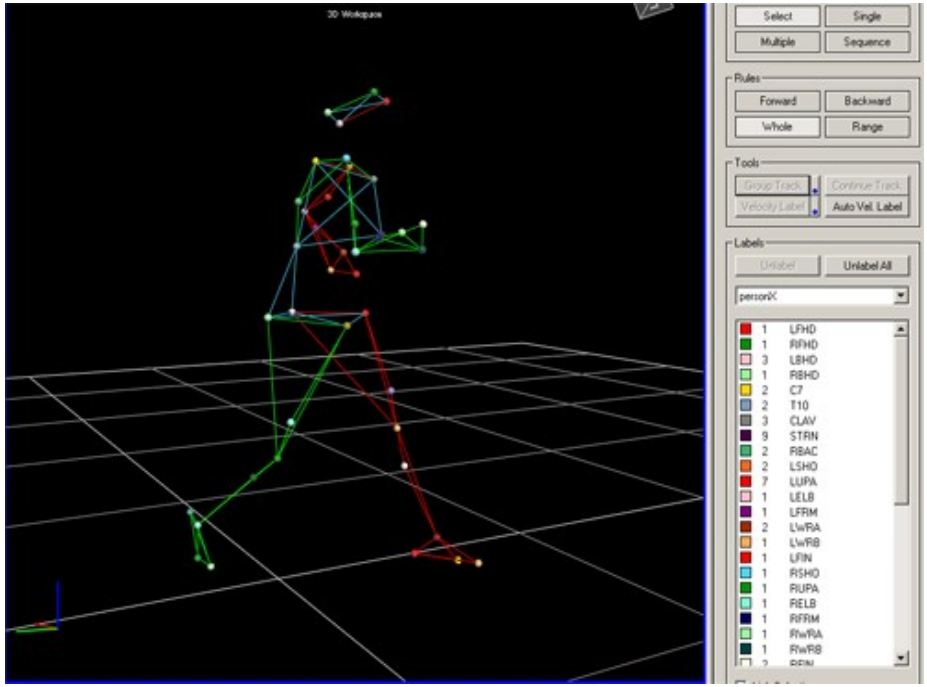
Optical Mocaps

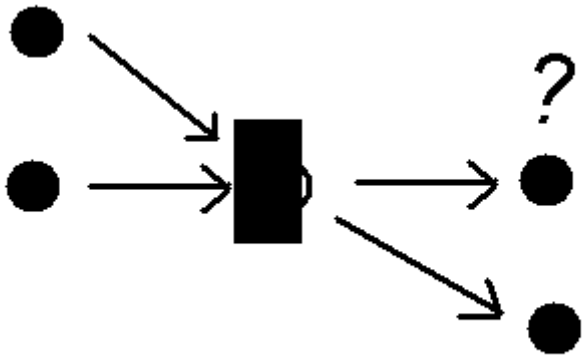
- The actor puts reflective markers on his/her body
- The actor is shot by multiple cameras
- Light source around the camera.
- The light source casts light towards the actor
- The light is reflected by the markers back to the camera
- The 3D location of the markers are computed by stereo vision



1. Labeling and Post-processing

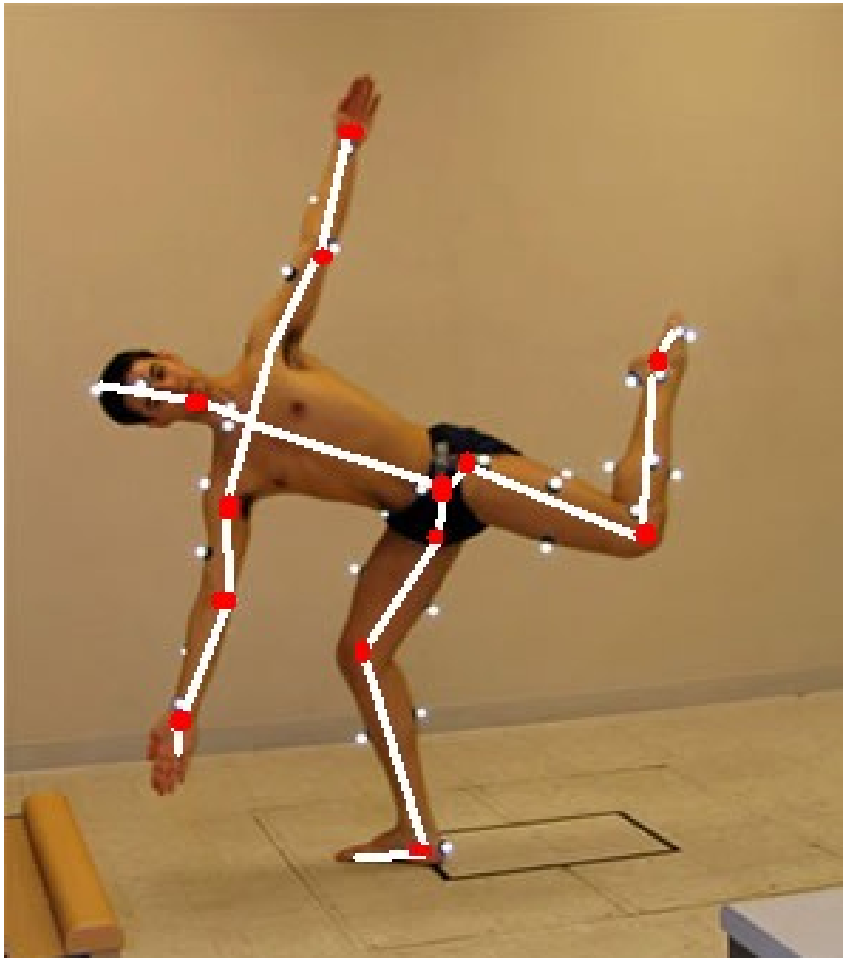
- The markers must be manually labelled first
- Once the markers get occluded, they have to be tagged manually again
  - The same process repeated for the whole motion
- Sometimes the body intersects, and then the system mix them up





2. Computing the center of the joints from the marker positions

- To compute the joint angles of the skeleton



Cons and Pros of Optical Mocaps

Advantages

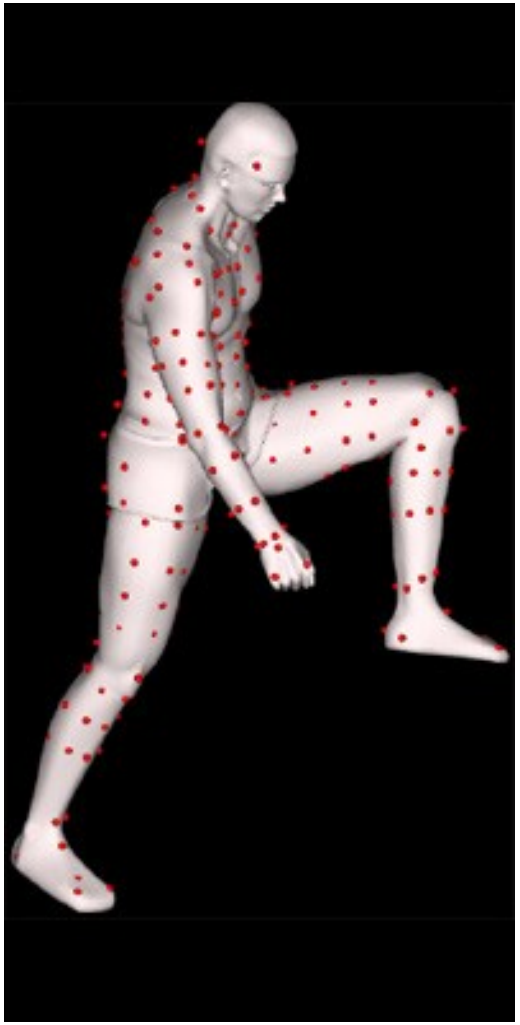
- Less intrusive (only the markers are attached to the body)
- Very accurate
- Can capture not only the human (animal) motion, but also skin movements

Shortcomings

- Suffer from occlusions (the body hiding the markers)
- A lot of post-processing is required if occlusion happens
  - Labelling which marker is which
- Need a large studio for a capturing outdoor movements

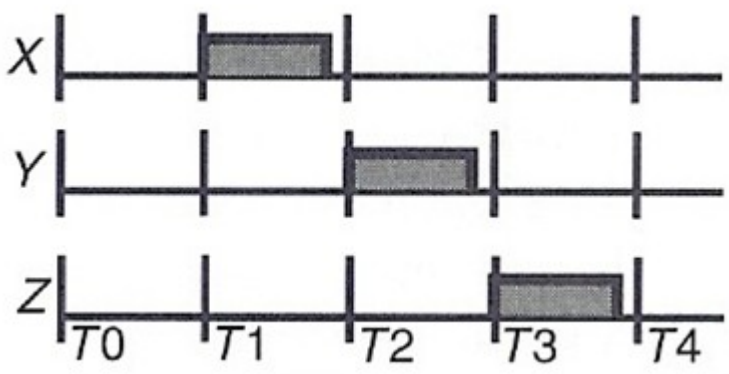
Demo movie of an optical Mocap system

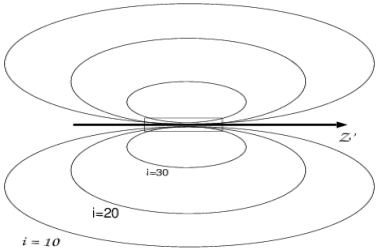
http://www.youtube.com/watch?v=mYjOg1xov_M

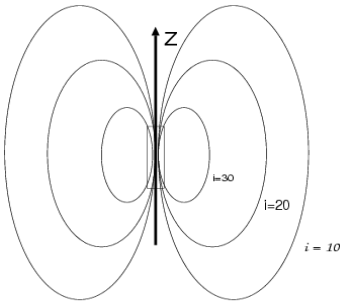


Magnetic Mocaps

- The transmitter produce three orthogonal magnetic fields sequentially



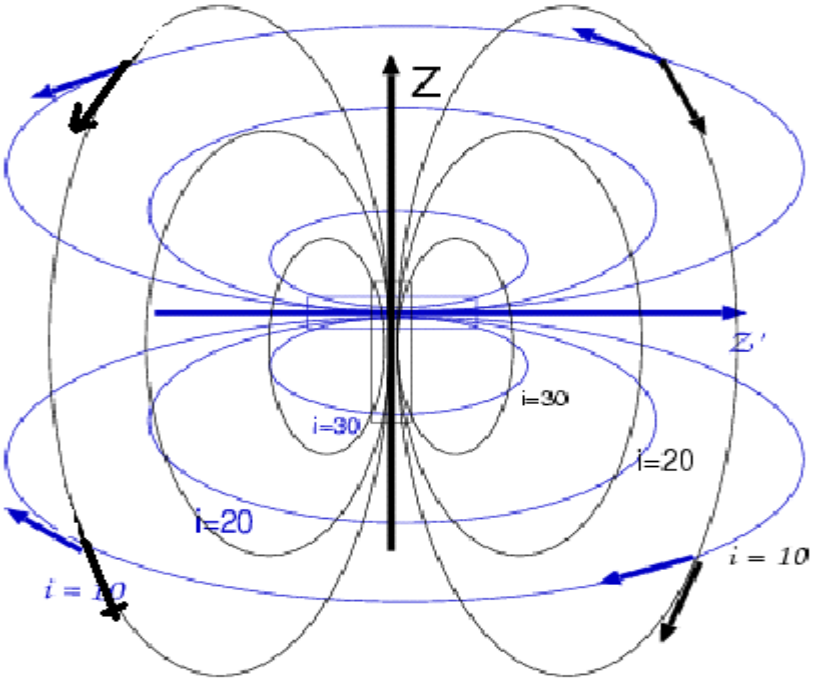




- The actor wears a suit to which the magnetometers are attached

Magnetic Mocaps

- The magnetometers on the body detects the magnetic field, and the 3D location can be computed by the amplitude of the magnetic field
- The farther you go away, the weaker the magnetic field is



Cons and Pros of Magnetic Mocaps

Advantages

- We do not have to worry about occlusion
  - Motions of close contact can be captured
- No manual post-processing is required

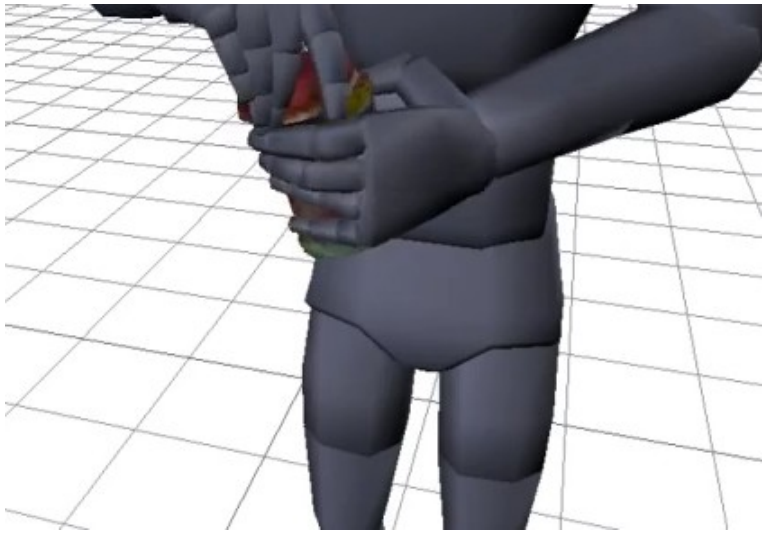
Shortcomings

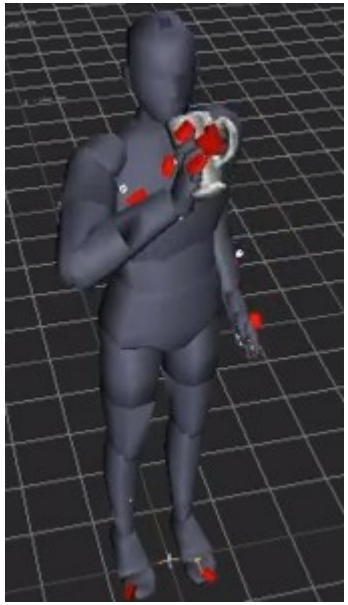
- Less accurate
  - The absolute positions are highly distorted
  - Easily affected by the noise
  - Cannot have metal/electronic devices in the capturing area
    - Affects the magnetic field
- The capturing volume is very small
  - Only 2-3 m away from the transmitter

Ediinburgh Interaction Database

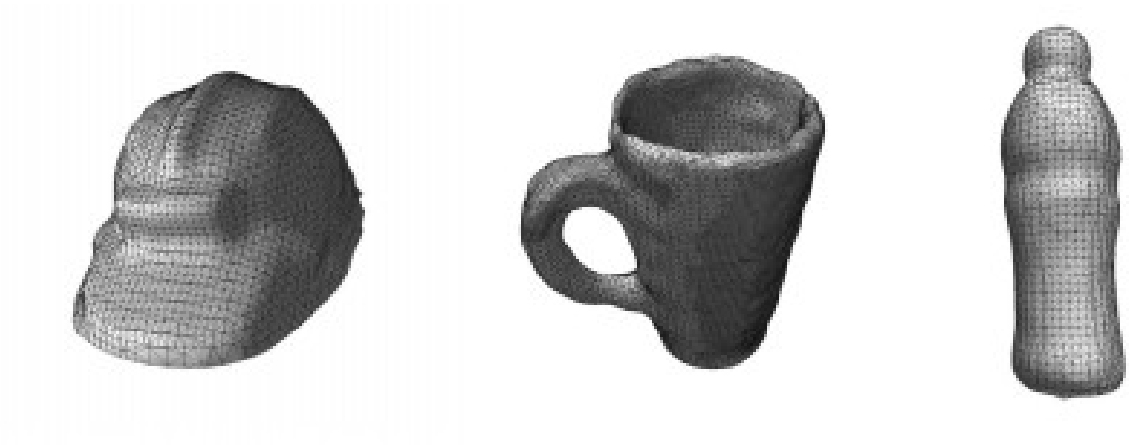
By Peter Sandilands, Myung Geol Choi

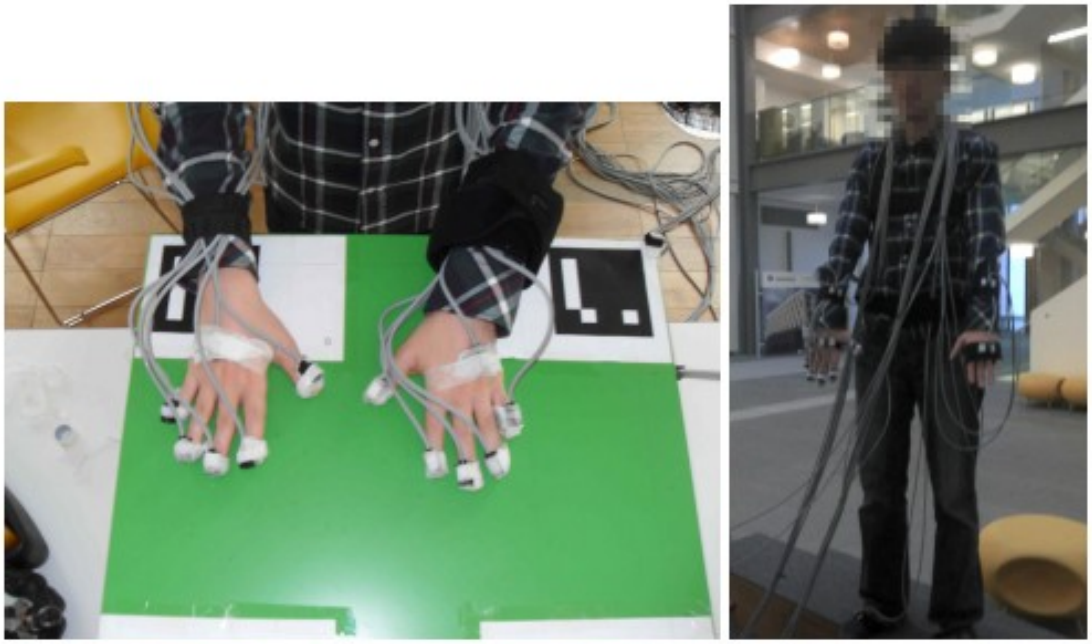
- We captured the human movements as well as the objects manipulated
- Also captured the geometry of the objects





http://homepages.inf.ed.ac.uk/s0569500/InteractionDatabase/interactiondb.html





https://www.youtube.com/watch?v=PGupXYUdX4c&list=PL0AE8CDDDA7BB450A

Inertial trackers

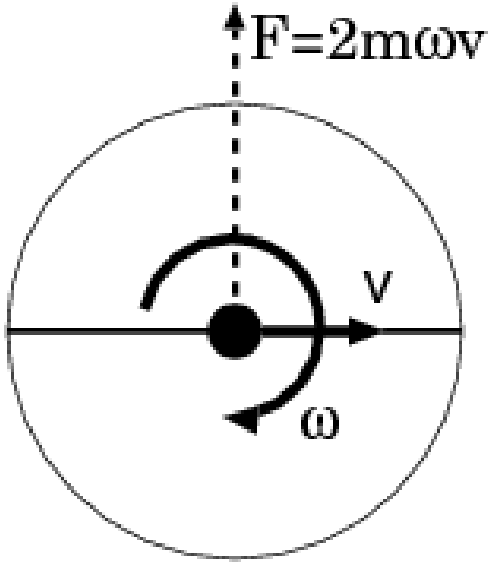
- Inertial trackers measure the rate of change in
  - Angular velocity - gyro sensor
  - Translational acceleration - accelerometer
- These values are integrated to compute the
  - Orientation and
  - Position

of the tracker

Orientation

- The rate of change in object orientation or angular velocity, is measured by Coriolis-typed gyroscopes

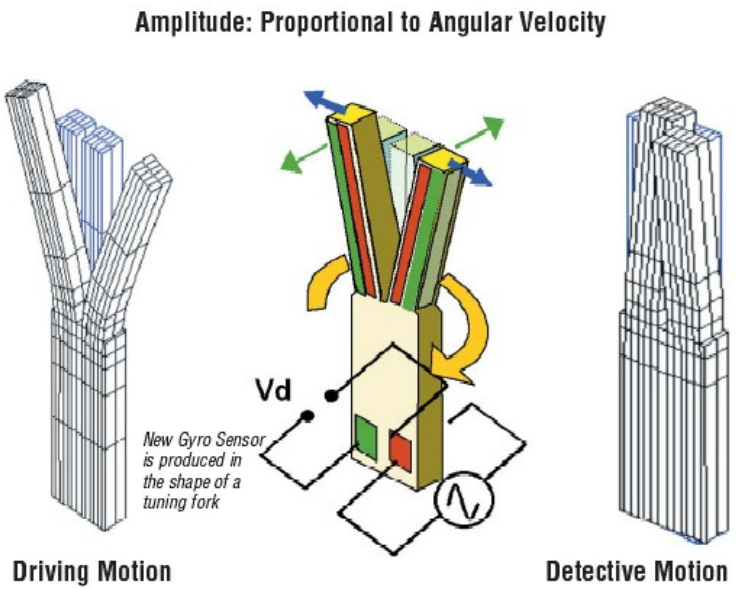
http://www.youtube.com/watch?v=O77grx9SgaU

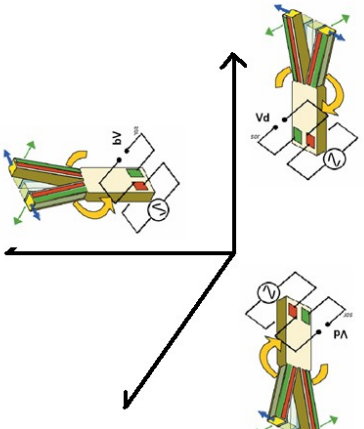


ω:angular velocity, v:velocity
m: mass, F: coriolis force

An example of a Gyro sensor

- Fujitsu Gyro Sensor
- The sensor is shaped like a tuning fork, and vibrates continuously.
- As the sensor turns, it is rotated and the Coriolis force affects it in the direction perpendicular to the vibration.
- this is converted into a proportional voltage, allowing the degree of rotation to be measured.
- **Amplitude: Proportional to Angular Velocity**





Translation

- The translation velocity or acceleration is calculated using accelerometers
- Three accelerometers machined coaxially
- the position of the tracker is calculated by double integration of the acceleration

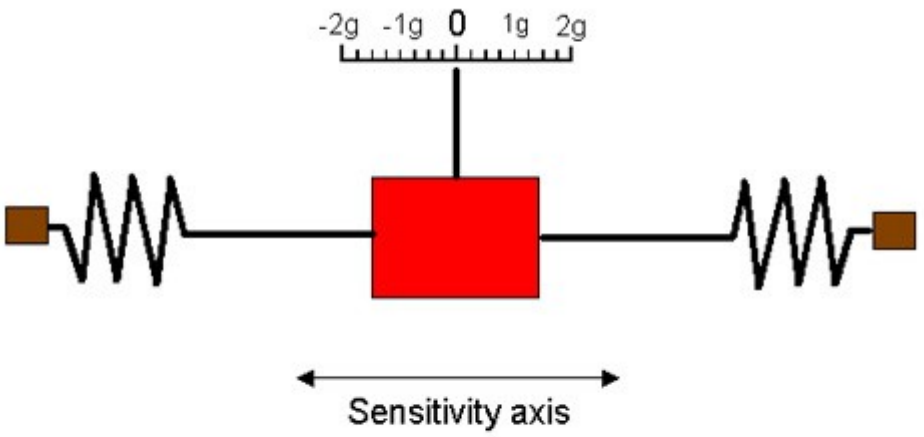


Fig. 1. Schematic structure of an accelerometer

CONS and PROS of inertia trackers

Advantages

- Unlimited range of tracking
- No line-of-sight constraints

Shortcomings

- Rapid accumulating errors, or drift
- Gyroscope bias leads to an *orientation error that increases proportionally with time* due to integration
- Accelerometer bias induces an error that *increases with the square of time*
- Commercial devices : 40 mm in 2sec
- Expensive ones: 40 mm in 200 sec
- The only answer is to periodically *reset the error using other types of trackers*

- $x' = x + v\,dt$
- $v' = v + a\,dt$

Demo movie of an inertial tracker-based motion capture system

http://www.youtube.com/watch?v=V0yT8mwg9nc

http://www.xsens.com/en/general/mvn

Mechanical Mocaps

- Kinematic structure composed of links interconnected using sensorized joints
- The mechanical joints can directly measure the rotation of the human joints

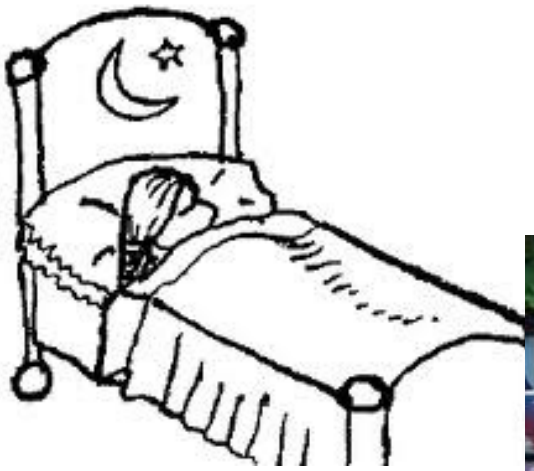
Advantages

- Very accurate
- Little latency
- Again, we don't have to worry about the occlusion
- Unlimited range of capturing

Shortcomings

- More interference with the actor
  - Affects the performance of the actor
- Vulnerable
- Need an additional sensor to detect the location of the body root

Which mocap system will be good for the following motions?



Summary

- Different mocap systems are appropriate for different movements
  - Optical mocap is the most prevalent system
  - Magnetic systems are good for capturing close interactions but the capture volume is small
- Many new systems based on depth sensors (like Kinect) and RGB cameras (OpenPose) are available recently, and things may change in the next few years.

https://www.youtube.com/watch?v=C1Sxk6zxWLM

CVPR paper video

on the BBC

Character Animation

- There are three methods
  - Create them manually
  - Use real human motion
  - Use physically based simulation

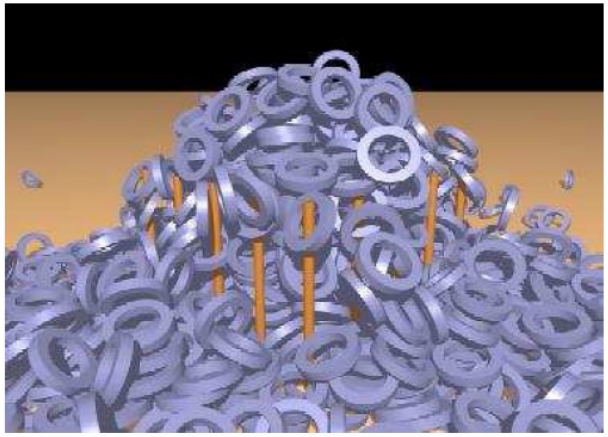


Overview

- Physically-based animation
  - Using Newton Physics to simulate events
  - Applicable to human animation
- Methods based on
  - Forward dynamics
  - Inverse dynamics
- Forward dynamics – need to decide torque
  - PD control

Physically-based animation

- Using Newton's laws of dynamics to simulate various phenomena
  - *Drop objects in the scene, and let them collide and see what happens*
  - *Blowing hair by a dryer*
  - *Add force to the bodies and torque to the joints and simulate the movements of human figures*



Newton's Law of Dynamics

- $$F = M\ddot{q} + v(q,\dot{q}) + G$$

$q \quad \dot{q} \quad \ddot{q}$

: generalized coords, velocity, acceleration

F : force, or torque made at the joints

- M : Mass matrix, v(q,q'): Coriolis force
- G: gravity

Forward / Inverse Dynamics

- Forward dynamics: Adding force and simulate what happens

$$\ddot{q} = M^{-1}(F - v(q,\dot{q}) + G)$$

OUTPUT INPUT

Then, update the velocity and position by the computed acceleration

$$\dot{q} = \dot{q}' + \ddot{q}\,dt \qquad q = q' + \dot{q}'dt$$

Forward / **Inverse** Dynamics

- *Inverse dynamics: Given a motion, calculate the force / torque*

$$F = M\ddot{q} + v(q,\dot{q}) + G$$

OUTPUT

INPUT

Using Forward Dynamics for Human Animation : **Problem:** How do we decide the internal force?

- Must decide how the muscles exert force
  - Passive motions
    - Falling down (No force or torque, rag-doll)
    - pushed and stepping back
  - Voluntary motions → Walking, Running

Passive motions - **Rag doll physics**

- The body just falls down powerlessly
- No active force exerted by the muscles

http://www.youtube.com/watch?v=VLsS58RU3NI
http://www.youtube.com/watch?v=7V-tGFQjcrM

- Some passive force
  - elastic force by the ligaments and muscles

Using Forward Dynamics for Human Animation : **Problem:** How do we decide the internal force?

- Must decide how the muscles exert force
  - Passive motions
    - Falling down (No force or torque, rag-doll)
    - pushed and stepping back
  - **Voluntary motions → Walking, Running**

Voluntary motions

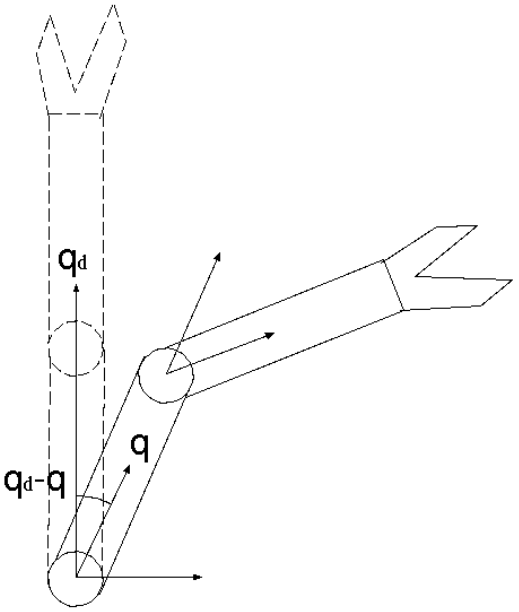
- Motions like walking, running, reaching
- Humans control the body by exerting force by the muscles
- To simulate such motions, need to determine the torque
  - PD control
  - More complex control methods (optimal control, evolutionary control, etc)

http://www.youtube.com/watch?v=EhaVY2vQL5g&feature=related

PD control : Introduction

- A method used in robotics
- The larger the difference between the current state and the desired state, the larger the force/torque is

– $F = a\,(q - q_d) + c\,(q' - q'_d)$



a, c : constants,

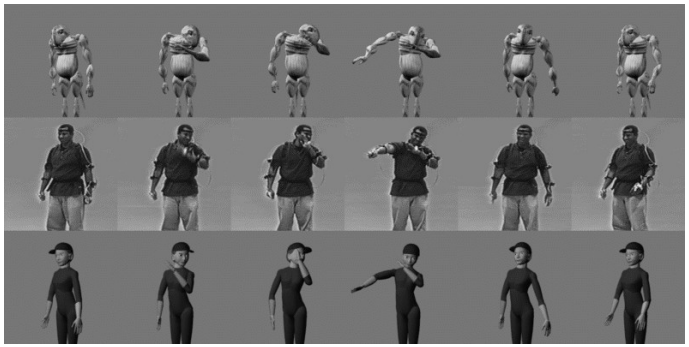
q , q' : current state/velocity

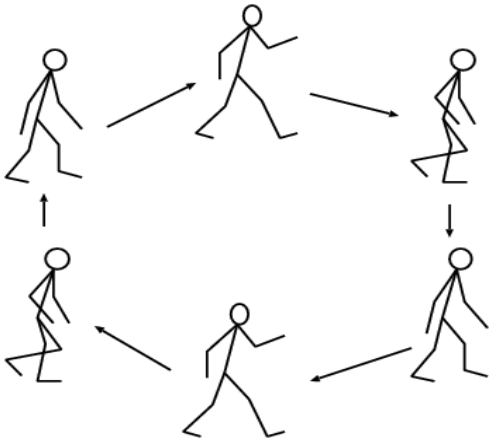
q_d , q'_d : desired state/velocity

Voluntary motions by PD control

- Prepare a number of keyframes
- Compare the current state of the avatar and the keyframes (desired state)
- Apply torque proportional to the difference of the current state and the target state

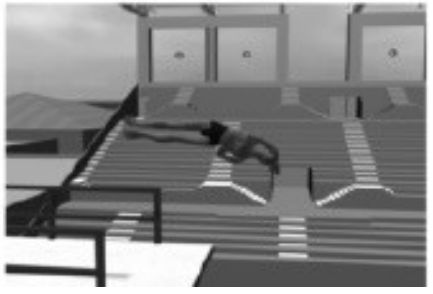
Switch the desired state once the body is close enough to it





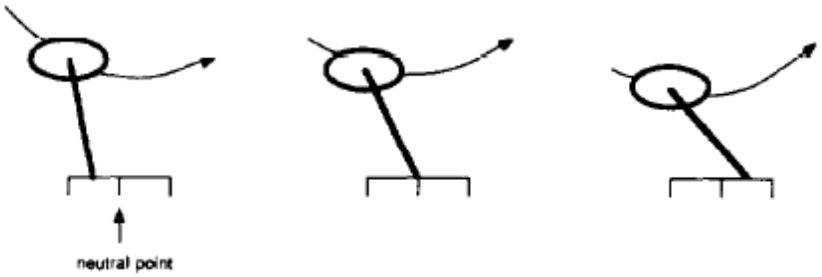
Simulating Athlete's Motions

- Diving
- Running
- Cycling



Maintaining balance while walking or running

- When walking or running, the next foot step must be decided such that the body does not fall down



- When the speed is too fast, step farther
- When the speed is too slow, step closer

$$x_{fgd} = \frac{\dot{x}\,T_s}{2} + k_{\dot{x}}\left(\dot{x} - \dot{x}_d\right)$$

x_{fgd} :displacement of forward the stepping foot from the projection of the center of gravity

T_s : duration of the gait cycle

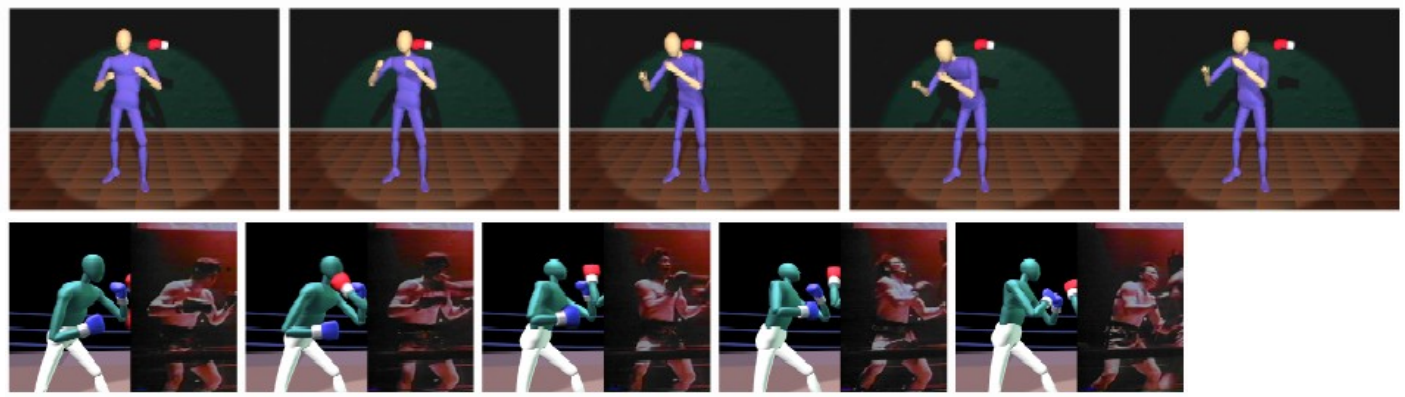
$\dot{x}, \dot{x}_d$: current and desired velocity

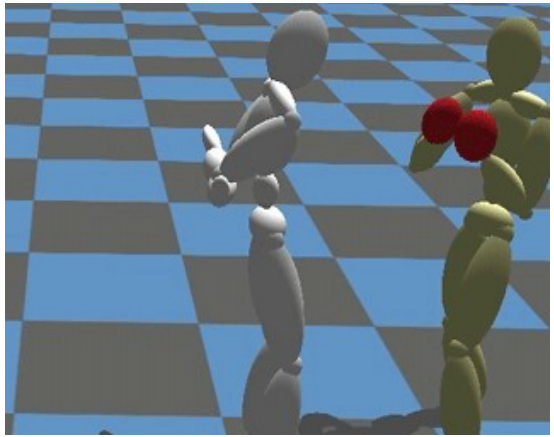
- Raibert and Hodgins, SIGGRAPH 1991

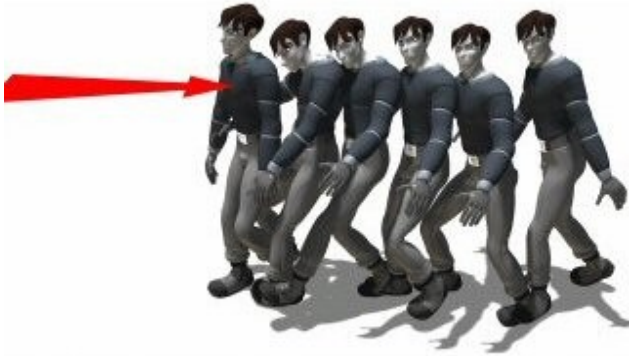
https://www.youtube.com/watch?v=R3_iq9Q_U6M

Response Motion by PD control

- Moving back to the original motion when perturbed
  - Feedback control
- Keeping balance or falling back

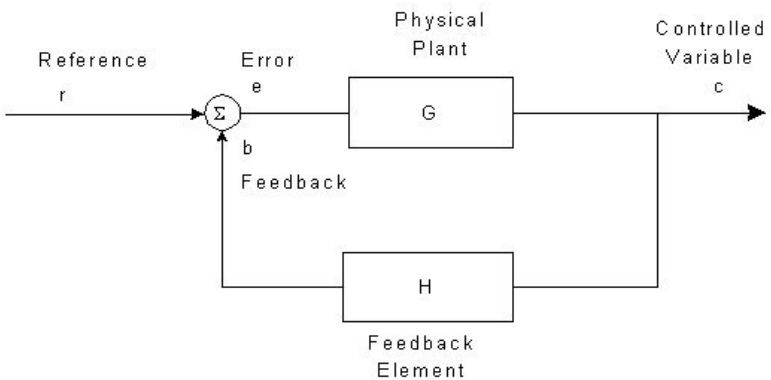






Feedback Control

- Moving back to the original posture / motion when perturbed



http://www.youtube.com/watch?v=Nb26DRMA01o

Quick Quiz again

- Which method to solve the following problem?
  - Find how fast you can breakdance?
  - Find how much forces are made by your muscles when punching?
  - Produce an animation of falling down
  - Produce an animation of hopping

Readings

•Calculating the joint centers

Skeletal Parameter Estimation from Optical Motion Capture Data
Adam G. Kirk et al.
IEEE Conf. on Computer Vision and Pattern Recognition (CVPR) 2005.

Automatic Joint Parameter Estimation from Magnetic Motion Capture Data James F. O'Brien Robert E. Bodenheimer, Jr. Gabriel J. Brostow Jessica K. Hodgins, GI2001
http://www.cc.gatech.edu/gvu/animation/Papers/obrien:2000:AJP.pdf

Motion capture
Sang Il Park, and Jessica K. Hodgins: Capturing and Animating Skin Deformation in Human Motion, *ACM Transactions on Graphics*, 25(3): 881-889 (2006)

Response motion
•Zordan, V. B., Hodgins, J. K., Motion capture-driven simulations that hit and react, ACM SIGGRAPH/Eurographics Symposium on Computer Animation, 2002, pp. 89-96.
•Zordan, V. B., Majkowska, A., Chiu, B., Fast, M., Dynamic Response for Motion Capture Animation , ACM SIGGRAPH 2005.
•Pushing People Around Okan Arikan David Forsyth James O'Brien
Symposium on Computer Animation (SCA) 2005

Locomotion
Raibert, Hodgins, Animation of Dynamic Legged Locomotion, SIGGRAPH'91

Jack Wang et al. Optimizing Walking Controllers for Uncertain Inputs and Environments, SIGGRAPH 2010