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



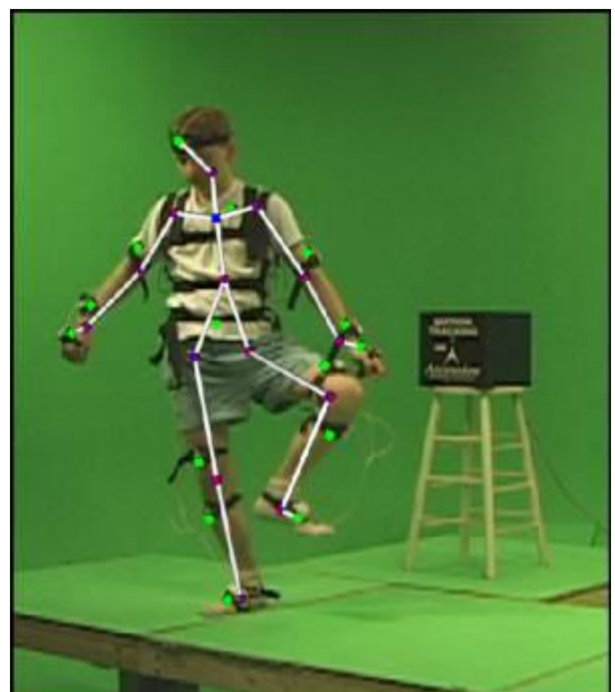
Using Real Human (Animal) Motion

Real human (animal) motion is realistic

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

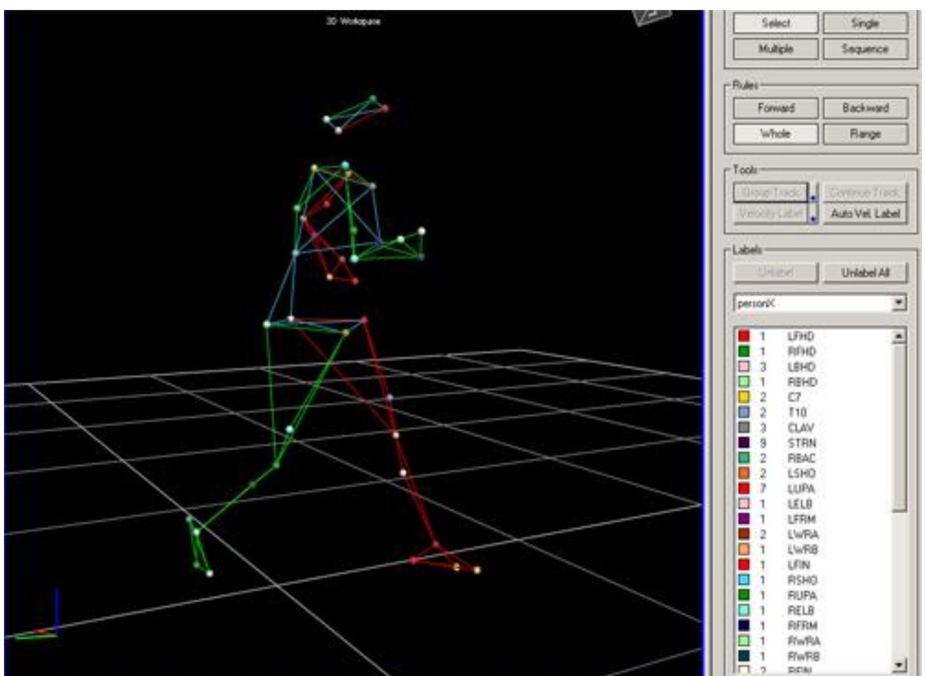


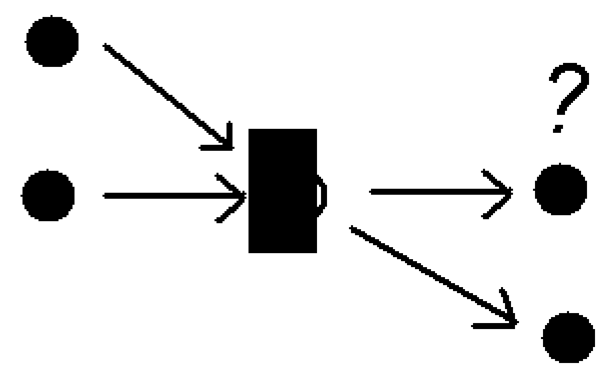
Optical Mocaps

- 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

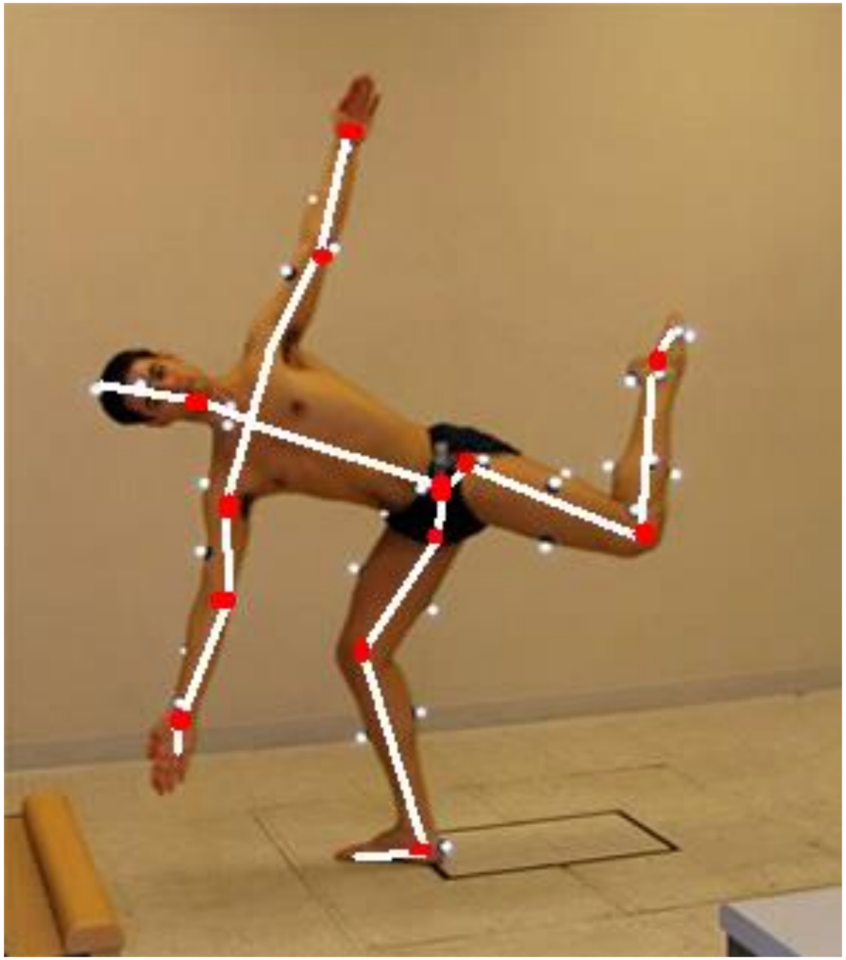
- The markers must be manually labeled first
- Once the markers get occluded, they have to be tagged manually again
  - The same process repeated for the whole motion
- Sometimes the body intersects, and then the system mix them up





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

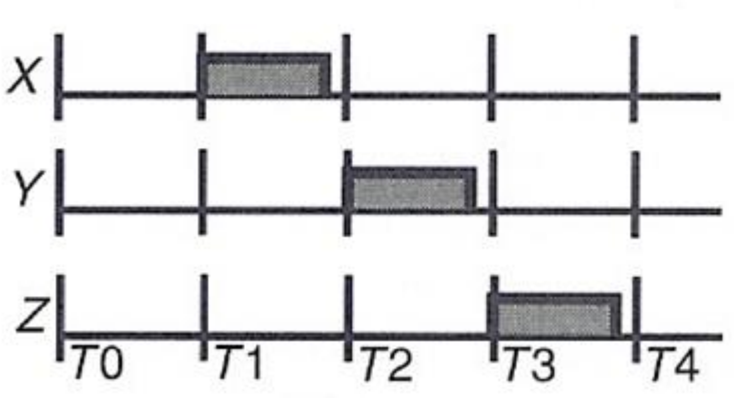
- Suffer from occlusions (the body hiding the markers)
- A lot of post-processing is required if occlusion happens
  - Labelling which marker is which
- Need a large studio for a capturing outdoor movements

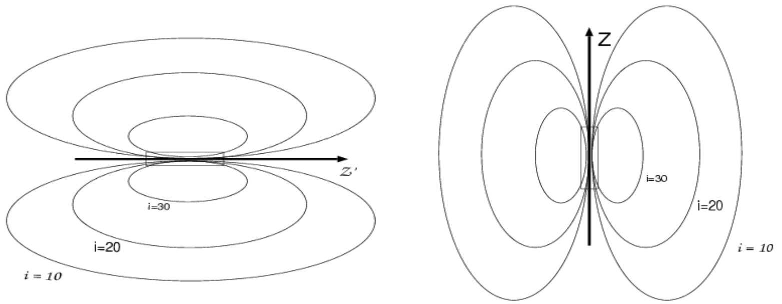
Demo movie of an optical Mocap system

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

Magnetic Mocaps

- The transmitter produce three orthogonal magnetic fields sequentially

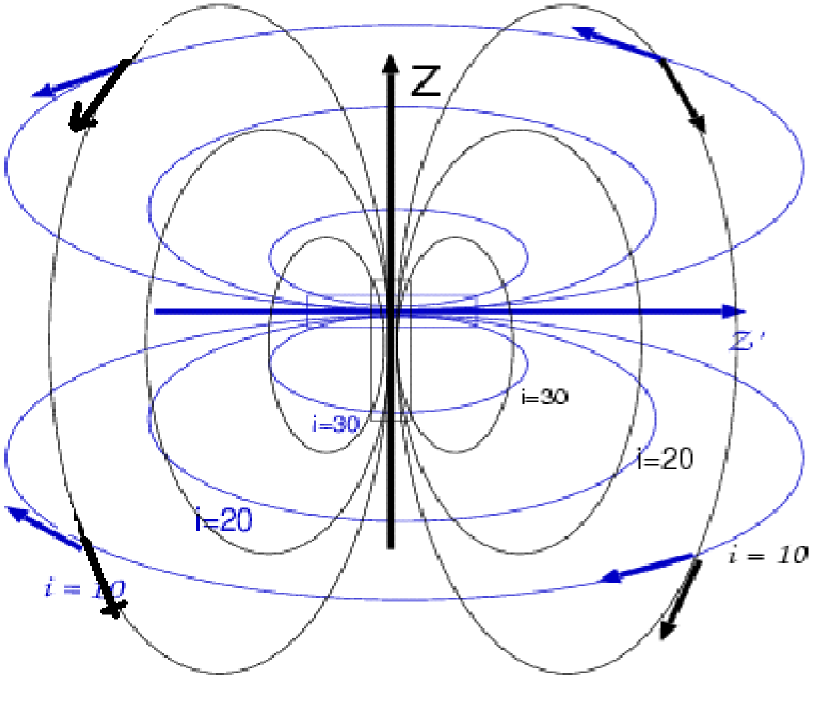




- The actor wears a suit to which the magnetometers are attached

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

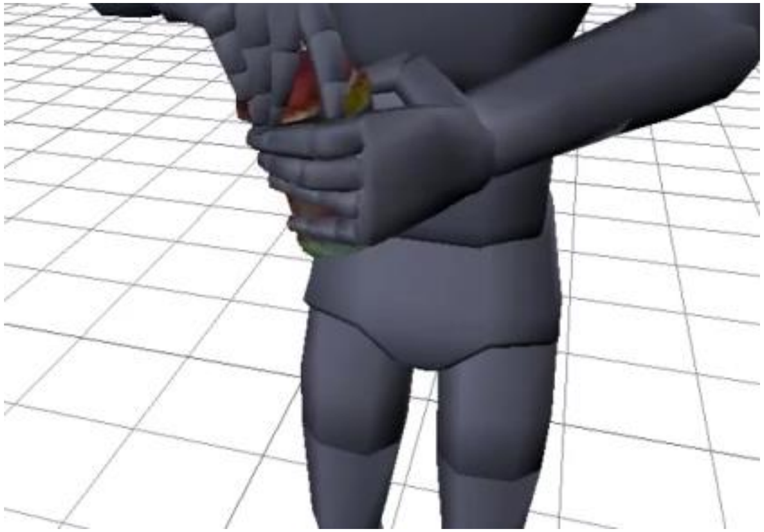
Shortcomings

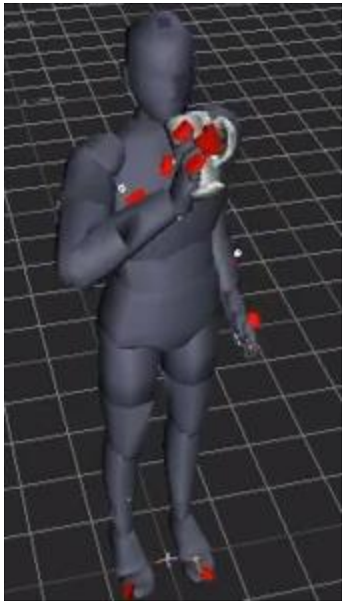
- Less accurate
  - The absolute positions are highly distorted
  - – Easily affected by the noise
  - – Cannot have metal/electronic devices in the capturing area
    - Affects the magnetic field
- The capturing volume is very small
  - – Only 2-3 m away from the transmitter

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

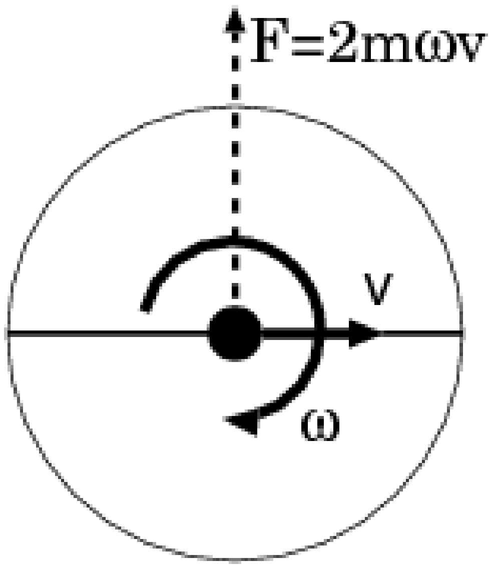
- Inertial trackers measure the rate of change in
  - Angular velocity - gyro sensor
  - Translational acceleration - accelerometer
- These values are integrated to compute the
  - Orientation and
  - Position

of the tracker

Orientation

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

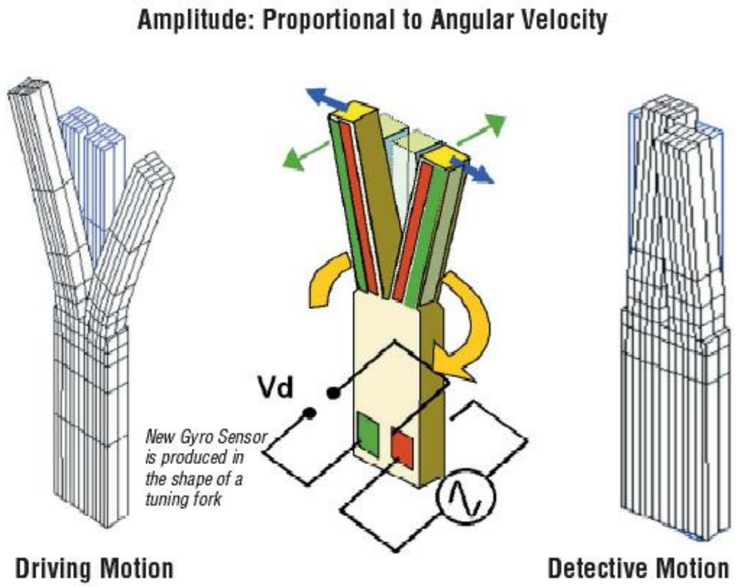
http://www.youtube.com/watch?v=O77grx9SgaU

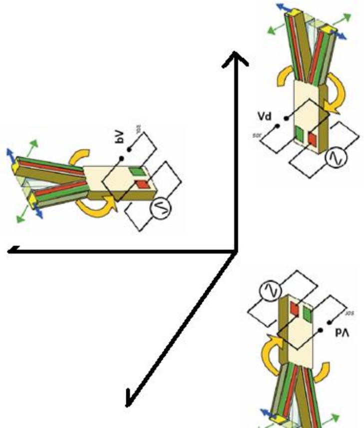


ω:angular velocity, v:velocity
m: mass, F: coriolis force

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

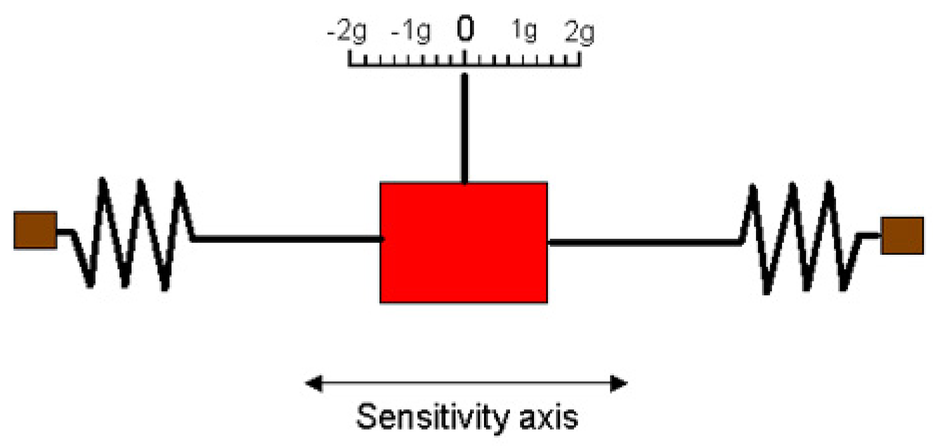


Fig. 1. Schematic structure of an accelerometer

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*

Demo movie of an inertial tracker-based motion capture system

http://www.youtube.com/watch?v=V0y
T8mwg9nc

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

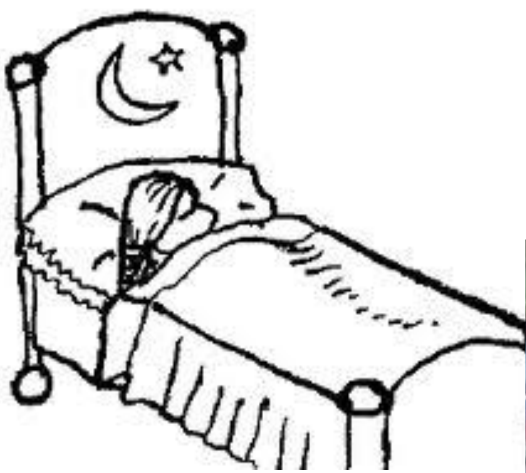
Advantages

- 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 prominent system
  - Magnetic systems are good for capturing close interactions but the capture volume is small
  - Inertia-based systems show more flexibility for the users
- **Many new systems based on depth sensors (like Kinect) 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

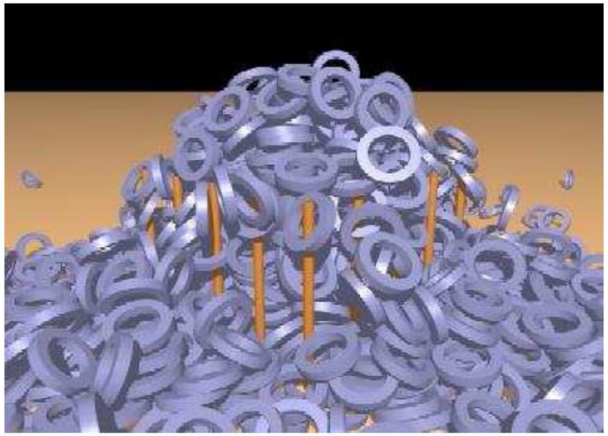


Overview

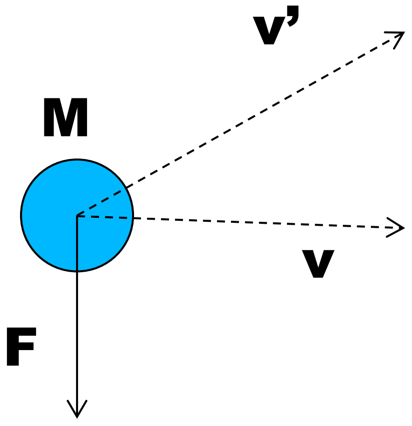
- **Physically-based animation**
  - Using Newton Physics to simulate events
  - Applicable to human animation
- **Methods based on**
  - Forward dynamics
  - Inverse dynamics
- **Forward dynamics – need to decide torque**
  - PD control

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 a

F : force

M : mass

a : acceleration

Given the force F ,

calculate the acceleration by a = F / M

then integrate

$$v = v' + a\,t, \quad x = x' + v\,t$$

Newton's Law of Dynamics

- For multi-body objects like human bodies, it is a bit more complex

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

$q\ \dot{q}\ \ddot{q}$ 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 ($\ddot{q}$) **INPUT** (F)

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: F

INPUT: $\ddot{q}$, q, $\dot{q}$

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

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, reinforcement learning etc.)

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

https://www.youtube.com/watch?time_continue=5&v=vppFvq2quQ0&feature=emb_logo

PD control : Introduction

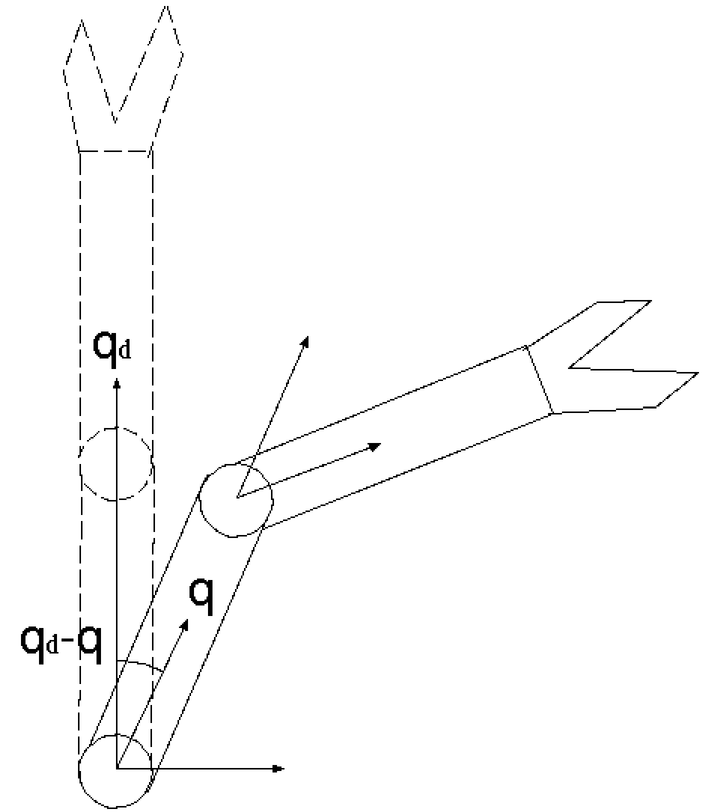
- A method used in robotics
- The larger the difference between the current state and the desired state, the larger the force/torque is

– $F = a\,(q - q_d) + c\,(q' - q'_d)$

a, c : constants,

q , q' : current state/velocity

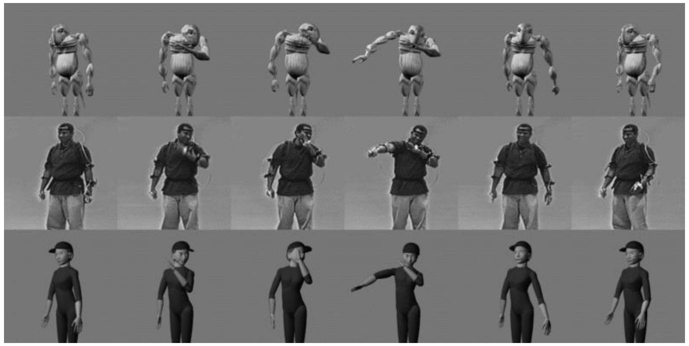
q_d , q'_d : desired state/velocity

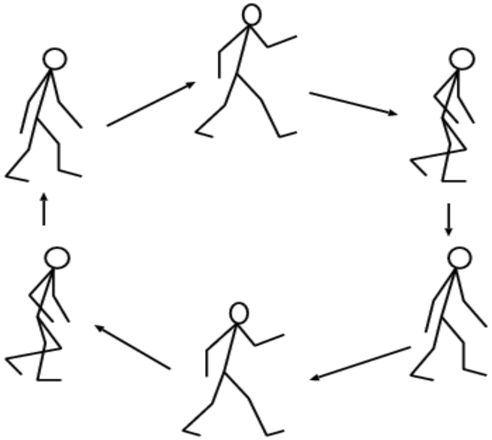


Voluntary motions by PD control

- 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

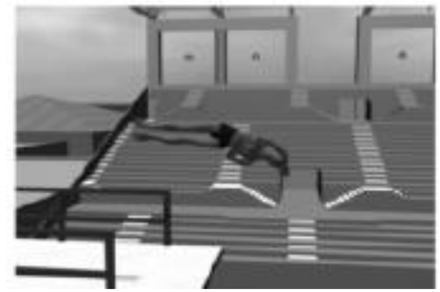
Switch the desired state once the body is close enough to it





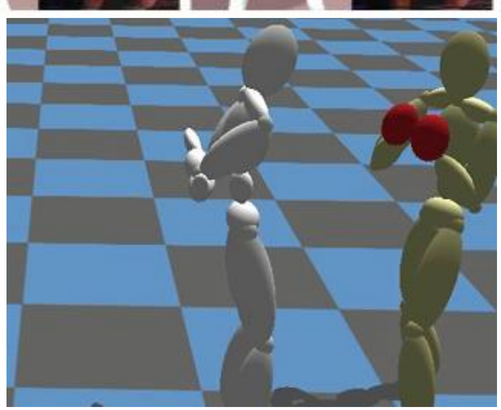
Simulating Athlete's Motions

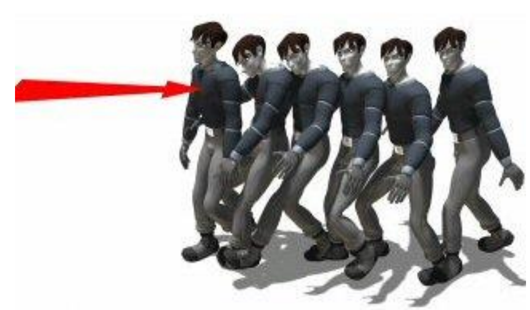
- **Diving**
- **Running**
- **Cycling**



Response Motion by PD control

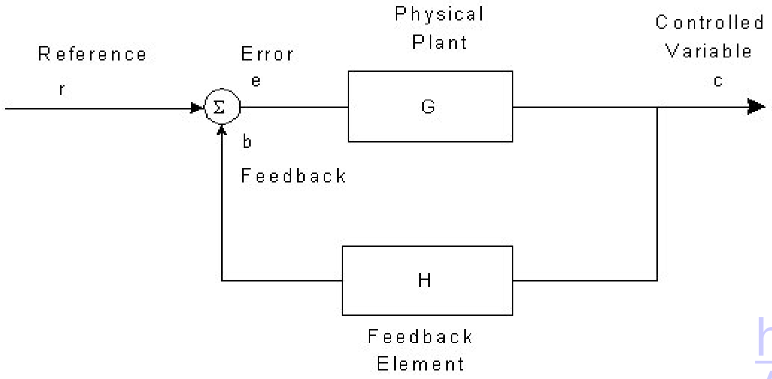
- **Moving back to the original motion when perturbed**
  - Feedback control
- **Keeping balance or falling back**





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

- 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.

- Locomotion
- Raibert, Hodgins, Animation of Dynamic Legged Locomotion, SIGGRAPH'91
- Jack Wang et al. Optimizing Walking Controllers for Uncertain Inputs and Environments, SIGGRAPH 2010

- State-of-the-Art Physics-Based Animation:
  SIGGRAPH Papers by Xue Bin Peng et. al.

DeepMimic: Example-Guided Deep Reinforcement Learning of Physics-Based Character Skills

Transactions on Graphics (Proc. ACM SIGGRAPH 2018)