Mapping optical motion capture data to skeletal motion using a physical model

Victor B. Zordan
Nicholas C. Van Der Horst

University of California, Riverside
Motivation
Motivation

Optical data + Skeleton → Posture

Problems: no perfect match, joint-center and rigid-body assumptions, limits on ranges of motion, aesthetic and production requirements
Motivation

Isn't this problem solved by inverse kinematics (IK) in commercial solvers?

Data is becoming more available (e.g. CMU mocap site)
BUT you want to map it to our own character
Money... Filmbox is expensive!

IK vs. our physical modeling approach
Direct mapping of data - landmark for landmark
Whole body solution - root gets no special priority
Easily avoids singularities - straight limbs not a problem
Avoids footskate - via ground contact reaction forces
Motivation

Recorded data is becoming more available (e.g. CMU site) but we want to map it to our own character

Commercial packages exist (like Kaydara's filmbox and Vicon's Motionbuilder) but they are expensive

Also, their solution is based on inverse kinematics (IK) which has known problems that lead to noticable flaws:

1) Ill-defined singularities yielding limbs that do not become fully straight
2) Indirect, root-centric mapping leading to errors that propogate, e.g. footskate
3) Redundancies corrected by adhoc heuristics causing various quirk artifacts
Background

Motion capture editing

Too many to mention, see mocap session SIGGRAPH ’02

Mapping to skeletons
Silaghi, Plankers, Fua, Boulic, Fua, Thalmann ’98
Molet, Boulic, Thalmann ’99
Monzani, Baerlocher, Boulic, Thalmann ’00
O`Brien, Bodenheimer, Brostow, Hodgins ’00
Ude, Mann, Riley, Atkeson ’00
Pollard, Hodgins, Riley, Atkeson ’02
Kovar, Schreiner, Gleicher ’02

Physics and motion capture
Rose, Guenter, Bodenheimer, Rose ’96
Popovic & Witkin ’99
Pollard ’99, Pollard & Behmaram-Mosavat ’00
Zordan & Hodgins ’02
Approach overview

Simulation is used offline to compute postures

Internal torque actuators allow the simulation to act as a flexible ragdoll

Force springs pull 'ragdoll' to reach the data, marker by marker

Contact (e.g. ground) may be added through force
Approach overview

Basic Algorithm

foreach (data sample) {
    update [yellow] markers
    while (not still) {
        compute torques
        compute body forces
        if (active)
            compute contact forces
        update simulation
    } //while
    record posture
} //for
Internal torque control

PD-servo's control 3D ball joints at each articulation point to resist bending

\[ \tau = k(\theta_d - \theta) - b(\dot{\theta}) \]

\( \theta_d \) from rest position

k and b are stiffness and damping, inertial scaled (Zordan & Hodgins '02)

No joint limits
Additional body forces

Force-driven virtual 'landmarks' placed by hand guide the simulated bodies to follow the markers

Springs pull the simulation to the marker data

\[ F_{\text{marker}} = -k_f X_{\text{error}} \]

Body motion is damped

\[ F_{\text{damping}} = -b_f V_{\text{body}} \]

Note, markers near joints affect both nearby bodies
Additional constraint forces

Avoiding foot/ground penetration and foot skate

Normal ground forces flatten the foot on ground via a penalty method

Marker data is used to tag when each foot is sliding or not

Horizontal friction forces (not shown) resist in opposite direction of the simulated point velocity when in slip
Implementation details & examples

39 Degrees of freedom - simulated in ODE (free!)

Runs about 2-3 frames/sec on 2.4 GHz Pentium IV

4 tuned parameters  - torque stiffness & damping
marker spring stiffness
body force damping
(plus, ground contact model)
Posture error

total marker absolute velocity (m/s)

simulation time steps

frame 300
frame 450
frame 600
frame 750
frame 900
Conclusion/future work

Simple, easy to implement, and inexpensive

Would dovetail nicely with a skeleton estimator

Likely requires a two-pass process for motion severe character retargeting

Would benefit from a specialized marker set (markers spread over body parts with highly repeatable landmarks, for example)

Should run interactively, to be used during the live motion capturee shoot
www.cs.ucr.edu/~rgl

Thank you!