Motion Capture (Mocap)

What is motion capture?

- Recording 3D live action
  - Track motion of reference points
  - Convert to joint angles
  - Use angles to drive an articulated model
  - Motion paths can then be combined to give greater control

Pros and Cons of Motion Capture

- Pros
  - All fine details of human motion will be recorded
    - if they can be captured
- Cons
  - Not so easy to
    - Edit
    - Generalize
    - Control
  - Not cheap

Applications

- Animation
- Special effects
- Robot control
- Interactive characters

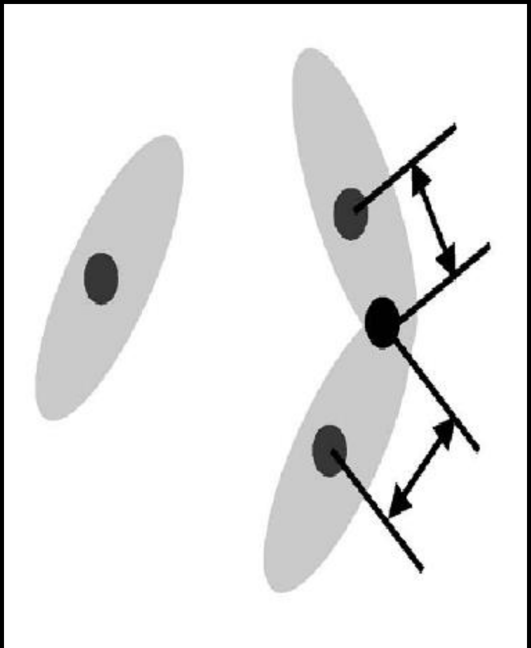
Computer Puppetry

- Using physical device to control animation

Shin et al., “Computer puppetry”

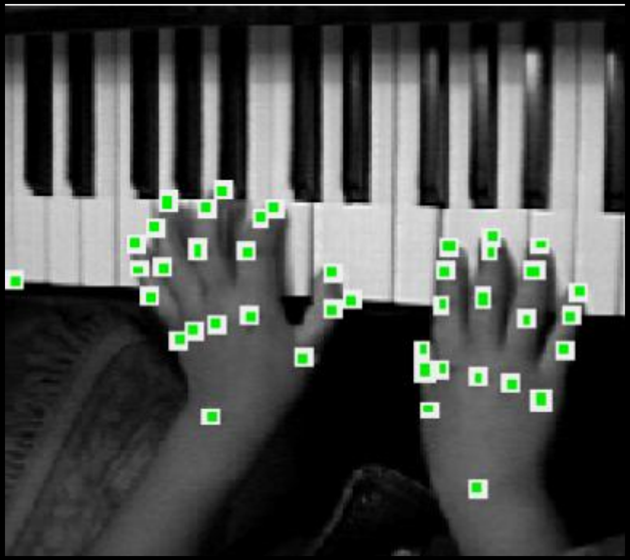
What is captured?

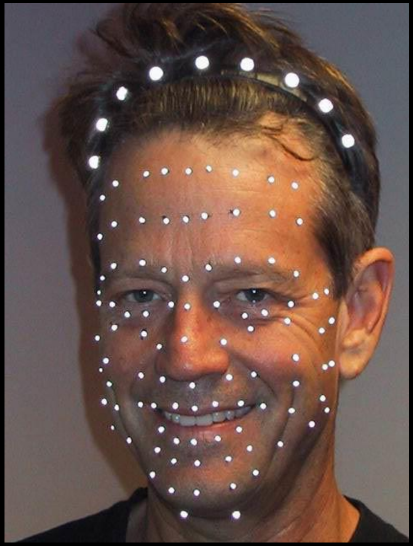
- What do we need to know?
  - X,Y, Z
  - roll, pitch, yaw
- Errors cause
  - Joints to come apart
  - Links to grow/shrink
  - Bad contact points



What is captured?

- Large and small scale
  - whole body
  - face, hands
  - animals



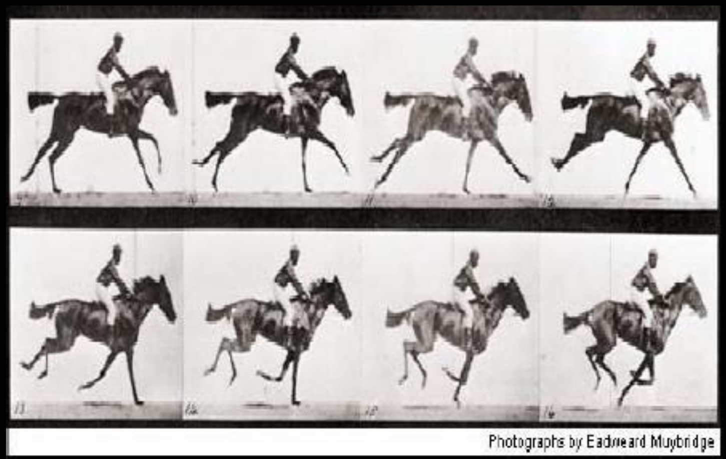


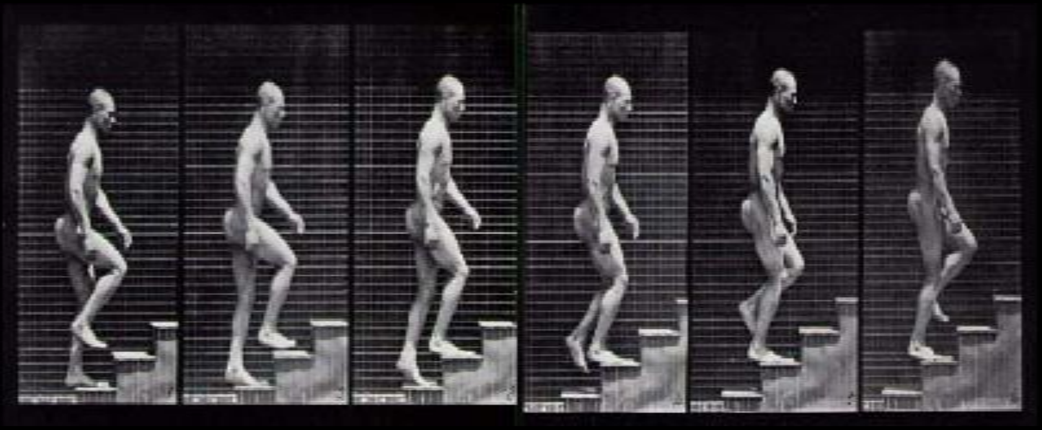
How to use the data?

- Off-line
  - Processed by filtering, inverse kinemtics
  - Produce libraries of motion trajectories
    - Choose among them
    - Blend between them
    - Modify on the fly
- On-line (performance animation)
  - Driving character directly based on what actor does in real time

History of the technology

- Recording motion for biomechanics
  - High accuracy
  - Fewer recorded points
  - Hand digitizing film
  - Supplement with force plate, muscle activity

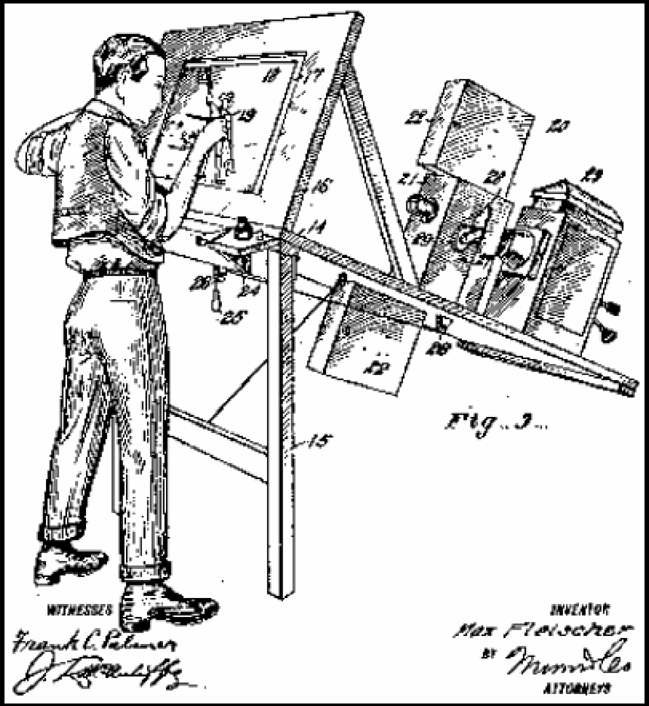




E. Muybridge, 1830-1904

History of the technology

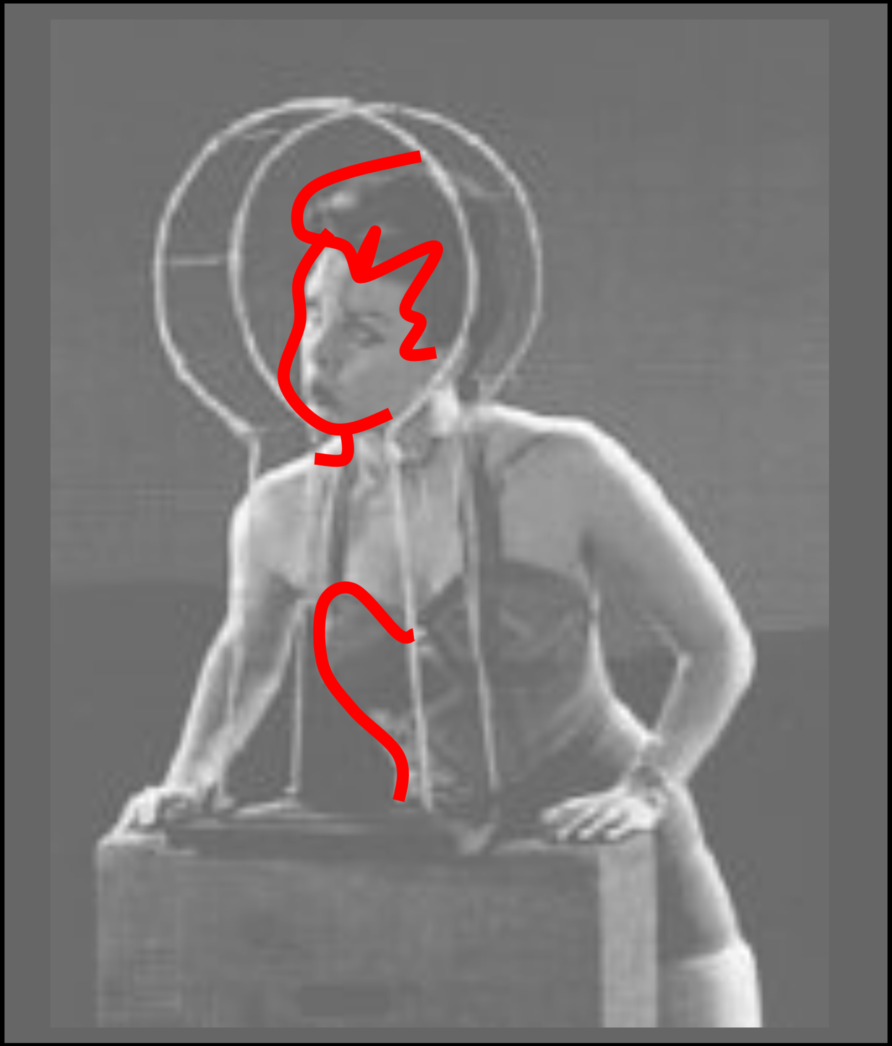
- Computer animation
  - Rotoscoping
- VR tracking technology
  - Less accuracy required
  - Fewer sensors



Fleischer, 1915

Rotoscoping

- Capturing video
- Tracing using transparent matte

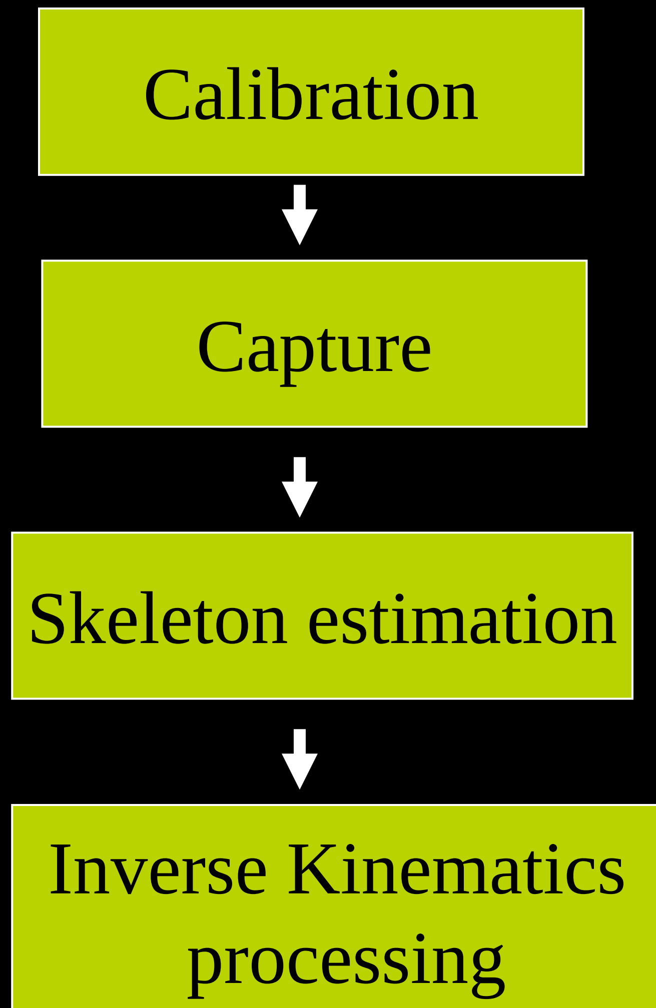


Rotoscoping

- Capturing video
- Tracing using transparent matte
- Post-processing

Johnston, et al., 1995

Production Pipeline



Motion Capture Systems

- Optical
  - 3D position of markers
- Magnetic
  - 6 DOF of a solid
- Mechanical
  - Exo-skeleton
- Inertial
  - gyroscope, accelerometer

Optical Motion Capture (Passive)

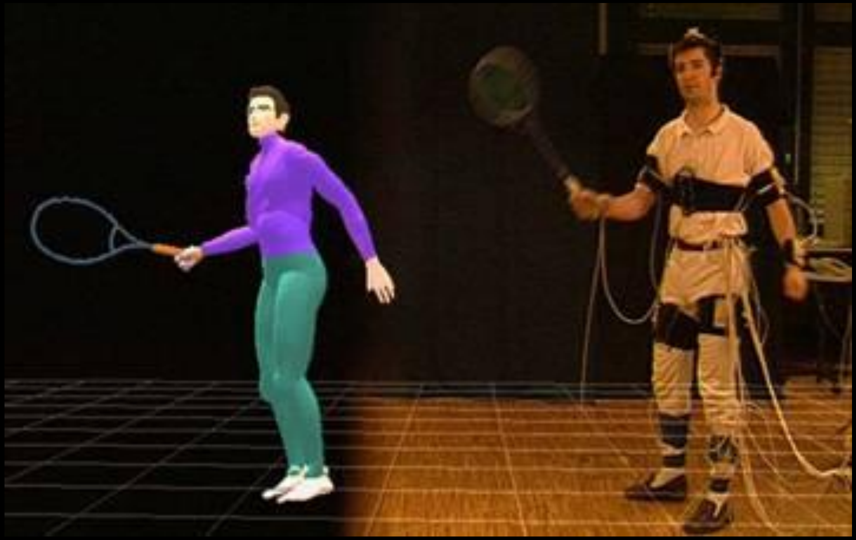
- Passive reflection
  - Camera
    - Infrared, visible, or near infrared strobes
    - High resolution (1 to 4 million pixels)
    - 120-240 frames/sec (max 2000 frames/sec)
  - Not outdoors
  - No glossy or reflective materials
  - Tight clothing
  - Occlusion of markers by limbs or props

Optical Motion Capture (Active)

- Each marker encoded by active LED pulse
- No marker confusion problem
- Outdoor capture
- 3,600 x 3,600 resolution
- 120 frames/sec (128 markers or four persons)
- 480 frames/sec (32 markers or single person)
- 1/3 the cost of passive systems

Magnetic Motion Capture

- Electromechanical transducer
- Heavier sensors
- Wires on body (wireless back to base station)
- Limited accuracy (~10x less accuracy than optical)



Magnetic Motion Capture (cont.)

- Smaller workspace
- Sensors are the cost
- Sensitive to EMI/metal
- Relatively cheaper than optical device

Ascension MotionStar Wireless

Mechanical Motion Capture

- Subject wears an exoskeleton
- No interference from light or magnetic field
- No marker confusions
- No range limit
- Some restriction of movement
- Absolute position is unknown

Mechanical Motion Capture

- Data glove
  - Bend sensor + optical tracking
  - 6 DOF
- [video]

http://www.vrealities.com/glove.html

Inertial Motion Capture

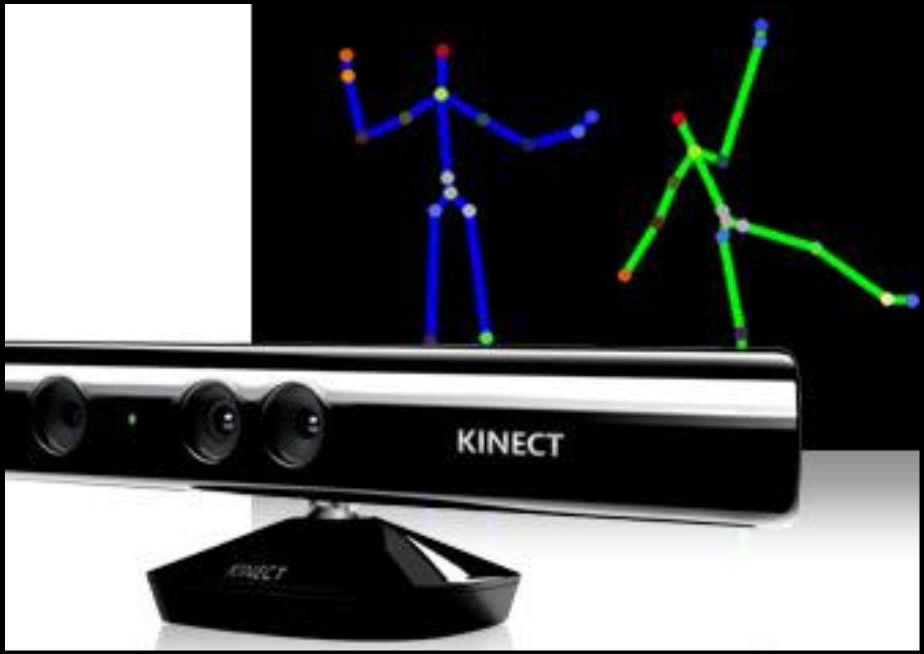
- Inertia sensors
  - gyroscope
  - accelerometer
- Outdoor capture
- Difficult to calibrate

Moven / xsen

Nintendo, Wii

RGBD Camera

- RGB + Depth Cameras
- Capture both skin deformation and skeleton motion



Technical Issues

- Resolution/range of motion
- Calibration
- Accuracy
  - Marker movement
  - Sensor noise
  - Restrictions on the environment
  - Capture rate
- Occlusion/correspondence

Recent Mocap Research

- Skin motion capture
- Outdoor motion capture
- Nonintrusive motion capture
  - Multiview vision approaches
  - Learning-based approaches

Skin Motion Capture
Park & Hodgins, SIGGRAPH'06

- Uses a conventional optical motion capture system

40-60 markers

Skin Motion Capture

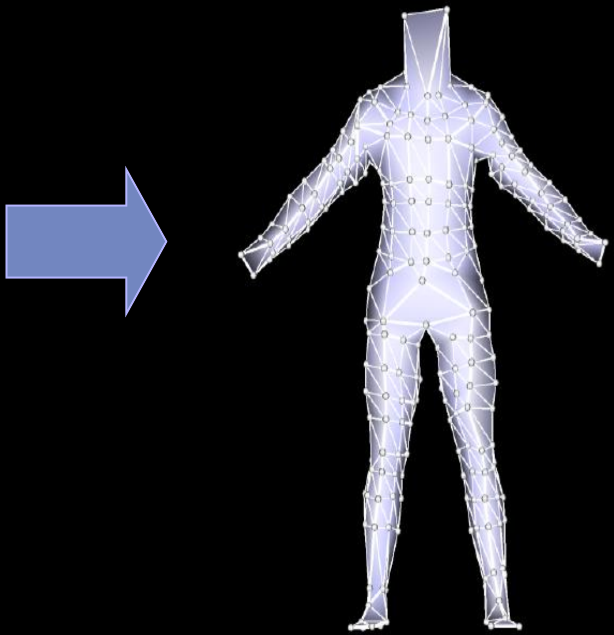
- Uses a conventional optical motion capture system

A dense set of markers

Skin Motion Capture

- Uses a conventional optical motion capture system

A dense set of markers



Skin Motion Capture

- Uses a conventional optical motion capture system

A dense set of markers

Detailed surface model

Skin Motion Capture

- Uses a conventional optical motion capture system

Data collection and cleaning

A dense set of markers

Detailed surface model

Skin Motion Capture

- Uses a conventional optical motion capture system

Data collection and cleaning

Skin Animation

A dense set of markers

Detailed surface model

Videos

- Park & Jessica, SIGGRAPH'06
- Lord of the rings: Gollum

Outdoor Capture

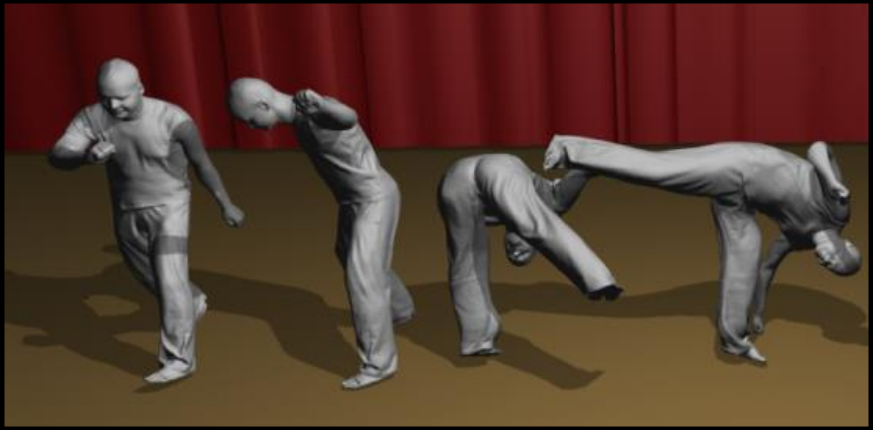
- Vlasic et al., “Practical Motion Capture in Everyday Surroundings,” SIGGRAPH’07
- Inertia sensors + ultrasonic measurements

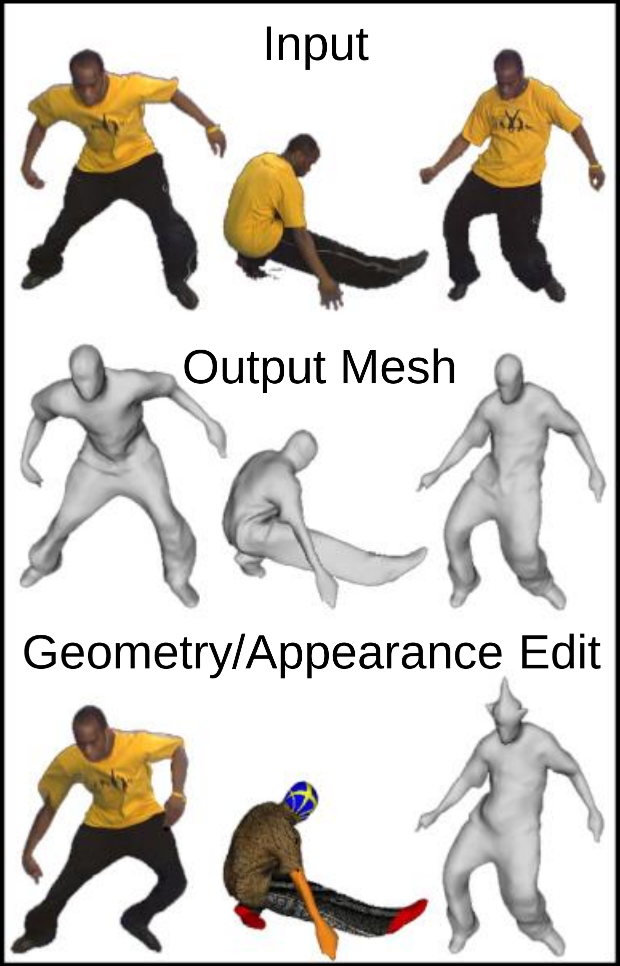
Correct MOCAP using high rate IMUs

- Kuo et al., Creating impactful characters: correcting human impact accelerations using high rate IMUs in dynamic activities, TOG'19
- Use FK (Jacobian) to predict an IMU's acceleration, which depends on joint angles
- Correct joint angles such that the predicted and measured accelerations at IMUs are matched
- Correction only applied during impact → won't affect other captured motion without impact!

Nonintrusive Motion Capture

- Capture 3D geometry and appearance
  - Vlasic et al., “Articulated Mesh Animation from Multi-view Silhouettes,” SIGGRAPH’08
  - Edilson de Aguiar, “Performance Capture from Sparse Multi-view Video,” SIGGRAPH ‘08

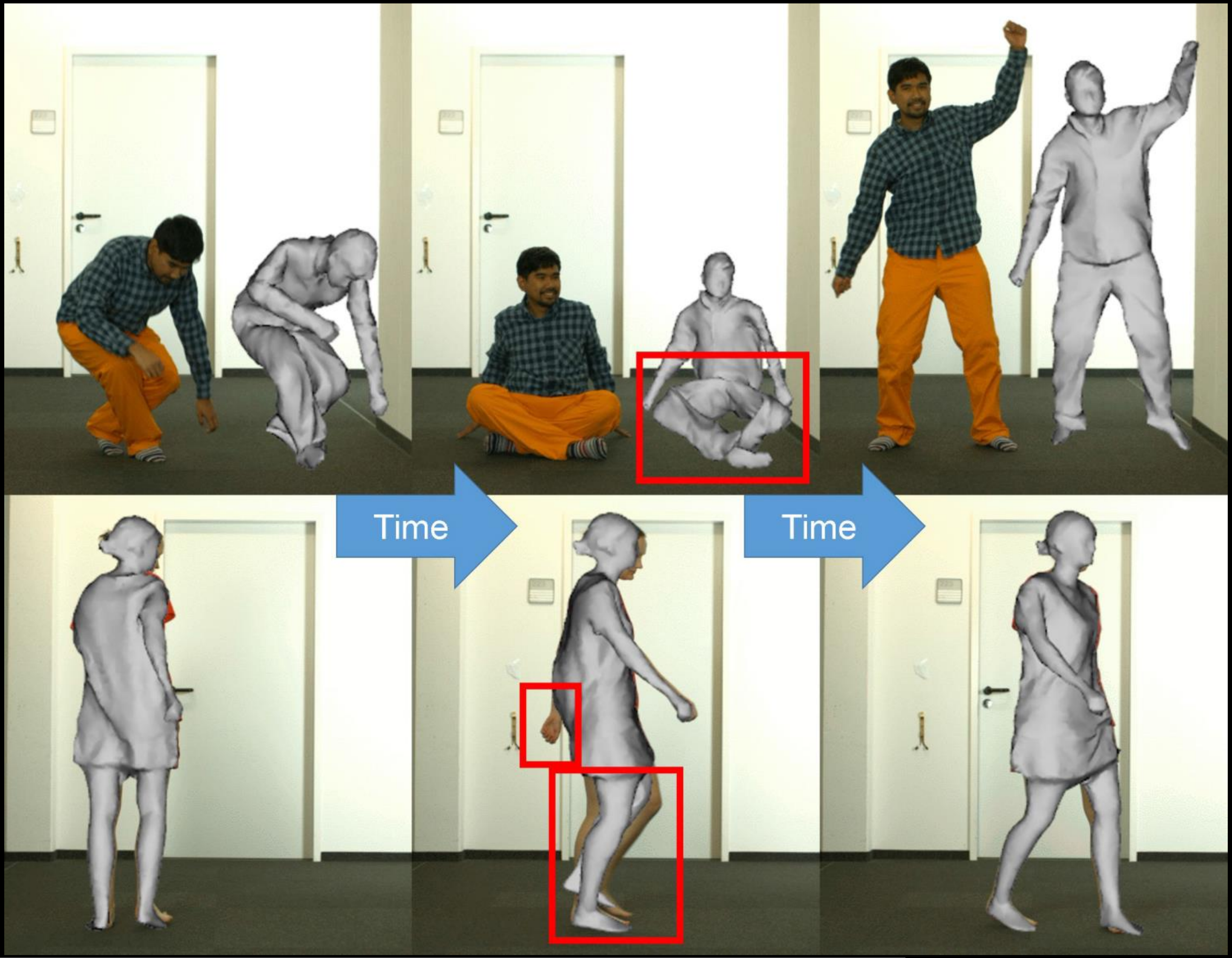




Real-time Markerless MOCAP from Single RGB Camera

- Many learning-based methods proposed recently in computer vision and graphics
- Skeleton capture
  - Mehta et al., VNect: real-time 3D human pose estimation with a single RGB camera, SIGGRAPH'17
- Geometry + Appearance
  - Habermann et al., LiveCap: Real-time Human Performance Capture from Monocular Video, TOG'19

Limitation of learning-based methods: extreme cases not in training data



Failure cases in LiveCap

Diffusion Models: PhysDiff, CVPR'23

Mocap Resources

- CMU Mocap database
  - http://mocap.cs.cmu.edu
  - 2605 motion clips, 23 categories
  - Free for research
- “Database Techniques With Motion Capture”, SIGGRAPH’07 course
  - Motion extraction and segmentation
  - Motion retrieval
  - Motion signal modeling