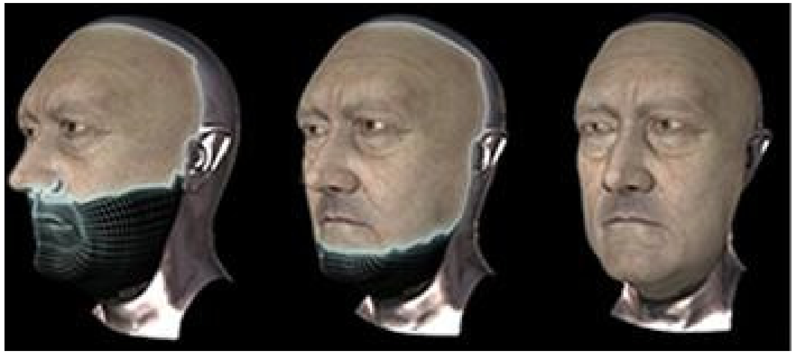
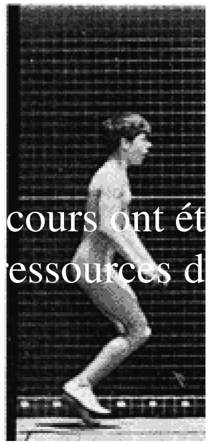


MOTION CAPTURE AND CO

Alexandre Meyer

Master Informatique



Plan: Motion Capture and Co

- Introduction and past of mocap
- …

The idea behind motion capture (mocap)

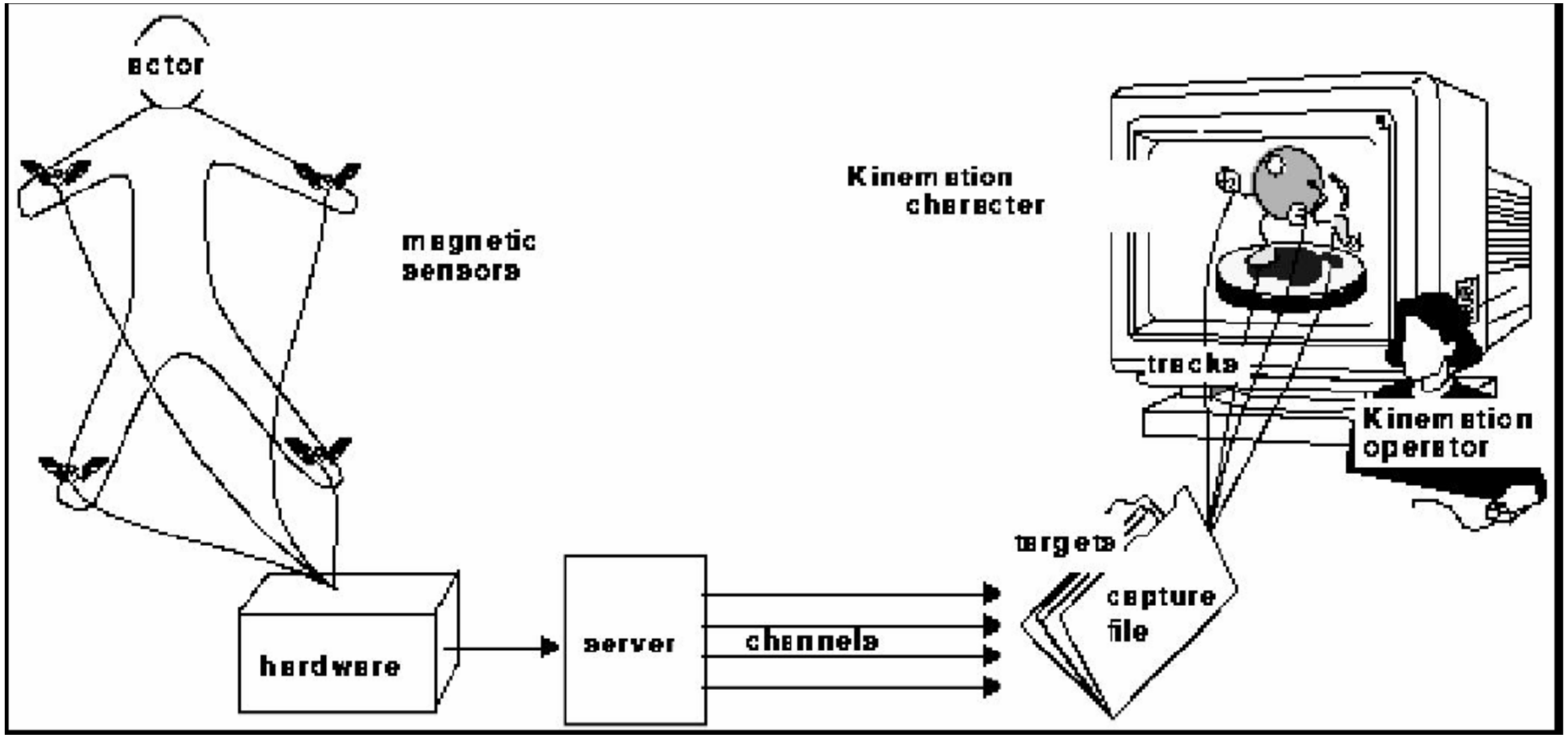
Modeling Motion

- Heuristics (Procedural)
  - Rules of thumb, guidelines, cheap hacks
  - Keyframing, traditional cel animation
- Simulation
  - Use of physics
  - Dynamics
- Use of measured data
  - Motion capture

The idea behind motion capture (mocap)

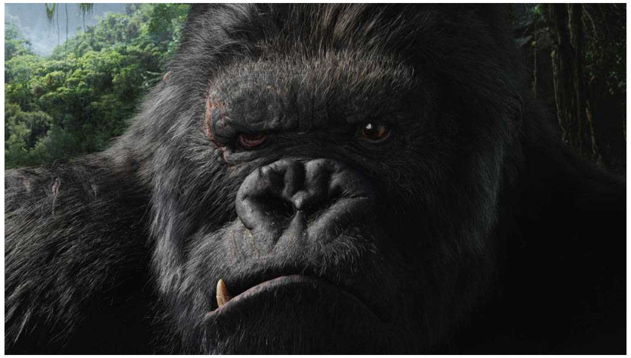
- You want realistic human motion?
  - Simulation: uhm!! Stuff!!
  - Use an actual human
- Motion capture is the recording of human body movement (or other movement) for immediate or delayed analysis and playback
- The person moves the way the character is supposed to move
- Motion capture employs special sensors, called trackers, to record the motion of a human performer
- The recorded data is then used to generate the motion for an animation

The idea behind motion capture (mocap)



Uses of motion capture

- Medicine
  - biomechanics
  - prosthetics
  - physical therapy
  - surgery
- Sports
  - motion analysis and improvement
- Military
  - targeting
- **Entertainment**
  - **film**
  - **games**



Two problems

motion capture + editing/retargeting

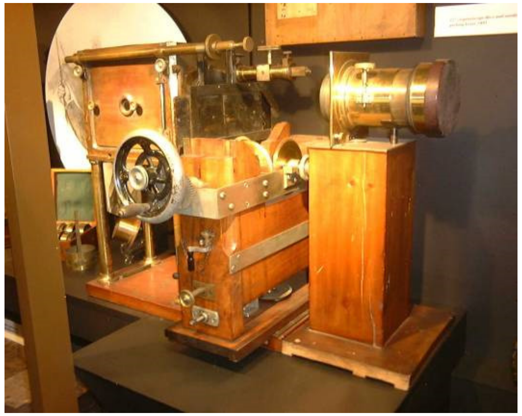
Motion capture

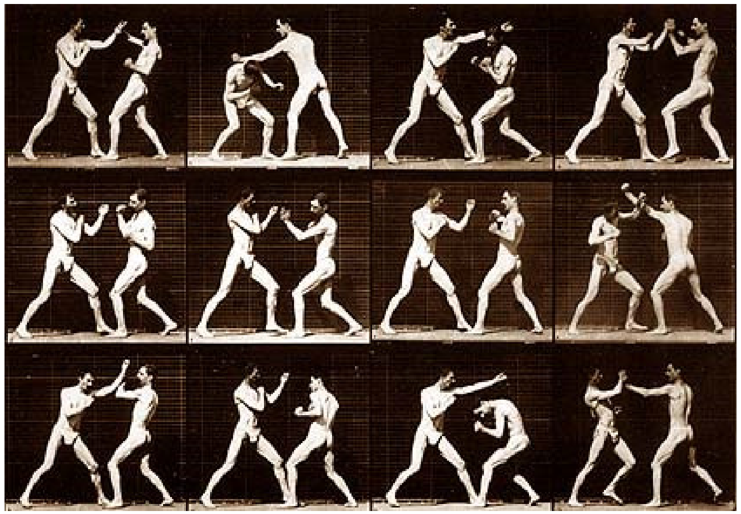
?

Editing/Retargeting, playback

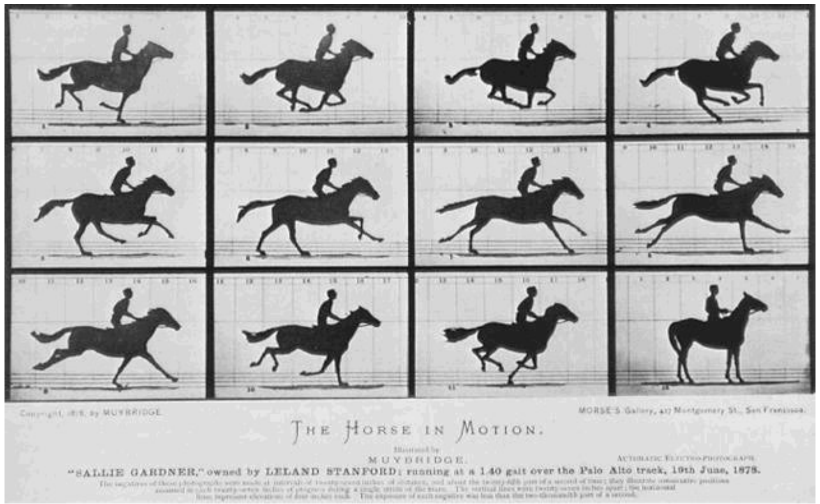
Eadweard Muybridge (1830-1904)

- “Father of the motion picture”
- several cameras – successive pictures
- photographs of human and animal motion
- zoopraxiscope (zoogyroscope, zoetrope) – a device for playing still images in sequence



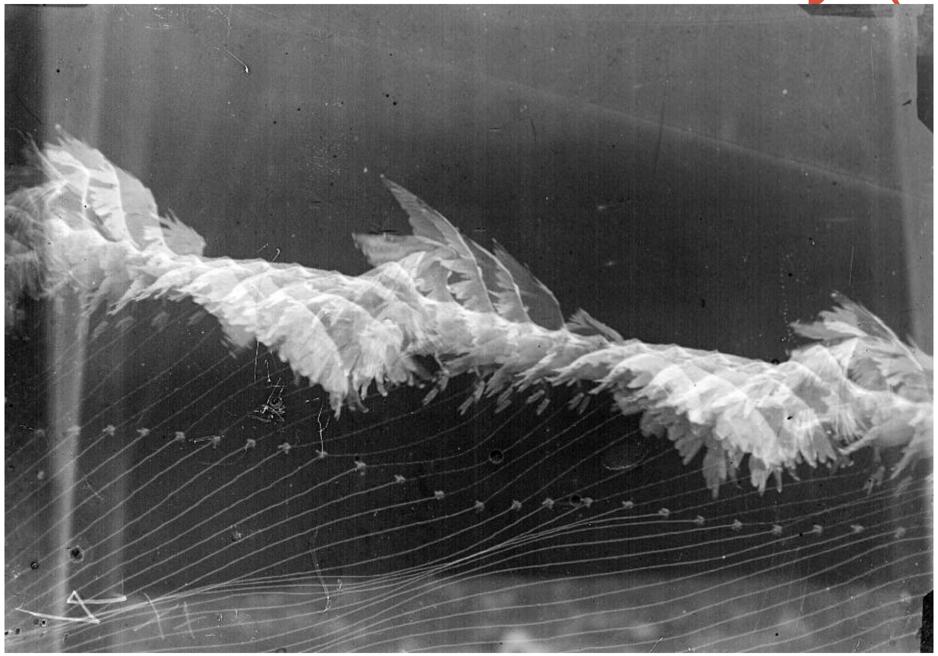


http://www.cotianet.com.br/photo/great/Muybridge.htm

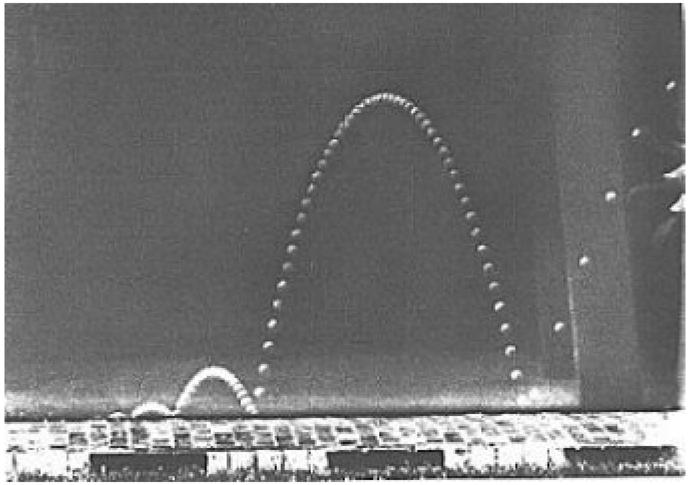


http://en.wikipedia.org/wiki/Image:The_Horse_in_Motion.jpg

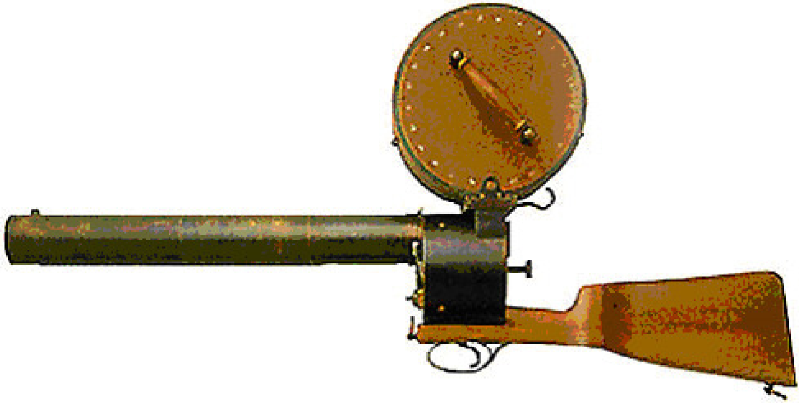
Etienne-Jules Marey (1830-1904)



http://www.nrw-forum.de/img_ausst/img_press/Marey.jp



http://www.inrp.fr/Tecne/Acexosp/Actimage/Images/Marey2.jpg

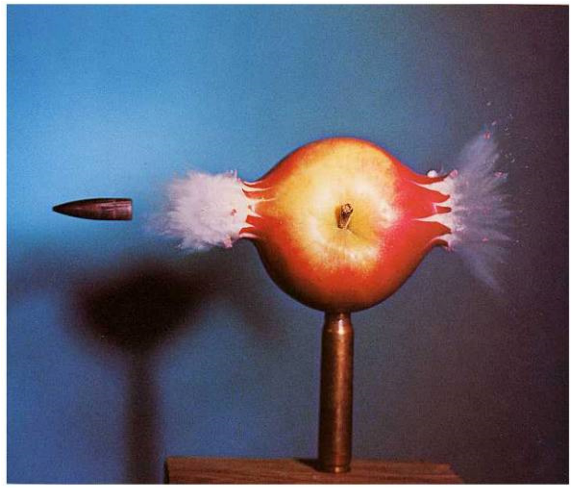


http://www.rickwisedp.com/St%20Marys/COMM%20158/images/Marey%20Photo%20Gun.jpg

Harold Edgerton (1903-1990)

- high speed and stop motion photography
- exposures as small as a millionth of a second
- electronic flash
- stroboscope

http://www.personal.psu.edu/users/a/r/ark176/Assignment%204.htm



http://www.personal.psu.edu/users/a/r/ark176/Assignment%204.htm

The rotoscope

- Max Fleischer, 1915
- **performer** is filmed
- frame by frame playback
- “animator” traces the frame
- produces realistic motion for animated films
- Disney, Snow White, 1940’s

Lee Harrison III, 60's and 70's

- SCANIMATE, ANIMAC, CAESER
- analog!
- prosthetic system, a motion capture harness
  - potentiometers, convert rotation or linear motion to a change in electrical resistance
  - Lincoln Logs as armatures
- TV flying logos
  - Electric Company

http://accad.osu.edu/~waynec/history/lesson12.html

“Modern” era of mocap, 1970’s-present

- more players
- commercial players
- multiple uses

- 70’s: development of magnetic systems
- 80’s: development of optical systems
- 90’s: mocap is hot,
- 00’s: mocap is used more frequently for feature films

Plan: Motion Capture and Co

- Introduction and past of mocap
- Motion capture with markers
  - Types of mocap systems
  - …

Types of mocap systems (Alberto Menache)

- Outside-In
  - sources (e.g., reflective markers) on body
  - external sensors (e.g., cameras)
  - optical systems
- Inside-Out
  - sensors on body
  - external sources
  - magnetic systems
- Inside-In
  - sources and sensor on body (e.g. cyber gloves)
  - mechanical systems

Implementation of a motion capture system

- Prosthetic
  - e.g. cyber glove
- Acoustic
  - sensor on the performer emit sound which is detected by captors
- Magnetic
  - Sensor on the performer captured signal emitted by the room structure
- Optical
  - Based on camera which tell the positions of sensor on performer

Liverman, The Animator’s Motion Capture Guide

Mechanical/prosthetic capture

- Inside-In
- **external structure** attached to **performer**
- structure detects changes
  - optic
  - mechanical

Gypsy4

cyberglove

http://infolab.usc.edu/more/facilitiesimages/glove.jpg

Mechanical/prosthetic capture

- advantages
  - computes rotations directly
  - portable, unlimited range
  - less expensive
  - can capture multiple performances simultaneously
  - no built in positional reference
- disadvantages
  - external structure unwieldy
  - cannot change the configuration, i.e., a hand capture can't be used for an arm

Acoustic capture

- **Outside/In**
- Active Markers –
  - **transmitters** are attached to the performer and sequentially emit audio signal, a “click”
- **receivers** measure the time to receive the signal, triangulate and **compute the position** of the transmitter
- advantages
  - no **occlusion**
- disadvantages
  - cables unwieldy
  - rate of transmission not high enough to support enough transmitters
  - size of the capture area is limited
  - sound reflections can reduce accuracy

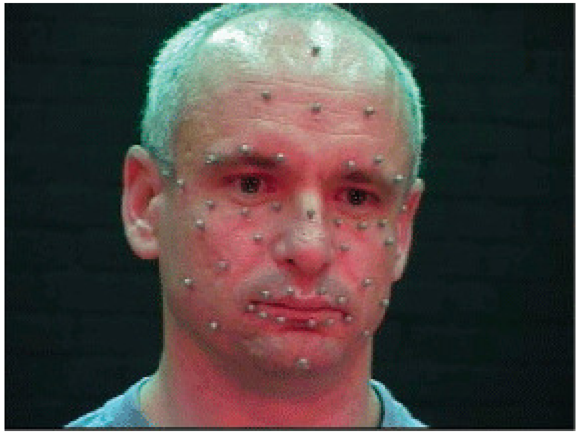
Magnetic capture

- **Outside/In**
- **receivers** are attached to the performer's body
- compute the **position and orientation** from receiver to central **magnetic transmitter**
  - AC and DC systems
- advantages
  - no occlusion
- disadvantages
  - cabling can interfere with movement (improvements?)
  - capture area can be limited by transmitter
  - metal in vicinity can interfere with system
  - capture volume can be limited

Optical capture

- **markers** are attached to a performer
  - **passive** reflective markers
  - **active** reflective markers

- a **system** of **cameras** record the position of the markers



passive

active

Optical capture (active): Ascension Reactor

- **active** optical system
  - 30 infrared (IR) markers
  - each marker fires sequentially (lik
- 544 sensors (“cameras”) alonc
  - each set of 4 parallel bars determ
    coordinate, either x, y, or z
- capture rate 900 measuremen
  frames/sec

http://www.ascension-tech.com/images/reactorlarge.jpg

Optical capture

- advantages
  - freedom of movement
  - high quality capture
  - high throughput
    - fast sampling (200 fps at a high resolution)
    - can capture fast motions
    - can have a large capture space
    - can capture many markers
  - cost $$$

- disadvantages
  - **occlusion**, markers are can be hidden from the camera
    - additional performers will increase occlusion
    - may be able to add redundant cameras
  - marker **crossover**, which marker are you looking at?
  - extensive post processing (the marker's have to be located and identified)

Major optical players

Motion Analysis

- http://www.motionanalysis.com
- Films
  - Lord of the Rings
  - King Kong
  - Matrix
  - Final Fantasy
- Games
  - NBA Live 2004
  - Grand Theft Auto III
  - Mortal Kombat 4 (Midway)

Vicon*Peak*

- http://www.viconpeak.com/
- Films
  - Polar Express
  - Harry Potter and the Prisoner of Azkaban
  - The Hulk
  - Spider Man
- Games
  - All-Star Baseball 2002
  - Buffy the Vampire Slayer
  - Everquest II
  - NHL 2K3 (Mocap by Red Eye Studio)

Plan: Motion Capture and Co

- Introduction and past of mocap
- Motion capture with markers
  - Different type of system
  - Mocap pipeline in details
  - …

Mocap pipeline

- planning for capture
- setup and calibrate system
- capture **performer**, obtain marker positions
- retarget to a **character**
- edit/cleanup

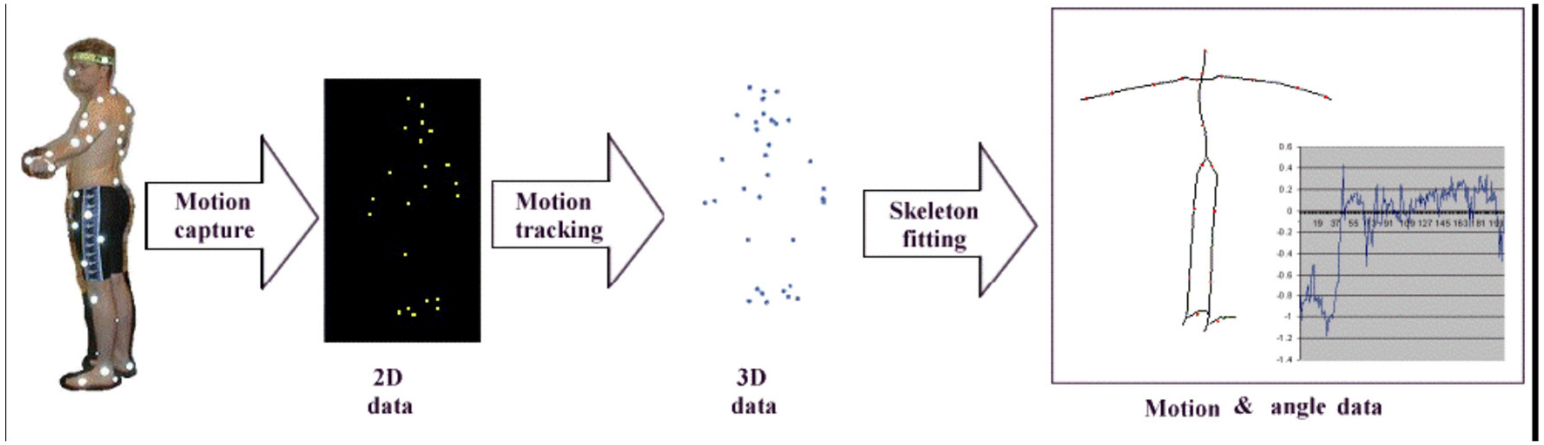
Skeleton mocap

- A target skeleton is defined
- Marker at each joint of the skeleton

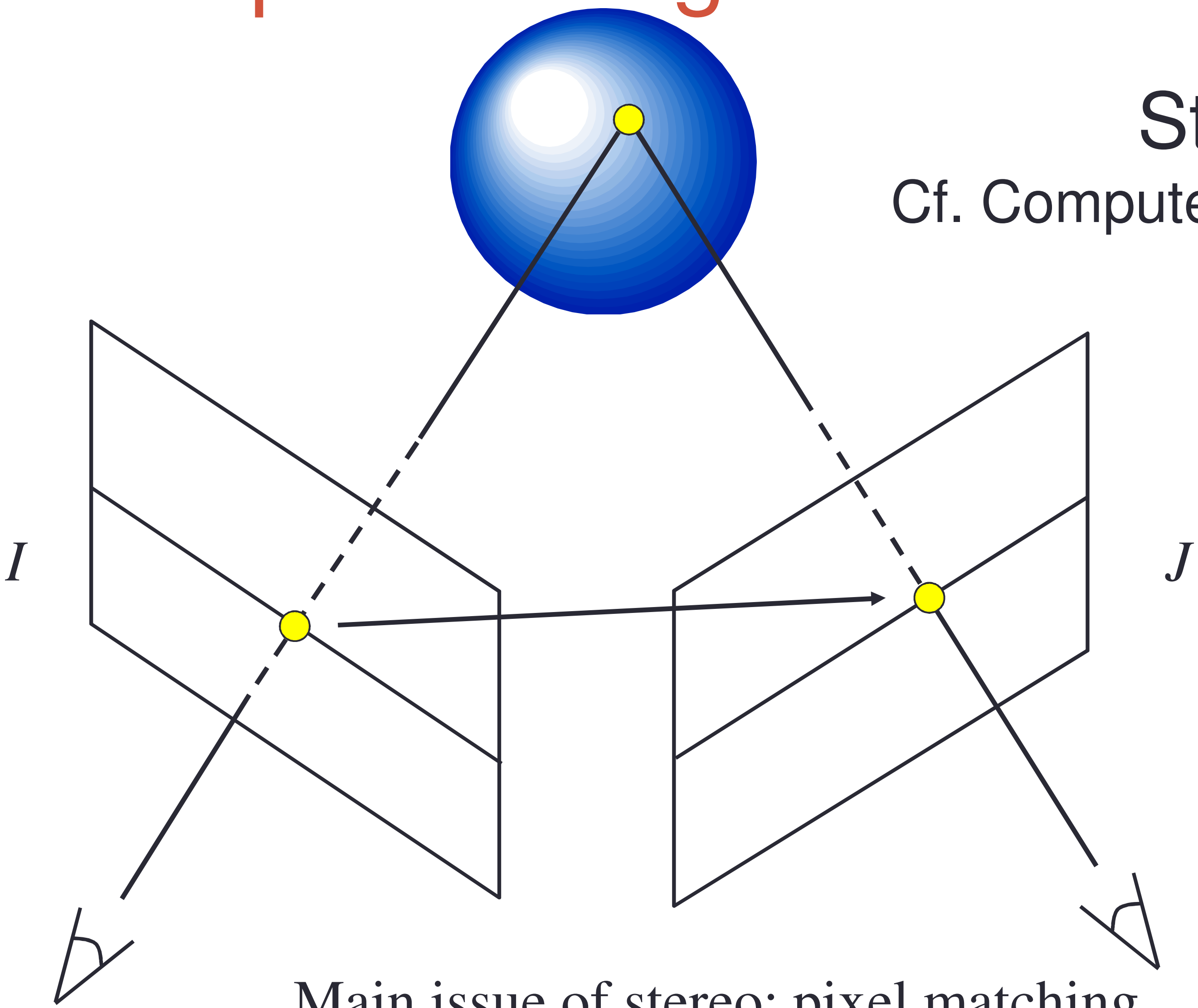
Skeleton mocap: problems for each frame

- Motion capture/Extraction:
  - markers need to be identified in the image→determines 2d position
  - problem: **occlusion**, marker is not seen → use more cameras
- Motion tracking:

  markers need to be convert to 3D points and labeled
  - compute 3d position: if a marker is seen by at least 2 cameras then its position in 3d space can be determined
  - which marker is which? (problem of skeleton fitting)



Principle 1: triangulation



Stereo

Cf. Computer Vision Course

Main issue of stereo: pixel matching

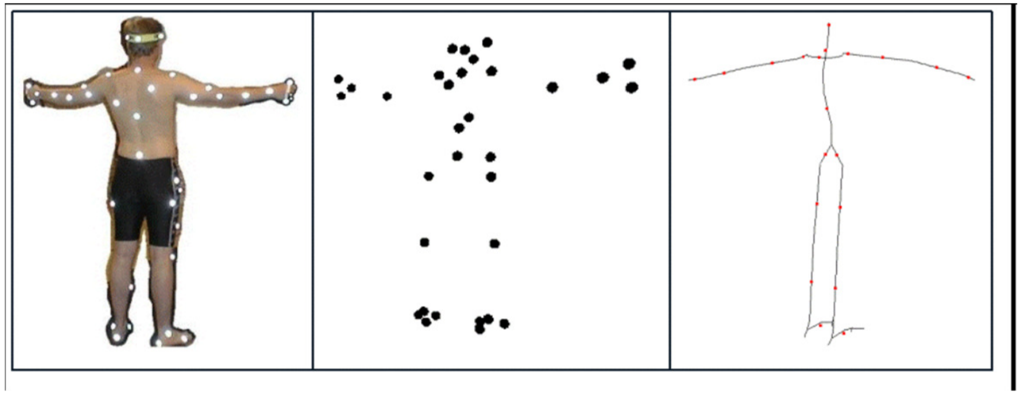
Skeleton mocap: Process of skeleton fitting

- Initial position before capture

  → identify correspondence between each marker and each joint
- During the motion, for each body joint
  - Based on previous position and speed, determine the area where the joint should be → determine the marker
- Problem: crossover, markers exchange labels

  Skeleton tracking (Kalman filter, etc.) if few miliseconds

  → May use DB of motions …or may require user intervention



Skeleton mocap example

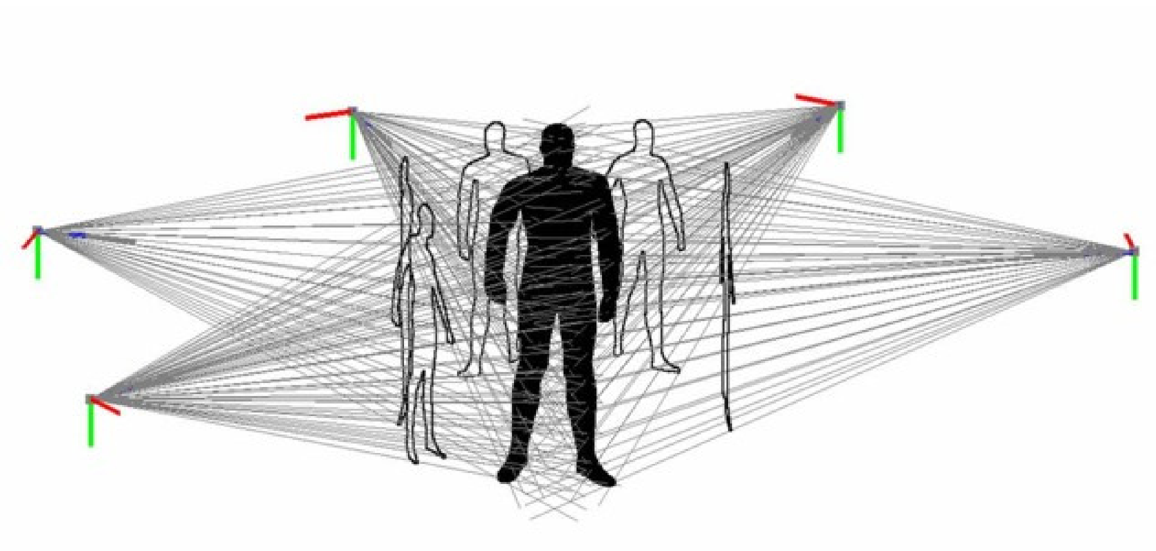
- Mocap_skeleton_10person.wmv

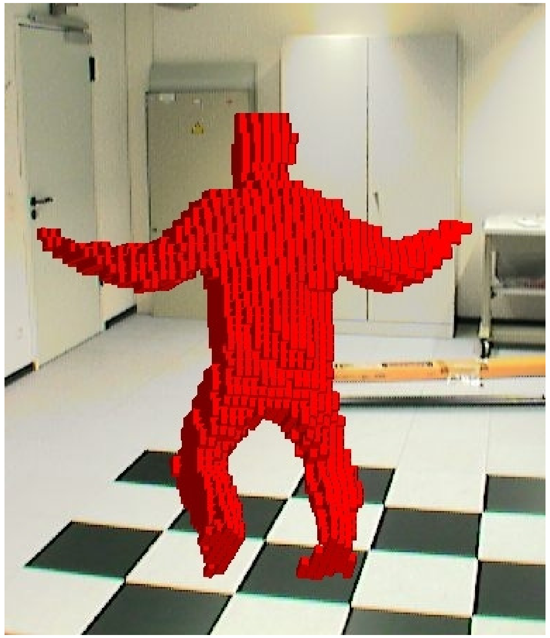
Plan: Motion Capture and Co

- Introduction and past of mocap
- Motion capture with markers
  - Different type of system
  - Mocap pipeline in details
  - Markerless motion capture

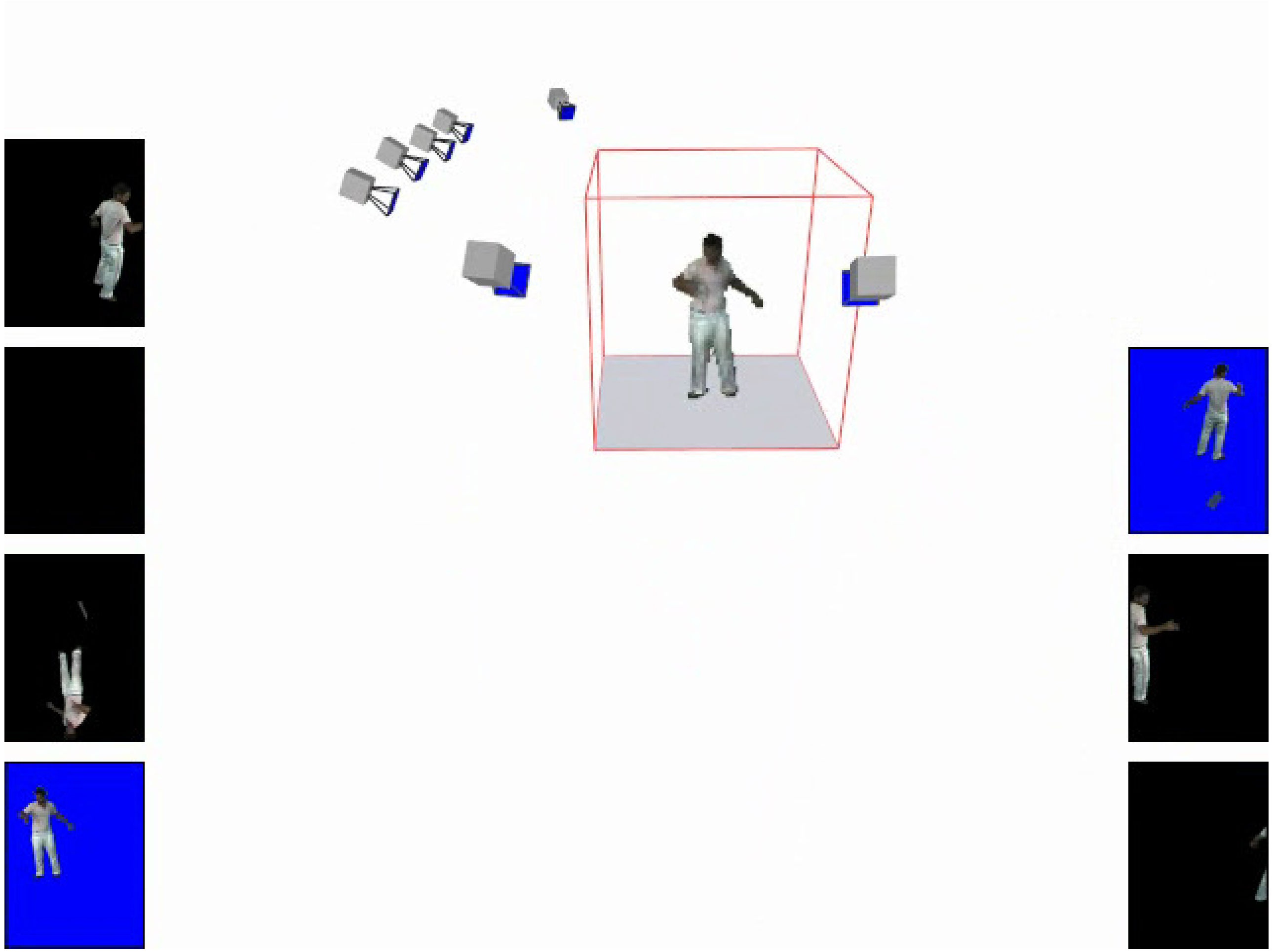
Markerless motion capture

- Less precise than marker-based mocap
- Visual hull + skeleton fitting
  - Visual hull ➔ volumetric data (voxel)
  - Volumetric data (voxel) ➔ skeleton





Example of visual hull

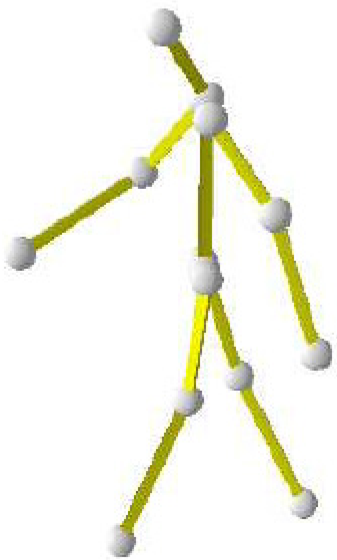


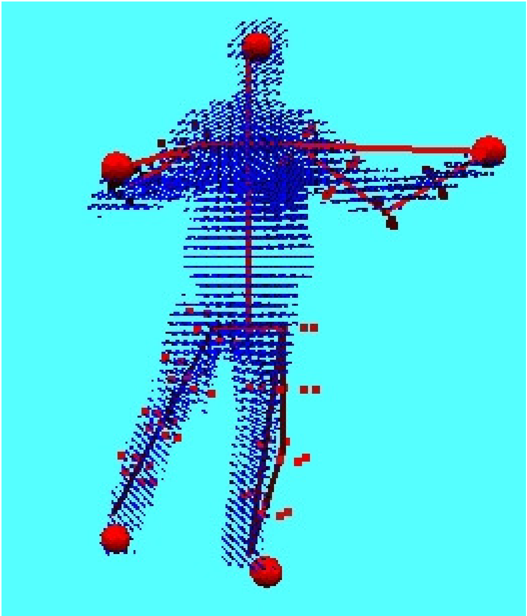
[Michoud etal 2007/10]

Markerless motion capture

- Visual hull + skeleton fitting
  - Skeleton fitting
    - Often based on a database of skeleton positions

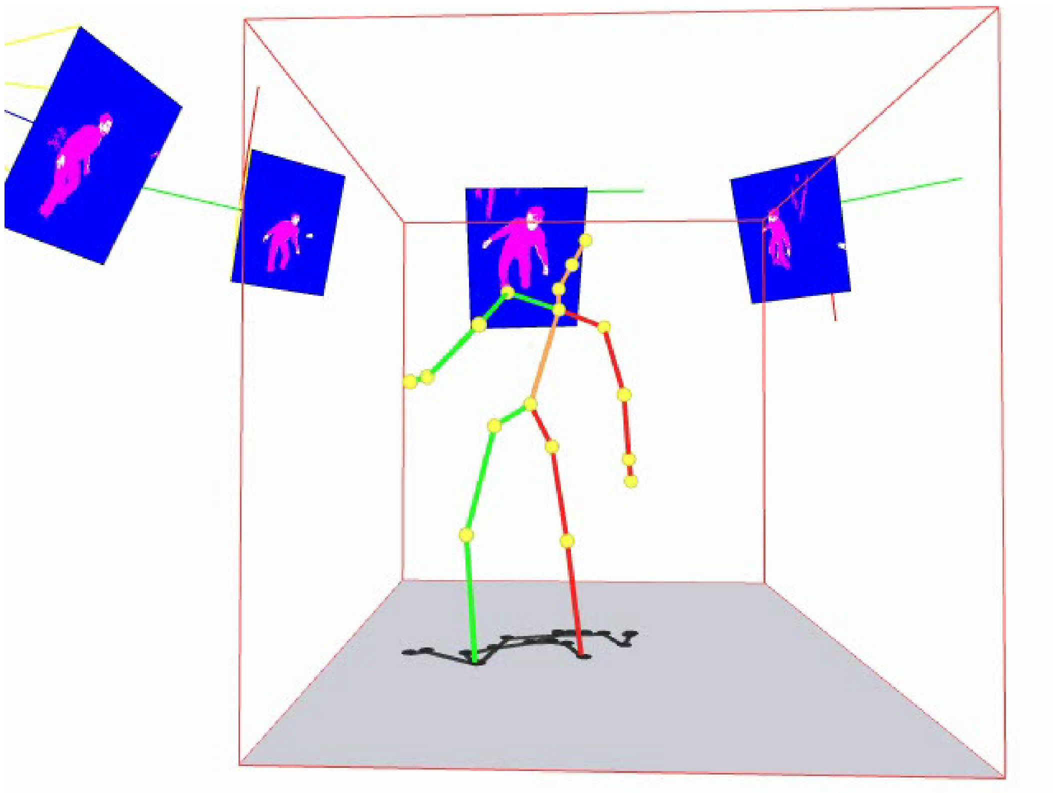
→Less precise than marker-based mocap





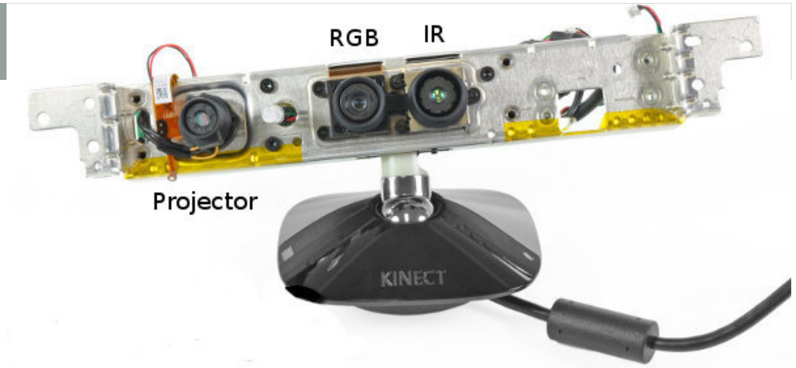
Markerless motion capture

- Video

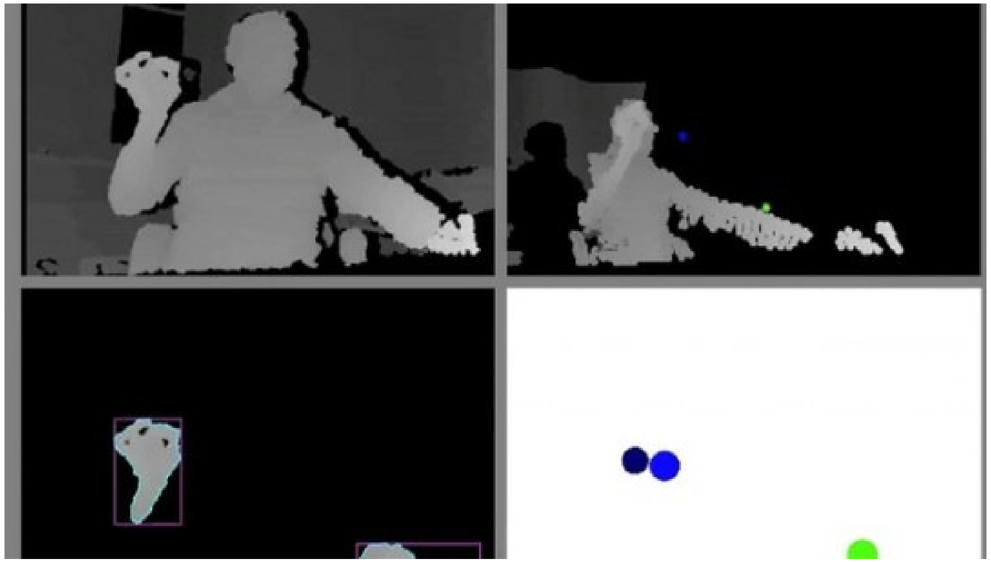


[Michoud etal 2007/10]

Kinect

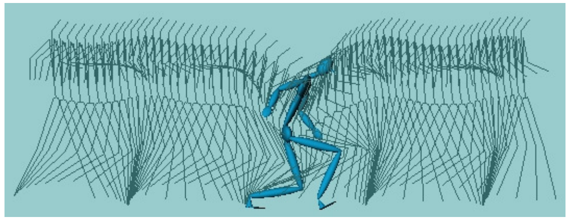


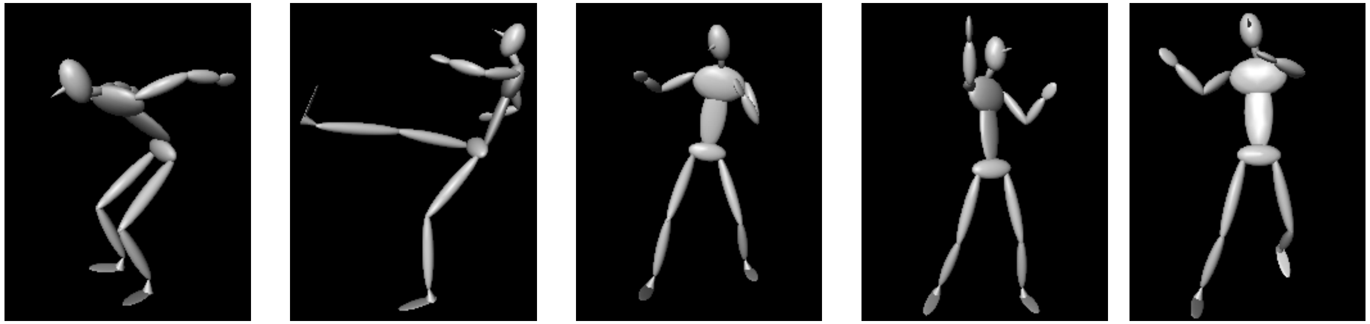
- Same idea of skeleton fitting
  - 3D volumetric data are a depth-buffer (~zbuffer)
    - Get from infra-red projector/camera
  - 20 million images with 200 distinct poses



Skeleton mocap

- Ok we got the skeleton





and now? We would like to capture skin/face/cloth

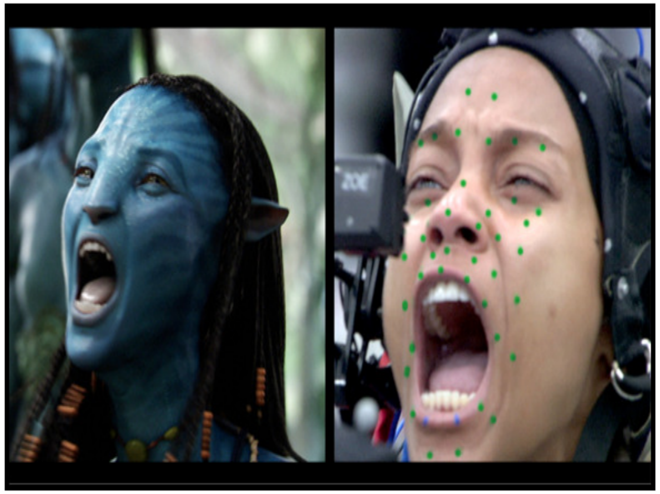
Plan: Motion Capture and Co

- Introduction and past of mocap
- Motion capture with markers
  - Different type of system
  - Mocap pipeline in details
  - Markerless motion capture
- Face/Skin Motion Capture
  - With markers

Motivation: Human Face Animations

- Face animations are difficult to model
- Movies and games increasingly use performance capture

[© IGN Entertainment (www.ign.com), Electronic Arts]

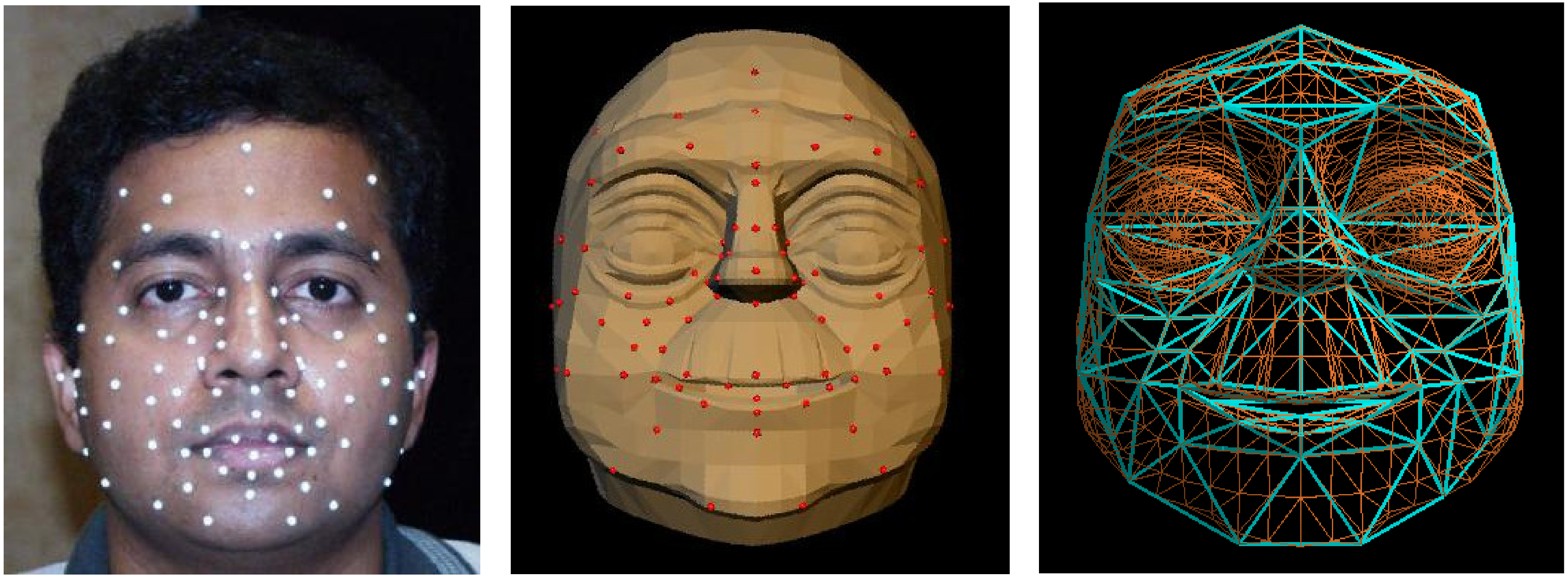


[www.thedailybeast.com]

[Guenter et al. '98]

[Bickel et al. '07]

Facial motion capture



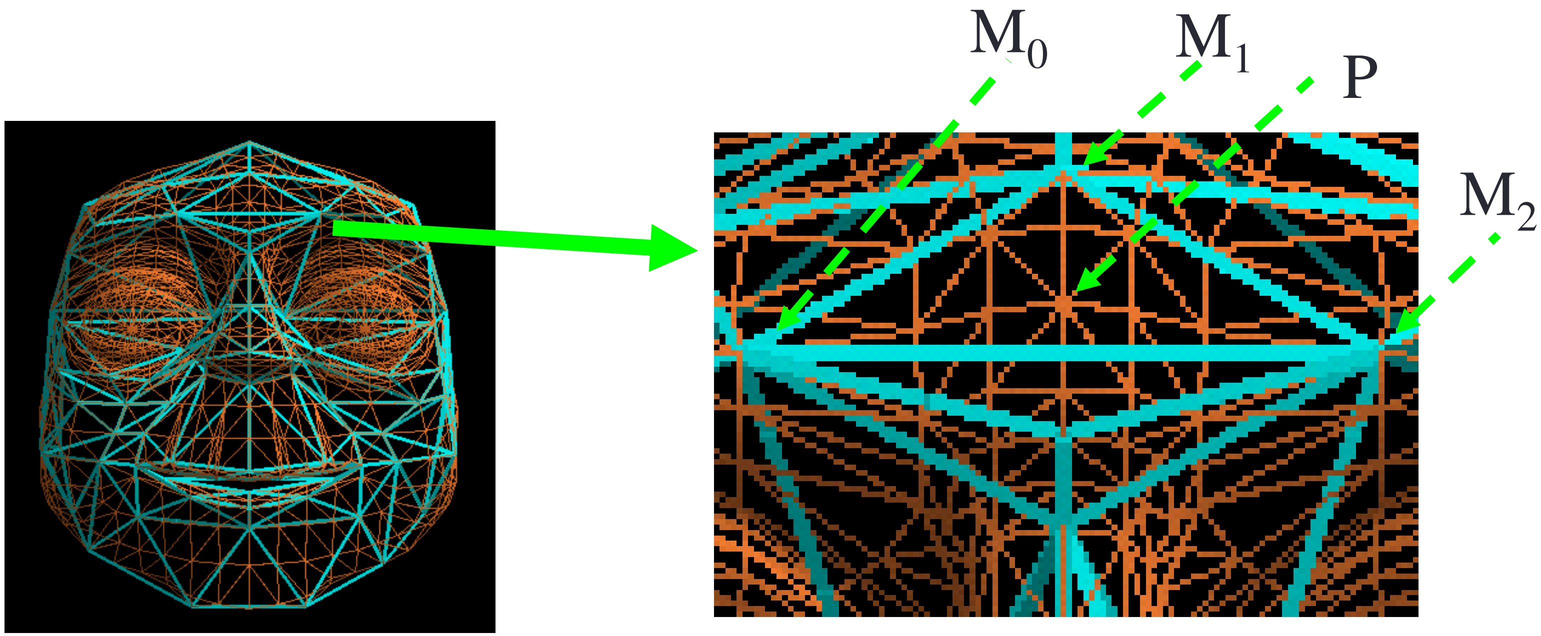
Marker based Motion Capture → applied to Gizmo

Two meshes (mesh of markers and mesh of face) need to match

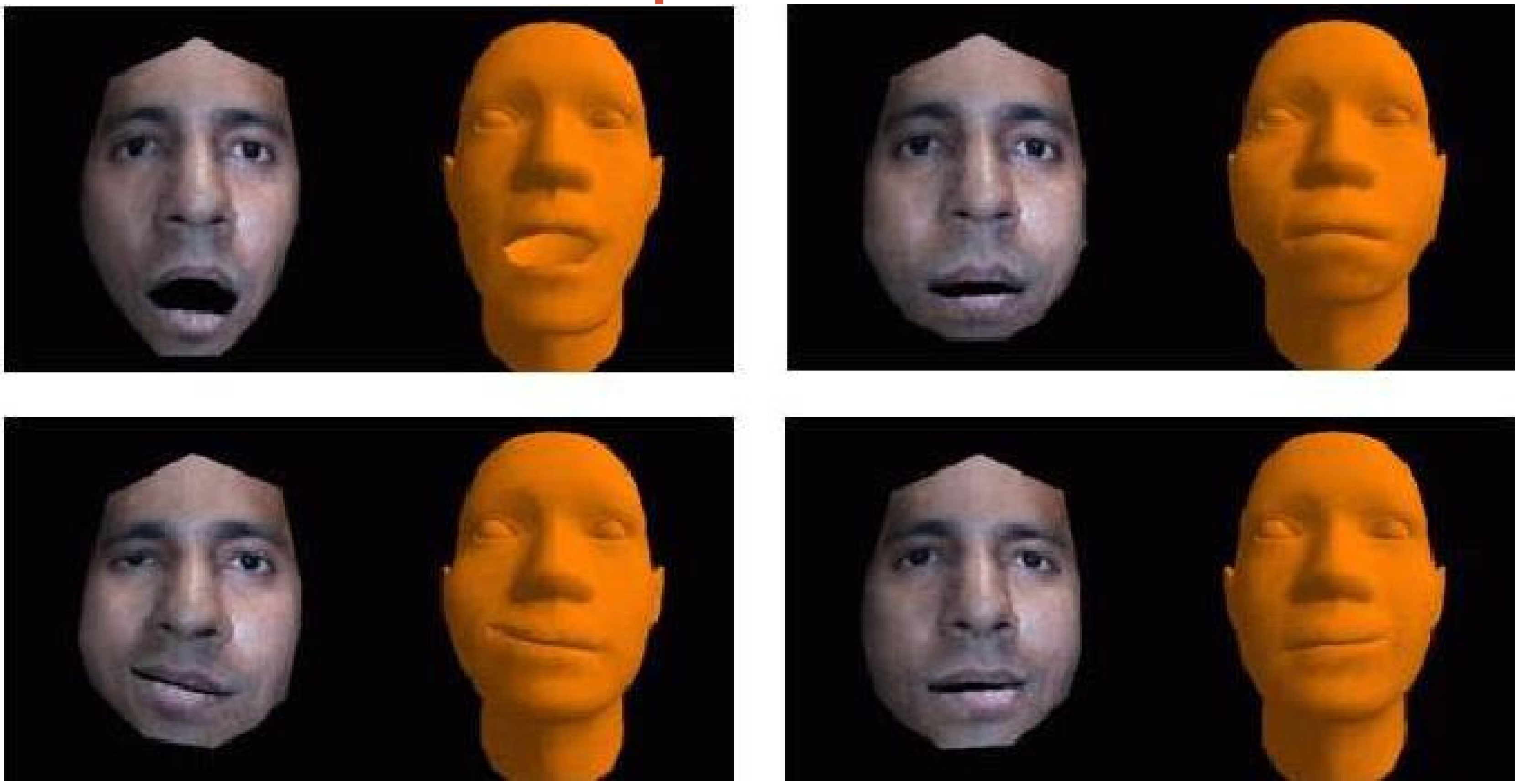
Facial motion capture

- Green: mesh of the markers; Red: mesh of the model
- P of the model → inside triangle $M_0M_1M_2$ of markers mesh
  Compute barycentric coordinates of P in the triangle

→ when M_i moves it is easy to compute the new position of P

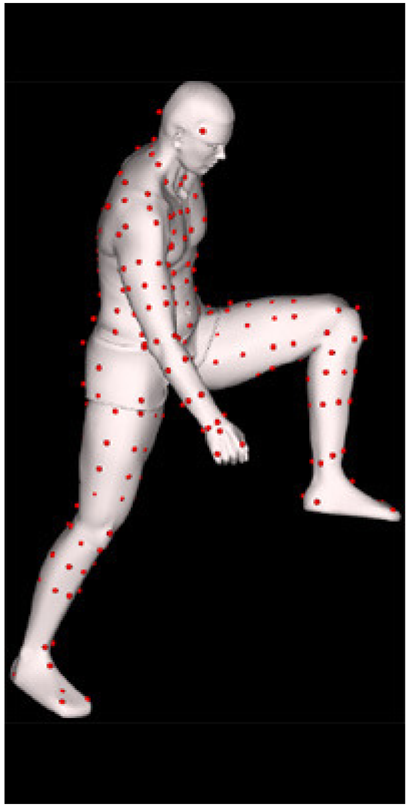


Facial motion capture



+ VIDEO: facial_mocap?.avi

Capture of the skin



Capturing and Animating Skin Deformation in Human Motion
Sang Il Park, Jessica K. Hodgins
SIGGRAPH 2006

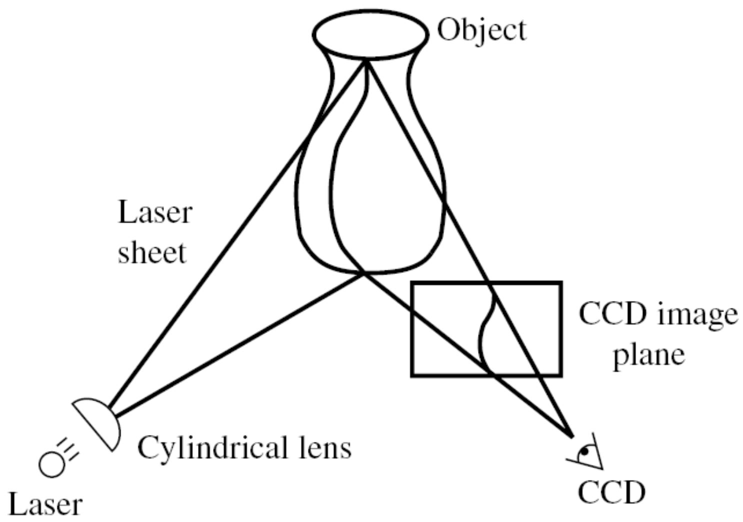
→ Video

http://graphics.cs.cmu.edu/projects/muscle/

Plan: Motion Capture and Co

- Introduction and past of mocap
- Motion capture with markers
  - Different type of system
  - Mocap pipeline in details
  - Markerless motion capture
- Face/Skin Motion Capture
  - With markers
  - With scanner/structured light

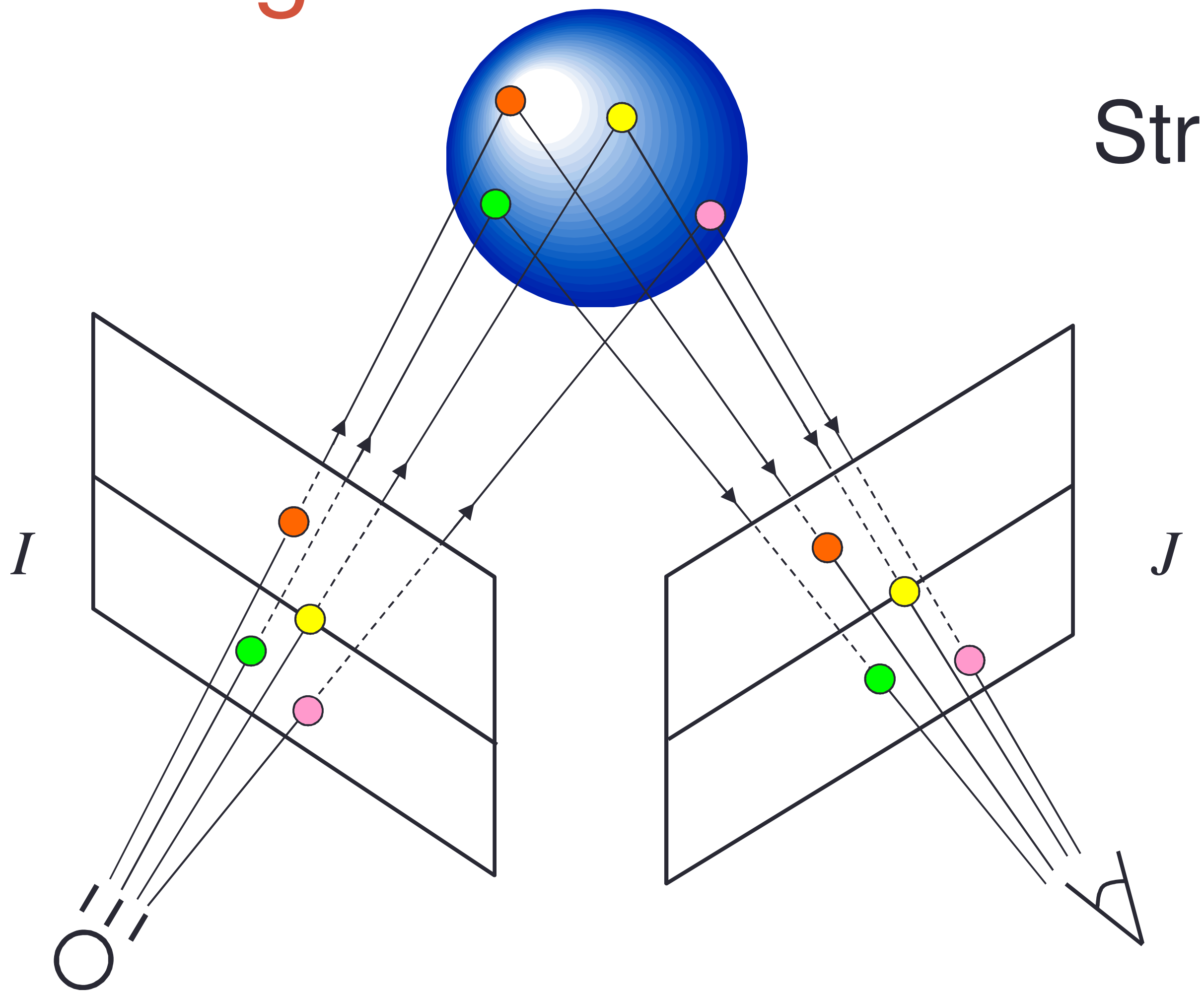
Laser scanner



Cyberware® face and head scanner

+ very accurate <0.01mm
– >10sec per scan ➔ inaccurate for motion of face

Triangulation with Structured light

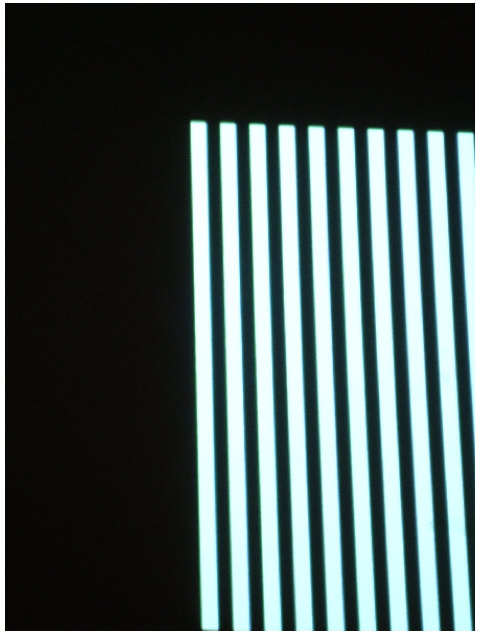


Structured light

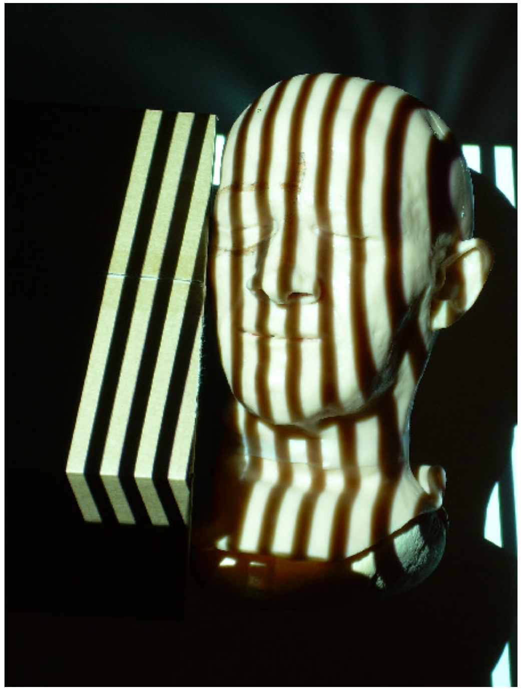
Remember: main issue of stereo is pixel matching
➔ solved here with color

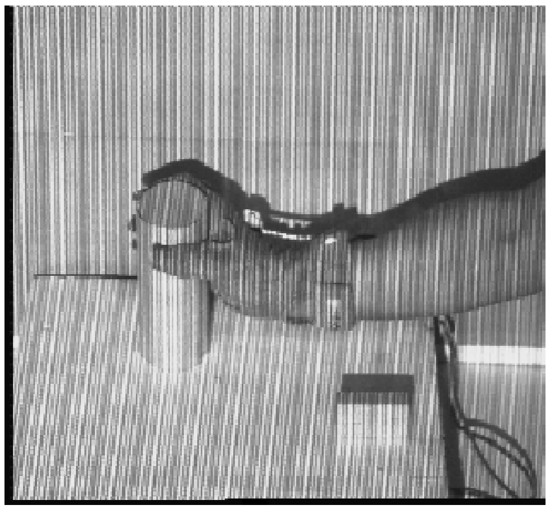
Structured light: Example

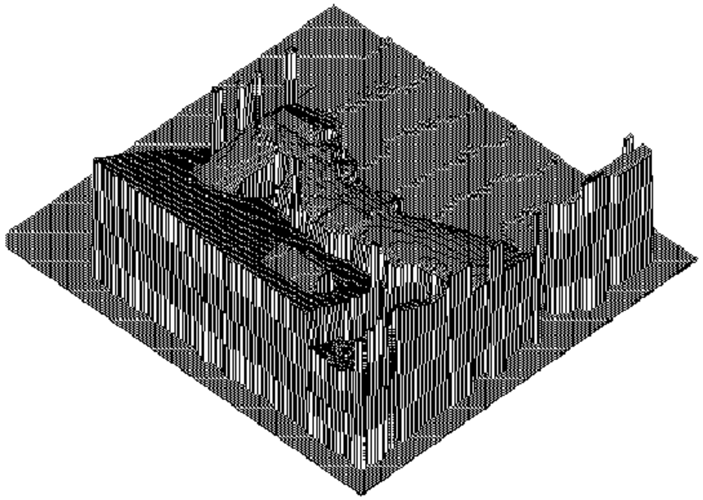
Projected
on the wall



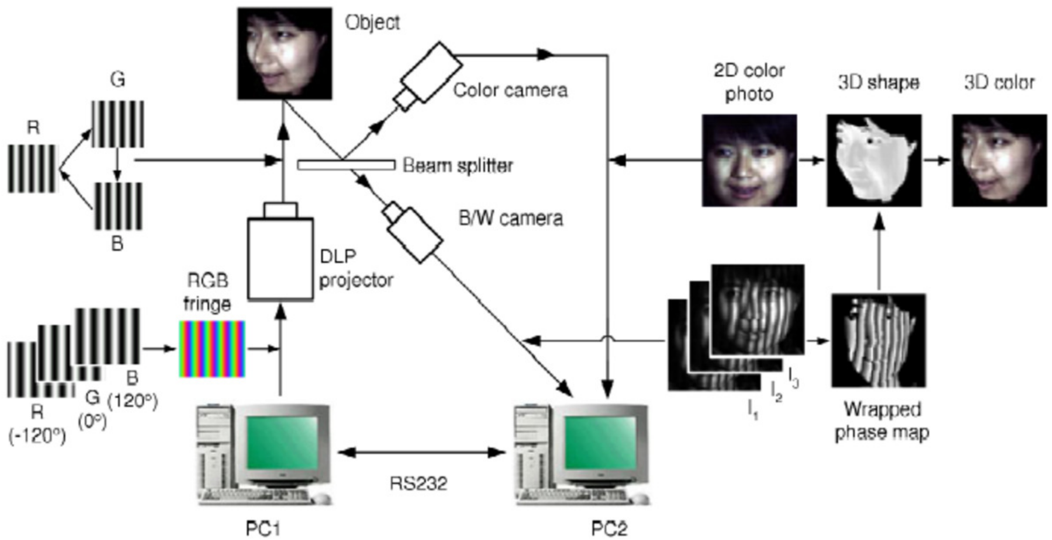
Projected
on a face

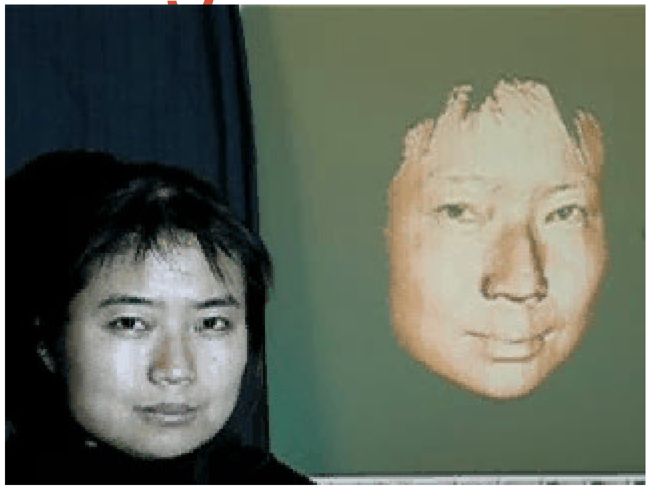


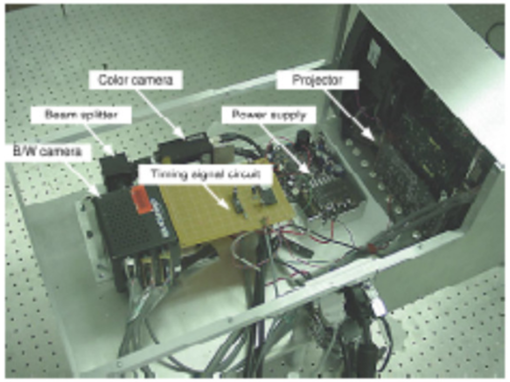




[Zhang05]: Digital fringe range sensor







+ Real time performance
– Phase ambiguity near discontinuities
– Customized device
– Capture from one viewpoint at a time

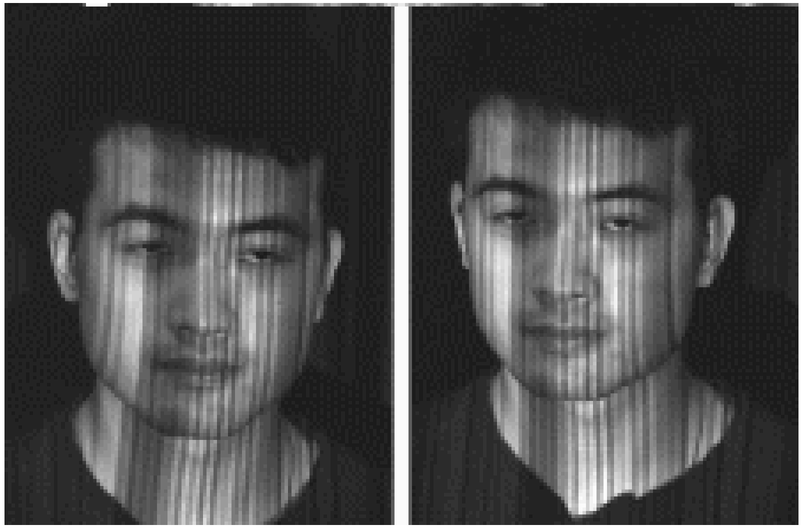
S. Zhang and P. Huang, “High-resolution Real-time 3-D Shape Measurement”, Journal of Optical Engineering, 2006

Working Volume: 10-2000mm - Accuracy: 0.025%

Spatial Resolution: 532x500 - Speed: 120Hz

[Zhang05]: Spacetime stereo

Input stereo video:

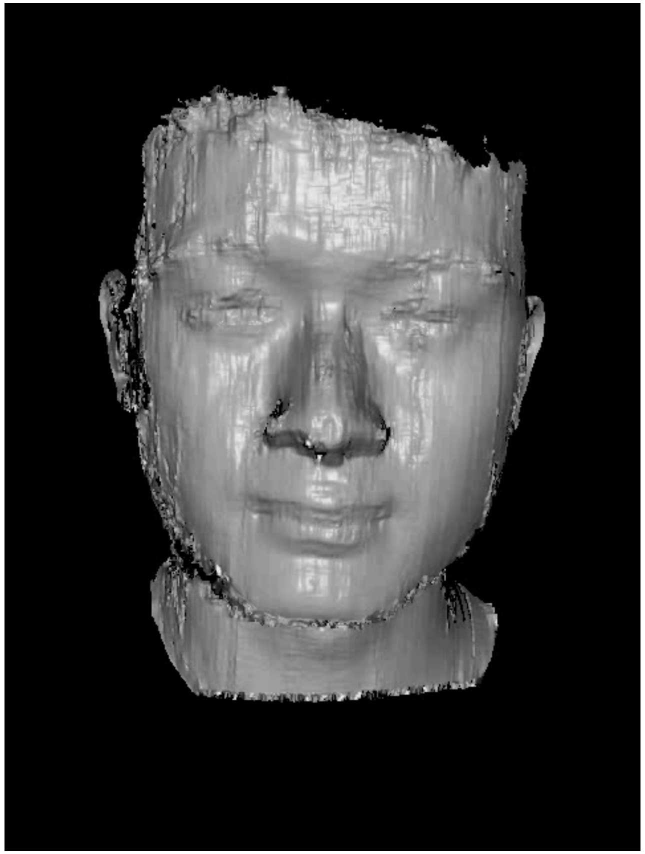


656x494x60fps videos captured by cameras

Markerless Face Capture and Automatic Model Construction Using Color Structured Light

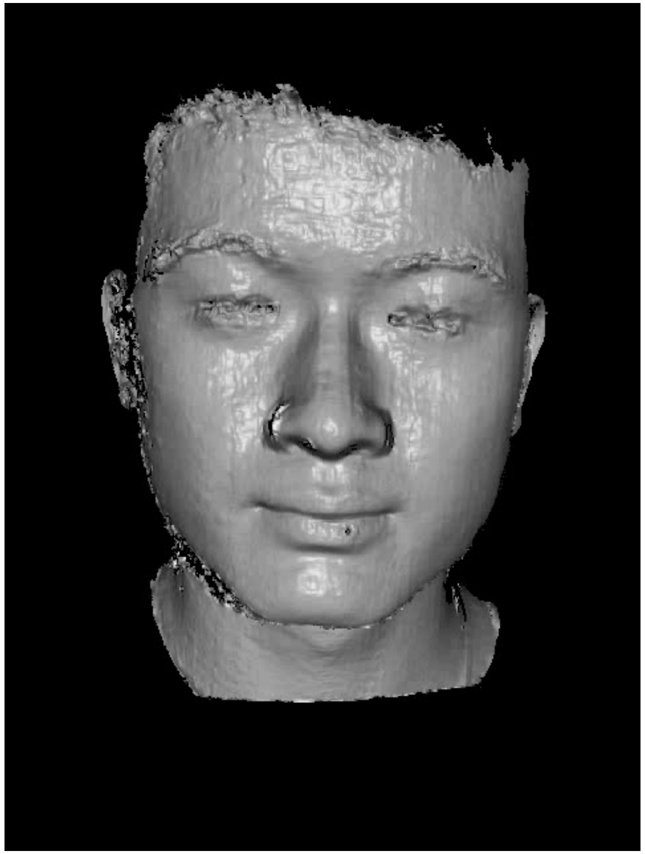
http://grail.cs.washington.edu/projects/stfaces/

Spacetime stereo, comparison



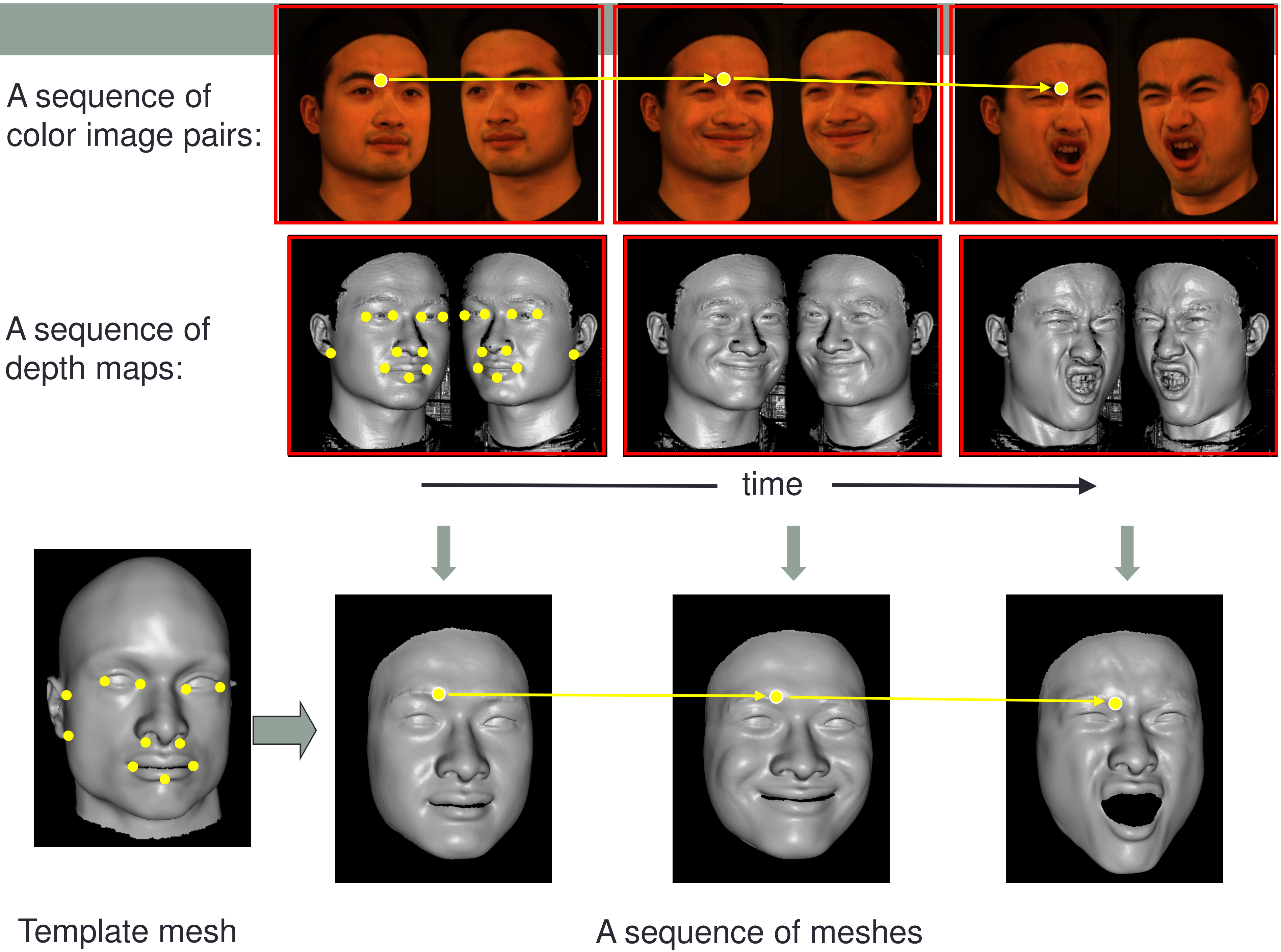
Frame-by-frame stereo

WxH=15x15 window



Spacetime stereo

WxHxT=9x5x5 window


A sequence of color image pairs:
A sequence of depth maps:
time
Template mesh
A sequence of meshes

Bilan: Face Capture with Markers

- Markers and face paint (inpainting required for texture)

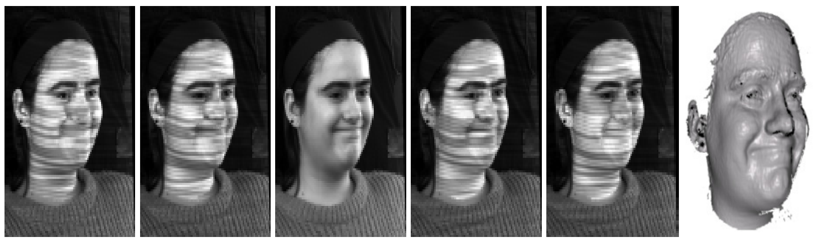
[Guenter et al. '98]

[Bickel et al. '07]

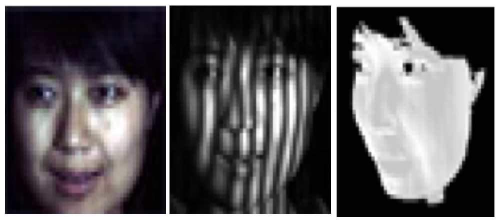
[Furukawa & Ponce '09]

[USC-ICT, Image Metrics]

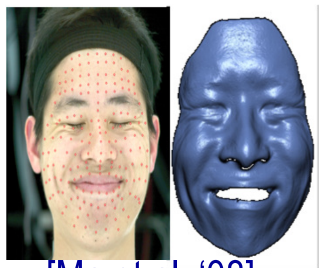
- Structured light (interleave regular light for texture)



[Zhang et al. '04]



[Wang et al. '04]



[Ma et al. '08]

Videos

- Video makerless_face_mocap_structuredlight.avi

- « makeup»-based Markers → MOVA
  - Phosphor
  - http://www.mova.com/technology.php

Plan: Motion Capture and Co

- Introduction and past of mocap
- Motion capture with markers
  - Different type of system
  - Mocap pipeline in details
  - Markerless motion capture
- Face/Skin Motion Capture
  - With markers
  - With scanner/structured light
  - Markerless [Bradley et al. 2010]

Passive Facial Performance Capture

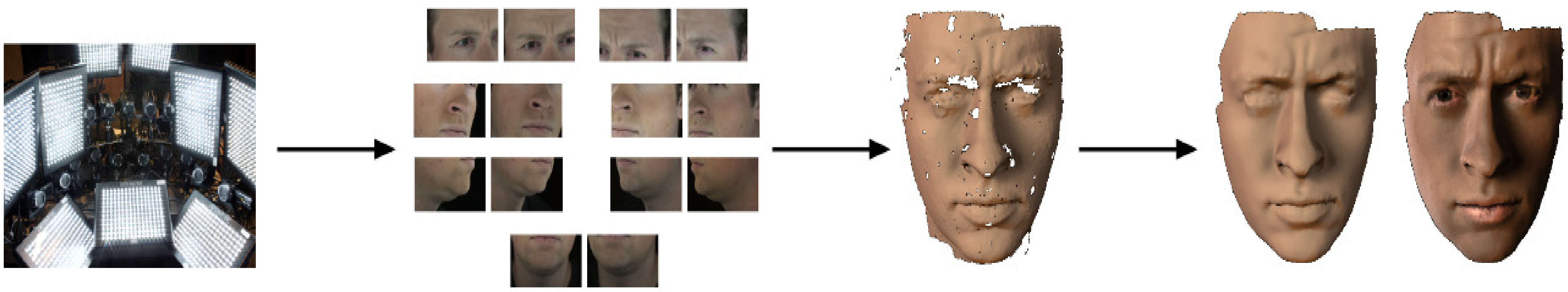
<u>Key Observations:</u>

(remember that stereo issue are matching)

1. Skin has high-frequency details up close (pores, freckles, etc..)
2. Details are stable over time

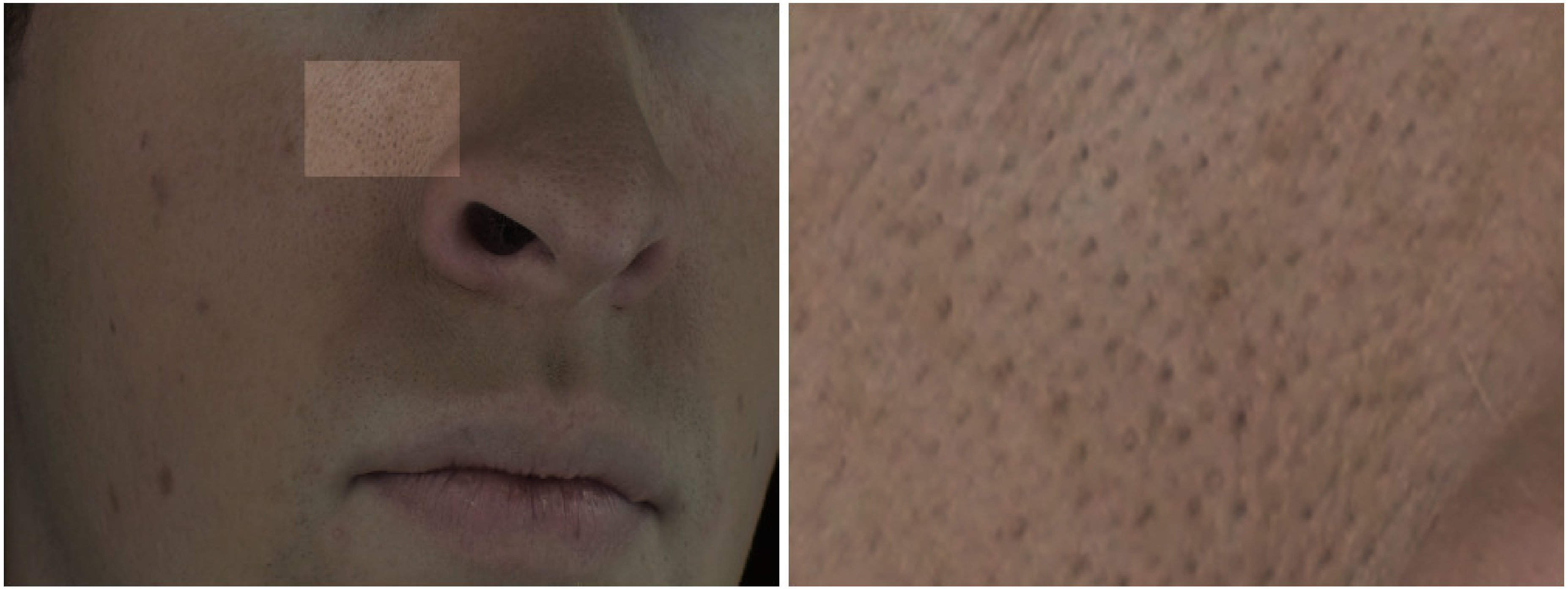
<u>Idea:</u>

- Capture skin details with optically zoomed camera setup
- Skin details allow for accurate 3D reconstruction



Skin Detail Acquisition

- 14 cameras – 7 binocular pairs – zoomed in
- Bright, uniform illumination – no structured lighting
  - →remember that stereo issue are pixel matching, solved here with skin details like pores, …



Remark: light is very important

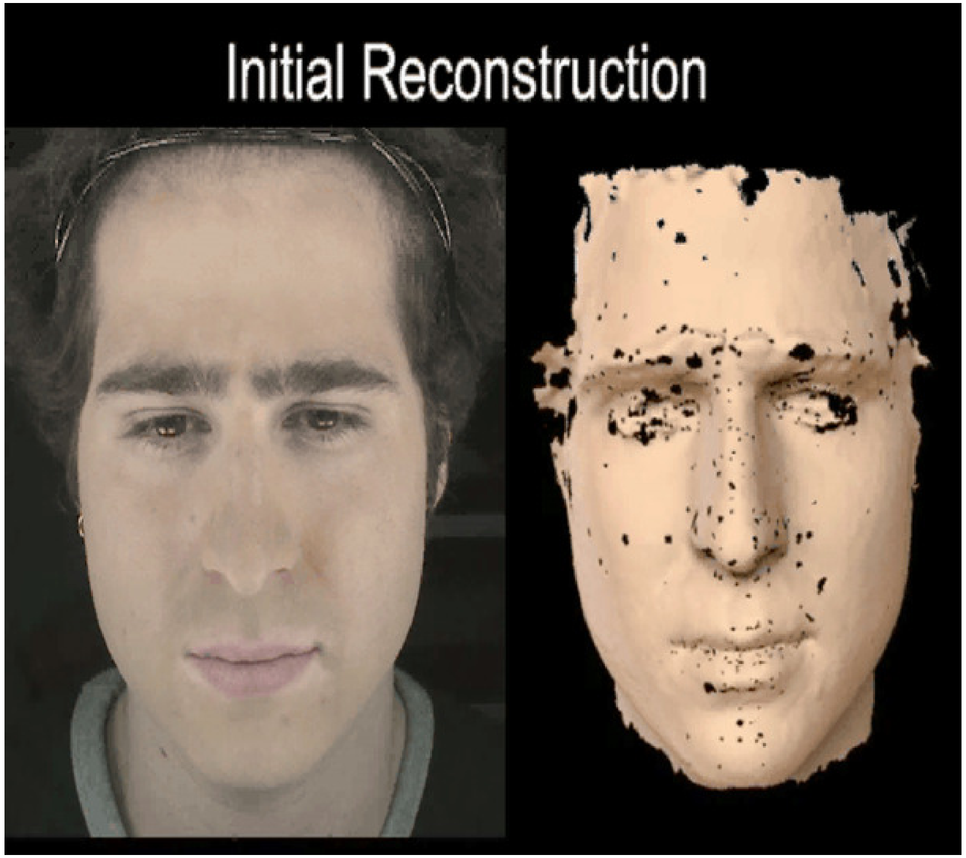
Multi-View Reconstruction

- Extended reconstruction method:
  Pair-wise stereo + merging

Input: multiple image pairs   Output: triangle mesh

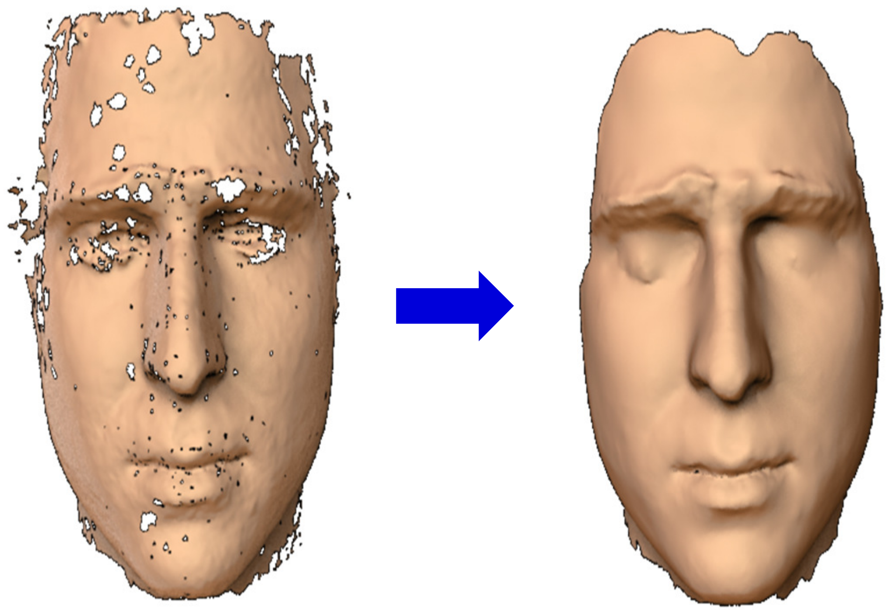
Multi-View Reconstruction

- Each frame reconstructed individually



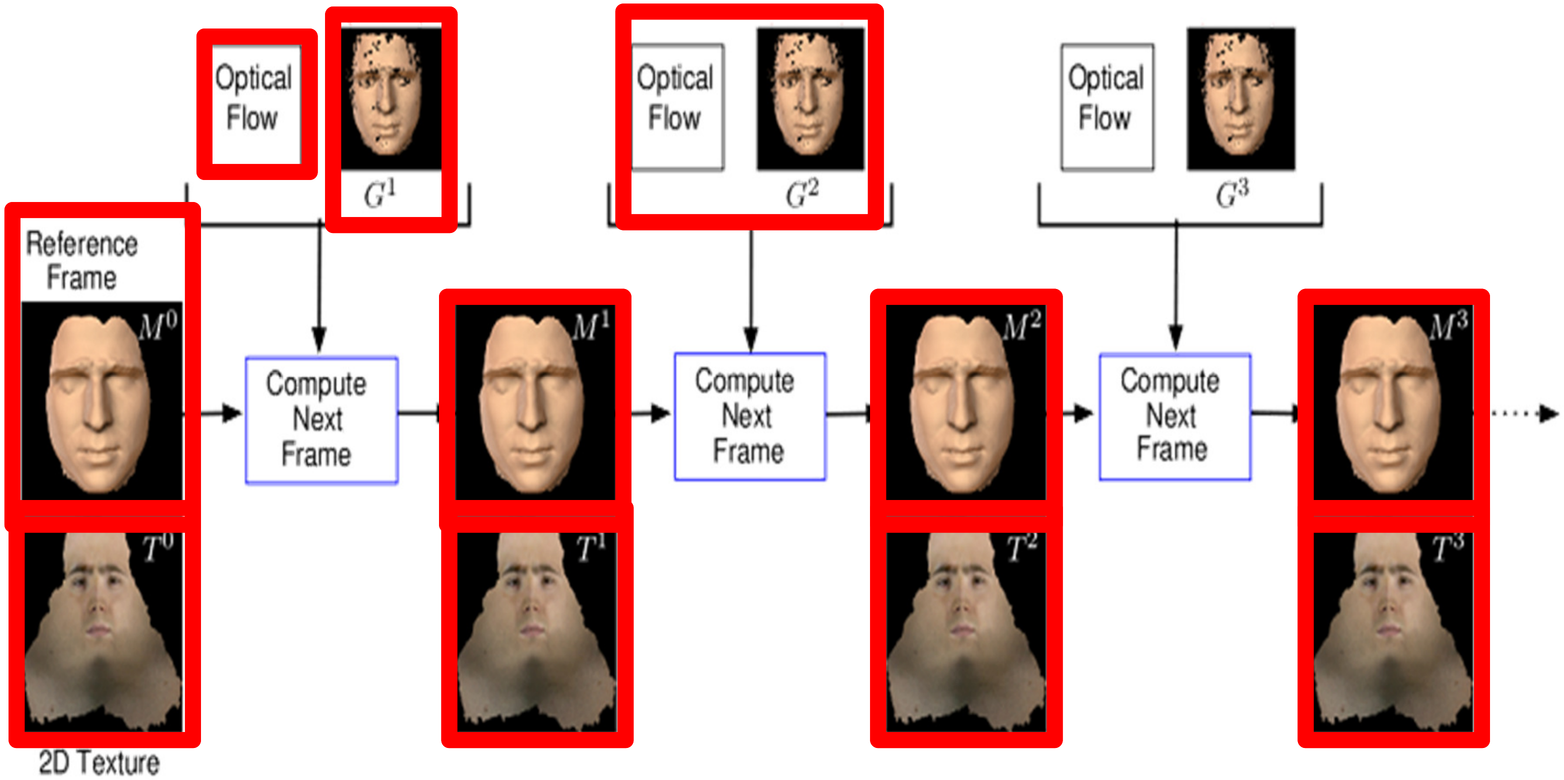
Manual Cleanup of First Frame

- Cut away hair and fill holes
- These steps performed only once per sequence

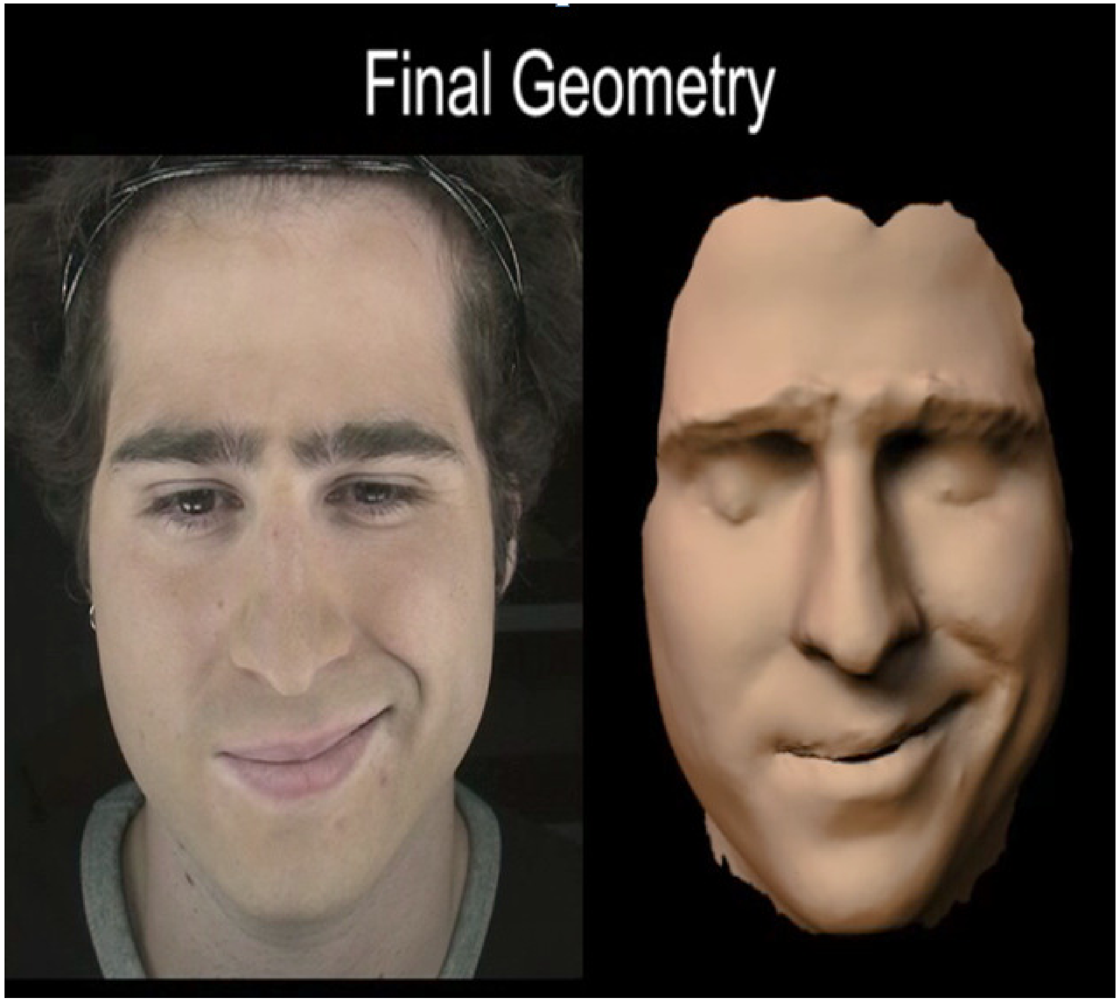


Temporal coherence

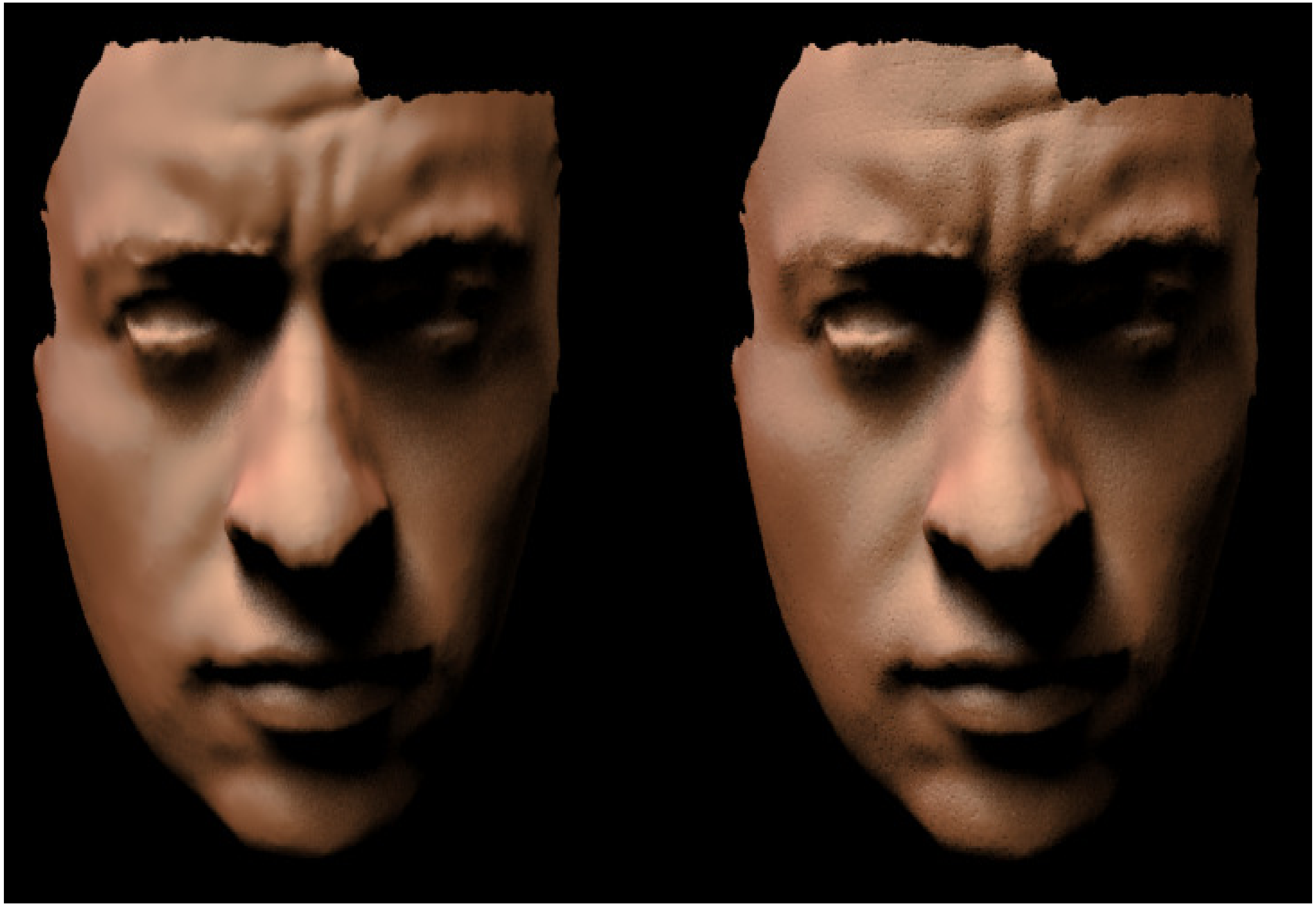
- Based on optical flow (2D motion vectors from video images)
  - Propagate first mesh forward using optical flow and initial geometry
  - Compute per-frame 2D textures



Results + video



Fine skin details: procedural



Plan: Motion Capture and Co

- Introduction and past of mocap
- Motion capture with markers
  - Different type of system
  - Mocap pipeline in details
  - Markerless motion capture
- Face/Skin Motion Capture
  - With markers
  - With scanner/structured light
  - Markerless [Bradley et al. 2010]
  - Cloth capture

Markerless Cloth Capture

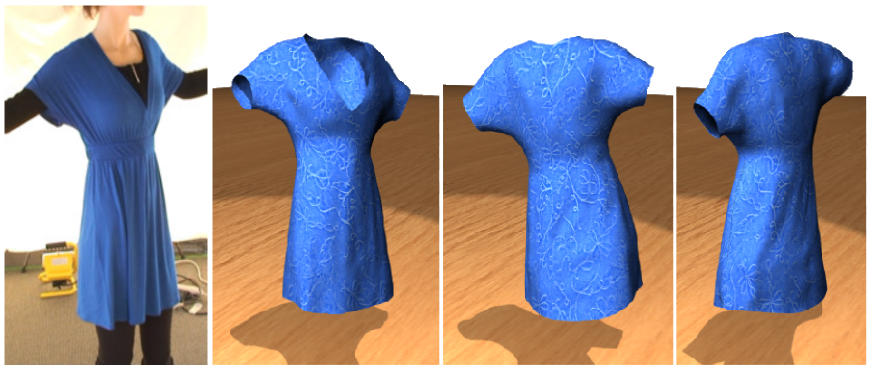
- Full bodies and garments

Template

[Vlasic et al. ‘08]

Template

[de Aguiar et al. ‘08]



[Bradley et al. ‘08]

[Vlasic et al. ‘09]

Conclusions

- Important tool, not the entire solution
- Stylistic choice – realism
- The performance matters
- Still requires
  - artistry
  - animation
  - a lot of work

- Techniques for editing/retargeting is important

Common errors when considering motion capture

- using motion capture makes the animator’s job easier
- using motion capture will save time
- using motion capture will save money
- people underestimate the amount of planning that is needed prior to the capture session
- people are unorganized during the capture session
- people underestimate the importance of using a good motion performer
- people think that they can fix bad motion data after the capture session

The Animator’s Motion Capture Guide, Liverman

References

- Matt Liverman, *The Animator's Motion Capture Guide: Organizing, Managing and Editing*
- Alberto Menache, *Understanding Motion Capture for Computer Animation and Video Games*

- David J Sturman, "*A Brief History of Motion Capture for Computer Character Animation", Character Motion Systems, SIGGRAPH 94, Course 9*
- *Many more on the web …*