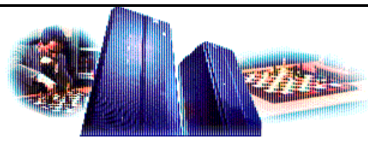
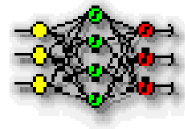




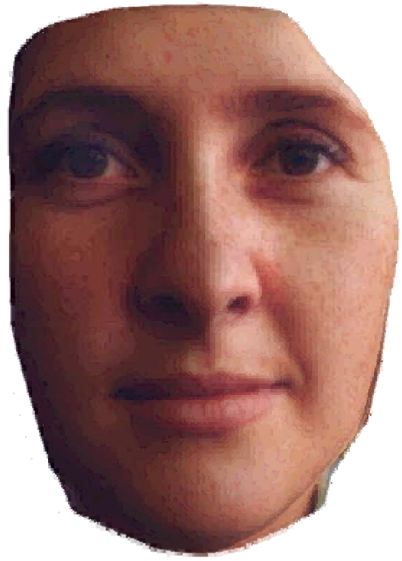
Introduzione alla Realtà Virtuale
Parte I

Prof. Alberto Borghese

Sommario

- Introduzione
- Sistemi di Input
- Generatori di mondi
- Motore di calcolo
- Sistemi di Output
- Conclusioni

Which is real, which is virtual?



Historical Perspective (I)

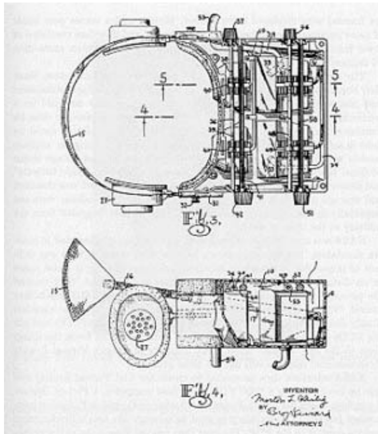
- *Virtual Worlds or Synthetic Environments*
- *Philosophical* and *Technologial* origin.

Philosophical background

Ontology and *Gnoseology.*

- Plato (world of the ideas) 428-348 a.C.
- Berkeley (sensorial experience is too limited) 1685-1753.
- Hegel (“what is rational is real..”) 1770-1831.
- New age.

Historical Perspective (II)



Morton Heilig 1956,
patented in 1961
Non fu mai costruito

projected film,
audio, vibration,
wind, odors.

Historical Perspective (III)

Technological background

- *Philco HMD, 1961.*
- *“Ultimate display”, Sutherland, 1970.*
- *Data Glove, VPL Research, 1988.*

Sutherland, Ivan E. 1968. "A Head-Mounted Three Dimensional Display," pp. 757-764 in Proceedings of the Fall Joint Computer Conference. AFIPS Press, Montvale, N.J.

Virtual Reality Systems

Key characteristics are:

Immersivity.

Interactivity.

VR should be able to stimulate the human sensorial systems
In a coordinated way.

A typical VR system

VR systems are constituted of:

• *Input systems* (measure the position *in* the environment and force *over* the environment.

• *World generators* (provides a realistic virtual world in which to act.

• *Computational engine* (computes the output, given the input and the virtual world).

• *Output systems* (outputs sensorial stimuli *on* the subject. Vision, sound, force … are generated as if they were provided *by* the virtual environment.

Sommario

- Introduzione
- Sistemi di Input (trackers)
- Generatori di mondi
- Motore di calcolo
- Sistemi di Output
- Conclusioni

Input systems

Measure human actions on the virtual environment.

•Position. Measure the position of the body segments inside the virtual environment.

• Force. Measure the force exerted by the body segments when in contact with a virtual object.

• Estimate the motor output of the human muscle-skeleton system.

Position systems

•Measure the position of the body segments inside the virtual environment.

- Motion capture (batch, complete information on the movement).
- Real-time trackers (real-time position).
- Gloves (specialized for hands).
- Gaze trackers.

Adopted technology

- Optoelectronics
  - Marker based
  - Computer vision.
- Magnetical
- Acoustical
- Mechanical
- Intertial

What is motion capture?

Ensemble of techniques and methodologies to acquire **automatically** the motion of the objects of interest.

Characteristics: sampling rate, accuracy, 2D/3D, real-time, motion amplitude, invasivity,….

Technology: opto-electronical, magnetical, ultrasound, intertial ….

Specific body parts: gloves, gaze trackers….

Applications are increasing (medical applications at the origin, now interest in the enterteinment, robotics, reverse engineering …)

Motion Capture and Synthesis

Reproduce digitally the motion of the body.

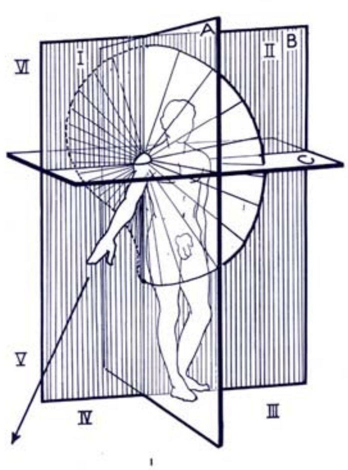
Time series of the position of the body segments
or
Time series of the motion of the articulations.

Analysis

Application of the time series to a 3D digital model of the body.

Synthesis

Description of the human skeleton



A – Frontal plane
B – Sagittal plane
C – Horizontal plane

Abduction/adduction
Flexion/extension
Axial rotation (V)

Definition of the interesting degrees of freedom.

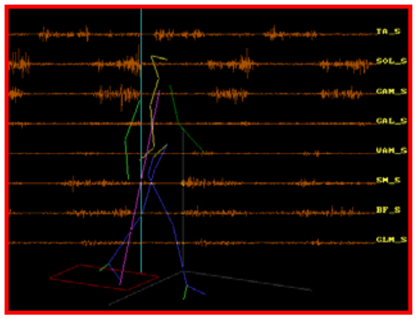
Clinical Motion Analysis

MOTION ANALYSER

FORCE TRANSDUCER

MATHEMATICAL MODELS

EMG



JOINT KINEMATICS

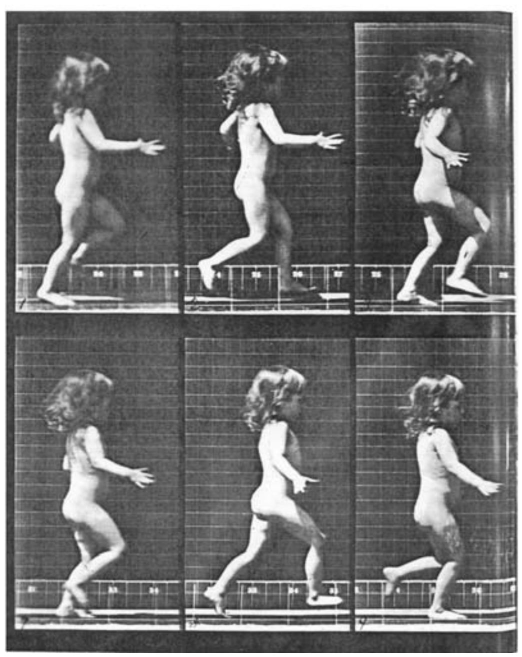
JOINT KINETICS

EXTERNAL FORCES

PLANTAR PRESSION

MUSCLE ACTIVATION AND FORCE

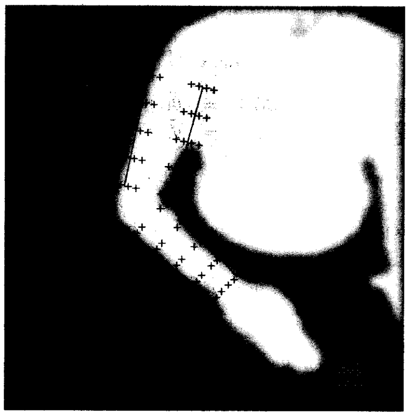
Edward Muybridge 1878-1901

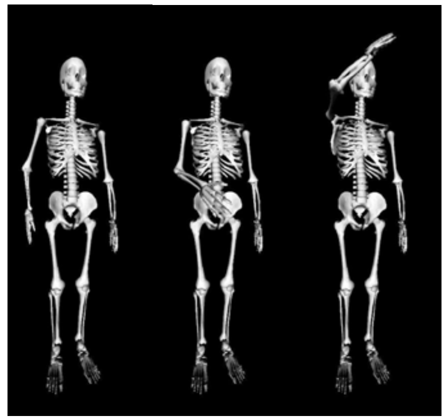


What is captured?

Silhouette (-> Skeleton)

Skeleton





Computer vision techniques

Bony segments or articulations (marker-based systems)

Tracking difficulties

<u>It is a complex problem because:</u>

• Dense set of markers. These may come very close one to the other in certain instants.

• Motion can be easily complex, as it involves rotation and twists of the different body parts (thing at a gymnastic movement).

•Multi-camera information and temporal information is required to achieve a robust tracking.

Computer vision techniques

Silhouette (-> Skeleton)

Set of difficult problems:

2D Image processing (silhouette identification, optical flow detectors…)

Multi-view invariants.

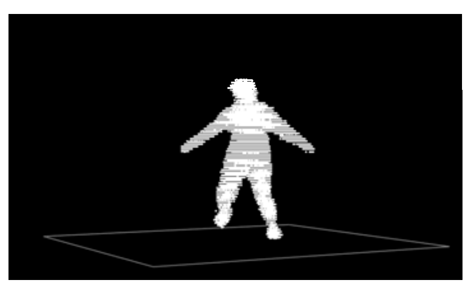
Smooth motion -> temporal filtering.

Skeleton fitting (different rigid motion for different segments).

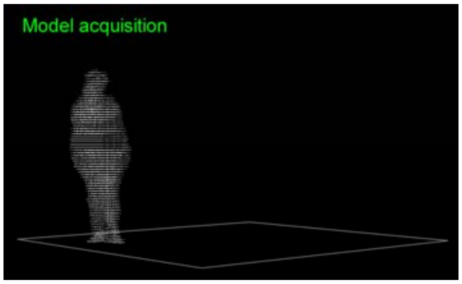
http://movement.stanford.edu/

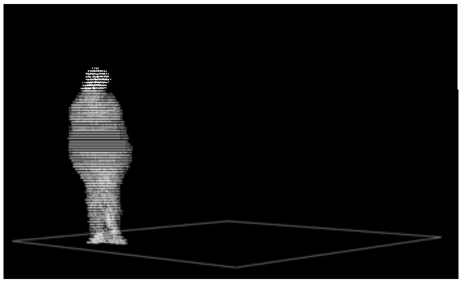
Results: stepping (640 x 480, 10Hz)

Mikic, Trivedi, Hunter



Results: cartwheel





Problems with motion capture

- Joints are points inside the body, markers are attached on the body surface.
- Joint are not fixed points: two adjacent bones rotate <u>and slide</u>.
- Joint are not spherical.
- Skin artifacts.

Body motion from footage

2 approcci:
- Probabilistico. Stima di un modello parametrizzato e dei parametri di movimento.
- Deterministico. Definisco un modello a-priori e stimo i parametri della camera e del movimento.

2D tracking

Duck-neglect project **http://homes.dsi.unimi.it/~borghese/Research/LinesResearch/Virtual/Virtual.html**

”Magic mirror” paradigm in which video of the player is overlayed with graphics generated by the computer.

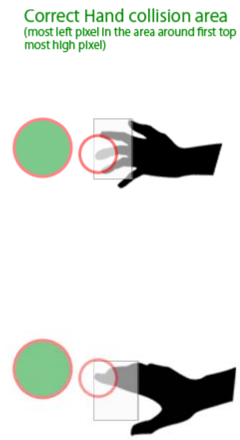
Background measurement. Thresholding.

Alternative is the difference between consecutive images (glaring and blurring require some filtering).

duckNeglet_video_v0.mov

2D collision detection

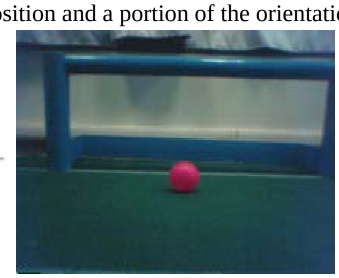
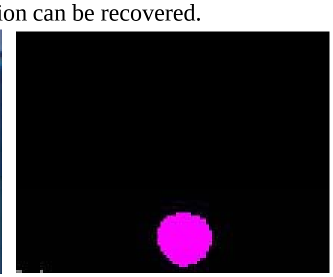
- Collision detection with target can be checked by analyzing the overlapping between part of the motion mask only in particular regions.
- Identification of the motion mask as the outermost part of the body. Approximated collision detection defining general shapes.



- Collision with targets gives hit, collision with distractors gives a miss.
- Same principles implemented with Sony EyeToy Webcam (2003).

2D color coded tracking

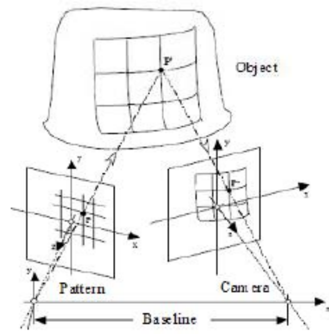
- Players could interact with a 3D scene by moving known brightly saturated colored objects that were visually tracked in PlayStation 2 (EyeToy Webcam). Threshold on color representation.
- Pose recovery can be accomplished robustly for certain shapes of known physical dimensions by measuring the statistical properties of the shape's 2D projection. In this manner, for a sphere the 3D position can be recovered (but no orientation), and for a cylinder, the 3D position and a portion of the orientation can be recovered.

- Multiple objects can be also be combined for complete 3D pose recovery, though occlusion issues arise.
- Perfect recognition in all lighting conditions is difficult.

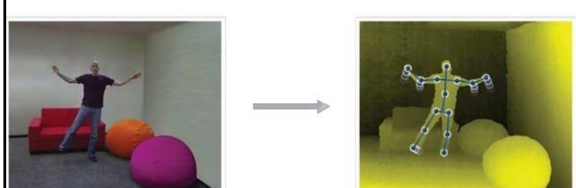
2.5D cameras (Kinect)

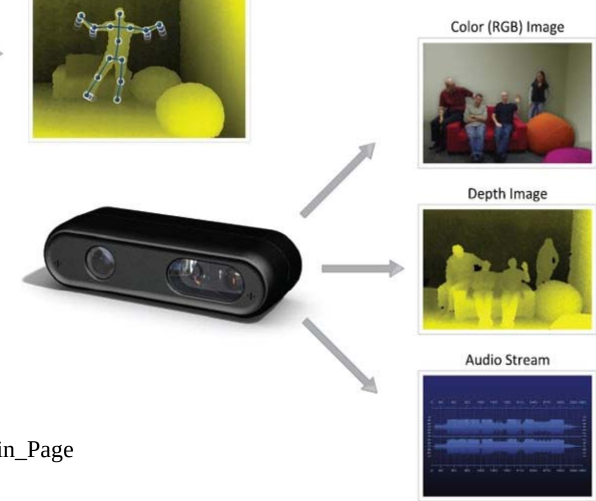
- 3D scanner with active pattern (IR)
- RGB camera
- Robust background separation
- Robust skeletal tracking



2.5D First SDK for Kinect

Primesense drivers, with skeleton tracking: http://www.primesense.comse.com





Open Source drivers:
http://openni.org
http://openkinect.org/wiki/Main_Page

2.5D tracking

Duck-neglect project **http://homes.dsi.unimi.it/~borghese/Research/LinesResearch/Virtual/Virtual.html**

Robust thresholding and tracking.

Sviluppi di giochi per la riabilitazione anche all’interno di FITREHAB http://www.innovation4welfare.eu/287/subprojects/fitrehab.html, coordinato da AIS-Lab.

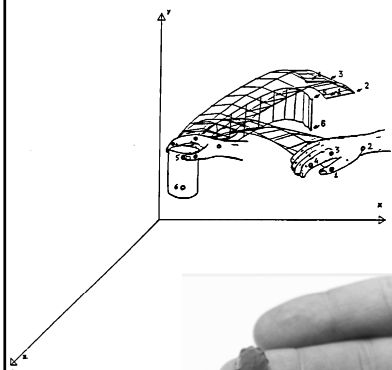
Markerless optical motion capture

www.organicmotion.com

- Clustering and labeling of each image with a probabilistic framework.
- Addition of temporal and spatial constraints.
- Special stage place is required.
- Cost and complexity

Why passive markers?

Minimum encoumbrance on the subject: markers do not require any powering and are hardly sensed by the subjects.



No constraint on the dimension of the working volume is prescribed.

How passive markers work?

Passive markers are constituted of a small plastic support covered with retro-reflecting material (3M™). It marks a certain repere point.

Video-cameras are equipped with a co-axial flash.

Markers appear much brighter than the background making their detection, on the video images, easier.

Sequential processing

1. Surveying the image of the moving subject on multiple cameras (*frequency & set-up*).
2. Markers extraction from the background scene (*accuracy & reliability*).
3. Computation of the "real" 2D position of the markers (*accuracy* <- *distortion*).

Low-level Vision

4. Matching on multiple cameras.
5. 3D Reconstruction (*accuracy*).
6. Model fitting (*labelling, classification*).

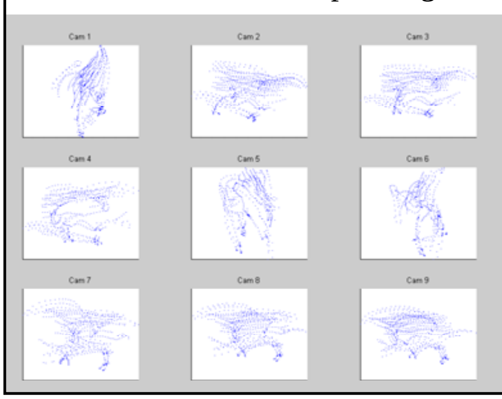
High-level Vision

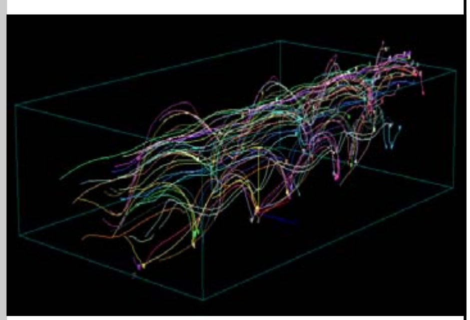
An implicit step is CALIBRATION.

Disadvantages of motion capture systems based on passive markers

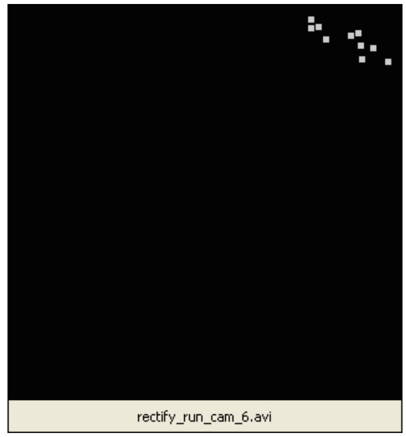
When a marker is hidden to the cameras by another body part (e.g. the arm which swings over the hip during gait), the motion capture looses track of it.

The multiple set of 2D data have to be correctly labaled and associated to their corresponding 3D markers.





Tracking difficulties



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- Multi-camera information and temporal information is required to achieve a robust tracking.

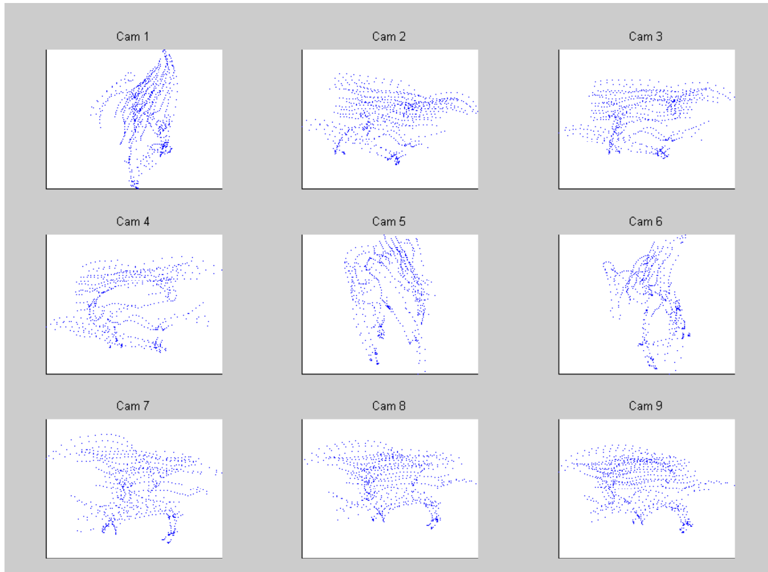
Tracking processing steps

ACQUISITION OF 2D POINTS

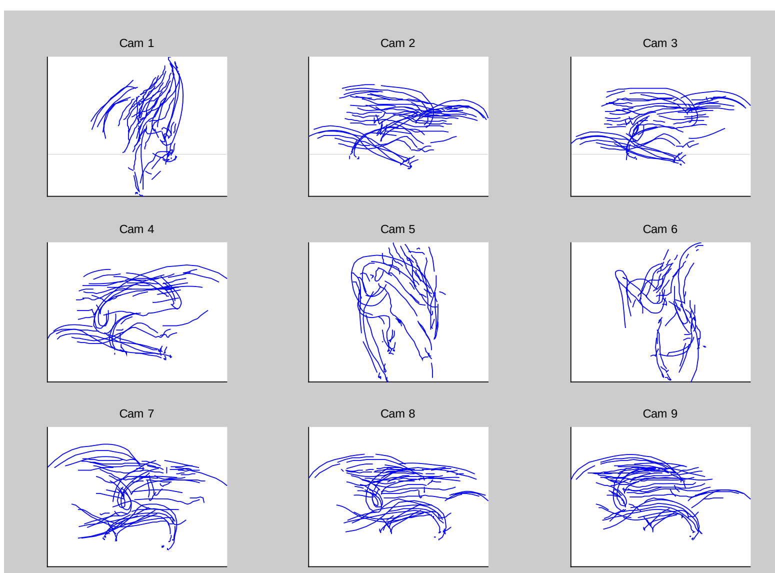
TRACKING:
1) From 2D points to 2D strings.
2) Pairing 2D strings with the epipolar constraint to create 3D strings.
3) Condensation of 3D strings.
4) Joining 3D strings.

RECTIFY:
5) Classification of 3D strings according to the markers arrangement.
6) Estimate of the 3D model of the subject from the strings data.
7) Estensione automatica della classificazione alle altre stringhe.

2D tracking

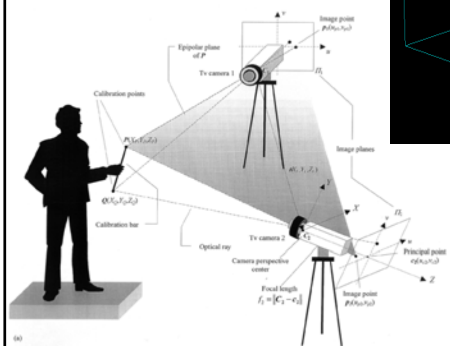


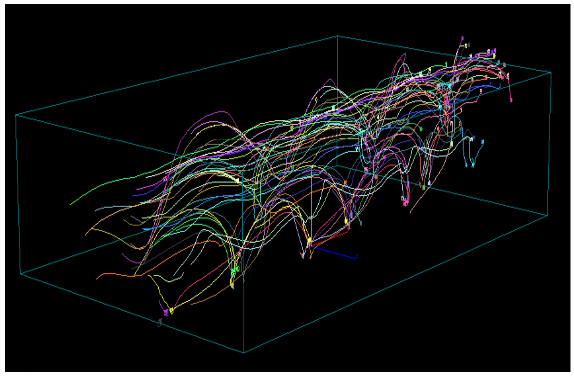
1) Creation of 2D strings



2) Matching 2D strings

Epipolarity constraint





3D strings

3) Condensation of 3D strings