Movement and Artificial Intelligence

M2 – INF 3002

AIDN: Interactive Analysis of Digital Data

Sylvie Gibet

Objectives of Movement and AI course

- Create experts in movement engineering, capable of having responsibility in the industry, integrating motion capture, machine learning and movement-based interaction

- Train project leaders able to design, implement, and manage interactive systems that enhance the sensorimotor and cognitive capabilities of the user: full-body interaction ?

The need for Movement and AI

- Industry: addressing the challenges where movement and AI can bring solutions (Web of the future)
- Networking: create a hub of professionals and experts
- Academic: pedagogical methods through R&D

Targeted competences

- Sensors, motion capture
- Movement analysis, training
- Movement modeling, and synthesis
- Gesture recognition (machine learning)
- User interaction / User experience (UI/UX)
- Humans, machines and connected objects
- AI and societal challenges

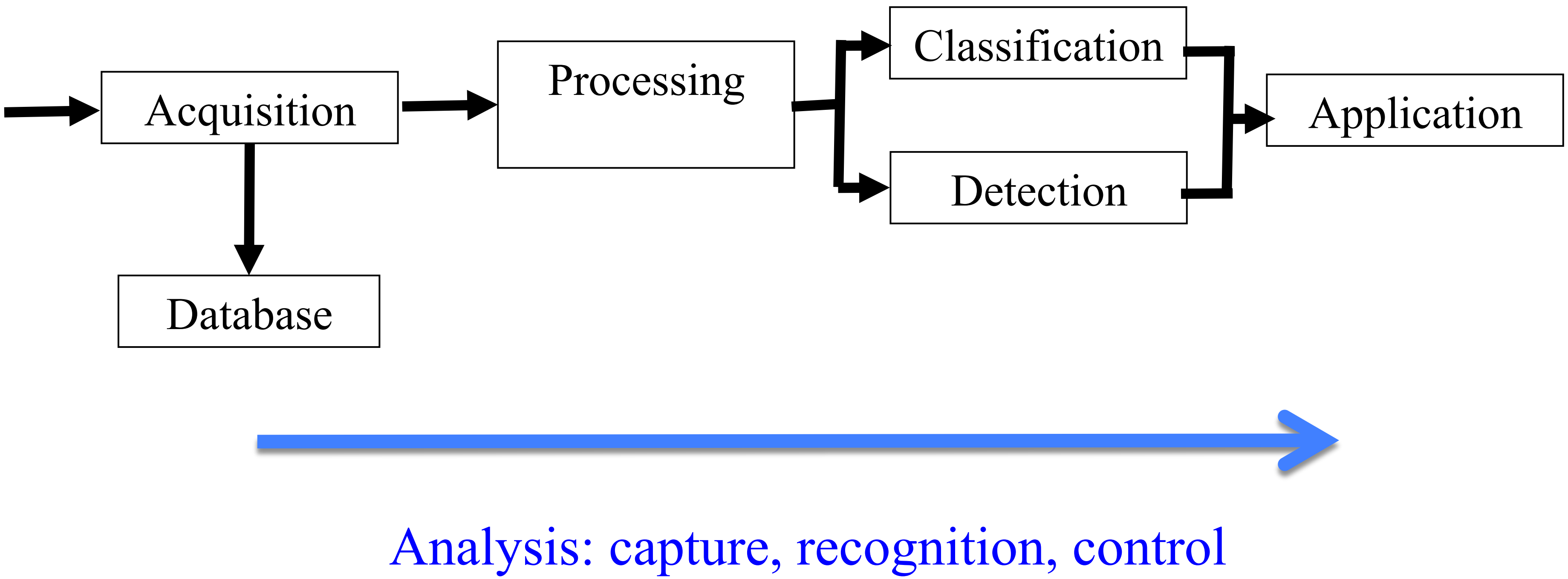
Movement engineers’ career

- Project leader in game design and gameplay
- Concept engineer for the development of movement-based interactive systems
- Development of novel interfaces and applications using Virtual Reality and Augmented Reality
- Creation of animation films

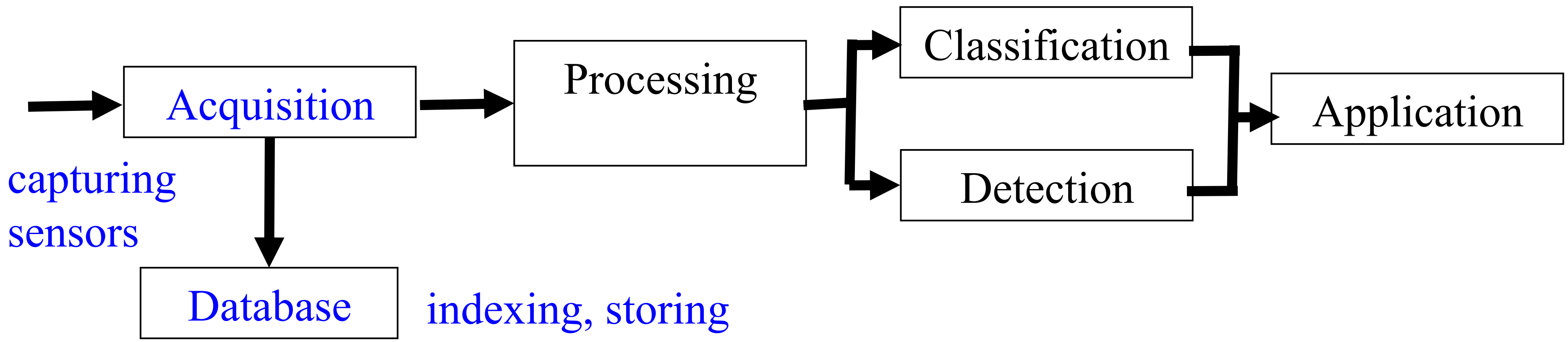
Targeted industrial sectors

- Creative industry
- Security and defense
- Smart automotive vehicles
- Manufacturing
- Medical applications: kinesitherapy (sport trauma), impairment
- Tele-operating systems (surgery, robotics, etc.)
- Arts, cultural industries and museums

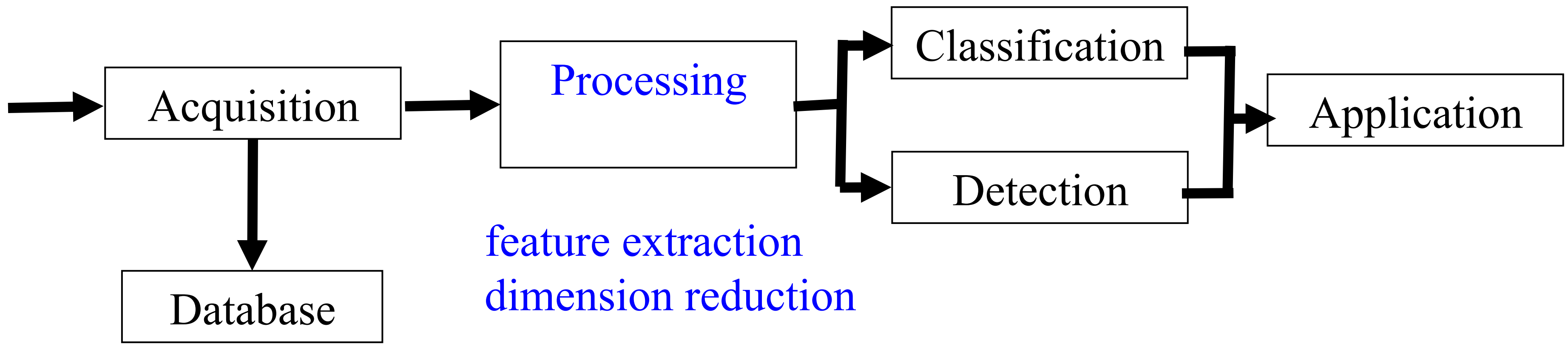
Motion Processing



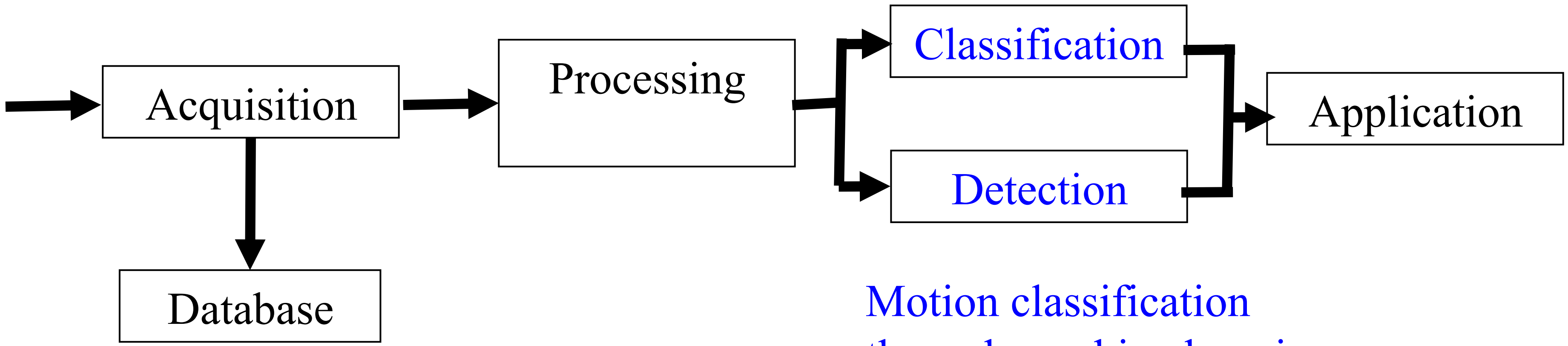
Motion Processing



Motion Processing

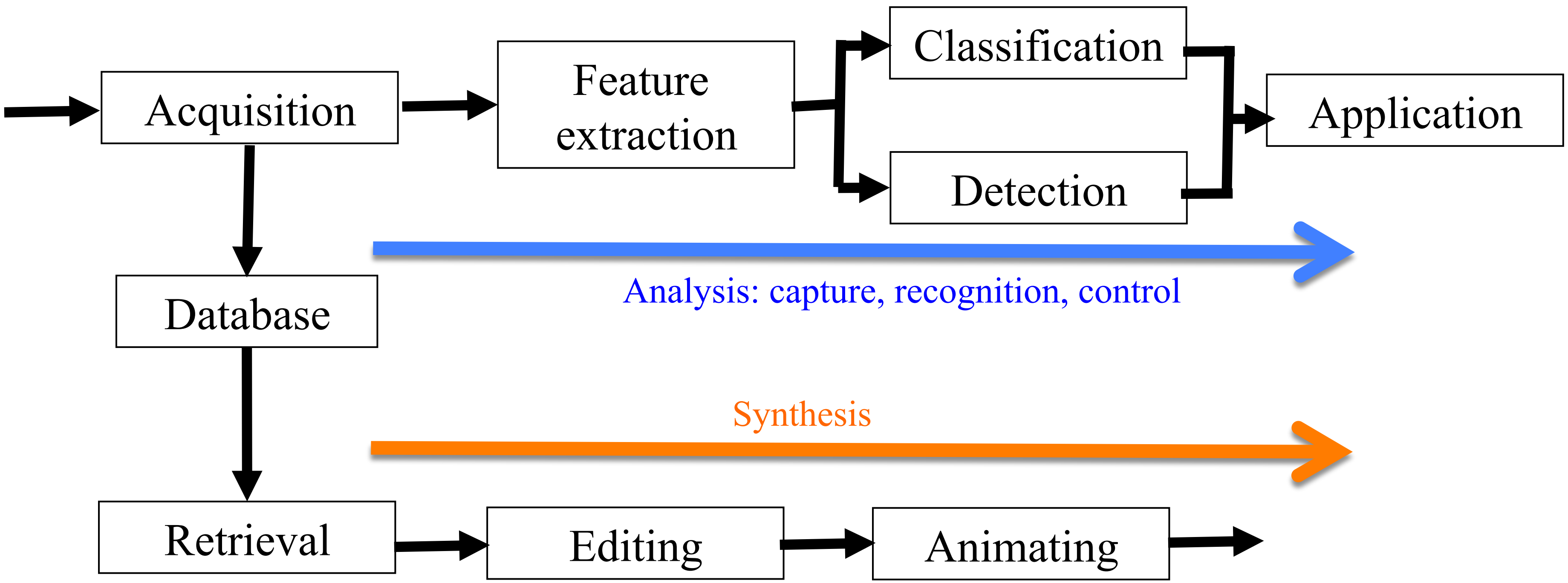


Motion Processing



Motion classification
through machine learning

Motion Processing



Outline of the course

- **Lecture 1.** Motion capture
  - Motion capture: sensors, pipeline, pre-processing, motion reconstruction
  - Skeleton and motion representation, quaternion
    - TP mocap
- **Lecture 2.** DTW
  - Dynamic programming
    - TD/TP DTW using gestural traces (Wacom tablet)
- **Lecture 3.** Supervised classification
  - Motion descriptors
  - Motion classification and recognition through machine learning
    - TP classification: Recognition of hand configurations (LSF alphabet), or facial expression

Outline of the course

- **Lecture 4.** Segmental classification
  - HMM
    - TP HMM
- **Lecture 5.** Synthesis
  - Forward kinematics
  - Inverse kinematics
  - Data-based synthesis: motion retrieval, editing
  - Facial expression analysis and synthesis
    - TP IK
- **Lecture 6.** Motion in neuroscience and linguistics
  - Typologies
  - Movement notations and languages
  - Perception of biological movement: motion laws
    - TP Unity

Practice

- **Project**
  - Unity 3D
  - Using gesture sensors and input devices to interact with a system:

    Leap motion, Myo system, Mocap (Qualisys), Kinect
  - Gestural interaction with simulations or games
  - Gesture recognition: tracking, classification, clustering

Organization of the course

- CM (3h/week): 6 weeks
- TD/TP (3h/week): 3 weeks
- Project: 3h/week: 4 weeks
- Evaluation:
  - Theoretical note (0.5)
  - Practical note (0.5)

Motion capture - Objectives

- Initiation to techniques and tools of motion capture
- Understand the general principles of measurement sensors
- Be able to fix an experimental protocol given a scientific problem

Motion capture - outline

- Introduction
- Mocap technology : Rotoscoping, Prosthetic, Electromagnetic, Optical, other
- MoCap Pipeline: setup, recording, post-processing
- Mocap output formats
- Motion representation

What is Motion capture

- Set of techniques and technologies (sensors) for measuring kinematic and dynamic variables that characterize the motion of a mobile entity (animal, human, or object)

- Variables = Cartesian position, angular position, quaternions, forces and moments
- Velocities and accelerations

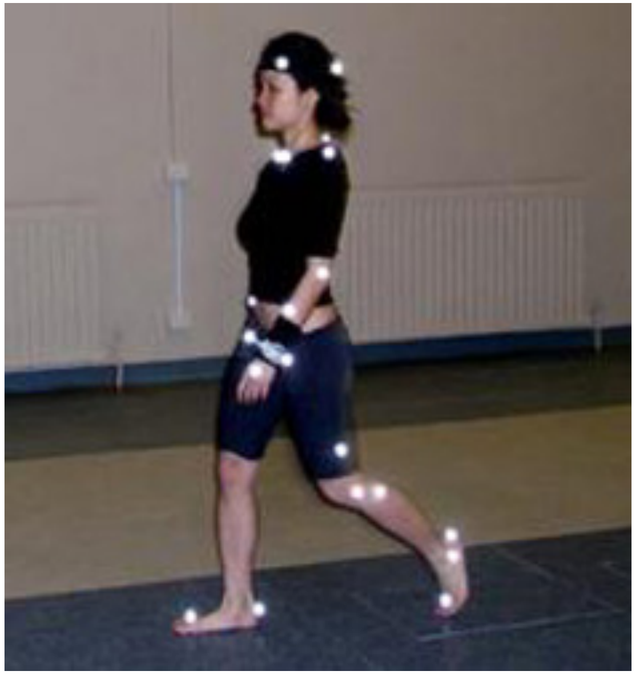
What is Motion capture

- Measure of physiological variables on the human body such as:
  - Heart rate, blood pressure,
  - Muscular activity (electromyogram EMG),
  - Brain activity (electroencephalogram EEG)
  - Respiratory rate, pulmonary volume
  - Temperature, etc.
- Characteristics:
  - Time series
  - Different rates, regularity or not
- Other similar problems:
  - Sensors form the environment (intelligent appartments, ...)
  - Different rates, regularity or not

What is Motion capture

A process by which a movement can be recorded digitally.

Motion capture of an object involves sensing, digitizing, and recording an object in motion
- Whole body
- Upper body
- Hands
- Face



Why Motion Capture

- Obtain rapidly realist movements, extracted from human motion or animals: difficult to obtain with keyframing techniques or with generative models (kinematics or dynamics).
- It becomes possible with the technological progress of the motion capture systems

Characteristics of Motion Capture

- Measure of movement on real subjects (kinematic movements: position and orientations)
- Little time-consuming (compared to other techniques), but expensive devices (becomes cheaper)
- Realistic and natural by essence (biologically plausible)
- Movement = captured signals: variations, programmability, adaptation to context and environments
- Low cost: large amount of data, many new sensors (accelerometers, wearable connected suits or objects

Interest of Motion Capture - ANALYSIS

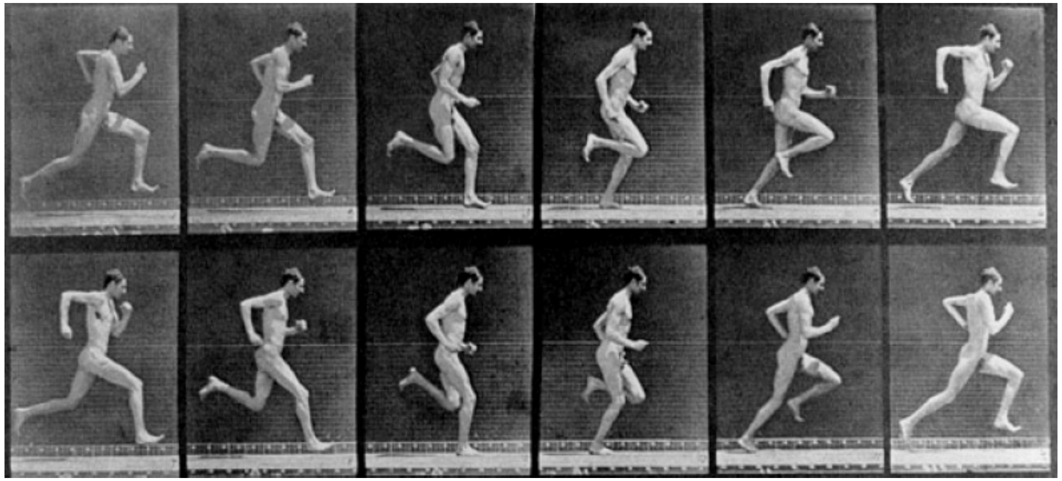
- Originally used for military tracking purposes.
- In sports, motion capture acts as a tool for biomechanical research that focuses on the mechanical functioning of the body, like how the heart and muscles work and move.
- Knowledge of human motion and activities
  - Determining biological, physiological features
  - Analysis of motor performances (biomechanical, statistical): sport, medecine, handicap (building exoskeleton), skilled and artistic performances (pedagogical tools)
  - Perception of motion: post-analysis (pedagogical tool)

Interest of Motion Capture - SYNTHESIS

- Animation: adaptation of captured motion to virtual worlds-> domain of animation films, video games,…
  - Play back: same morphology, varying the appearance (models, clothing, etc.)
  - Adaptation of the data to other morphologies (motion retargeting)
  - Adaptation to changes of the environnement
  - Generation of new motions: :
    - Deformation
    - Learning the motions (style) and re-incorporating the knowlege in new motion
    - Combining small motion clips to generate new motions

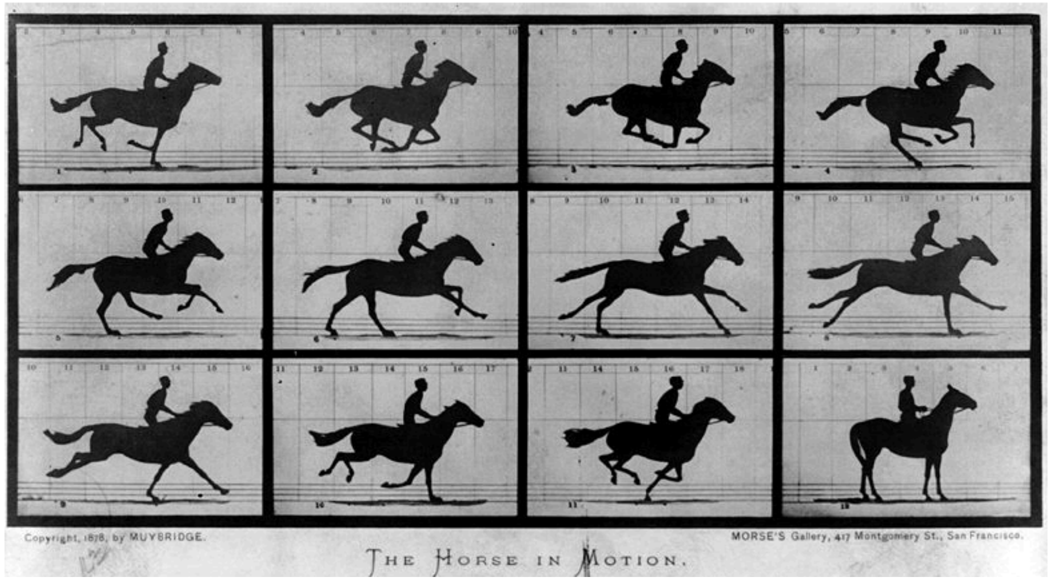
History of Motion Capture

The Motion Capture began in late 1800's when Etienne Jules Marey and Edward Muybridge performed motion studies on various animals and humans



Edward J. Muybridge, 1830-1904

http://en.wikipedia.org/wiki/Eadweard_Muybridge



Rotoscoping

Rotoscoping is an animation technique in which the animators trace over live action film movement frame by frame, for use in animated films. The pre-recorded images are projected onto a frosted glass panel and are re-drawn by an animator. This equipment is called rotoscope

Tom Goes To The Mayor

Motion Capture Technology

There are primarily four methods in motion capture

- Mechanical
- Magnetic
- Inertial
- Optical

Mechanical technology

- Potentiometers at joints

change voltage according to angular rotation of the rods.

- Gyroscope at the hips
- Prosthetic Motion Capture uses Potentiometers on the aforementioned plastic exoskeleton that an actor must "wear", and then act out his or her movements.
- Advantages: very accurate and transmits real-time data at a far greater range than any other technology.
- Drawbacks: very "intrusive device"

A gypsy3 prosthetic suite

Magnetic

- Magnetic sensors and transmitters
- This approach has a central magnet with several receivers attached to the actor's body. The receivers capture and record the actors movements and save them to the computer.
- The emitter generates an EM field modulated at low frequencies which is detected by the receivers. The captured data is then filtered and amplified

A suit with magnetic sensors

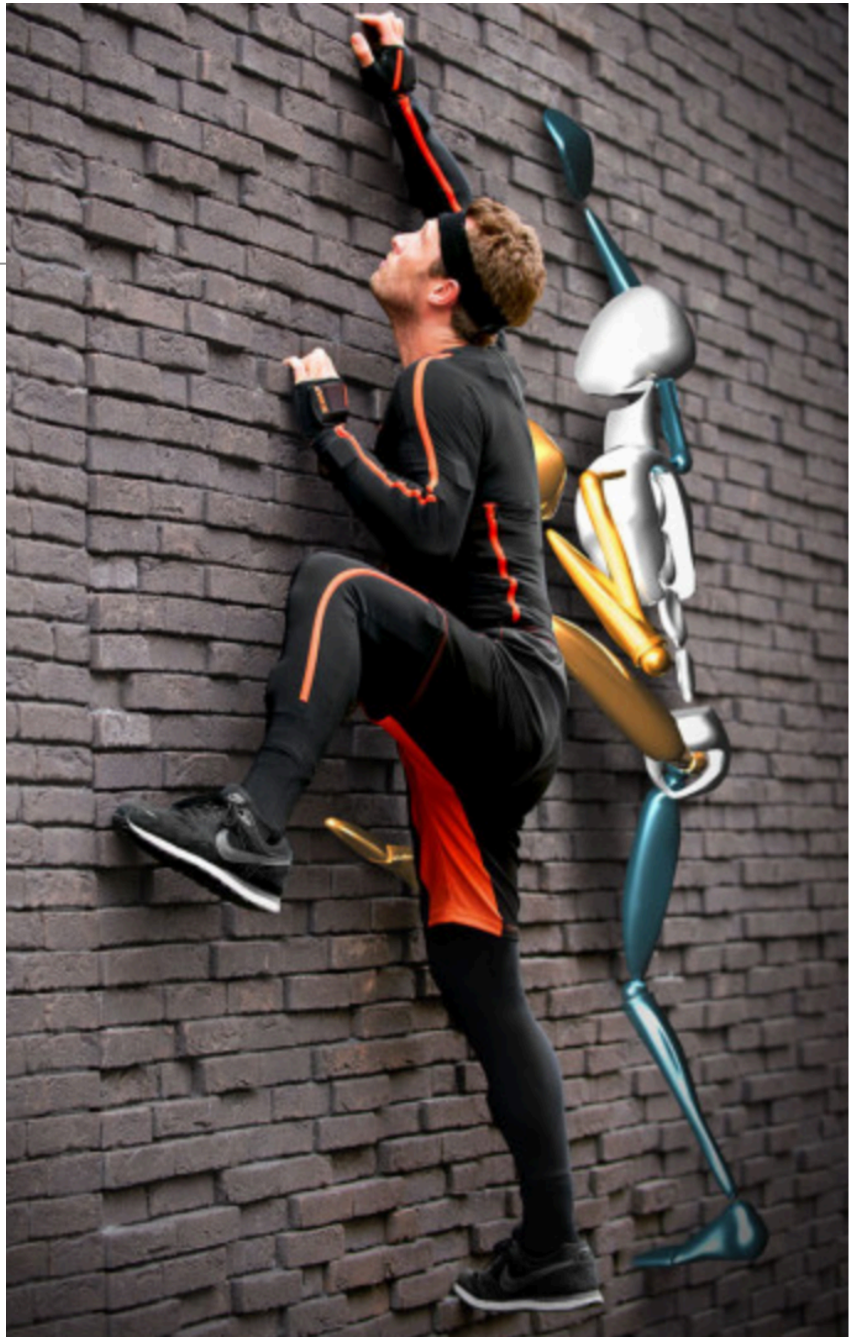
Magnetic

- Advantages
  - Direct access to the 6 dof of each sensor
  - Minimal processing, real-time
  - No occlusion
- Drawbacks
  - No homogeneity of the field
  - Sensitivity to EM disturbances
  - Wires
  - Limitation of the measurement area
  - Low precision: necessity of filtering
  - Low acquisition sampling (around 150 Hz)

Inertial

- Accelerometers
- Gyroscopes

- Xsens: inertial motion capture with full magnetic immunity
  - Technical tests?
  - Sampling rate?
  - Range of capturing? (In/Out?)



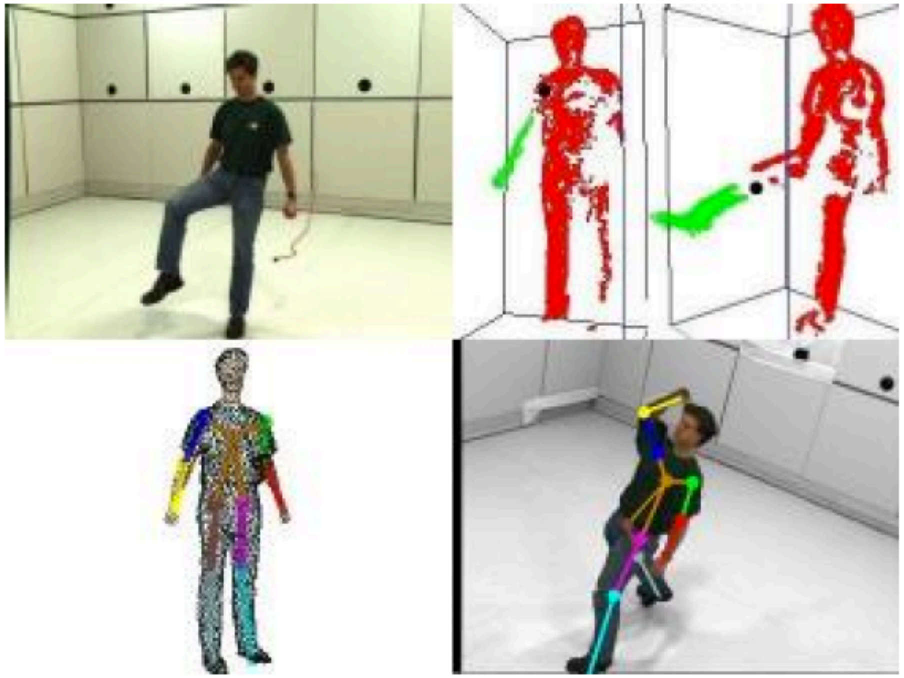
Xsens motion suits

Optical MoCap

- Markerless
  - Monocular

Monocular Human Motion Capture with a Mixture of Regressors, A Agarwal and B. Triggs, CVPR 2005

  - Multi-cameras

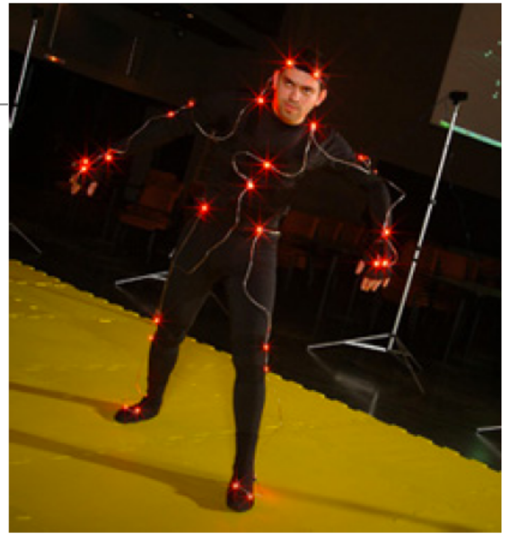


3D Human Kinematic Modeling and Markerless Motion Capture, G. Cheung, S. Baker, T. Kanade, CVPR2003

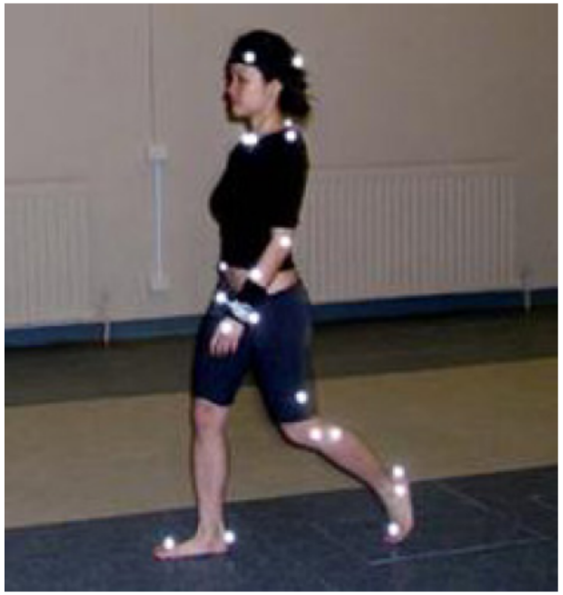
Mocap with markers

- Infrared cameras

Active



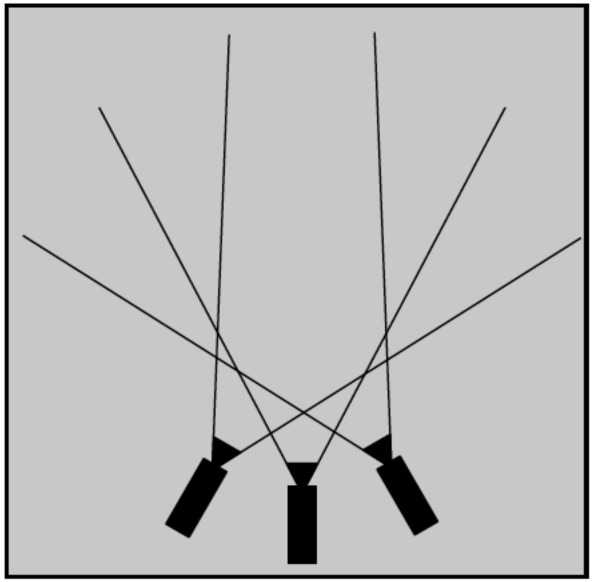
Passive



VICON-MX
Qualisys

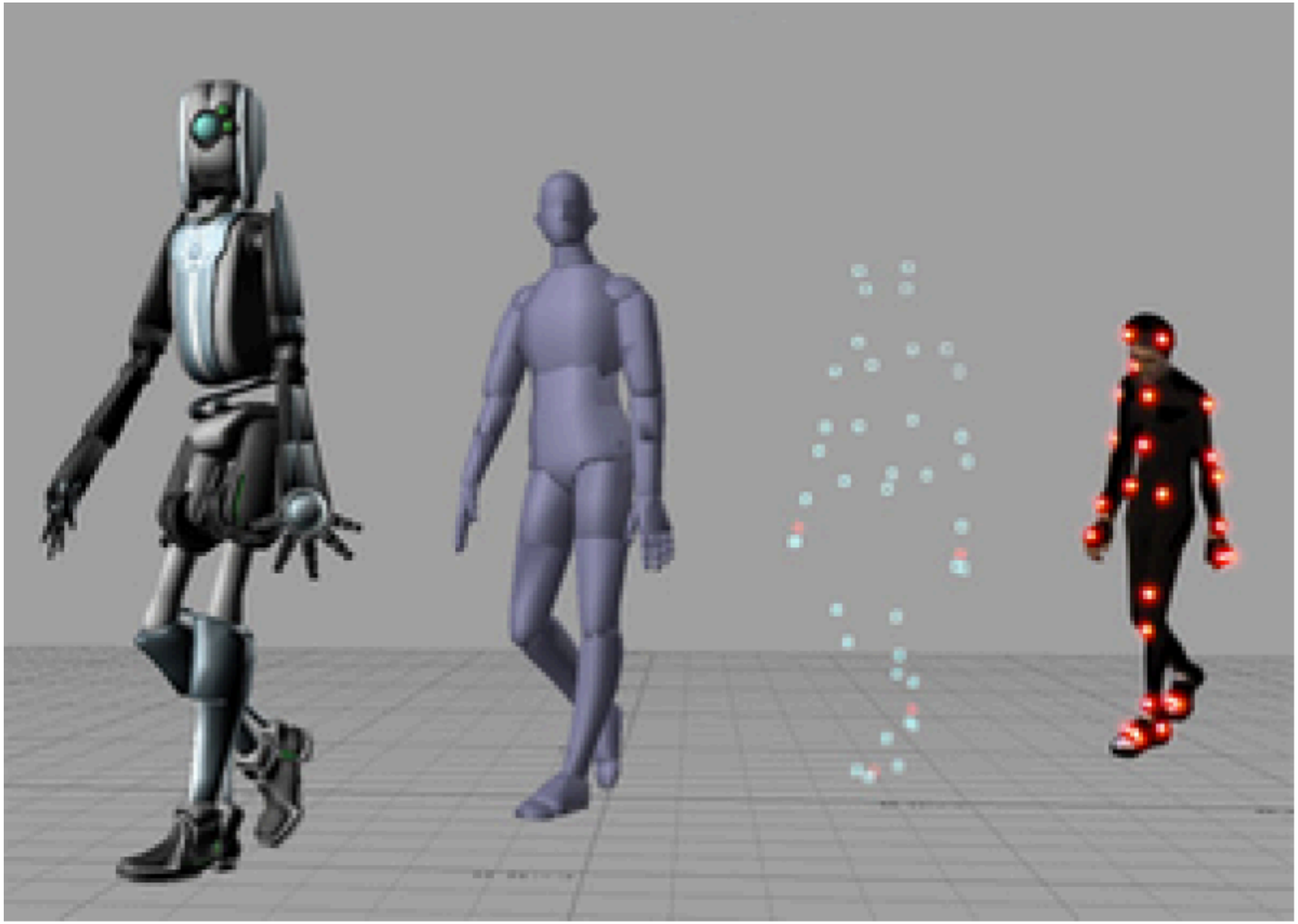
Optical

- Advantages
  - High precision of the captured data (< 1mm)
  - High number of markers with different sizes
  - Easy to modify the position of the markers
  - Possibility to estimate the internal skeleton
  - No cable: subject weakly constrained in his movements
  - Large captured area (in gymnasiums)
  - High aquisition frequency (from 30 Hz to 500 Hz)



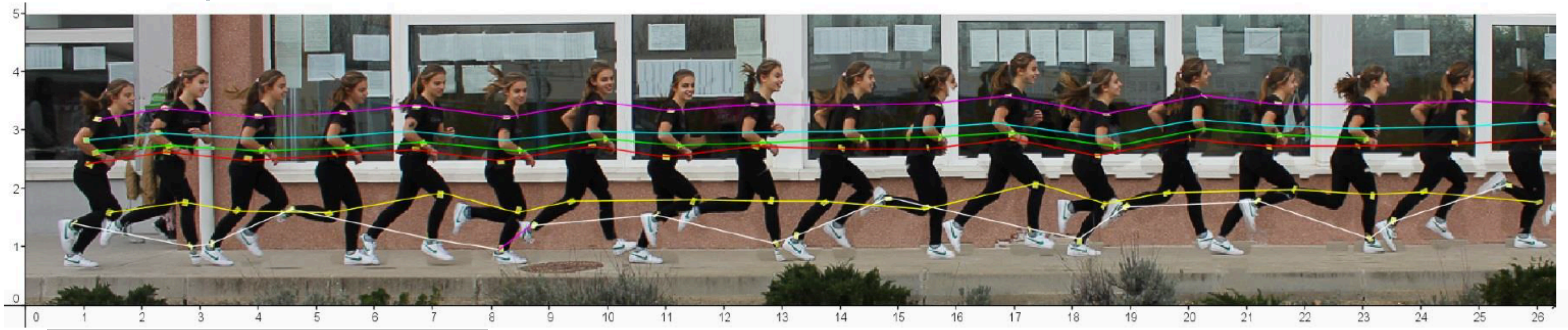
- Drawbacks
  - Time consuming: labelling,
  - Occlusion, marker swap -> heavy post-processing
  - Expensive systems
  - High complexity for 3D reconstructing joint centers
  - Positioning of markers (soft tissue, clothing, bones)
  - Lighting interferences (apparition of ghosts), cameras limitations

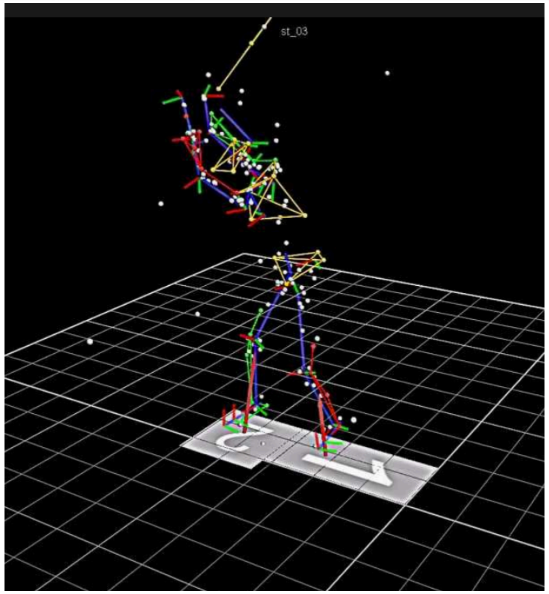
Optical MoCap with markers - pipeline



Mocap with markers: different uses

- **Analysis of human motion**
  - Sport



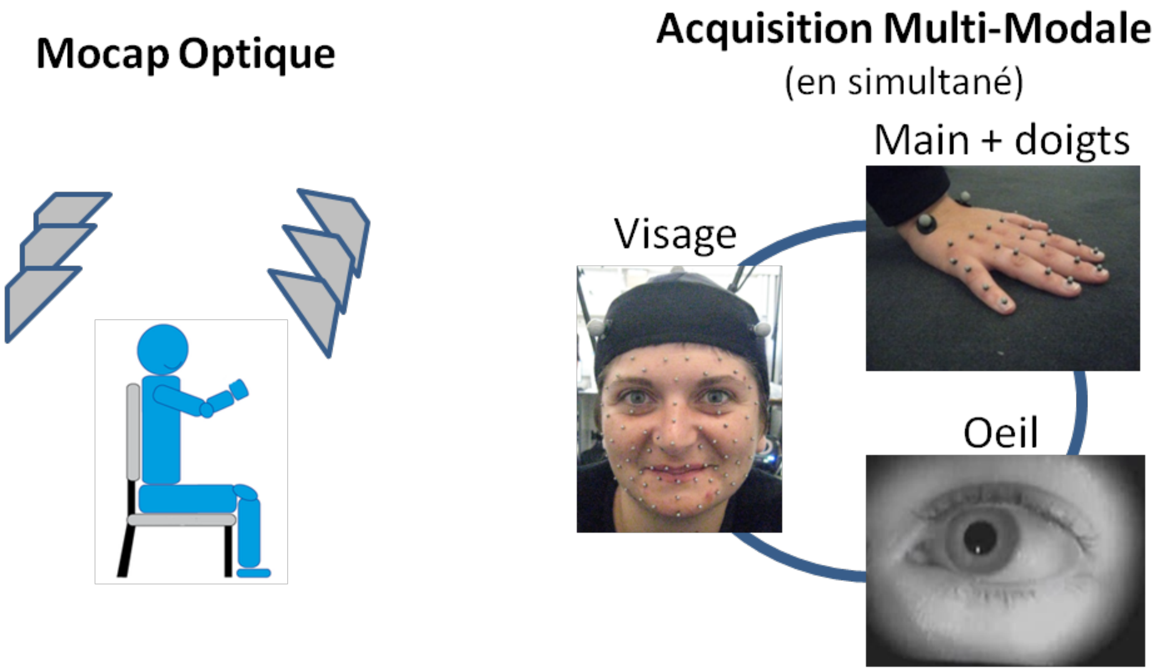


Skilled movements

Mocap with markers: different uses

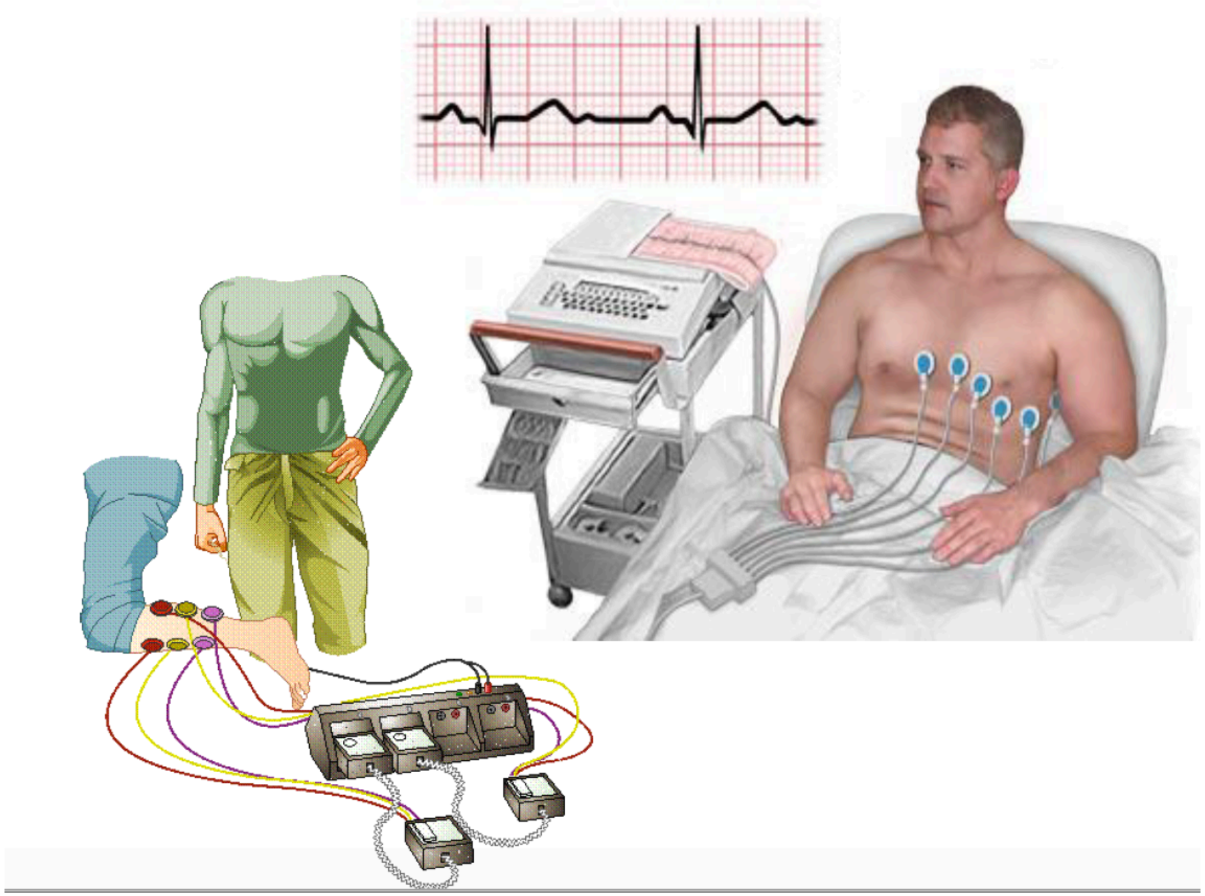
- **SIGN3D (IRISA): recording, editing phrases in LSF**
  - Corpus: HD mocap data (facial, hand, body movements)
  - Multi-level linguistic data (annotation)

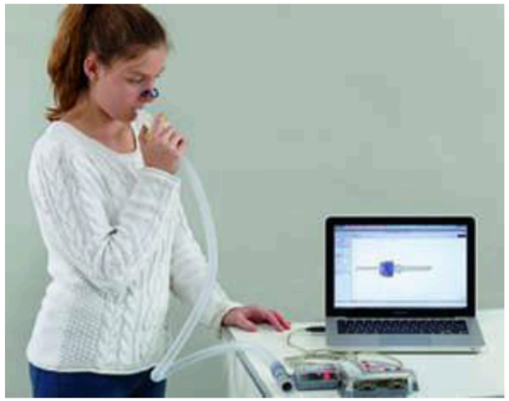
Chaîne d'acquisition de capture du mouvement



Mocap with markers: different uses

- **Medecine, telemedecine**





Mocap with markers: different uses

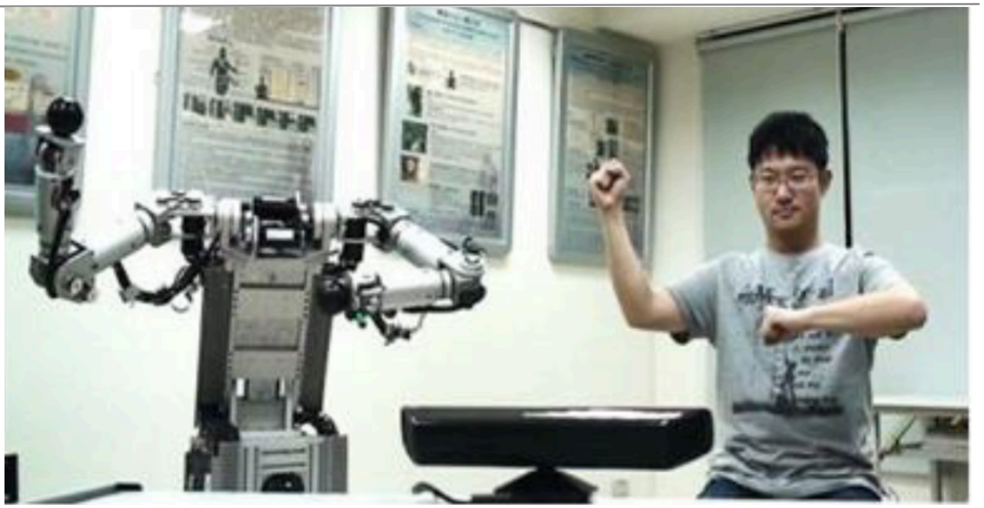
- **Mocap for cinematography**

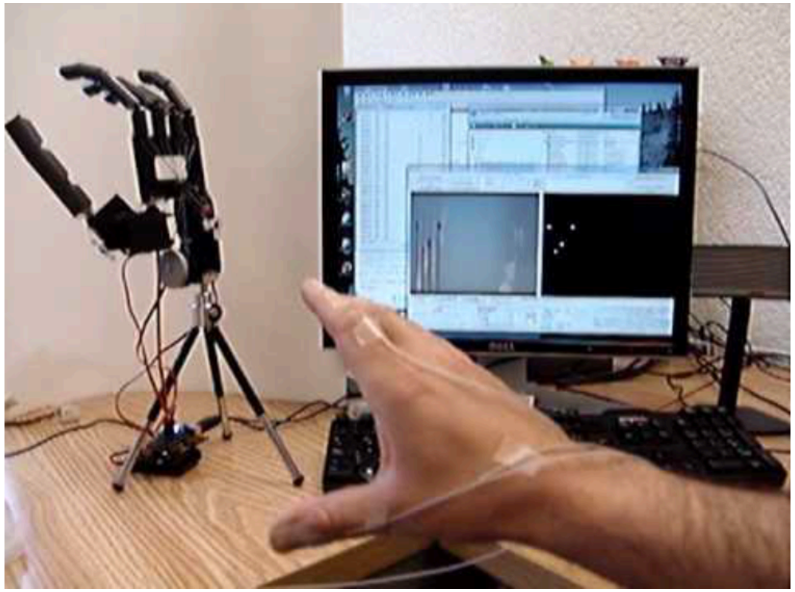
Mocap with markers: different uses

- **Mocap for video games**

Mocap with markers: different uses

- **Mocap for robotics**

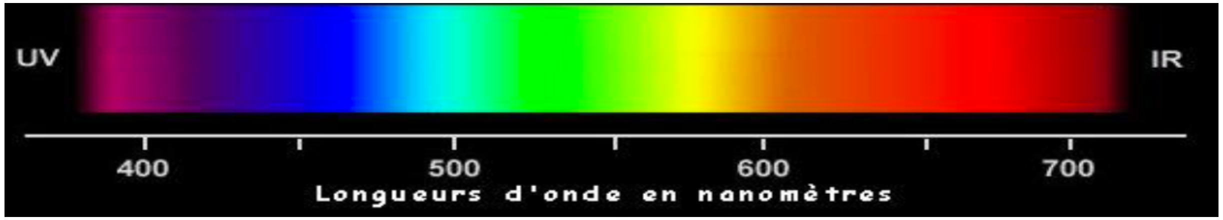


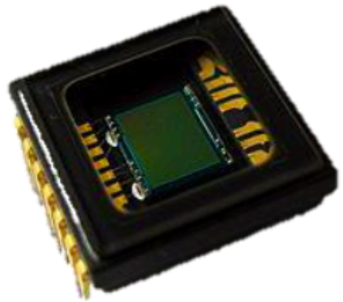


What sensors?

Optical sensors

Camera-based technologies, operating in spectral ranges from 300nm (Untra violet, UV) to 800 nm (Infrarouge, IR), including the visible spectral domain from 400 nm (Violet) to 750 nm (Rouge)





What sensors?

Optical sensors: Leap Motion

Technology developed since 2008 from M. Buckwald and D. Holz for hand movement recognition

Using 2 monochromatic IR cameras and 3 infrared LEDs, the device observes a roughly hemispherical area, to a distance of about 1 meter. The LEDs generate pattern-less IR light and the cameras generate almost 200 frames per second of reflected data.

What sensors?

Optical sensors

Uses IR cameras and PIR (near IR) to detect reflecting markers and achieving visual tracking tasks.

Measured and computed data: 3D joint data, angular velocity and acceleration

Precision: 1 mm

Vicon MX:
LED's: 4-16M pixels, 60-1000 fps

What sensors?

- **Optical sensor: Kinect**

IR light is projected onto the objects, and the image is processed by the sensor to reconstitute the depth. Conversely to traditional optical systems with markers, only one camera is used with this technique

What sensors?

Electric sensors

Electrocardiogram (ECG)

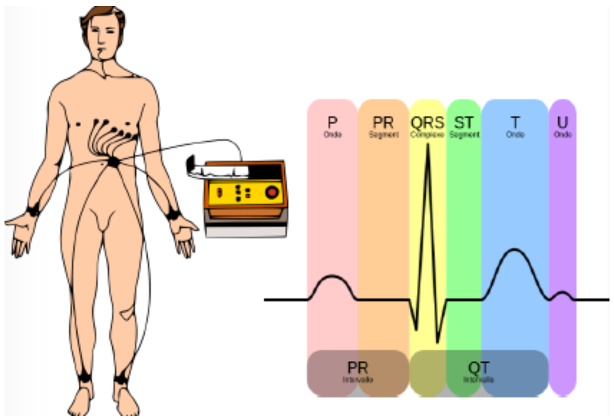
- Low electric signal (about mV)

- Temporal precision (T < 0.5 ms)

- Necessity to correct and amplify the signal (digital filtering)

- Several waves detected in an ECG

- When producing a physical effort, averaging methods to eliminate the artefacts due to the movements



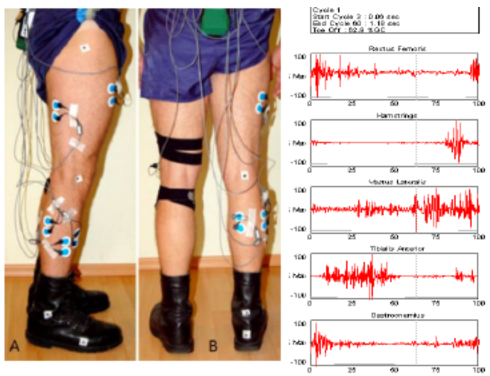
Electromyiogram (EMG)

- Electric signal from the peripherical nervous system

- Detecting, from electrods, electric potentials emitted by muscles during their contraction

- Surfacic EMG (non intrusif)

- Low noisy signals, necessity to filter and amplify them



Electroencephalogram (EEG)

- Principle: analogous to and EMG, but operates on the head (crane) to detect brain electric signals

- Filtering: as for ECG or EMG

Conclusion

Each technology of motion capture has its own advantages and weaknesses. For each studied variable, there is no perfect sensor.

Using a measurement tool necessitates a knowledge of the studied phenomenum. A badly located sensor will lead to wrong and inoperable data.

For your project: determine, by using a rigorous scientific approach, the optimal solution(s) (technological and experimental) to answer a specific issue

Sources

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