Virtual Reality in Medical Robotics

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Virtual Reality

- One of the core technologies of the modern Human Machine Interface (HMI) science
- Human Machine Systems – one of the 14 technical committees of IFToMM

→ A multi disciplinary science with roots in Computer Graphics and Robotics

Virtual Reality (II)

- The science of Human Machine communication via natural sensorial channels
- Usually the machine **outputs** signals that are perceived through the human senses
- Multi – modal interface → several senses

→ Virtual Reality is a technology for OUTPUT ?

VR ←→ 3 "I"

- Immersion
- Imagination
- **Interaction**
- Burdea and Coiffet (2004):

but

- INTERACTION = INPUT and OUTPUT
- Conclusion: Virtual Reality = INPUT and OUTPUT
- We call them "modalities".

VR modalities

- OUTPUT: Most known and developed VR technologies
- One sense = one "modality"
- Really addressing the 5 human senses.

Most common "modalities":

- Visual sense
- Touch (Haptic feedback)
- Audio

- smell
- taste

VR INPUT Modalities

- The human communicates to the machine
- The "modalities" do not correspond to human senses

  …but to "machine sensing"
- Still they must be NATURAL and easy for the human

→*Input modality = NATURAL human communication mean*

- Examples of input modalities:
  - Speech
  - Gestures

  → we name them: "**explicit** input"

implicit INPUT

- Tracking based input: most attractive input modalities
- The user is tracked: head, hands, whole body, eyes, electrical signals (including neuro) etc

→ A much larger range of “sources”

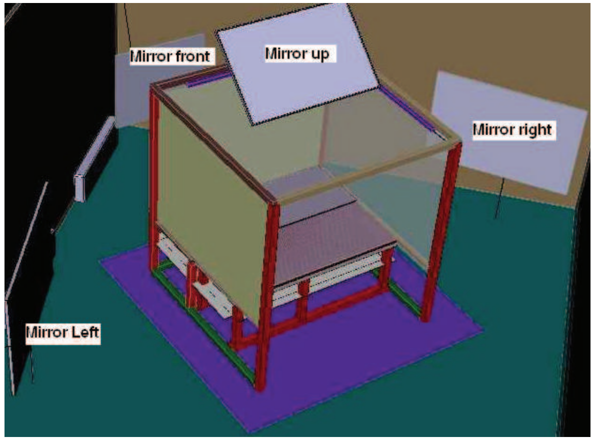
- Minim cognitive load for the user
- Simple to use → more complex to develop
- Examples of implicit input modalities:
    - Navigation
    - Pointing

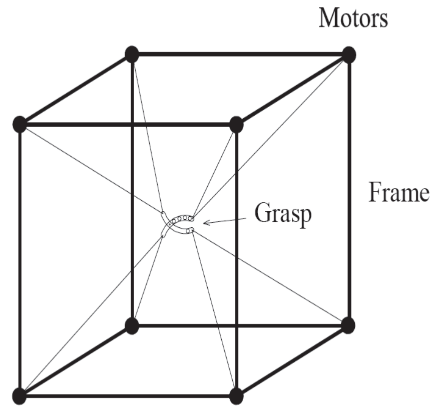
Multi-Modal Interfaces

- The big concept in 2000's
  - Input modalities
  - Output modalities
- Many challenges and research topics:
  - fusion of modalities (for input)
  - fission of modalities (for output)
  - conversion from one modality to another →
  - compensation of one another

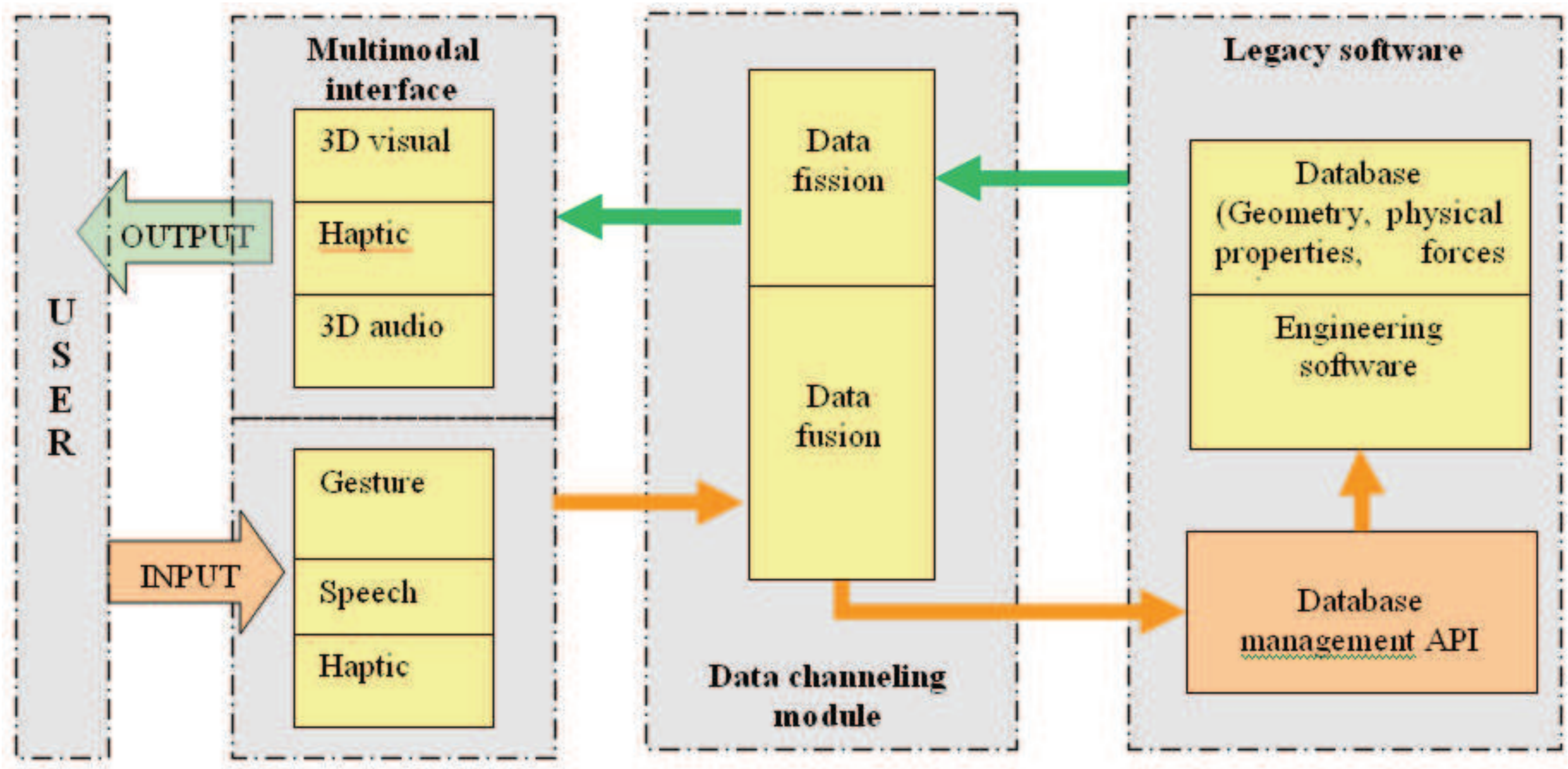
Example: Immersive interfaces

- For output:
  - 3D visualisation
  - Haptic devices
  - 3D audio
- For input:
  - Tracking
  - Gesture
  - Speech

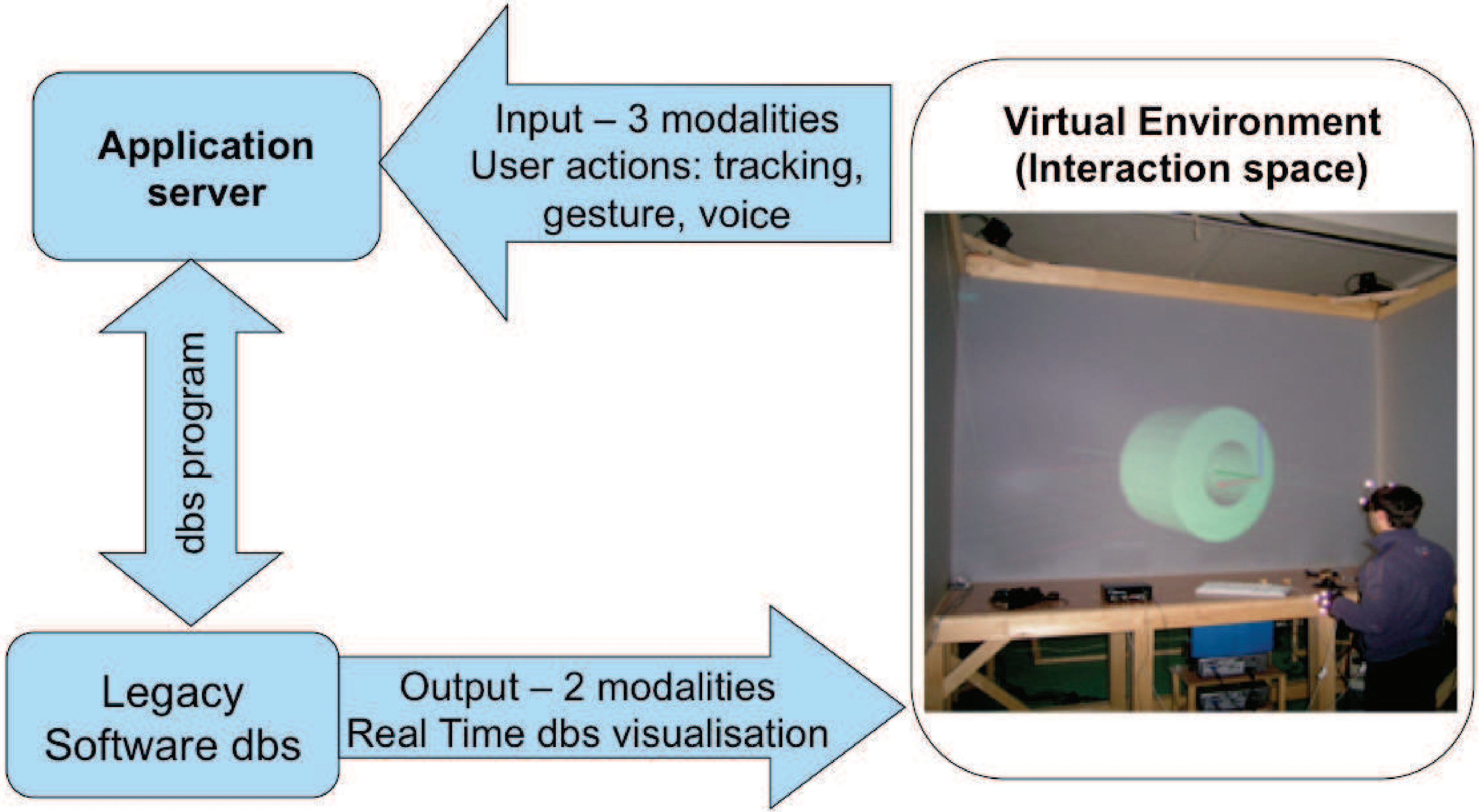




Typical core interface



Typical VR interface for existing applications



VR applications in Medical Robotics

→ Multi-modal interfaces :
- simulation, planning and training
- remote medicine, tele-presence

→ Individual modalities used to cmpensate the lost or degradation of one sense or human ability
- Rehabilitation
- Ambient Assistive Living

VR modalities that are important for Medical Robotics

- Haptic: mainly rehabilitation, but also surgical training)
- 3D Visual: pre-operatory planning, augmented reality
- Tracking: Ambient assisting living, remote medicine

→ a number of projects completed, ongoing or just started at UTBv

“Haptic modality”

- Admitance control – genuine haptic input: the user force is measured and sensed by the machine
  - Not very often used
- Traditionaly → haptic feedback = output (impedance control)
- This could be also equivalent to haptic input because of Newton’s “action-reaction” principle
- The force feedback is “resisted” by the human operator or viceversa
- Many haptic applications in medical robotics: rehabilitation, robotic surgery and training. Most important: rehabilitation

Why is haptic control important in rehabilitation?

•Able people can always be resisted (to simulate grasping of an object, for example)

• Disabled workers need sometimes to be *assisted*, and as they progress to be resisted. – A transition between assistance and resistance is needed for rehabilitation, which is case-dependent;

• Could/should be done by intelligent agent software programmed/prescribed by the medical specialist.

• Another technique is by haptic disturbances - make control more difficult – thus improving motor control capabilities

• Sometimes disturbances are designed to create useful "after effects".

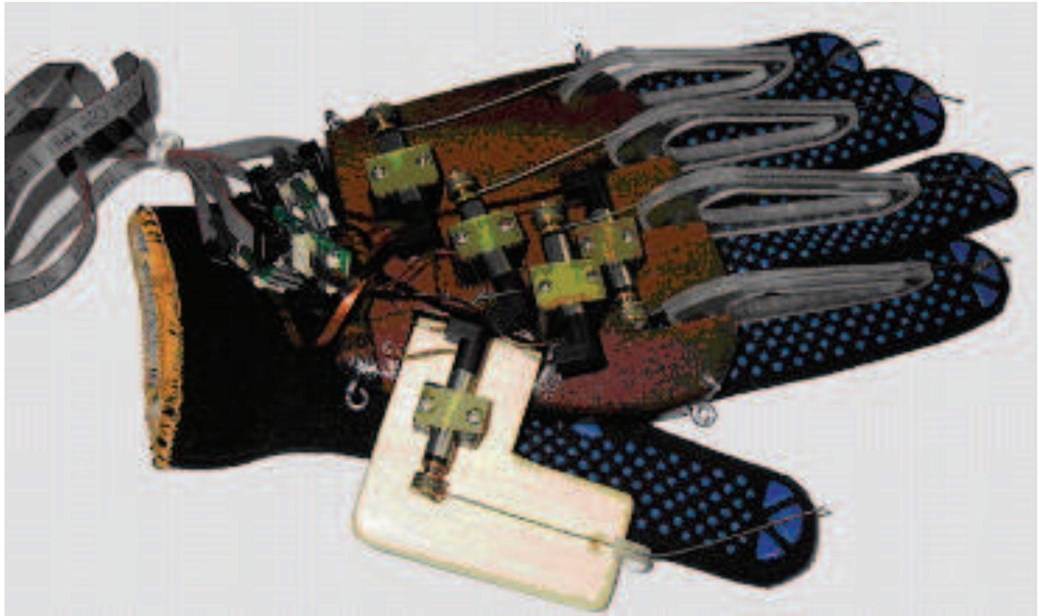
Typical methodology

- When the patient is unable to move, the robot moves the patient' s arm to the target
- If the patient moves inappropriately, the robot guides the arm towards a nominal trajectory to the target – like a haptic channel
- As the patient improves, the robot provides less assistance

haptic gloves for hand rehabilitation

Most important features: max force, lightweight, workspace

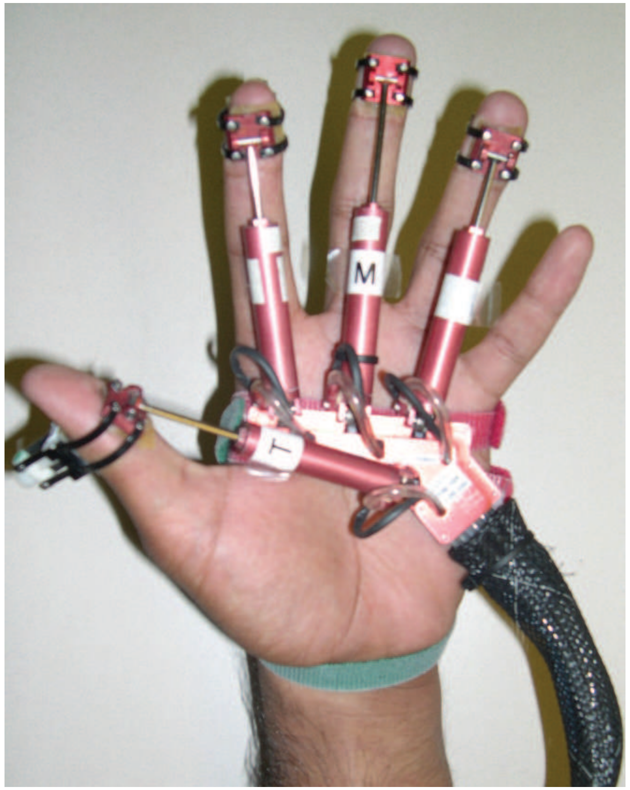
Rutger Master, 2002

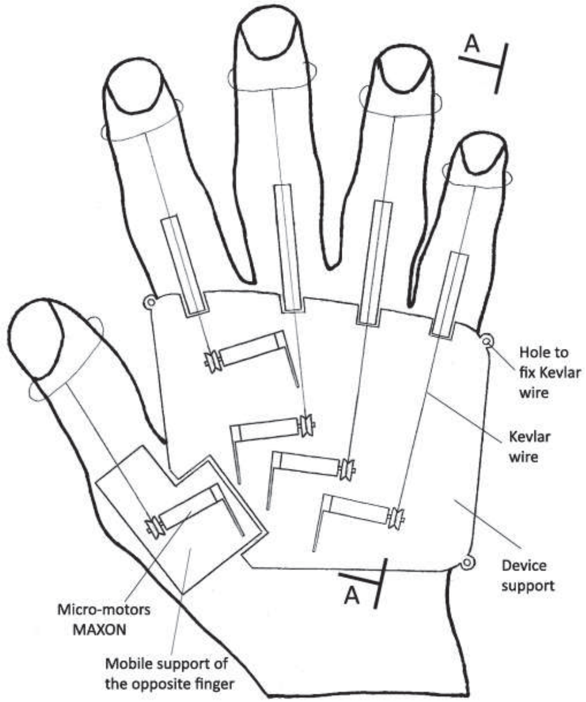


Univ. Transilvania, 2006

Project VEGA

Performances





- The VEGA glove uses a sensing/feedback exoskeleton, producing 9 N per finger (16 N - Rutger Master).
- Similar weight
- Workspace limitations (for Rutgers)

Multi-modal, collaborative VR: “Project MERVI: Collaborative Pre-surgery Planning in a Tele-immersive Environment using VR Technology”

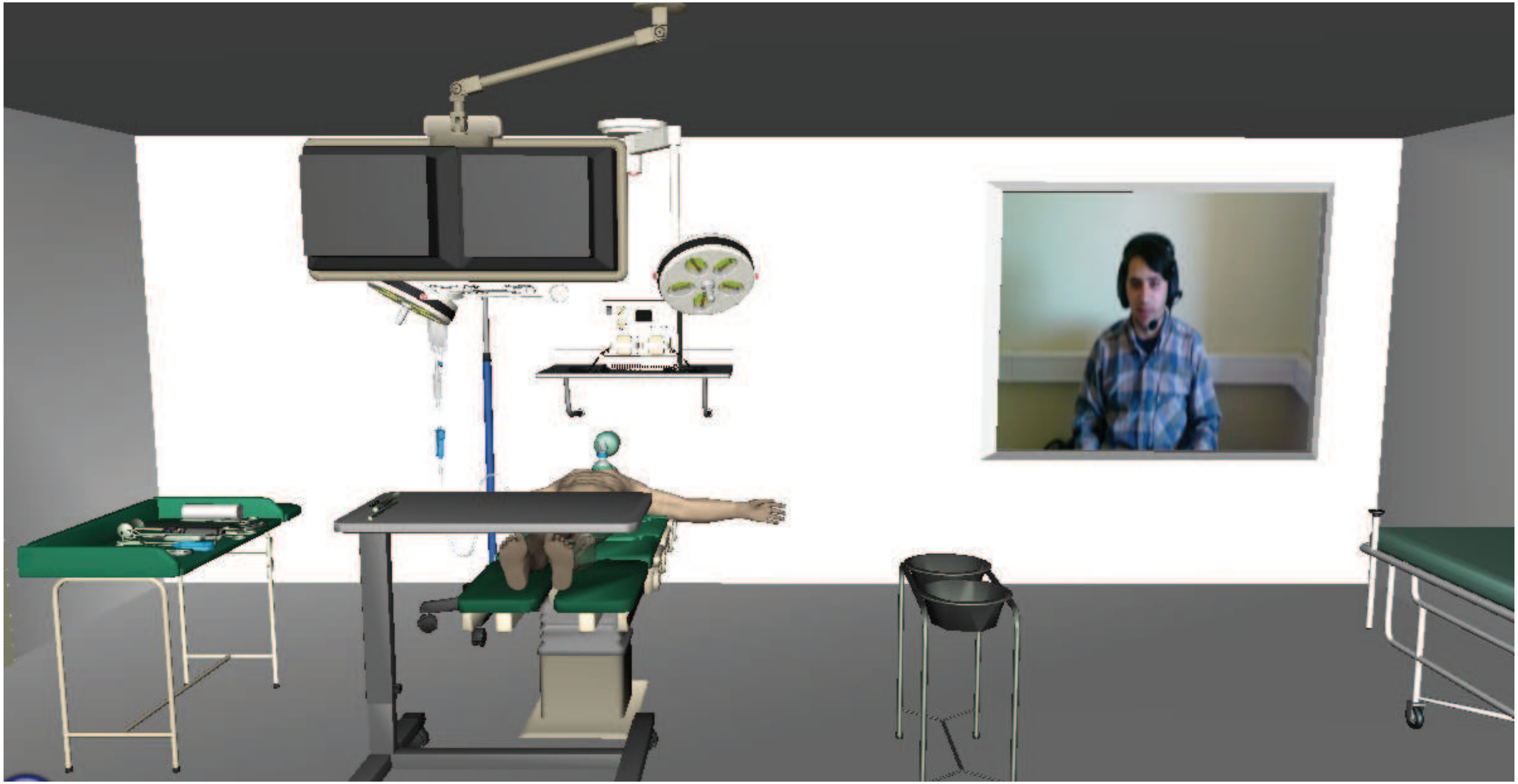
The goal

- Collaboration between remote medical teams

- Remote assisted surgery

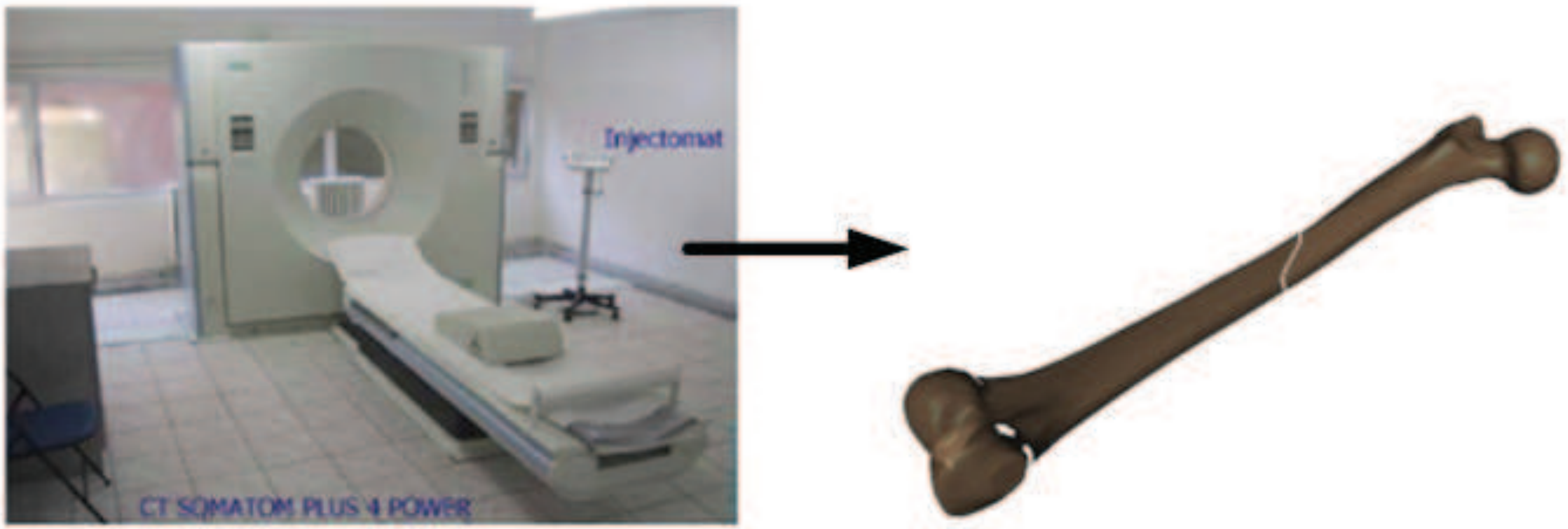
- Reduced time of bone surgery using a pre-operatory planning

Surgery Room Simulation



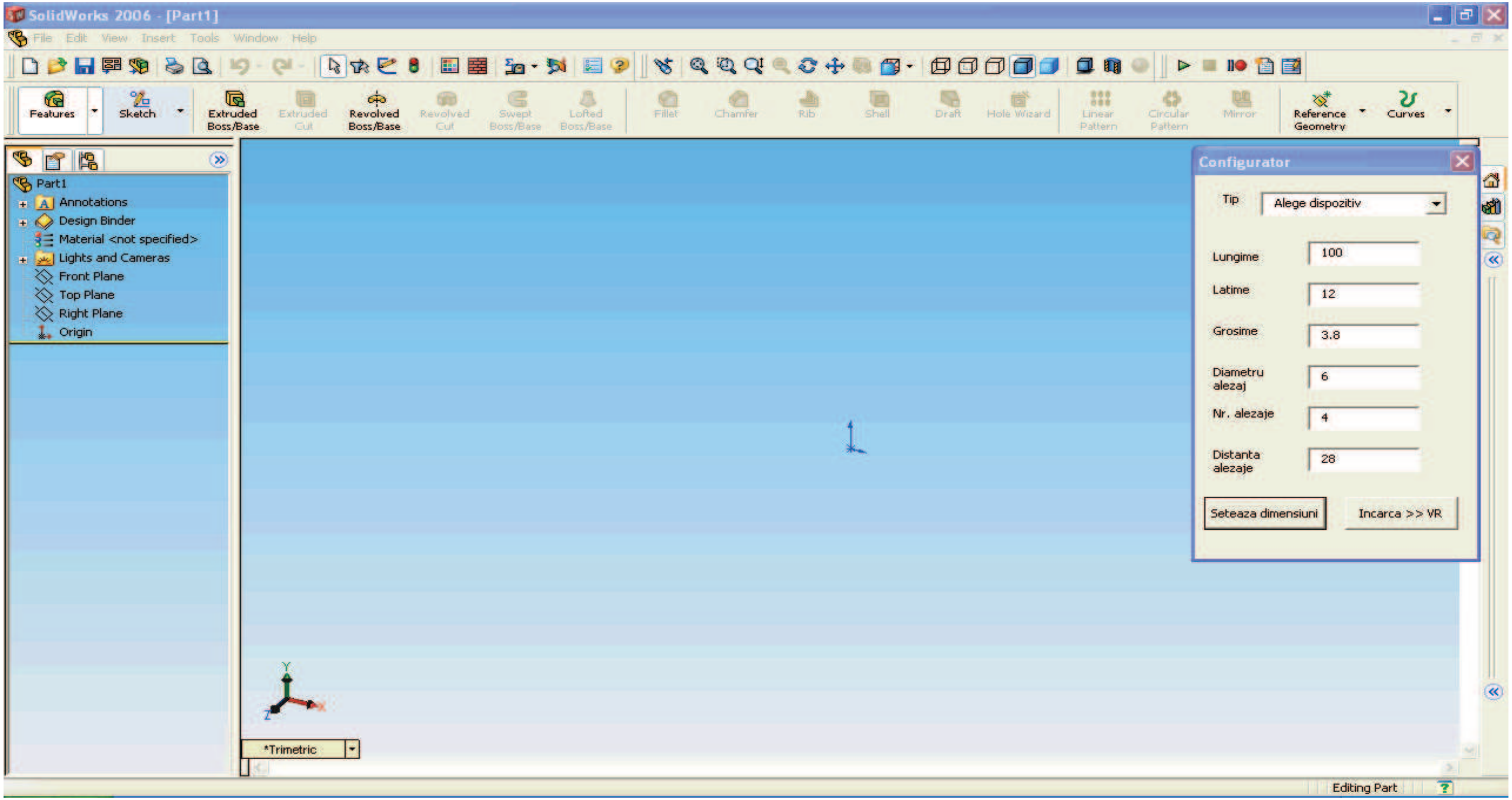
3D bone fracture model

- Using SIEMENS SOMATOM CT

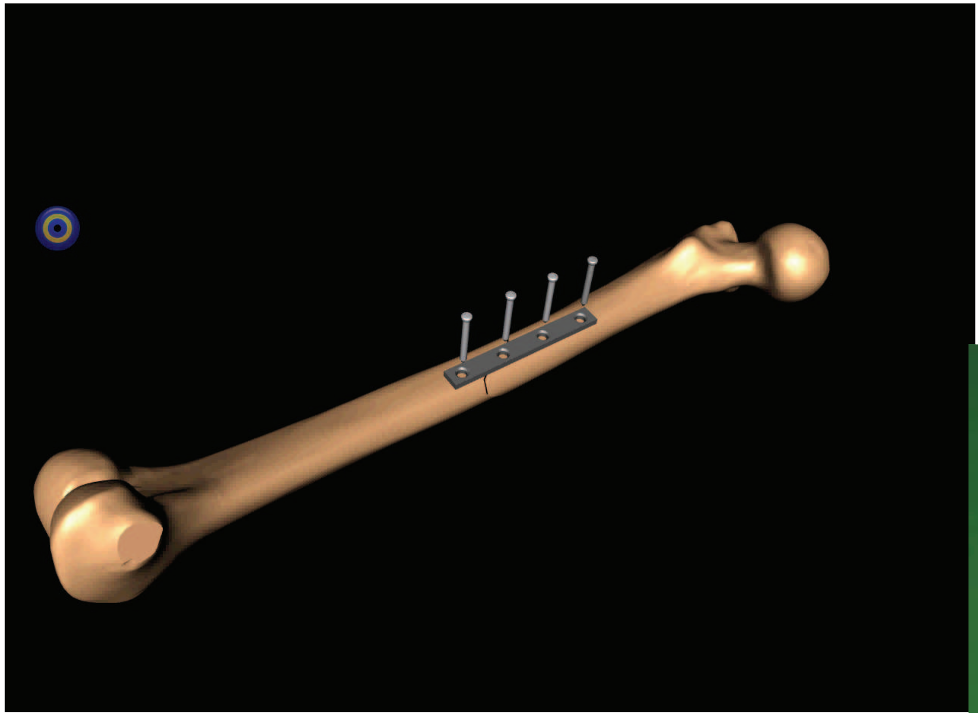


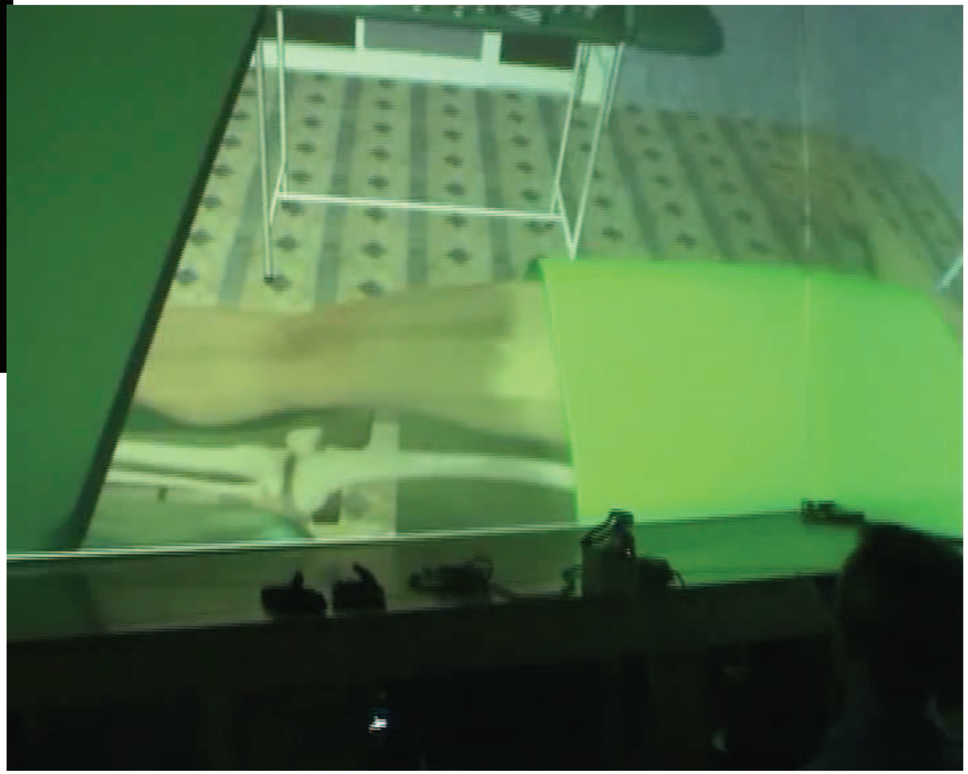
Bone fracture evaluation

Engineering of implants



Virtual testing of implants





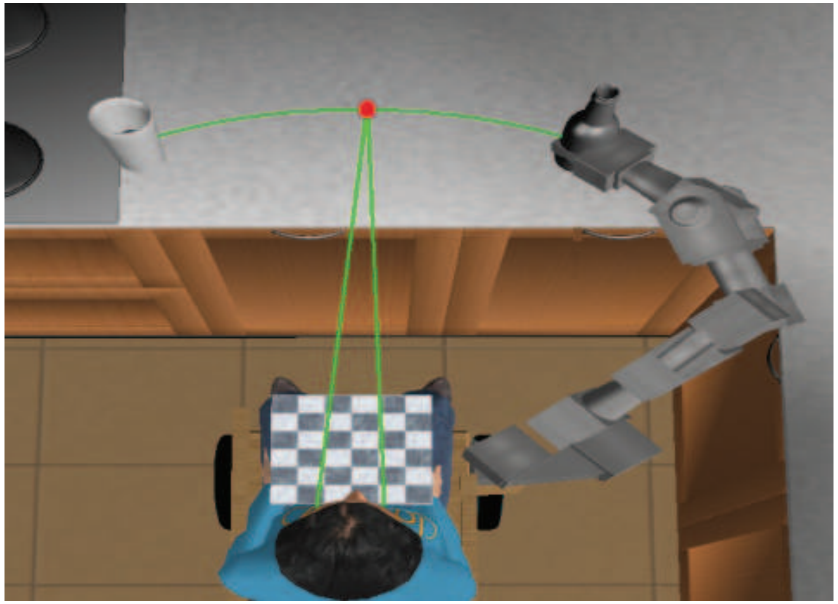
"Tracking"

Most input modalities are based on tracking

One of the most important: Navigation

- Zero cognitive load
- Essential function: moving in virtual environment
- Currently: navigation by mouse, gesture etc.
- VR challenge: natural navigation

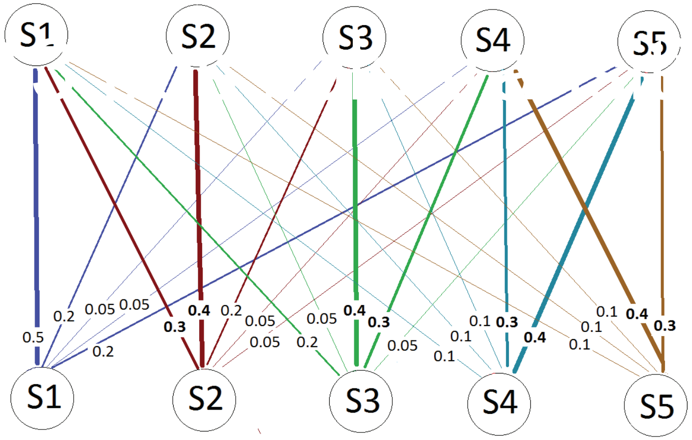
Project TRIMA: Eye tracking



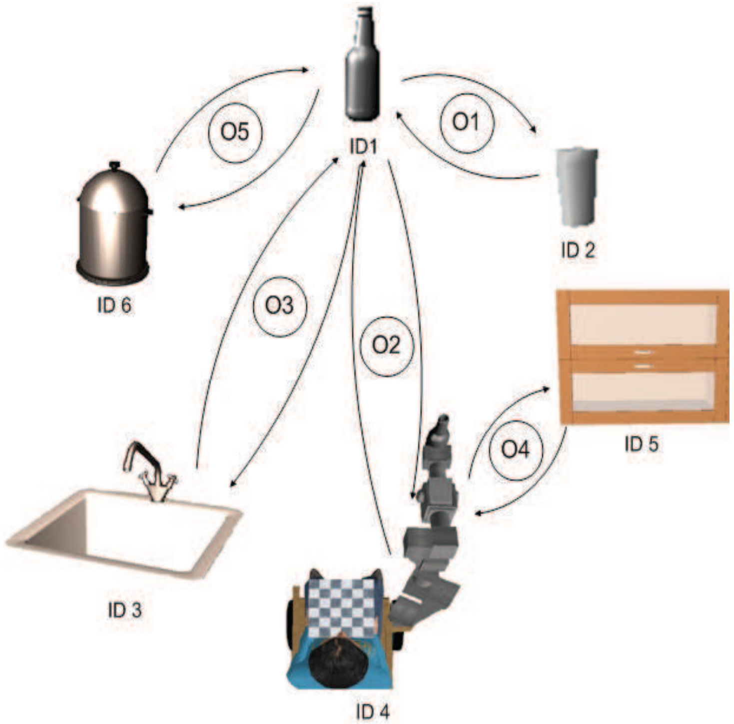
Where and What the user gazes at ?

Eye based interaction: blinks and winks

Intent identification with Hidden Markov Chains



	O(t)	O(t+1)
S1 (O1)	ID1	ID2
S2 (O2)	ID1	ID4
S3 (O3)	ID1	ID3
S4 (O4)	ID4	ID5
S5 (O5)	ID1	ID5

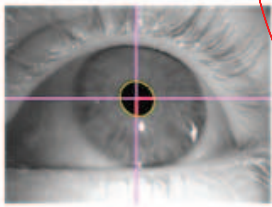


Correct intent identification rate 94%

Applications

Desktop applications

Car industry

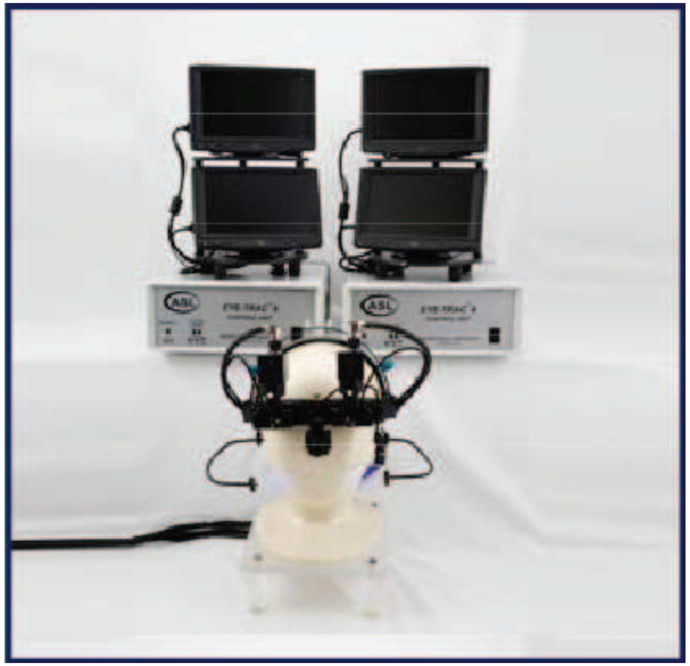


Direct command of assisting robots

Interaction metaphors

- Pointing with the eyes
- Selection by blinks
- Various other gestures by combinations of blinks and winks

Technical Description of ASL Eye-Track 6 H6-BN



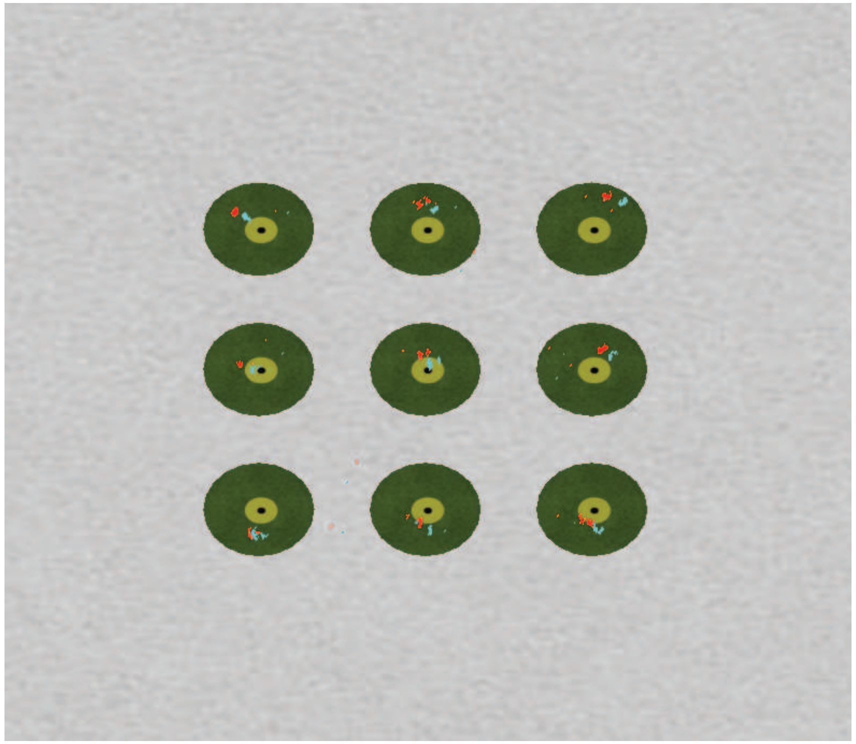
Head Tracker	6 DOF Head Tracking
Sampling Rate:	120/240/360Hz
Gaze Position Accuracy:	0.5° to 1°
Tracking Range:	50° Horizontal, 45° Vertical or more
System Accuracy:	0.5° visual angle or less
Resolution:	0.1° of visual angle
Technology:	Video based Eye Tracking with Bright Pupil illumination
System Calibration:	Automatic and with 5 to 9 points

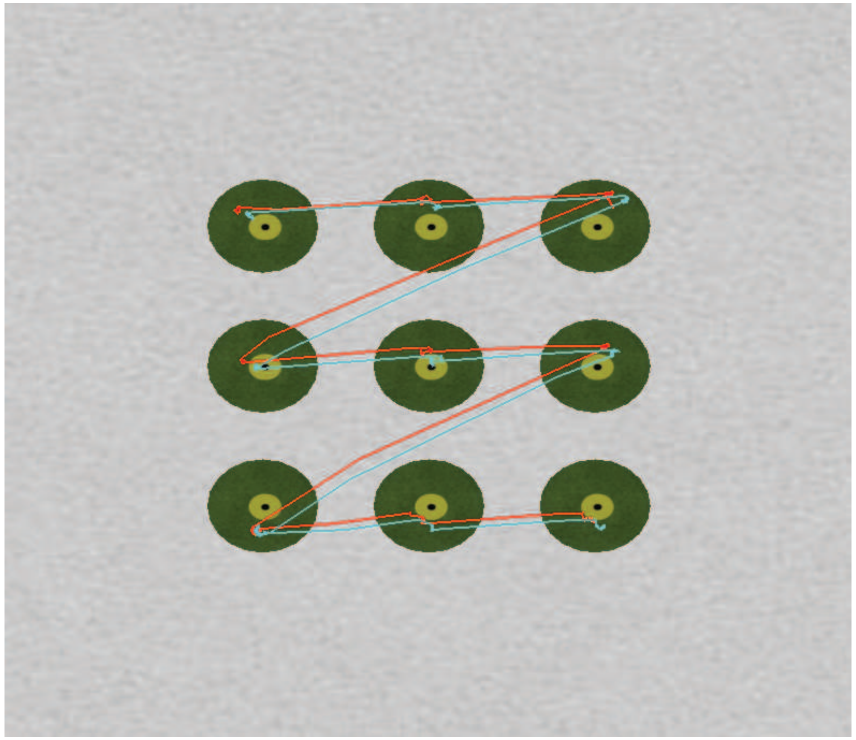
Testing the precision of the eye tracker on a plane surface

The cloud of points are the correspondent of fixations on a certain object.

The red and cyan points are the projection on the gazed objects of each eye gaze lines.

The lines connecting the dots show the path followed by the eyes.

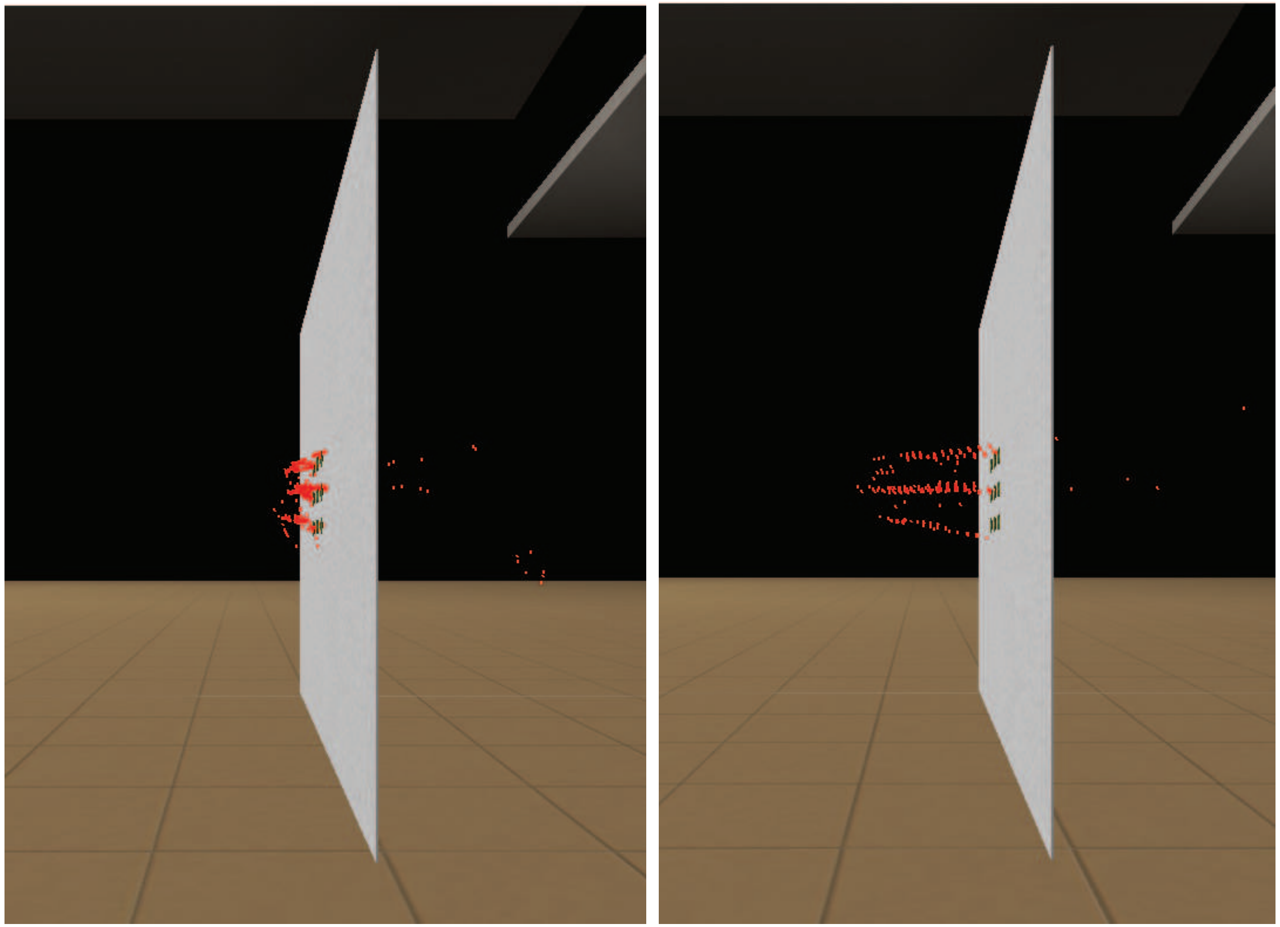




Testing the precision of eye tracking in tridimensional space

- Precision of the convergence point measurement is less accurate at distances greater than 2 m.

- a) The plane is placed at 0.5 m away from the user
- b) The plane is placed at 1.5 m away from the user



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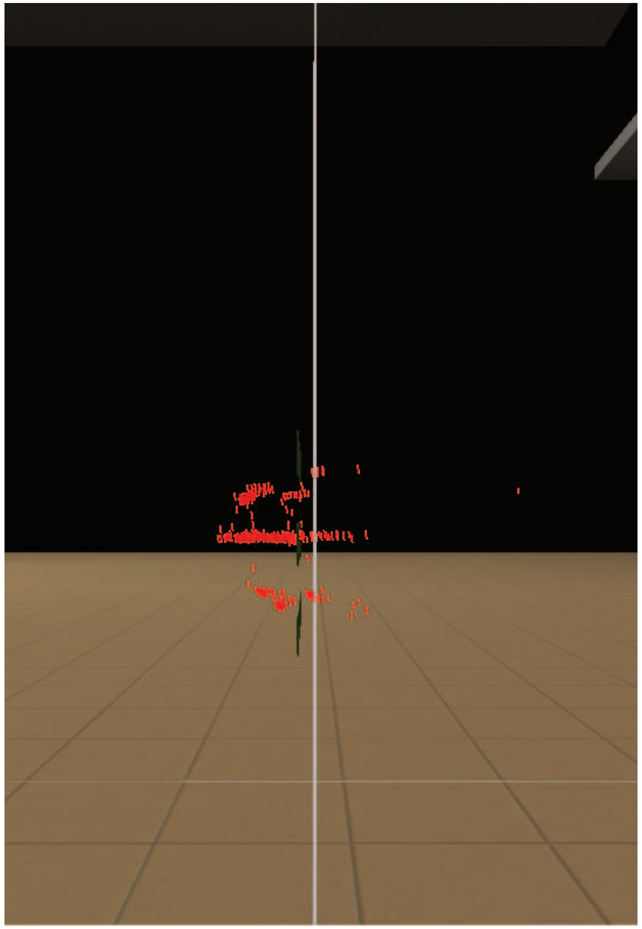
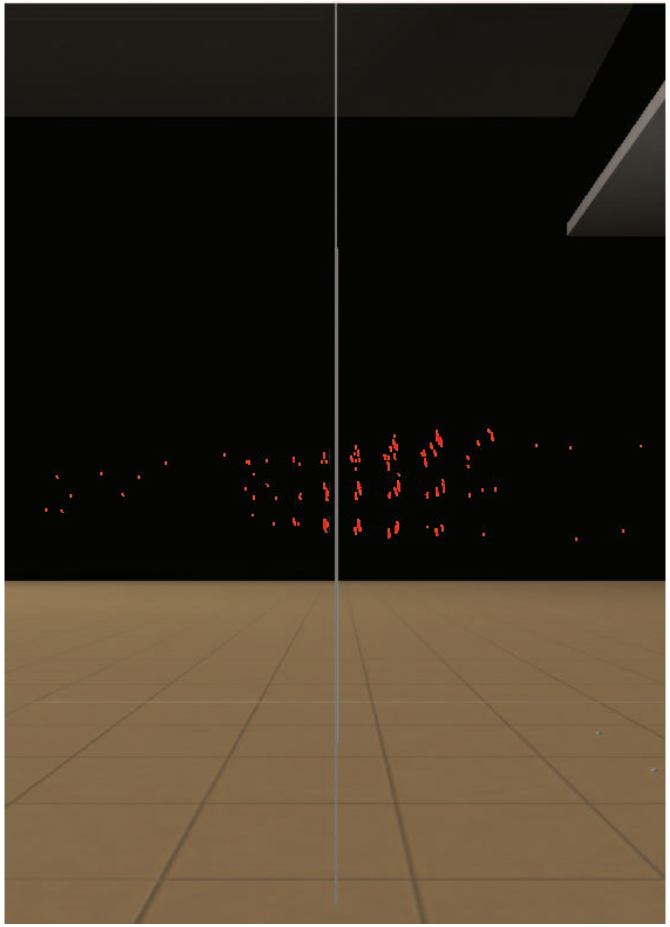
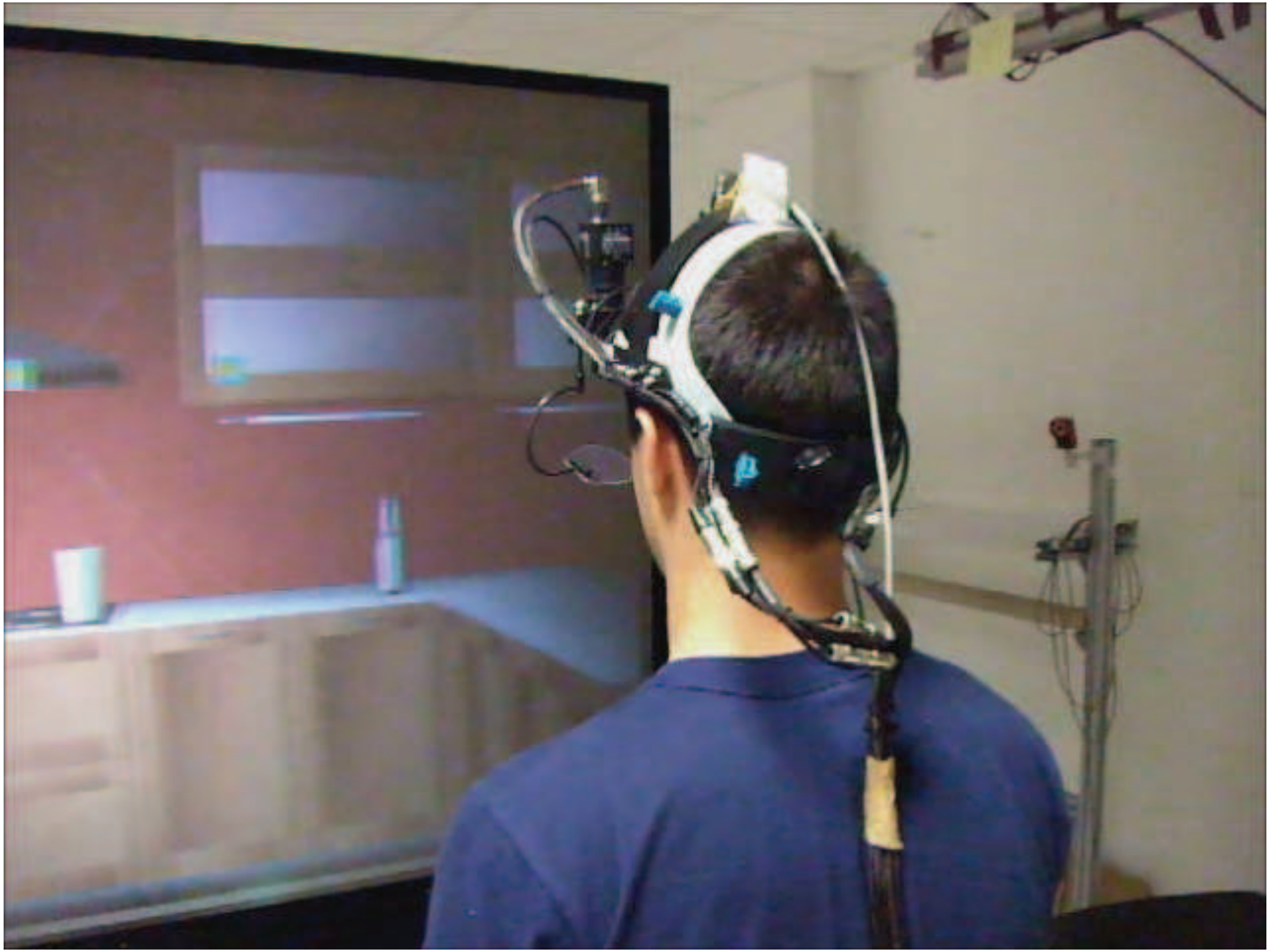




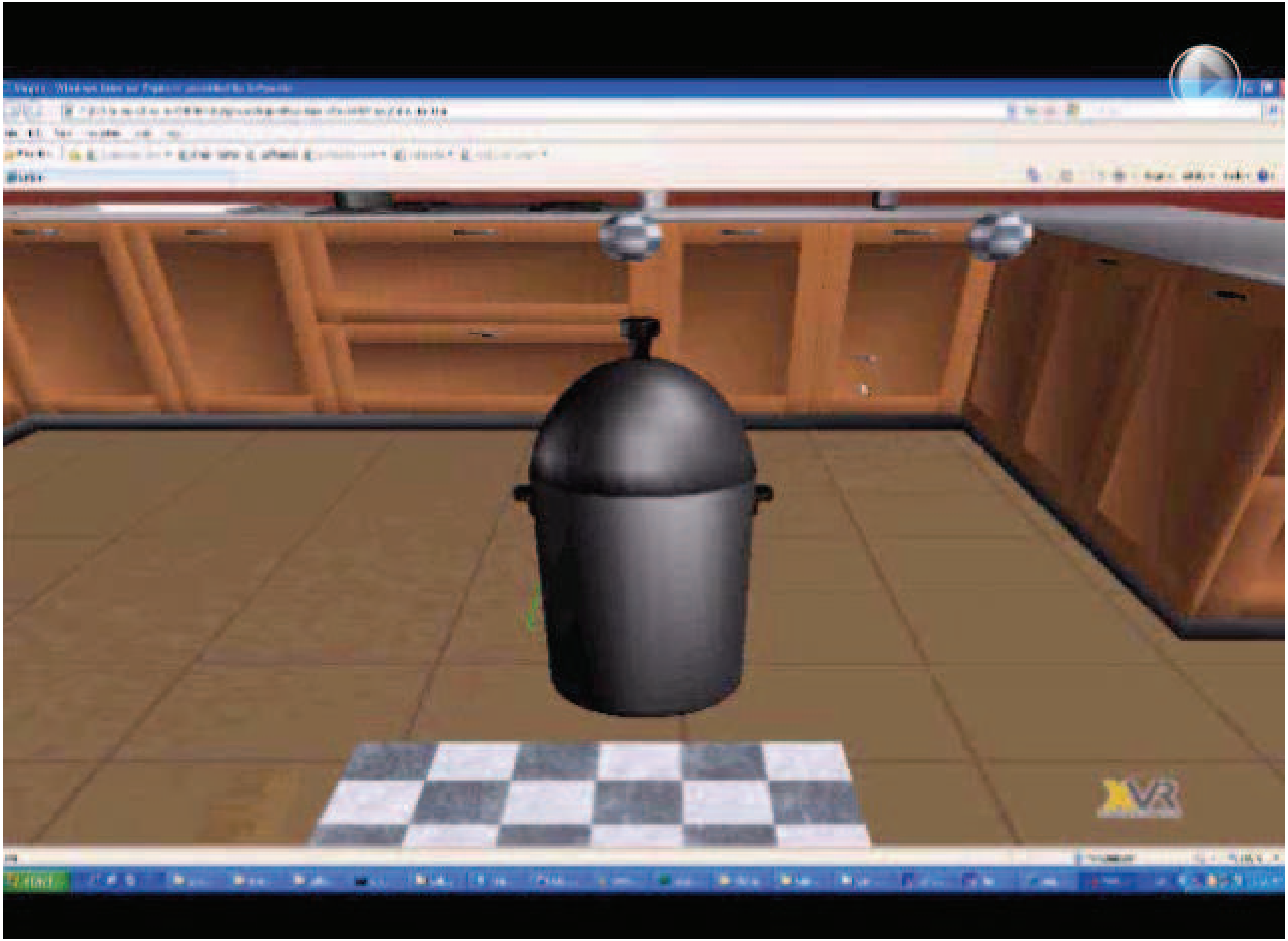
Selection of virtual objects: by gaze



Selection of virtual objects by head movements

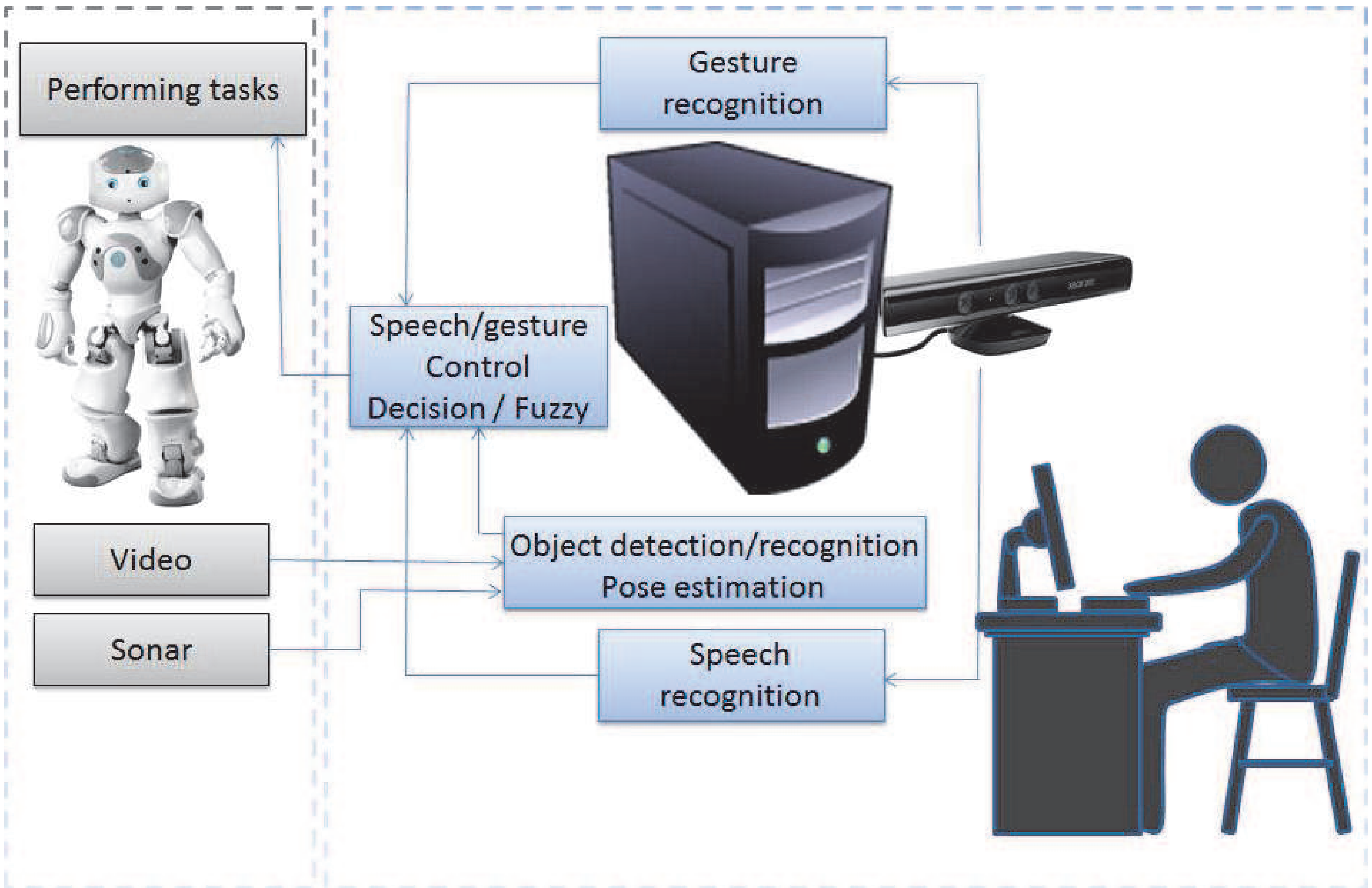
3D Puzzle by Optical Finger Tracking

Ambient assisting living application

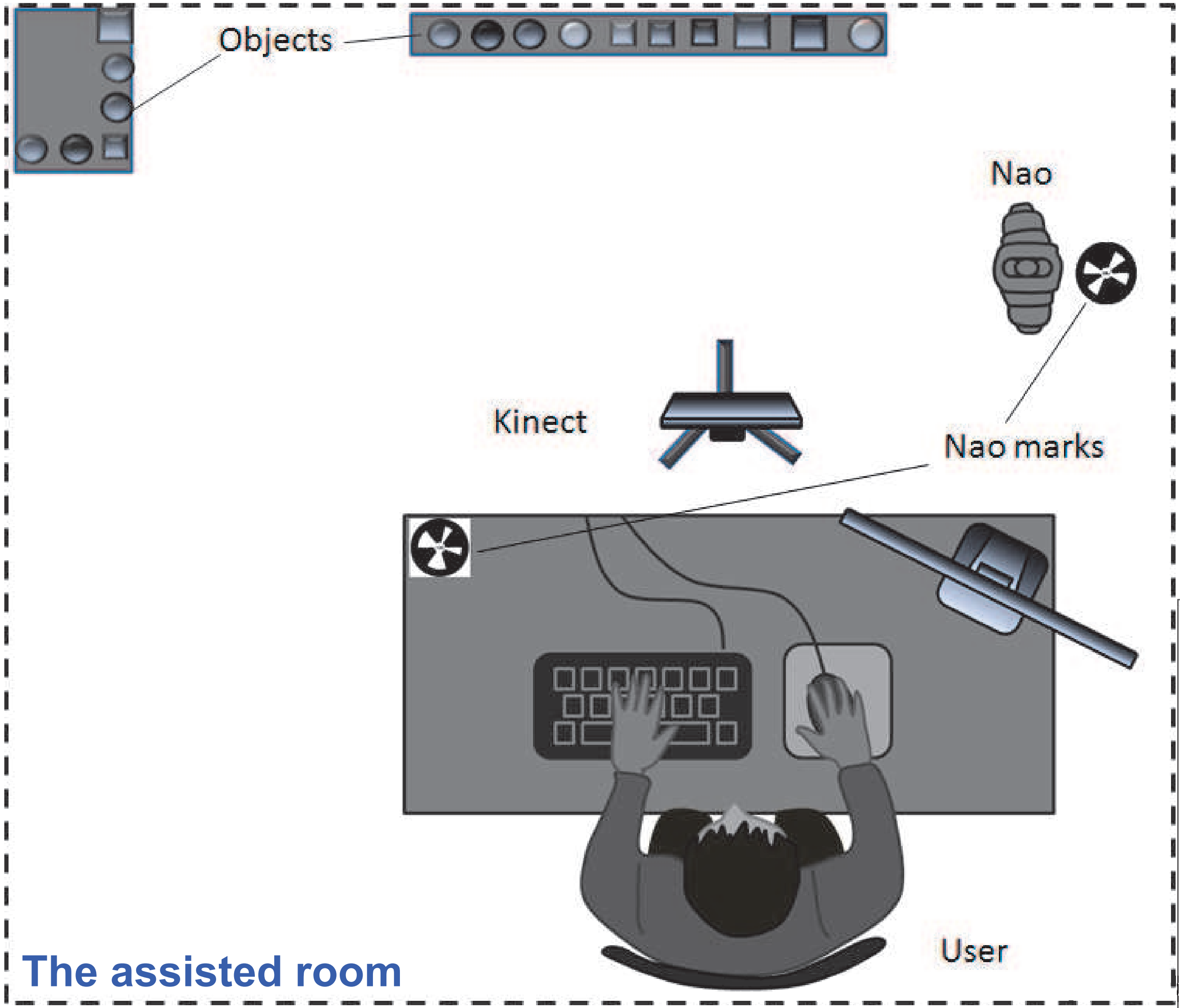


“Point and command” interaction metaphor for AAL

- Multi-modal input for Assistive humanoid robots
- Modalities involved: speech, tracking (kinect) and natural gesture
- Goal: Natural interaction with a robot-assistant in home/office environment



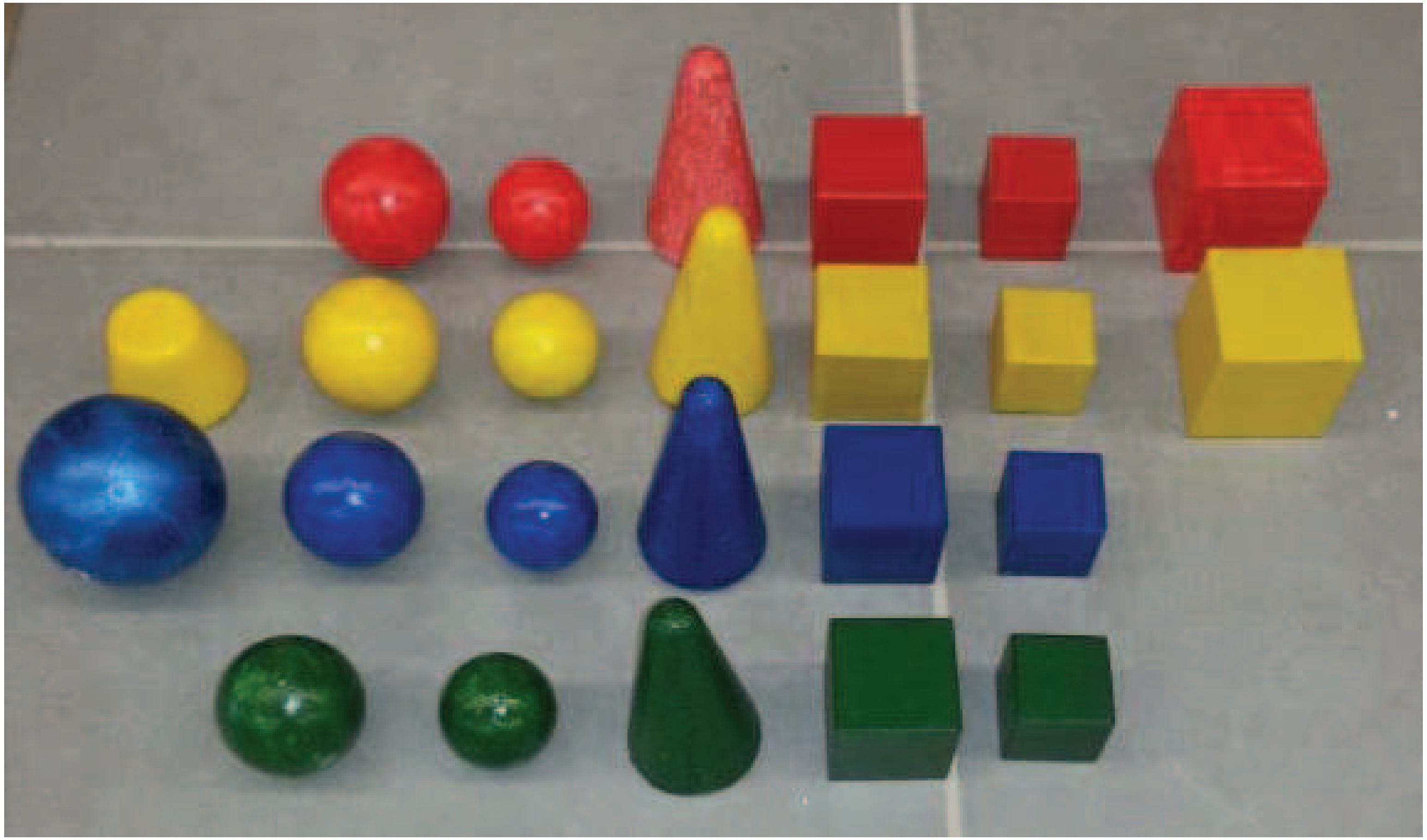
Layout of the room



Robot communication: voice and gestures

Behaviors like « shruged » or « confused »

Objects used for experiment



NAO searching for the red ball

NAO grabbing the ball

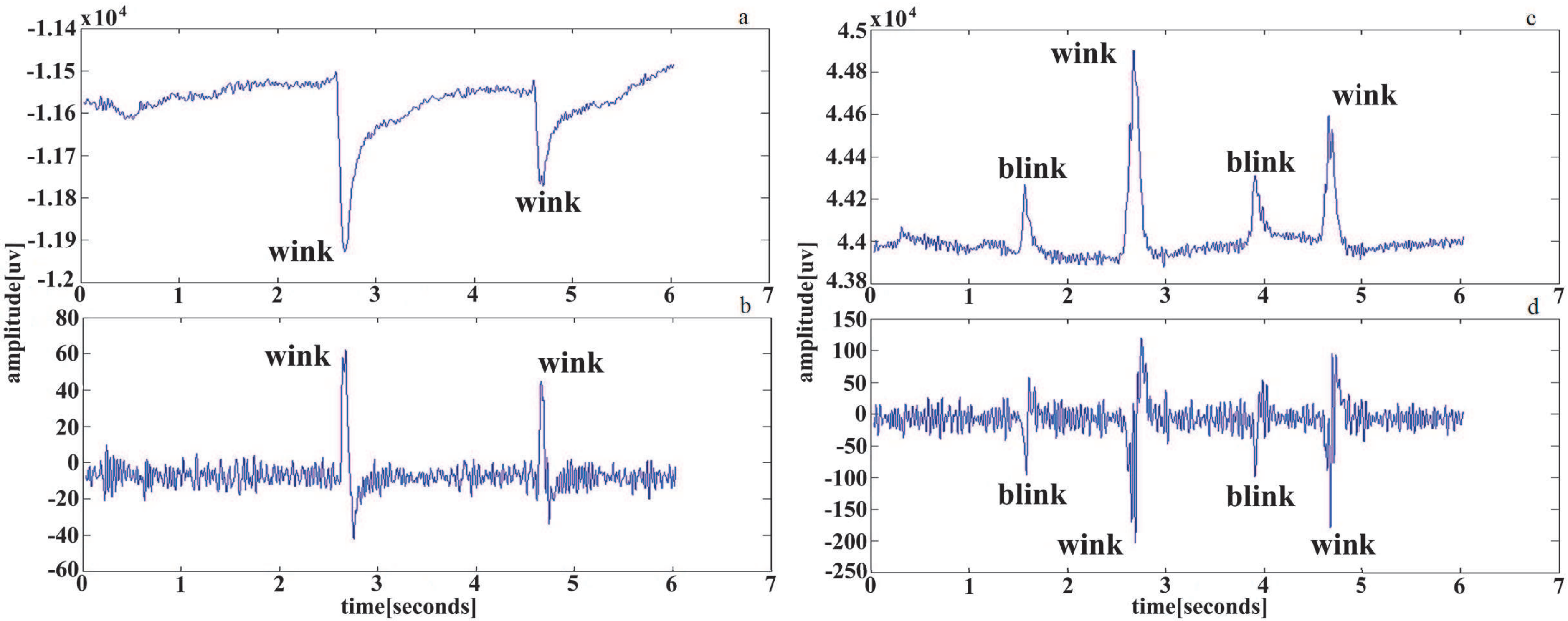
Nao brings the ball

Gaze tracking by ElectroOculoGraphy (EOG)

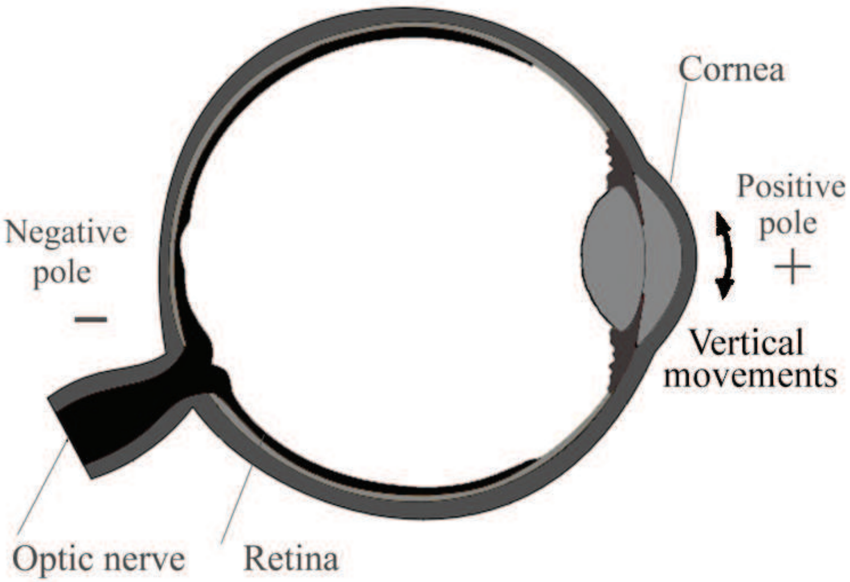
EOG

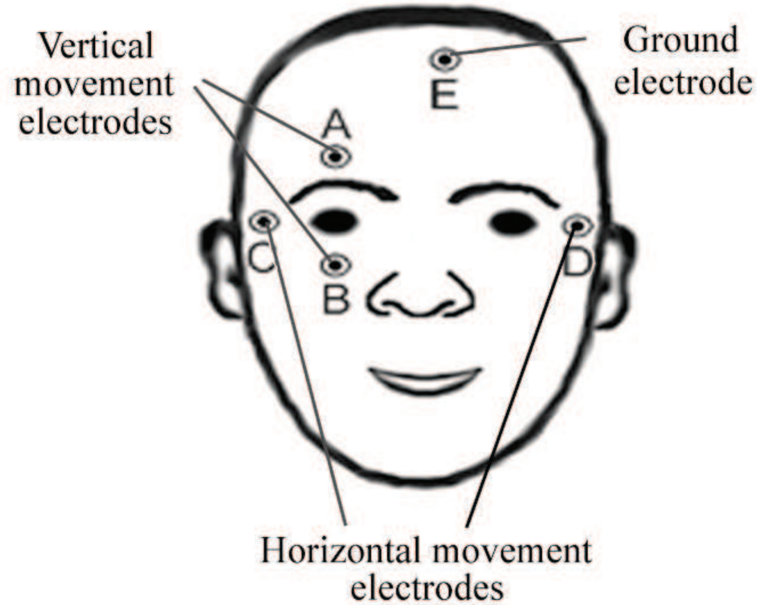
- EOG=measuring the resting potential of the retina by electrodes (Deng et al., 2010; Lv et al., 2010).
- The human eye can be seen as an electrical dipole:
  - positive pole =cornea
  - negative pole at the retina
- By measuring the voltage in reference positions around the eyes, → the electric signal varies as the eye-movement changes (Barea et al., 2002a; Venkataraman et al., 2005).

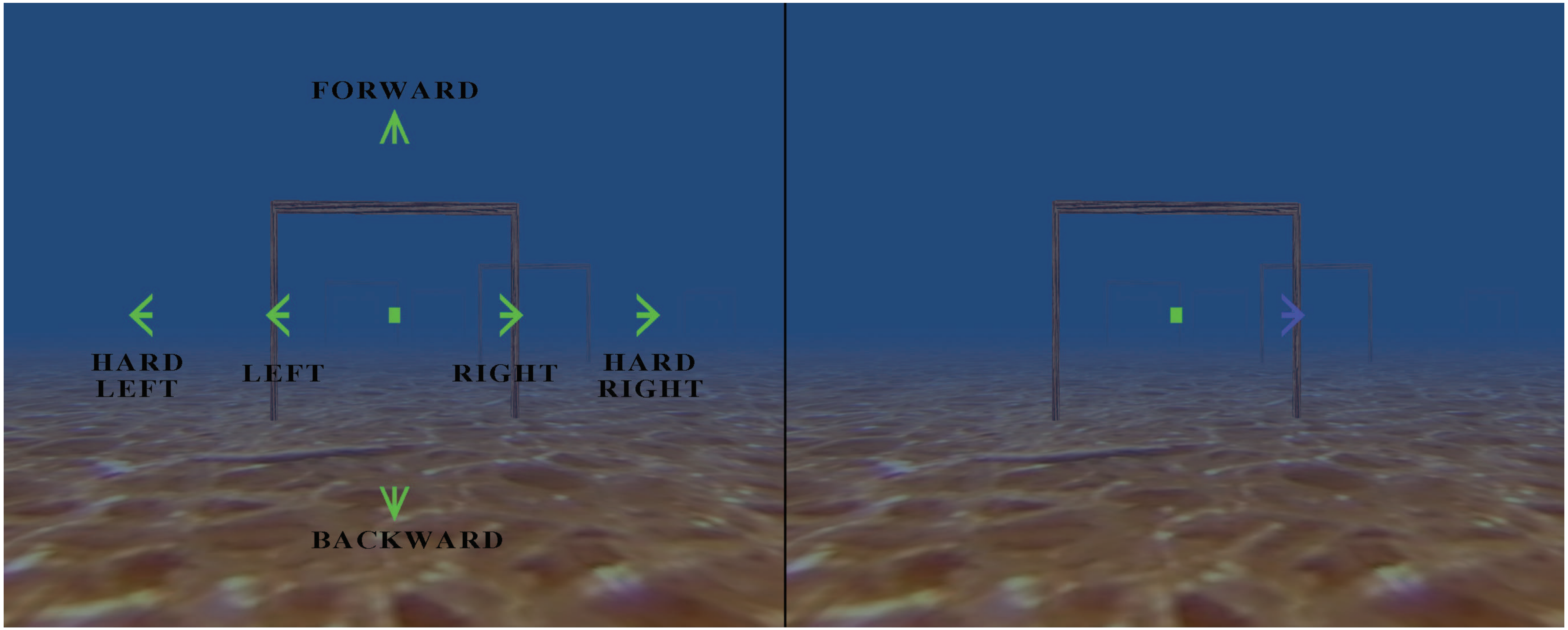
Based on feature identification



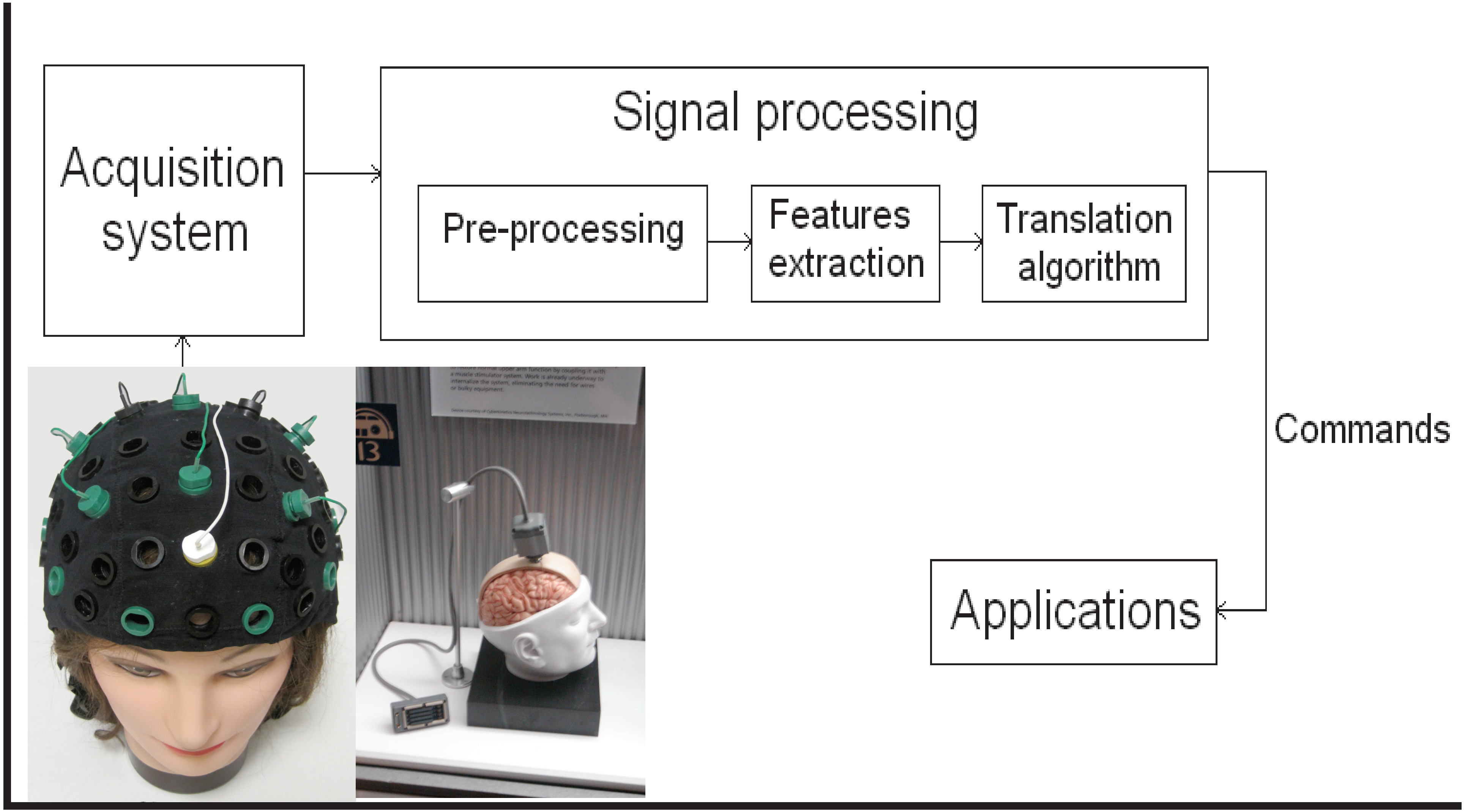
Postelnicu C., Girbacia F., Talaba D., 2012


Cornea
Positive pole
+
Negative pole
−
Vertical movements
Optic nerve
Retina


Vertical movement electrodes
Ground electrode
A
B
C
D
E
Horizontal movement electrodes


FORWARD
HARD LEFT
LEFT
RIGHT
HARD RIGHT
BACKWARD

From brain to Computer: bio-signals tracking with BCI



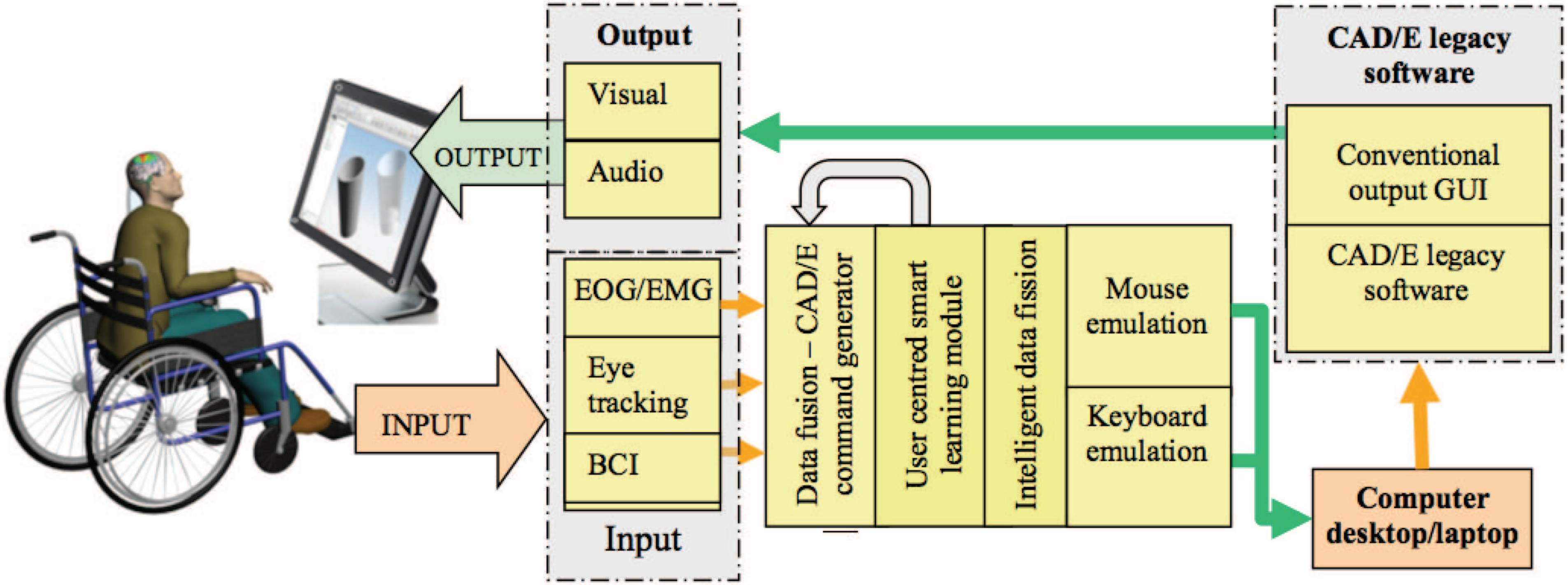
Project: THINK

(Ongoing project, 2014 - 2017)

Interface between human brain and computer to explore "just-by-**THINK**ing" Computer Aided Design and Engineering

- brings research to the very edge of HCI/BCI, focusing on the concept "just by thinking"
- extremely limited voluntary muscle movement to be considered (just the eyes muscles).
- *The holistic solution proposed in this project is targeting the needs of people that cannot move at all.*

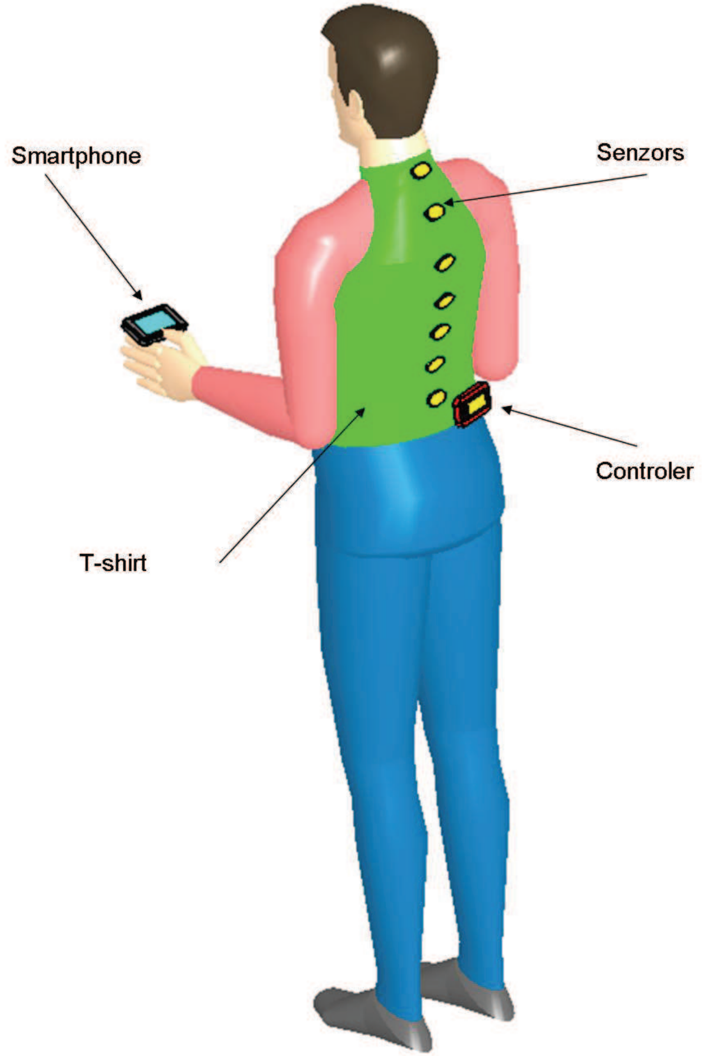
Concept and methodology



INPUT from wearable devices, sensor and intelligent "Things"

- A ICT branch of research of which Virtual Reality and Robotics is taking unlimited benefits

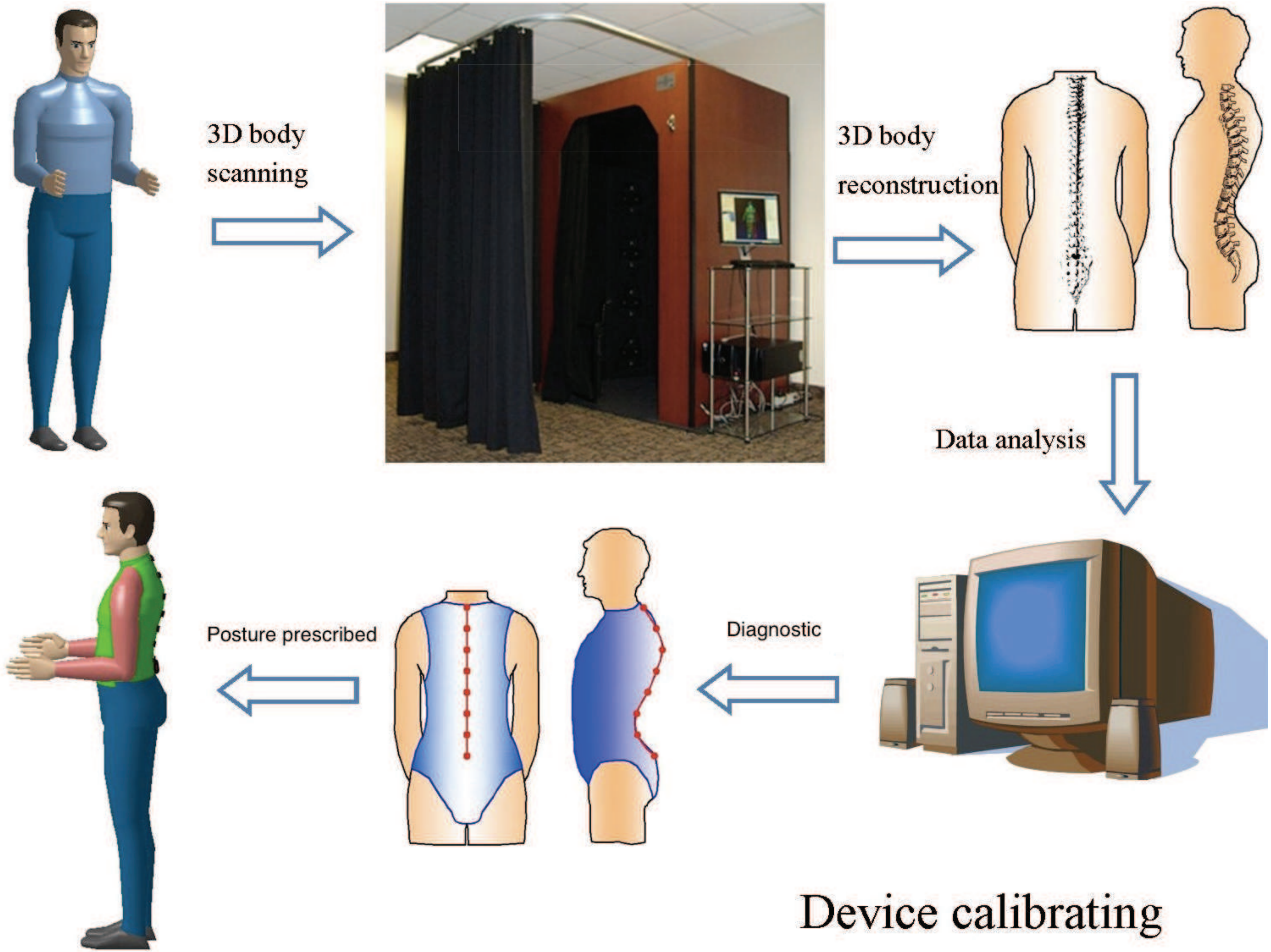
Project “Spine”



Project “SPINE”

(Ongoing project, 2014 - 2017)

Intelligent clothes


3D body
scanning
3D body
reconstruction
Data analysis
Diagnostic
Posture prescribed
Device calibrating

Control of posture – similar principles as for haptics

- Not always final posture could be prescribed from the first time – a transition between initial and final posture could be prescribed in a multi-phase treatment, which is case-dependent;
- Should be done by a specialized software application, based on a "medical prescription". The prescribed "therapy" may consider progress parameters, measured continuously.
- Another possible prescription → posture disturbances - forcing limit postures – thus improving control capabilities
- Disturbances could be designed to create useful "after effects".

Prevent and cure

- Healthy ageing: detection of pre-disposition before it is too late
- Efficient treatment → avoid systematically harmful postures, stimulate therapeutic ones
- Information communication between the doctor and patient system: progress monitoring, multi-phase treatments, etc.

Conclusions

- Most of the VR Output modalities (3D visual, haptic and audio) – already technology
- Input modalities development is the new focus in Virtual Reality
- Challenging issues related to the human behavior
- Interdisciplinary research: Mechanical & Cognition & IT & Electronics etc

Thank you !

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