

# Haptics in Collaborative Environments

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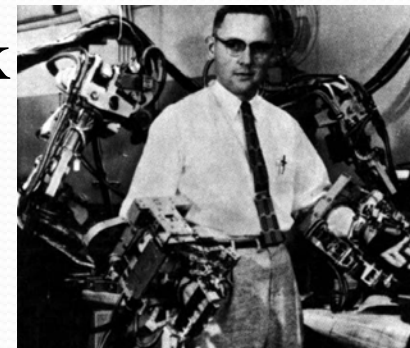
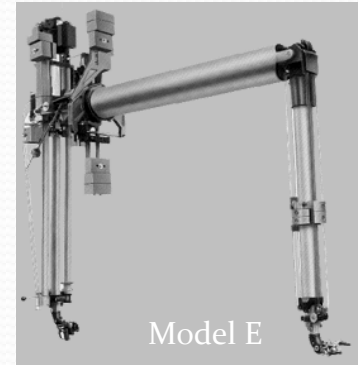
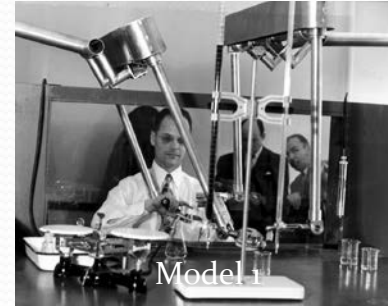
Univ. Paris-Sud / LIMSI-CNRS, France

# Contents

- What is haptics ?
- Physiology of haptics
- Haptic devices
- Haptic interaction with real environments
- Haptic interaction with virtual environments
- Haptic interaction with collaborative environments
- Haptic interaction in affective communication

# Story of Haptics

- 1945: 1st master-slave system
  - Based on a mechanical link
  - Manipulation of radioactive materials
  - Ray Goertz : Argonne National Lab (USA)
- 1954: Introduction of electromechanical actuators
  - Argonne National Lab (USA)
- 1958: 1st exoskeleton system with force feedback
  - Handyman
  - Ralph Mosher : General Electric (USA)



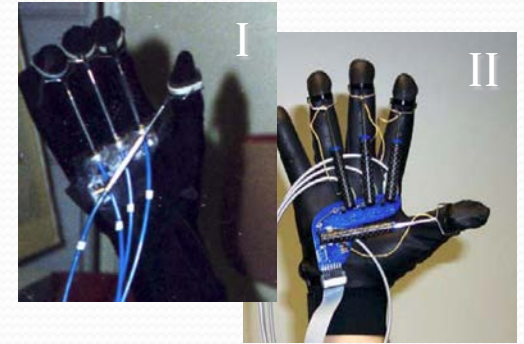
# Story of Haptics

- 70's: work of Frederick Brooks on haptic feedback
  - Projects: GROPE I, II and III
    - Beginning of the 1st Project: 1967
  - Univ. of North Carolina at Chapel Hill (USA)
  - Application: Molecular Docking
  - Development of a haptic interface
    - Manipulation and interaction with molecules
    - Perception of physics of the nano-world
    - GROPE I: 2DoF interface
    - GROPE II & III: 6DoF interface
      - Based on the « Argonne Remote Manipulator »



# Story of Haptics

- 1991 Rutgers Masters I
  - Work of Grigore Burdea
- 1993 Development of the « PHANToM » interface
  - MIT Artificial Intelligence Laboratory
    - Marketing : Sensable
- 2001 Launch of « HAPTION »
  - CEA Startup



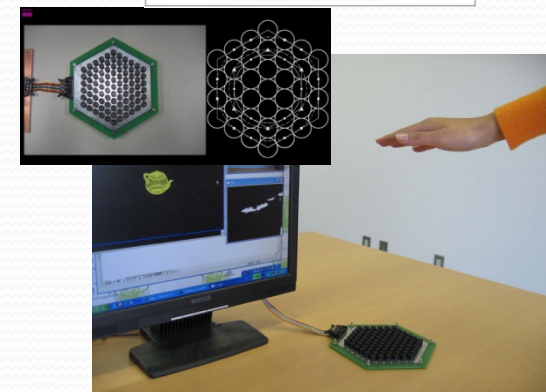
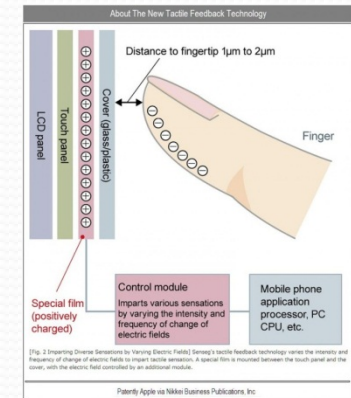
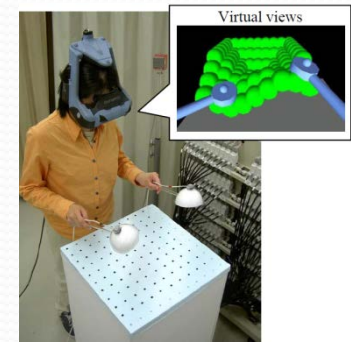
# Story of Haptics

- 1998 Launch of Desktop de Sensable
  - ~ 17 000 euro
- 2004 Launch of Omni de Sensable
  - ~ 1700 euro
- 2007 Launch of Novint of Falcon
  - ~ 150 euro
  - For video games



# Story of Haptics

- 2003: « Arrayed Air Jet Based Haptic Display »
  - Cyber Space Laboratory (Japan)
  - Air jet actuators coupled with an effector
- 2008: Senseg « E-Sense »
  - Texture Sensory Interface
  - Electrostatic stimulation
  - Surfaces: smartphone, tablet, etc.
- 2008 : « Airborne Ultrasound Tactile Display »
  - Univ. Tokyo (Japan)
  - Based on ultrasound transducers



# Story of Haptics

- 2009: Multiplatform Haptic API
  - REACHIN API/ HAPTX
  - Reachin
  - Sensable, Haption, Novint, etc.



# Haptic companies

## Europe

- **Haption**, France  
<http://www.haption.com>
- **DIDHAPTIC**, France  
<http://www.didhaptic.com>
- **Ergos Technologies**, France  
<http://www.ergos-technologies.com>
- **Force Dimension**, Switzerland  
<http://www.forcedimension.com>
- **MOOG**, The Netherland  
<http://www.moog.com/>
- **REACHIN**, Sweden  
<http://www.reachin.se>
- **Senseg**, Finland  
<http://www.senseg.com>
- **UK HAPTICS**, UK  
<http://www.ukhaptics.co.uk>
- **HiWave**, UK  
<http://www.hi-wave.com>

## USA

- **SensAble Technologies**  
<http://www.sensable.com>
- **Immersion**  
<http://www.immersion.com>
- **Novint Technologies**  
<http://home.novint.com>
- **Precision Microdrives**  
<http://www.precisionmicrodrives.com>
- **Atmel**  
<http://www2.atmel.com>

## Canada

- **Tactile Labs**  
<http://www.tactilelabs.com>

# Haptic organizations

- **The IEEE Technical Committee on Haptics**  
<http://www.worldhaptics.org>
- **The EuroHaptics Society**  
<http://www.eurohaptics.org>
- **The EuroVR Special Interest Group on Haptics**  
<http://hapticsig.org>
- **The Korea Haptics Community**  
<http://www.haptics.or.kr>
- **The International Society for Haptics**  
<http://www.isfh.org>

# Haptics conferences and journals

- **Conferences**

- EuroHaptics conference
- Worldhaptics conference
- Haptics Symposium
- IEEE International Symposium on Haptic Audio Visual Environments and Games (HAVE)
- International Workshop on Haptic and Audio Interaction Design (HAID)
- ACM CHI, IEEE ICRA, IEEE IROS,...

- **Journals**

- The IEEE Transactions on Haptics (ToH)
- The Electronic Journal of Haptics Research (Haptics-e)
- The ACM Transactions on Applied Perception (ACM TAP)
- The IEEE Transactions on Visualization and Computer Graphics (TVCG)
- ACM ToCHI, IEEE ToR,...



# Definitions

# Haptics

- The term haptic comes from the greek word “haptein” which means touch.
- It was introduced in the late 19th century by an Austrian historian of art “**Riegl**” (Haptik)
  - “Art progresses by revealing a world of sensitivity from the haptic to the optic”.
- In psychology of perception, the term "haptic" comes from “**James Gibson**” in 1966
  - American psychologist who proposed in the 1970s a "revolutionary" theory of human perception.
- The term was used by “**Gilles Deleuze**” in 1989
  - In Virtual Reality literature widely read on the American Campus
  - Scientists was inspired by the literature of Gilles Deleuze and integrate this word in scientific vocabulary.
- Haptic: "The scientific study of touch" ©Larousse: Psychophysics, technologies, applications, etc.



# Hand functions

# Hand functions

- Hand (haptic and gestural channels) has three different, complementary and overlapping functions :
  - Epistemic function: using the hand as an organ of perception through the haptic sense
  - Ergotic function : corresponds to the use of the hand as an organ of action on the environment
  - Semiotic functions: communication of information

# Epistemic function

- Active mode
  - Perception is the result of an action
  - The perception of information physically alter its support

# Epistemic function

- Haptic exploration of objects involves two procedures :
  1. First, non-specialized procedures :
    - Exploration of the envelope
    - Involves the whole hand
    - Provides approximate information on several properties
    - Gives an overall knowledge about manipulated objects
  2. Then, specific procedures :
    - Skin friction is adapted to textures
    - Lifting is suitable for the weight
    - Pressure is adapted to the hardness of the material
    - The static contact gives information about the temperature
      - Also some knowledge on the shape, size, texture and hardness
    - Tracking the contours gives a precise knowledge about the shape and the size
      - Also some knowledge on the texture and hardness of the objects
- For example, for shapes, we begin with the perception of the envelope, then tracking the contours

# Specialization of Haptics

- Functional specialization of modalities: each modality is efficient for the processing and the perception of specific features and is less effective for others:
  - Visual modality : spatial analysis
    - Spatial integration of the signal
  - Auditory modality : frequency analysis
  - Haptic modality : local analysis
    - The haptic modality is very efficient for the perception of material properties of objects: texture (roughness, hardness, elasticity, porosity), stiffness, etc.
    - Touch is not specialized in spatial perception, vision is more efficient
      - The perception of geometry requires coordinated movements over time
        - Temporal integration of the signal
        - Limitations of Haptic memory
    - Haptic modality completes the other modalities

# Specialization of Haptics

	Processing capabilities bits/sec	acuity
• Haptic (Finger)	$10^2$	5 ms
• Hearing	$10^4$	0.01 ms
• Sight	$10^6 \sim 10^9$	25 ms

# Ergotic function

- The haptic mode is used to control movements and actions
- Sensorimotor loop
  - A strong coupling
    - Action depends on the haptic perception
    - Haptic perception depends on the action
  - The action-perception time loop (gesture / haptic) is a smaller than that of visual or hearing channel

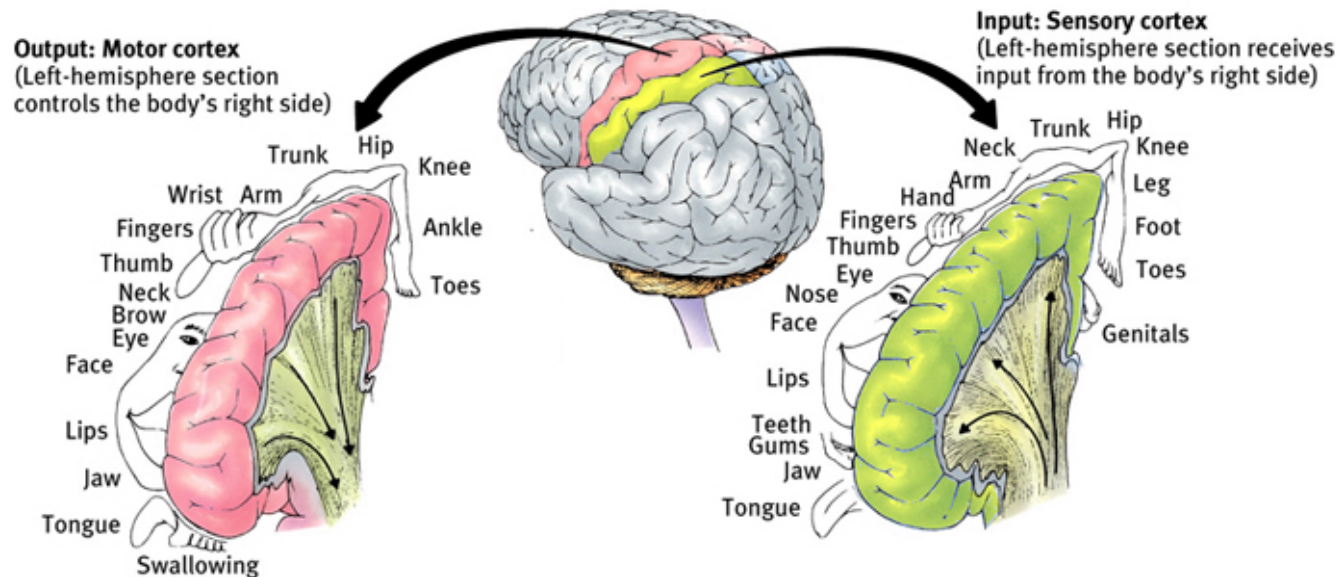
# Physiology of Haptic



Motor Homunculus

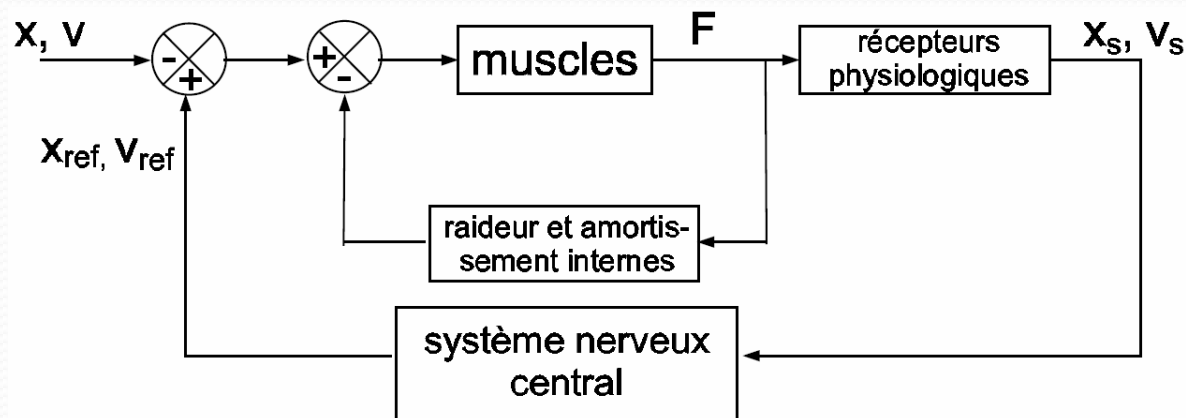


Sensory Homunculus



# Ergotic function

- The control of a human limb is based on two loops:
  - A fast loop which depends on mechanical features of the member (few hundred Hz)
  - A slow loop of nervous control whose bandwidth is between 1 and 10 Hz depending on the performed task :
    - 2-5 Hz for periodic signals
    - Up to 5 Hz for paths learned
    - About 10 Hz for reflex actions



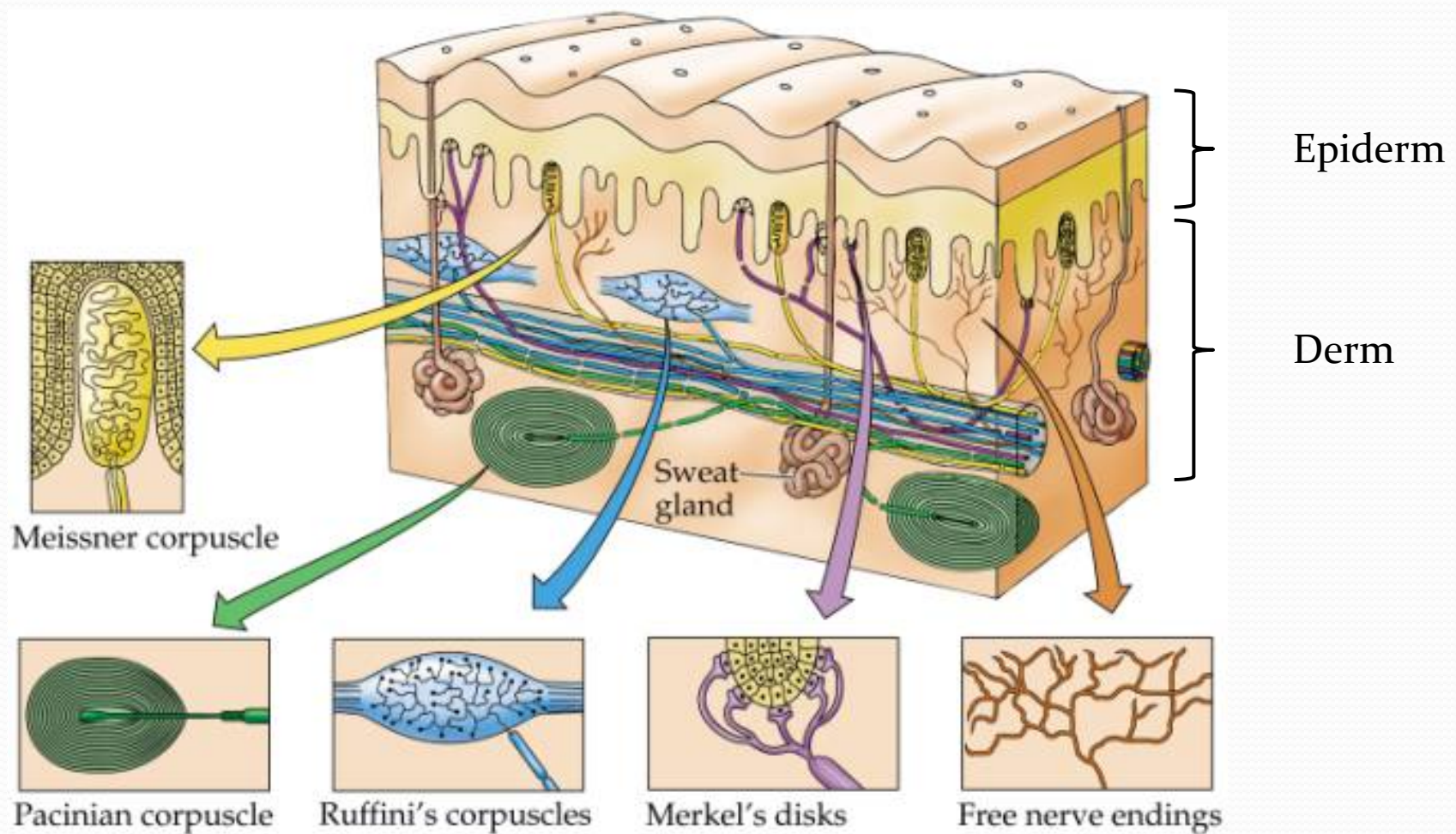
# Physiology of Haptic

- The sense of haptic includes two sensory modalities with undefined psychophysical and physiological borders:
  - Tactile
  - Kinesthesia

# Tactile modality

- Provides skin information on the contact of skin with the environment.
- This mode allows the perception of surface properties of objects :
  - Roughness
  - Shifts
  - edge detection
  - etc.
- We focus more on the spatial distribution force than on the amplitude of the force.







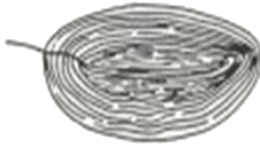

# Physiology of tactile



# Physiology of tactile

- There are five types of sensors depending on the type of stimulus:
  - Nerve endings (nociceptors)
    - Sensitive to pain
  - Mechanoreceptors
    - Meissner corpuscles
      - Bandwidth from 20 to 50 Hz
      - 43% of the tactile receptors of the hand.
      - Surface discontinuities, surface geometry, curvature, speed
    - Merkel discs
      - Bandwidth from 0 to 10 Hz
      - 25% of the receptors of the hand
      - Pressure, texture, vibration
    - Pacinian corpuscles
      - Bandwidth from 70 to 10000 Hz
      - 13% of the receptors of the hand
      - Acceleration, vibrations
    - Ruffini corpuscles
      - Bandwidth from 0 to 10 Hz
      - 19% of the receptors of the hand
      - Intensity and direction of static forces: lateral skin stretching

# Physiology of tactile

Corpuscule de Meissner	Disque de Merkel	Corpuscule de Pacini	Terminaison de Ruffini
			
			
Etroits, bien délimités	Etroits, bien délimités	Etendus, limites floues	Etendus, limites floues
Adaptation rapide	Adaptation lente	Adaptation rapide	Adaptation lente

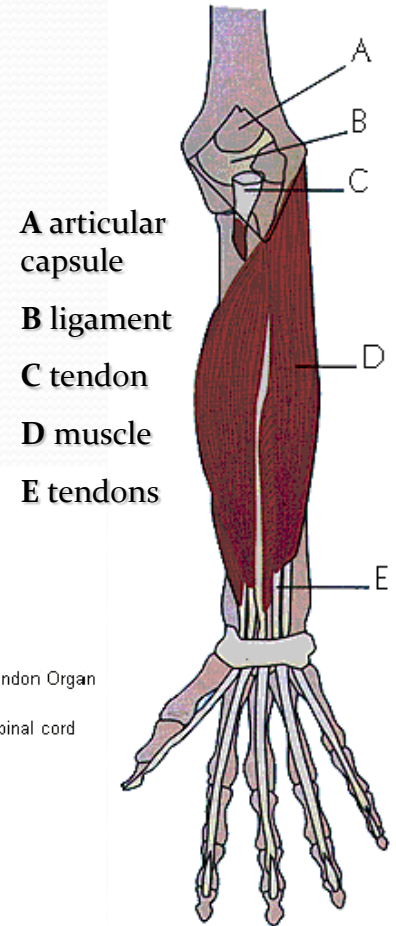
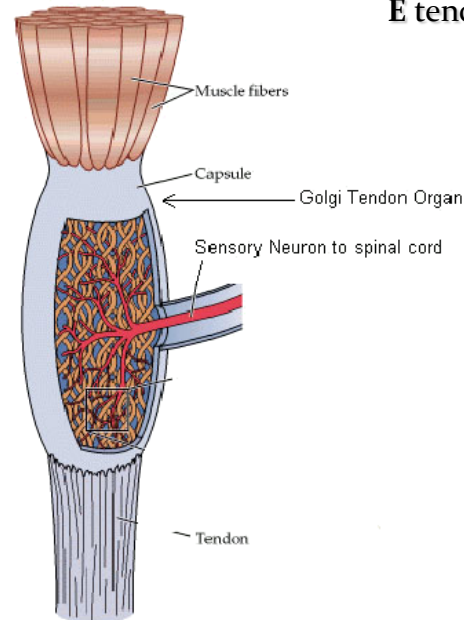
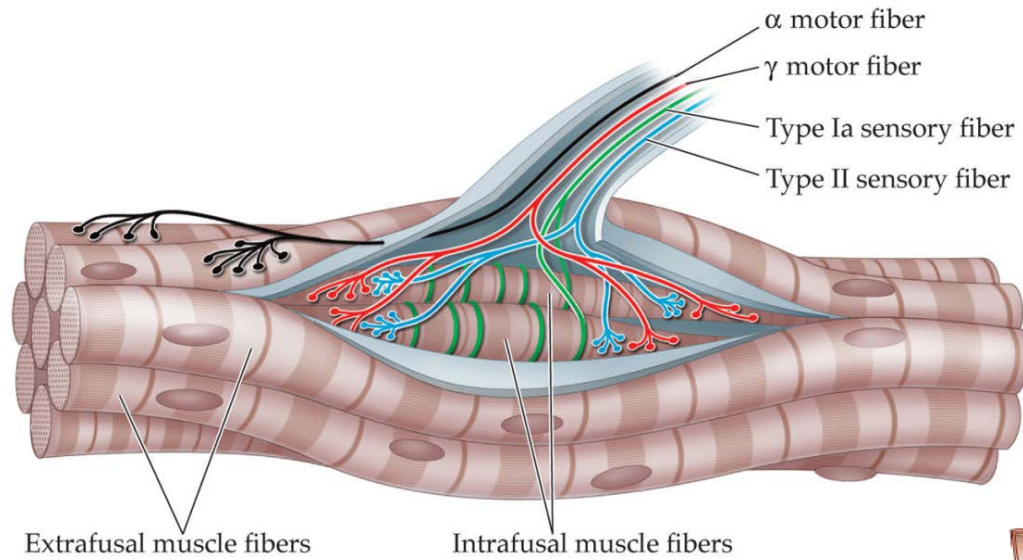
# Physiology of tactile

<b>Feature</b>	<b>Meissner Corpuscles</b>	<b>Pacinian Corpuscles</b>	<b>Merkel's Disks</b>	<b>Ruffini Endings</b>
Rate of adaptation	Rapid	Rapid	Slow	Slow
Location	Superficial dermis	Dermis and subcutaneous	Basal epidermis	Dermis and subcutaneous
Mean receptive area	13 mm <sup>2</sup>	101 mm <sup>2</sup>	11 mm <sup>2</sup>	59 mm <sup>2</sup>
Spatial resolution	Poor	Very poor	Good	Fair
Sensory units	43%	13%	25%	19%
Response frequency range	10 - 200 Hz	70 - 1,000 Hz	0.4 - 100 Hz	0.4 - 100 Hz
Min. threshold frequency	40 Hz	200-250 Hz	50 Hz	50 Hz
Sensitive to temperature	No	Yes	Yes	At > 100 Hz
Spatial summation	Yes	No	No	Unknown
Temporal summation	Yes	No	No	Yes
Physical parameter sensed	Skin curvature, velocity, local shape, flutter, slip	Vibration, slip, acceleration	Skin curvature, local shape, pressure	Skin stretch, local force

# Kinesthetic modality

- Kinesthesia:
  - Perception of the proper motions of our body.
  - Perception of muscular effort.
- This mode supports the perception:
  - Contact forces
  - Hardness of objects
  - Weight of objects
  - Inertia of objects
  - etc.

# Physiology of kinesthetic



# Physiology of kinesthetic

- Kinesthetic sensors are located in:
  - Muscle spindles
    - Located inside the muscle.
    - Their density varies with the type of muscle.
    - The spindles encode the muscle length (II) and the speed of its variations (1a).
    - Muscle fatigue is also involved in the perception of the force.
  - Golgi tendon receptors
    - They are located at the junction between the muscle fibers and tendon tissue.
    - They are sensitive to tension and muscle contraction.
    - They measure the forces and regulate muscle contraction at the same time.
  - Mechanoreceptors are also involved in the perception of kinesthetic feedback
    - The Ruffini corpuscles (slowly adapting): they are inside the joint capsules.
    - The corpuscles of Golgi: they are mainly located in the ligament tissue.
    - Pacinian corpuscles (fast-adapting): are distributed between the accessories tissues of the joints and the joint capsule.
    - They encode movement and extreme joint deflections.

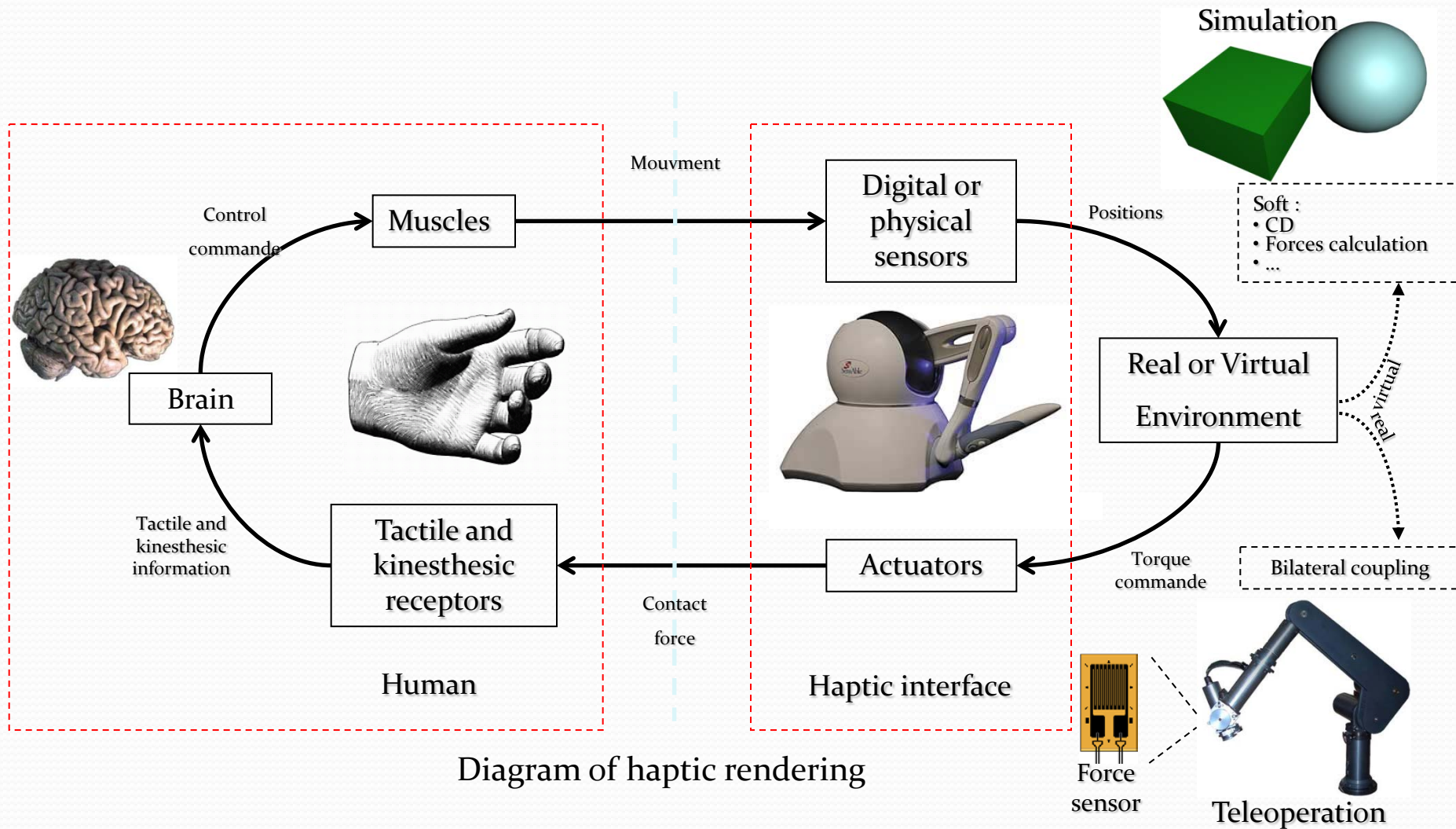
# Passive vs. Active perception

- Based on tactile and kinesthetic modalities, there are two types of haptic perception:
  - Passive or cutaneous perception: It results from the stimulation of a part of the skin while the body segment is immobile,
  - Active or tactile-kinaesthetic perception : It results from the stimulation of the skin resulting from active movements of exploration of the hand into contact with the object.



# Haptic interfaces

# Haptic interfaces



# Haptic interfaces

- Components:
  - Digital or physical sensors
  - Actuators
  - Electronics for Control

# Sensors

- Digital or physical sensors:
  - Position sensors
    - Optical encoders, potentiometers, optical fiber, strain gauges, etc.
  - Force Sensors
    - Strain gauges, capacitor sensors, optical sensors
    - Current measurement
    - Force estimation : based on a physical model

# Actuators

## Force feedback actuators

- Electromagnetic
  - Generates force without movement
  - Difficult to stabilize
- Hydraulic
  - Important force
  - Messy and expensive
- Pneumatic
  - Less dangerous than the hydraulic technology (air is more elastic)
  - Bandwidth smaller than the hydraulic
- Friction
  - Consists to stop/break the movement without creating one (passive technique)
- Motor
  - For a given voltage a torque is generated
  - Impossible to provide the maximum torque for a continuous effort generation=>destruction of the motor

# Actuators

## Tactile feedback actuators

- Vibrotactile
  - Based on electromechanical vibrators
- Array of needles
  - Same system as the devices for reading the braille
- Piezoelectric
  - A stationary wave travels the surface and allows to feel an indentation effect when the finger move on the surface
  - At the scale of the micro-meter
- Shape-memory alloys (SMAs)
  - Alloys having the property to alternate between two forms previously stored when the temperature varies around a critical temperature
- Electro-tactile
  - Stimulate the skin with electrical impulses

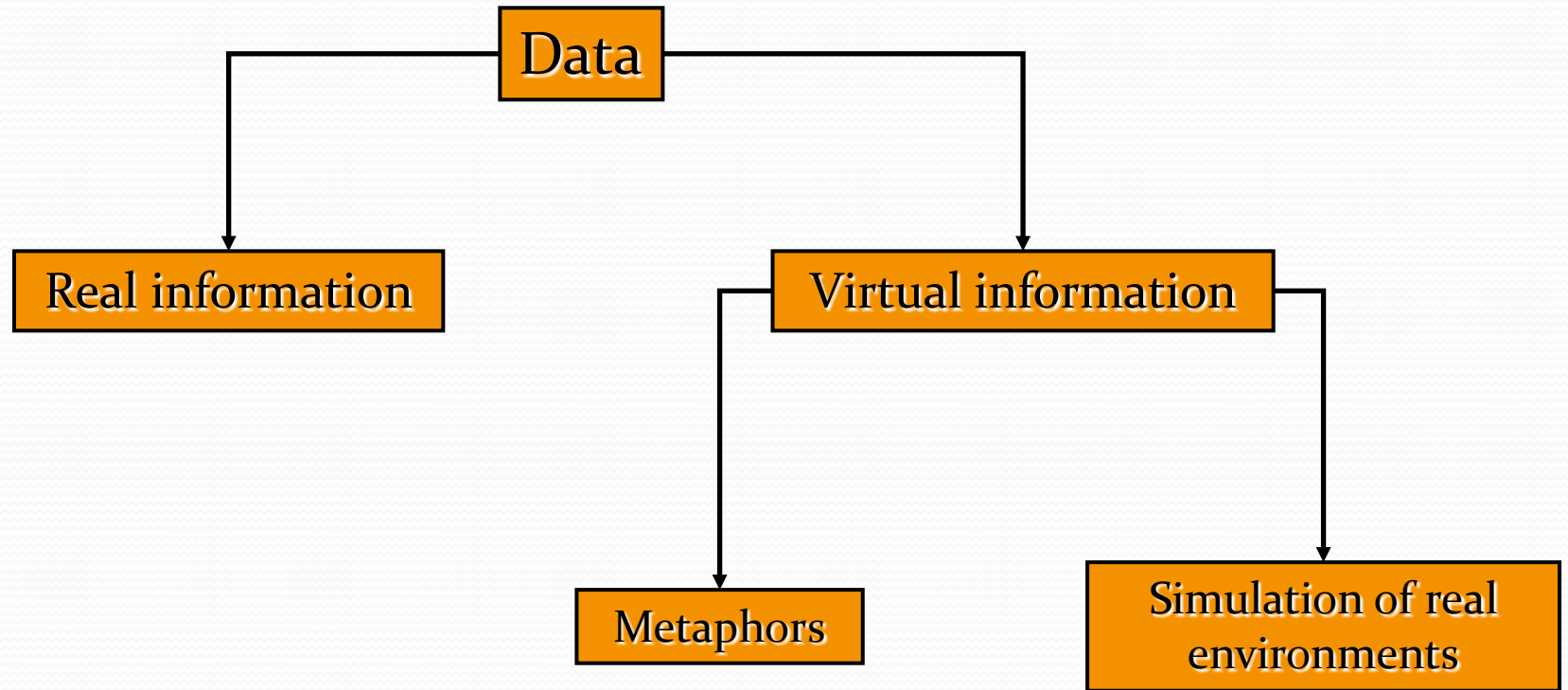
# Features of haptic devices

- Workspace
  - Cinematic architecture of the device: Volume, Shape
- Number of DoF
  - Active & passive
- Nominal resolution of force and positioning
- Bandwidth
  - Mechanics, actuators and control
- Maximum force
  - Instantaneous and continuous
- Supported rendering method
  - Pulse, penalty, etc..
- Features of the mechanical structure
  - Inertia, weight, viscosity, friction, etc..



# Haptic rendering

# Haptic data



# Haptic data

- Real information (or physical)
  - Information based on the use of mechanical sensors:
    - For instance force or position sensors attached to the robot's end-effector
  - This information allows the operator through the ergotic function and corresponding haptic feedback:
    - To perform tasks with more dexterity: Interaction + +
    - To immerse the operator in the task: Immersion + +
  - Different modes of coupling between the control arm (haptic interface) and manipulation arm (remote robot )
    - known as “Master-Slave systems”

# Real information



Master

Slave

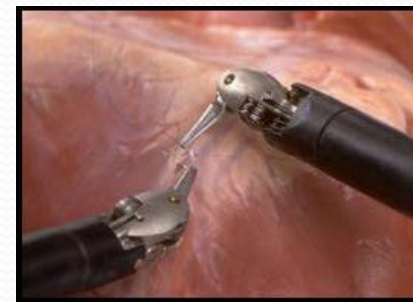


sensors:  
& Forces  
Positions

positions



forces

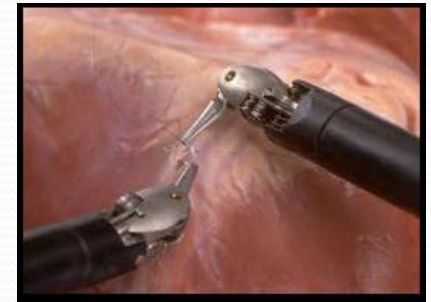
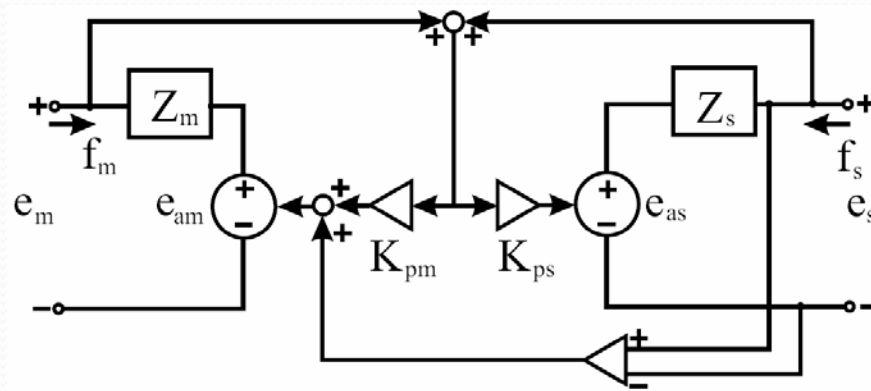


sensors:  
& Forces  
Positions

# Real information



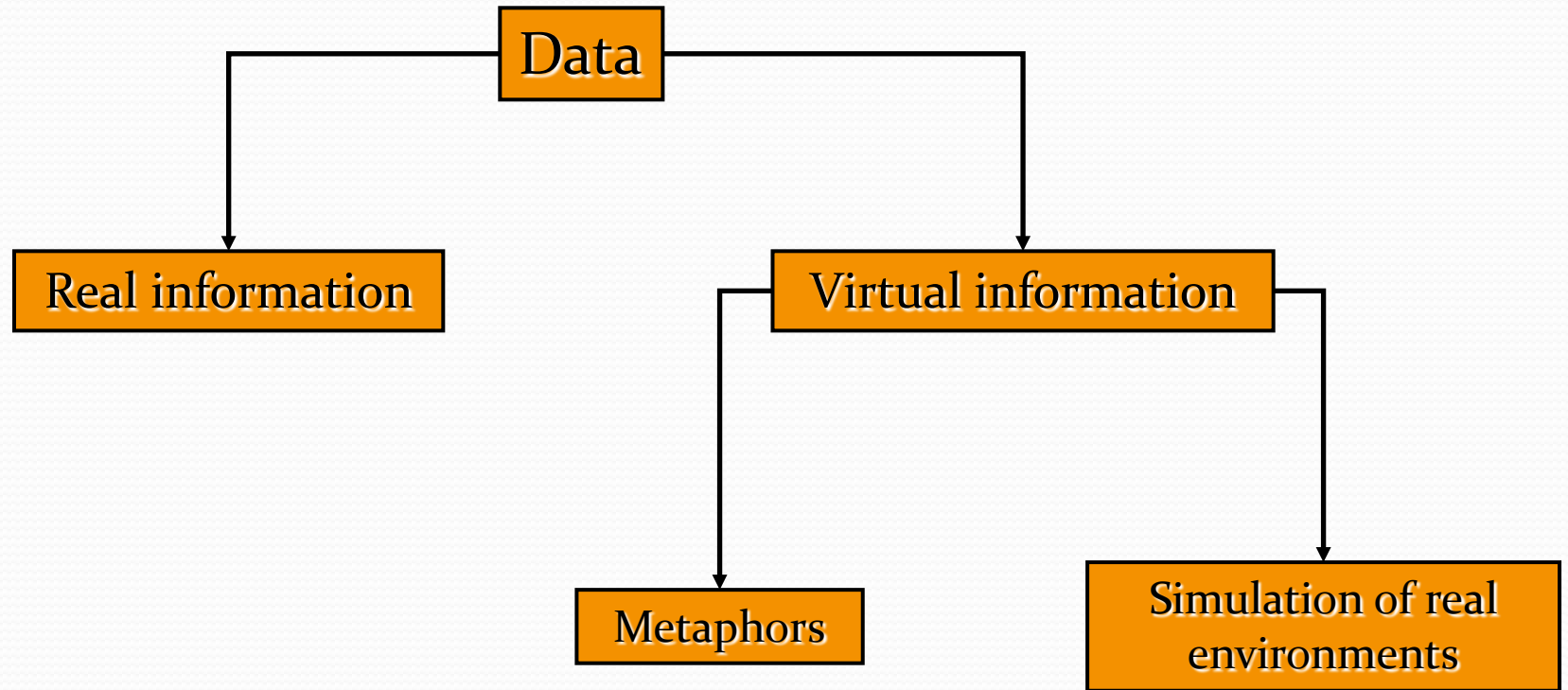
Sensors:  
& Forces  
Positions



Sensors:  
& Forces  
Positions

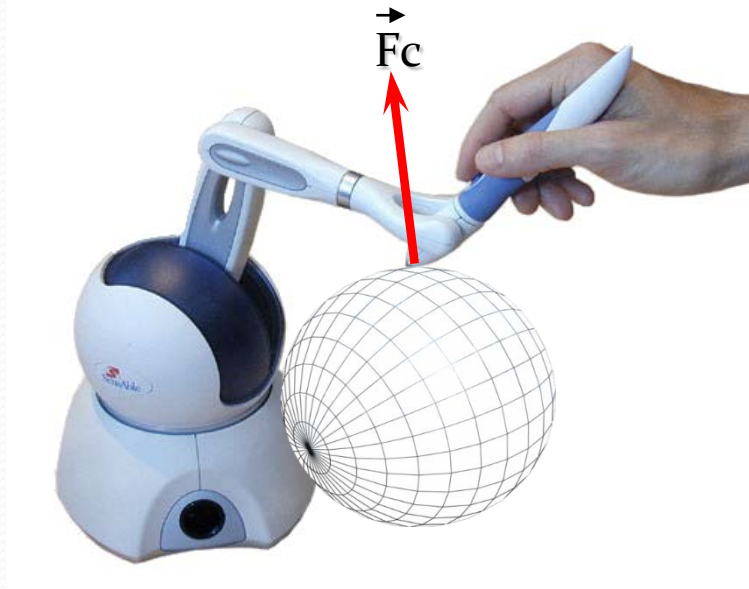
Position and Force Feedback architecture

# Haptic data



# Virtual information

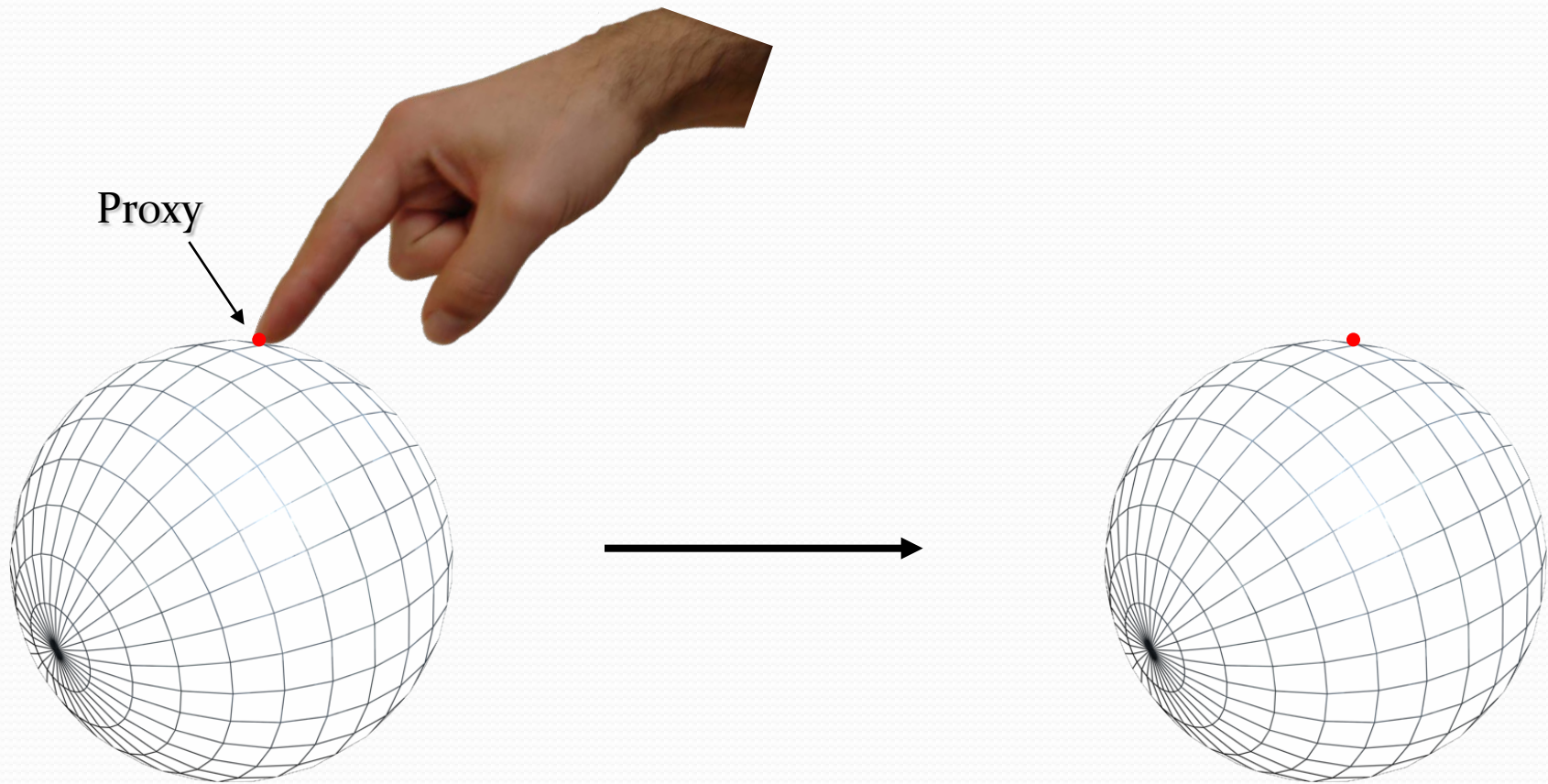
- Simulation of real environments
  - Corresponds to interaction with virtual environments simulating real environments
  - The interaction is similar with the real environment: holding objects, perception of objects, etc.
  - Different levels of modeling => realism of the interaction



# Collision detection

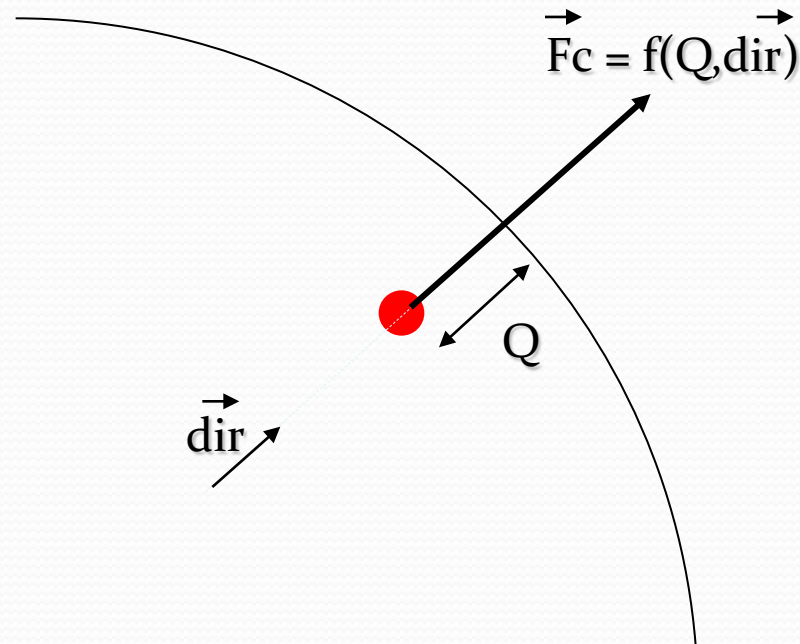
Depends on adopted geometrical model

Approximation of the finger with a Proxy : Point

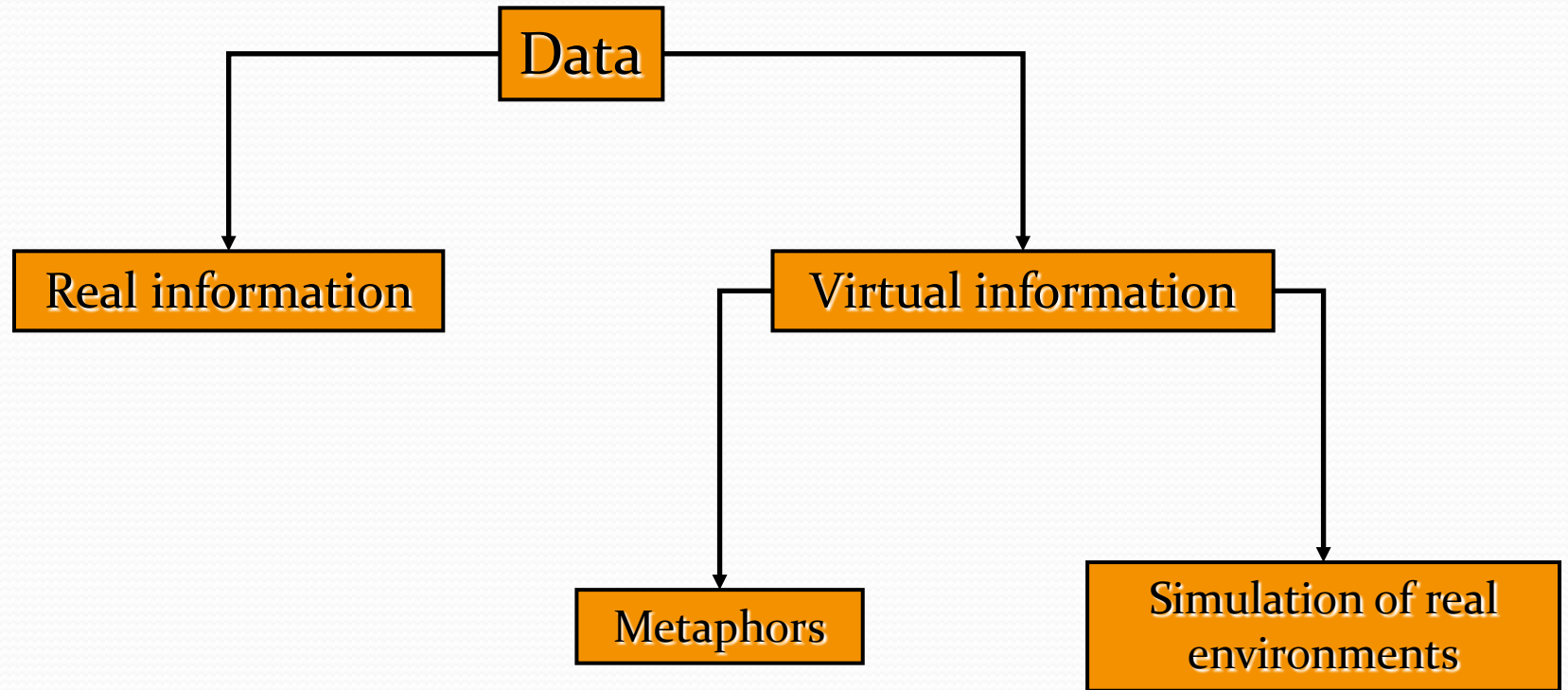


# Collisions responses

- Calculation of the contact force
  - Requires the penetration distance + direction
    - The direction must be orthogonal to the tangent of the nearest point on the surface:
      - The surface normal at this point



# Haptic data



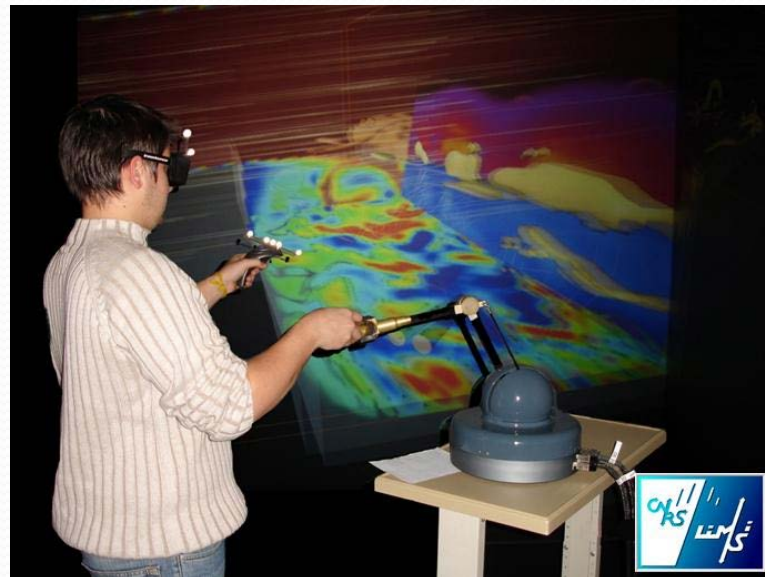
# Virtual information

- Metaphors

- Important contribution of virtual reality in the field of teleoperation assistance, training simulator, manipulation of abstract data, etc.
- They do not have necessarily a direct sense
- Three main categories:
  - Intermediate representation: physical representation of abstract data
  - Sensory substitution: replace visual or auditory feedbacks with haptics
  - Metaphors of assistance: virtual guides or virtual fixtures

# Virtual information

- Intermediate representation
  - Help users to interpret multi-attribute data, to apprehend and understand complex phenomena (shock waves, various streams, etc.).
- Haptic rendering enriches a non-haptic information: distance, radiation



# Virtual information

- Sensory substitution: replace visual or auditory feedback with haptics
  - Complete or replace the visual or sound feedback when they are not sufficient or not available
    - Assistance to the blind



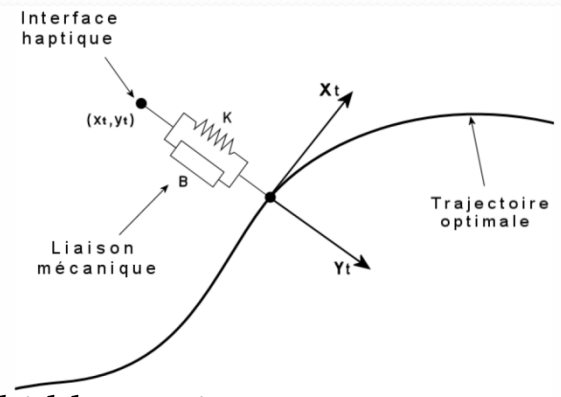
Haptic Radar

# Virtual information

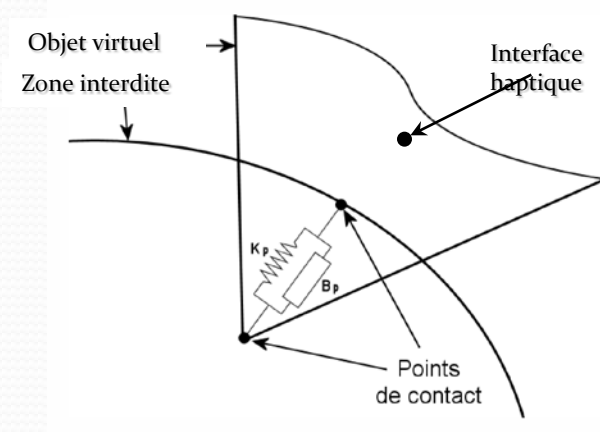
- Metaphors of assistance: virtual guides and virtual fixtures
  - The advantage of these tools is the reduction of the complexity of the tasks
    - The mental effort required by the task is considerably reduced
    - The operator can more easily focus on the gesture or the most critical steps of the task
  - The metaphors correspond to a tool specific to the performed task
  - The metaphors can have abstract shapes and shaped to fit to particular task or a particular need
  - It is possible to combine several metaphors according several strategies to achieve complex tasks

# Virtual information

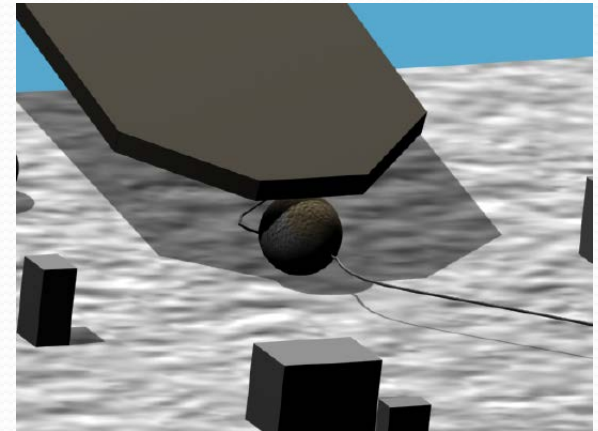
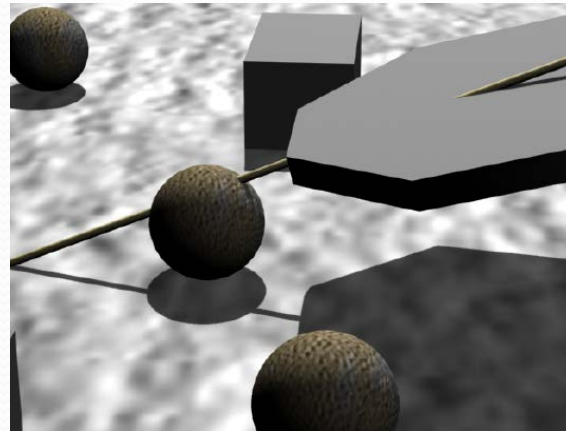
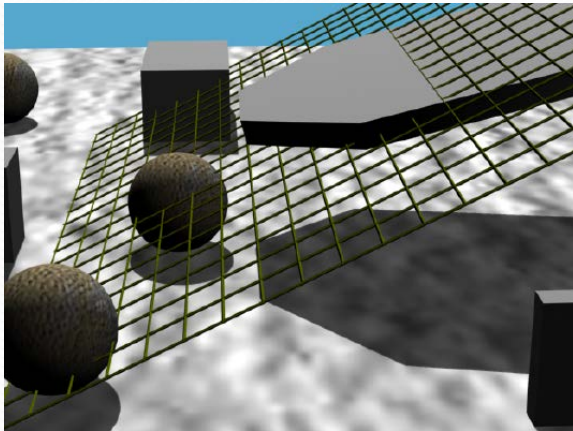
- The virtual guides can also be classified according to their objective
  - Guides that enable following a constraint



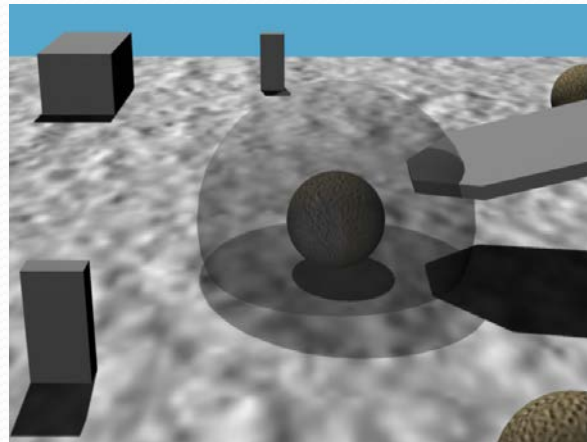
- Guides that enable avoiding forbidden regions



# Virtual information



Active and passive virtual guides : follow constraints



Active and passive virtual guides : avoid of forbidden region



# Haptics and collaborative environments

# Hand functions

- Hand (haptic and gestural channels) has three different, complementary and overlapping functions :
  - Epistemic function: using the hand as an organ of perception through the haptic sense
  - Ergotic function : corresponds to the use of the hand as an organ of action on the environment
  - Semiotic functions: communication of information
    - Gestural communication without contact (deaf and mute, gestures, etc.)
    - **Communication through contact**
      - **Collaborative interaction**
      - **Affective interaction**

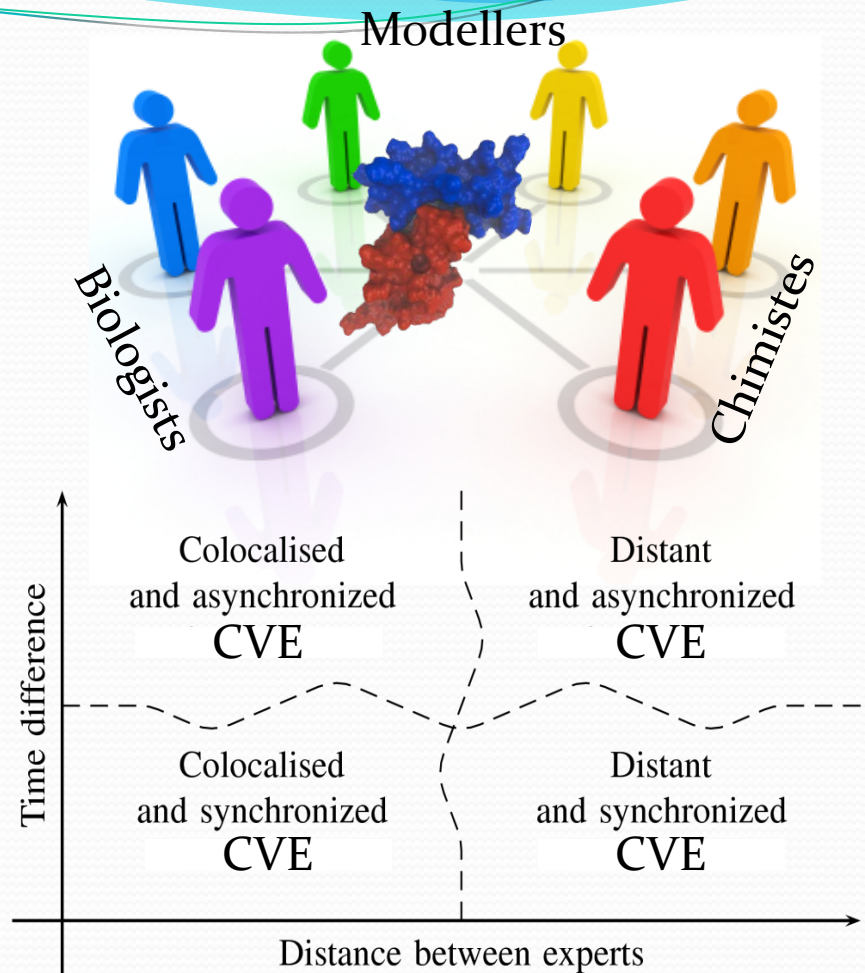
# Collaborative Virtual Environments

- Objectives:
  - Involving experts from several fields
  - Sharing workload between several users
  - Learning and training
  - etc.

- Involved factors:
  - Nature of the task
  - Type of communication
  - Space and time dimensions

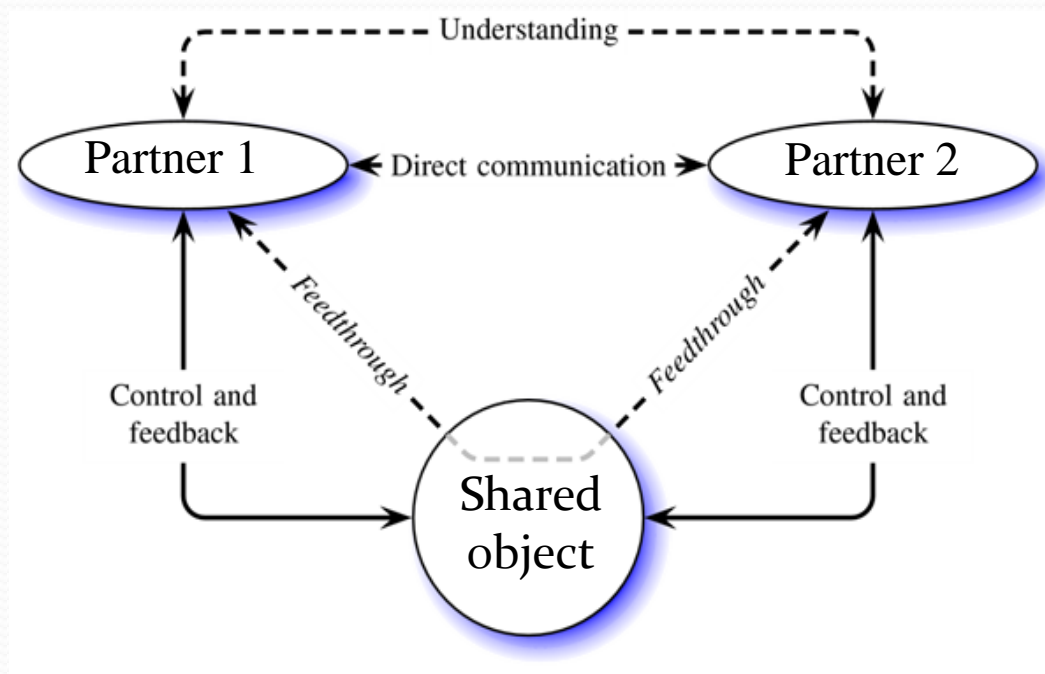
- Levels of interactions

- Loosely-coupled collaboration
  - No or asynchronous manipulation of objects : sequential interaction with the shared object
- **Closely-coupled collaboration**
  - Synchronous manipulation of objects: simultaneous interaction with the shared object



## Ellis's space-time matrix

# Communication mechanisms



- Direct communication:
  - Natural way to communicate: verbal, gesture, emotion, vocal activities, etc.
- Haptic feedthrough:
  - Occurs between participants through shared artefacts which plays the role of a mediator: kinematical and physical information

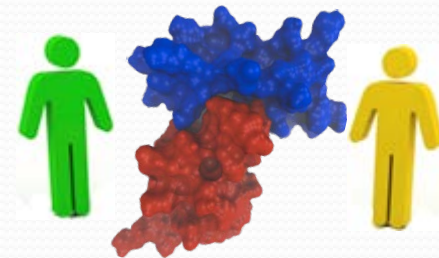
# Limits of communication in CVE

- CVE introduces limitations on natural communication process
- Two main classes of constraints:
  - Distance to the virtual environment
    - No-located gestural interaction and visual feedback
    - Limits of sensorial feedbacks



- Distance between partners

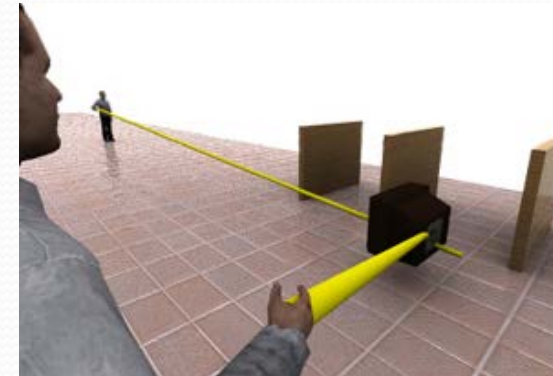
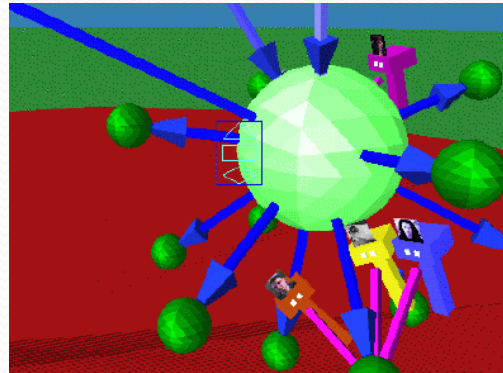
- Physical distance: work in different physical environments
- Virtual distance: collaborations occurring in large and/or complex virtual environments



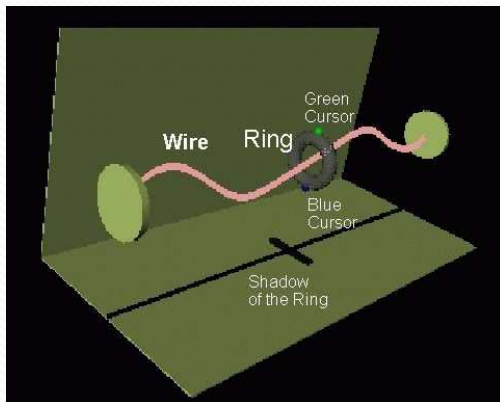
- Inhibits inter-referential communication, workspace and activity awareness

# Communication functions of haptics

- Visual based communication tools
  - Passive approaches
- Haptic based communication [Crossley et al. (1997)]
  - Non-intrusive communication
  - Improve coordination during closely coupled manipulation
  - Perception of the actions and the activities of partners



Braz, et al. (2008)



Basdogan et al. (2000)

Improve the group performance



Sallnäs et al. (2000)

Improve the social presence between users

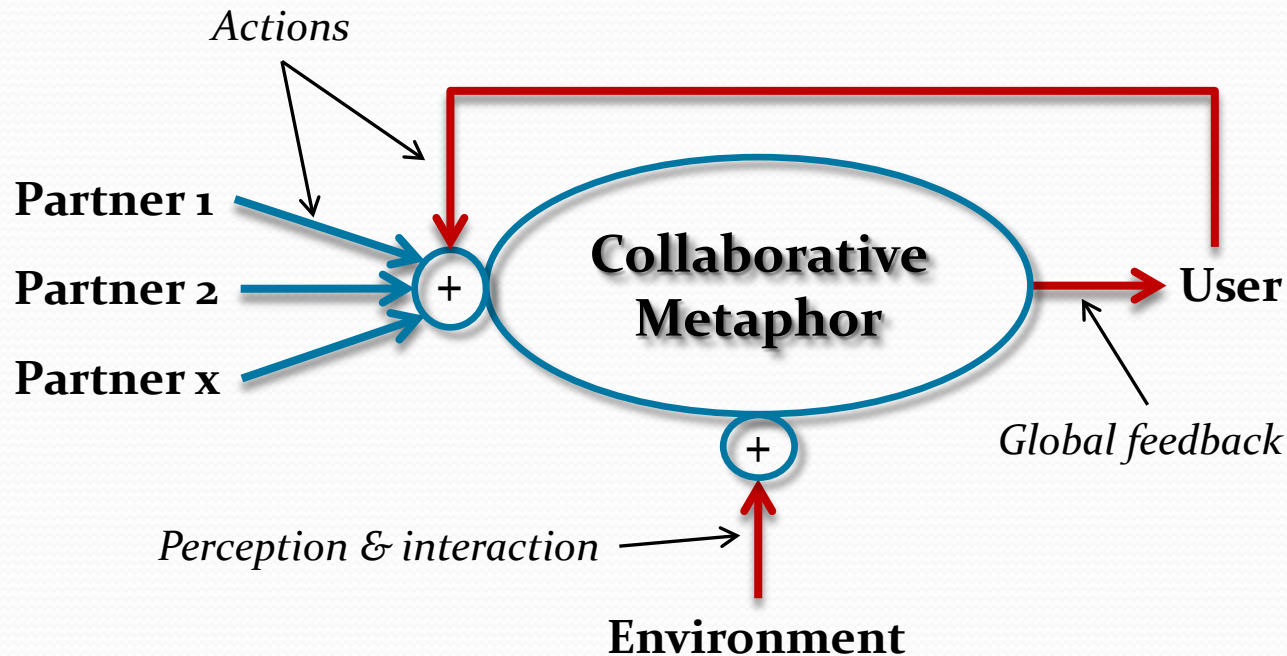


Reed and Peshkin (2008)

Emergence of collaborative strategies without the need of verbal communication

# Collaborative haptic metaphor

- Improve standard haptic communication with additional functions
  - From the **Virtual Fixture** [Rosenberg, 1993] to the **Collaborative Metaphor**



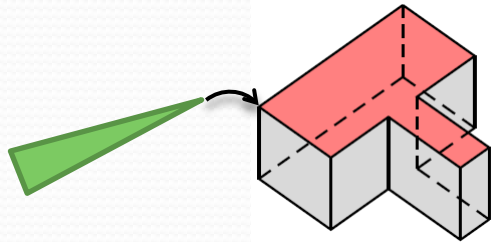
- Improve the communication of information with different levels of abstraction:
  - Physical information
  - Designation of targets
  - Information related to the partner's activity
  - etc.



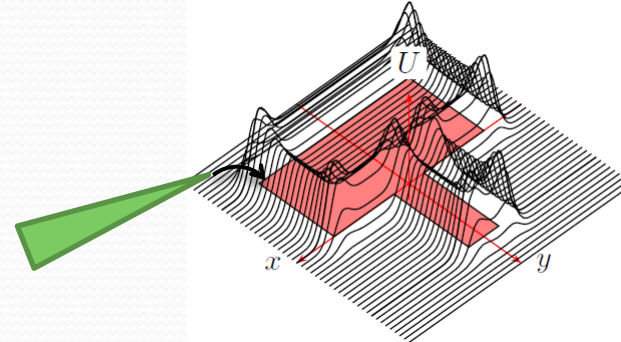
# Collaborative tasks

# Collaborative selection in CVE

- One-user selection
  - Important factors: depth perception, shape complexity, etc.
  - Several solutions have been successfully investigated:
    - force models, gesture velocity, etc.

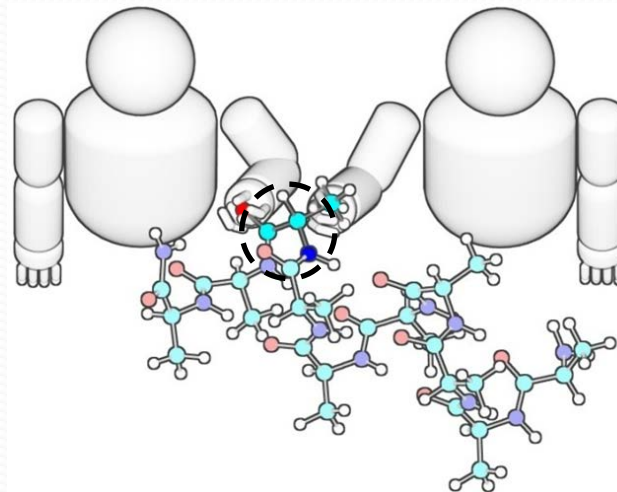


3D model



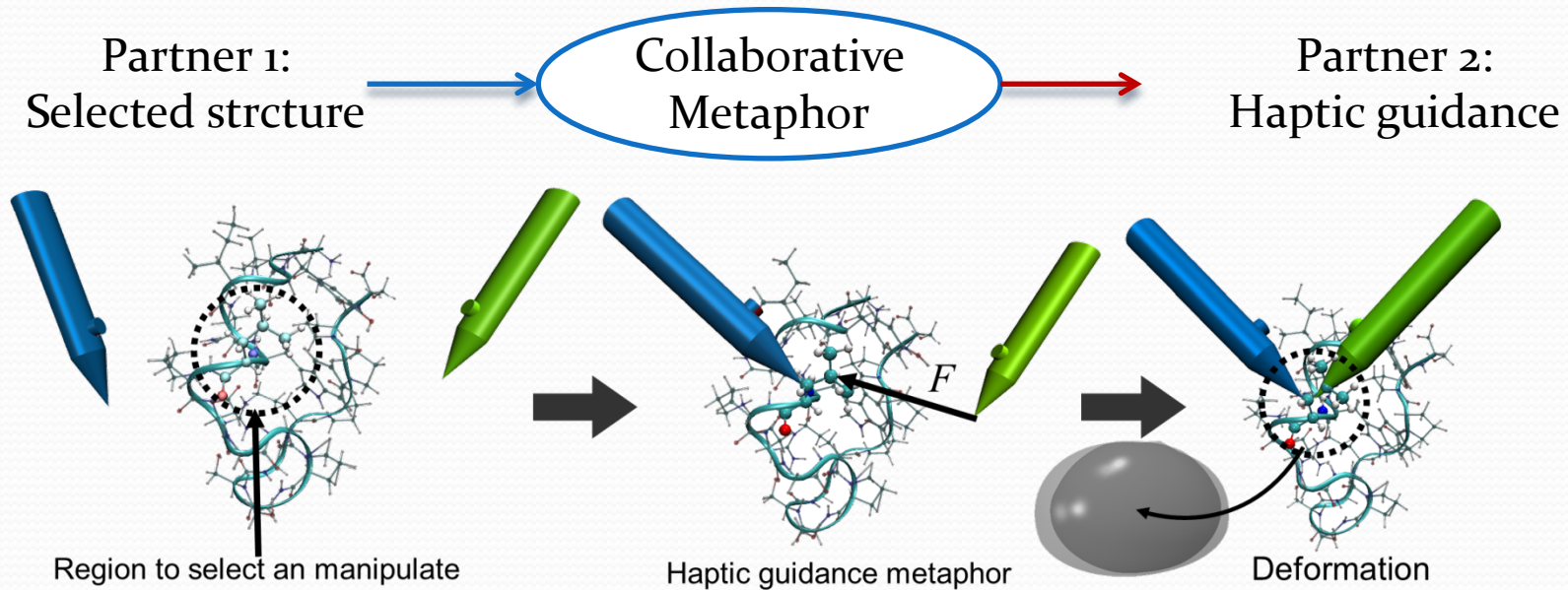
Force model  
[Simard *et al.*, 2009]

- Collaborative selection:
  - Good understanding of the partner's workspace
  - Good coordination between their actions



# Haptic based collaborative selection

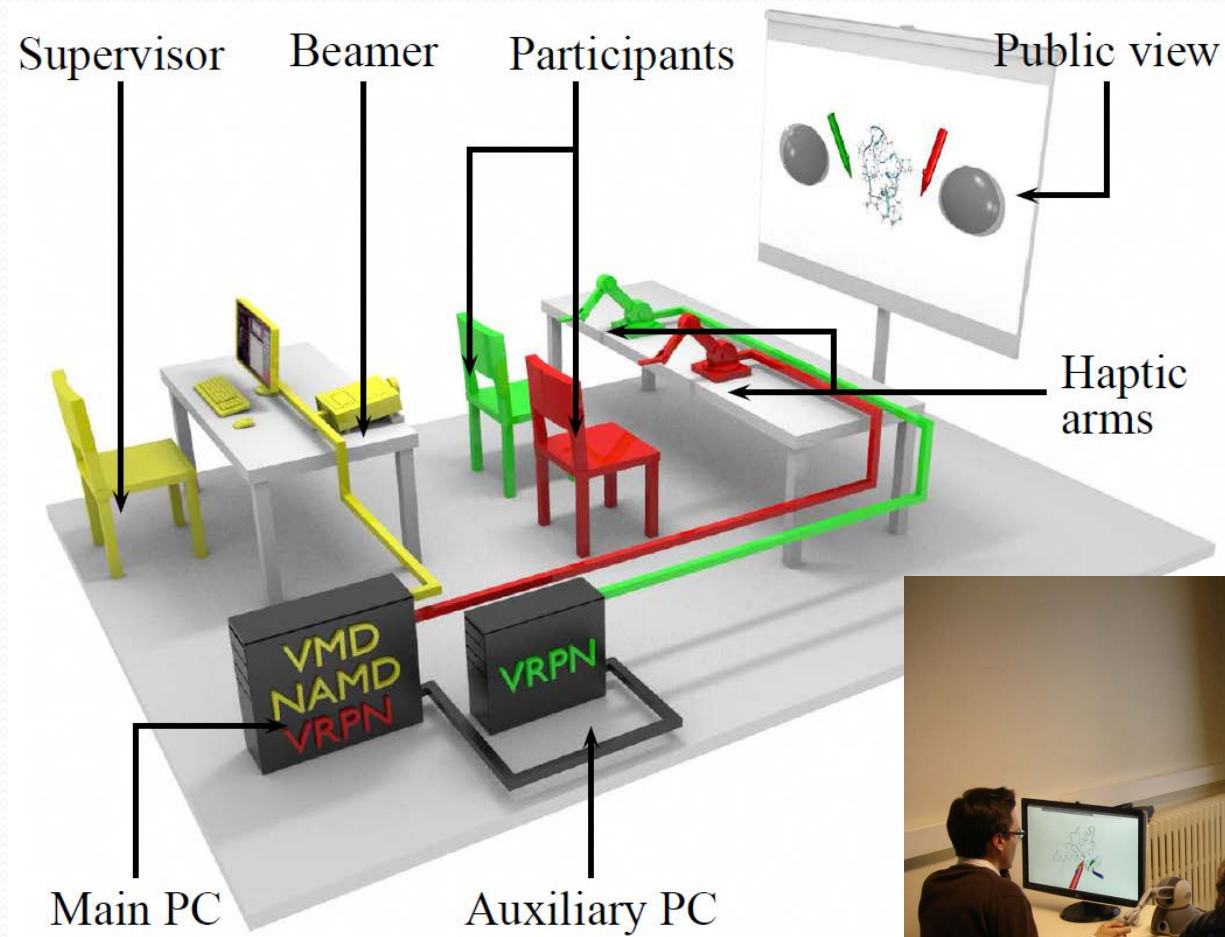
- Guidance in position strategy to physically indicate to the partner the 3D position of the target
  - Simplify communication between users
  - Avoid depth perception issues
  - Avoid wrong selections and manipulations



- Spring-time force function which increases gradually with time
  - Avoids important variations of force

$$\vec{F} = \begin{cases} t/t_{max} \times k \times (P_a - P_c) & , \text{if } t < t_{max} \\ k \times (P_a - P_c) & , \text{if } t \geq t_{max} \end{cases}$$

# Experimental procedure



Synchronous and colocated CVE

# Results

- Objective results

- **Improvement of working performance**

- Reduction of the completion time and crossed distance
- Reduction of the reaction time
- Reduction of wrong selections
- Increase of the mean speed of the two participants

- **Improvement of learning**

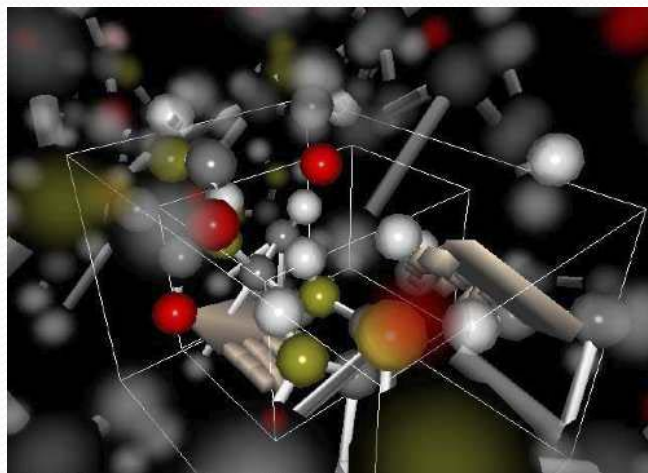
- Partners reached quickly the optimal efficiency
- Enabled the more experienced user to implicitly convey and explain some features of the molecular structures

- Subjective results

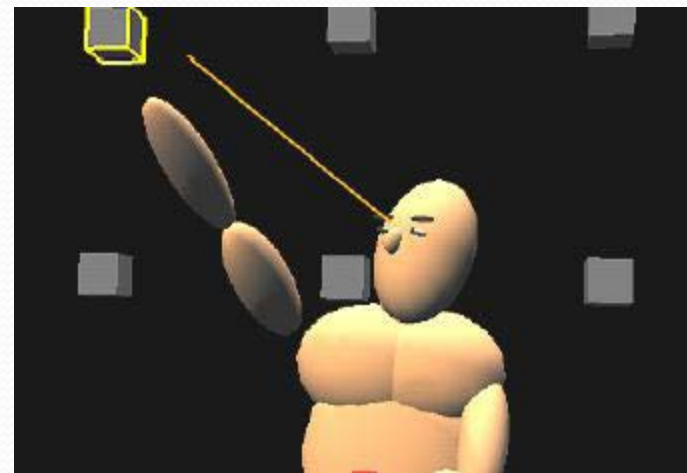
- Users perceive an improvement of performance
- Users consider the collaborative metaphor as an effective assistance tool

# Designation in CVE

- Designation and pointing in a 3D environment
  - Indicate to the partner a given target
- Present several constraints compared with similar tasks in a real environment
  - Limits of inter-referential communication in CVE
- Visual based solutions



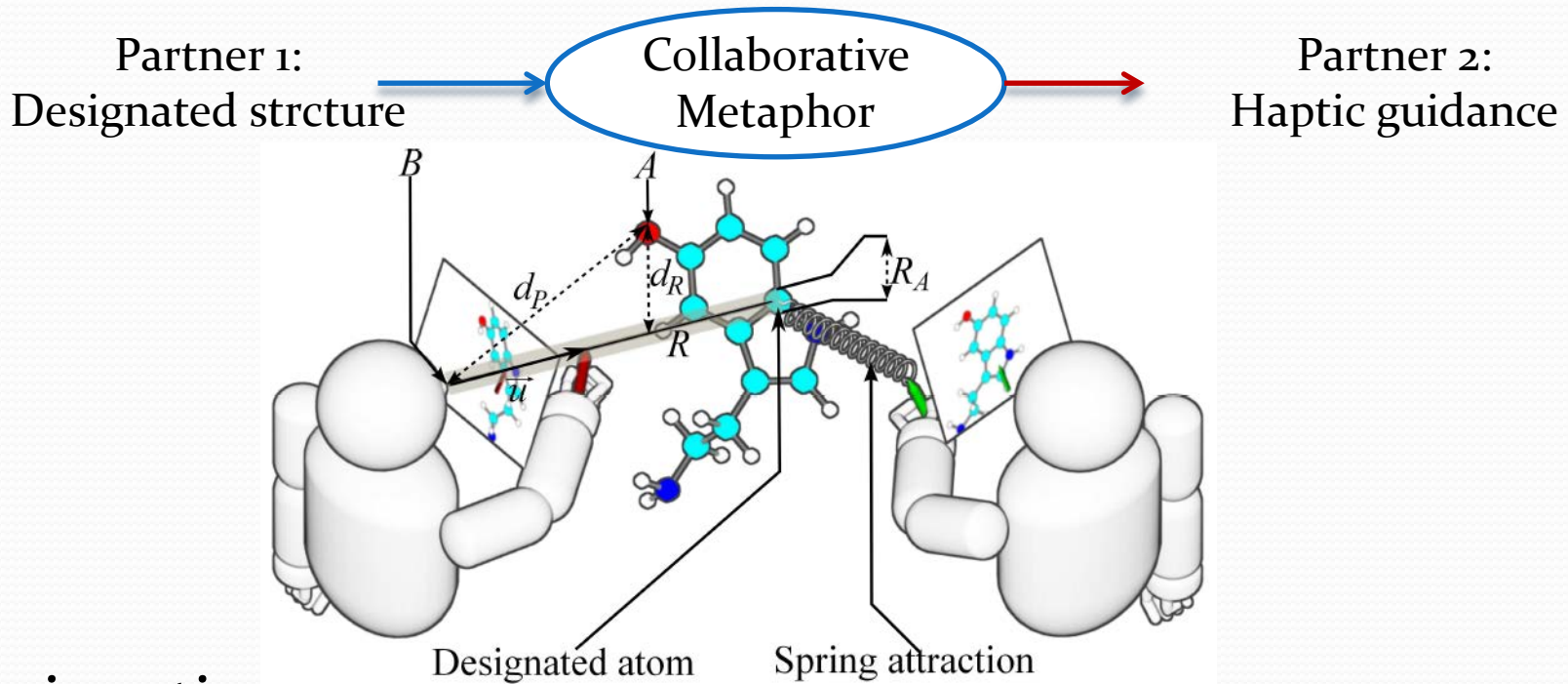
Chastine, J. C. Brooks et al. 2005



Kiyokawa et al. 1998

# Haptic based designation

- Based on the image-plane technique
  - Spatially isomorphic: prevents unnecessary 3D actions because it uses a depth insensitive selection technique

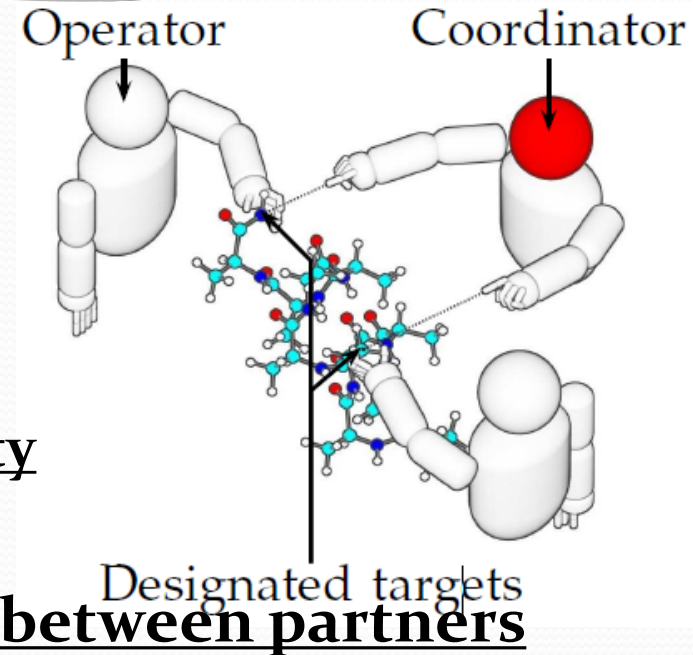


- Spring-time force function

$$\vec{F} = \begin{cases} t/t_{max} \cdot k \cdot (P_a - P_c) & , \text{ if } t < t_{max} \\ k \cdot (P_a - P_c) & , \text{ if } t \geq t_{max} \end{cases}$$

# Results

- No improvement of performance
- Improvement of working efficiency
  - Reduction of the overall level of activity
- Better sharing of the global workload between partners
- Slight decrease of verbal communication
- Adapted to tasks requiring local manipulations
  - Manipulation of close residues or on the same residues



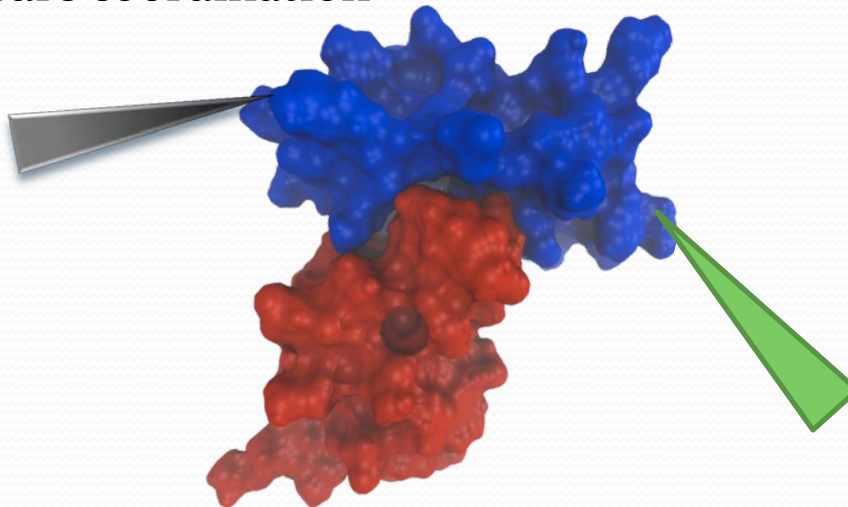
# Coordination of movements in CVE

- Collaborative moving of shared objects in CVE requires a good coordination between the partner's actions



- CVE and complex environments limit the awareness about the partner's action
  - limit the gesture coordination

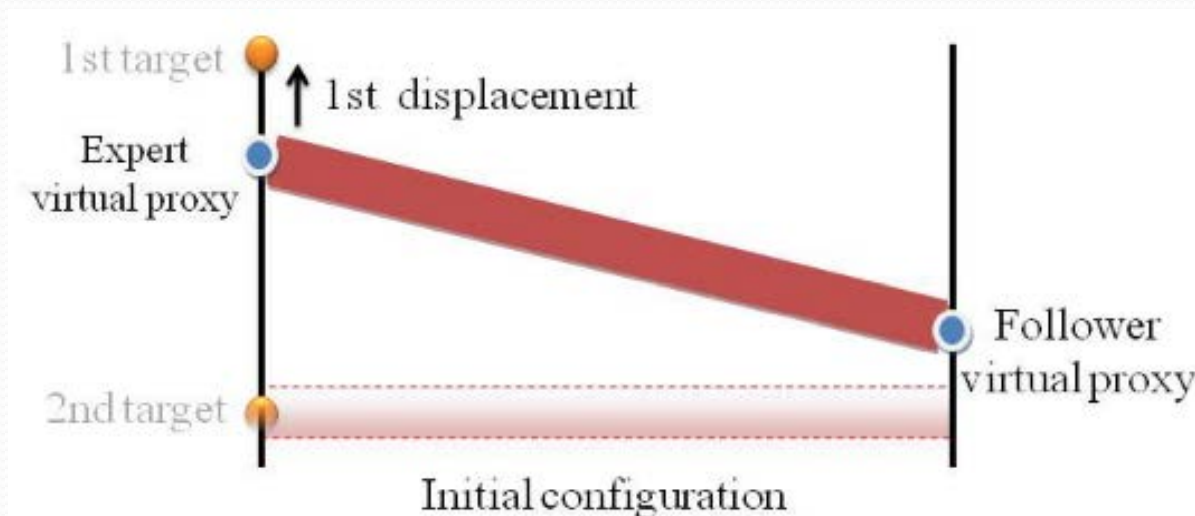
Partner 1  
Ex: expert



Partner 2  
Ex: follower

# Haptic based communication metaphor

- Augmentation of feedthrough with new kinematic information to improve coordination
  - Difference of positions between the two partners
  - Difference of velocity between the two partners
  - Change of the movement's direction



Experimented 1DoF assembly task: the expert participant is asked to reach a series of targets (high/low), the follower participant follows the expert

# Communication metaphor

Partner 1:  
Kinematical information

Collaborative  
Metaphor

Partner 2:  
Haptic rendering

- Suitable and intuitive metaphors: differentiable, identifiable, learnable, good reactivity

- Communication of the difference of positions:

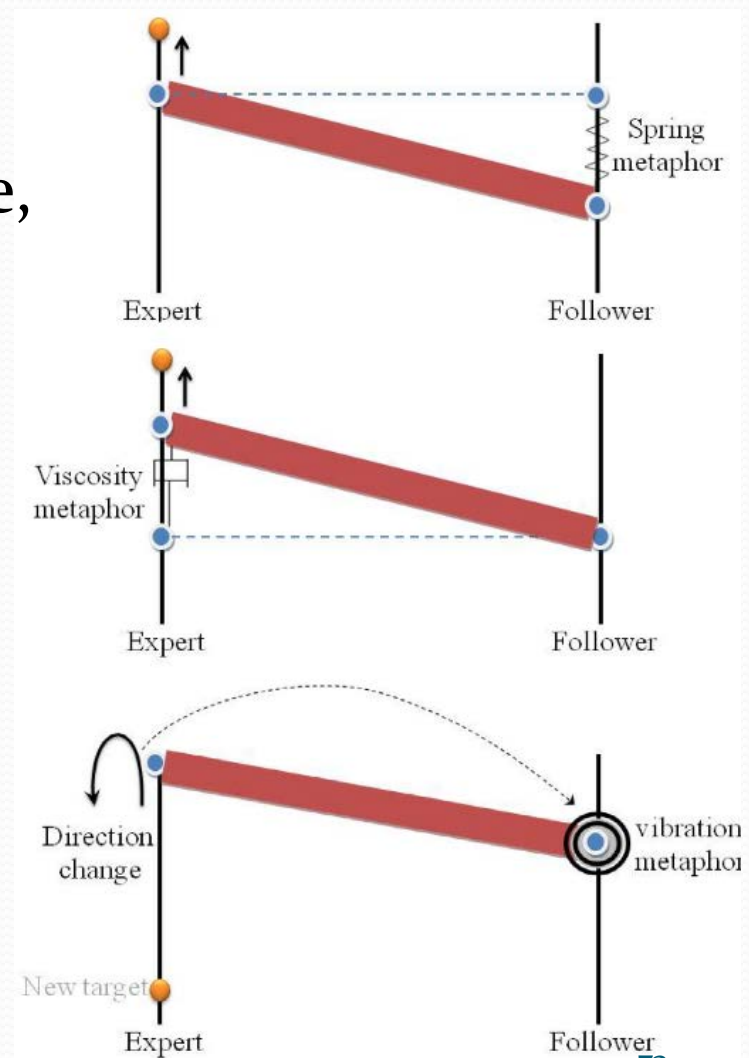
- Spring model

- Communication of the difference of velocity:

- Viscosity model

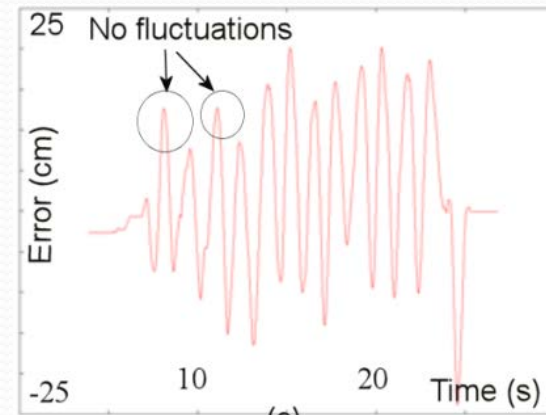
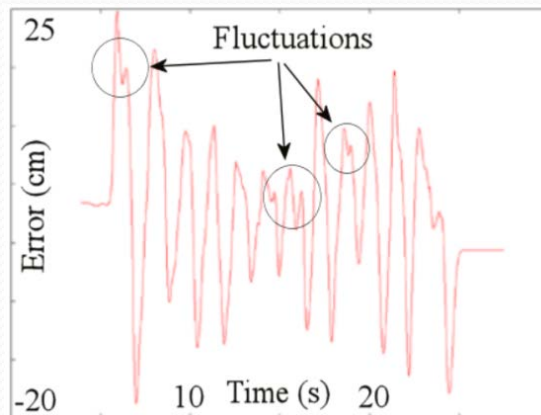
- Notification of direction change :

- Vibration



# Results for 1DoF assembly task

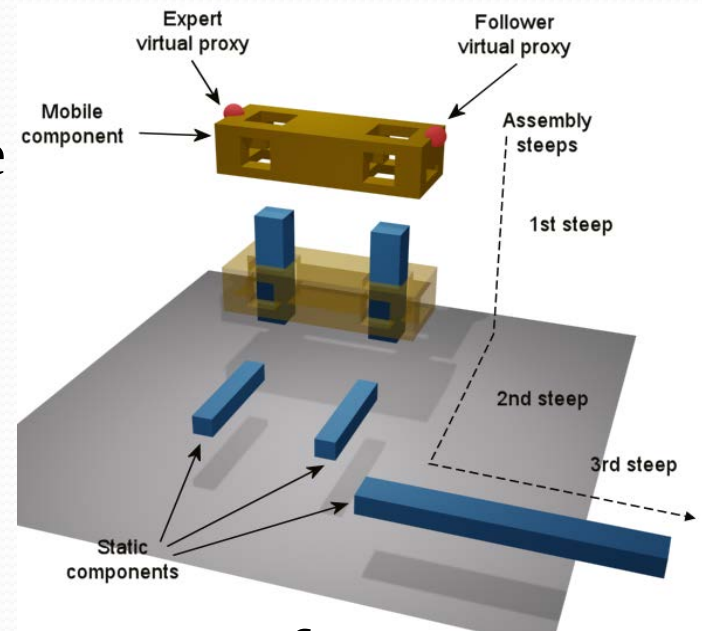
- Spring decreases the mean position error between the two partners during the movement
  - Guidance tool to easily reach the configuration of the fastest partner
- Viscosity increases the mean force applied on fastest partner which tends to slow his gesture
  - More easily following of the assembly movement for the slower partner
- Vibration decreases the mean fluctuations error during the changes of direction
  - Reduction of the delay for the follower reaction



# Results for 3DoF assembly task

- Objective results

- Reduction of collisions with the 3D environment
  - Avoidance of obstacles has a direct link with the level of coordination
- Augmentation of the execution time
  - Viscosity greatly slows the movement of the expert partner



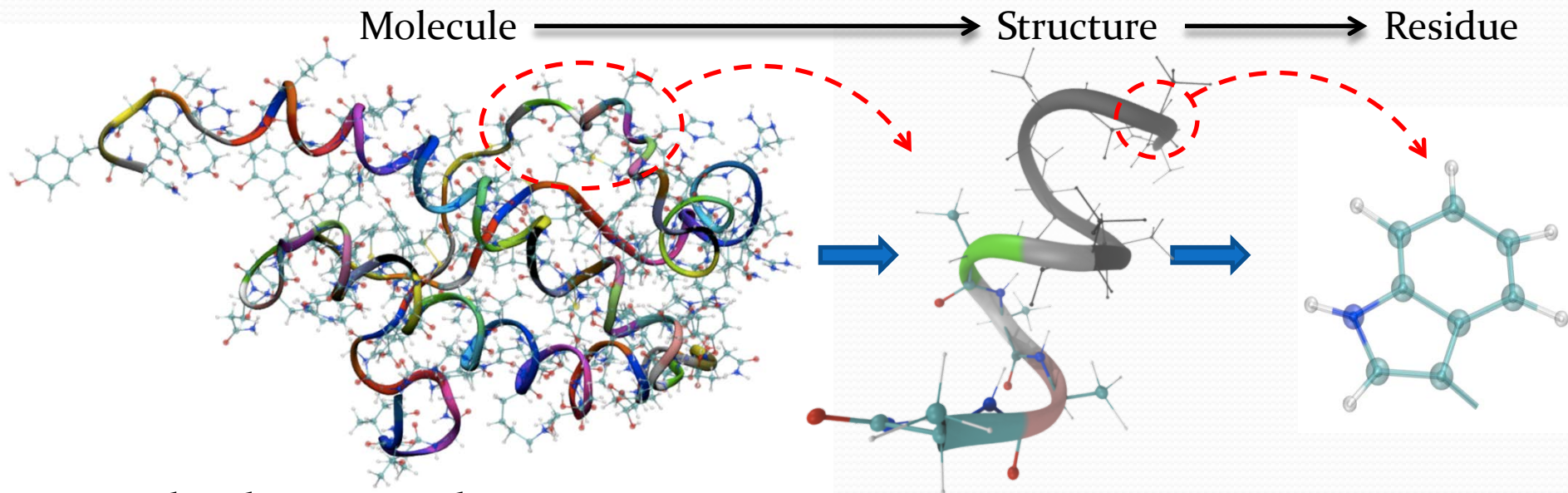
- Subjective results

- Better understanding of actions and gestures of partners
- Role of communication metaphors
  - Guidance tool for important force factors: viscosity and spring
  - Communication mechanism for soft force factors

# Adjustment of manipulation scale in CVE

- Context: collaborative 3D modelling

- Multilevel manipulation of 3D meshes
  - Requires the manipulation at the same scales of the model
- e.g., molecular modelling
  - Manipulation of large structures -> modify the overall conformation
  - Manipulation of small structures -> adjust the local conformations

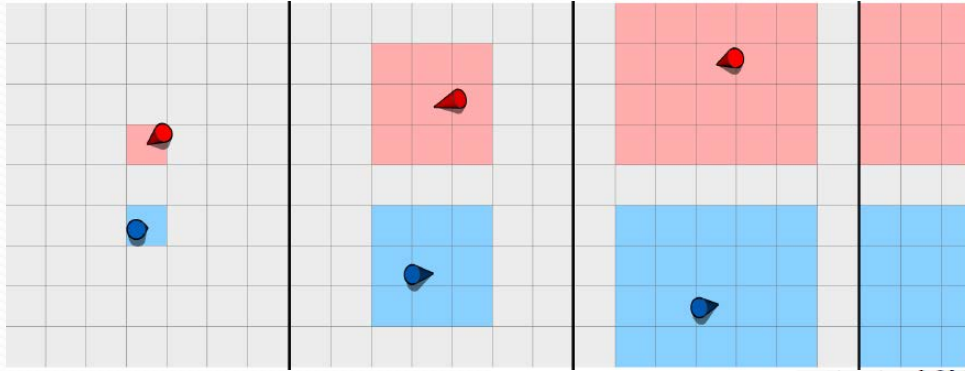


- Standard approach

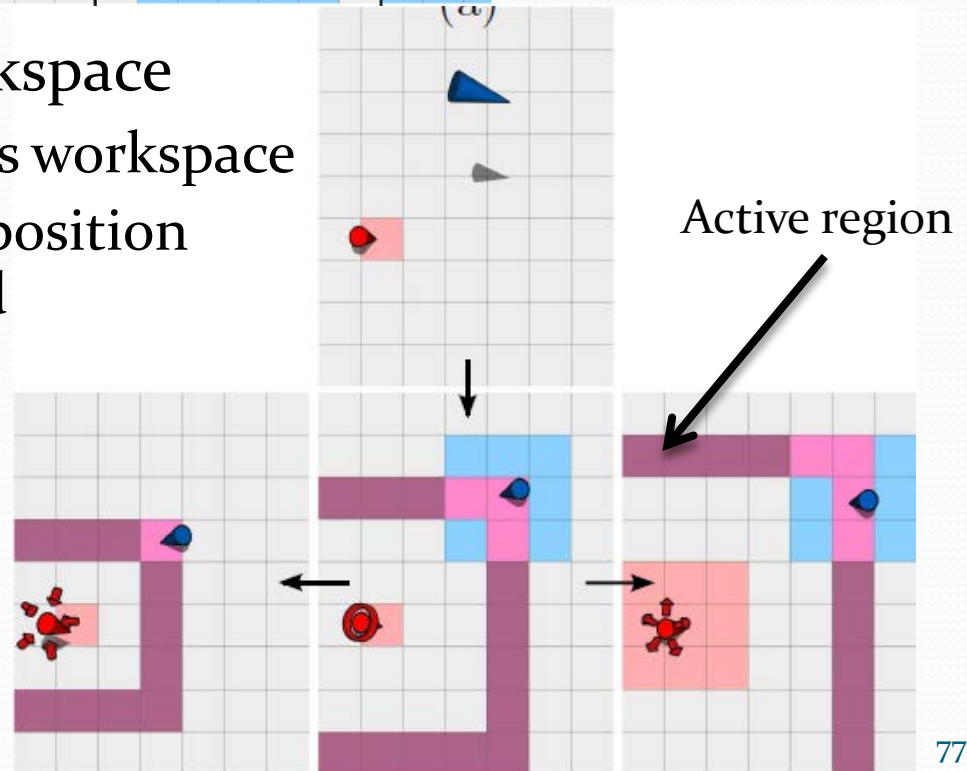
- Individual and explicit specification of the required scale

# Dynamic adjustment of manipulation scale

- Increase or reduce the manipulation scale
  - Criterion : geometric distance separating the two partners



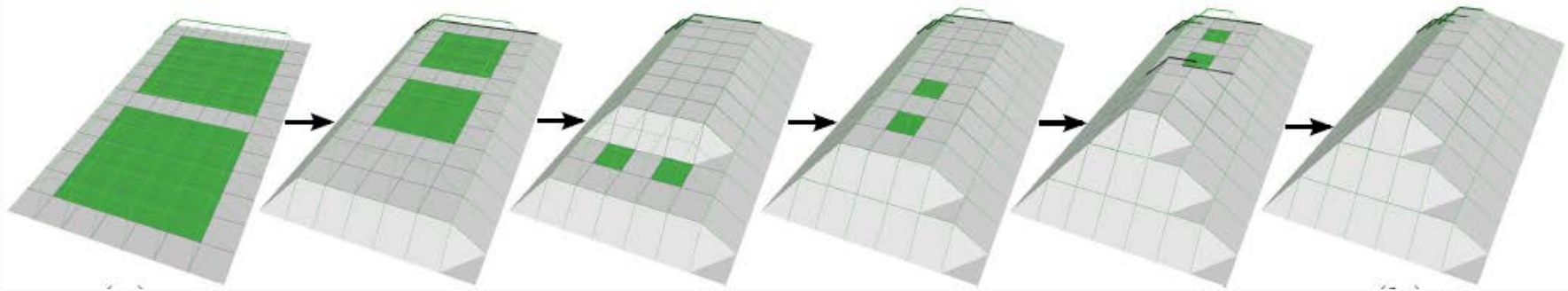
- Control of the partner's workspace
  - Modification of the partner's workspace
  - Active region on which the position of the partner is constrained
  - Modification procedure
    - Push/Pull



# Improve the shared situation awareness



- Increase the mutual awareness
  - Mutual acceptance procedure to force partners to work together
  - Haptic notification of the scale change



# Results

- No significant improvement of performance
  - Time and score
- Improvement of working efficiency
  - Reduction of actions without reducing the performance
- Improves the workload balance during the deformation process
- **No improvement of the shared situation awareness**
  - **Better balance between situation awareness and shared situation awareness**
  - The user is better shared between his activity and the partner's activity
    - Better management of the overall deformation process

# Conclusion and perspectives

- Importance of the verbal communication even if efficient communication tools are provided
- Develop methods to evaluate the shared situation awareness: workspace, activity, action, etc.
- Investigation of audio-haptic strategies to convey spatial features
- Develop new haptic devices adapted with CVE needs and constraints

# Hand functions

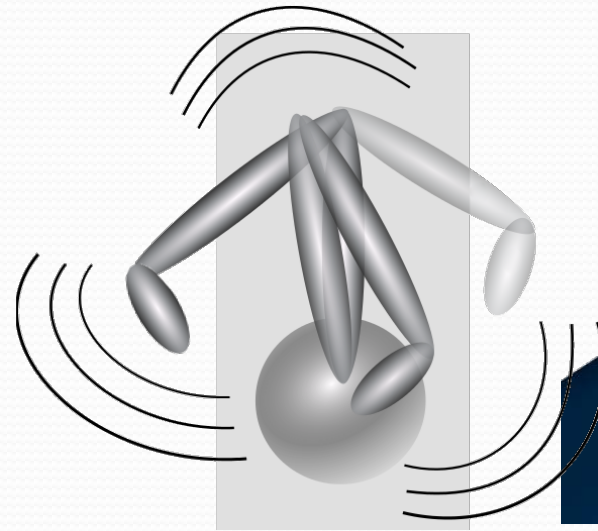
- Hand (haptic and gestural channels) has three different, complementary and overlapping functions :
  - Epistemic function: using the hand as an organ of perception through the haptic sense
  - Ergotic function : corresponds to the use of the hand as an organ of action on the environment
  - Semiotic functions: communication of information
    - Gestural communication without contact
    - **Communication through contact**
      - **Collaborative interaction**
      - **Affective interaction**

# Affective interaction

- Affective communication
  - Facial expression, voice features, body posture, etc.
- Interpersonnel contact
  - Supports complementary/redundant information
    - Intensity, pleasure, dominance, etc.



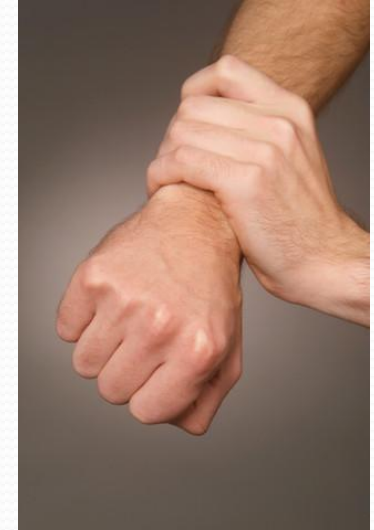
# Why haptics for emotions in VE



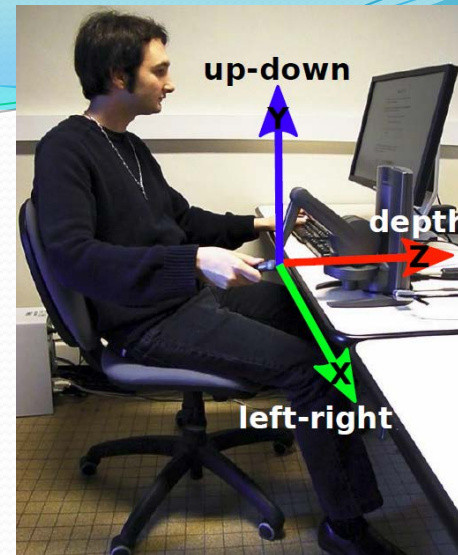
- The facial expressions of some emotions expressed with virtual humans are too similar:
  - Haptic expressions to discriminate emotions
  - Haptic expressions to perceive different levels of the same emotion

# First works

- [Hertenstein, 2006]: studied the role of touch to communicate different emotions
  - Direct/real contact between participants
  - Recognition > 60%
- [Bailenson, 2007]: developed a haptic system to record and display emotion (handshaking)
  - Haptic display of recorded expressions
  - Recognition < 20%
  - 2 DoF, rigid arm, no heat transfer, etc.



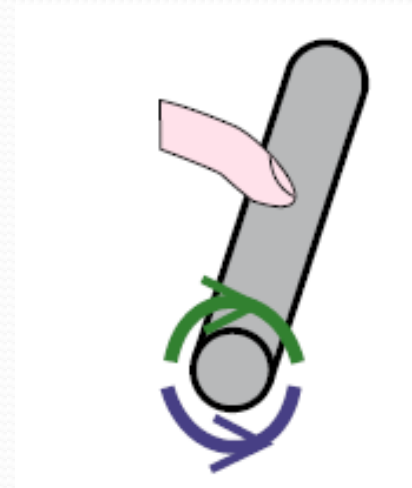
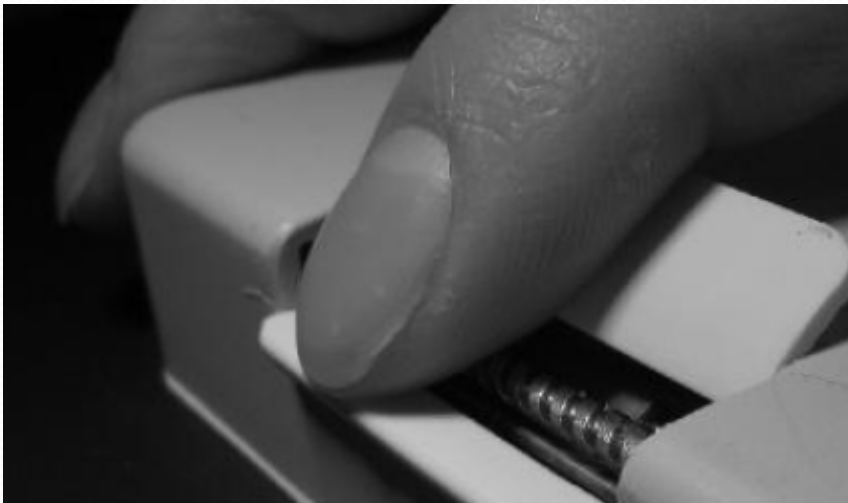
# 3D haptic expressions



- 3DoF haptic expressions (Kinesthetic feedback) [Gaffary, 2012]
  - New parameters: fluidity, contraction level, repetitivity, etc.
  - Identification of general features of affective haptic expressions
    - e.g., Joy presents a high mean duration and fluidity, etc.
  - Identification of discriminative features between close emotions
    - e.g., for “Irritation” and “Rage”: mean speed (“Irritation”: 16 m.s, “Rage”: 33 m.s), fluidity (“Irritation”: 3:0 m.s-2, “Rage”: 11 m.s-2), the contraction index (“Irritation”: 27 m, “Rage”: 54 m), etc.
- Results:
  - Kinesthetic feedback mainly communicates emotions with an important activation level (rage, etc.).
  - Basic Kinesthetic feedback can not support the pleasure dimension.

# Tactile strategies

- Rotating cylinders to generate tactile stimulus on fingers [Salminen, 2008].
- Feedbacks: continuous/discontinuous, fast/slow, etc.
- Results
  - Discontinuous and fast stimuli are associated with unpleasant emotions
  - Continuous and slow stimuli are associated with pleasant emotions



# Advanced tactile stimulation

- The Haptic Creature [Yohanan,
- Different actuators for
- Stimuli: Breath, Purr, etc.
- Results:
  - Better perception of the pleasure dimension
  - Better recognition of positive emotions

Responses	Vibrotactile mechanisms		
	Ears	Breath	Purr
Playing dead	Flaccid	None	None
Asleep	Flaccid	Slow	None
Content	Medium	Medium	Slow
Happy	Erect	Medium	Medium
Upset	Erect	Fast	Fast

