Symbiotic Human-Computer Interaction

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Abstract

The presentation will address basic principles and discuss examples of symbiotic human-computer interaction for the next evolutionary stage of the computing technology.

It is expected that current "human-computer interaction" (HCI) interfaces will evolve into more efficient multimedia HCI symbiotic partnerships in which humans will contribute human-specific capabilities complementing those of the computer.

It will be a symbiotic relationship in which each partner will lead in some cases and provide assistance in others. The leader/assistant role of a partner will be decided on the basis of maximizing the overall efficiency of the symbiotic team.
The classic measurement process: an early example of human-transducer cooperation
Robots emulate humans
The definition given by M. Bradley: "Robotics is the intelligent connection of the perception to action" considers robotics from a system integration perspective, indicating how robots are doing things.

Programmable robots (manipulators, vehicles) provide the action function.

A variety of sensors provide the perception capability.

Computers provide the framework for integration/connection as well as the intelligence needed to coordinate in a meaningful way the perception and action capabilities.
**Robot Controller - Hierarchical Architecture**

**Artificial intelligence level**, where the program will accept a command such as *Pick up the bearing* and decompose it into a sequence of lower level commands based on a strategic model of the task.

**Control mode level** where the motions of the system are modelled, including the dynamic interactions between the different mechanisms, trajectories planned, and grasp points selected. From this model a control strategy is formulated, and control commands issued to the next lower level.

**Servo system level** where actuators control the mechanism parameters using feedback of internal sensory data, and paths are modified on the basis of external sensory data. Also failure detection and correction mechanisms are implemented at this level.
ACTUATORS
SENSORS (EXTEROCEPTORS)

Model (human’s image) of the real world as he/she perceives it through his/her sensory organs

Off-Line Programming by Human

ROBOT CONTROL SYSTEM

MULTI-SENSOR FUSION

WORLD MODEL

MULTI-CARRIER COMMUNICATION MECHANISMS

DISTRIBUTED COMPUTING FRAMEWORK

HIGH LEVEL INFORMATION EXCHANGE MECHANISMS: XML, Grammars,...

HYBRID DELIBERATIVE/REACTIVE CONTROL

NATURAL ENVIRONMENT

WIRELESS COMMUNICATION NETWORK

ACTUATORS

SENSORS (EXTEROCEPTORS)

Traditional human-computer interaction
Video and haptic virtual reality interfaces allow a human operator to interactively control a remote robot manipulator equipped with video camera and tactile sensors.
**Early (80s) Video and Haptic Telerobotic System**


(a) The robotic tactile sensor, and (b) the human tactile feedback
It allows any user $USER(k) \ (k=1, \ldots, NU)$ to experience the haptic hands-on feeling while dexterously manipulating remote physical objects via a given robotic telemanipulator $ROBOT(k) \ (k=1, \ldots, NR)$ equipped with haptic and video sensors. An impedance-reflecting virtual operation theatre contains the composite geometric & haptic models of the kinematic and dynamic interaction behaviour of all manipulated objects. Haptic transport protocols allow to compensate for network lag and preserve synchronization in shared object manipulation.
Human-Computer Interaction in the Tele-Robotic Manipulation System

The **robotic telemanipulation system** has a bilateral architecture allowing to connect the *human operator* and the *telerobotic manipulator* as transparently as possible.

*Conformal (1:1) mapping of human & robot sensory and perception frameworks*

Using a *head mounted display* for augmented visual virtual reality and a *haptic feedback* system, the human operator controls the operation of a *remote robot manipulator equipped with video camera and tactile sensors* placed in robots hand.

The tactile sensors provide the *cutaneous information* at the remote robotic operation site. The joint sensors of the robot arm provide the *kinesthetic information*.

A *tactile human-computer interface* provides the *cutaneous feedback* allowing the human operator to feel with his/her own sense of touch the same sensation as that acquired by the remote robot hand from its artificial tactile sensor. A robot-like kinematic structure provides the *kinesthetic feedback* for the haptic human-computer interface.
Human-Computer interaction for symbiotic operations
The *time clutch* concept is used to disengage *synchrony between operator specification time and tele-robot operation time* during path specifications. In order to avoid fatal errors and reduce the effect of the communication delay, we are using a *distributed virtual environment allowing to maintain a shared world model* of the physical environment where the telemanipulation operation is conducted.

Another critical requirement is the need to maintain the *synchronism between the visual and the haptic feedback*. While being two distinct sensing modalities, both haptic perception and vision measure the same type of geometric parameters of the 3D objects that are manipulated.
Visual-, geometric-, force-, and touch – domain human-feedback devices
Biologically inspired robotic manipulator consists of a robot arm an instrumented passive-compliant wrist and a 16-by-16 tactile probe. Position sensors placed in joints and on the instrumented passive-compliant wrist provide the kinesthetic information. The compliant wrist allows the robot-hand equipped with tactile sensors to accommodate the constraints of the explored object surface and thus to increase the amount of cutaneous tactile information.
The tactile probe is based on a 16-by-16 matrix of Force Sensing Resistor (FSR) elements spaced 1.58 mm apart on a 6.5 cm² (1 square inch) area. The FSR elements exhibit exponentially decreasing electrical resistance with applied normal force: the resistance changes by two orders of magnitude over a pressure range of 1 N/cm² to 100 N/cm².
The **elastic overlay** has a protective damping effect against impulsive contact forces and its elasticity resets the transducer system when the probe ceases to touch the object. However, they may cause considerable blurring distortions in the sensing process if they are not properly controlled. We avoided it by replacing the one-piece pad with a custom-designed elastic overlay consisting of a relatively thin membrane with protruding round tabs.

![16-by-16 median filtered tactile image of a washer.](image-url)
Human Kinesthetic Perception

The *kinesthetic* sensing provides information about the positions and velocities of the kinematic structure of the hand.

The human *kinesthetic* capability has a much lower frequency band than the *cutaneous* perception provided by the fingertips.
• Uses 18-22 linear sensors – electrical strain gauges;
• Angles are obtained by measuring voltages on a Wheatstone bridge;
• 112 gestures/sec “filtered”.
• Sensor resolution 0.5 degrees, but errors accumulate to the fingertip (open kinematic chain);
• Sensor repeatability 1 degree
• Needs calibration when put on the hand
CyberGrasp™

CyberGrasp™ Pack

CyberForce™

*Immersion 3D Interaction*  [http://www.immersion.com/]
Commercial Virtual Hand Toolkit for CyberGlove/Grasp providing the kinesthetic human-computer interface
The cutaneous/tactile sensing provides information about contact force, contact geometric profile and the temperature of the touched object.

There are various cutaneous mechanoreceptors located in the outer layers of the skin. These receptors are specialized nervous cells or neurons. The free nerve endings are the most numerous and play an active role in the perception of pain, cold and warmth.

These mechanoreceptors have preferential frequency response characteristics: the highest sensitivity for the Pacinian Corpuscles (PC) units is around 250-300 Hz but they respond from 30 Hz to very high frequencies. The Rapidly Adapting (RA) units effective frequency range is between 10 and 200 Hz, with more sensitivity below 100 Hz. The Slowly Adapting (SA) units respond at low frequencies, under 40-50 Hz.

( The human kinesthelic function has a much lower frequency band.)
Two-point limen test: 2.5 mm fingertip, 11 mm for palm, 67 mm for thigh (from [Burdea & Coiffet 2003]).

Immersionn_3D Interaction  <http://www.immersion.com/>
Tactile/Cutaneous Feedback to the Human Operator

A tactile monitor placed on the operator's palm should allow the human teleoperator to virtually feel by touch the object profile measured by the tactile sensors placed in the jaws of the robot gripper.
Cutaneous tactile HCI developed at the University of Ottawa in the early 90s. It consists of an 8-by-8 array of electromagnetic vibrotactile stimulators. The active area is 6.5 cm² (same as the tactile sensor). The figure shows a curved edge tactile feedback.
Human operator and intelligent sensor-based systems work together as *symbionts* (*cyborgs*) each contributing the best of their specific abilities.

Proper control of these operations require *human-computer interfaces* capabilities allowing the human operator to experience the feeling of virtual immersion in the working environment.
Interfaces enhancing the performance figures of the human’s natural capabilities

Eye glasses, binoculars, IR night vision device, HMD for augmented VR, ...

Hearing amplifier

gloves (baseball glove), hand tools (pliers)

footwear, skates, bike, exoskeleton,

ARTIFICIALLY ENHANCED HUMAN = SYNBIONT?
Prosthetic interfaces enhancing the performance figures of the human’s natural capabilities (including survivability)

ARTIFICIALLY ENHANCED HUMAN = SYNBIONT
Interfaces enhancing the performance figures of the human’s natural capabilities

**Artificially Enhanced Human = Synbiонт!**

- **Brain**
- **Eye**
  - Eye + Artificial Cornea
- **Ear + Hearing Aid (Implant)**
- **Pacemaker**
- **Hand**
- **Artificial Hand**
- **Knee Joint + Titanium Knee Joint**

**Healthy or Crippled Human Being**

- **PDA**
  - eye glasses, binoculars, IR night vision device, HMD for augmented VR, ...
- **gloves (baseball glove), hand tools (pliers)**
- **footwear, skates, bike, exoskeleton,..**
Human beings are only valuable in this symbiotic partnership to the degree that their capabilities complement those of the computers:

(i) humans are still far more intelligent than any computer, are able to act on incomplete or ambiguous instructions, able to adapt to a variety of computer interfaces, and able to interact directly with other humans,

(ii) humans are mobile being able to leave the vicinity of the computer, perform complex tasks in a variety of different environments, and then return to report on the outcome,

(iii) humans can recognize visual, auditory, olfactory, gustatory, and haptic stimuli,

(iv) humans are dexterous, which allows them to precisely manipulate a wide variety of objects,

(v) humans are emotional, varying the characteristics of response, depending on the global state of each individual.

Humans are very high-bandwidth creatures:

- their visual system is capable of perceiving more than a hundred megabits of information per second, and
- their largest sense organ, the skin is capable of perceiving nearly that much as well.
- human speech conveys information in the form of intonation and inflection as well as the actual words uttered.

People communicate through "body language" which includes facial expressions and eye movements.

Symbionts will combine intrinsic machine-sensing reactive behavior with higher-order human-oriented world-model representations of the immersive virtual reality.
Human-to-human communication and cooperation require a common language and an underlying system of shared knowledge and common values. In order to achieve a similar degree of human-to-computer interaction and cooperation, a symbiotic framework should be developed to allow for the management of heterogeneous functions and knowledge.
Asimov’s laws of the robotics:

1st law: “A robot must not harm a human being or, through inaction allow one to come to harm”.

2nd law: “A robot must always obey human beings unless that is in conflict with the 1st law”.

3rd law: “A robot must protect itself from harm unless that is in conflict with the 1st and 2nd law”.

Cyber/Machine Concept Representation Language

Symbiont Concept Representation Language

Human Concept Representation Language

Cyber/Machine Society/World
{Intelligent Robot Agents}

Symbiont Society/World
{Cyborgs}

Human Society/World
{Human Beings}
Cyber/Machine Concept Representation Language

Human Concept Representation Language

Symbiont Concept Representation Language

Multi-Cultural Human & Cyber & Symbiont Hyper-Society World

Hyper-Society Common Concept Representation Meta-Language

Human Concept Representation Language
Asimov’s laws of the robotics:

0th law: “A robot may not injure humanity or, through inaction, allow humanity to come to harm.”

1st law- updated: “A robot must not harm a human being or, through inaction allow one to come to harm, unless this would violate the 0th law.”

2nd law: “A robot must always obey human beings unless that is in conflict with the 1st law”.

3rd law: “A robot must protect itself from harm unless that is in conflict with the 1st and 2nd law.”

BORG Hyper-Society
Common Concept
Representation
Meta-Language
Moral, Ethical, Theological, Legal, Biological, Psychological Social, Economic,… Challenges in a BORG Hyper-Society World

\[
[\text{Normal Human Partner}] + [\text{Pacemaker-fitted Human Partner}] = [\text{Acceptable Married (incl. Lovers)_Couple}]
\]

\[
[\text{Normal Human Partner}] + [\text{Advanced Augmented Symbiont Partner}] = [\text{Acceptable Married (incl. Lovers)_Couple}] ?
\]

\[
[\text{Normal Human Partner}] + [\text{Robot Partner}] = [\text{Acceptable Married (incl. Lovers)_Couple}] ???
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=> Absolutely ! … according to Asimov’s “Prelude to the Foundation”
. . or an alternative ➔ No Robots !!! No Symbionts !!!
The GALACTIC EMPIRE:

- Robots banned . . but Eto Demerzel.
- Hari Seldon’s Psychohistory.
- The FOUNDATION => SECOND GALACTIC EMPIRE
Publications