Sensor Enabled Robotic Telemanipulation

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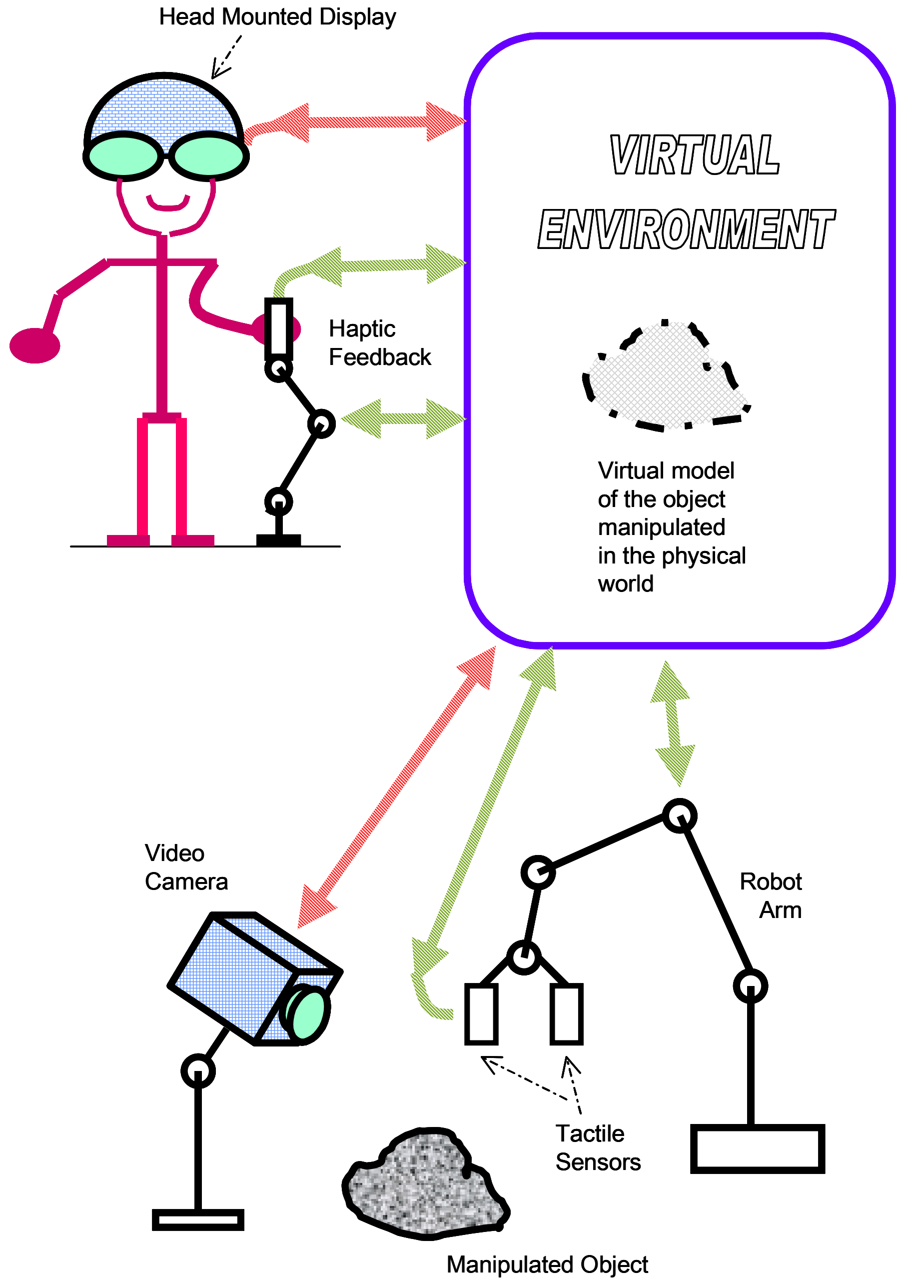
Robotic telemanipulation

is an object-oriented act which requires not only specialized *robotic hands with articulated fingers* but also *tactile, force and kinesthetic sensors* for the precise control of the forces and motions exerted on the manipulated object. As fully autonomous robotic dexterous manipulation is impractical in changing and unstructured environments, an alternative approach is to *combine the low-level robot computer control with the higher-level perception and task planning abilities of a human operator* equipped with adequate *human computer interfaces* (HCI).

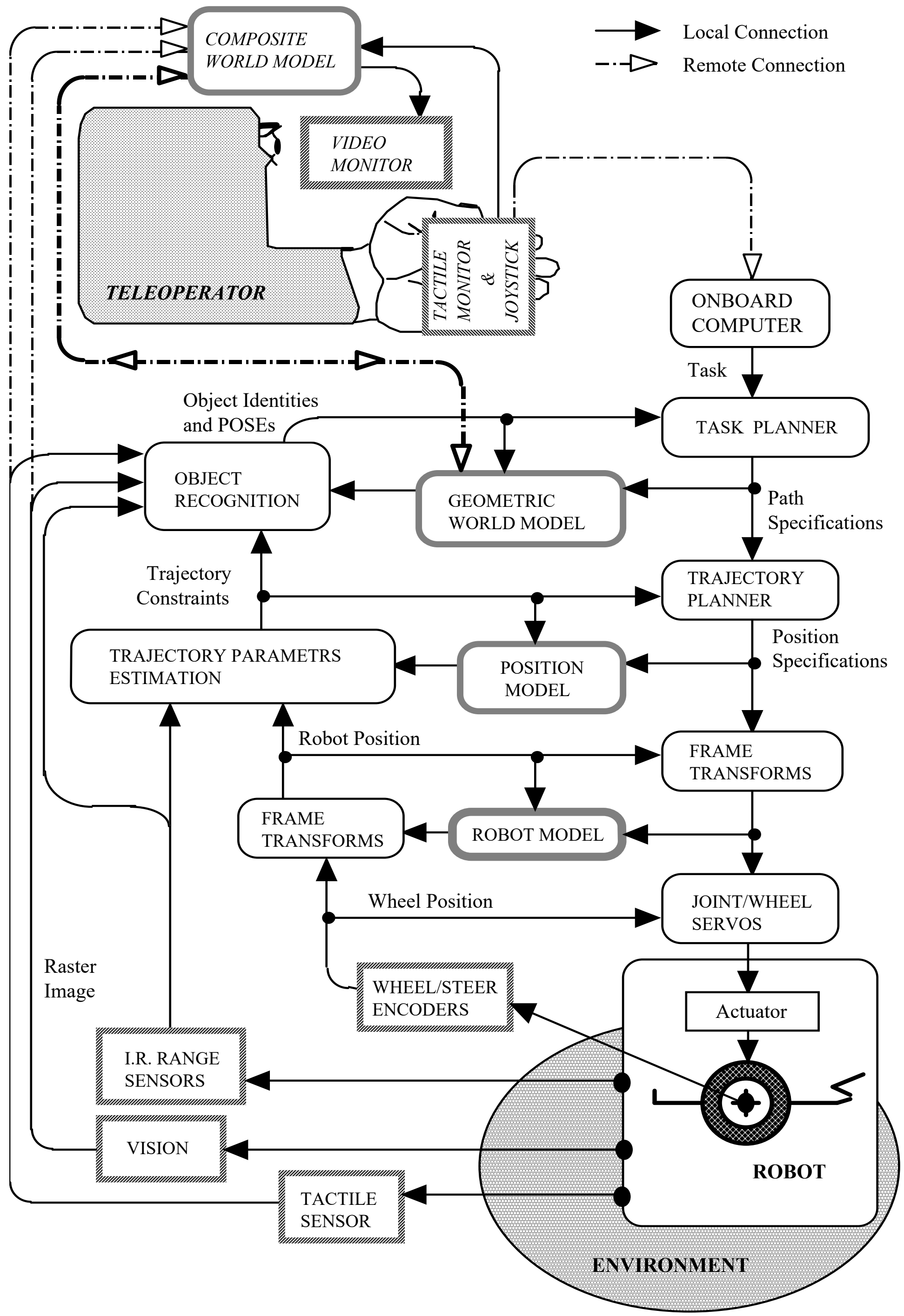


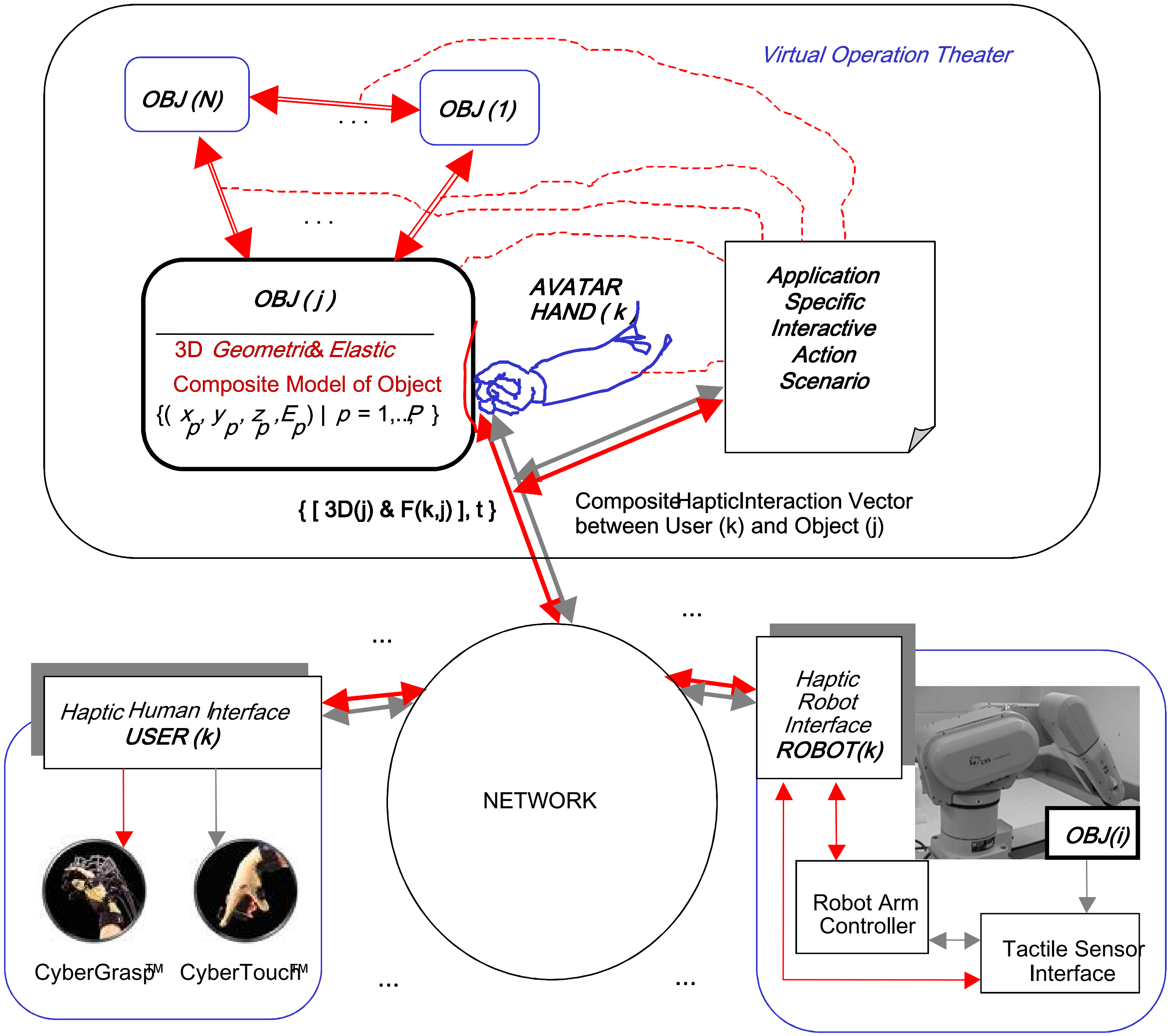
- **Telemanipulation systems** should have a bilateral architecture that allows a *human operator* to *connect in a transparent manner to a remote robotic manipulator*.

- ***Human Computer Interfaces*** (HCI) should provide easily perceivable and *task-related sensory displays (monitors) which fit naturally* the perception capabilities of the human operator.

- The potential of the emergent haptic perception technologies is significant for *applications* requiring object telemanipulation such as: (i) robot-assisted handling of materials in industry, hazardous environments, high risk security operations, or difficult to reach environments, (ii) telelearning in hands-on virtual laboratory environments for science and arts**,** (iii) telemedicine and medical training simulators.

Model-based telepresence control of a robot





Interactive Model-Based Hapto-Visual Teleoperation - a human operator equipped with haptic HCI can telemanipulate physical objects with the help of a robotic equipped with haptic sensors.

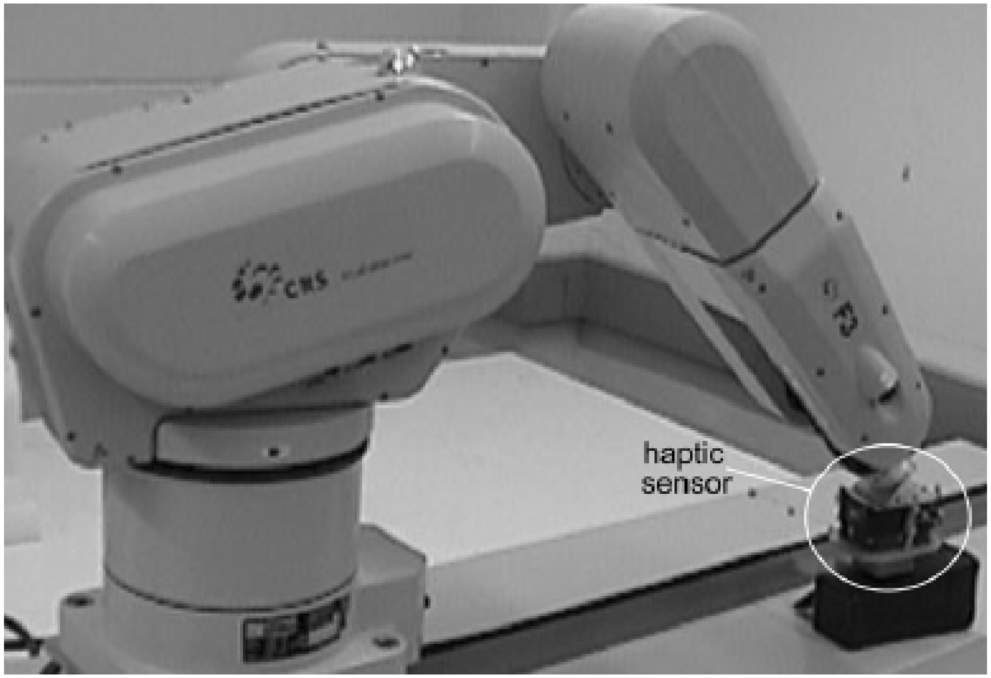
Robot Haptic Sensors

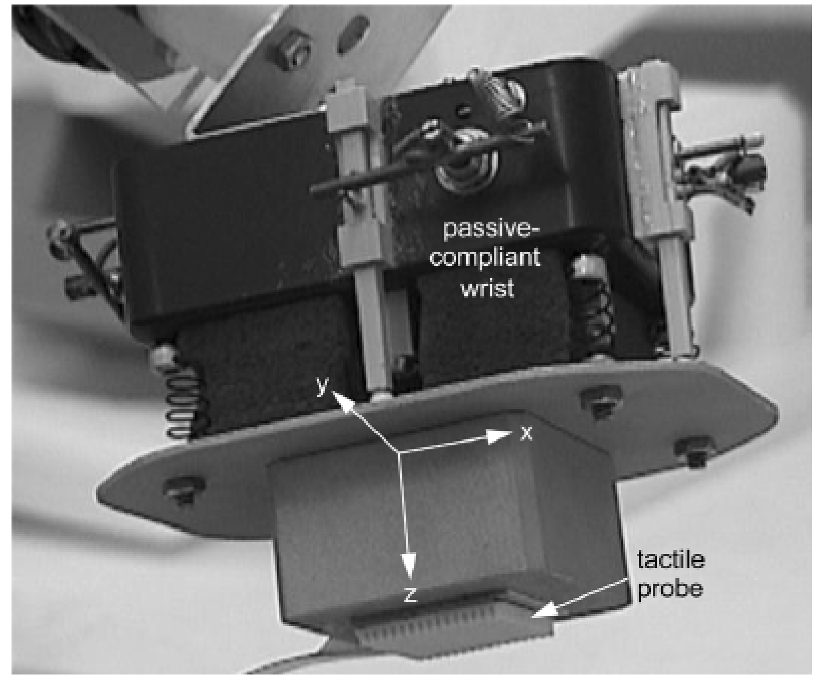
Haptic perception is the result of an active deliberate contact exploratory sensing act.

A **tactile probe** provides the local “cutaneous” information about the touched area of the object.

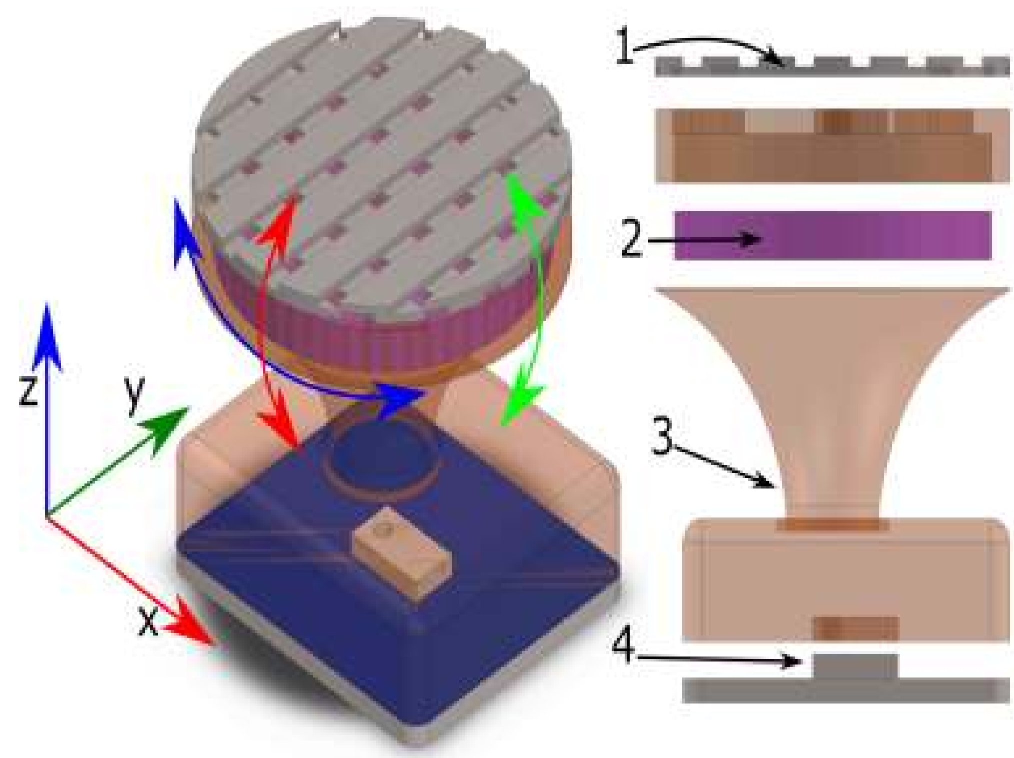
A **robotic carrier** providing the “kinesthetic” capability is used to move the tactile probe around on the explored object surface and to provide the contact force needed for the probe to extract the desired cutaneous information (e.g. local 3D geometric shape, elastic properties, and/or thermic impedance) of the touched object area .

The local *information provided by the tactile probe is integrated with the kinesthetic position parameters of the carrier* resulting in a *composite* **haptic model** (global geometric and elastic profiles, thermic impedance map) of the explored 3D object.





Biology-inspired robot haptic perception system consists of a **robot** “**finger”,** an instrumented **passive-compliant wrist** and a **tactile probe** array. Position sensors placed in the robot joints and on the instrumented passive-compliant wrist provide the kinesthetic information. The compliant wrist allows the probe to accommodate the constraints of the touched object surface and thus to increase the local cutaneous information extracted during the active exploration process under the force provided by the robot.

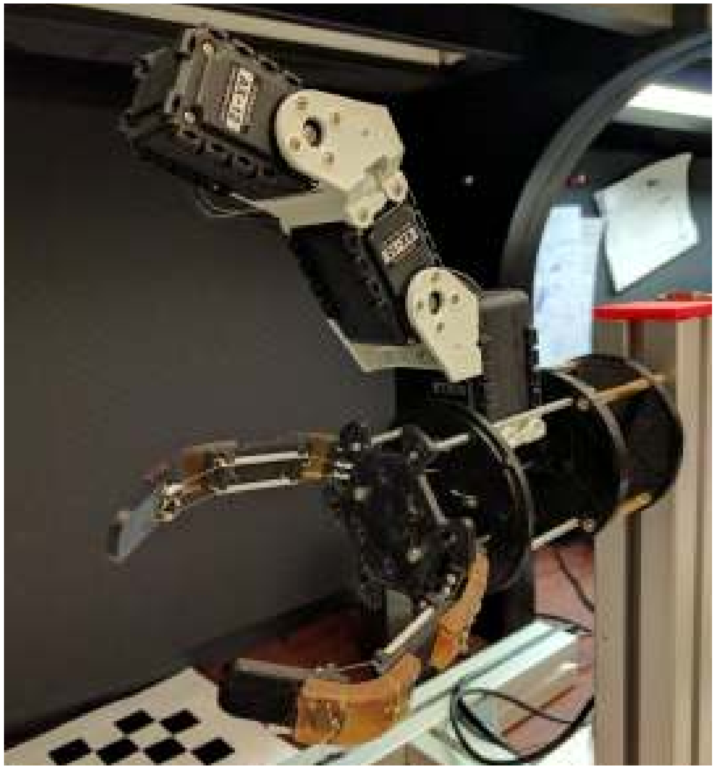


Bio-Inspired Tactile Sensing Module: (1) Merkel disk- and Meissner corpuscle–like shape, pressure, local skin deformation, and slippage sensitive tactile array - 32 taxels; (2) Rufinni corpuscle–like vibration and stretch sensitive MARG sensor; (3) compliant structure; (4) Pacinian corpuscule-like deep pressure sensor;

[from T.E. Alves de Oliveira, A.-M. Cretu, E.M. Petriu, “Multimodal Bio-Inspired Tactile Sensing Module,” *IEEE Sensors Journal*, Vol. 17, Issue 11, pp. 3231 – 3243, 2017]

Multi-Finger Dexterous Robot Hand

Vision, tactile, and flex joint sensors allow tracking finger phalanges' position, provide information of the object's unknown orientation for in-hand manipulation by **the two -finger underactuated hand with a fully-actuated intelligent thumb** capable of trajectory planning. A **fuzzy logic controller** allows to obtain a stable grasp After grasp, the manipulate object can be reoriented by the thumb taking advantage of the compliance of the flex joint fingers

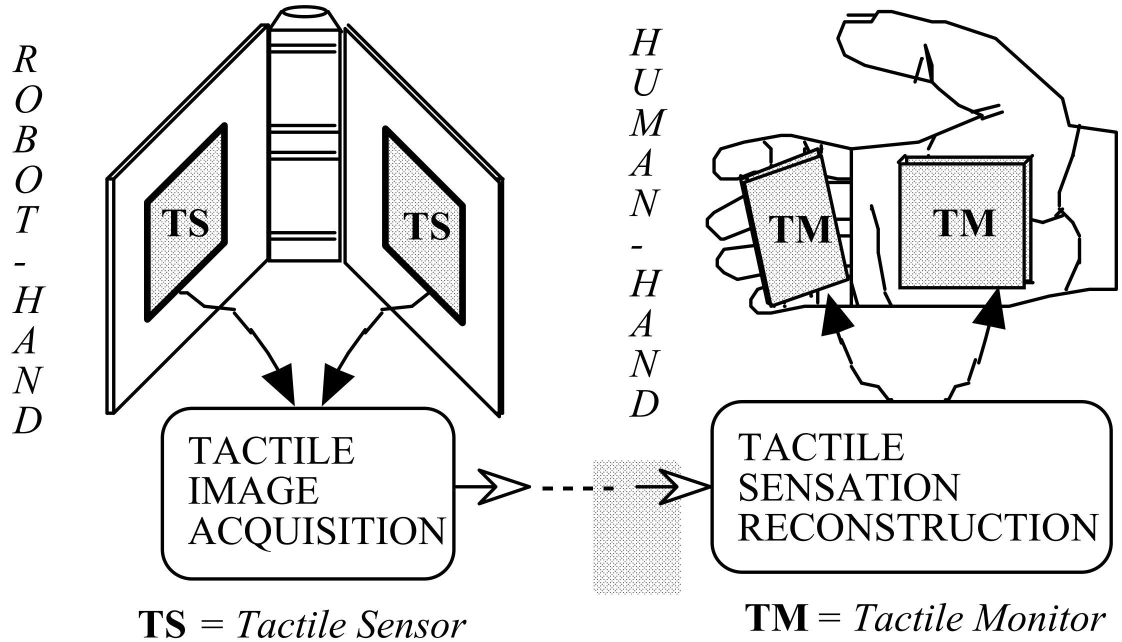


[from V. Prado da Fonseca, D.J. Kucherhan, T. E. Alves de Oliveira, D. Zhi, E.M. Petriu "Fuzzy Controlled Object Manipulation using a Three-Fingered Robotic Hand," 10th *Annual IEEE Int. Systems Conference - SysCon 2017*, pp. 346 - 351, Montreal, Que, April 2017].

Haptic Human Interfaces

- These interfaces should allow the human operator to
- experience natural-like, *conformal to the reality*, feeling of geometric profile, force, texture, elasticity temperature, etc.

- These interfaces should have easily perceivable and *sensor-transparent information displays* (monitors) in such a way to offer a 1:1 mapping of the corresponding human sensory modality.

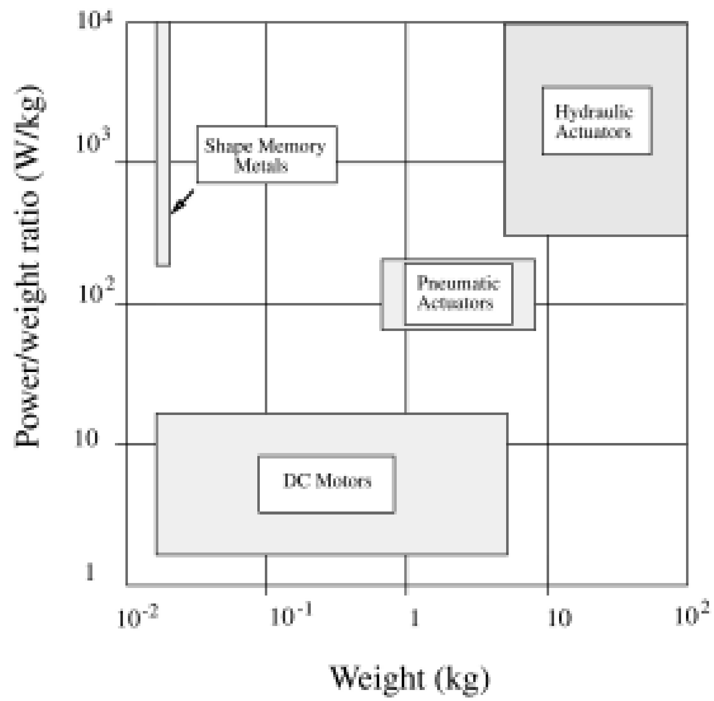


A **tactile monitor** placed on the operator's palm allows the human teleoperator to virtually feel by touch the object profile measured by the tactile sensors placed in the jaws of the robot gripper (from [E.M. Petriu, W.S. McMath, "Tactile Operator Interface for Semi-autonomous Robotic Applications," *Proc.Int. Symposium on Artificial Intell. Robotics Automat. in Space, i-SAIRS'92*, pp.77-82, Toulouse, France, 1992.])

Haptic Feedback Actuator Requirements
(*from [Burdea & Coiffet 2003]*)

- need to maximize power/weight ratio;
- need to have high power/volume ratio;
- need to have high bandwidth;
- need to have high dynamic range (fidelity);
- need to be safe for the user

⇨ None of the current actuator technology satisfies all these requirements.



Actuator comparison based on P/W ratio (*from [Burdea & Coiffet 2003]*)

Immersionn_3D Interaction <http://www.immersion.com/>

CyberGlove®

CyberTouch™

CyberGrasp™

CyberForce®

Immersionn_3D Interaction <http://www.immersion.com/>

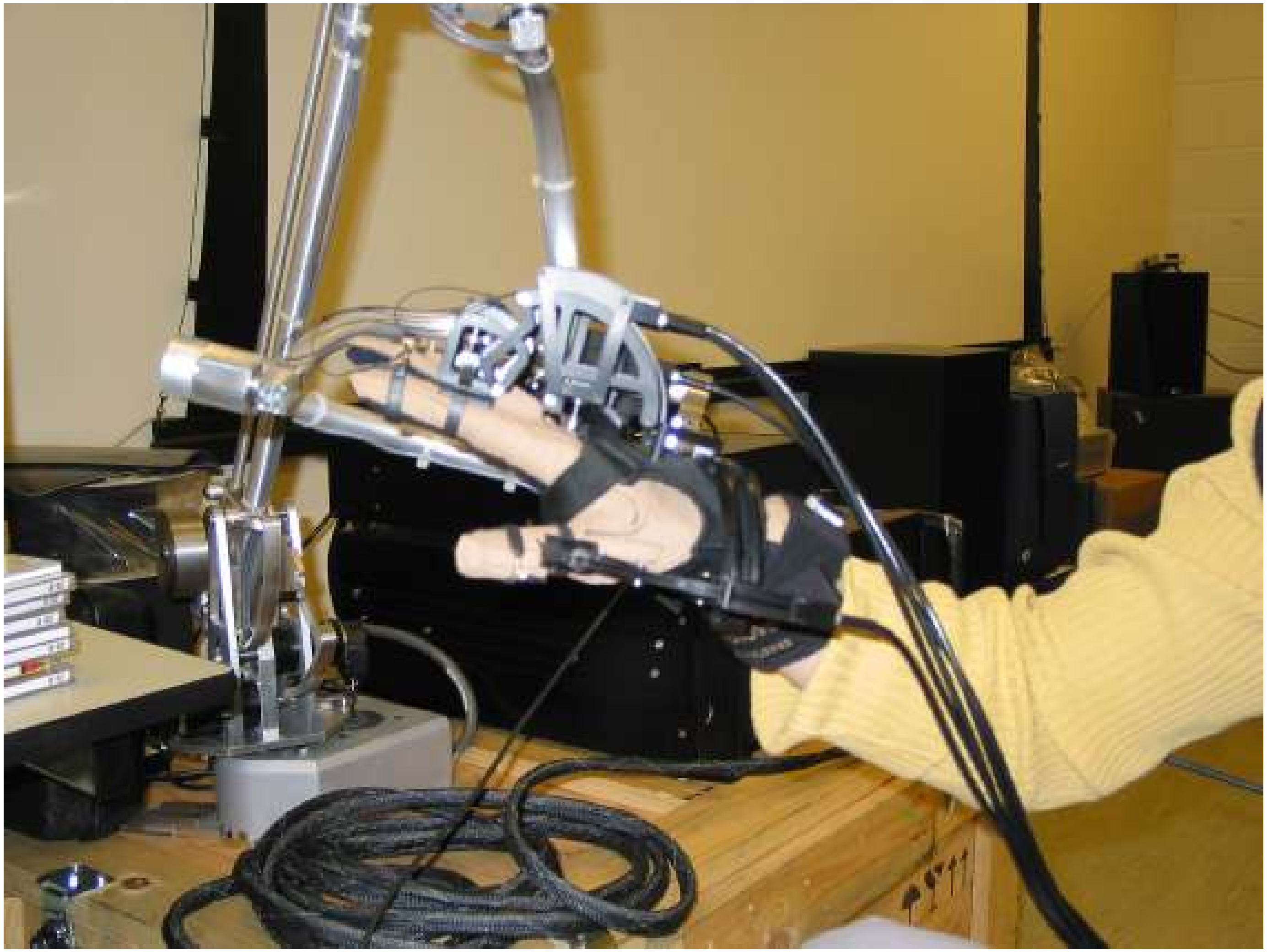
CyberGlove®

- uses 18-22 linear sensors – electrical strain gauges;
- angles are obtained by measuring voltages on a Wheastone 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

6 individually
controlled
vibrotactile
actuators

0-125 Hz frequency;
1.2 N amplitude at 125 Hz.

CyberTouch Glove (Virtex) (*from [Burdea & Coiffet 2003]*)



Commercial “Virtual Hand Toolkit for CyberGlove/Grasp”
providing the kinesthetic human feedback interface

Canadian Space Agency:

In 1981, Canada confirmed its position as a world leader in space technology with the development of the Remote Manipulator System, or **Canadarm**. The RMS can be used: to deploy and retrieve satellites, to hold targets, to explore samples, and to manipulate hardware for the Space Shuttle.

In 1988, Canada agreed to join the international partners to build a permanently inhabited Space Station. Canada's contribution is to design, manufacture, and operate a robotic system, the **Mobile Servicing System** (MSS), for assembly, maintenance, and servicing tasks on the Space Station.

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Vision-Based Sensing and Control for Space Robotics Applications

Michael E. Stieber, *Member, IEEE*, Michael McKay, George Vukovich, *Member, IEEE*, and Emil Petriu, *Senior Member, IEEE*

***Abstract*—The following problems arise in the precise positioning of payloads by space manipulators:**

1) **the precise measurement of the relative position and motion of objects in the workspace of the robot;**
2) **the design of a control system, which is robust and performs well in spite of the effects of structural flexibility and oscillations typically associated with space robots.**

This paper discusses the solution to the measurement problem by a vision system using photogrammatic image processing to determine the motion of objects in real time. Performance characteristics are presented. The control problem is addressed by a new technique dealing effectively with the challenge posed by the noncollocated sensor/actuator configuration on the flexible robot structure. The laboratory implementation of the measurement and control concepts is discussed. Preliminary results validate the concepts.

***Index Terms*— Artificial vision, control, measurement of motion, photogrammetry, robotics.**

I. Introduction

ROBOTIC systems will play an important role in reducing hazards and increasing productivity of humans in space. A prime example is the Mobile Servicing System (MSS) shown in Fig. 1 which is presently being developed by the Canadian Space Agency for the assembly and external maintenance of the International Space Station (ISS) [1]. As the tasks performed by space robots become more complex, the need for more human-like characteristics emerges. As with humans, the sense of sight is essential to enabling efficient interaction with the environment. More important than the sense of sight per se is the ability to process images in such a way as to enable more efficient, accurate and autonomous control of the robot.

This paper addresses measurement and control problems associated with the precise positioning of large space robot manipulators like the Space Station Remote Manipulator System (SSRMS) shown in Fig. 1, which typically have a very high payload-to-manipulator mass ratio (e.g. 116 000 kg/1500 kg for SSRMS) and relatively low stiffness, resulting in highly time-variant dynamic behavior with significant low-frequency oscillations. A theoretical concept for the systematic design of an instrumentation architecture for such systems was presented in [2]. This paper discusses the experimental implementation and evaluation of this concept in a laboratory setting. Section II discusses the measurement of the manipulator payload motion, including the contributions due to structural flexibility, relative to other objects in the manipulator workspace using a vision system. In Section III we extend the theoretical concept of [2] to the case of partially noncollocated sensor/actuator configurations on flexible structures and discuss the design and performance of a control system for the laboratory robot.

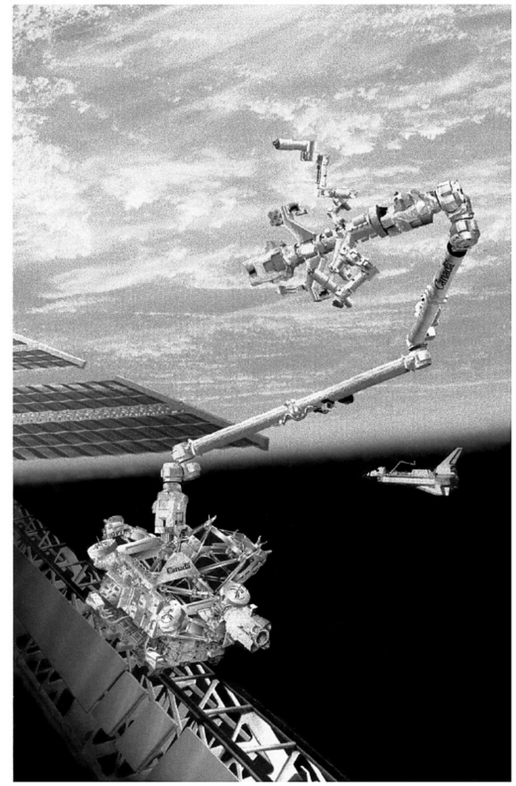

Fig. 1. Mobile Servicing System on the International Space Station.

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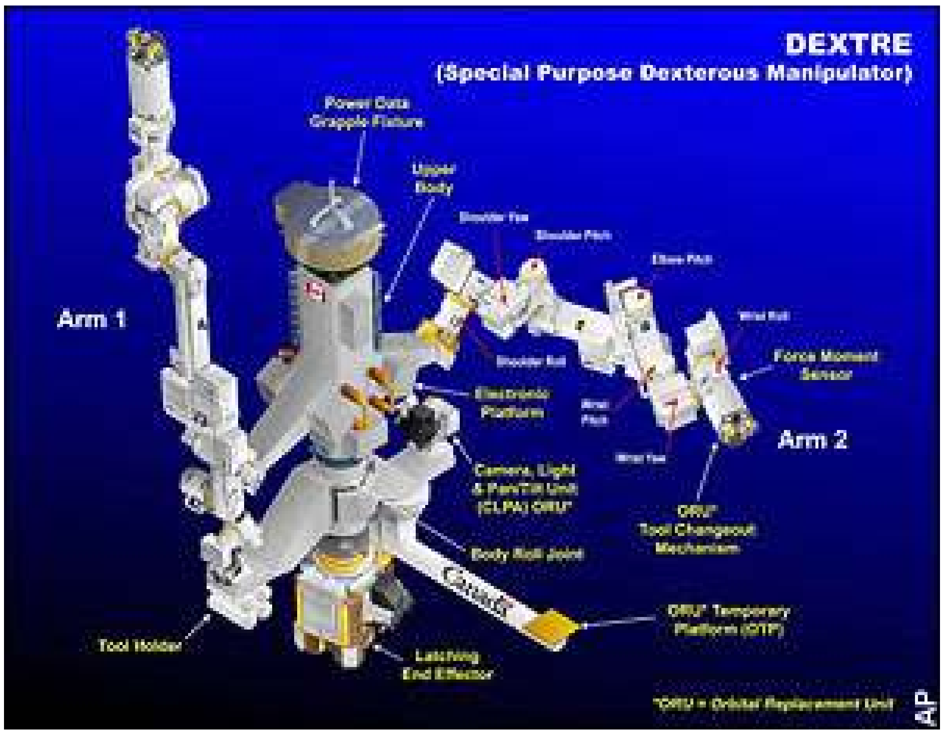
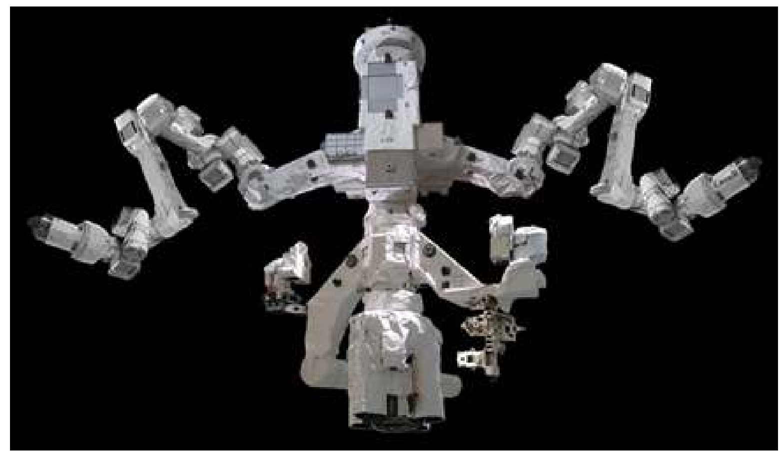
Canadian space robot 'Dextre' a high-tech marvel

Updated Mon. Mar. 10 2008 8:35 AM ET CTV.ca News Staff

,,,, Dextre the robot will be the latest Canadian-built addition to the International Space Station. "Dextre is the second arm for the station built by Canada," astronaut Steve Swanson told Canada AM on Monday from Cape Canaveral. "And its task is to do jobs that are more of a fine, finesse manipulator-type activity. Usually we would do spacewalks to change out components that have broken on the station. But now with Dextre, we can do that from inside and use Dextre's arms to do things that a human could do."





http://www.ctv.ca/mar/static/dextre/

Da Vinci Surgical System is a robotic surgical system made by the American company Intuitive Surgical. Approved by the Food and Drug Administration (FDA) in 2000, it is designed to facilitate complex surgery using a minimally invasive approach, and is controlled by a surgeon from a console.

Da Vinci System allows the surgeon's hand movements to be translated into smaller, precise movements of tiny instruments inside the patient's body.

As of June 30, 2014, there were installed 3,102 units worldwide. …. an estimated 200,000 surgeries conducted in 2012