Elective in Robotics

Geomagic Touch

Prof. Alessandro De Luca

Dipartimento di Ingegneria Informatica
Automatica e Gestionale Antonio Ruberti

Sapienza
Università di Roma

Geomagic Touch haptic device

2 devices available at DIAG Robotics Lab

Phantom Omni (it is the same!)

PHANTOM Omni ⇒ now Geomagic Touch

SensAble Technologies ⇒ now 3D Systems

Geomagic Touch data sheet

Force feedback workspace	~6.4 W x 4.8 H x 2.8 D in > 160 W x 120 H x 70 D mm
Footprint (Physical area device base occupies on desk)	6 5/8 W x 8 D in ~168 W x 203 D mm
Weight (device only)	3 lbs 15 oz (1.42 kg)
Range of motion	Hand movement pivoting at wrist
Nominal position resolution	> 450 dpi ~ 0.055 mm
Backdrive friction	< 1 oz (0.26 N)
Maximum exertable force at nominal (orthogonal arms) position	0.75 lbf (3.3 N)
Continuous exertable force (24 hrs)	0.2 lbf (0.88 N)
Stiffness	X axis > 7.3 lbs / in (1.26 N / mm)
	Y axis > 13.4 lbs / in (2.31 N / mm)
	Z axis > 5.9 lbs / in (1.02 N / mm)
Inertia (apparent mass at tip)	~0.101 lbm (45 g)
Force feedback (**3** Degrees of Freedom)	x, y, z
Position sensing [Stylus gimbal]	x, y, z (digital encoders)
(**6** Degrees of Freedom)	[Pitch, roll, yaw (± 5% linearity potentiometers)
Interface	RJ45 compliant on-board Ethernet Port or USB Port
Supported platforms	Intel or AMD-based PCs
OpenHaptics®Toolkit compatibility	Yes

Geomagic Touch in action

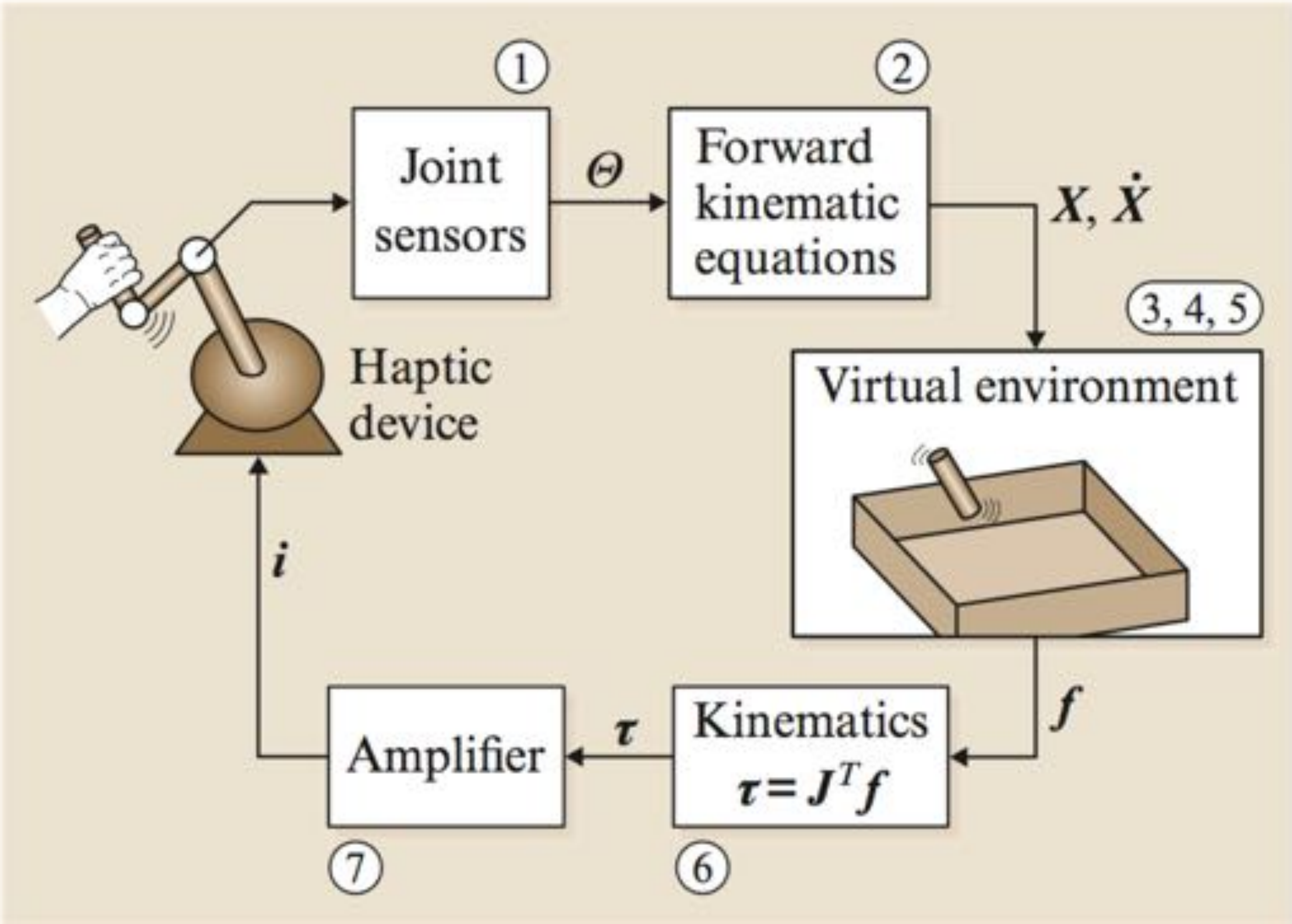
(actually, a Sensable Omni...)

video

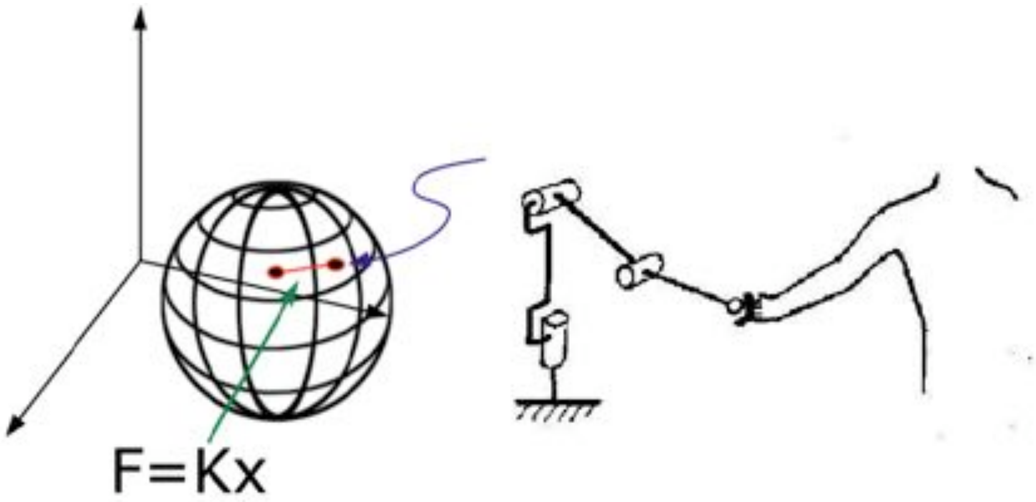
https://youtu.be/REA97hRX0WQ

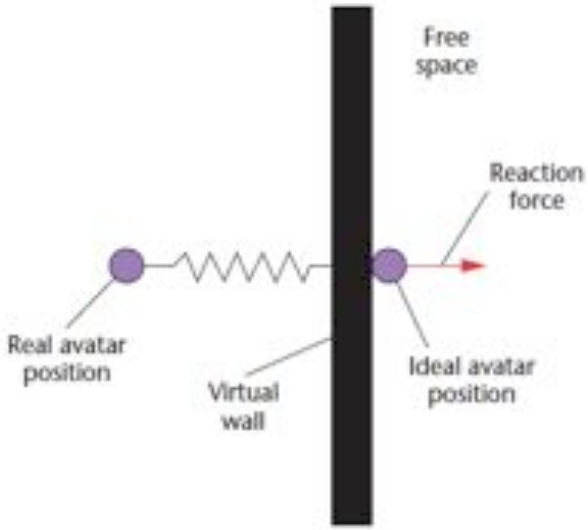
Haptic rendering control loop

① joint displacement sensing (on device)
② (direct) kinematics
③ collision detection (environment geometry)
④ surface point determination
⑤ force calculation
⑥ kineto-statics
⑦ actuation (on device)

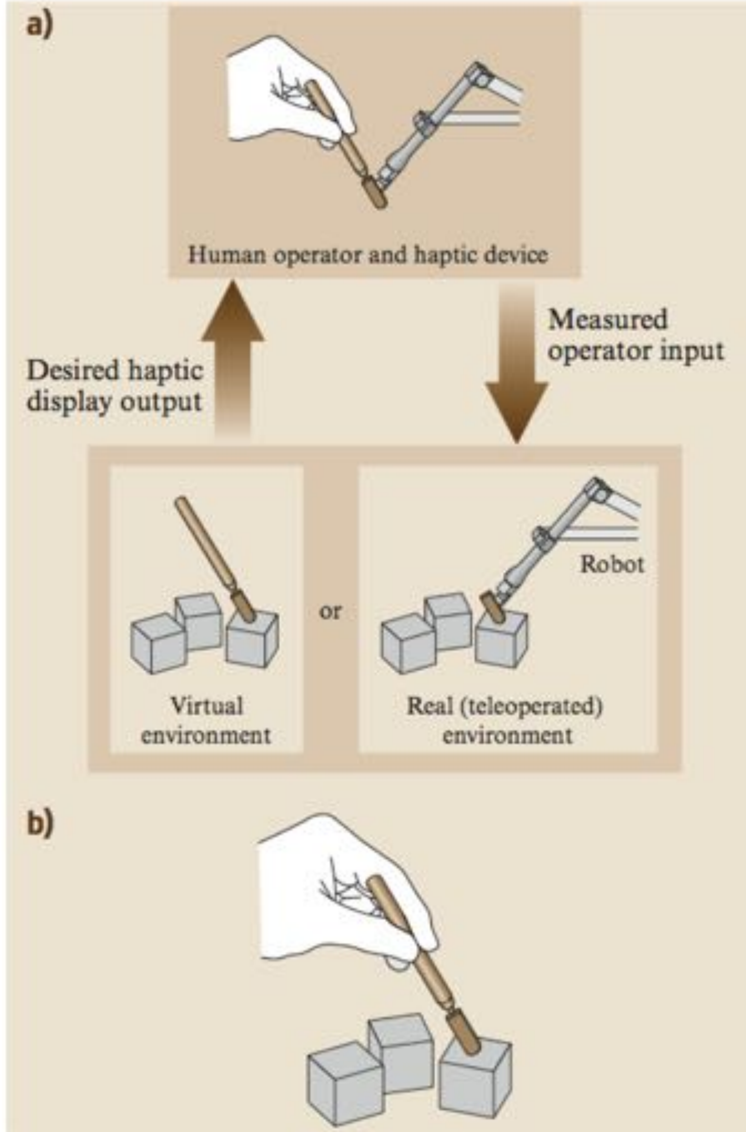


Force feedback from Virtual or Real world





virtual environment compliance modeled with a spring/damper



Force generation signals

© Allison M. Okamura, 2015

desired force (in software)

counts

D/A

volts

amplifiers

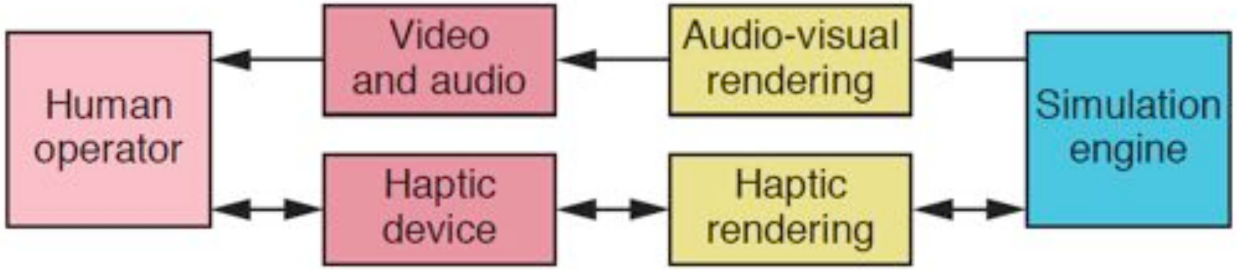
voltage or current

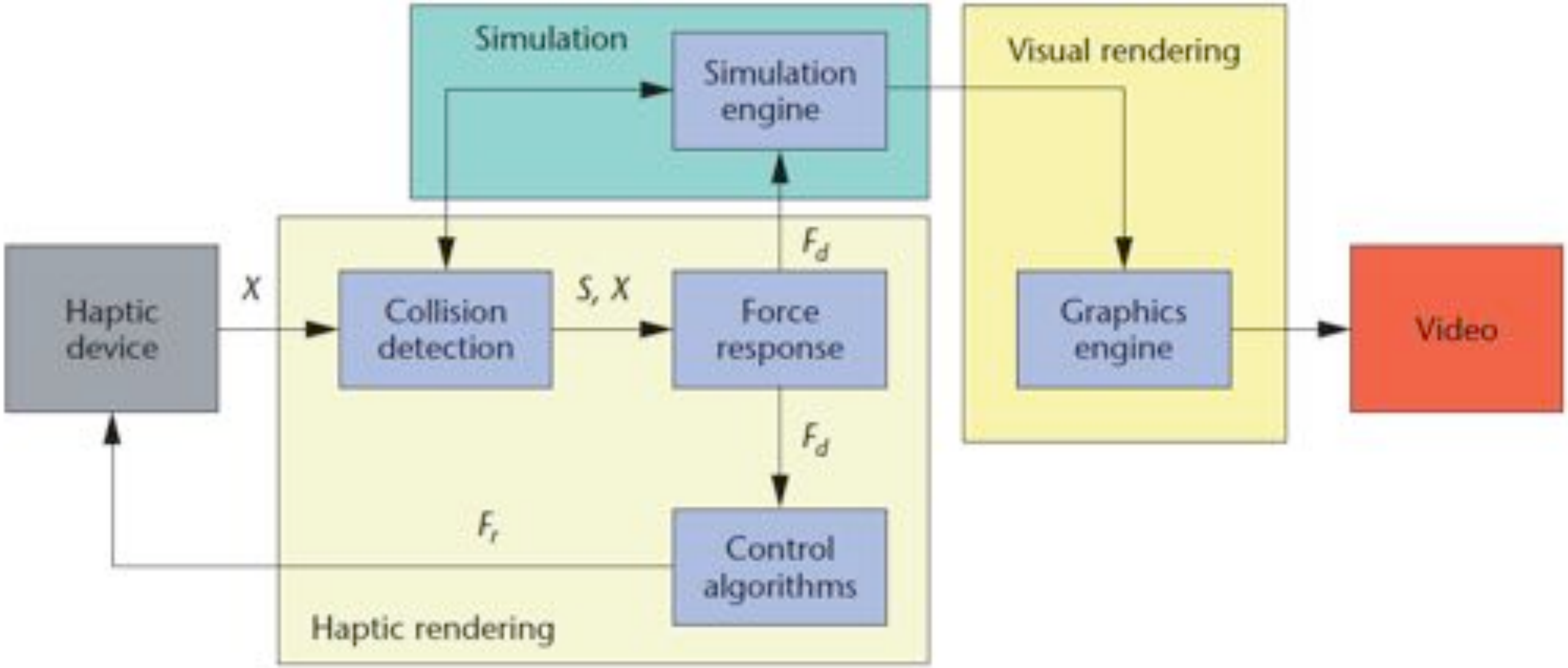
actuator torques

transmissions and kinematics

end-point (3D) force

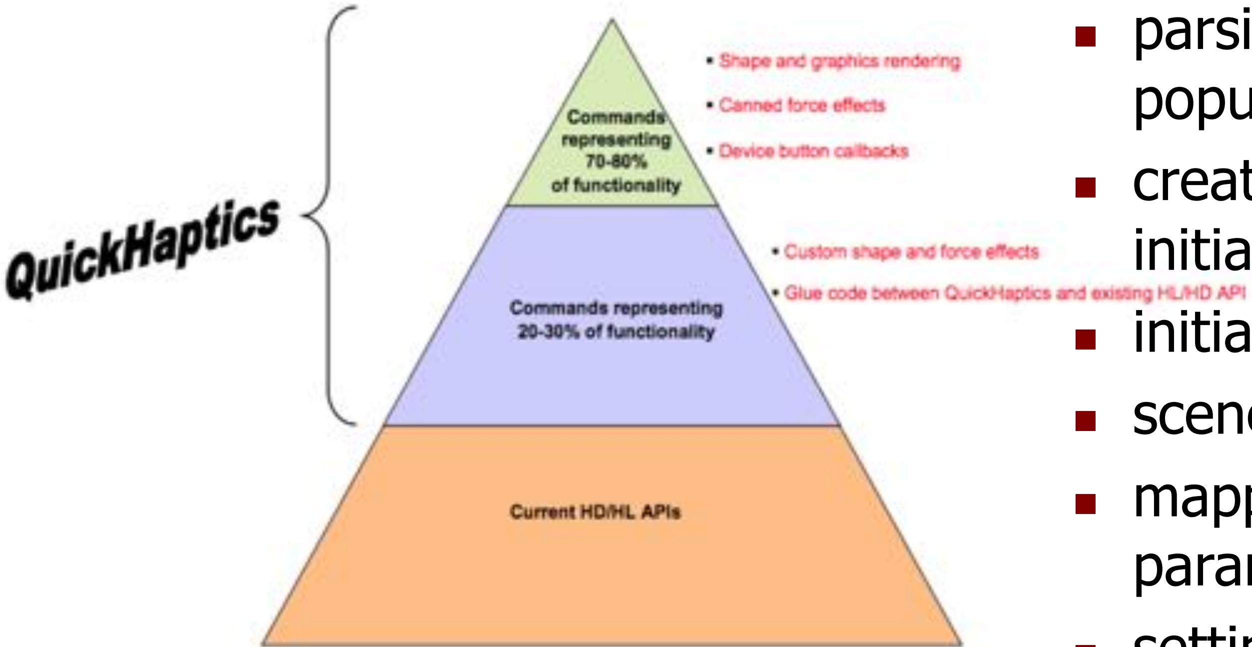
Haptic/visual rendering architecture





OpenHaptics 3.3.0

makes programming simpler by encapsulating the basic common steps to all haptics/graphics applications in C++ classes of the QuickHaptics micro API



common steps

- parsing geometry files from popular animation packages
- creating graphics windows and initializing OpenGL environment
- initializing the haptic devices
- scene and camera design
- mapping force and stiffness parameters to objects in the scene
- setting up callback responses to interaction devices

OpenHaptics Toolkit

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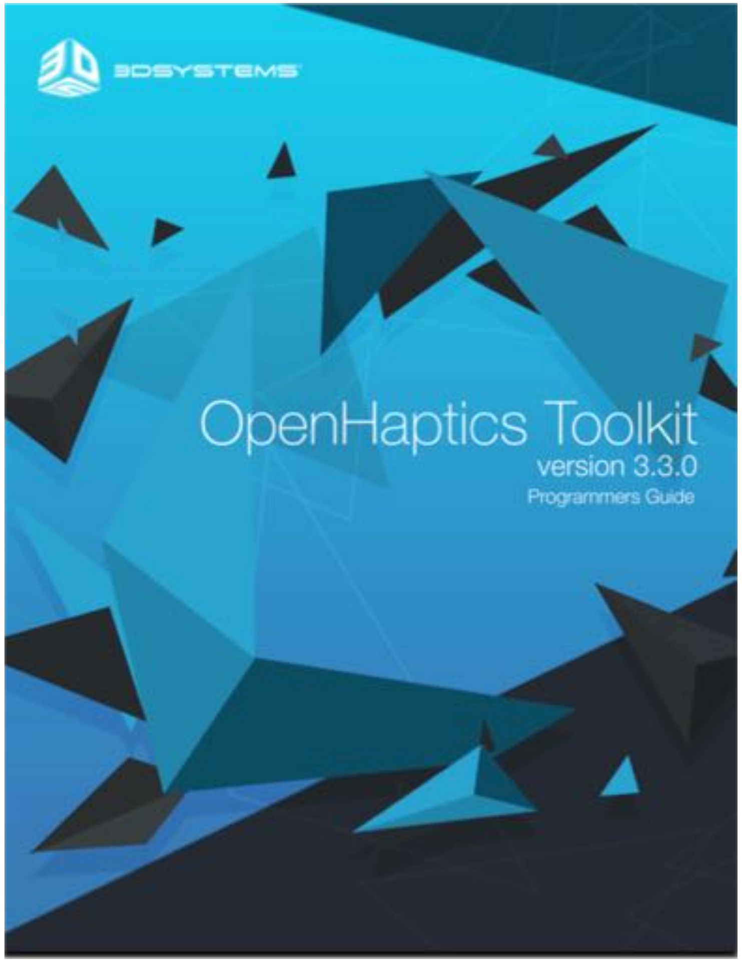

OpenHaptics Toolkit

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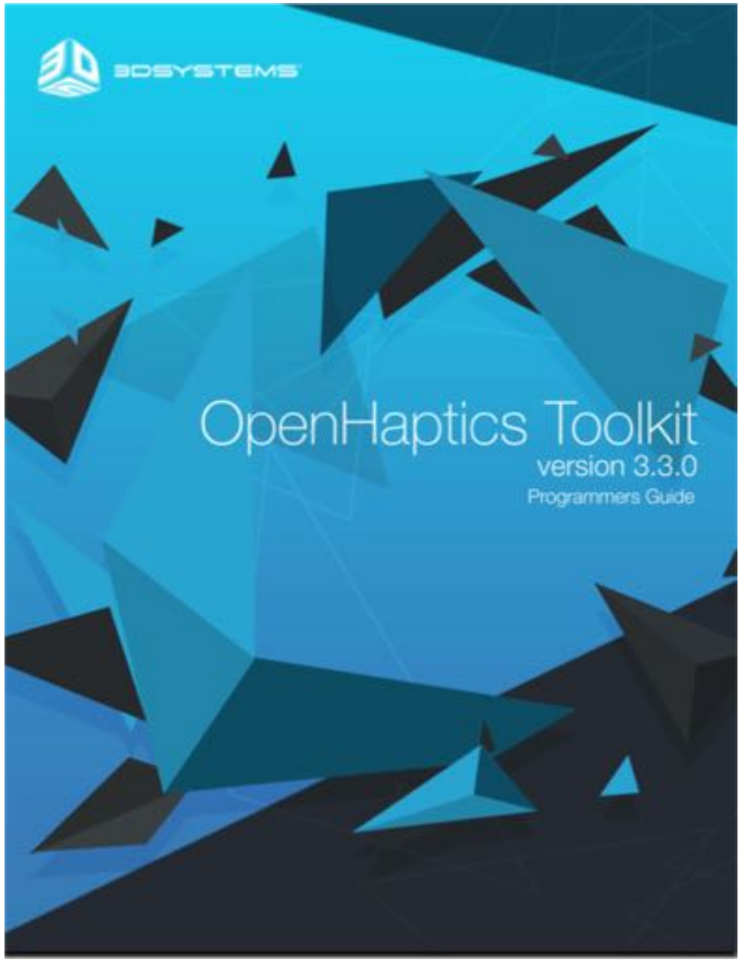

Haptic Device API

Haptic Library API

OpenHaptics Toolkit

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Vector Utilities

The <HDU/hduVector.h> header exposes a simple API for common vector operations in three dimensional space. the functions follows:

Default constructor

```
hduVector3Dd vec1;
vec1.set(1.0, 1.0, 1.0);
```

Constructor from three values

```
hduVector3Dd vec2(2.0, 3.0, 4.0);
```

Constructor from an array

```
HDdouble x[3] = {1.0, 2.0, 3.0};
hduVector3Dd xvec = hduVector3Dd(x);
```

Assignment

```
hduVector3Dd vec3 = hduVector3Dd(2.0, 3.0, 4.0);
```

Usual operations:

```
vec3 = vec2 + 4.0* vec1;
```

Magnitude:

```
HDdouble magn = vec3. magnitude();
```

Dot product:

```
HDdouble  dprod = dotProduct(vec1, vec2);
```

Cross product:

```
hduVector3Dd vec4 = crossProduct(vec1, vec2);
```

Normalize:

```
vec4.normalize();
```

Matrix Utilities

The <HDU/hduMatrix.h> header exposes a simple API for common matrix operations.

Default constructor

```
hduMatrix mat1;  // the identity matrix by default

HDdouble a[4][4] = {
                {a1,a2,a3,a4},
                {a5,a6,a7,a8},
                {a9,a10,a11,a12},
                {a13,a14,a15,a16}
        };
mat1.set(a);
```

Constructor from sixteen values

```
hduMatrix mat(a1,a2,a3,a4,a5,a6,a7,a8,
        a9,a10,a11,a12,a13,a14,a15,a16);
```

Constructor from an array

```
HDdouble a[4][4] = {
                {a1,a2,a3,a4},
                {a5,a6,a7,a8},
                {a9,a10,a11,a12},
                {a13,a14,a15,a16}
        };
hduMatrix mat2(a);
```

Assignment

```
hduMatrix mat3 = mat2;
```

Get values

```
double vals[4][4];
mat3.get(rotVals);
```

Usual operations

```
mat3 = mat2 + 4.0 * mat1;
```

Invert

```
mat3 = mat2.getInverse();
```

Transpose:

```
mat3 = mat2.transpose();
```

Create a rotation

```
hduMatrix rot;
rot = createRotation(vec1, 30.0*DEGTORAD);
HDdouble rotVals[4][4];
rot.get(rotVals);
glMultMatrixd((double*)rotVals);
```

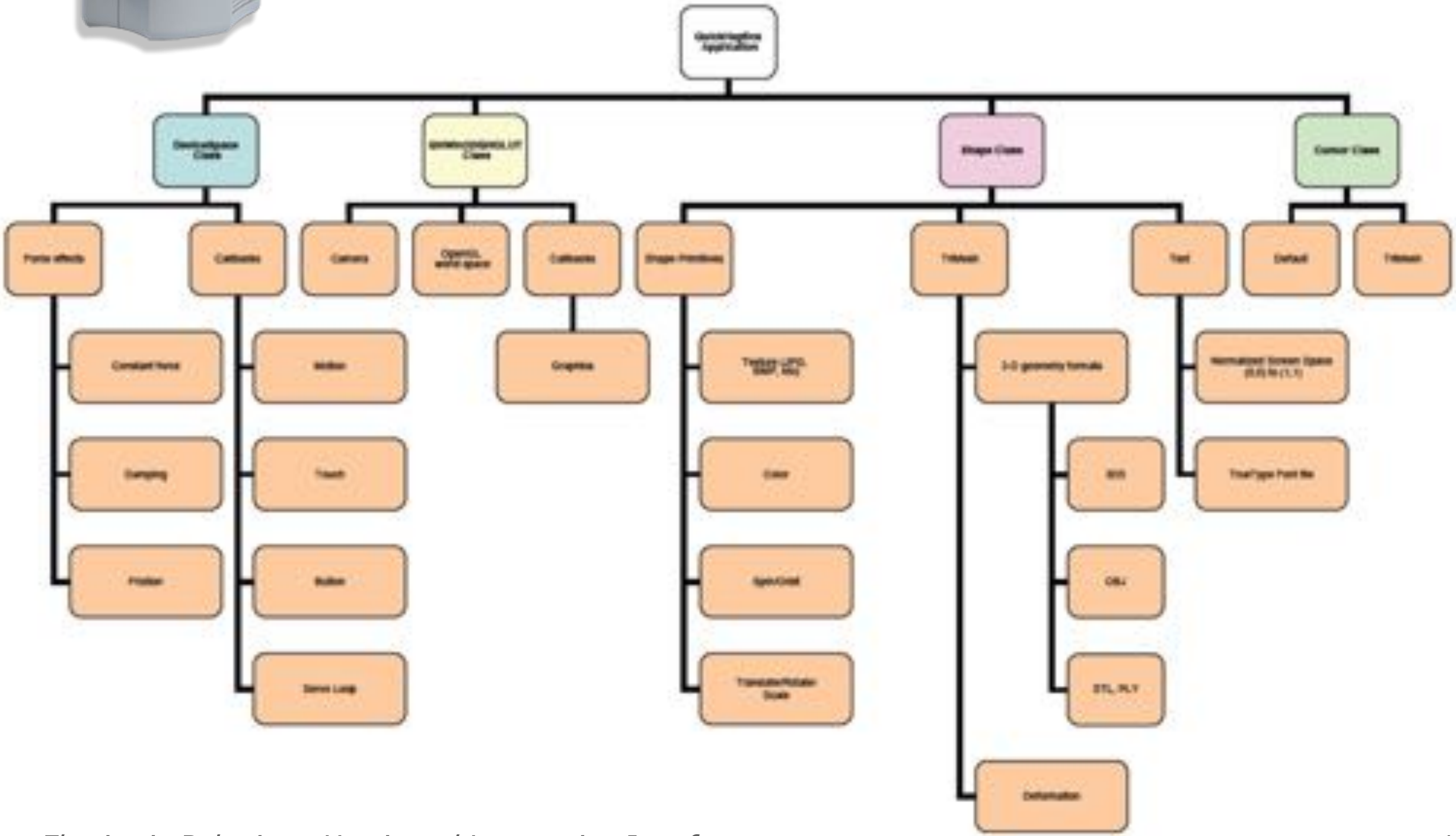
QuickHaptics micro API
classes and properties

implemented in C++, with
4 primary functional classes

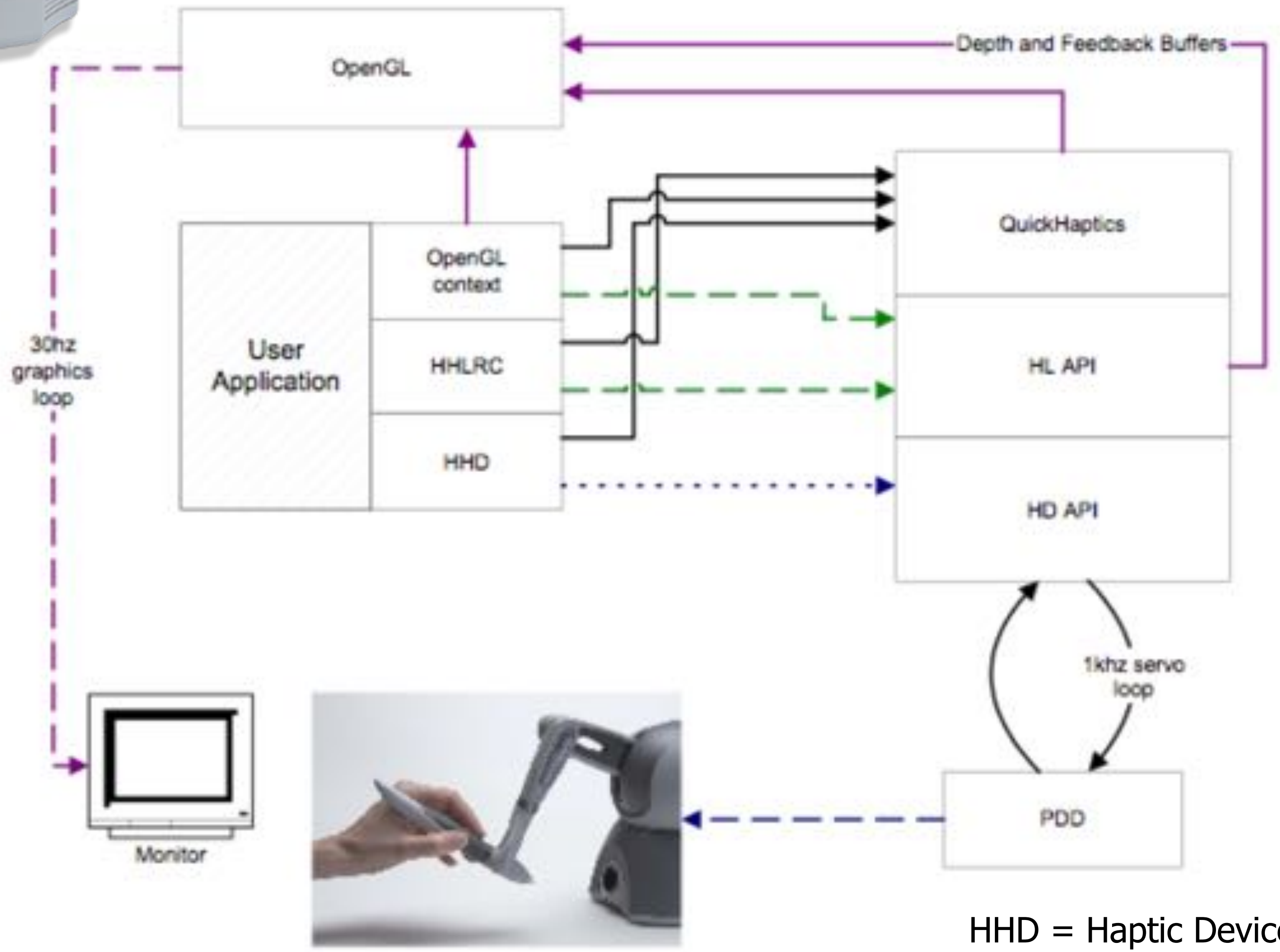
location of the
Haptic Interface Point (HIP)
on the Touch device

- DeviceSpace
  - workspace of motion for haptic device
- QHRenderer (OpenGL)
  - on-screen window that renders shapes from a camera viewpoint and lets the user feel those shapes via the device
- Shape
  - base class for one or more geometric objects that can be rendered both graphically and haptically
- Cursor
  - graphical representation of the end point of the second link of the device (HIP)

QuickHaptics micro API
classes and properties



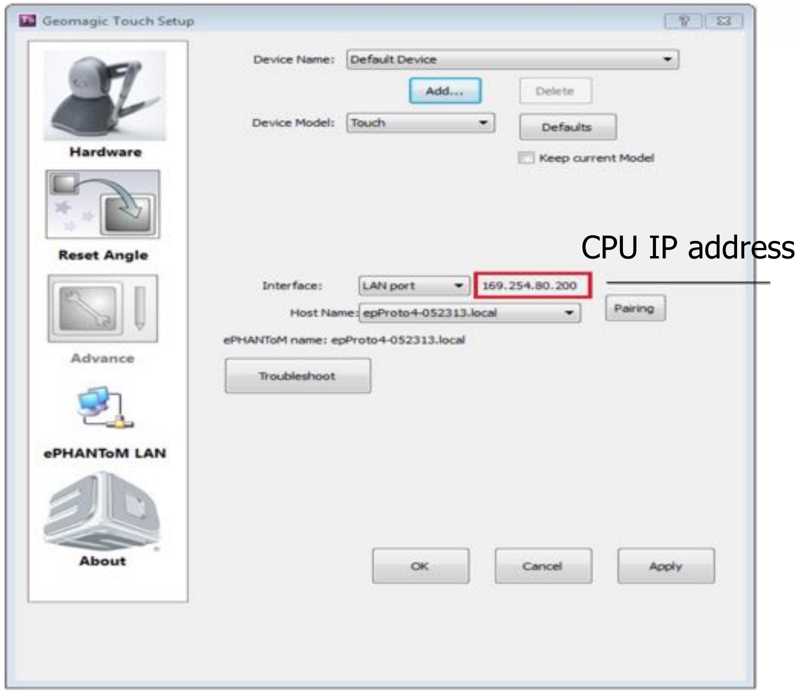
OpenHaptics Overview



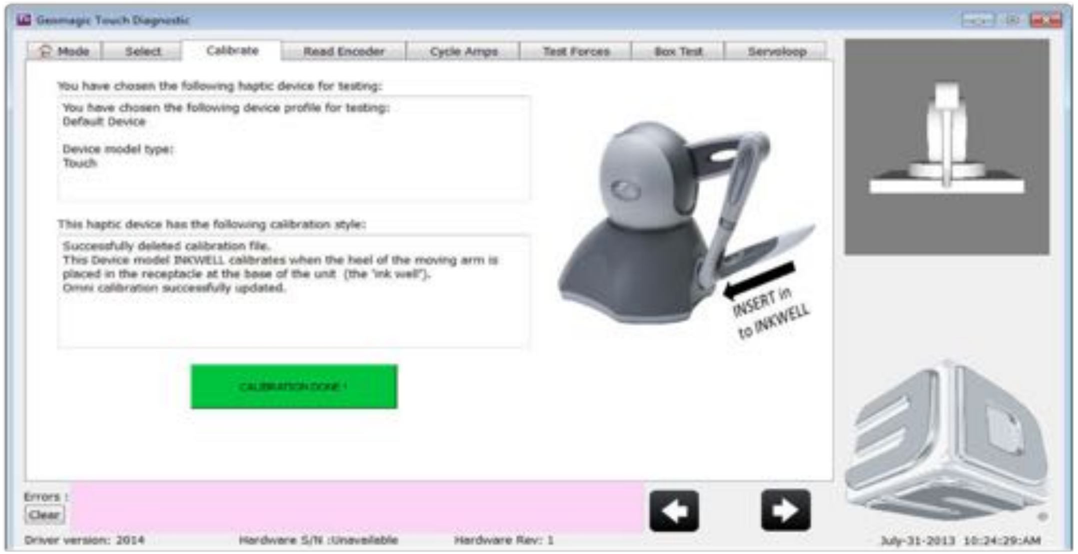
HHD = Haptic Device Handle
HHLRC = Haptic Rendering Context
PDD = ... Control

Setting up the system

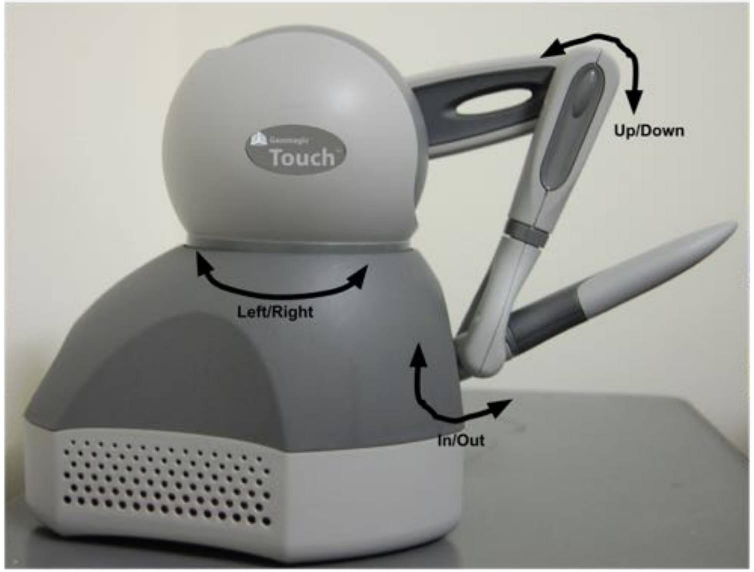
pairing the device



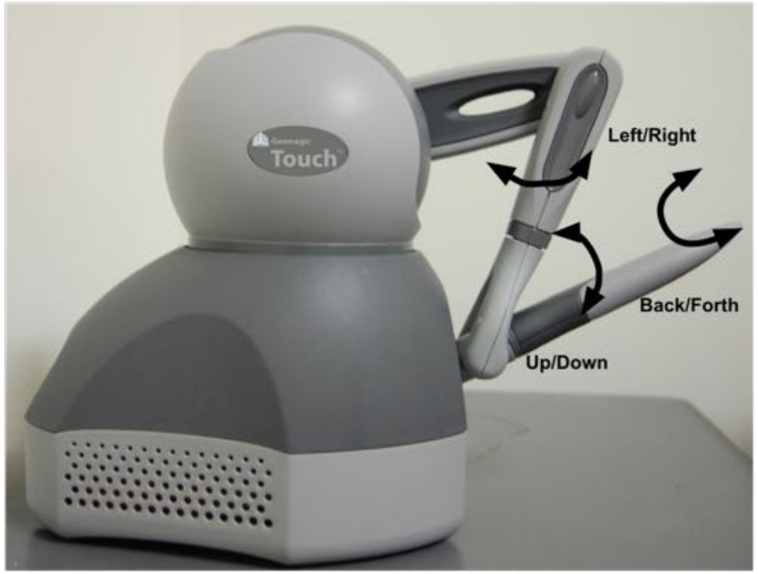
calibrating the device (stylus in the ink well)



Range of device motion

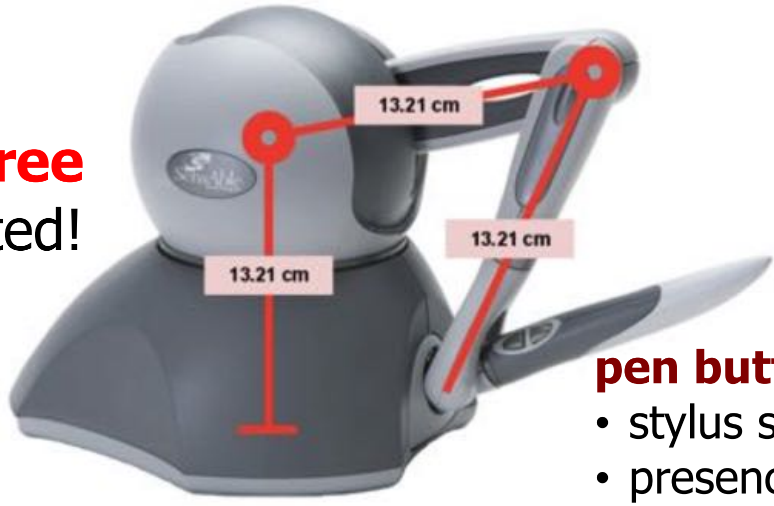


macro movements



micro movements
(of the stylus)
with fixed HIP

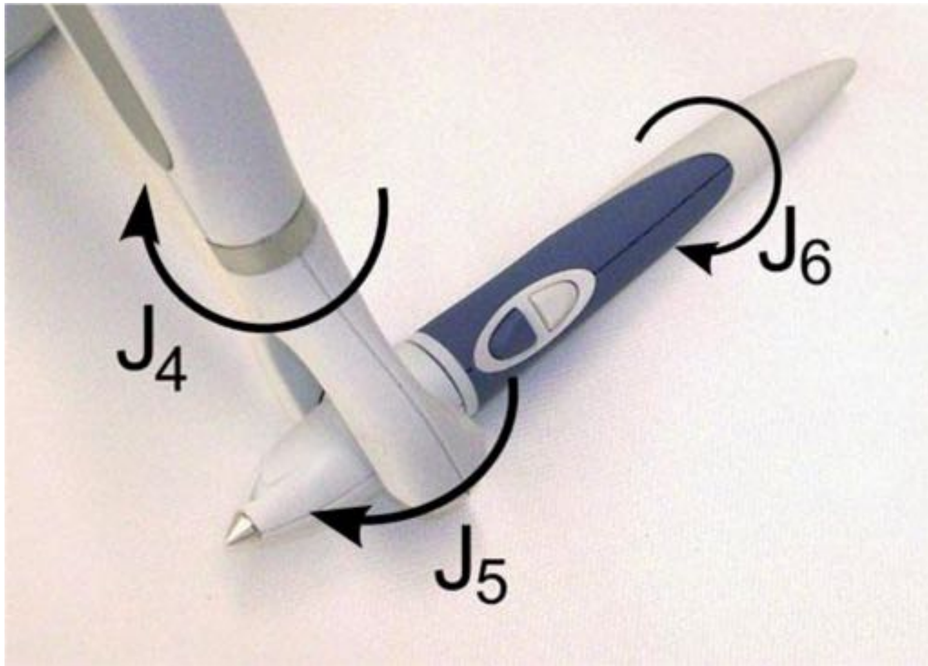
only the **first three** joints are actuated!



pen buttons

- stylus switch ON if pressing **dark** gray button
- presence switch ON if pressing light gray button

Degrees of freedom



first three joints
(positioning of the HIP):
actuated

last three joints as spherical wrist
(orientation of the stylus):
passive

What could be studied?

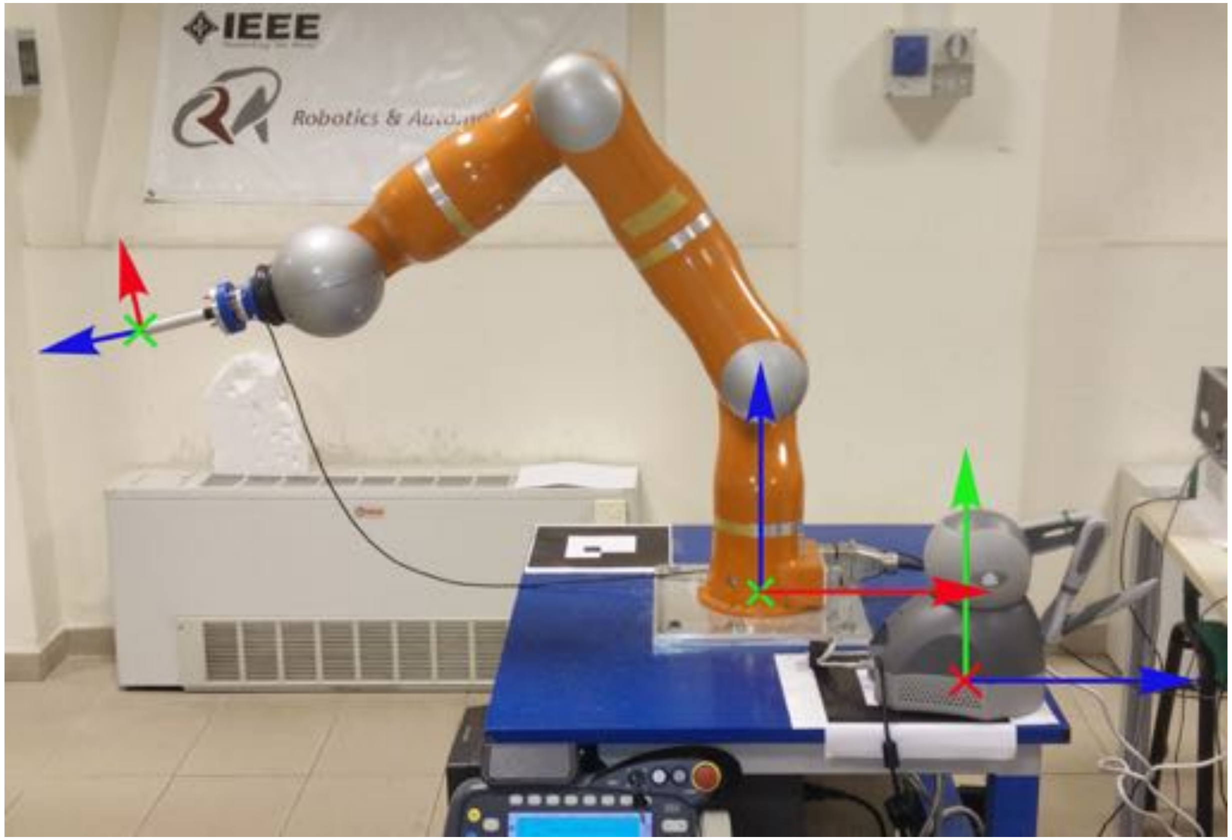
- DH parameters and forward kinematics
- inverse kinematics
- Jacobian matrix and singularities
- joint level PD and PID control
- trajectory planning (joint space vs. task space)
- various haptic (force) rendering laws
  - force fields, “god point”, hard and soft contacts

- *on-going development of a software environment for the simulation of the haptic device...*

Medical application

Laboratory test bed
with KUKA LWR4

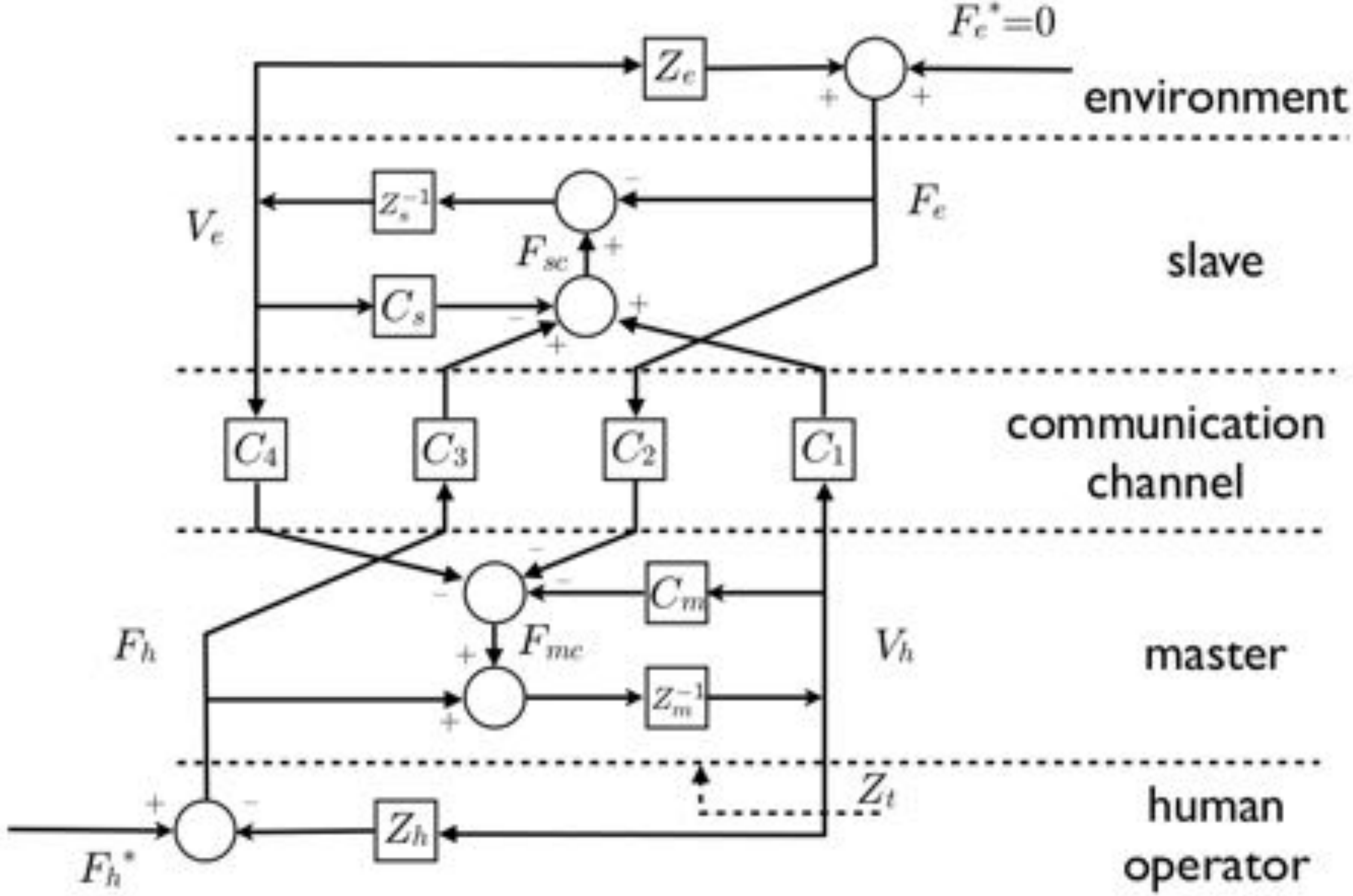
reference frames



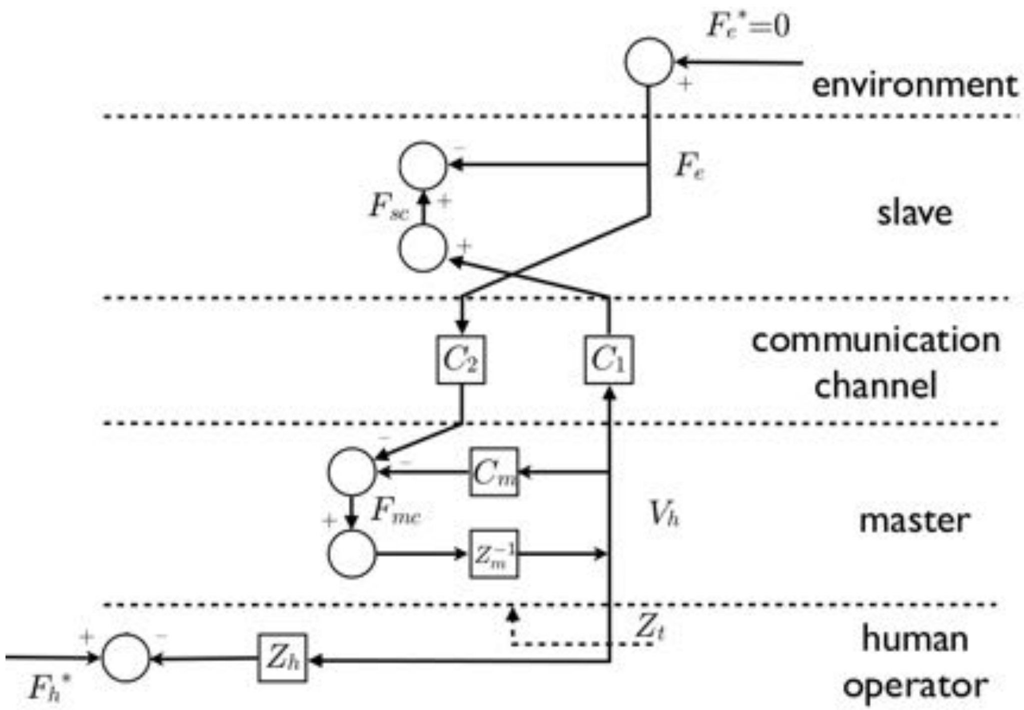
slave = KUKA robot manipulator

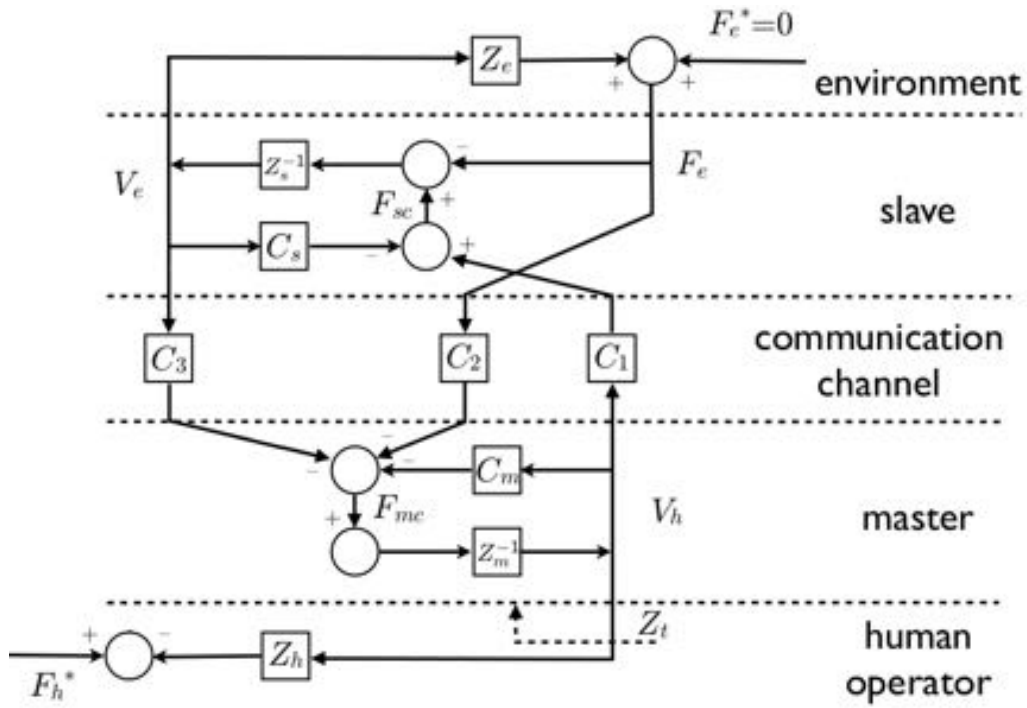
master = Touch haptic device

Teleoperation control
(4-way) general scheme



Teleoperation control
2-way and final 3-way implemented solution





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"hands on" trial

First demo presented in April 2016 by Andrea Perica and Francesco Iodice

Medical Robotics & Robotics II - Project Report
Academic year 2014/2015

Remote needle insertion with reconstructed force feedback

Evangelista Daniele[1], Iodice Francesco[2], Monorchio Luca[3], Perica Andrea[4]

Abstract
Telematics operation in medical robotics is the new frontier of surgery in which several factors must be taken into account, e.g. to ensure the health of the patient the sensibility of the force feedback that the robot sends to the surgeon must be reconstructed with extremely accuracy. This is a fundamental priority in this project, just think about how it can be helpful to feel physical contacts while staying in a different place, also very far away from the surgery room. Nevertheless, these applications are set to become the future of surgery entrusting a large part of the work from the surgeon to the medical robots.

[1] *Master in Artificial Intelligence and Robotics, mat. 1665872*
[2] *Master in Artificial Intelligence and Robotics, mat. 1651209*
[3] *Master in Artificial Intelligence and Robotics, mat. 1650427*
[4] *Master in Control Engineering, mat 1313336*

Contents

Introduction

In the last years robots have improved the quality of human life in many contexts, from factory to personal uses. However, today, fast technology evolution brings the human mind to think "how can this technology be used to improve safety and accuracy especially in medical applications?". Medical Robotics is the responsible branch for those problematics, starting from disease discovery to surgery applications. Advanced tools and sensors have been developed in the past years of research, one example of medical robots, already in use in many surgery scenarios is the Da Vinci Surgical System. It is a surgical robot designed to facilitate complex surgeries using a minimally invasive approach like prostatectomies, cardiac valve repair and gynecologic surgical procedures.

The project that we are going to illustrate is called "Remote needle insertion with reconstructed force feedback", a telematics operation in which a haptic interface (from now called *master device*) manages the movements of a robot (from now called *slave device*) that will be responsible mainly for two tasks: needle insertion and force feedback response. Actually this application could be used from a surgeon to operate a patient from a different location with respect to the surgery room and, at the same time, perceiving all the forces coming from robot/patient interactions. The experiments have been done in the Laboratory of Robotics in the Dipartimento di Ingegneria Automatica e Gestionale at La Sapienza University of Rome.
The master device is the *Phantom Geomagic Touch* interface, a haptic device designed by *Geomagic*, instead the slave device is the *KUKA LWR Robot* developed by *KUKA Industries*.

In the next paragraphs the principal aspects of all the work will be illustrated, starting from formalization of the problem ending with the principal issues and solutions that we have been encountered during the way and some of the performed experiments. We will see how the obtained results show accurately that the needle insertion with feedback force reconstraction is an important aspect for the medical robotics applications, and lots of further improvements can be done in this direction.

This year demo is on December 1, 2017 16:00-18:00, c/o room A4
introduced by Prof. Marilena Vendittelli