Introduction to the Geomagic Touch haptic device and the relative software libraries

Faculty of Information Engineering, Computer Science and Statistics
M.Sc. in Artificial Intelligence and Robotics
AA 2016-2017

Sapienza Università di Roma

Professor:
Alessandro De Luca

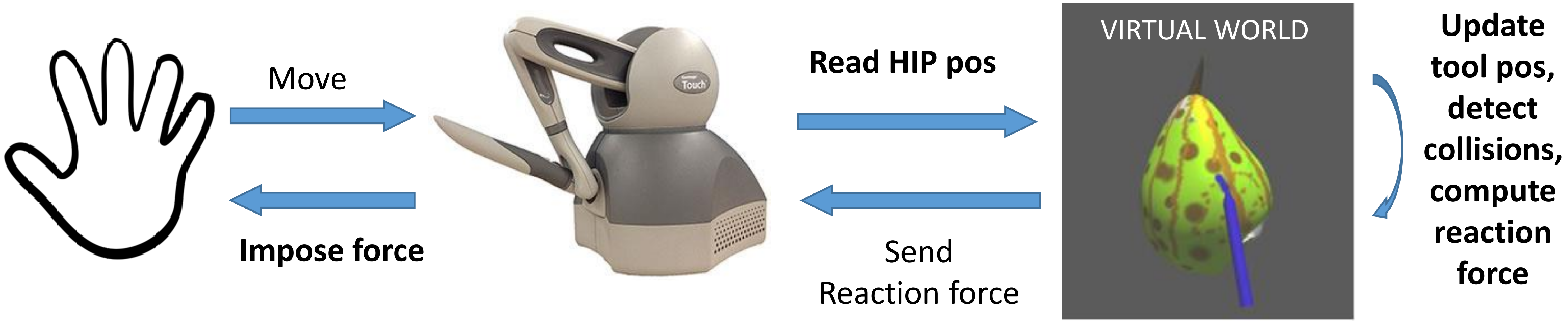
Presenters:
Andrea Gigli, Irvin Aloise, Mirco Colosi

Haptic Interfaces

Robotic devices that allow physical interaction with a virtual environment or a teleoperated system.

Haptic Rendering

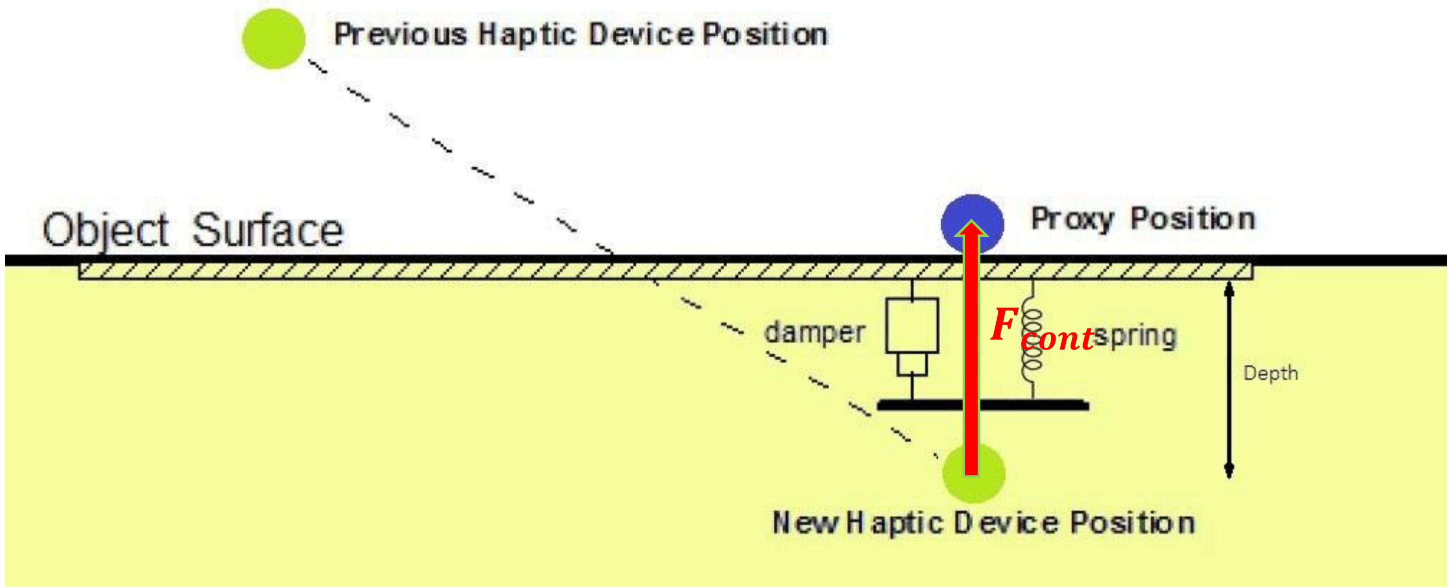
Idea: HIP (Haptic Interface Point) coupled with a tool in virtual space. When the tool collides with a virtual object, the user feels an artificial reaction force.



Different kind of forces: Contact forces, Friction forces, Teleoperation forces, Effects..

CONTACT FORCES

Interaction between virtual HIP (vHIP) and virtual object = spring-damper system

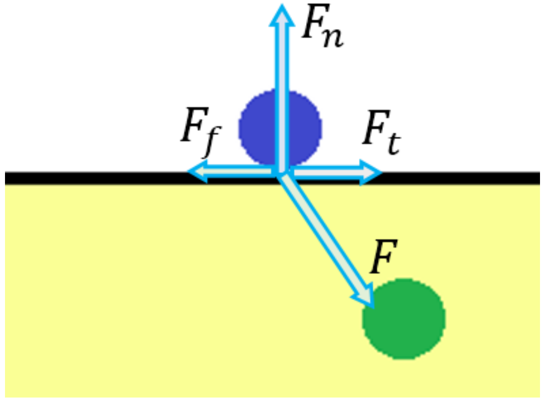


When vHIP inside object:

- Compute Proxy point
- Direct the reaction force from the vHIP toward the proxy
- $F_{cont} = k * depth + b * vel$
  depth = depth of penetration
  vel = velocity of the vHIP

[Example from OpenHaptics: 'HapticMaterials']

Friction Forces

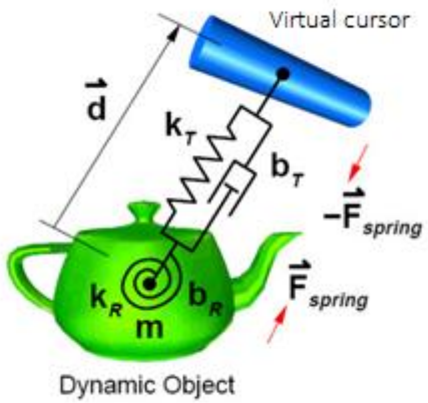


Static and dynamic friction forces are computed on the proxy

$$F_{f_s} = \mu_s * F_n$$
$$F_{f_d} = \mu_d * F_n$$
$$\text{no movement if } F_{f_s} > F_t$$

- Slight modification of the proxy algorithm for contact forces

Virtual coupling forces



“Feel” the inertia of a virtual body connected to the vHIP.

- Typical of position/position teleoperation schemes.

[Example from OpenHaptics: ‘SimpleRigidBodyDynamics’]()

Force Effects

Forces that arise from the movement in a portion of the virtual space.
Not linked to any virtual object.

- Viscous friction
- Stick-slip effect
- Vibration

[Example from CHAI3D: ‘Effects’]

Constraints = Virtual Fixtures

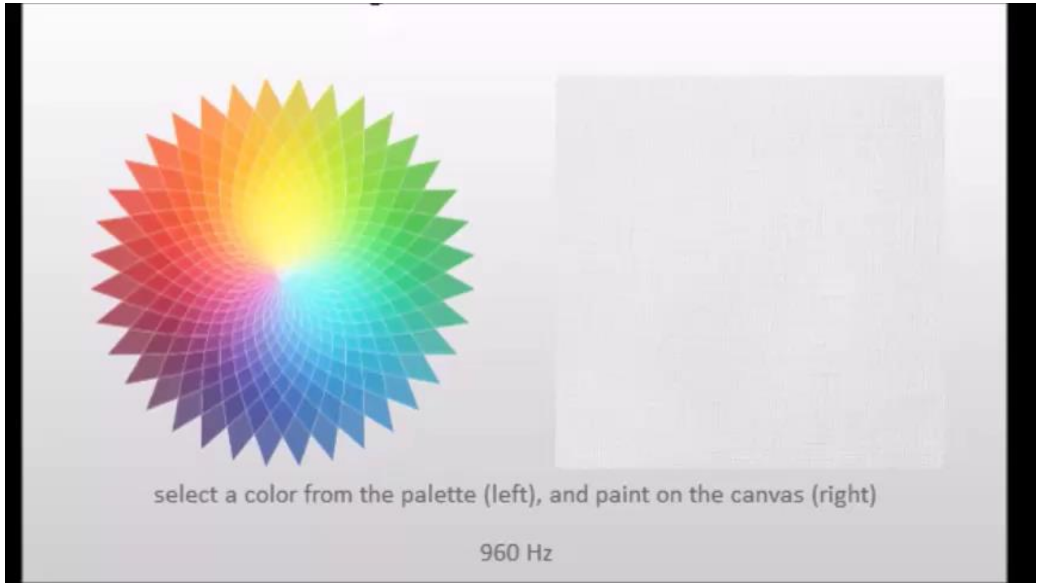
Attractive/Repulsive forces that constraint the vHIP (then the HIP!) to a specific geometric region (dot, line, plane, surface) in the virtual environment.

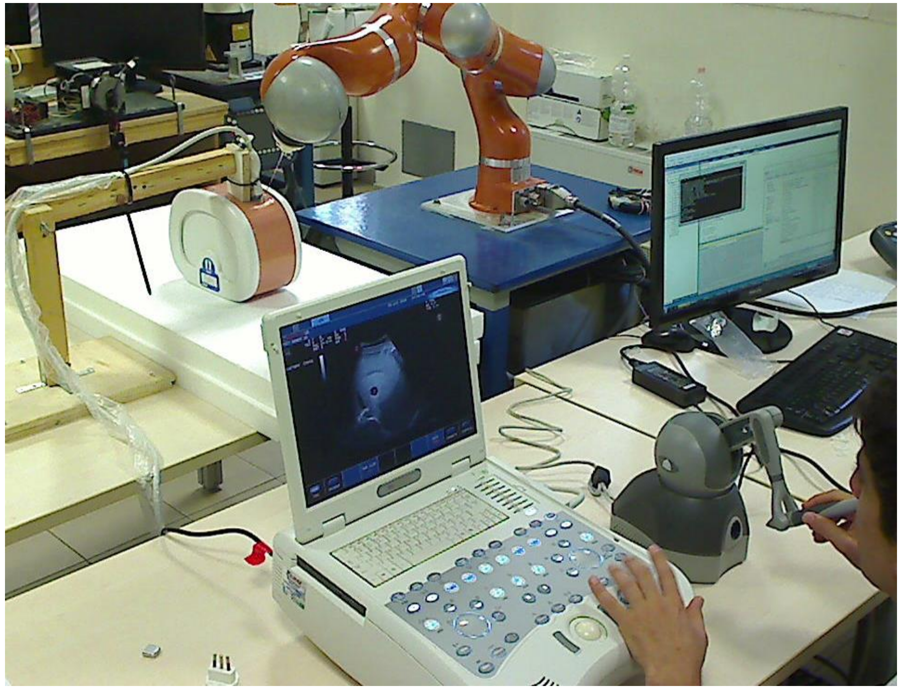
- Elastic/Magnetic attraction toward a constraint
- Viscous friction in forbidden directions

[Example from OpenHaptics: ‘Constraints’]

Applications of Haptic Interfaces

- Touch surfaces
- Manipulate objects (move, deform, decompose)
- Create new objects (object carving, 3D painting)
- Navigation in virtual environments
- Teleoperation of virtual or real robots
- Coordination of a team of robots





Examples from CHAI3D:
'Textures', 'Magnets', 'Effects',
'Paint' , 'Map' , 'Object' , 'Voxel'

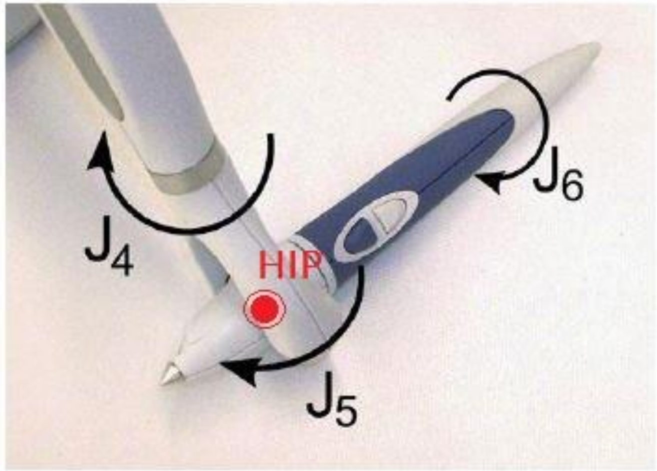
GEOMAGIC TOUCH

- Geomagic Touch by 3D System (previously called Phantom Omni by SensAble Technologies)
- 2 buttons
- Compatible with OpenHaptics 3.4 and CHAI3D libraries.

Workspace	~6.4 W x 4.8 H x 2.8 D in > 160 W x 120 H x 70 D mm
Range of motion	Hand movement pivoting at wrist
Nominal position resolution	> 450 dpi ~0.055 mm
Maximum exertable force and torque at nominal position (orthogonal arms)	0.75 lbf/3.3 N
Stiffness	x-axis > 7.3 lb/in (1.26 N/mm) y-axis > 13.4 lb/in (2.31 N/mm) z-axis > 5.9 lb/in (1.02 N/mm)
Force feedback	x, y, z
Position sensing/input **[Stylus gimbal]**	x, y, z (digital encoders) [Roll, pitch, yaw (± 5% linearity potentiometers)]
Interface	RJ45 Compliant Ethernet Port

GEOMAGIC TOUCH

First three joints are actuated



Last three joints form a passive spherical wrist

HIP (Haptic Interface Point) is the center of the spherical wrist

OpenHaptics Toolkit 3.4

Proprietary (3DSystems) C++ libraries that allow:

- Interfacing with all the haptic devices of the Phantom family (by 3DSystems)
- Development of software for interaction with a virtual environment through the interface
- Integrated functions for graphic and haptic rendering of the virtual scene

3 groups of API from high-level to low-level: QuickHaptics, HLAPI, HDAPI

Quick haptics

Briefly: High-level API. Easy to use. User just has to define the shapes using given function. Graphic and haptic rendering managed by OpenHaptics.

What you can do with QuickHaptics:

- Create simple shapes
- Interact with the shapes graphically and haptically
- Use pre-defined force effects
- Define callbacks on contact event

QUICK HAPTICS (2)

What you are required to do:

- Create a window where to graphically render the scene
- Define the device space
- Define the shapes and their properties
- Define the cursor (collect informations about device and shapes)

What QuickHaptics will manage:

- Insertion of many default parameters
- Communication with the device
- Graphic and haptic rendering
- Collisions
- Synchronization between graphic rendering loop (30Hz) and haptic rendering loop (1000Hz)

Disadvantages: API functions are very “closed”, you don’t have access to many informations and cannot perform complex tasks.

HLAPI (Haptic Library API)

Briefly: User has to define shapes and graphic rendering using OpenGL formalism. Haptic rendering managed by OpenHaptics.

What you can do with HLAPI:

- Create complex graphic and haptic scene using OpenGL formalism
- Define custom callbacks for a set of events
- Define constraints (virtual fixtures)

What you are required to do:

- Define shapes using openGL formalism (vertices, edges, transformations, material properties). The physical properties are treated as classical OpenGl properties

What HLAPI will manage:

- HLAPI uses graphic informations to compute collisions and haptic rendering
- Communication with the device
- Synchronization of graphic and haptic rendering

HDAPI (Haptic Device API)

Briefly: Low-level API. Difficult to use. User must define shapes, graphic rendering (OpenGL) and also collisions and haptic rendering. You can do a lot but not everything works as expected..

What you can do with HDAPI:

- Directly impose custom forces to the device
- Read low-level sensor data from the device (joint velocities, torques)
- Define custom haptic rendering and collision detection algorithms
- Define custom effects

What you are required to do:

- Separately define functions for graphics rendering, collision detection and haptic rendering
- Use efficient collision detection and haptic rendering algorithms (they run once for every haptic loop iteration)
- Manage the synchronization of the graphic loop (30Hz) and the haptic loop (1000Hz)

What HDAPI will manage:

- Initialization and communication with the device

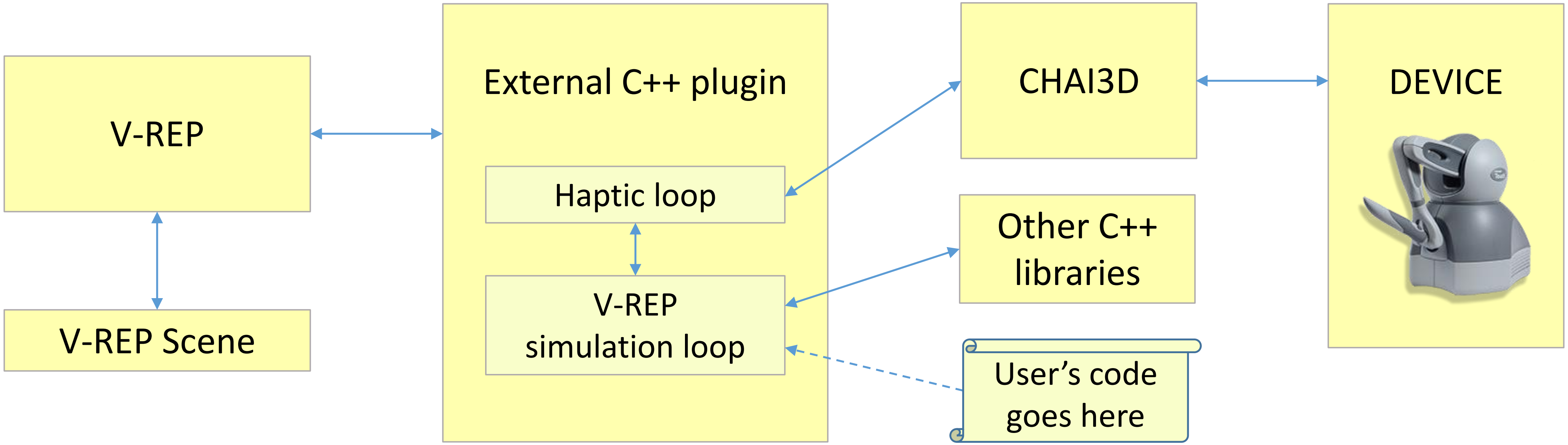
CHAI3D (Computer Haptics and Active Interface)

- Open-source multi-platform set of C++ libraries for haptics and visualization
- Released in 2004 by AI Lab at Stanford University + EPFL + University of Siena

Features:

- Allows communication with several haptic devices (both 3 and 6 dof)
- Manages graphic and haptic rendering. Has its own graphic engine (OpenGL based), provides multiple collision detection and force rendering algorithms
- Allow to read/impose values to/from the haptic device
- Has a clear documentation
- Provides integration modules for third party softwares like V-REP

INTERACTION SCHEME BETWEEN CHAI3D AND V-REP



SYSTEM SETTING

Besides the device is recognized both in Windows and Ubuntu, the following procedure has been used and tested on Windows 10 only.

The following procedure is explained in detail in the appendix guide.

1. Download and install Geomagic touch drivers
2. Download and install OpenHaptics or CHAI3D libraries
3. Both libraries require Microsoft Visual Studio

- Note about the structure of the folders of OpenHaptics and CHAI3D (bin, doc, examples)

4. Do the pairing and calibration procedure (Geomagic Driver)
5. Run the compiled program and have fun

THANKS FOR YOUR ATTENTION

APPENDIX:
GUIDE TO INSTALLATION OF GEOMAGIC DRIVER, OPENHAPTICS AND CHAI3D

Notes:

- Besides the device is recognized both in Windows and Ubuntu, the following procedure has been used and tested on Windows 10 only.
- OpenHaptics requires Microsoft Visual Studio 2005/2008/2010, while CHAI3D requires Microsoft Visual Studio 2012/2013/2015.

INSTALLATION OF GEOMAGIC DRIVER AND OPENHAPTICS

1. From *https://3dsystems.teamplatform.com/pages/102774?t=r4nk8zvqwa91* download the Geomagic touch driver for windows '*Geomagic_Touch_Device_Driver_2016.1.1.exe*' and the OpenHaptics v3.4 '*OpenHaptics_Developer_Edition_v3.4.0.zip*'
2. Install the Geomagic touch driver using the install (.exe)
3. Install the OpenHaptics using the install (.exe)

GUIDE TO INSTALLATION OF GEOMAGIC DRIVER, OPENHAPTICS AND CHAI3D

INSTALLATION OF CHAI3D

Note: CHAI3D requires Geomagic drivers but not nevessarily OpenHaptics. To use chai3d module for V-REP you need V-REP already installed in your computer (download from here *http://www.coppeliarobotics.com/downloads.html*).

1. From http://www.chai3d.org/download/releases download the '*Multiplatform (Windows / Linux/ Mac OS X)*' version of CHAI3D
2. CHAI3D does not require installation, then unzip the archive in the location where you want the main folder of CHAI3D to be (e.g. '*C:*')
3. In the '*doc*' folder you will find the documentation of CHAI3D. Please open '*getting-started.html*' and select '*on Windows visual studio*' to get the instructions to compile the CHAI3D examples. The 'root folder' mentioned in the instruction is the folder '*chai3d-3.1.1*' which contains all the other chai3d folders (included '*doc*').
4. In the same way you can compile the examples relative to the external modules (eg V-REP). For V-REP, go in '*chai3d-3.1.1/modules/V-REP/doc/getting-started*' and follow the instructions to compile the chai3d-vrep examples (similar to point 3).

INTERFACE THE DEVICE WITH PC, USE OPENHAPTICS AND CHAI3D

CONNECT THE DEVICE TO THE PC:

1. Connect the device Ethernet port 1 with the Ethernet port of the pc
2. In the installation directory of Geomagic DRIVERS (usually '*programs\3DSystems\Geomagic*'…) launch '*Geomagic_Touch_Setup.exe*'. Select '*Geomagic Touch*' under the '*Device Model*' box, click '*pairing*' and fastly press the button on the back of the Geomagic Touch. Click '*apply*' and exit.
3. In the installation directory of Geomagic DRIVERS (usually '*programs\3DSystems\Geomagic*'…) launch '*Geomagic_Touch_Diagnostic.exe*', click on the right arrow which is at the bottom-right of the window, until you arrive at the '*Calibration*' page. Wait for the '*Calibrate*' button to become green (or force calibration by clicking on it).
4. In case of 'communication error' please disconnect the Ethernet cable and repeat the procedure from point 2

WORK WITH OPENHAPTICS:

- The reference folder usually is '*C:\OpenHaptics\Developer\3.4.0*' . In this folder you can find the documentation ('*docs*') and useful examples ('*examples*').

Interface the device with PC, use OpenHaptics and CHAI3D

- The examples' binaries are contained in '*examples\bin*' , while the sources are in '*examples\HL*' and '*examples\HD*'.
- Use Visual studio 2005, 2008, 2010 to open an example project (e.g. use Visual Studio 2010 to open the file '*examples\HL\graphics\Events\Events_VS2010.vcxproj*')
- If you modify and compile the previous example for x64 systems, the generated binary program will be saved in examples\HL\bin\x64\HL\.
- A good way to start using OpenHaptics is to create a copy of an example folder (in the '*examples*' folder itself!!!), modify the example with Visual Studio, compile and see what happens..

WORK WITH CHAI3D

- The root folder usually is 'chai3d-3.1.1' that you have extracted from the archive during the installation of CHAI3D. In this folder you can find the documentation ('*docs*'), useful examples ('*example*') and the binaries of the compiled examples (*'bin'*).
- As before use Visual Studio 2012/2013/2015 to open an example project, modify it, and compile it. The binaries will be saved in '*chai3d-3.1.1\bin*'.