Picture for information only : Virtuose 6D

# Haptic device VIRTUOSE 6D

# TAO Option

## *Technical specification*

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## INTRODUCTION

The Virtuose 6D is a standard product from the company HAPTION. The TAO option corresponds to the adaption of this product to the needs of nuclear remote-handling applications with force-feedback. With the years, it has become a standard product by itself. Those specificities are the followings:

The VIRTUOSE 6D TAO is composed of a mechanical structure equipped with motors and position sensors. It ends with an ergonomic handle, hereafter referred as TREH. The device electronics integrate a computer board, which control the motors in real-time, based on the data received via a fast digital transmission median and an EtherCAT board.

The VIRTUOSE 6D TAO is the only force-feedback system of the market today, which offers the following characteristics:

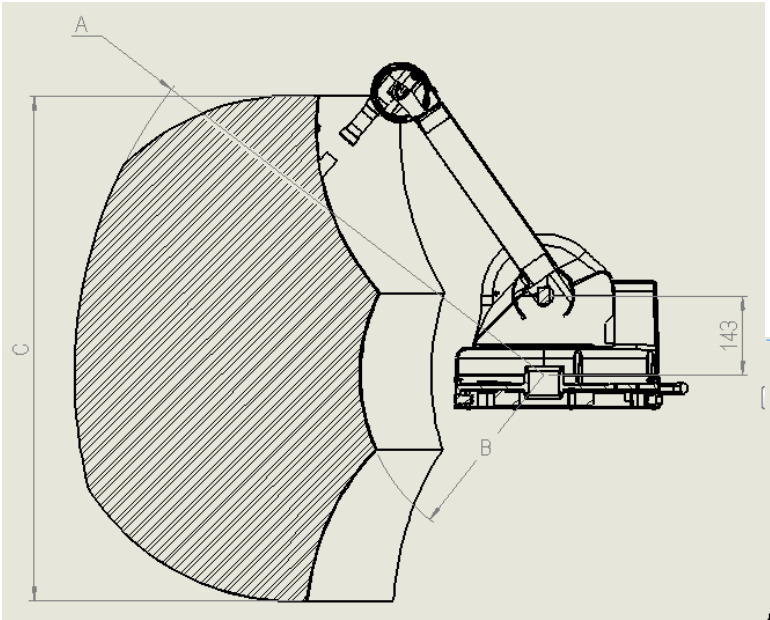
- Force-feedback on all 6 degrees-of-freedom (3 translations and 3 rotations)
- Operational workspace corresponding to the movements of a human arm: (1300 mm x 658 mm x 1080 mm) and (330°, 100°, 270°)
- Maximum peak force of 70 N, in the centre of the workspace at 0.7 m axe 1 i.e. high enough to simulate the handling of heavy objects
- Maximum continuous force of 30 N, in the centre of the workspace at 0.7 m axe 1
- Maximum rotation torque of 5.0 Nm, i.e. high enough for two-handed handling of large virtual objects
- Cartesian position resolutions better than 0.02mm
- Exact static compensation of the device's own weight
- External emergency stop button
- Adding of a button box on the axe 5
- Modular end-effector equipped with programmable switches
- Possibility to chain emergency stop buttons between the master and the slave arm accordingly to the TAO2000 recommendations
- Possibility to use the Ethercat communication system between the card drive and the command PC
- Use of a TREH handle with a pinch (right-hand by default)
- Possibility to add an instrumented rotating table
- Reduced weight, transportable without specific equipment
- Development kit (API) available for the major operating systems
- Demonstrated compatibility with the major software applications on the market today, using dedicated plug-ins: Catia V5, Delmia V5, Siemens Tecnomatix Process Simulate, SolidWorks, Unity 3D (Middle VR).
- "Drivers (binary and/or source code) available for: Python, Worldviz Vizard, ROS, Chai3d, ODE, Matlab SIMULINK, Nvidia Flex"

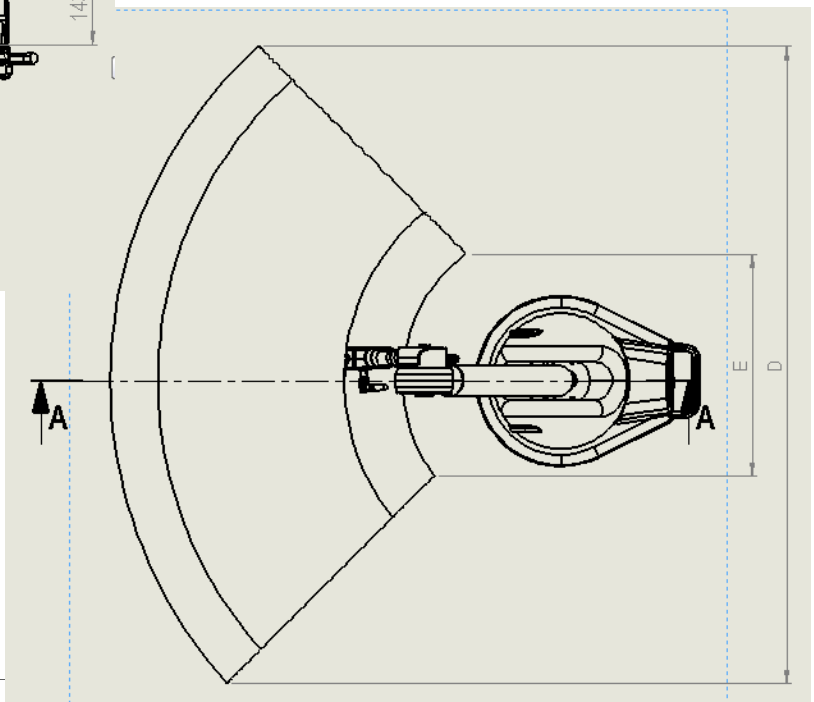
VIRTUOSE is a trademark of the company HAPTION.

The Virtuose 6D TAO is based on the Virtuose 6D family product, by consequence you can chose the level of performance for force and torque you would like.

| **Parameters** | **Virtuose 6D 50cm** | **Virtuose 6D high Force (*)** |
|---|---|---|
| # Dofs – Active Dfos | 6 - 6 | 6 - 6 |

| | | |
|---|---|---|
| Maximum Force | 34 N<br>X=0,63 Y=0 Z=0 | 70 N<br>X=0,5 Y=0 Z=0 |
| Continuos Force | 9.5 N<br>X=0,63 Y=0 Z=0 | Up to 30 N<br>X=0,5 Y=0 Z=0 |
| Maximum Torque Force | 3.1 Nm or 5.0 Nm | |
| Continuos Torque Force | 1 Nm or 1.4 Nm | |
| Software Stiffness | 1800 N/m | Up to 8000 N/m |
| Workspace | A = 940<br>B = 370<br>C = 1010<br>D = 1330<br>E = 465 | |
| Torque | 330° - 130°- 270° | |



## ELECTRO-MECHANICAL ARCHITECTURE

### *Kinematics*

The VIRTUOSE 6D is composed of two main articulated segments fixed on a rotating base. The second segment ends with an articulated wrist, which can rotate around three concurrent axes. As a consequence, the haptic interface is a 6 degrees-of-freedom device, with force-feedback in all directions. The workspace of the VIRTUOSE 6D is large enough to include a cube 45 cm in size.

### *Static weight compensation*

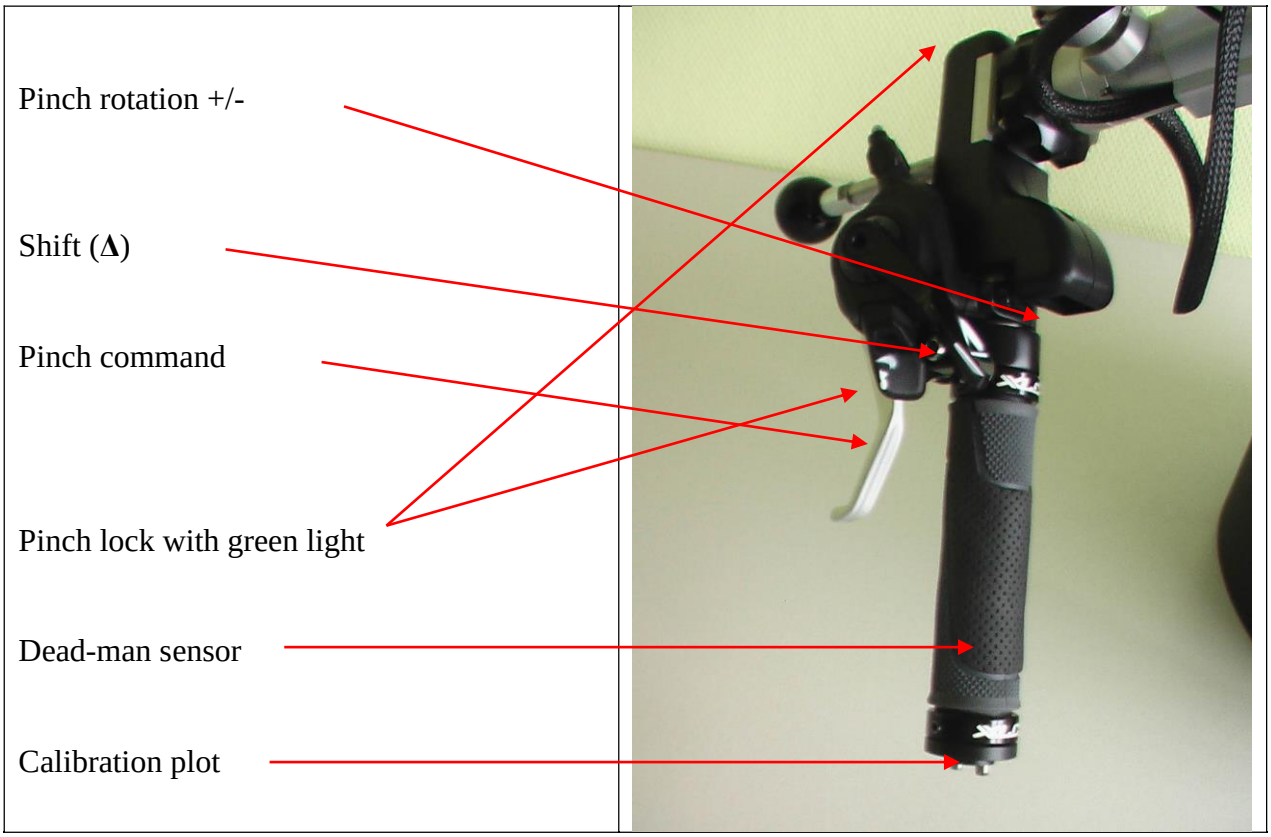
The VIRTUOSE 6D is equipped with a static weight compensation system. As a consequence, the user does not feel the weight of the device structure and the end-effector. Together with the low inertia, the reduced friction in the axes, and the absence of singularities in the architecture, it increases the quality of transparency, and reinforces the sense of immersion. The weight compensation can be modified using 2 adjustment screws, in order to compensate the weight of an additional tool (plus or minus one hundred grams).

### *Specific end-effector for the Virtuose 6D TAO*

The TREH handle is equipped with:

- 4 buttons (Pinch lock and offset)
- A trigger (Pinch command)
- A connecting base used as a calibration plot
- A capacitive dead-man sensor integrated in the handle
- A led to indicate the pinch lock status

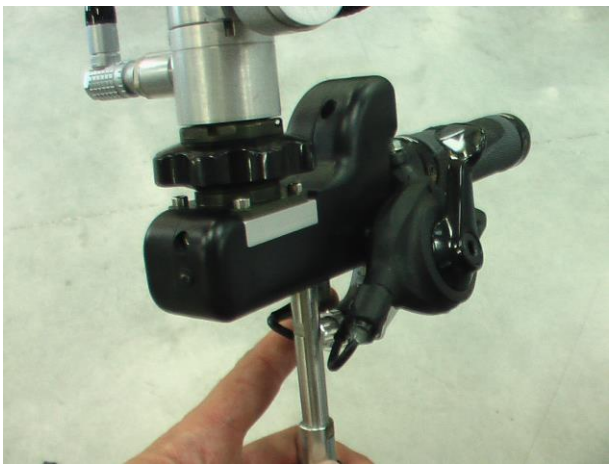
Those elements are positioned in the following way:




When the arm is under power, a green light can be seen at the center of the POWER button.

*Modularity of the end-effector*

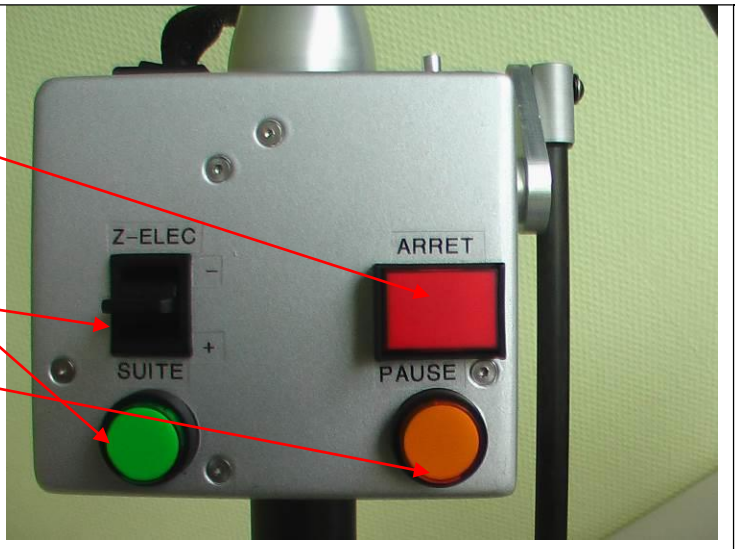
The user takes hold of the haptic device using a gripper or handle placed at the tip (called "end-effector"). The end-effector is easy to remove and replace, so that a frequent change of tool is possible, in order to customize the application and reinforce the sensation of immersion. The connector has the format of AMPHENOL MS3102A.



The gripping tool is equipped with four push-buttons. One of the push-buttons is dedicated to the offset function (see the control system functionalities hereafter). The state of the three other buttons can be accessed using the VIRTUOSE API.

*Button box*

The forearm of the Virtuose 6D TAO can be equipped with a button box, you can have access to the button through the Virtuose API or with the TAO2000.

<table>
<tr>
<td>Mode stop<br>+ red light<br><br>TAO program suite<br>Without light<br><br>Electrical Z command<br><br>Interruption of master/slave mode<br>+ yellow light</td>
<td> 
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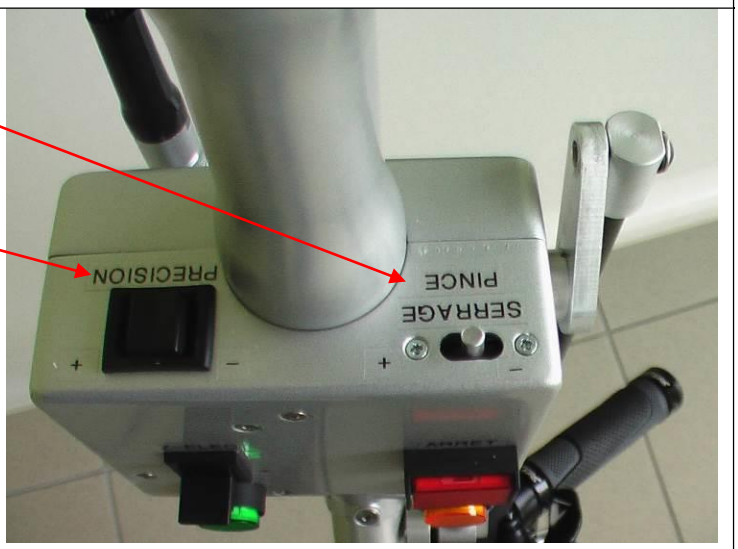
<td>Command of the maximum clamping force of the pinch<br><br>Command of the precision</td>
<td> 
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*Actuation*

All axes of the VIRTUOSE 6D are equipped with electric DC motors and electro-optical encoders. The motors are driven by specific amplifiers, which offer an optimal control quality.

The first three axes are based on capstan drives: the motor torque is transmitted by a cable, which is running on pulleys with different diameters, thus amplifying the torque. A capstan transmission is reversible by nature, free from friction and backlash.

The last three axes at the wrist use reduction systems of type “Harmonic Drive”. They offer outstanding performances within a small volume, and are almost free from backlash. However, they generate some viscous friction, which is compensated by the control software, thanks to the measurement of the rotation speed and the calibration of the viscosity constant during assembly.

*Protections*

The VIRTUOSE 6D is completely equipped with protection covers for the force transmission mechanics.

*Safety*

The gripping tool of the VIRTUOSE 6D is equipped with a proximity sensor, connected to a "dead-man" function. As long as the user does not hold the gripping tool in his hand, and as soon as he releases it, the motors are switched off, and no active movement can occur.

## CONTROL ELECTRONICS

The control electronics include one motor driving board embedded in the device base, and one external power supply. The card includes an embedded DSP processor who does the low level drives to ensure the linearity of the efforts. The connection to the host workstation is done via a RJ45 cable connected at the back of the device. The device is delivered with an external AC/DC power supply.


The choice of individual components and the quality of assembly and cabling guarantee the compatibility with current EMC standards.

## CONTROL SOFTWARE

The control software runs on the host workstation. It is installed as a service (Microsoft Windows) or a daemon (Linux). It is only active when a simulation is running, so that it does not consume CPU cycles when the haptic device is not used.

Each haptic device VIRTUOSE 6D is delivered with a unique, non-transferrable license of the control software, attached to the control electronics. The license does not include the source code. All functionalities of the control software are accessed through the VIRTUOSE API.

## PROGRAMMING INTERFACE (VIRTUOSE API)

By VirtuoseAPI, we designate equally:

- The software functions of the haptic device, which are accessible from the host workstation
- The files necessary to compile a software application making use of the haptic device
- The dynamic library controlling the haptic device from the host workstation

In terms of delivery, the VirtuoseAPI includes the following components:

1. One header file, written in C and C++, defining all API functions
2. One binary file linked as static library, necessary for compiling a software application
3. One binary file linked as dynamic library, necessary for running a software application

4. The programming manual, written in English

The VirtuoseAPI is available for the following platforms:

- Microsoft Windows™ XP/2K/Vista/7/10 for 32 bits and 64 bits processors (multithread version only)
- Linux 2.4 and 2.6 for i586 and amd64 processors

Each haptic device is delivered with a free and unlimited license of the VIRTUOSE API. It does not include the transmission of source code.

## VIRTUOSE FUNCTIONALITIES

### *Control modes*

The VIRTUOSE 6D accepts two different Cartesian control modes: impedance (force input, position output) and virtual mechanism. The latter can be seen as an admittance control mode (position input, force output), however it offers superior dynamic characteristics. It consists in the insertion, between the simulation and the haptic device, of a virtual 6-dof mechanism (described by its kinematics), which can be either free (all degrees of freedom are active) or constrained (along a segment, a plane, a ball-and-socket, etc.).

### *Attachment to a virtual object*

When in the virtual mechanism mode, the VIRTUOSE 6D calculates optimal values for the attachment parameters, and guarantees the stability of the global control loop. The only prerequisite is that the simulation use a constant time-stepping integrator, such as Euler.

### *Safety assurance*

At every moment, the VIRTUOSE 6D checks the conformity of data received from the simulation. In case of incoherence (discontinuity or uncontrolled oscillation), the motors are turned off so as to avoid any injury to the user.

### *Offset*

The offset function cuts the link between the VIRTUOSE 6D and the simulation temporarily, so that the user can move back towards the centre of the workspace when approaching mechanical limits. The function is activated by pressing and holding one of the push-buttons on the gripping tool. It is also running when the dead-man sensor is inactive and when the auxiliary power supply is off. It is possible to cancel the offset function, in order to achieve co-localization.

### *Scaling*

The control software of the VIRTUOSE 6D can scale forces and positions up or down, so that the user can work in virtual environments of various sizes. The scale factors can be changed dynamically, i.e. without interrupting the force feedback.

### *Reference frames*

The control software of the VIRTUOSE 6D manages several reference frames, in order to guarantee the coherence between the user movements and their representation in the simulation. Three transformations are defined, and can be modified using the API:

- The transformation from the base frame to the observation frame describes the position of the VIRTUOSE 6D relative to the viewing screen; it cannot be modified dynamically during the simulation.
- The transformation from the observation frame to the global frame describes the position of the virtual camera inside the virtual environment; it can be modified dynamically.

- The transformation from the centre of mass of the virtual object to the grip frame; it is defined once for every attachment.

*Virtual guides*

Complementary to classical virtual mechanisms (constrained along a segment, a plane, a ball-and-socket, etc.), the "virtual guides" are very useful for training applications. They consist in a constraint along an arbitrary 6-dof track, which can be either recorded before or specified by control points. It is possible to save a recorded track and reuse it afterwards.

*Hybrid position/speed control*

This is an extension of the virtual mechanism control. When the user leaves a zone defined around the centre of the device workspace, then the VIRTUOSE 6D leaves the position control mode and enters a speed control mode. A constant force is applied, to bring back the user inside the central zone. Using the hybrid position/speed mode, it is possible to navigate inside very large virtual worlds, without using the offset function.

*System status*

Using the API, the simulation can access a state vector, which includes the push-buttons on the handle (up or down), the auxiliary power supply (on or off), and the proximity of mechanical limits (for each axis, upper or lower limit).

*Mathematical functions*

The control software of the VIRTUOSE 6D uses an internal representation of rotations based on quaternions. In order to avoid errors while interfacing with user applications, the API offers mathematical functions for converting quaternions to and from standard transforms.

*Failure diagnosis*

The control software of the VIRTUOSE 6D detects hardware failures and enters a safety mode when one occurs. The user can access the failure diagnosis using the API.

## TECHNICAL CHARACTERISTICS

| | |
|---|---|
| **Number of motors** | 6 |
| **Type of motors** | DC |
| **Output power of motors** | 150W (axes 1 to 3) and 20 W (axes 4 to 6) in 48V |
| **Power supply** | 110 to 240 VAC one-phase |
| **Operational workspace** | See spec in Page 3 |
| **Maximum translation force (center of the workspace)** | Up to 70 N |
| **Continuous translation force (center of the workspace)** | Up to 30 N |
| **Maximum rotation force** | Up to 5.0 Nm |
| **Continuous rotation force** | Up to 1.4 Nm |
| **Maximum control stiffness (translation)** | Up to 8000 N / m |
| **Maximum control stiffness (rotation)** | 30 Nm / rad |
| **Apparent inertia** | 1 kg |
| **Position resolution** | 0.02 mm – 0.003° |

## COMPATIBLE SOFTWARE

The VIRTUOSE 6D is compatible with various software applications and packages. Examples are:

### *IPSI*

The IPSI (Interactive Physics Simulation Interface) library developed by Haption is an haptic-enabled physic engine for rigid-body simulation including kinematic joints. IPSI implements a lean client/server technology, so as to minimize the time needed to integrate it into any 3D application. The "server" part of IPSI is available for Microsoft Windows 32 and 64 bits. The "client" part is available for the same platform, as well as for Linux 32 and 64 bits. IPSI is based on software licensed by CEA LIST.

### *CATIA V5 and Delmia V5 (R19 and up, for Microsoft Windows 32 and 64 bits)*

The IFC (Interactive Fitting for Catia) plugin, developed by Haption and based on IPSI, is dedicated to the simulation of assembly and maintenance tasks within the V5 environment.

RTI Delmia V5 (Realtime Interactive with Delmia Human) plugin, developed by Haption and based on IPSI, is dedicated to manufacturing simulation with human realtime interaction within V5 environment.

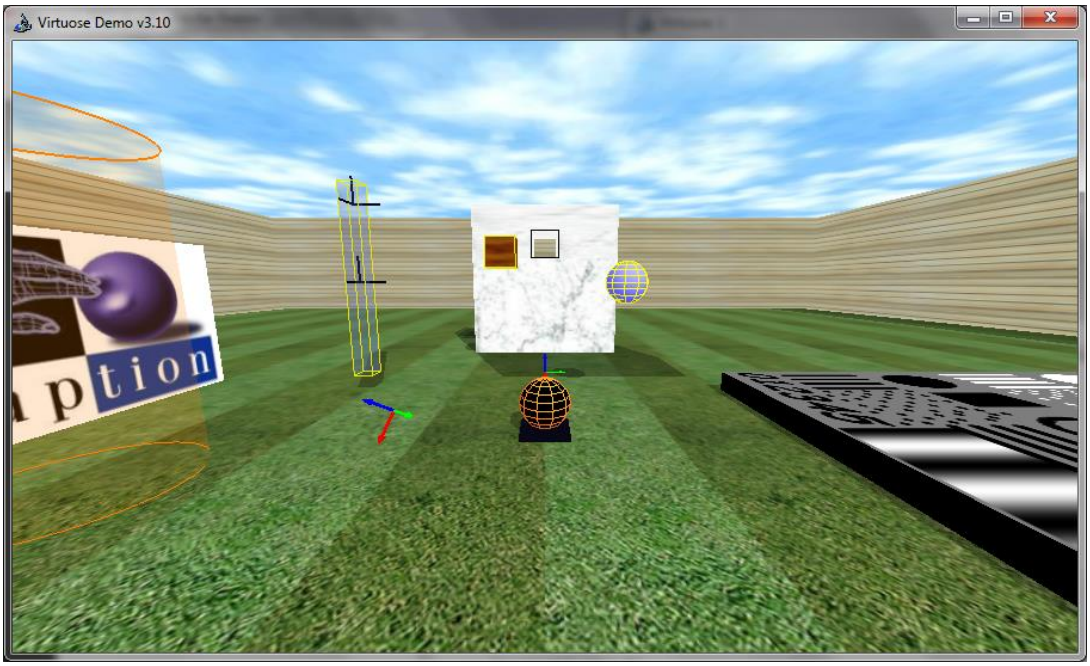
### *SolidWorks (2010 and up, for Microsoft Windows 32 and 64 bits)*

The IFS (Interactive Fitting for SolidWorks) plugin, developed by Haption and based on IPSI, brings haptic interaction to the SolidWorks platform.

## ASSOCIATED SERVICES

### *Test software*

Our haptic devices are supplied with a test software called *VirtuoseDemo*. VirtuoseDemo is a small simulation program, using the Open Source physics library ODE™ (Open Dynamic Engine) and an OpenGL viewer. The source code of VirtuoseDemo is available on request, free of charge.





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### *Hotline*

HAPTION provides a hotline service (communication fees paid by the customer), open from 9 AM to 6 PM Paris time on working days, for one year after the date of delivery.

### *Packaging*

The VIRTUOSE 6D is packaged in one wood box with protective foam bags.

## OPTIONS

### *Fan-less power supply*

For noise-sensitive environments, the external power supply is also available in a fan-less version.

### *EtherCAT protocol*

The default connectivity of the VIRTUOSE 6D uses a standard UDP protocol on Ethernet/RJ45. Alternatively, the same device can be ordered with embedded EtherCAT fieldbus, which allows for higher reliability in sensitive environments.

### *Tools*

The tip of the VIRTUOSE 6D is equipped with a mechanical and electrical interface, allowing fast removal and replacement of the gripping tool. As an option, we propose simple modules for fixating standard tools or specific parts on the VIRTUOSE 6D. Those modules repeat all electrical signals, including the push-buttons and the proximity sensor.

### *Mechanical stand*

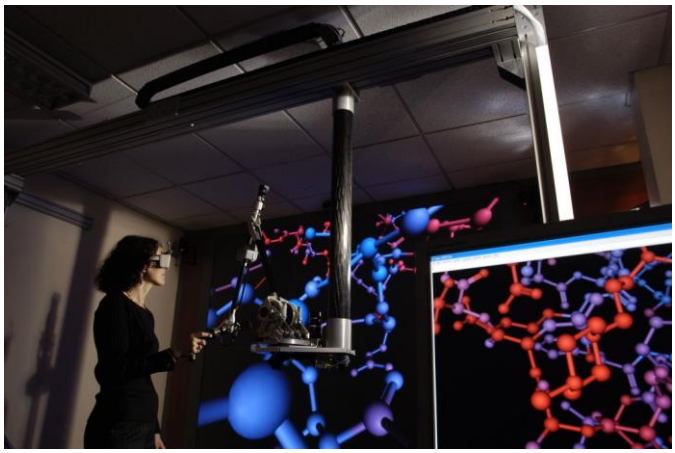
In order to optimize the integration of the haptic device VIRTUOSE 6D into all kinds of immersive systems, Haption has designed a special mechanical stand. It guarantees the vertical stability of the device without any fixation point, so as to allow for a quick set-up. It is also available in "upside-down" configuration, which offers the most comfortable mode of operation.

*VIRTUOSE 6D in "upside-down" configuration inside a CAVE™ (picture © PSA Peugeot Citroën)*

*Dynamic movable plateform: SCALE1™*

The Virtuose 6D product is compatible with the dynamic locator SCALE 1, which extends the workspace to the complete volume of an immersive lie CAVE ™, or in front an immersive WALL

Setup of the LIMSI: 3DOFs



Setup of CEA: 1 DOF



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