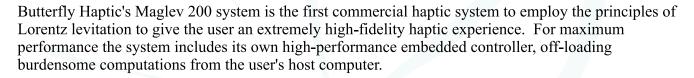# Butterfly Haptics

Maglev 200^{TM} Magnetic Levitation Haptic Interface

A breakthrough in haptics

Maglev Haptics^{TM} is a revolutionary new technology for high-fidelity interaction with virtual or remote environments through the sense of touch. The user grasps a handle rigidly attached to a flotor levitated by strong magnetic fields. The handle can be freely moved in six degrees of freedom through a comfortable motion range, sending position and orientation information to the user's application. The application, in turn, outputs forces and torques to the handle.

Available haptic-interaction devices are small back-driven robot arms, which include mechanical elements that can limit fidelity due to friction, backlash, link bending, and motor cogging. These drawbacks are eliminated with Maglev Haptics^{TM}.

Butterfly Haptic's Maglev 200 system is the first commercial haptic system to employ the principles of Lorentz levitation to give the user an extremely high-fidelity haptic experience. For maximum performance the system includes its own high-performance embedded controller, off-loading burdensome computations from the user's host computer.

The hardware incorporates several highly innovative design features and advanced manufacturing technologies to provide high quality and reliable operation at a reasonable cost.

Innovative features

Six degrees of freedom
Single moving part
Zero static friction
Zero mechanical backlash
High bandwidths
High position resolution
Wide stiffness range
Mechanical simplicity

Advanced applications

Medical/dental training
Microsurgery
Data set visualization
Character animation
Effort-reflected flight
Computer aided design
Remote robot control
Micro/nano manipulation

Butterfly Haptics

Maglev 200^{TM} *Magnetic Levitation Haptic Interface*

The Butterfly Haptics Maglev 200 system includes the Model 201 device, Model 202 controller, cables, detachable mouse-like handle, desktop mounting kit, manuals, and client-side software (API, graphical monitor, and demos).

Top View

Bottom View

Model 201 Device

Design features

```
Degrees of Freedom ............ 6, upgradable to 7
Amplifiers .................... Low Noise Linear
Handle ........................ Interchangeable
Included Handle ............... Mouse-Like
Handle Buttons ................ 2
Device Pose ................... Adjustable 0-90 deg.
Device Mass (Model 201)........ 18 Kg
Device Diameter................ 0.40 m sphere
Controller Mass (Model 202) ... 14.5 Kg
Controller Dimensions ......... 0.20 x 0.45 x 0.53 m
Power Requirements ............ 115V/6A, 230V/3A
```

Performance characteristics

```
Translational Workspace ........ 24 mm Dia.Sphere
Rotational Range ............... +/-8 deg (see note 1)
Position Resolution (1 sigma)... < 2.0 microns
Angular Resolution (1 sigma).... 3.6 arcsec
Position Bandwidth (-3dB) ...... 140 Hz
Force Bandwidth at Manipulandum. >2000 Hz
Peak Force (Z axis) ............ 40 N
Force Resolution ............... 20 mN
Peak Torque (Z axis) ........... 3.6 Nm
Maximum Translational Stiffness  50 N/mm
Minimum Translational Stiffness  0.002 N/mm
Maximum Rotational Stiffness ... 5.1 Nm/deg
Minimum Rotational Stiffness ... 0.01 Nm/deg
Backdrive Static Friction ...... 0.0 N
Mechanical Backlash ............ 0.0 microns
Perceived Mass (Flotor)........ 616 g
Maximum Servo Rate ............. 4000 Hz
Levitation Power ............... 4.5 W
Stray Field at Handle .......... 0.001T
```


Front View

Software

```
Embedded RT Operating System ... QNX 6.3
Communication .................. 100 Mb/s Ethernet
User Interface (C/C++ Language). Structured API
Testing and Debugging Facility ..Graphical Monitor
Host OS Compatibility .......... Linux, Windows
Haptic API Compatibility ....... CHAI 3D, MATLAB®
```

Note 1: Rotational range is reduced near the limits of the
        translational workspace.

Back View

Model 202 Controller