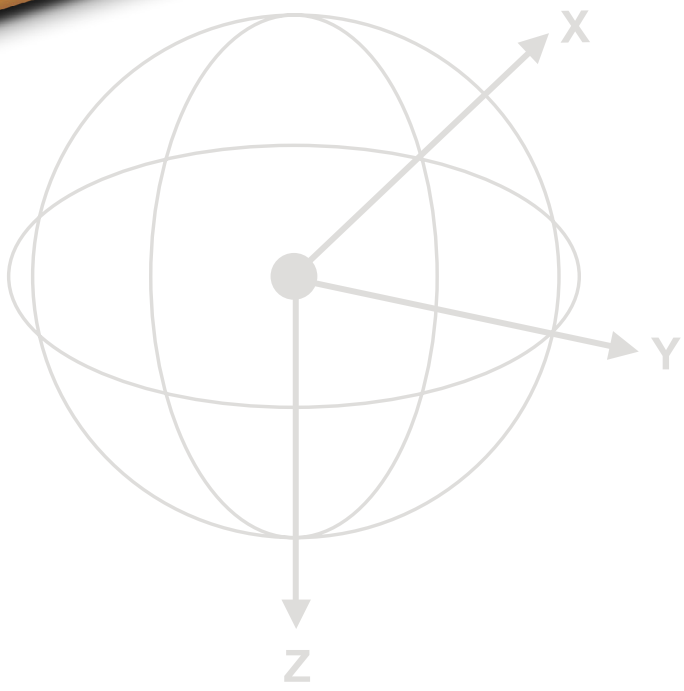
POLHEMUS
INNOVATION IN MOTION™



SELECTING THE OPTIMAL MOTION TRACKER FOR MEDICAL TRAINING SIMULATORS

What 40 Years in Simulation Has Taught Us About Fidelity, Performance, Reliability and Creating a Commercially Successful Simulator.

CONTENTS

POLHEMUS
COLCHESTER, VERMONT, USA
AUGUST 2014

Introduction

A motion tracker is a critical component in many of today's medical training simulators. Choosing the right tracker can help ensure a high fidelity simulator that is cost effective, reliable and easy to use. Choosing the wrong system can lead to increased development costs, reduced fidelity, high cost of ownership for customers, and potentially, failure in the market.
Below are lessons learned from over 40 years in providing motion trackers to military, industrial and medical training simulator manufacturers.

Medical Training Simulators Present Unique Challenges for Tracker Selection

One of the challenges in developing effective medical training simulators is creating a user interface that is as real as the real thing. To achieve a high level of fidelity, a simulator designed to train a specific procedure should have an interface that is indistinguishable from the real thing. Motion tracking sensors are often a fundamental part of the user interface and are the link between the physical world and the computer generated virtual or simulated world. They measure, for example, the insertion path of an intubation tube, and feed that info to the simulator's computer. But the sensors should not change the look, feel, or weight of the instruments or devices being handled by the student. In this example, an optical tracker would be a poor choice, as intubation tubes do not have reflective markers attached.

Another challenge is that many of the movements being measured are free form, rather than in a fixed linear direction, such as that of aileron pedals in an aircraft cockpit simulator. The motions of an ultrasound probe during an examination are anything but linear, and in fact are often rotating as well. This requires 6DOF (six degrees of freedom) tracking, measuring both position (x, y, z) and orientation (azimuth, pitch and roll). Many motion tracking technologies only offer 3DOF, either measuring position or orientation, but not both.

And finally, many of the medical procedures targeted for simulation training require the tracking of an instrument or device for which there is no line-of-sight. This precludes the use of optical or video tracking. Line-of-sight can be blocked by the movement of medical staff, or because the instrument or device being tracked is inserted into a mannequin. Transvaginal ultrasound and catheterization are good examples.

Regarding cost, although perceptions exist that the medical community is well funded; to the contrary, the medical education community often has severe budget challenges. This puts pressure not only on the price point of the simulator, but also the requirements that it be easy to set up and use, does not require special facilities, requires little to no consumables, and perhaps be portable for ease of sharing.

Motion Tracker Choices

In general, the accuracy required for medical training simulators is quite high. Positional accuracy required is in the 0.5mm to 2.0mm range, and for orientation, from 0.2 to 1.0 degrees. Sampling rates are not as critical because the motions being tracked are typically not high speed. Trackers with at least 60Hz sampling are generally acceptable. Latency, or lag, the time between

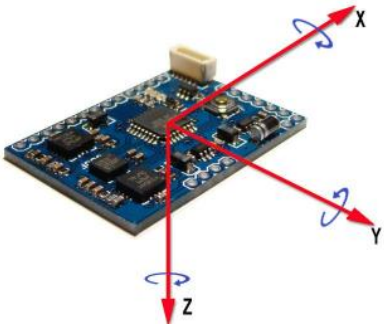
an actual movement and when it is reported to the PC, can be important for simulators that are immersive, particularly those using head mounted displays. With these types of simulators, motion tracking lag in excess of about 20ms can cause motion sickness.

These performance requirements, along with reliability and repeatability, preclude the use of video game motion controllers for medical simulation applications. Industrial motion trackers which can meet these criteria fall into three categories: Inertial, Magnetic and Optical. Here are some of the Pros and Cons of each:

IMUs (Inertial Measurement Units) – IMUs typically contain three orthogonal rate-gyroscopes and three orthogonal accelerometers, measuring angular velocity and linear acceleration respectively. They often also include magnetometers.

Pros

- Relatively inexpensive.
- Often available in wireless versions.
- Instantaneous rotation measurements can be quite accurate (before drift errors accumulate).



Cons

- Only measures rotation (3DOF), not position.
- Significant measurement drift due to earth's rotation and accumulated error.
- Overall sensor size can be large ~ 4cm x4cm x2cm.
- Proximity to metal and magnetic fields causes measurement errors.

Optical trackers – Optical trackers use cameras to track the position of markers attached to the object being tracked. Three or more markers are required to define the position and orientation of a single point. In the example below, five markers are used to track the position of a hand controller.

Pros

- Can be very accurate.
- Accuracy is unaffected by the presence of metal.
- Wireless.

Cons

- Line-of-sight to the camera(s) is required, so markers are always external to the object – not embeddable.
- Accurate systems can be very expensive.
- Passive (reflective) markers add consumable cost.
- Setup and calibration can be difficult.
- Can be sensitive to ambient lighting.
- Marker clusters can be large and cumbersome.

Magnetic Trackers – Magnetic motion tracking sensors contain three orthogonal coils which measure minute changes in current as they move within the magnetic field produced by the tracker's source. Because they operate using magnetic fields (as opposed to visible light) the sensors and source can be embedded inside devices, probes, mannequins, etc. Magnetic trackers come in both AC and DC versions, and there are significant differences between the two.

Pros

- Measures position and orientation (6DOF).
- Very accurate.
- Low latency.
- Embeddable sensors (no line-of-sight required).
- Relatively inexpensive.
- No calibration required.
- No drift.
- Not affected by ambient light.
- AC magnetic trackers are available in wireless.

Polhemus *Patriot* ™
AC magnetic tracker

Cons

- Measurements can be affected by close proximity to large metal objects (true for both AC and DC versions).
- Some DC magnetic trackers are not pacemaker safe.
- Two or more DC magnetic trackers cannot be used in close proximity to each other.

Technical and Environmental Considerations

Accuracy and repeatability requirements were discussed earlier, but there are other important technical and environmental factors to consider when selecting a tracker:

– Will the simulator need to be portable, easily moved from room to room or building to building? If so, the tracker could be an issue if it is difficult or time consuming to set-up, or needs calibration after being moved or environmental conditions such as lighting change.
– Is it possible that two or more simulators will be used in close proximity, such as a classroom with multiple students each using their own system? Some tracking systems, such as DC magnetic, cannot operate within close proximity to each other due to cross talk errors.
– Will the simulator be used outdoors? Nearly all optical trackers would be excluded from this scenario.
– Are the sensors plug and play compatible with any tracker electronics unit? If not, the logistics of keeping sensor/tracker box pairs together becomes an issue and potential source of downtime.
– Does the tracker have the necessary safety certifications such as IEC 60601-1 Ed. 2 1997 and IEC 60601-1-2 Ed. 3 2007?

Cost Considerations

Most of the cost considerations are obvious, such as system purchase price, sensor replacement price, repair costs, warranty, etc. Beyond these standard costs, there could also be consumable costs, as is the case of reflective markers in optical systems.

Successful Medical Training Simulators – Case Studies

Considering the pros and cons of these three tracker types, and the various technical, environmental and cost considerations, it becomes clear why AC magnetic trackers have become a preferred choice for medical training simulators. The components (source and sensor) can be embedded, and thereby invisible to the user, which adds to the realism and fidelity of the simulator components, whether they are ultrasound probes, catheters or surgical instruments. AC magnetic sensors measure both position and orientation, and with accuracy exceeding the requirements of today's medical procedures. They are portable, simple to setup and need no calibration.

Polhemus has been supplying motion tracking systems for training simulators for over 40 years, including aircraft cockpit simulators, welding and industrial spray paint simulators, and for many years, simulators for medical applications. Below are a few examples of commercially successful medical training simulators powered by Polhemus.

CAE Healthcare
http://caehealthcare.com/eng/ultrasound-simulators/vimedix

MedSim
http://polhemus.com/case-study/detail/polhemus-patriot-tracks-the-positioning-of-ultrasound-probe-for-training-an

SimSurgery
http://polhemus.com/case-study/detail/simsurgery-finds-success-with-sep-simulator-powered-by-polhemus-patriot