Advancements in 3D Interactive Devices for Virtual Environments

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Abstract

New commercially available interactive 3D tracking devices and systems for use in virtual environments are discussed. InterSense originally introduced the IS-900 scalable-area hybrid tracking system for virtual environments in 1999. In response to customer requests, we have almost completely revamped the system over the past two years. The major changes include a drastic 3-fold reduction in the size and weight of the wearable sensor devices, introduction of wireless tracking capability, a standardized I^2C interface to allow OEM system integrators to add additional custom controls, and evolution of the system software interfaces, the performance, and the price. This paper will briefly describe the underlying technology changes that have allowed these advances to occur, and will outline some of the configuration possibilities that are now supported. Specific examples of how these devices and systems are being used to improve productivity in oil & gas seismic analysis & well field planning; automotive design & test; and, industrial/military training applications will be used to illustrate. Customization standards and future developments are discussed.

Keywords:
Motion Tracking, Wireless Tracking, I^2C Bus, Tracking in Virtual Environments, Inertial Tracking

Categories and Subject Descriptors: H.5.2 [User Interfaces]: Input devices and strategies; I.3.6 [Methodology and Techniques]: Interaction techniques; I.3.7 [Computer Graphics]: Virtual Reality

1. Introduction

The trend towards projection technology has lead to the creation of powerful, interactive immersive environments that typically require a tracker to manipulate and interact with graphical objects. [1]. While research & development continues to enhance and productize these systems, many immersive displays are rapidly being deployed as productive tools by industry. Known by a variety of different trade names (CAVE®s, PowerWalls™, iCenters™, RealityCenters™, etc…), all of these systems are becoming more cost effective and the devices used to interact in these virtual environments are becoming easier to use.

InterSense continues to work with the visionaries who originally conceived of these new work environments and with the end-users who are benefiting with improved productivity, work flow and enhanced employee training. This experience is being used today to produce interactive tracking devices and systems that address the needs of the end-user, while maintaining the maturing vision of researchers and developers of immersive environments.

2. Background

Since its inception in 1996, InterSense has developed tracking systems based on hybrid inertial tracking technology [2]. The first product, the IS-300, was a three degree-of-freedom (3-DOF), body-worn, sourceless inertial orientation tracker used primarily for head-tracking with Head Mounted Displays (HMD's). Following this, for tracking with six degrees-of-freedom (6-DOF) in room-sized areas, the IS-600 acoustic/inertial hybrid tracking system was developed. Although used primarily with HMD's, early experiments for tracking in large projected immersive environments with the IS-600 were conducted at the University of Illinois-EVL; Brown University; and, in industry with Pyramid Systems and Trimension. At this time, the most prevalent trackers used in immersive projection environments were magnetic systems offered by Polhemus and Ascension. While the magnetic systems performed adequately for some applications, as the tracked environments became larger, calibration and maintenance of magnetic systems became more time consuming [4]. Although the IS-

600 did not provide an ideal solution for large area projection environments, the initial tests showed promise and interest. The next-generation tracking product, the IS-900, based on a new Constellation™ tracking architecture which had originally been developed in 1997 for a wearable augmented reality project at Boeing [3], added the ability to expand the system over very large tracking areas and use multiple tracked devices with no decrease in performance.

The basic difference between the IS-900 and the IS-600 is the reversal of the roles of ultrasonic emitters and receivers. In the IS-900, the emitters form a constellation of reference points fixed in the environment (typically on the ceiling or around the frames of display screens) and the receiving microphones are on the tracked devices. Because of this, an ultrasonic chirp emitted by one of the emitters in the constellation can be simultaneously detected by any number of tracked devices. The IS-900's reversed ultrasonic design not only allows the system to track an unlimited number of devices without any decrease in the ultrasonic update rate, but it also eliminates any measurement latency due to the slow speed of sound [3].

3. Original IS-900 Configuration

In 1998, as the augmented reality market faltered, a trend emerged in virtual environments away from HMDs and towards large-scale, projection-based environments. Thus, the Constellation technology was re-engineered into the IS-900 product and designed for use in these new projection-based environments. The first installation of the IS-900 was at Brown University's Virtual Environment Navigation Lab (VENLab)[5] built by the Dept. of Cognitive and Linguistic Sciences. The IS-900 installation at the VENLab consisted of 172 discrete ultrasonic transmitters placed in a 50 x 50 foot area tracking an immersive HMD. The system was used to study the cognitive aspects of human navigation in large walk-through virtual environments.

The IS-900 product was publicly unveiled at SIGGRAPH 1999 with demonstration software developed by Brown University using Sense8's WorldToolKit. The tracked devices released with the original IS-900 systems (shown in Figure 1a-c) utilized a new InertiaCube design (Figure 1d) fused with a digitally enhanced acoustic ranging technique designed to improve accuracy and interference rejection over the acoustic technology used in the IS-600 [8].

As shown in Figure 1d, the InertiaCube used in the original IS-900 devices was already reduced to approximately 1 in.^{3}, as compared to 1.7 in.^{3} for the InertiaCube in the IS-300. This new design, developed for the IS-900, provided many features needed to support all of InterSense's future product developments by utilizing the latest in Micromachined Electro-Mechanical Systems (MEMS) inertial components. It provided a simple and rugged, self-aligning cubic construction to support automated calibration procedures and a proprietary communication bus format (Station Protocol). As a high-speed, serial communication link, Station Protocol supported transfer of data from multiple sensors (inertial, acoustic) and user inputs (buttons, joysticks, encoders, etc…) from tracked devices to the IS-900 processor.

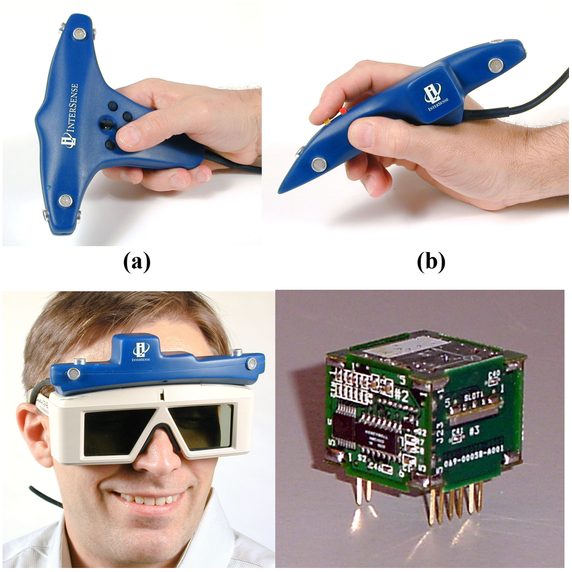


Figure 1: Original IS-900 Wand (a), Stylus (b), & Head-Tracker (c), and InertiaCube (d) common to them all

To meet the 6-DOF accuracy requirements of both HMDs and typical projection-based immersive environments, our tests and analysis determined that a minimal receiver microphone separation of 6 inches was required in the original IS-900 tracking devices. The ultrasonic microphones chosen had a receiver cone angle of approx. 90 degrees, so to achieve a full 360-degree coverage with a tracked device, as with the original IS-900 wand shown in Figure 1a, four receiver microphones were used on each end of the tracked device.

While the original IS-900 was unique in the industry and getting good performance reviews for tracking over large areas without the field distortion effects found in magnetic systems, many end-users complained about the size and weight of the tracked devices. In addition, we recognized that wireless support for the IS-900 was still a high priority for future releases.

4. Advancements to the Tracker

As the original IS-900 systems were being installed worldwide in virtual environments at universities and with commercial systems provided by Fakespace, Trimension, Mechdyne, SGI and others, InterSense continued working towards a smaller and wireless version of the tracking devices. The priority of these developments was first to miniaturize and reduce weight while keeping in mind a simple path to wireless implementation.

4.1. Miniaturization, new ultrasonic technology and integrated inertial-acoustic processing

To support these goals, an approach was needed to reduce the number of components on the tracked devices and simplify the communication interface. At the same time, we set a very stringent power budget for the new devices in order to facilitate prolonged wireless operation with small batteries. Having achieved suitable performance specifications for immersive environments in the original IS-900 devices, the challenge of designing smaller, lower-power packages without sacrificing performance required changes in the inertial and acoustic sensing technologies, and a meticulous re-design of the signal processing electronics.

One of the key breakthroughs that enabled the miniaturization was the switch to a new and tiny ultrasonic microphone technology. The original IS-900 devices used a standard 40 kHz narrowband piezoelectric ultrasonic transducer with 10 mm diameter. In the new devices we use a novel wideband microphone with a miniscule 3 mm diameter. Figure 2 shows a size comparison. While we still use a 40 kHz ultrasonic signal for ranging, the wider bandwidth of the new microphone enables us to detect the distinct phase-modulated signature in our acoustic signal more reliably. In addition to taking up less room in the tracking device, the small size of the microphone has another very important benefit: because its diameter is less than half the wavelength (9 mm) of the acoustic waves, the response of a microphone in free air is completely omni-directional. For ruggedness, we mount the microphones slightly recessed into the surface of the device, which cuts the sensitivity to approximately one hemisphere. Still, this is much wider than the 90-degree reception cone of the previous microphones, thus allowing at least a 2-fold reduction in the number of microphones needed for full 360-degree coverage of a tracked device. By reducing the sensor count on the device, the amount of circuitry needed to process the acoustics is also reduced.

A second key benefit also stems directly from the tiny size of the new microphones. With the old transducers, the front face was an open grill, with a speaker cone mounted behind it. However, due to manufacturing variations, the location and direction of the acoustical center of percussion of this cone could vary considerably within the housing. This caused asymmetrical range measurement errors of up to 3 mm for some off-axis range measurements. InterSense applied rigorous analysis techniques to characterize these errors and tune the Kalman filters to perform optimally in the presence of these unknown measurement biases, but it was impossible to calibrate them out completely. With the new microphones, the acoustical center is directly in the center of the pinhole aperture on the microphone, which can be precisely placed on the 3D device package, thus eliminating the largest source of measurement error. As a result, it was possible to reduce the baseline separation between microphones from 14.48 cm on the original head-tracker to 7.49 cm on the new MiniTrax head-tracker while maintaining the same level of accuracy

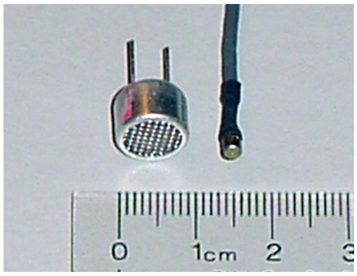
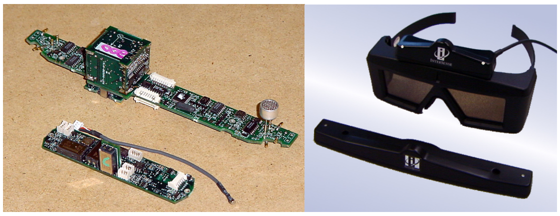


Figure 2: Original vs. MiniTrax receiver microphone

A third advantage of the new MiniTrax ultrasonic receivers is that the microphones have built-in pre-amplifiers capable of driving signal through a "pigtail" of up to 1 meter of very thin flexible cable. This is very useful for tracking large objects such as the stinger missile tube shown in Figure 17 below, as the microphones can be remote mounted from the MiniTrax board with considerable separation allowing very high angular accuracy.

In addition to changing microphones and greatly simplifying the signal conditioning electronics required for the acoustic signal processing, the miniaturization of the tracking devices required additional economies of design, including integrating the inertial and acoustic signal processing onto a single microprocessor. Figure 3a shows a size comparison of the original and MiniTrax circuit boards. The original device used a stand-alone InertiaCube assembly with its own internal microprocessor, and a second microprocessor on the main board dedicated to acoustic signal detection and communications. Since the microprocessors were amongst the heaviest power-consumers in the design, the new board uses a single microprocessor using less than 1/10 the power of the two microprocessors in the previous design. Using new optimized signal processing algorithms and carefully handcrafted firmware, this slower microprocessor is still able to perform all the necessary processing for all 6 inertial sensors and 2 channels of simultaneous acoustic detection (multiplexed between 4 microphones), as well as serial communications to the base unit. Newer, smaller components also contribute significantly to the striking size reduction.



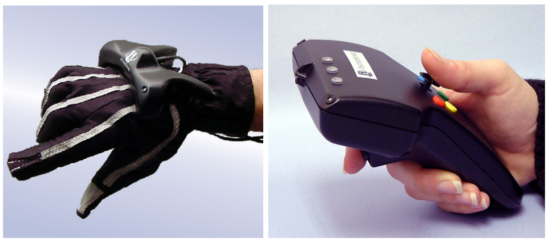
(a) (b)

Figure 3: Original Head Tracker vs. MiniTrax Head tracker circuit boards (a) and two MiniTrax Head Trackers—Standard and High Accuracy (b)

Shown in Figure 3b, the MiniTrax head trackers are available in two versions—the standard version that maintains the tracking accuracy of the original designs (2.0 to 3.0 mm positional and < 0.5 degrees orientational static accuracies) and the high accuracy head tracker, which achieves 0.25 degree orientational static accuracy. The MiniTrax implementation reduced weight over the original design by a factor of three, and lowered power consumption from about 1 W to about 150 mW, which is crucial for battery-powered wireless applications.

4.2. Ergonomic improvements

The size & weight reduction of the inertial and acoustic sensors and electronics for the MiniTrax head-tracker lead to simplified designs for other tracked devices. The hand tracker shown in Figure 4a is ergonomically shaped to easily fit over the back of a hand or glove. A total of four ultrasonic receiver microphones are positioned to provide full 360-degree tracking coverage with the hand in natural active or at-rest positions.



(a) (b)

Figure 4: MiniTrax Hand Tracker mounted on Fakespace Pinch Glove (a) and MiniTrax Wand (b)

The MiniTrax Wand design, shown in Figure 4b, adds a sixth button in the trigger position and uses a molded finger grip. The MiniTrax Wand package can fit the wireless transmitter and battery inside, or it can be configured with a short tether connecting to either the belt clip wireless module or the extension cable to the IS-900 Processor.

The MiniTrax wand also takes advantage of a new standard I^2C interface socket on the MiniTrax board for reading in the analog joystick and buttons. This interface is discussed in the Section 4.6.1.

4.3. Wireless tracking

Picking a wireless communication interface for the IS-900 MiniTrax devices proved to be a lengthy and difficult process. New wireless technologies were appearing on the market at a rapid pace, and considerable effort was spent evaluating each technology to make sure it met our technical requirements, had staying power, and was eligible for unlicensed use in every country.

Short-range narrowband telemetry chips were initially investigated as an attractive option because of their low power consumption, small size and simplicity, but no single chip could be found which could provide 4 concurrent channels at sufficient data rates and could be configured to operate in the ISM bands of many different countries using the same technology. Bluetooth was able to offer enough bandwidth and enough channels while operating in the globally available 2.4 GHz ISM band, but it was unable to meet the stringent synchronization requirements for making precise ultrasonic time-of-flight range measurements. In the end, an off-the-shelf 2.4 GHz frequency-hopping spread-spectrum telemetry card was modified to provide dedicated channels for real-time synchronization while maintaining the robustness of spread spectrum frequency hopping to assure compatibility with other 2.4 GHz wireless systems (such as Bluetooth and 802.11b) that might be used in the vicinity of the tracker.

Practical considerations with regard to product line compatibility and upgradeability were also considered. The wireless system was designed to support up to four independent devices running on one IS-900 system. Enough wireless channels are provided so multiple IS-900 wireless systems can be running simultaneously in the same vicinity. Finally, an extension cable that is plug-compatible with the wireless transmitter/receiver pair enables customers to initially purchase wired MiniTrax devices and later upgrade to wireless operation simply by replacing the extension cable with a belt-worn battery/transmitter module and a compatible receiver module. If desired, the cable can still be used as a back-up connection scheme, e.g. during recharging of the wireless battery/transmitter modules. A 3.6 V, 1600 mAH lithium ion rechargeable battery was chosen to be lightweight for either body worn or handheld use, with capacity to last one workday (8 hours) without recharging. Figures 5a & 5b show the different wireless tracked device configurations.

(a) (b)

Figure 5: Wireless Head Tracker with belt-worn battery/transmitter module (a) and Wireless Tracked Wand (internal battery & transmitter) shown with a single channel receiver (b)

4.4. Simplified sensor network architecture

The original IS-900 tracked devices used a proprietary serial bus architecture known as Station Protocol. This architecture was conceived to allow a unified communication protocol between the base processor and all tracked devices and the ultrasonic transmitter constellation. The Station Protocol bus used an I^2C-like addressing scheme; supported up to 1 Mbit/s data rates so that multiple tracked stations could be daisy-chained on a single cable connection to the base unit; and, employed RS-485-style differential signaling to transmit these data rates over long cables. The Station Protocol required specialized interface code between the processor and each device, which made custom or OEM device development impractical on a small scale. During the design of the MiniTrax devices, a standard RS-232 communication protocol was picked between all tracking devices, the ultrasonic referencing constellation and the base processor. For backward compatibility with the original IS-900 Processors, small RS-232 to Station Protocol converters are used.

The choice of a standard communication protocol for all device interfaces on the new IS-900 system simplifies design standards for OEM devices and provides greater flexibility in IS-900 base processor design using COTS components. Most importantly, it makes it far easier to develop wireless links between the devices and the base unit, since many wireless technologies are available to support RS-232 data rates, while far fewer can handle the high data rates of the Station Protocol bus. The 115.2 kbits/s data rate of RS-232 is sufficient for communications between one tracked station and the base processor with no compromise to performance. Although the original Station Protocol was designed to support multiple stations on the bus, this capability was never utilized in the shipping product line, so giving it up in favor of wireless capability and lower complexity was no sacrifice. As Figure 6 illustrates, this simplified sensor networking architecture means that each wireless tracked device uses a separate transmitter/receiver pair operating on its own radio channel. This means it is possible for a customer to upgrade some of the devices to wireless operation, while continuing to use others in tethered mode.

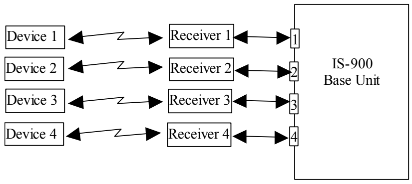


Figure 6: Separate point-to-point wireless links are used for each tracked device

4.5. IS-900 Serial Processor

The original IS-900 processor, based on a PC104 stack with custom I/O circuits to the tracking devices and ultrasonic Constellation array, was housed in a 3U chassis.

Figure 7: New IS-900 Serial Processor

Figure 7 shows the new IS-900 serial processor. Because of the switch to standard serial communications hardware, the new processor was able to increase the number of station ports from 4 to 7, increase the processing speed dramatically, and at the same time reduce the complexity of the electronics, resulting in a smaller 1U chassis with greater ruggedness and reliability.

4.6. OEM capabilities

Building on the standard interfaces and serial processor of the IS-900 system provides system integrators and OEM customers a broader range of options in deploying customized tracking configurations.

4.6.1. Inter-IC Bus (I^2C)

The I^2C bus is an industry standard interface developed by Philips nearly 20 years ago to establish a simple 2-wire communication standard between a variety of IC's and interface devices [7]. The MiniTrax board (Figure 3a) includes a 4-pin header for interfacing auxiliary digital and analog signals such as buttons and potentiometers into the tracker. Using this interface, OEM's and systems integrators can embed the IS-900 tracking sensors into their own 3D interaction devices, and pass all the data from their custom controls through the tracking system interface, taking advantage of the tracker's wireless link, if desired. The I^2C implementation allows up to 4 bytes of auxiliary data for input and output, simultaneously, from the MiniTrax board per cycle. By alternating input and output cycles, it would be possible, for example, to simultaneously read control signals from a variety of buttons and potentiometers and write feedback data to various indicators, LEDs, buzzers, or tactile displays.

Designers have the choice of using InterSense's existing 23 x 23 mm button/joystick board directly or as a reference design. It supports six digital I/O connections and two 12-bit analog inputs, or can be used as a development platform for implementing custom processor boards using the same processor and existing sample code.

4.6.2. Smart beacon architecture & extended ultrasonic range

The original IS-900 systems used an ultrasonic constellation consisting of discrete transmitters (beacons) each having a unique pre-programmed identification or reference number. Three beacons ("SoniDiscs") are conveniently packaged in an aluminum "SoniStrip" (Figure 8) in both 4 and 6 foot lengths (two beacons in a 2 foot length). A typical system ships with six SoniStrips, which may be mounted either above or around an immersive display. This approach required manufacturing and stocking of several unique SoniStrips, as the beacon reference numbers for each transmitter in a given IS-900 system had to be unique.

The smart beacon architecture is designed to overcome the pre-programmed ultrasonic transmitter IDs requirement; provide a programmable volume control to support longer range configurations; and, implement an RS-232 interface for use with the simplified serial sensor network. In standard IS-900 configurations, the ultrasonic transmitters are mounted in the same form factor as the original IS-900 SoniStrips (Figure 8) with either two or three SoniDiscs installed in each SoniStrip.

Figure 8: IS-900 SoniStrips

With the smart beacon architecture, each SoniStrip is identical until wired into an IS-900 system. The process of connecting the SoniStrips through a serial distribution hub (Figure 9) configures each ultrasonic transmitter with a unique identification upon system power up.

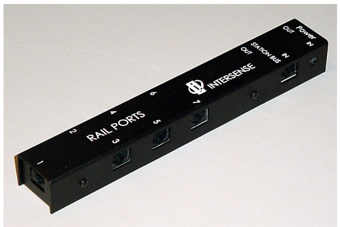


Figure 9: Serial SoniStrip distribution hub

The standard distribution hub supports up to seven SoniStrips per hub, each having three ultrasonic transmitters (SoniDiscs). The fixed port number on the hub assigns the unique SoniDisc ID to each transmitter during power up. Up to seven hubs can be connected in a daisy chain with each hub in the chain being numerically sequenced during power up to assign it's group of SoniDiscs with their unique IDs. A total of 147 SoniDiscs are supported through one serial port of the IS-900 processor. In a typical installation, this covers approximately a 72 m^2 tracking area. Adding additional chains of hubs and SoniStrips to additional serial ports on the IS-900 processor can further expand the tracking area.

By default, hubs receive 12 VDC power from the IS-900 processor, which can provide the standard vertical tracking range of 3 meters that was supported in the original IS-900 systems. With the smart beacons, an external 15 VDC supply can optionally be connected to the serial hub to increase the tracking range to 4 meters.

4.6.3. Modular beacon mounting system

Tracking systems are being installed in a wide variety of environments including large spaces for studio, museum and entertainment applications down to small cockpit or desktop environments for flight simulators, design workstations or virtual training applications.

While the SoniStrip array addresses most standard immersive display applications, a modular approach to the ultrasonic array is desired to cover a larger range of tracking applications. With a typical installation of SoniStrips in a large room environment, the SoniStrips are mounted in a grid pattern on the ceiling, spaced roughly 1 meter apart. Once installed, the full array is measured with an optical sighting tool ("Total Station") to determine the exact location of each beacon. These measured coordinates are downloaded into the IS-900 processor to establish a tracking constellation reference for the environment.

For smaller installations, a fixed, factory calibrated beacon configuration provides a quick and simple way to set-up the tracking volume without the need for surveying. Shown in Figure 10, two fixed constellation configurations are now part of the standard IS-900 systems—the SoniWing, which uses six transmitters to track volumes up to 1.5 x 1.5 x 2 meters, and the Fixed Frame, which supports nine ultrasonic transmitters for tracking volumes up to 2.5 x 2.5 x 3 meters.

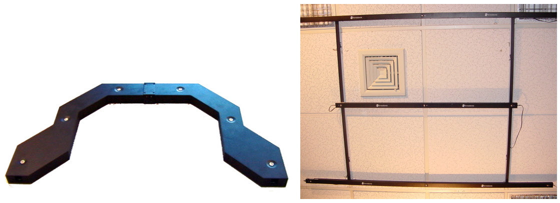


Figure 10: SoniWing and Fixed Frame

In certain OEM or custom installations, the SoniDiscs need to be installed in specific positions. For these applications, each SoniDisc is mounted individually in its own package that can be interconnected with standard Ethernet CAT5 cabling. The transducer elements may be remotely mounted up to 25 cm from the SoniDisc electronics to provide very unobtrusive transmitter reference points for visually sensitive applications (like in a six-sided CAVE®). Figure 11 shows a discrete SoniDisc package with standard aluminum extrusions for customized mounting configurations.

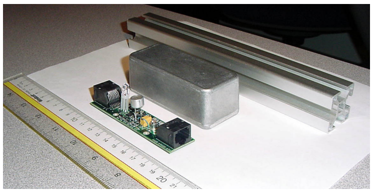


Figure 11: Discrete SoniDisc mounting options

5. Standard configurations and options

Several standard configurations are available for the IS-900 system. Details and specifications of these configurations are at the InterSense website and left out here for brevity.

5.1. PCTracker

The IS-900 PCTracker is a low cost configuration designed to run directly off a standard Windows PC connected through one or two serial ports. The PC runs with an enhanced version of the InterSense .dll and processes data from up to two tracked devices and a small-area constellation comprising up to nine SoniDiscs.

5.2. SimTracker

Supporting up to 36 SoniDiscs and four MiniTrax trackers, the IS-900 SimTracker is delivered in it's standard configuration with either the SoniWing or Fixed Frame. Processing is done with the IS-900 Serial Processor and can also be upgraded to provide wireless connectivity to the tracking devices.

5.3. VETracker

The IS-900 VETracker provides the maximum expansion capabilities for the IS-900 system, supporting up to seven trackers with a maximum of 147 SoniDiscs (or six trackers with a maximum of 294 SoniDiscs). Wireless tracking is also available in this configuration.

6. Enhanced Software Interfaces & Tools

6.1. Software Developers Kit (SDK)

The InterSense SDK provides a standardized interface for applications using InterSense tracking systems. The InterSense applications programmers interface (API) provides software developers with a consistent and guaranteed programming interface that will allow applications to operate efficiently with all past, current and future InterSense tracking products. As updates to the libraries are released to support new product configurations, applications using the API only need new versions of the libraries to remain compatible. This simplifies support and allows easy upgrades for both hardware and software.

At the core of the API are the InterSense libraries. These libraries take the form of a Dynamic Link Library (.dll) for Windows and a Shared Object Library (.so) for Linux, SGI IRIX and Sun Solaris operating systems. Tracker control, configuration and data access are available to third-party applications through these libraries. Example code is provided for interfacing to these libraries.

6.2. Configuration software improvements

The standard configuration tool for all InterSense trackers is ISDEMO. ISDEMO is a Windows program that provides a simple way to set-up, configure and test an IS-900 system. Many recent enhancements to ISDEMO also provide greater flexibility for supporting different IS-900 tracking configurations, including Ethernet interfacing, self-test capabilities and Internet remote diagnostic support.

A tool designed to assist in the constellation design process is also included in ISDEMO (Figure 12). It uses a volumetric color map visualization to interactively display the Geometric Dilution of Precision (GDOP) of ultrasonic position determination at test points throughout the tracking volume[3]. Candidate constellations are user configured using ISDEMO's simple CAD-like interface. The ultrasonic range measurements provide drift correction for the inertial tracking and, to a large degree, determine the accuracy and stability of the system. Optimizing the arrangement of ultrasonic beacons using this tool can greatly improve tracking system performance.

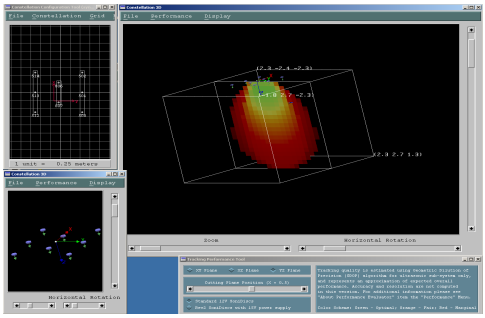


Figure 12: GDOP constellation evaluator

6.3. Compatible 3rd party programs

Some of the third-party developers who have implemented our API into their products, conferring compatibility to InterSense's full product line include:

- AuSIM GoldMiner™, RollingNugget™ and reCREate™ for 3D audio simulation (www.ausim3d.com).
- Brainstorm eStudio and M3 for real-time, 3D graphics production and presentations (www.brainstorm.es).
- EON Realities EON Immersive VR application development software (www.eonreality.com).
- Iowa State open source VR Juggler virtual reality development tools (www.vrjuggler.org).
- National Instruments LabVIEW instrumentation and measurement software (www.ni.com/ask).
- TGS amiraVR visualization software (www.tgs.com).
- Virginia Tech open source DIVERSE development environment (http://thor.sv.vt.edu/diverse).
- VRCO trackd software for CAVE™ and immersive display tracking interfaces including Schlumberger's Inside Reality Software and Sense8's WorldToolKit with the Immersive Display Option (www.vrco.com).

7. Productivity in Virtual Environments

Tracking systems are being used in a wide variety of design, planning, simulation and training applications. When properly implemented, the use of trackers in these environments should be transparent to the user, providing a natural means of interacting with the application.

In the examples below, tracking systems, including the IS-900, are being integrated into applications yielding significant productivity gains and cost savings.

7.1. Seismic analysis and well planning on oil & gas fields

In the area of oil and gas exploration and field management, Schlumberger is an industry-leading service company. Their software division, Schlumberger Information Solutions (SIS), develops and supports a powerful immersive application, Inside Reality, based upon technology developed by Norsk Hydro and Christian Michelsen Research AS. Inside Reality is used in immersive, tracked environments for interactive well planning, real-time geosteering and geophysical analysis [9].

With Inside Reality, tracking is an essential part of the user paradigm. Projected in a 3D immersive environment, integrated datasets consisting of 3D seismic data, geological interpretations, reservoir models, and well data is combined in a common virtual world. Geologists, engineers and managers collaborate in this virtual environment to analyze the data and to plan and optimize new well paths with the goal of maximizing production (Figure 13).

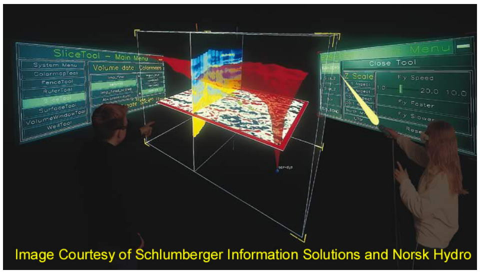


Figure 13: Inside Reality with 3D interactive devices

Through the use of tracked wands with buttons, interactive 2D slice planes are used to analyze seismic data sets or 3D probes to obtain the best view of possible new well locations. Buttons are used to activate and manipulate different types of graphical objects, like existing wells, or can be used to draw and plan new wells. Simple gestures, both with and without buttons pressed, are used to scale data sets and dismiss floating menus.

A significant benefit from the IS-900 Wireless Wand and Head Tracker when used with Inside Reality is the elimination of "trip hazards" associated with wired tracking devices. In dark immersive environments with several people viewing datasets, the use of wired tracking devices becomes a major safety issue. In addition, the wireless devices reduce awareness of the tracking equipment, thus increasing the immersion effect, which allows the user to concentrate on the data and work tasks.

The design of the software was built with tracking as an integral part, giving geologists a natural way to interact with the data so they may concentrate on the task of maximizing oil field production. The success of this approach is proving itself with tremendous savings of time and money by helping oil companies to reduce planning cycles, improve well placement, and maximize well profitability.

7.2. Simulated welding training

In welding schools, most of the training time is spent for gesture control. This costs a lot of raw material to the training organization and is a painful step for the trainee. InterSense partner Immersion SA has developed a virtual welding workbench for the WAVE project. This project is supported in the Fifth Framework program by the European Commission in the IST initiative and is included in the cluster of projects EUTIST-AMI (www.eutist-ami.org) regarding Agents and Middleware Technologies applied in real industrial environments. WAVE is developed in partnership by CS and AFPA WAVE will be initially deployed in all AFPA welding centers in FRANCE in 2004 [10].

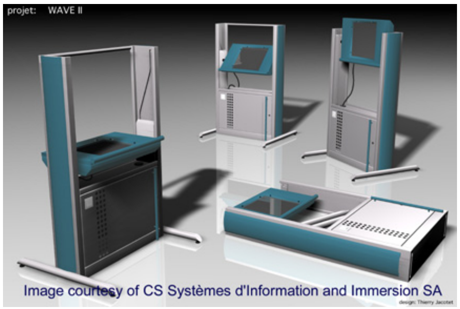


Figure 14: WAVE welding simulator workbench

The primary goal of WAVE is to train students in mastering welding gesture. The main advantage is the reduction of raw material cost. WAVE is designed to introduce and familiarize students learning welding. It does not replace the real training, but will make up about a third of the overall training process.

Shown conceptually in Figure 14, the WAVE welding simulator is the first commercial application of the IS-900 PCTracker. The WAVE virtual workbench runs on a standard PC platform with an adjustable flat panel monitor, which is positioned to simulate different welding procedures. As shown in Figure 15, the IS-900's SoniDiscs are mounted around the flat panel monitor and the welding torch is tracked with a MiniTrax Head Tracker.

In its deliverable configuration, the MiniTrax components are integrated into the torch and the SoniDiscs are embedded into the bezel of the virtual workbench. Since the workbench is required to track the torch at any angle, an encoder reports angle of the workbench and the proper normal vectors for the SoniDiscs are sent to the IS-900 PCTracker software for dynamic configuration of the Constellation array each time the workbench tilt is changed.

The WAVE architecture is designed for use in other networked training scenarios. Each workbench is monitored in real-time by a supervisor workstation. The supervisor workstation also acts as a central database and control manager to handle trainee information and results.

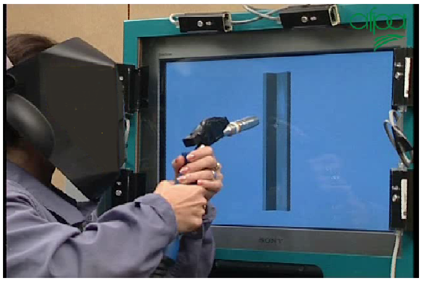


Figure 15: Prototype WAVE using IS-900 PCTracker

7.3. Virtual automotive design and analysis

At General Motors, a major overhaul of the automotive design process is taking place. Time to market for new vehicle designs is down from three years to 18 months. At the center of this change is the use of 3D software and virtual technology allowing modeling, testing and design review to be conducted with computer models [11].

Innovative software and hardware developers at the GM R&D Centers are laying the groundwork for this digital overhaul at GM. Collaborative visualization is being used across multiple CAVE®s and other immersive displays to share designs and data worldwide between GM design centers. The participants in these sessions use both active tracked and passive stereo visualization to interact, communicate and share ideas [12].

In this collaborative virtual environment, tracking plays a key roll to give engineers at different sites head-tracked perspectives of a new vehicle design from all angles. Virtual crash testing is also being explored allowing designers to place themselves visually close to parts under crash conditions. During remote collaborations, tracked wands are used to point and highlight areas of interest across the shared virtual space.

7.4. Stinger missile trainer

Weapons training is essential to any combat soldier. As weapons technology becomes more advanced and costly to operate on a per round basis, combining a simulated weapons training scenario with live fire exercises is becoming the standard approach for most armed forces.

The Stinger Missile Trainer is a 40 foot diameter dome with projected terrain and aircraft images. The dome allows the trainees a full 360-degree surround scene and 70 degree vertical field of view. The system trains up to three gunners individually or simultaneously, to identify, acquire, and track airborne targets then launch a Stinger missile.

In the initial implementation of this training system, each weapon had a cable back to the control computer, which drastically reduced the mobility of the training soldiers and caused tangle and trip hazards.

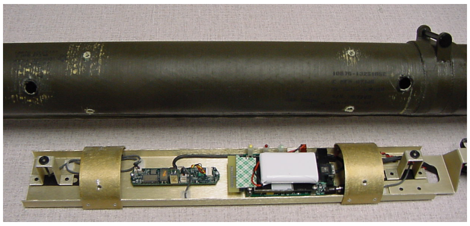


Figure 17: Tracked wireless Stinger missile weapon simulator using I^2C interface

With engineering support from InterSense, the system integrator for this project designed an I^2C interface to send all of the acquisition, lock and fire data along with tracking to the IS-900 processor via the InterSense wireless link. In addition, a custom high accuracy inertial-acoustic tracking station was designed using MiniTrax technology to improve on the overall accuracy of the training scenario. The tracking station (Figure 17) is mounted inside of the Stinger Missile tube with two holes drilled for the ultrasonic receiver microphones.

The SoniStrips are mounted on the central projector platform and provide a 20 foot diameter tracking area in the center of the dome. With removal of the wires and a larger tracking area then in its original configuration, a safer and more realistic training scenario is realized.

8. Summary

We have briefly summarized recent improvements to the IS-900 inertial/acoustic hybrid tracking system, as well as a few example applications, which take advantage of some of the new capabilities and flexibilities. All these improvements have been made, and future changes will continue to be made, in response to feedback from our users, who know best what tracking system characteristics are desirable for interacting seamlessly with graphics in immersive projection environments.

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