1 Intelligent Earth Ltd – Company Background

Intelligent Earth Ltd is an Artificial Intelligence (AI) applications company specializing in intelligent image processing. The Intelligent Earth Directors have an academic background in AI and advanced image processing.

The Company received global publicity after success with a humanoid robot Doki, a platform for showcasing in-house face detection, face recognition, gender detection, and 'attractiveness measurement'. It also developed the world's first reactive advertising system, AdSwitch, using proprietary gender and age detection software.

Subsequently, the Association of Chief Police Officers' Facial Images National Database (FIND) project in the UK contacted the company for advice on using artificial intelligence to develop and characterize image quality automatically for the UK National Database. This ultimately resulted in the development of the prizewinning and market leading FIND CPS (Custody Photography System) – 'the software that makes FIND work' - now being installed by many of the UK's police forces.

The company's latest technology, HOLOS, is outlined in detail below.

2 HOLOS Overview

HOLOS (High-speed Object Location and Orientation Sensing) technology enables the detection of the precise 3D location and 3D orientation of objects in real-time. HOLOS uses a single camera, a patterned sphere illuminated by IR or visible light LEDs (see figure 1), and intelligent image processing software, to calculate the precise absolute 3D position and the precise absolute 3D orientation of objects attached to the sphere, such as a games controller (see figure 2 and 7), or 'magic pen' (see figure 3 and 7). This calculation resolves the sphere center and exact 3D orientation relative to the camera from a single image frame.

Sphere position is detected with millimeter precision. The x and y location is given to a precision of less than 2 mms within the interactive space of up to 3.2 meters wide. The z axis precision varies with the sphere's distance from the camera, but is always within a precision of less than 5 mms up to 3.2 meters from the camera. Using one camera, the sphere's orientation is detected with a precision of 1/20th of a degree and over a range of 300 degrees (full 360 degrees is possible for certain applications).

3 Technological Barriers Overcome

Seven technological barriers have been overcome to develop the HOLOS technology:

1. The robust detection of the sphere against complex backgrounds. In the case of a HOLOS presentation product, this may include complicated projected or displayed images, and bright office lighting.
2. The system camera can only see a 2D version of the 3D pattern. This 2D information alone must convey both the 3D position of the sphere and its 3D orientation. This allows, for example, the calculation of the pentip location of a Magic Pen with a sphere at its back, even if the pentip is occluded.
3. The location and orientation must be obtained with precision, in both pen and games controller applications. This precision is required because in both the pen and games controller, there is a magnification of angular error caused by the sphere's distance from the point of action of the product, for example, the pen tip of the Magic Pen (see figure 4).
4. Robust detection of the 3D rotation of the sphere over a large range of at least 180 degrees is required. There are out-of-plane rotations in the camera image when parts of the 3D pattern rotate into and out of the camera view. Standard pattern detection methods cannot be applied because the 2D pattern's appearance changes in a non-linear way and violates the 'brightness constancy assumption.'
5. In order to get a reasonable range from webcam level optics, image analysis needs to work with images of sphere patterns smaller than 15 pixels wide. To uphold the mm detection accuracy, as regards position at this range, the pattern's 2D detection is required to have a precision down to 1/30th of a pixel or less (see figures 5 and 6).
6. In order for the system to work with low cost webcams, this precision must be achieved despite inaccurate camera pixels due to motion blurring, lens distortion, CMOS pixel noise, and limited depth of field, all due to the low-cost optics.
7. The HOLOS system must run fast enough to achieve the experience of fluid motion and a seemingly instant response for the user while also minimizing the load on the processor.

The system uses an optimized proprietary algorithm, working with less than 20mb of RAM. HOLOS reaches detection speeds of 100 detects/sec, using a fraction of the computing power of one average processor core, to deliver perfect HOLOS presentation pen and games controller applications, even when using only a low cost webcam as a sensor. The detection algorithm does not currently use the GPU. For more details see algorithm performance tables 1-3.

4 Relevance to Potential Applications

HOLOS technology applications are designed by incorporating a holosphere into a games controller, virtual pen, or any device where high-speed absolute position and absolute orientation of that device is necessary for the device functionality to be computed. Four key applications, which may be considered together or separately, are as follows:

4.1 Juiccee Games Controller

The HOLOS tech games controller, working name 'Juiccee,' is a new level of controller, capable of replacing the Wii, and ultrasonic-based controllers. HOLOS' positional precision is allied with its capability to deliver absolute precise 3D orientation information fast enough to completely upgrade the user immersive experience.

4.2 Magic Pen

The Magic Pen, diagram in figure 3, shows how a holosphere is incorporated into a pen which can then be used for presentations, virtual whiteboard sessions, virtual desktops, 3D mouse and many other applications.

The Magic Pen provides reliable 3D interactive, portable, scalable, self-calibrating virtual whiteboard functionality, sweeping aside expensive, touch-sensitive, high carbon-footprint, high maintenance, smart boards, or less functional, costly, wall-attached, non-3D, sensor products. The Magic Pen can turn any standard screen or monitor into a 3D interactive graphics tablet.

4.3 Virtual Desktop

The application of HOLOS to a Magic Pen device brings a virtual desktop to life. The user can carry a phone size device with an incorporated micro-projector and project the desktop at whatever size is needed, and work on it with a HOLOS Magic Pen. This ability to work without a hardware display, moves computing on to another level and fits with the movement towards virtualization. Using a Magic Pen, users can draw and interact in 3D with an A4 sized virtual screen projected from a pocket-sized PDA (see figure 7).

4.4 Disruptive Technology

HOLOS has been called a disruptive technology, with other potential applications in position and orientation checking in manufacture, building and design, robotic assembly lines, and machinery and vehicle docking, as a 3D sculpturing tool, and in virtual and augmented reality applications.

5 Uniqueness of HOLOS versus existing systems

No other commercially available technology can precisely and simultaneously detect the absolute 3D position and absolute 3D orientation of objects, while at the same time having commercially competitive pricing to fit the consumer electronics marketplace.

Current games controllers either on the market or close-to-market, are able to detect absolute 2D or 3D position alone, using triangulation, either based on LEDs, as in the Wii controller, or ultrasonic time-of-flight, as in PDP's GameTrak controller. 3D orientation is currently only detected in a relative and approximate way using gyroscopic and angular rate sensors, which exhibit integration drift and build up error over time, for example, the Wii Motion Plus module, PDPs GameTrak, or Sony's Motion Controller.

The current non-HOLOS state of the art is complex and expensive, requiring various on-board sensors, micro processors and sender/receivers and current controllers lack absolute orientation. In September 2009, the GameTrak people at PDP applied for a patent for a calibration setup with additional LEDs and a camera in the controller (WO 2009/112822 A2) to try to deal with the integration drift in the sensors.

Games controllers and other devices based on HOLOS, also have two distinct advantages over controller-free, gesture-based input. Firstly, in many applications the users' haptic experience is important, as humans have a tool users' intuition. Secondly, the HOLOS detector can achieve a high precision as it matches the fixed dimensions of the HOLOS controller with the virtual one exactly. This way the user can communicate even very subtle motion to the software and a very fine-grain immersive experience can be achieved.

In the presentation market, interactive whiteboard products that have to be attached to walls, such as Mimio and E-beam, only detect 2D position and not orientation, as do small area 2D pens such as for example the Siso Tablo, or Logitech's digital pen.

The HOLOS Magic Pen is unique among current interactive white board solutions for several reasons: Firstly, it's the only solution where the sensor can be integrated into the projector, or the presenter's laptop. Secondly, true 3D interaction and augmented reality applications are possible. Thirdly, the camera faces the screen, which allows the system to self-calibrate. No manual calibration procedure is needed at setup time. Fourthly, the interactive projection can be scaled to any size.

6 Patent Protection

Intelligent Earth HOLOS technology is patent pending (IPN: WO 2008/056180), with a priority date of 10/11/2006, in USA, Europe, Japan, India and Canada.

7 Development Team Biographies

7.1 David Cumming, CEO, Intelligent Earth Ltd

An innovative and experienced engineer, David has led and been involved in a number of high profile, technically difficult image processing projects. David has worked on Space Shuttle deep space navigation experiments (design and coding of neural network analytical system for deep space navigation), classified military projects, humanoid robot vision and UK Government's National Database project. David designed and developed Doki, the 'UK's best-known robot,' according to the International Joint Conference on Artificial Intelligence 2005. David also unveiled the world's first intelligent reactive advertising system, AdSwitch, in May, 2005. David is a graduate of the University of Glasgow, the Robert Gordon University in Aberdeen, and after working for his PhD at the University of Reading (unfinished) he was central to the development of the UK's Facial Images National Database custody photography system – 'the software that makes FIND work' according to the media.

7.2 Stefan Veeser, CTO, Intelligent Earth Ltd

Stefan Veeser is an expert scientific programmer with a background in AI, Mathematics and Physics. Stefan has gained experience working within several of the top European academic AI research groups, such as the Visual Information Processing Group at the Dept. of Computing, Imperial College, London, the Evolutionary Algorithms Group at the Dept. of AI at Edinburgh University, and the Institute for Logic and Deduction systems at Karlsruhe University in Germany. Stefan is an expert in machine learning, and carried out highly-regarded research into the evidence-based learning of finite state automata, and differential gel-matching for the Proteomics project. Stefan has directed Intelligent Earth's development of a collection of proprietary and commercially valuable code for advanced image processing, including his role as lead programmer for the FIND custody photography system – for which the Company received an award at the Home Office Scientific Development Branch Exhibition in 2007. Stefan also wrote the majority of the code for Doki the robot.

8 Figures

Figure 1: 3D Pattern Projection

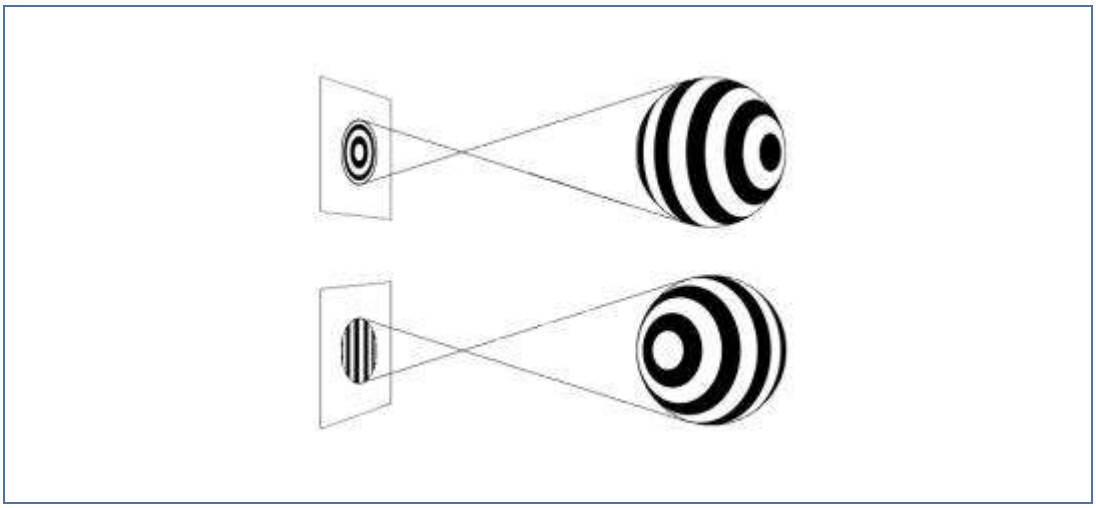


Figure 2: Games Controller Range

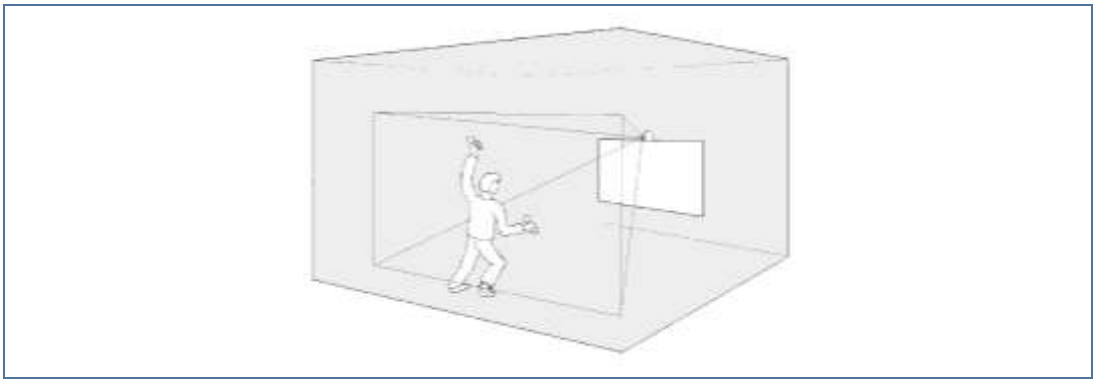


Figure 3: The Magic Pen (schematic)

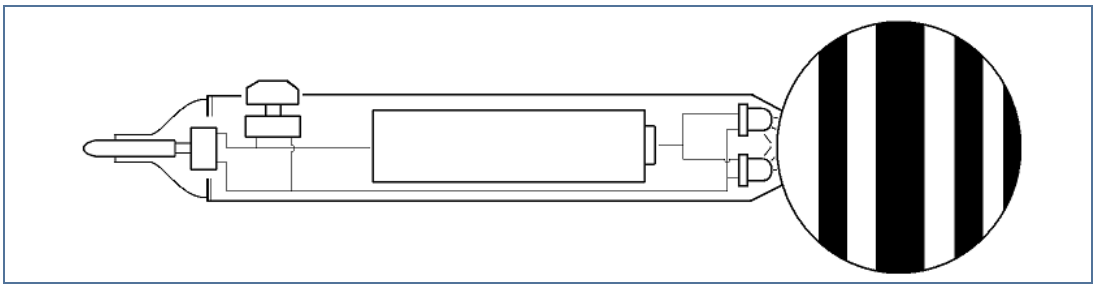


Figure 4: Error Magnification I

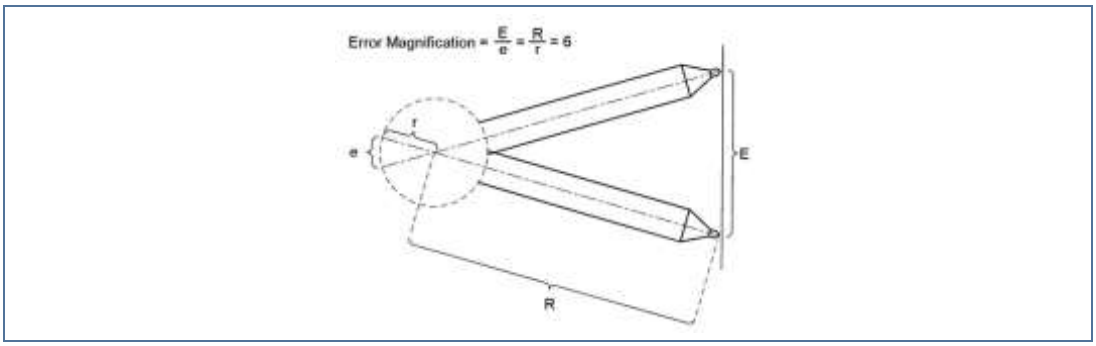


Figure 5: Error Magnification II

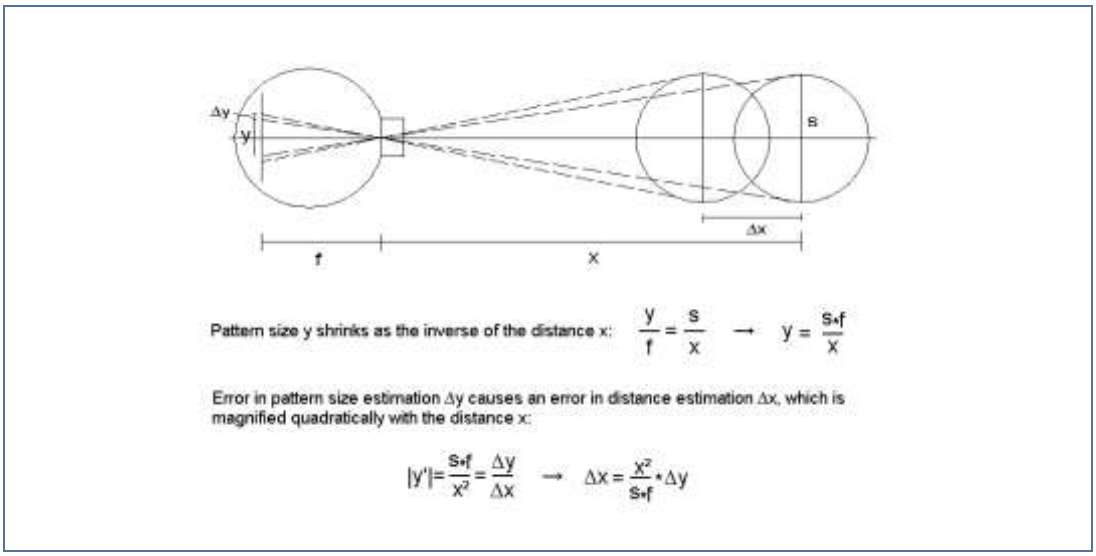


Figure 6: Distance Estimate Related to Pattern Size Estimate

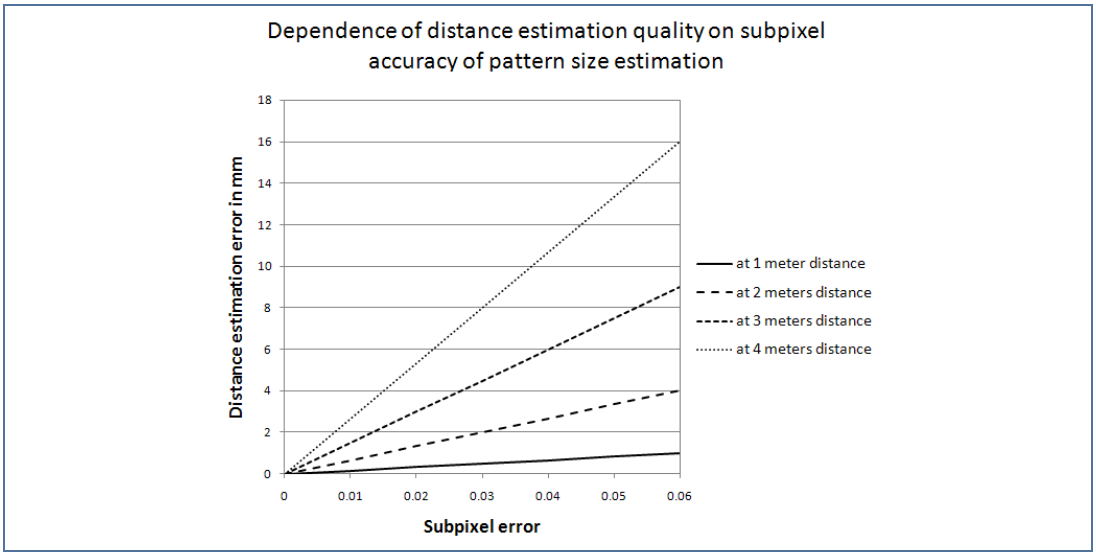
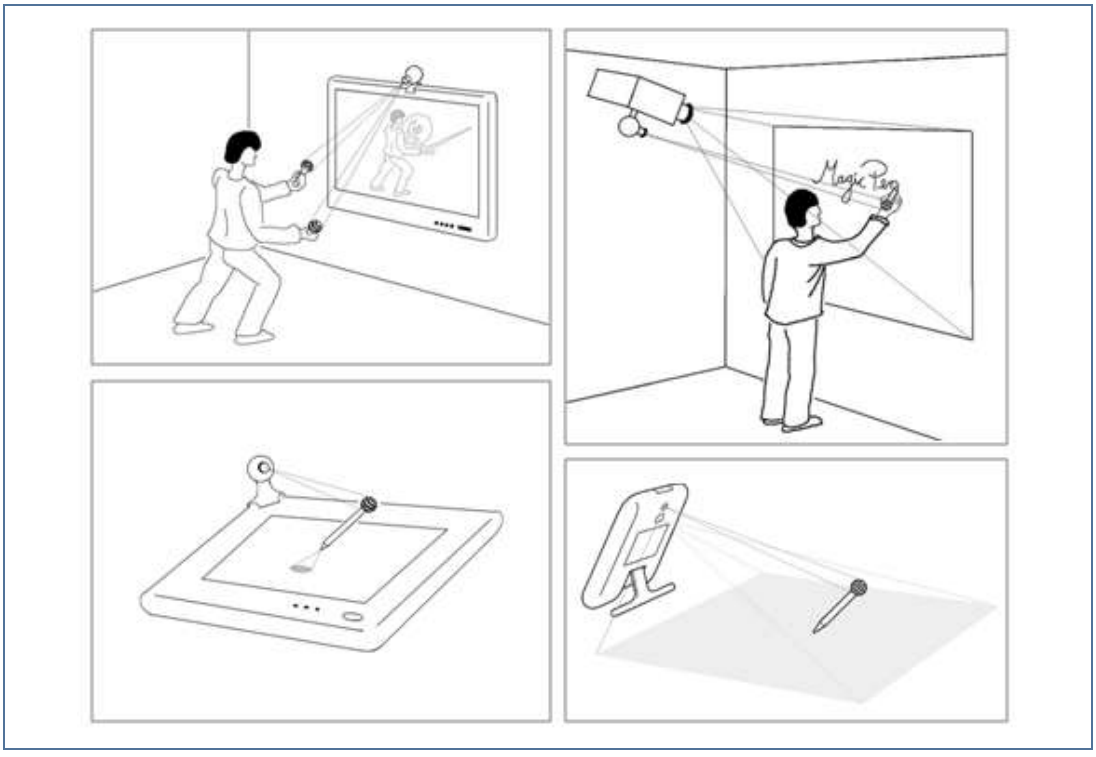


Figure 7: Four Applications of HOLOS



9 Tables

Table 1: Magic Pen

Performance Parameters for Magic Pen Application	
Sphere Size	Ø 44 mm (approx. table tennis ball size)
Sphere Illumination	IR
Max Screen Size for Magic Pen	>120 inch diagonal
3d Pen tip position detection accuracy	X,Y < 3 mm Z < 7 mm
Screen Distance to camera	Up to 5.5 meters for camera AOV 25 °
Ambient brightness tolerance	350 LUX (works in bright office light)
Battery duration	2 business days usage

Table 2: Games Controller

Performance Parameters for Games Controller Application	
Sphere Size	Ø 50 mm
Illumination	visible
Active Volume	Max 3.2 meters left/right Max 2.4 meters up/down Up to 3.5 forward for camera AOV 45 ° Up to 2.6 forward for camera AOV 60 ° See Figure 2
Accuracy sphere centre	<2 mm left/right <2 mm up/down <10 mm forward/backward
Accuracy sphere orientation	< 1/20 °
Range sphere orientation	Approx. 300 °
Ambient brightness tolerance	up to 450 LUX
Battery Duration	up to 6 hours

Table 3: HOLOS DLL

HOLOS DLL General	
Speed	Up to 100 detects per second, using only a faction of a single core, does not use GPU
RAM consumption	20 MB constant
Multi sphere detection	4 or more possible
Number of rings in pattern	as low as 2
Compatible camera resolution	as low as VGA 640x480
Compatible camera quality	as low as £25
Manually generated code	45,000 lines