Institution:
University of Cambridge

Unit of Assessment:
UoA11

Title of case study:
Ubisense

1. Summary of the impact (indicative maximum 100 words)

University of Cambridge research on the principles of 'sentient computing' led to the foundation of spin-out company Ubisense, which has grown into a leading location solutions company. By the end of 2011, Ubisense had 170 employees and was floated on AIM with a valuation of £38.6million. It serves customers such as BMW, Airbus, Aston Martin and the US Army. Deployment of the Ubisense Real Time Location System has improved production line accuracy and efficiency by up to 10%.

2. Underpinning research (indicative maximum 500 words)

The research was undertaken by Professor Andy Hopper, who joined the University of Cambridge in 1977, became Reader in 1992 and Professor in 1997. He was appointed Head of the Computer Laboratory and Professor of Computer Technology in 2004. From 1999 onwards, the research was undertaken collaboratively with Dr Andy Ward at AT&T Laboratories Cambridge. Professor Hopper led the research project throughout.

The research was founded on the notion that computers monitoring or controlling anything in the real world need to be able to sense the environment they operate in – commonly referred to as "sentient computing".

As humans we make sense of our surroundings using sight and sound. These tools help us understand the identification, location and motion of things so we can interpret the world around us. Without this information even basic actions are impaired and complex activities are beyond reach. Automatic monitoring and the control of processes need a similar level of situational awareness, which is where real-time location system (RTLS) technology can help.

The Computer Laboratory's first-generation work was the Active Badge system, which used infrared transmitters and detectors. This located people and equipment to the granularity of a single room. After developing the location technology (1989-92), the research (1992-96) investigated systems architecture, design, and implementation, along with some prototype applications [1]. One such early application was routing of telephone calls to the telephone nearest the location of the person wearing the badge [2].

While Active Badges allowed investigation of location-based systems and services, the technology was insufficiently precise for many potential applications. The second generation of research therefore aimed to implement devices that could locate positions to within 15 cm and to investigate the systems and applications issues raised by such precision. The Active Bat, developed between 1997 and 2002 [3], using ultrasound transmitters and detectors, was initially accurate to 14 cm at 95% confidence, sufficiently good for that investigation. Further developments pushed accuracy to 3 cm at 95% confidence [4]. The key research, however, was not the location technology itself but rather what kind of systems one could build to use such precise location data and how such systems should be constructed and managed.

Reference 4 describes the first full implementation of a distributed system which can handle and process fine-grain location information in real-time. This implementation was in the offices of AT&T, the collaborating research laboratory, and took place in 1999–2001. This particular implementation used 750 receiver units and 200 active bat devices. This large-scale prototype required research into various systems-level services including mechanisms for formalising imprecise spatial relationships, timeline-based data storage, proximity-based applications, and user-interfaces based on bat location and orientation.

Reference 5 describes a sentient platform for context-aware computing that enables applications to follow mobile users through identification of a small sensor tag. This was a key test of the underlying systems. In addition to the fine-grained location system, it required research into how to implement a detailed data model, a persistent distributed object system, resource monitors, and a

spatial monitoring service. The work was conducted in 2000–02, overlapping in time with the research reported in Reference 4.

The Computer Laboratory's academic research having laid the foundations for such systems, the spin-out company, Ubisense, investigated other location technologies, settling on radio-based tags for the third generation of the location technology.

Note: For most of his career at the University of Cambridge (1977–1997, 2004–present), Hopper was affiliated with the Computer Laboratory. For the period 1997–2004, he was head of the *Laboratory for Communications Engineering* at the Department of Engineering, which Lab was transferred in its entirety to the Computer Laboratory in 2004, being renamed the *Digital Technology Group*. Hopper, his research group, and any research produced by them are therefore considered part of UoA 11 for this REF exercise.

3. References to the research (indicative maximum of six references)

*[1] Andy Harter and Andy Hopper. "A distributed location system for the active office." *IEEE Network* **8**(1):62-70 (1994).
DOI: http://dx.doi.org/10.1109/65.260080

[2] A Hopper, R Want, RM Needham, DJ Wheeler. "Locating and authentication system." US Patent 5,493,283 (1996).
Web: http://www.google.co.uk/patents?vid=USPAT5493283

*[3] Andy Ward, Alan Jones, and Andy Hopper. "A new location technique for the active office." *IEEE Personal Communications* **4**(5):42-47 (1997).
DOI: http://dx.doi.org/10.1109/98.626982

[4] Mike Addlesee, Rupert Curwen, Steve Hodges, Joe Newman, Pete Steggles, Andy Ward, and Andy Hopper, "Implementing a Sentient Computing System", *IEEE Computer* **34**(8):50-56 (Aug 2001). ISSN: 0018-9126.
DOI: http://dx.doi.org/10.1109/2.940013

[5] Andy Harter, Andy Hopper, Pete Steggles, Andy Ward, and Paul Webster, "The Anatomy of a Context-Aware Application", *Wireless Networks* **8**:187-197 (Feb 2002).
DOI: http://dx.doi.org/10.1023/A:1013767926256

*Indicates those references most representative of the overall quality of the research.

4. Details of the impact (indicative maximum 750 words)

Ubisense was founded in 2002, with Professor Hopper as Chairman, to commercialise the location solutions applications of the research. Within two years it had merged with TenSails LLP, who had been collaborating with Ubisense since its foundation.

The company's first profitable quarter was in 2008, with annual revenue of £9.7million in that year. By the end of 2011, the company had floated on AIM with a valuation of £38.6million. Annual revenue in 2012 was £24.3M and the company had 184 employees. [6]

The Ubisense Real Time Location System (RTLS) is used inside manufacturing plants to track components, tools and people, identifying inconsistencies and enabling customized production. Customers include BMW, Airbus, Aston Martin, Daimler, Atlas Copco and the US Army. The design and implementation of the RTLS is based on and develops the techniques, systems, and methods investigated and built during the University research described above:

"*Professor Hopper's group investigated a range of technologies which could be used for indoor fine-grained positioning and studied the performance of each technique in detail. The group also developed scalable distributed computing systems which could process (in real-time) the large volumes of data generated by fine-grain positioning systems, and convert a 'firehose' of raw position data into a more manageable stream of application-relevant spatial events. Even though Ubisense has undertaken a considerable amount of research and development of its own in the commercial arena since 2002, it is still possible to trace the lineage of systems back to this original work.*" CTO and VP Engineering, Ubisense [11].

In 2009, Ubisense and Atlas Copco signed a collaboration agreement for the research and

development of the Atlas Copco-branded Tool Location System (TLS) software. As of February 2012, this software had been deployed by BMW, Jaguar Land Rover, Audi, BM, Hyundai and PACCAR, among others [7]. TLS uses sensors inside manufacturing plants to monitor the position of tools and assets to an accuracy of 15cm. One example of use is that a human-operated tool can be set to tighten a given bolt to the correct torque, the human having only to position the tool correctly rather than worry about the tool's settings. This ensures that tightening is performed at the correct tool setting and the correct workstation, increasing productivity, accuracy and quality while reducing costs. This work is a natural extension and successor of the above research in proximity-based applications (the tool must be near the asset) and also develops on the above research that experimented with active bats as user-interface devices (the position and orientation of the tool being part of the user-interface).

TLS is incorporated into the Ubisense Smart Factory System [9], which automates the recognition of tool and vehicle interactions on the production line, continuously tracking and ID-matching each vehicle as it moves along the production line. Again, this can trace its origins back to the University research that investigated how one can build systems that handle imprecise spatial relationships and dynamically changing databases of object location. An example of the productivity increase is Ubisense's recent equipping of a major European car manufacturer's factory with over 400 sensors and 1000 tags. This enabled the manufacturer to eliminate a barcode scan operation, saving approximately 6 seconds per tool operation. This represented an efficiency gain of up to 10% for the company.[11]

In 2009, Aston Martin adopted the Ubisense Process Tracker to track its sports cars through the finishing process at its headquarters in Gaydon, Warwickshire. This provides Aston Martin with analysis and optimisation of each step in the process, as well as raising an alert if a car deviates from the process.[13]

In 2011, Ubisense signed a ten-year global licensing agreement with Airbus, which now has Ubisense tracking technology installed at 10 sites. In the same year Ubisense won contracts with PACCAR and Hyundai.[7]

In 2012, a major European automotive group entered a deal worth over £800,000 to deploy TLS in combination with Ubisense Assembly Control Solution. [14]

Ubisense has also developed a 3D viewing package to aid in training for Military Operations in Urban Terrain, which is used by the US and French Armies. Installing a sensor network throughout the training facility allows precision tracking in 3D, improving the safety and efficiency of training exercises. This application can trace its roots to the University research in the use of bats as 3D location devices, including the work that investigated how to improve precision and bound inaccuracies. It has been installed at Fort Bliss in Texas [8] as well as the National Training Centre at Fort Irwin, California, providing improved quality at reduced costs.

Many other applications can be obtained from the Ubisense website [12].

In 2012, the company received two Queen's Awards to Industry: one for International Trade and one for Innovation.

5. Sources to corroborate the impact (indicative maximum of 10 references)

[6]. Ubisense 2012 annual report:
http://www.ubisense.net/en/media/downloads/ir/reports/68294_ubisense_group_plc_annual_report_2012.pdf

[7]. Business Weekly report on Ubisense:
http://www.businessweekly.co.uk/tech-trail/tech-profiles/13630-ubisense-on-course-to-be-cambridges-next-p1bn-company

[8]. Military Location Driven Training System:
http://www.ubisense.net/en/news-and-events/press-releases/ubisense-announces-military-location-driven-training-system.html

[9]. Information about the Smart Factory System: RFID Journal
http://www.rfidjournal.com/article/articleview/10345

[10]. Ubisense solutions for French military training exercises: GAVAP
http://www.gavap.com/home.php?menuV=SYMULZUB&menuH=Produits&langue=en

[11]. Letter from CTO and VP Engineering, Ubisense

[12]. Ubisense press releases:
http://www.ubisense.net/en/news-and-events/press-releases.html?year=2013

[13]. Press release on Aston Martin 2009 adoption of Ubisense Process Tracker:
http://www.ubisense.net/en/news-and-events/press-releases/aston-martin-knows-precisely-where-their-cars-are-in-production-in-real-time-with-ubisense.html

[14]. Press release on Ubisense 2012 deal with major European automotive group:
http://www.ubisense.net/en/news-and-events/press-releases/2nd-largest-european-automotive-group-selects.html