Institution: Robert Gordon University

Unit of Assessment: 11 Computer Science and Informatics

Title of case study: Ambient, context-aware and mobile applications – AmbieSense
1. Summary of the impact (indicative maximum 100 words)

The primary impact is AmbieSense Ltd., a start-up that has had up to 8 employees/consultants. The Company pioneered ambient, context-aware mobile applications and has been able to maintain its technological edge throughout. Secondary impact is through products developed and used by companies including Lonely Planet, Oslo Airport. AmbieSense Ltd. products and services have wide reach and social impact: Tourist trails; outdoor museums; educational historic trails. Customers include public sector: Aberdeen City Council. Benefits are a quality content experience delivered in a context-sensitive manner (social/economic). The significance is: information-rich touristic physical space; an enriching educational experience, connecting pupils with environments. Other technologies have also been built on the AmbieSense platform and patents have cited the underpinning work, demonstrating impact on professional services.

2. Underpinning research (indicative maximum 500 words)

Our track-record in search, context of information need, and query patterns research has been established over 15 years. Rather uniquely, we augmented theoretical research of algorithms with an end-user perspective, and evaluated our methods also within real contexts of use.

Our research insights stemmed from analysing user queries in search systems, detecting patterns of information need and behaviour within web search, and providing *context-aware search* for more effective results. This extended to *mobile* search and *ambient* information environments where other contextual factors affect user information needs within changing physical spaces.

Context-Aware search: Our approach automatically grouped a user's consecutive search activities on the same topic into one search session (1998-2002). We highlighted the significance of log analysis in identifying the context of information need and importance of the temporal dimension. We combined evidence extracted from statistical data from Web search logs with observations of real use of the system in situ. Outcomes were: a significant improvement over previous methods of session identification [**R1**]; an information retrieval (search) system that included context learning with improved ranking of search results; user evaluation insights, and Microsoft patent citation. (EPSRC Grant No: GR/R11742/01)

Mobile contexts: We extended our research to include search and browsing in mobile contexts (2001-2004) where the contexts of information needs are more dynamic. We developed mobile search and enabled information pop-ups sensitive to location and patterns of needs of tourists and travellers [**R2**, **R3**]. This research was through EU-AmbieSense project. Lonely Planet, Reuters, Oslo Airport and Sevilla Global (city council) were partners providing content. Outcomes were a mobile information system; partner mobile products/apps (Lonely Planet, and Oslo Airport); insights on users' search behaviours in mobile contexts. Mobile search is now well established, but our early work, at a time when smart phones were just emerging, was pioneering. (EU FP5 IST 2001-34244)

Ambient: The right information at the right time, right place was a key focus in EU AmbieSense research. Thus, we augmented physical space and objects with digital information [**R4**]. The ambient information environment was provided through: wireless sensors; a software platform to manage and deliver the information; and mobiles to which the information is served. Novel wireless hardware (from partner SINTEF, Norway) enabled digital content distribution and the use of spatial and temporal features in our context-aware search. The outcome was three tiers [**R3**, **R5**] for information storing, and retrieval: portable (on the mobile); embedded (in local wireless servers); and remote (on remote servers). This architecture is also well-suited to support Internet-of-Things. A further outcome was partner sites (Oslo Airport, Sevilla city).

The strength of the underpinning research in mobile, context, and ambient computing within EU-AmbieSense is also shown by it having been chosen as input for the EU FP6 Work Programme and Calls. Ten further projects were a direct result of this research and innovation.

Users: Through our user-centred observation and evaluation approach, we identified several contextual factors in bringing relevant information to specific situations effectively [**R2**]. We showed that using the users' context, and including location, interests and time-of-day, enabled systems to better meet their needs. Our personalised, and context-sensitive system was tested on a very large scale with real tourists in real situations [**R6**]. Evaluation outcomes and insights led to a start-up, AmbieSense Ltd. The continued research in temporal context also led to recent successful approach within real-time social media content and information needs [REF2: Goker, 2013].

Key researchers

Ayse Goker:	Lecturer/Senior Lecturer/Reader 1998 – 2006; City University 2006 – 2013; Professor 2013 ->
David Harper:	Professor 1993 – 2007; Google 2007 ->
Stuart Watt:	Senior Lecturer/Reader, 2002 – 2007.
Daqing He:	Research Fellow, 1999 – 2002.
Murat Yakici:	Research Assistant, 2001 – 2004.
Ralf Bierig:	PhD student, 2001 – 2006.
Srikanth Nuti:	Research Assistant, 2002 – 2004.
Hannah Cumming:	Research Assistant, 2002 – 2004.

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

*Note: Key references are marked with an asterisk *.*

[R1]* He D., Göker A., and Harper D.J. Combining Evidence for Automatic Web Session Identification. Information Processing & Management Journal, Special Issue on "Context in Information Retrieval", Volume 38, Issue 5, pp. 727-742, September 2002.

[156 Google citations; Scopus Citation over 90.]
Impact Factor: 0.817; 5yr Impact Factor: 1.388

[R2]* Göker A., Watt S., Myrhaug H.I., Whitehead N., Yakici M., Bierig R., Nuti S.K., Cumming H. Ambient, personalised and context-sensitive information systems for mobile users. ACM International Conference Proceeding Series. Proceedings of the 2nd European Union Symposium on Ambient intelligence, Eindhoven, Netherlands. November 2004. pp 19-24. http://dl.acm.org/citation.cfm?id=1031424   *[Google citations 36]*

[R3] Mountain, D., Myrhaug, H., and Göker, A. Mobile Search. In: Göker, A., and Davies, J. (Eds) *Information Retrieval: Searching in the 21st Century*. John Wiley and Sons, 2009, pp.103-130. DOI: 10.1002/9780470033647.ch6   *[Google citations 3, 27]*

[R4] Myrhaug H.I., and Göker, A. AmbieSense - interactive information channels in the surroundings of the mobile user. Proc 10th International Conference on Human-Computer Interaction, Crete, Greece, 2003, Lawrence Erlbaum Associates, Inc. pp. 1158-1162.

[Google citations 11]

[R5] Myrhaug H., Whitehead N., Göker A., Faegri T.E., and Lech T.C. AmbieSense – a system and reference architecture for personalised and context-sensitive information services for mobile users. Proc Second International Symposium on Ambient Intelligence, LNCS 3295. November 2004, Eindhoven, Netherlands, Springer Verlag. pp 327-338.

[Google citations 21; Scopus Citation: 6]

[R6]* Göker, A., and Myrhaug, H. (2008) "Evaluation of a mobile information system in context" Information Processing & Management, Volume 44, Issue 1, January 2008, Pages 39-65. In Special Issue on "Evaluating Interactive Information Retrieval Systems" Eds: Borlund P., and Ruthven I. http://dx.doi.org/10.1016/j.ipm.2007.03.011
[36 Google citations; 21 Scopus citations.]   Impact Factor: 0.817; 5yr Impact Factor: 1.388

Research Grants

EPSRC Grant No: GR/R11742/01. *Facilitating Information Retrieval by User-Adaptive Learning.* 2000-2002. Principal Investigator: Göker, A. Total: £60K. Collaborator: Reuters Ltd.

EU-FP5 IST 2001-34244. AmbieSense: Ambient, personalised, and context-sensitive information systems for mobile users. 4/1/2002 – 9/30/2004. PI at RGU: Göker, A. Total Project Budget: €5.7 Million. RGU budget: €534K. Partners: SINTEF Telecom & Informatics (coordinator), Siemens AG, Lonely Planet Publications, Oslo Airport, Reuters Ltd., NTNU, Sevilla Global, YellowMap, CognIT.

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

There are economic and social impacts. The economic are the ongoing start-up, patent citation, and others' products. The social are: improved public services for cities, education, and tourists; input to standards, and enabling use of outcomes and technology by others.

Background Gartner defines *context-aware computing* as the concept of leveraging information about the end user to improve the quality of the interaction and considers it a growth market [**I1**].

Pathway to impact

The pathway to impact included a start-up company, external recognition through awards and publicity in mainstream media with commercial demonstrators based on underpinning work in ambient, context-aware and mobile computing.

Funding, for the start-up, AmbieSense Ltd., registered in 2005 began through a *Royal Society of Edinburgh Enterprise Fellowship* for Göker (£65K, 2004-2005) and access to business mentoring. A Technology Transfer Entrepreneurship (EPSRC) and funding from Scottish Enterprise and Grampian followed (£20K, 2004-2005; £4K 2004-2006). Mirrored support from Innovation Norway (£60K, 2005-2006) along with investor funding focused on SINTEF hardware used. AmbieSense Ltd. has grown organically since, with a maximum of eight staff and consultants.

External awards showed the relevance of the work to industry and commerce. Göker was a finalist in the highly-competitive *Blackberry Women in IT Award (2005)*, and part of a team that was selected for the Entrepreneurship Development Program (2009) at MIT (*Massachusetts Institute of Technology)* Boston, USA.

Commercial demonstrations were presented by AmbieSense Ltd (e.g. [**I2**]). This continued to build on EU-AmbieSense media coverage around very large scale trials in Oslo Airport and Sevilla city centre with 238 users, 438 responses to surveys (see also [**R6**]). The press coverage included UK, Spain, Germany, Norway, and Euronews. BBC Radio Scotland and Scotsman on Sunday were amongst mainstream media.

Reach & Significance

Economic Impact

Ongoing start-up: AmbieSense Ltd. is an ongoing business that was based on our underpinning *ambient, mobile, and context-aware* research. It continues to provide innovative products and services for the distribution and delivery of content in mobile environments. Using contextual information has enabled AmbieSense to remain competitive and maintain technological edge as an SME [**I3**]. In 2008-2013 it had up to seven employees/ consultants, without VC/Angel funding applications.

Patent citation: The underpinning work on *context-aware search*, user logs and sessions was cited by a Microsoft patent US7657519 [**I4**], which follows an earlier citation by Lucent-US7194454.

Mobile Apps: The research outputs of EU-AmbieSense on *mobile contexts* have been used to produce apps offered by Lonely Planet (Citysync on PalmOS, later mobile guides with Java support) and Oslo Airport (19.5 million passengers, Jan-Oct 2013, app for download to mobiles via website and airport wifi).

Social Impact

The main impact is social through children's history trails and tourists via Seville-Spain, Bunratty-Ireland. Further social impact is through contribution to standards and enabling others' work.

History trails: AmbieSense Ltd. designed and developed a historic Victorian trail for Aberdeen city centre, for public sector customers Aberdeen City Council and Aberdeen Environment Education. The route has 20 points of interest and was aimed primarily at school children 8-12 years old. The products and service spanned a five year period (2004-2009), In the period 2008-2009, it involved around 1000 users, with 6-8 guided trails a month being carried out in term time, each with around 20-40 students. Teachers were able to choose between a paper-based and mobile version of the trail for use. The mobile system was used for around 30%-50% of the trails. The hardware devices are still fully functional after almost ten years. The core images and text were originally supplied by Aberdeen City Council and the trail provided a data-recording and interaction mechanism, via email, to help the users share their experiences. The system was reported by end-users to be both engaging and educational [**I3**, **I5**].

Tourist trails, remote sites: In 2007-08, AmbieSense developed a mobile guide for the Bunratty Castle and Folk Park experience, in collaboration with Failte Ireland, Shannon Heritage and the University of Limerick Tourism Department. The mobile guide was designed to encourage visitors to explore the Folk park and particular areas that had been less explored and often unmanned. The technology has also enabled other projects including Historic Scotland's Living History (2011-present) [**I6**]. This includes AmbieSense's wireless information points and a mobile app for visitors to Historic Scotland sites that will improve the delivery of information at remote locations. It exemplifies our holistic approach to impact where we recognise that different staff can pick up others' research in new projects (REF3a).

Public service in cities and tourists: Sevilla city council (Sevilla Global), as part of an ongoing wireless and Smart Cities initiative, provided (until 2009) the AmbieSense platform as an example of the application to develop new public services. The services included the use of wireless information points and mobile city content. Furthermore, Sevilla through its participation in TURAS project (www.turas-cities.org, Nov 2011), put forward its AmbieSense infrastructure to help cities develop resilience and sustainability. Sevilla is one of Europe's top destinations. (e.g. 2 million tourists /year 2011-2012).

Professional Services Impact

Standards and open source: The AmbieSense context and user model is now available via Github as an open-source Java project. Also, there is an impact on standards. The model has been used as part of a recently-submitted contribution towards MPEG standards on user models [**I7**]. The standard is used by software developers for multimedia content storage and delivery.

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

[I1]   Context-Aware Computing Will Provide Significant Competitive Advantage. Gartner Press Release September 28, 2009. http://www.gartner.com/newsroom/id/1190313

[I2]   EyeForTravel 2009. Report, presentation, and tutorial presented at EyeForTravel "Travel Distributions Summit Europe". London, May 2009. *http://events.eyefortravel.com/school-of-mobile/source-mobile-solutions.asp* and *http://www.pr.com/press-release/159499*

[I3]   CTO, AmbieSense Ltd. Letter describing AmbieSense Ltd, its products, and impact at AmbieSense Ltd.

[I4]   Patent US7657519. Forming intent-based clusters and employing same by search. Microsoft Corporation. Filing date 30/9/2004. Publication date 2/2/2010.

[I5]   Aberdeen City Council and Aberdeen Environmental Education Centre. Letter on behalf of the Council with regard to impact of AmbieSense technology on schools/education and the Council.

[I6]   "Living History", an innovation project funded by Smart Tourism for Historic Scotland. The mobile app delivers information to users using AmbieSense's wireless info points. *www.smarttourism.org/projects*

[I7]   SocialSensor report D5.2 (2013) With colleagues at the University of Klagenfurt, the AmbieSense user & context model has been used to propose extensions to the MPEG-7 and MPEG-21 standards.