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Recent Advances in Ambient Intelligence and Context-Aware Computing

Kevin Curran

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Recent Advances in Ambient Intelligence and Context-Aware Computing

Kevin Curran
University of Ulster, UK

A volume in the Advances in Computational Intelligence and Robotics (ACIR) Book Series

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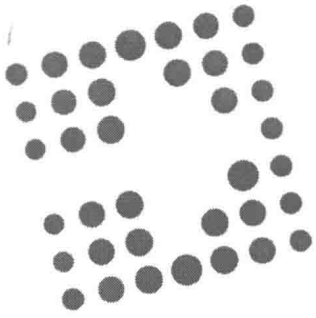

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Preface

INTRODUCTION

The subject matter of this book is based around Contextual Computing. Contextual Computing (aka Context awareness) is the ability for a device, object, or service to be aware of not only the user's surroundings but about the user, their views, behaviours, and their interests (Deak et al., 2013). They adapt their functionality and behaviour to the user and his or her situation. To do so, they need context information about the user's environment (e.g., about different kinds of real world objects). It is about improving the quality of interaction with the user or the object. It is akin to giving the object intelligence to obtain information on the user and use it to enhance the user's experience. Contextual computing is different from the simple sensor-based applications seen on smart phones today. Instead of the user having to go and look for something like hotels, this device would already know what kind of hotel you are looking for by using the information gathered on what hotels they have picked in the past and what facilities they used (i.e. swimming pool, spa) and suggest hotels nearby based on those preferences.

Context relates to both human factors and physical environment factors. Human factors include information on the user: this is their emotional state, their habits, and interests. It also includes the user's environment (e.g. their group dynamics, social interactions, and co-location of others). It also takes into account the user's tasks (e.g. engaged tasks, general goals, and their spontaneous activity). These categories help define the person involved with the object. The physical environment factors include location (e.g. the user's absolute position, relative position) along with co-location and infrastructure (e.g. the users surrounding resources for computation, communication and task performance [Deak et al., 2014]). Physical conditions as in light, pressure, noise, and atmosphere of the area also play a role. Typically, these models contain data about real world objects and virtual information objects that are relevant at a certain location. The main purpose of a context model is to provide dynamic context data at runtime on request for different applications.

CREATING COMPELLING USER EXPERIENCES

Ambient Intelligence plays a major role in today's world. To create compelling user experience requires a great deal of research into the understanding of consumer behaviour and needs. Convenience is the number one achievement when creating a device. Less complications means it is more appealing. The key to making context work is when the design is people-centred. This will work out what they want, what their preferences are, what target market is out there, and whom to aim for. This is very important

when creating and device as well as creating experiences for the customers. Context-awareness can make computing devices more responsive to individual needs and help to intelligently personalize apps and services (Deak et al., 2010). Ideally, future computers will become adapted to a person enhancing their lifestyle and helping them make important choices. There are many examples, such as by using information gathered on your location and your previous preferences of food they can guide you to a restaurant nearby which can accommodate your preferences. It can improve health and fitness by taking all the information about activities, eating habits, and giving guidance and recommendations to suit each user. The remote control of a TV could be used in contextual computing scenarios by identifying the person that is holding it and displaying options suited to that viewer (Feng & Curran, 2009). Contextual computing is aware of its environment and circumstances and can respond intelligently. A future Internet capable of embracing this concept and delivering context-aware services to users and artefacts elevates this to a persuasive sensing and acting knowledge network. This would be a network able to make decisions, actuate environmental objects, and assist users. The future of computing is all about devices that will not only be smarter than today's devices but will also be more aware of the habits and day-to-day lives of their users. Context-aware computing has not found commercial success, but as phones get smarter and tablets become popular, the company hopes users will have a device where apps disappear and become part of the gadget's intelligence (Schacter et al., 1993).

ACTIVITY RECOGNITION

A key research area within Contextual Computing is Activity Recognition, which involves combining the hard senses, which are accelerometers (measuring relative motion), location sensing, ambient light, and ambient audio, with soft senses, which include device activity, social networking actions, and calendar data. Knowing and combining these senses will help the research team reach their goal of transforming a computer into an intelligent assistant, which will intelligently guide, instruct, encourage, inform, and support the user's activities in a personal way. There are many ways this form of context awareness could be useful. Technologies involved for this awareness are wireless communication, speech recognition, image processing or recognition, motion detectors or sensors design, parallel processing, a computer network, and an operating system (Furey et al., 2011; Dreyfus, 1979).

Activity recognition aims to recognize the actions and goals of one or more users from a series of observations on the users' actions and their environmental conditions. Using hard sensing and soft sensing the device is able to carry out the activity fusion algorithm that enables the device to help the user in different situations. For example, if a person had diabetes, the device could tell if the person has taken their medication, if they are sleeping and eating, and if they are doing well. This is done through activity recognition using hard and soft senses (Kleindorfer & Martin, 1983; Agre & Chapman, 1990). The goal is to enable computers to have similar capabilities as humans for recognizing people's activities (Condell et al., 2012). If we develop computers that can reliably recognize people's various activities, we can dramatically improve the way people interact with computers, and we will have a huge impact on behaviour, social, and cognitive sciences (Carlin & Curran, 2014; Moravec, 2010; Knox et al., 2009).

BOOK OVERVIEW

In "Combined Ambient and Wearable Sensors for Gesture-Based Environmental Control in the Home," Coffey and Ward claim that home-based therapy will need to play a huge role in the future if we are to achieve effective and cost efficient forms of rehabilitation. Creative solutions are already being implemented by researchers with the development of revolutionary applications for healthcare leveraging commercially available technology. In this chapter, the authors endeavour to contribute to this goal, describing their ongoing contributions through the application of combined ambient and wearable sensors for gesture-based environmental control. The authors describe in detail the development of three novel systems: an autonomous sensor glove that classifies hand gestures and controls Infrared (IR)-based devices, a smart watch that recognises motion gestures to interact with Radio Frequency (RF) controlled devices, and a hybrid (sensor glove and LEAP motion controller) sensor solution

In "Services and Monitors for Dependability Assessment of Mobile Health Monitoring Systems," Testa, Coronato, Cinque, and De Pietro outline how the problem of failure detection and management in mHealth monitoring systems is becoming more and more critical and the use of wireless technologies and the adoption of commodity hardware/software platforms poses new challenges on the their correct functioning. Remote and continuous monitoring of patient's vital signs is the target of an emerging business market that aims both to improve the quality of life of patients and to reduce costs of national healthcare services. In this chapter, they present the results of a detailed Failure Modes and Effects Analysis (FMEA) conducted to identify the typical dependability threats of health monitoring systems and a design of a set of services and monitors for the assurance of high degrees of dependability to generic mobile health monitoring systems. Moreover, they describe a case study realized to detect failures at runtime.

Bond and Curran in "A Camera-Based System for Determining Hand Range of Movement Measurements in Rheumatoid Arthritis" discuss how rheumatoid arthritis affects around 1% of the world's population. Detection of the disease relies heavily on observation by physicians. The effectiveness of these kinds of tests is dependent on the ability and experience and can vary depending on the observer. This chapter aims to investigate the use of Xbox Kinect camera for monitoring in rheumatoid arthritis patients as a cost-effective and precise method of assessment. A system has been developed that implements the Kinect sensor for usage in a hand recognition and digit measurement capacity. This system performs the tasks usually completed by a physician such as digit dimension monitoring and exercise observations. With the system being designed to be portable and easy-to-use, it is an ideal solution for both the physician monitoring patients in a clinic as well as posing a possible solution for patients wishing to monitor their own condition in their homes.

In "Rehabilitation Systems in Ambient Assisted Living Environments," Middleton, Harte, and Ward provide a review of Ambient Assisted Living (AAL) in the context of movement-based rehabilitation. The authors analyse the need for AAL solutions and how they can overcome many of the drawbacks associated with traditional rehabilitation. They discuss the benefits and challenges of rehabilitation within the AAL paradigm and the well-known benefits that the telerehabilitation and telemedicine models have already established. The authors review the top ambient technologies in use today, detailing their advantages and shortcomings. The review focuses primarily on areas such as motion capture, serious games, and robotic rehabilitation. The authors carry out a structured search of two well-known databases to find the most recent advances and present the most interesting lines of research and development. Finally, the authors discuss the review findings and draw conclusions on the future of personalised rehabilitation within an AAL paradigm.

McKelvey and Curran in "Developing Team Work in IT Education to Foster Student Engagement" posit that Teamwork is an important aspect that should be provided by both employers and employees. This chapter proposes relating this ethos to an educational environment in order to foster encouragement among students. Students demonstrating professionalism can provide important discussion points that can help the class environment run more efficiently. When issues arise in a class, students learn not to hesitate in speaking up. Many co-workers fail to work as a team because people do not voice their opinions on certain matters. Learning how to voice that opinion can aid students/employees in progressing an assignment without hindering any other processes. This chapter outlines how to incorporate teamwork into IT educational environments in order to encourage students to engage more with the process.

In "Common Problems Faced when Developing Applications for Mobile Devices," Curran, Carlin, and McMahon discuss how mobile application development is relatively new and has seen growth of late. With this rapid expansion, there are growing pains within industry, as the usual time given to the evolution of an industry to learn from past mistakes has been significantly shortened and is even going on within the currently saturated market. Because of this, inexperienced developers are attempting to design applications based on what is of yet a shady set of design principals. This is providing problems during the development process and can be seen to be stifling innovation, as many developers have yet to get a grasp on the shift between traditional software engineering and what it means to implicate these designs on a mobile device. An outline is given of the possible benefits and drawbacks when creating a native, Web-based, or hybrid application for a mobile device, and potential revenue streams and business models that developers can use to monetize their applications are also discussed.

In "Human Behaviour Recognition in Ambient Intelligent Environments," Guesgen and Marsland discuss how the recognition of human behaviour from sensor observations is an important area of research in smart homes and ambient intelligence. In this chapter, the authors introduce the idea of spatio-temporal footprints, which are local patterns in space and time that should be similar across repeated occurrences of the same behaviour. They discuss the spatial and temporal mapping requirements of these footprints, together with how they may be used. As possible formalisms for implementing spatio-temporal footprints, the authors discuss and evaluate probability theory, fuzzy sets, and the Dempster-Shafer theory.

In "Ambient Intelligence in the Bedroom," Van Deun, Willemen, Verhaert, Haex, Van Huffel, and Vander Sloten discuss how Over the past years, ambient intelligence has infiltrated our lives through various home applications, enabled by the decreasing size and cost of computing technology. While in transport or industry, its presence has become second nature; some areas, such as our bedroom, have remained fairly untouched. Since our bedroom hosts the beginning and end of our daily activities, it needs to assist us in the recovery and preparation of daily activities. Therefore, it holds an enormous opportunity for AI applications, which do exactly what is needed: sensibly assist the user, learn his preferences, and react to his/her mood and needs. This chapter outlines the different ways of assisting the user in his/her intelligent bedroom: ways to monitor health, improve both physical and mental recovery during the night by automatically optimising the environment, as well as automate a number of tedious tasks that reoccur at every start and end of the day.

Weinel, Cunningham, Picking, and Williams in "Holophonor: Designing the Visual Music Instruments of the Future" consider the technological feasibility of the Holophonor, a fictional audio-visual instrument from the science fiction cartoon *Futurama*. In a previous book chapter ("Holophonor: On the Future Technology of Visual Music"), the Holophonor was used as a means through which to consider the next steps for visual music research. It was proposed that the Holophonor exhibits many of the ideal qualities that should be sought in a visual music performance instrument. An evaluation of the technological feasibility of building a real-world version of the Holophonor is then given, with reference to existing technologies.

In "Smart Home Energy Management," Lillis, O'Sullivan, Holz, Muldoon, O'Grady, and O'Hare outline how autonomically managing energy within the home is a formidable challenge, as any solution needs to interoperate with a decidedly heterogeneous network of sensors and appliances, not just in terms of technologies and protocols but also by managing smart as well as "dumb" appliances. Furthermore, as studies have shown that simply providing energy usage feedback to homeowners is inadequate in realising long-term behavioural change, autonomic energy management has the potential to deliver concrete and lasting energy savings without the need for user interventions. However, this necessitates that such interventions be performed in an intelligent and context-aware fashion, all the while taking into account system as well as user constraints and preferences. Thus, this chapter proposes the augmentation of home area networks with autonomic computing capabilities.

In "Application Mobility: Concept and Design," Johansson and Wiberg discuss how mobility has become an omnipresent part of our modern IT society. Alongside the general taxonomy of mobile users, terminals, sessions, and services, there are also more specialized forms of mobility. Context-Awareness Supported Application Mobility (CASAM) or "Application Mobility" is one such form that is explored in this chapter. CASAM builds on the idea of using context to move an application between different devices during its execution in order to provide relevant information and/or services. The authors use a concept-driven approach to advance mobile systems research, integrating it with a more traditional user-centric method and a case study, further exploring the concept of CASAM.

In "CAFCLA: A Framework to Design, Develop, and Deploy AmI-Based Collaborative Learning Applications," Garcíaa, Alonsoa, Tapiaa, and Corchadoa discuss how Ambient Intelligence (AmI) promotes the integration of Information and Communication Technologies (ICT) in daily life in order to ease the execution of everyday tasks. In this sense, education becomes a field where AmI can improve the learning process by means of context-aware technologies. However, it is necessary to develop new tools that can be adapted to a wide range of technologies and application scenarios. Here is where Agent Technology can demonstrate its potential. This chapter presents CAFCLA, a multi-agent framework that allows developing learning applications based on the pedagogical CSCL (Computer-Supported Collaborative Learning) approach and the Ambient Intelligence paradigm.

In "Contemporary Gold Rush or Scientific Advancement: A Review of Social Network Analysis Approaches and their Impact," Quinn, Chen, and Mulvenna outline following the expansion and mass adoption of Online Social Networks, the impact upon the domain of Social Network Analysis has been a rapid evolution in terms of approach, developing sophisticated methods to capture and understand individual and community interactions. This chapter provides a comprehensive review, examining state-of-the-art Social Network Analysis research and practices, highlighting key trends within the domain. In section 1, the authors examine the growing awareness concerning data as a marketable and scientific commodity. Section 2 reviews the context of Online Social Networking, highlighting key approaches for analysing Online Social Networks. In section 3, they consider modelling motivations of networks, discussing models in line with tie formation approaches. Section 4 outlines data collection approaches along with common structural properties observed in related literature. The authors discuss future directions and emerging approaches, notably semantic social networks and social interaction analysis before conclusions are provided.

In "Current Trends in Interoperability, Scalability, and Security of Pervasive Healthcare Systems," Brugués, Pegueroles, Bromuri, and Schumacher discuss how *the development of pervasive healthcare systems consists of applying ubiquitous computing in the healthcare context. The systems developed in this research field have the goals of offering better healthcare services, promoting the well-being of*

the people, and assisting healthcare professionals in their tasks. The aim of the chapter is to give an overview of the main research efforts in the area of pervasive healthcare systems and to identify which are the main research challenges in this topic of research.

Weinel, Cunningham, Picking, and Williams, in "Holophonor: On the Future Technology of Visual Music," discuss the progression of visual music and related audio-visual artworks through the 20th Century and considers the next steps for this field of research. The principles of visual music are described, with reference to the films of early pioneers such as John Whitney. A further exploration of the wider spectrum of subsequent work in various audio-visual art forms is then given. These include visualisations, light synthesizers, VJ performances, digital audio-visual artworks, projection mapping artworks, and interactive visual music artworks. Through consideration of visual music as a continuum of related work, the authors consider the Holophonor, a fictional audio-visual instrument, as an example of the ideal visual music instrument of the future.

In "Smart Displays in Ambient Intelligence Environments," Ribeiro and José outline that a public display that is able to present the right information at the right time is a very compelling concept. However, realising or even approaching this ability to autonomously select appropriate content based on some interpretation of the surrounding social context represents a major challenge. This chapter provides an overview of the key challenges involved and an exploration of some of the main alternatives available. It also describes a novel content adaptation framework that defines the key building blocks for supporting autonomous selection of the Web sources for presentation on public displays. This framework is based on a place model that combines content suggestions expressed by multiple place visitors with those expressed by the place owner.

In "A Literacy and Numeracy E-Learning Mobile Application for Pre-Schoolers," McCarroll and Curran discuss how the Northern Ireland pre-school curriculum promotes educational development through enabling learning environments and active learning through play and exploration. Enabling learning environments are rich in books, pictures, signs, symbols, rhymes, and multimedia technology. Through play and exploration, children are engaged in activities that interest and preoccupy them. This chapter outlines a "SmartFun" literacy and numeracy E-Learning application. "SmartFun" is a fun, engaging environment to promote the early learning of letters and numbers for pre-school and primary one children.

In "Light Therapy in Smart Healthcare Facilities for Older Adults: An Overview," van Hoof, Aarts, Westerlaken, Schrader, Wouters, Weffers, and Aries discuss how light therapy is applied as treatment for a variety of problems related to health and ageing, including dementia. Light therapy is administered via light boxes, light showers, and ambient bright light using ceiling-mounted luminaires. Long-term care facilities are currently installing dynamic lighting systems with the aim to improve the well-being of residents with dementia and to decrease behavioural symptoms. The aim of this chapter is to provide an overview of the application of ceiling-mounted dynamic lighting systems as a part of intelligent home automation systems found in healthcare facilities. Examples of such systems are provided and their implementation in practice is discussed.

In "Context-Aware Mobile and Wearable Device Interfaces," Ahlrichs, Iben, and Lawo begin by providing an overview of recent research on context aware mobile and wearable computing. Starting from the observation of recent developments on Smartphones and research done in wearable computing, the focus is on possibilities to unobtrusively support the use of mobile and wearable devices. There is the observation that size and form matters when dealing with these devices; multimodality concerning input and output is important, and context information can be used to satisfy the requirement of unobtrusiveness.

CONCLUSION

We are not yet at the stage where wearable computers are able to take the place of our mobile phones, but as the miniaturisation of computer chips and components continues, we are getting very close to mass consumer products on the market. Meanwhile, curved screens allow us to embed mobiles into clothing and furniture, ushering in a ubiquitous world of communications. Ultimately, that appears to be how the industry views market demand: for devices that "disappear" into our surroundings and just "know" what to do in order to make our lives more bearable, more productive, and more creative. It may be that is what we actually want; it may be that advances in technology lead companies to develop solutions that entice us into believing it is what we want. Either way, why carry it when you can wear it? Sounds simple when put like that.

TARGET AUDIENCE

The target audience is under-graduate and post-graduate students and researchers in an IT-related discipline.

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