INVISIBLE INFORMATION SYSTEMS

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Abstract

This article introduces the concept of 'invisible information systems', information systems that seamlessly integrate with and support collective work activity especially in routine operational contexts. Systems designed by traditional methods and implemented with traditional computing technology tend to 'get in the way' of skilful time-constrained performance in these work domains. We argue that the way to create invisible information systems is to incorporate an alternative approach to the design of computing technologies (ubicomp) into our own alternative approach to the design of information systems (situated analysis and design methodology). The situated analysis and design methodology provides a conceptual framework for information systems that support rather than get in the way of collective action in pursuit of operational goals. Developments in ubicomp, which aims to seamlessly support the actions of an individual user, provide the technical means for the physical realisation of such system designs. The resulting invisible information systems are lightweight, and more effective and efficient than traditionally- designed information systems based on traditional models of computing.

Keywords: *IS methodologies, situated action, invisible information systems, ubiquitous computing, information system analysis and design, situated computing*

1 INTRODUCTION

This article introduces the concept of '*invisible information systems*', information systems that seamlessly integrate with and support collective work activity especially in routine operational contexts. Systems designed by traditional methods and implemented with traditional computing technology tend to 'get in the way' of skilful time-constrained performance in these work domains. We argue that the way to create *invisible information systems* is to incorporate an alternative approach to the design of computing technologies (ubicomp) into our own alternative approach to the design of information systems (situated analysis and design methodology).

We are involved in a long term project of developing an information systems analysis and design methodology that focuses on collective action in pursuit of operational goals. This situated analysis and design methodology, which explicitly takes account of the situated nature of action, can overcome the fundamental problem of information systems that 'get in the way' of operations (Johnston and Milton 2002; Johnston et al. 2005; Waller et al. 2007). It provides a conceptual framework for the design of a socio-technical assemblage whereby actors have the information they need in order to achieve collective goals effectively and efficiently (Waller et al. 2007).

However, appropriate technologies are required for the physical realisation of information systems designed using the situated analysis and design methodology. More than a decade ago, the computer scientist, Mark Weiser, observed that traditional computers tend to get in the way of what a user wants to do. In response, he presented a vision of 'invisible' computers, computers which would seamlessly support actors, "weav(ing) themselves into the fabric of everyday life until they are indistinguishable from it" (Weiser 1991:94). The legacy of Weiser's vision is the range of developments under the general rubric of ubicomp.

We show that ubicomp technologies are suitable for application to the situated analysis and design methodology; indeed Mark Weiser was inspired by the same situated approach to action (for example, (Suchman 1987; Lave and Wenger 1991) as we were in developing the situated analysis and design methodology. However, while the situated analysis and design methodology is concerned with supporting *collective* action, ubicomp technologies have largely been designed to support *individual* action.

Invisible information systems are the result of incorporating ubicomp technologies into the situated analysis and design methodology. These *invisible information systems* are indistinguishable from the environment and practices of the organisation. They are lightweight, and more effective and efficient than traditionally-designed information systems based on traditional models of computing.

2 HOW INFORMATION SYSTEMS GET IN THE WAY OF THE ACTION

It is widely acknowledged that a substantial proportion of Information Systems (IS) projects fail, with estimates of failure rates as high as 50% (Standish Group International 1995; Clegg et al. 1996; Fortune and Peters 2005). Analyses of why IS projects fail tend to focus on technical factors, such as the performance of the system, and organisational factors, such as the quality of project management, communication, management support and user acceptance (Yap et al. 1992; Cannon 1994; Gowan and Mathieu 1996; Glass 1998). Some commentators consider that insufficient account is taken of the influence of the environment (Pinto and Mantel 1990; Hougham 1996; Fortune and White 2006).

Johnston et al (2002; 2005) suggest a more fundamental reason for the failure of IS systems, specifically those IS systems designed to support real-time operations of the organisation. They suggest that the problem lies with a misconceptualisation of how the IS can best support these operations.

Conventional information systems are based on the widely held view that the way people act purposefully is by constructing and reasoning about mental models of the world. Previous publications have identified this as the deliberative theory of action (Johnston and Milton 2002; Johnston et al. 2005). Informed by this deliberative theory of action, the role that information systems play in supporting human activity is conceived of in representational terms. An information system provides a computerised model of the world which is updated as the world changes (through transaction processing), and presented to the user as an enhancement of the mental models they use as they deliberate upon action (Weber 1997).

Drawing on work undertaken in artificial intelligence (Agre 1997), situated cognition (Lave and Wenger 1991; Clancey 1997), animal behaviour (Hendriks-Jansen 1996), ecological psychology (Gibson 1979; Heft 2001) and situated action (Suchman 1987), Johnston et al (2002; 2005) argue that the deliberative theory of action misconceives of how people routinely act in order to achieve goals. Rather, they contend that people acting routinely respond directly to structures in the environment to attain goals, including collective goals. This is the situated theory of action.

While the representation approach, based on the deliberative theory of action, is appropriate to support many managerial tasks, this is an inappropriately heavyweight approach to supporting operations (Johnston 1995; Johnston and Brennan 1996). In practice this translates to poor performance of the IS (eg slow response times) and low user acceptance, that is, some of the reasons identified in the literature. Another way of thinking about the result of this misconceptualisation is that the IS 'gets in the way' of the activities of the operation rather than supporting them.

3 DESIGNING INFORMATION SYSTEMS TO SUPPORT ACTION: THE SITUATED ANALYSIS AND DESIGN METHODOLOGY

We are engaged in a long-term project to develop a situated information systems analysis and design methodology (Johnston and Milton 2002; Johnston et al. 2005; Waller et al. 2007). Based on the situated theory of action, this is a radical alternative to conventional information systems analysis and design methodologies.

A situated approach to systems analysis and design demands a focus on the situated nature of action. This in turn leads to a different understanding of how best to provide information support. Unlike conventional systems such as Enterprise Resource Planning systems which are designed first and foremost to provide information for managing, the primary purpose of these 'situated' information systems, designed using the situated analysis and design methodology, is to support routine action in work systems. Moreover, unlike conventional information systems, these 'situated' systems, do not attempt to represent the real world. Rather, the general principle behind the 'situated' system is that it informs users (actors) when to do something and what to do without their need for recourse to a representation of the state of the world.

Two important aspects of actions were identified in developing the methodology, and these form the basis of the intervention.

- **Actions have a context -** Actions are always performed in an action context; that is, actions are conducted by an actor in time and space, making use of resources.
- **Actions have dependencies -** An action may be dependent on other actions having being performed before it can be performed.

The consequences of these aspects of actions are that in order to act, an actor needs to know what to do next, how to do it and when to do it. Another way of saying this is that in order to perform an action, an actor needs to know that action is feasible in the world (that they can perform that action with the time, space and resources at hand). The actor also needs to know that the action is possible now, that is, that the action dependencies have been satisfied. Information about the action context and the action dependencies are both necessary and sufficient for the actor to act routinely.

3.1 Information Systems designed using the situated analysis and design methodology

The principle of the situated approach to information system design is to make use of these two characteristics of actions as points of leverage. Rather than representing the world, the information system can provide actors with direct access to the possibilities for action (affordances) present in the actor's environment. Of course, in this context, the affordances relate to actions which will help achieve the operational goals of the work systems. There are two aspects to this support: making the affordances present and making the affordances known.

- Affordances are made present through **manipulating the action possibility space.** Environmental structures can be manipulated to control which actions are actually feasible for the actor.
- Affordances are made known through **indicating the possibility of action**.

In other words, the environment of the actor is manipulated so that only relevant actions are possible and the actor is informed that an action is possible 'now' without needing to refer to a representation of the state of the world.

Information systems designed through this dual approach of indicating the possibility of action and manipulating the action possibility space are likely to be more lightweight than information systems designed using traditional approach. They are also likely to be more efficient and effective, through supporting routine action, which is generally marginalized in conventional IS methodologies. Unlike conventional information systems, as well as increasing temporal efficiency, situated systems also aim to increase human efficiency; in particular, to reduce wasted human effort in search of information. The designs produced in the project case studies, (Johnston et al. 2005; Waller et al. 2006) have provided evidence that systems designed using the situated analysis and design methodology are more lightweight than those designed using conventional methodologies.

4 UBICOMP: TECHNOLOGIES DESIGNED TO SUPPORT ACTION

The previous section has outlined the principles provided by the situated analysis and design methodology for the design of information systems to support collective actions in pursuit of operational goals. In a nutshell, this is involves the dual approach of indicating the possibility of action and manipulating the action possibility space. These principles can be regarded as a specification of the generic requirements for the system. Appropriate technologies are required for the successful physical realisation of systems designed using the situated analysis and design methodology. A brief overview of relevant development in ubiquitous computing will demonstrate the potential applicability of these technological developments to information systems designed using the situated analysis and design methodology.

Traditionally, computers for individual use are based on the same conceptual model as was described in the previous section with respect to traditional information systems. In other words, traditionally, personal computers are designed to assist us through providing a representation of the world which we can reflect on before action. This leads to the same problems in terms of supporting action that were identified with traditional information systems. This is the requirement to move away from acting in the world to 'use' the computer. In the case of the desktop computer, there is an obvious physical move away from acting in the world to 'using' the computer. Regardless of location, traditionally designed personal computers require the user to shift their attention away from what they are doing to concentrate on using the computer (Norman 1999).

Over the last ten years there has been an alternative stream of developments in computing technology. These involve thinking outside the beige box, about how best to design computers that seamlessly support action in the world. Often referred to collectively as ubiquitous computing or ubicomp, these developments include pervasive computing, context-aware computing, mobile computing, and situated computing, although these terms are sometimes used fairly loosely or used by different commentators to refer to different things. Indeed, some commentators use the term 'ubiquitous computing' to refer to any form of computing that differs from the traditional desktop computer (Garfield 2005). The situation has not changed significantly in this respect since Abowd et al's comment that 'the field remains somewhat poorly defined and diverse'(2002:22). Hence it is necessary in this paper to state what is meant by the different terms used. Figure 1 uses the term 'ubicomp' to refer to this whole alternative stream of development, and depicts the relationship between the different types of 'ubicomp' applications, drawing on fairly common usage. The terms in Figure 1 are explained in the following brief overview. It should be borne in mind that to date, the development of ubicomp technologies to date has largely been technology-driven. As yet, few ubicomp technologies are deployed in real world situations; most exist in controlled experimental environments (Hansen et al. 2006) and some exist as ideas only.

The term 'ubiquitous computing' is sometimes used to refer to a vision of digitising all information, and making it available at anytime and in any place (Grudin 2002). This ***anytime-anywhere computing*** emphasizes access to the same information everywhere, whether by computers located everywhere or users carrying a mobile device (Baresi et al. 2005). In other words, the user is immersed in a 'global computing environment' (Singh et al. 2006).

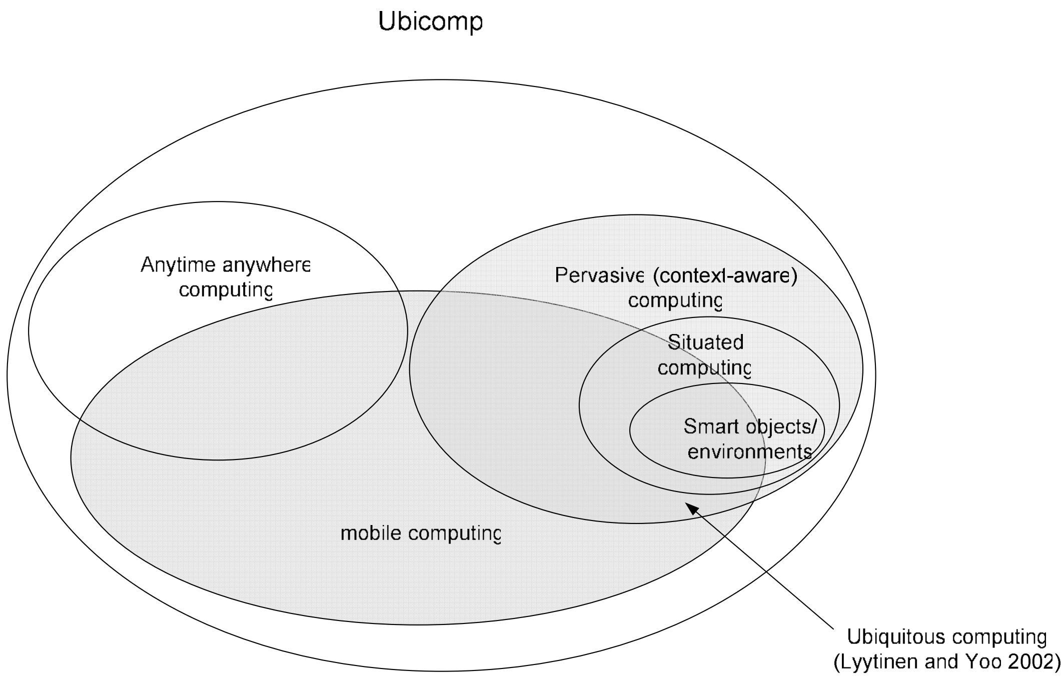

Figure 1. Relationship between different approaches/technologies grouped under the rubric of ubicomp

One of the problems identified with anytime, anywhere computing is that the computing model does not update as the user moves location (Lyytinen and Yoo 2002). This problem is addressed by ***pervasive computing***, sometimes referred to as ***context-aware computing***. Pervasive computing technologies are those where the computer senses and responds to changes in the environment in which it is embedded, in some cases automatically updating its model of the world (Lyytinen and Yoo 2002). As indicated in Figure 1, Lyytinen and Yoo (2002) reserve the term 'ubiquitous computing' for the intersection of pervasive computing technologies with ***mobile computing;*** here the term 'mobile computing' refers simply to the capacity for mobility. Using this definition, Singh et al express it as follows: 'Ubiquitous computing uses mobile computing 'to provide pervasive computing environments to a human user as s/he moves from one location to another' (2006:422).

A possible consequence of pervasive computing is the 'information pollution' (McCullough 2004) of a proliferation of pervasive computing devices. Within the field of pervasive computing are those who advocate parsimony by paying attention not just to the setting but to how the user is engaging with the setting. This basically means getting the right information to the right person at the right time (Dey 2001; Fano and Gershman 2002; Lyytinen et al. 2004; Roussos et al. 2005; Streitz and Nixon 2005).

Situated computing (Hull et al. 1997) is the subset of pervasive computing that follows this principle of parsimony. Situated computing is based on the idea that contextual information is provided to people only when and where they need it. Examples include the next-generation alarm clock designed by (Landry et al. 2004). This alarm clock not only informs the user when to wake up, it also supports the user in deciding when they should get out of bed, what they should wear and when they should leave for work. Landry et al argue that although the user's routine will be sufficient most of the time, there are circumstances in which the usual routine will not be adequate. The user needs to know about any circumstances that will require them to adjust their routine. So the alarm clock alerts the user, for example, if the weather is likely to be markedly different from the previous day, or if traffic conditions are likely to be more congested than normal. In this way, the alarm clock provides the minimum amount of relevant information to support the user in deciding what to do next.

Other situated computing artifacts include handheld navigational aids that tell the user when to turn (Roussos et al. 2005) and 'situated reminders' (Hull et al. 1997). Similarly, there have been projects to develop artifacts which alert the user when an opportunity arises to interact with a person who has similar interests (for example, the Digital Aura (Ferscha et al. 2004) and Sparks(Chew et al. 2005)). This class of artefacts which indicate the possibility for action to the user are clearly of potential use in information systems designed using the situated analysis and design methodology.

Except in the case of 'smartphones', the prefix '***smart***' is often used to indicate that objects or environments are augmented with sensor-based computers (Siegemund et al. 2005). For example smart rooms can adjust the lighting, temperature, and airflow in response to the numbers of people in the room and so facilitate particular activities in the room (Cooperstock et al. 1997; McCarthy 2001). Smart objects embedded with active RFID tags (Stanford 2003) can similarly respond to changes in their environment and may infer human activity (Smith et al. 2005). Smart security systems respond to the detection of authorized human beings and unlock doors to enable entry or exit. Basically, the 'smart' computing artifact alters the structures of the environment to control possible actions. In other words, it manipulates the action possibility space.

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The preceding overview of ubicomp indicates that smart objects or environments and situated computing artefacts are especially suitable for systems designed using the the situated analysis and design methodology. The design principles of this methodology require that the information system manipulate the environment of the actor so that only relevant actions are possible and indicate to the actor when a relevant action is possible. Smart objects or environments manipulate the action possibility space so as to constrain or enable particular actions while situated computing artefacts indicate to the user the possibility for action.

Although, in terms of principles for design, situated computing and smart environments most closely align with situated IS methodology, all of the technologies developed under the ubicomp rubric have potential application to information systems designed using the situated methodology. For example, smartphone technology (mobile phone with GPRS) was useful in part of the solution for the case study described in Johnston et al.(2005). Similarly, mobility and multiple points of access to information via an intranet played a part in the solution suggested in Waller et al.(2006) In other words, the situated analysis and design methodology provides a conceptual framework for the application of ubicomp devices.

Figure 2 shows how ubicomp can be applied to the situated IS analysis and design methodology to produce *invisible information systems*. The situated IS analysis and design methodology provides a conceptual framework for collective action in pursuit of operational goals. In turn, ubicomp provides the technological capabilities to implement the design principles of the situated IS analysis and design methodology. The resulting *invisible* *information systems* seamlessly support collective action in pursuit of operational goals. These *invisible information systems* are indistinguishable from the environment and practices of the organisation.

It is perhaps not surprising that the person credited with inventing the idea of ubicomp, Mark Weiser (1993b), was inspired by much of the same work that inspired the development of the situated analysis and design methodology; for example, Suchman's (1987) and Lave and Wenger's (1991) work on shared understandings of situations, Gibson 's (1979) work on affordances and Heidegger's (1973) work on availability.

Weiser was critical of traditional computers which he claimed get in the way of what we want to do. His vision was for 'invisible' computers that "weave themselves into the fabric of everyday life until they are indistinguishable from it"(1991:94). Norman (1999) echoed Weiser's vision in "The Invisible

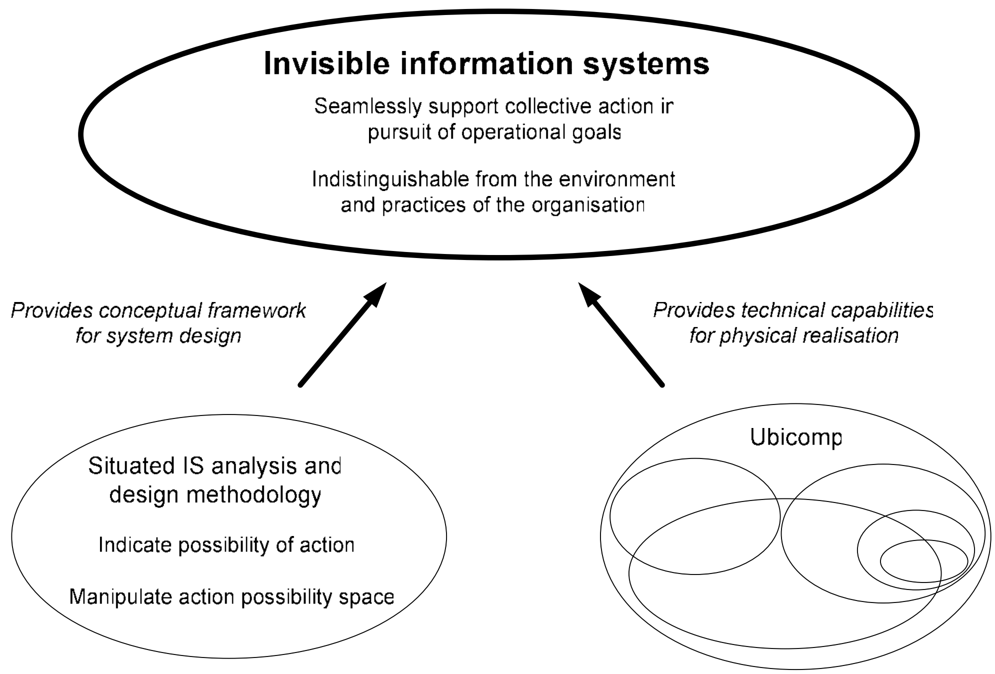

Figure 2. Applying ubicomp technologies to the situated analysis and design methodology

Computer". Here, invisibility is more than just an interface issue (Russell et al. 2005). A computer is invisible when the user can focus on what they are doing rather than on the computing artefact (Weiser 1993a). This notion of invisibility aligns with the goal of situated information systems, to seamlessly support the action in an unobtrusive way. However, it should be noted that the nature of the action supported is quite different. While Weiser's (1991; 1993a) overall aim was to enhance living through using technology to support *individual* actions, the situated IS analysis and design methodology is concerned with using systems to support *collective* action.

6 CONCLUSION

This paper has built on our previous work which argues that a fundamental reason for IS failure is that traditionally designed information systems get in the way of an organisation's activities. We have sketched a vision for *invisible information systems* as an alternative to traditionally designed information systems, particularly to support collective work activities in pursuit of operational goals.

The situated IS analysis and design methodology provides a conceptual framework for achieving this vision of *invisible information systems*; current and projected developments in ubicomp provide the technical means. We have shown that situated computing artefacts as well as smart objects and environments are particularly suitable to be applied to the design of situated information systems. Smart objects or environments manipulate the action possibility space so as to constrain or enable particular actions while situated computing artefacts indicate to the user the possibility for action.

The advantages of applying ubicomp to the situated IS analysis and design methodology are twofold. Technical advances in ubicomp can be usefully exploited, rather than the technology-driven development of sophisticated technologies with no obvious practical use. Secondly, and more importantly, it enables *invisible information systems*, information systems which support people and organisations in what they want to do rather than get in the way. These *invisible information systems* are indistinguishable from the environment and practices of the organisation.

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