A Human Work Interaction Design (HWID) perspective on Internet- and sensor based ICT systems for climate management

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ABSTRACT

Internet- and sensor based ICT systems for climate management in greenhouses presents challenges for the understanding of how technology mediates the interaction between humans and specific work contexts, which is the topic of the field of Human Work Interaction Design (HWID). In this paper, we will analyze and discuss how to combine empirical work analysis with interaction design techniques, with a focus on sensor-based prototypes. The proposed method is action research that will use a combination of theory from usability, work analysis, and prototyping techniques. We wish to investigate possibilities for designing, using and evaluating interactive sensor based prototypes for designing systems, learning key skills, and enhancing current training methods, all of this in a work context.

Author Keywords

Human Work Interaction Design, sensor-based prototypes, usability, work analysis.

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

Internet- and sensor based ICT systems for climate management in greenhouses presents challenges for the understanding of how technology mediates the interaction between humans and specific work contexts, which is the topic of the field of Human Work Interaction Design (HWID) (Pejtersen, Orngreen, & Clemmensen, 2008). Currently greenhouse growers spend several hours daily with the computer, working with the greenhouse climate management systems. What are they doing? Is it all functional, rational problem solving? Is it process control? Is it learning? Is it enjoyment, pure fun? What are the social, cultural, organizational and technical contexts of the computerized climate management? Insight into the needs and reasons for spending much time on a certain task using a computer can help in planning future software systems for the needs of the growers and to contribute to reducing unnecessary work time and stress while increasing time for pleasure, eventually increasing work efficiency and reducing labour costs.

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Human Work Interaction Design (HWID)

This paper contributes to the field of Human Computer Interaction and in particular to Human Work Interaction Design (HWID) which is the topic of IFIP (international federation for in-formation processing) WG (working group) 13.6 on HWID. HWID is concerned with how technology mediates the interaction between humans and specific work contexts, and touches upon topics such as; e.g. cross-cultural usability testing, user personas, usability evaluation method in medical context, usable techniques for hand-writing recognition, mobile application for construction workers, promoting usability in large enterprises, design conversations, social usability in second life for distance learning students, interactive kiosks for museums and more (Katre, Orngreen, Yammiyavar, & Clemmensen, 2010). The research advances and supports international usability research, including mobile usability, usability in safety critical domains, aesthetic approaches to usability and user experience, user innovation, and empirical studies of usability. These research areas are complemented with the research presented in this paper and its proposed focus on usability in contexts.

Domain knowledge: Climate management

Near stress conditions can be identified and characterized in relation to different plant species in a greenhouse under dynamic climate conditions. This e.g. includes effect of high or low humidity that might often be associated with energy saving conditions and cause disease problems. Combining the different technical possibilities of measuring microclimate, enable the application of crop specific models for a large range of climate management purposes. Plants can be established under standard growth conditions and subjected to a desired degree of dynamic temperature, humidity and light conditions combined with different screen conditions and light use. For example, different greenhouse crops have very different needs for climate control. Among them are year round roses, cucumbers, seasonal poinsettia. However, they have the common denominator of large energy requirement both in terms of temperature and light. The management of a dynamic climate may induce physiological changes, and characterization and quantification of these may have importance for the interaction design of the systems for climate management. In a sense, climate management situations are comparable to well-known types of safety critical, emergency and disaster situations, by the urgency of reactions, the disastrous long term consequences, and the decision making aspects of the situations. In this paper, we will analyse and discuss how to combine empirical work analysis with interaction design techniques, with a focus on sensor-based prototypes. In particular we want to discuss the pedagogical aspects of allowing users to train themselves on key scenarios for climate management. The paper is thus narrowly focused on climate management in greenhouses, but takes up the broad discussion of how people adapt and learn to act in new (often extreme) situations. Online worlds (which include simulations, virtual environments, augmented reality, and massive multiplayer games) have potential to aid in training staff to deal with crisis situations. In our paper we focus on a new type of online world that we call sensor based prototypes. We wish to investigate possibilities for designing, using and evaluating interactive sensor based prototypes for learning key skills and enhancing current training methods.

Sensor-based interaction design prototypes

One of the challenges we are faced with when talking about sensor-based prototypes are how to actually do the *physical* modelling. In example, it is difficult to create and test a real sensor-based prototype. Some of the reasons for this are that it requires a different skill set than other prototyping efforts such as Internet programming or standard GUI design. In terms of creating/visualizing a normal user interface intended for a PC, we can usually resort to a drag and drop editor, which are already part of a programming language integrated development environment (IDE). This holds true for languages found in the Microsoft .NET suite and the Java programming language. In the latter case, the popular Eclipse programming environment provides a visual editor. It forms an easily approachable and inexpensive prototyping platform.

In a sensor-based environment, we are not so fortunate. If the requirement is that the sensor-based prototype is dynamic/responsive in any way, then we are required to connect the sensors to each other and to the intended management console. In order to do so, we would need the skillset of electronic engineers and/or mechanical engineers. The electronics and sensors have to be wired, and prototyping boards will be manufactured. It is possible to do so, but at an additional cost (both in terms of time and money) than purely software based prototyping.

A second option is to settle for a modular prototyping platform such as Lego Mindstorms. It features the Lego construction that many is already familiar with. Moreover, it is a candidate for sensor-based prototyping because the Lego Mindstorms NXT ships with various sensors. There are ongoing efforts to provide this platform as a prototyping platform for languages such as C and Java (see http://nxtgcc.sf.net).

Evaluation of sensor-based prototypes

A key element in evaluation the use of prototypes - also prototypes of online worlds - is usability and user experience measures (Hartmann et al., 2006). International standards define quality in the use of ICT systems in terms of a single concept „usability‟ with three aspects: effectiveness, efficiency, and satisfaction, achieved in a specified context of use (9241-11, 1998). The idea that usability can be treated as a unified concept „u‟, analogous to Spearman‟s „g‟ for general intelligence, has found support in reviews of usability test practice in major US companies (Sauro & Lewis, 2009). In contrast to this idea, theoretical work has shown that many really different images of usability appear to be relevant (Hertzum, 2010): 1) Universal usability, i.e. the systems can be used by everybody, 2) Situational usability, i.e. quality-in-use of a system in a specified situation with its users, tasks, and wider context of use, 3) Perceived usability, i.e. the user‟s attitude towards a system based on his or her interaction with it, 4) Hedonic usability i.e. joy of use, 5) Organizational usability, i.e. groups of people collaborating in an organizational setting, 6) Cultural usability, i.e. different meanings depending on the users‟ cultural background.

Analyzing usability in context is important for connecting empirical work analysis and interaction design of the ICT system to explain how technology mediates the interaction between humans and specific work contexts. Industrial techniques (Preece, Rogers, & Sharp, 2007) often give - seemingly - similar results when applied in diverse social, cultural, organizational and technical settings, but experience shows that we need a deep understanding of the different contexts to interpret the results, and to transform it into interaction design. Empirical work analysis offers such deep understanding by studying closely the work, how it does (or does nor) follow plans and procedures, what great and small troubles that people run into during their work, what those who really know the work can tell us about it, and where the work actually is done in our mobilized world (Button & Sharrock, 2009). A promising approach in combining empirical work analysis and interaction design is the use of throwaway (rapidly made, easily discarded), sensor-based prototypes. First, prototypes are low-cost and flexible constructions, which allows for evaluating a number of different setups that with the use of sensors can include more contexts. Secondly, there is an advantage about reproducibility; namely that such prototypes can be reconstructed from simple and clear building instructions, making the evaluations of the prototypes more easily verifiable by other researchers (March & Smith, 1995; Storey, 2008). Specifically, the focus will be set on the three questions:

1. Is there a measure „u" of usability, i.e. is there a single, unified concept of usability that can capture the relation between the human and the computer across the different social, cultural, technical and organizational contexts of an ICT system?

2. How do empirical work analysis (studies of work and the workplace) inform and interact with paper design sketches and functional prototypes?

3. What are the benefits of using sensor based prototypes in ICT user interface design?

METHOD

To answer the research questions, we suggest an action research based approach where researchers work closely with greenhouse growers and consultancy houses, and with software developing vendors that are specialized in systems for climate management. These parties will together have to perform a full iteration of user inter-face development activities on the different components (e.g., climate control, decision support, communication platform) of a greenhouse management system. The iteration will 1) be based on an agile interaction design lifecycle model with usability evaluation as the central element (Hartson & Hix, 1989) to ensure useful user interface designs will be a results, and 2) be overlaid with extensive data collection and systematic reflection on findings, including reflective exercises with stakeholders, to ensure answers to the research questions. Existing systems and modules will firstly be evaluated one for one. Based on that, improvement will be worked out and sketches and prototypes created for each part of the system. To ensure a complete working system, where the complimentary sub-systems are embedded, the researchers may take the lead and create a guideline, and, in cooperation with the industry partners, give suggestions for a complete system house style that ensures a high usability, good user experience, and a clear common style, keeping however the separate functions of each sub-system apart.

EXPECTED RESULTS

The researchers will, in collaboration with the industry partners, be responsible for delivering different research products:

1. Usability and user experience specifications for the primary target user groups.

a. diary study with ten greenhouse growers, two weeks, elicitation diary

b. work observation, two greenhouse growers, onsite, six weeks, participating as an apprentice, following the growers around, screen capture of climate management computer use

c. repeated individual interview, primary stakeholders: 4 growers, 4 advisors,

d. online community, e.g. internet based communication and knowledge sharing tool, establishing a user community

2. Analysis of the climate management task, based on:

a. hierarchical task analysis, ten interviews with experts from consultancy houses

b. persona creation, one person per target user group (e.g., small/large, flower/vegetable nurseries), use of existing marketing statistical data, if necessary questionnaires

c. scenario writing, usage scenarios, two focus groups with four-five growers in each

3. Evaluation of effectiveness, efficiency and aesthetics of prototype through:

a. think aloud usability testing, repeated four times, five participants each time

b. heuristic aesthetic evaluation, repeated four times, focus group interviews,

c. task time performance prediction

4. Conceptual design of the interaction between gardener and system by:

a. sketches, post-it note, at least ten different sketches, animated sketches

5. Prototypes that demonstrate key aspects of the interaction between the software users (typically the growers) and system:

a. horizontal, flat, broad functionality, paper, html, java or similar, more than 4 prototypes

b. sensor based vertical throwaway prototypes, a series of at least five experiments with simulated sensor based climate management with useful functions and a basic set of sen-sors, using Lego Mindstorm programmed in Java, with two group of participants (10 expert users (greenhouse growers), 100 novice users (university students))

6. Implementation user evaluation:

a. work observation of the grower"s work with the new climate management system

b. diary study with four growers, two X one week, feedback diary

DISCUSSION

The idea that we can use Lego Mindstorm sensor based vertical throwaway prototypes to do interaction design will hopefully be versatile. Other research in reflective physical prototyping through integrated design, test, and analysis have shown that, after an initial period of learning the prototyping tool's interface, participants will spend the major parts of their time doing design thinking, i.e. thinking and talking about how the interaction design should be from the user's point of view, instead of wondering about how to implement a particular behavior in the user interface (Hartmann, et al., 2006). What is currently less clear is how explorative and sketch-like such sensor-based prototypes will be. Sketches support different kinds of design thinking (Goldschmidt, 2003).

An interactive, sensor-based prototype may be used as a greenhouse environment simulator, e.g., in the form of a scaled down version of greenhouse including real-time monitoring control systems(Cenedese, Schenato, & Vitturi, 2008). Greenhouse environment simulators have been designed to be used as educational tools for e.g. demonstrating the physics and biology of greenhouse systems and environmental control principles (Fitz-Rodríguez et al., 2009; Pearce, Murphy, & Smith, 2008; Pearce, Smith, Nansen, & Murphy, 2009). For example, scenarios can be simulated to show how a specific greenhouse design would respond environmentally for different climate conditions (e.g., four seasons of the year, or four geographical locations), and to evaluate how system designs work for achieving the desired environmental conditions (Fitz-Rodríguez, et al., 2009; Speetjens, Janssen, Van Straten, Gieling, & Stigter, 2008).

The user is one of the key factors in successful climate management, due to the need for leaving part of the decision freedom in the hands of the grower. Current approaches for user accepted climate management rely on a concept of division of responsibilities, where the short-term effects, e.g., photosynthesis and evapo-transpiration, are controlled by automated systems, while the long-term effects are left to the grower working with flexible decision support system based on crop models (Van Straten, Challa, & Buwalda, 2000). The measures of usability will thus have to be able to accommodate these kinds of two-levels supervisory control activity models. As data from the different metrics will provide insights into different aspects (Pyla et al., 2009), this will provide challenges to the idea of integrated usability concept.

While the HWID research is concerned with how technology mediates the interaction between humans and specific work contexts, it is not clear what concept turns out to be central or the cases studied. Recent studies of work psychology and design suggest that socio-cultural concepts such as processes of trust-building, social identification and community-based learning may be highly important(Rohde, 2007).

CONCLUSION

The expected results of HWID research include application of HWID in a new domain, green-house horticulture, and how the combination of empirical work analysis and interaction design theories and techniques function in this domain. This includes the results on the benefit of using sensor based prototypes in interaction design.

The idea of developing a single, unified metric for usability across different software platforms, functionalities and user groups is controversial; some studies show that there is a high correlation between the different measures of usability, e.g. effectiveness, efficiency, satisfaction, while other studies show a low correlation between such measures. Thus the evidence for and against this idea that we will gain from the proposed research will enter a current debate in the international research community.

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