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Integrating Human-Computer Interaction Development into SDLC: A Methodology

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ABSTRACT

Incorporating a human computer interaction (HCI) perspective into the systems development life cycle (SDLC) is critical to information systems (IS) success and in turn to the success of businesses. However, modern SDLC models are based more on organizational needs than human needs. The human interaction aspect of an information system is considered far too little (only the screen interface) and far too late in the IS development process (only at the design stage). Thus there is often a gap between satisfying organizational needs and supporting and enriching human users as they use the system for their tasks. This problem can be fixed by carefully integrating HCI development into the SDLC process to achieve a truly human-centered IS development approach. This tutorial presents a methodology for such human-centered IS development where human requirements for the whole system are emphasized. An example of applying such methodology is used to illustrate the important concepts and techniques.

Keywords

Systems Development Life Cycle (SDLC), Human-Computer Interaction (HCI), Human Factors in Information Systems (HFIS), Systems Development Methodology, User-Centered Design, Human-Centered Systems Development, Information Systems

INTRODUCTION

In his AMCIS 2003 keynote speech entitled "The Future of the Internet," Patrick listed numerous frustrations and difficulties of using corporate websites from a consumer's perspective (Patrick, 2003), indicating the significance and importance of HCI considerations for business applications in today's world. Patrick's call for an emphasis on the usefulness and usability of information systems from the perspective of the user is just the most recent in a long line of such suggestions. Incorporating a human computer interaction (HCI) perspective into the systems development life cycle (SDLC) is critical to information system (IS) success and in turn to the success of businesses. As early as the first volume of *MIS Quarterly*, Bostrom and Heinen suggest that information systems failures could be attributed to "faulty design choices" (p.17) resulting from the lack of emphasis on the human/social aspects of system use (Bostrom and Heinen, 1977). The Technology Acceptance Model demonstrates the importance of both the perceived usefulness and the perceived ease of use on user acceptance of IS (Venkatesh et al., 2003, Davis, 1989). The role of the IS professional in industry changed over time and indicates a need for a better understanding of human-computer interaction. The advent of outsourcing as a primary approach to the development of systems (frequently staffed by off-shore firms) also increases the importance of HCI issues. In addition, as consumers handle more and more of their own services, HCI becomes increasingly critical to business success (Carey et al., 2004).

There is a lack of clarity about HCI and its role in the systems development life cycle (SDLC). One misperception of HCI is that it only is about the final user interface design, such as form design, menu layout, choice of colors, icon design, and screen layout of display interfaces. Many popular Systems Analysis and Design (SA&D) textbooks contain only one or two chapters in the design stage of SDLC to cover these user interface issues. Undeniably, these are HCI considerations in Information Systems development, but they are far from being exclusive or being the most important ones. Very often, users of an IS are most frustrated or annoyed by problems that are beyond the computer screen level. Illogical overall organization of data/information in the system, lack of task support, misfit between the nature of the task and the support provided, difficulty of navigation, and inconsistent mental models of system operation are among the major problems or difficulties users experience. These incompatibilities may affect user reaction, acceptance, and use of the information system. These

problems may be rooted in the neglect of complex human cognitive, affective, and behavioral factors and the dynamics of human interactions with technologies. These issues affect users' interaction with the information system and may be addressed during HCI development practices. A better understanding of various human cognitive, affective, and behavioral factors involved in users tasks, problem solving processes and interaction contexts is required to address these problems. Just as it is important to understand systems requirements as early as possible, it is critical that human technology interaction should be addressed at the beginning of SDLC.

Another erroneous perception is that HCI is only about usability. ISO defines usability as "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use (Bevan, 2001)." Usability is considered as part of system acceptability (Nielsen, 1993). In the software engineering community, usability is more narrowly associated with user interface design and is defined as "a set of attributes that bear on the effort needed for use, and on the individual assessment of such use, by a stated or implied set of users (Bevan, 2001)." Although usability has been a dominant part of the HCI field, abundant empirical studies on user technology acceptance prove that usability is neither the only nor the most important predictor of system acceptance and usage (Venkatesh et al., 2003, Davis, 1989). Recent research and practice in IS, HCI and other related fields go beyond usability and explore other factors affecting the human interactions with technologies. Users' affective reactions and their holistic experiences with technology are gaining more attention and becoming more important (Agarwal and Karahanna, 2000, Zhang et al., 2002). This shift from a user-centered to a human-centered perspective requires more understanding about humans and their interactions with tasks and technologies.

In general, HCI is concerned with the ways humans interact with information, technologies, and tasks within various contexts (Zhang et al., 2002). HCI issues include all possible aspects that affect humans interacting with a system during the entire life cycle of the system; thus HCI issues exist during the system development stage, the use stage, and the system impact stage (Zhang and Li, 2004). This human-centeredness approach considers human requirements of the whole system (not just the user interface) and focuses on the entire interaction including usability and the broader user experience.

In the development of organizational information systems, the modern SA&D approach focuses on system functionalities and data requirements to meet organizational needs. Analysts define what a system should do from the systems' perspective. The HCI approach focuses on human-machine interactions and collaborations, and defines what a system should do from a user's perspective. HCI considers users cognitive, affective, and physical constraints and their impacts on system development and use. HCI development distinguishes between the user's responsibilities and the system's responsibilities during user interaction with the system. To develop information systems to meet both organizational and user needs, modern SA&D concerns and HCI concerns should be integrated in a unified methodology for information systems development. Despite some attempts in the past to tie user factors into the systems development life cycle (Mantei and Teorey, 1989), we as teachers and researchers have not provided a clear methodology for integrating HCI into the SDLC. Such a methodology can help us to prepare our students to develop truly human-centered organizational information systems that benefit the human users and ultimately contribute to successful businesses.

In this tutorial, we propose a methodology for developing information systems that considers both the modern SA&D and HCI approaches. Our goal is that the methodology, along with its philosophy, strategies, principles, and techniques or methods, should be instrumental for developing information systems that meet both organizational and human needs. We call this integrated approach the Human-Centered Systems Development Life Cycle (HCSDLC) Model.

This tutorial provides both the 'why' and the 'how' of building HCI into systems development. It demonstrates that the term 'human-centered systems development' can be broadened both for user-centered systems functionalities and for human-centered human-computer interaction development. The tutorial emphasizes the systematic and theory-based application and operationalization of human-centeredness during all stages of SDLC. A philosophy and a set of high-level principles are laid out. We then discuss activities and methods for each of the main stages of the HCSDLC model. Due to the maturity of modern SA&D approaches and limited space in the paper, we focus on the HCI development part of the methodology and refer to the modern SA&D counterparts only when necessary. An E-Commerce website development is used as an example to illustrate the step-by-step procedure of applying the methodology.

MODERN SDLC: A BRIEF REVIEW

The SDLC model is a commonly accepted modern approach for describing the complex processes and issues involved in information systems development. This model has four phases that interact with each other: Project Planning and Selection, Systems Analysis, Systems Design, and Systems Implementation & Operation (Valacich et al., 2004). Figure 1(a) details the specific activities inside each phase of the SDLC model. It lists the activities and implies that there are iterations among the activities within each phase and among the phases. Note that user interface design is one task inside the design stage and is

typically covered as one or two chapters in a modern SA&D textbook for a one-semester course. Modern SDLC and some systems development methods, such as RAD, JAD, and prototyping, attempt to capture user requirements (that is, systems functionalities) as early and accurately as possible. These methods, however, are not typically used to capture HCI factors that affect user interactions.

A HUMAN-CENTERED SYSTEM DEVELOPMENT METHODOLOGY

We limit our methodology to developing organizational information systems, which is similar to many modern SA&D textbooks. Our philosophy is that information systems development should meet both organizational and individual's needs, thus all relevant human factors should be incorporated in the SDLC as early as possible. Several strategies under this philosophy are listed in Table 1.

Figure 1 depicts the proposed methodology in contrast to the modern SA&D methodology: (a) is a typical SDLC model while (b) is the HCSDLC model that covers both SA&D and HCI development. The vertical line in the middle of (b) roughly divides the different emphasis of the modern SA&D and the HCI development. The four boxes that run across by the vertical line, Project Selection/Project Planning, Requirements Determination, Alternative Selection, and Prototyping are about the same activities that occur in both SA&D and HCI development. Note that for the SA&D side of (b), user interface design activity is removed, as it should be replaced by the entire HCI side of (b). HCI development thus involves all phases of the SDLC. The HCSDLC methodology indicates that a successful development of an information system should consider all the activities as depicted in (b).

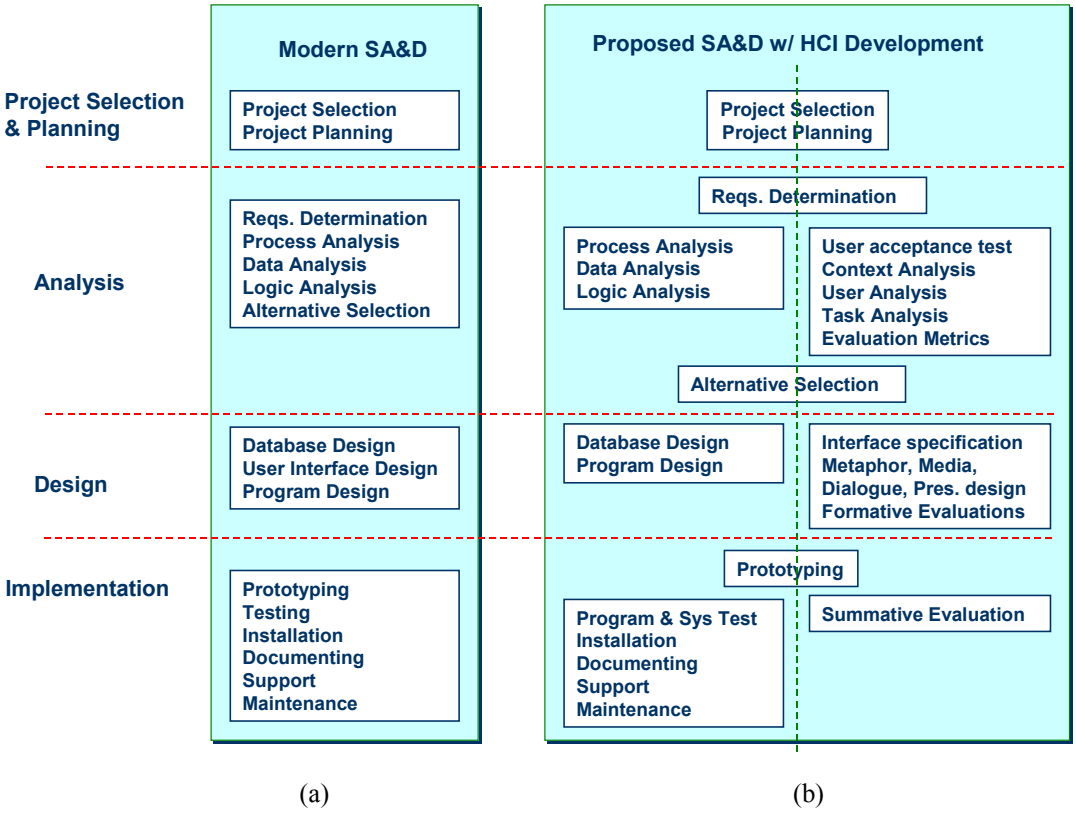

Figure 1. Modern SA&D vs. Proposed Human-Centered Systems Development Methodology

HCI Principles and Guidelines

The methodology includes a set of HCI principles (high level and context-free design goals based on theories in psychology, information systems, human-computer interaction, and other disciplines) and guidelines (specific and usually context-dependent rules for designers to follow to achieve the principles) that can be applied to the HCI development. The high level principles are shown in Table 2. These principles are derived from psychological theories and past experiences in developing interactive systems. Some of them are well recognized in the HCI literature, such as the HCI principles and eight golden rules

by Shneiderman (Shneiderman, 1998), works by Nielsen (Nielsen, 1993, Nielsen, 2000), and recommendations from Rubinstein and Hersh (Rubinstein and Hersh, 1984), among others.

1.	Early focus on understanding and determining both organizational and human needs.
2.	HCI development in parallel with modern SA&D activities, rather than one activity in the SA&D process.
3.	Evaluations through out the entire process.
4.	Iterative process.
5.	Emphasize not only the usefulness, and usability, but also user experiences.

Table 1. Human-Centered SDLC Strategies

1.	Improve users' task performance and reduce their effort.
2.	Prevent disastrous user errors.
3.	Strive for fit between the tasks, information needed, and information presented.
4.	Enable enjoyable, engaging and satisfying interaction experiences.
5.	Promote trust.
6.	Keep design simple.

Table 2. HCI Principles

The Project Selection and Planning Phase

In this phase, the HCI and SA&D issues and activities are the same. The organization's total information needs are analyzed and arranged, a potential information system project is identified and an argument for continuing or not continuing the project is presented (Valacich et al., 2004). In the discussion that follows, we use the development of a fictitious e-commerce website to illustrate each phase of the methodology. Assume that a decision is made to develop a website for a company that sells international gourmet foods over the Internet. We refer this example as the e-gourmet website.

The Analysis Phase

In SA&D, the analysis phase involves determining the system requirements, structuring requirements according to their interrelationships (normally conducted by process analysis, data analysis, and logic analysis), and generating and selecting design alternatives (Valacich et al., 2004). From the HCI perspective, requirement determination is still one of the most important activities and alternative generation and selection is also necessary before subsequent design is conducted. In addition, HCI analysis includes user-acceptance test based on the system requirements, and HCI evaluation metrics that are derived from context analysis, task analysis, and user analysis. In the e-gourmet example, the determined system requirements could be (1) taking online orders by using credit cards, (2) providing recipes of certain dishes, (3) providing explanations/history of ingredients and dishes, and (4) providing a forum for buyers to exchange recipes and cooking experiences.

To determine the likelihood of target users' accepting a system's usefulness, a *user acceptance test* is proposed right after the requirements are determined. Errors in requirements specifications are a major contributor to costly software project failures. Verifying requirements of a new system based on user evaluation of specifications measured during the earliest stages is beneficial (Davis and Venkatesh, 2004). Two longitudinal field experiments show that pre-prototype usefulness measured by target users, who received information about a system's functionality without direct hands-on experience, can closely approximate hands-on usefulness measures, and predict usage intentions and behavior up to six months after implementation. This distinction is key because, compared to ease-of-use, usefulness is generally much more strongly linked to future usage intentions and behaviors. A paper-based survey and paper-based prototypes or mock-ups, can be administered to target users using Davis and Venkatesh's (2004) instrument. Based on the testing results, designers and managers can decide whether to (a) go forward as planned, (b) modify or refine requirements to improve acceptability, or (c) abandon to avert major losses (Davis and Venkatesh, 2004).

Once a user acceptance test is passed, three major analyses will determine the HCI evaluation metrics. *Context analysis* includes understanding the technical, environmental,

and social settings where the information systems will be used. It examines whether and how the physical and social environment interaction with the physiological and psychological characteristics of the user would impact HCI. Aspects include: (1) Physical context: where are the tasks carried out, what entities and resources are implicated in task operation, what physical structures and entities are necessary to understand observed task action? In e-gourmet, the physical context analysis indicates that users may order or browse the website from anywhere that has access to the Internet. (2) Technical context: which is about the technology infrastructure, platforms, hardware and system software, network/wireless connection? In e-gourmet, users may use browse the website using PC, Palm PDAs, or Mobile phones. (3) Organizational context: what is the larger system where this information system is embedded, what are the interactions with other entities in the organization? In e-gourmet, this website reflects the business strategies of the organization and thus is subject to business

decision changes made at the strategy level. (4) Social and cultural context: what are the social or cultural factors that may affect users attitude and eventual use of the information system? In e-gourmet, the website can be accessed from any country with any culture that provides credit cards with USD exchange. A cost-benefit analysis determines that the e-gourmet company could support 4 languages: English, Spanish, Chinese, and Korean. Overall, context analysis can provide ideas for design factors such as metaphor creation/selection, pattern of communications between users and between users and the system, distribution of users and objects they use.

User analysis identifies the target users and their characteristics including (1) demographic data, such as age, gender, education, occupation, cultural background, any special needs, computer training and knowledge, and experience with similar systems/products; (2) traits and intelligence, such as cognitive styles, affective traits, and skill sets or capability; and (3) job or task related factors, such as job characteristics, knowledge of application domain and job familiarity, frequency of computer use for the job, and usage constraints. In e-gourmet, user analysis reveals that users (1) are upper middle income male or female shoppers with any occupation, cosmopolitan and immigrant US users or outside US who speak one of the four languages; (2) have basic computer knowledge and experiences, and basic understanding of buying things through the Internet; and (3) may buy from the website with a frequency ranging from once per month to daily with any dollar amount.

Task analysis is concerned with understanding what users' goals are and what they do to achieve their goals. It also includes scenarios and conditions under which humans perform the tasks. Task analysis describes behaviors at three abstract levels: goals, tasks, and actions. The objective of task analysis is to identify opportunities to support user activities. For example, sound may be used to draw attention on a visually loaded screen or sequence of presentation may be altered to help ameliorate biases caused by primacy and recency effects. In HCI, task analysis also distinguishes between what computers do, and what humans do. It examines the task workflow and the distribution of work and work skills among users. A key issue in building new systems is to realize that the new systems change skill sets and obstruct current workflow. Development of a new system must take into account the movement from one type of structured work environment to another. There should be alignment and consistency between task analyses and the high-level process analyses (such as level-0 DFD) in SA&D. Certain techniques such as use cases and scenarios can be used for both process and task analyses. In addition, existing techniques on task analysis (e.g., Hierarchical Task Analysis) can be applied at this stage.

In e-gourmet, a task analysis identifies the following four aspects. User goals and use cases identifies five cases: (1) buy particular foods or ingredients that users already know about, (2) look for ingredients that make a known dish, (3) learn about a particular dish, its ingredients, and how to make it, (4) browse to decide what to cook for a particular occasion, and (5) recommend the site to others. Cognitive, affective, and behavioral analysis of user tasks shows that (1) in case 1, a user may forget the official name but remembers the characteristics of some food (thus may need to do a query on certain attributes of food to find it first); (2) when examining an ingredient, users may need to refer to the dishes where this ingredient is used. The same is true when examining a dish where ingredients/receipt would be needed; (3) esthetically pleasing presentation would encourage browsing (cases 3 & 4) and eventually purchasing (cases 1 & 2) and recommending (case 5); and (4) users may use the forum for peer recommendations and exchange of receipts or cooking experiences (case 5). Workflow analysis finds that case 1 would need a sequence of actions to be finished; stopping of the task can occur at any stage of the sequence; and users may want to go back to any of the previous stages; and case 4 may lead to any of cases 1-3. General work distribution between users and the website/machine suggests that users make selections, and the website provides options and all related and relevant info for each choice.

Evaluation metrics specify the goals of human computer interaction. Most commonly considered aspects include user task-related aspects such as learnability, effectiveness, efficiency, and satisfaction that are regular usability dimensions, and user experiences that are recently advocated by a number of researchers (Zhang et al., 2002, Preece et al., 2002). These metrics guide the tasks in the design phase and provide the benchmarks for the summative evaluation in the implementation phase. The metrics can be streamlined with the Common Industry Format (CIF) that is designed for summative usability tests (Bevan et al., 2002). The first column of Table 3 summarizes the general goals of the evaluation metrics. We add "safe to use" to cover systems such as mission critical or even E-commerce systems where safety and security are paramount. Consistent with Preece and colleagues (Preece et al., 2002), we put satisfaction (a prior usability category) in the user experience category. Each item in Table 3 may be quantified based on past studies or industry standards. For example, the right column of Table 3 demonstrates the possible evaluation metrics for the e-gourmet website.

Consistent with SA&D, before transforming all gathered and structured information into design ideas, there is a need to *select the final alterative* for the proposed information system owing to the facts that (1) the competing ideas from different users on what the system should do, and (2) the multiple alternatives for an implementation environment for any new system (Valacich et al., 2004). Although SA&D emphasizes functionality in selecting design strategies, the approach of generating and selecting best alternatives can also be applied to HCI design strategies. The deliverables can include (1) three

substantially different design strategies (low, middle and high) that come from different requirements specifications and HCI evaluation metrics. And (2) a design strategy judged most likely to lead to the most desirable system, from functionality, usability and user experience perspectives.

General HCI Evaluation Metrics	E-gourmet Example
Usability goals	
• Fewer errors • Efficient • Easy to learn • Easy to remember • Safe to use	• New users are able to navigate and use the main functions within 5 minutes. • Users are able to get to the main tasks with one click • Ordering a type of foods should be done within 1 minute in normal network traffic and with no more than 4 clicks/actions. • Error rate should be less than 1 in every 10 users for each main task. • The complaining rate of usability problems should be less than 1 in every 10 users
User experience goals	
• Aesthetically pleasing • Enjoyable, entertaining, fun • Motivating, engaging • Trustworthy • Satisfying	• 80% of the tested shoppers should have (a) aesthetic, (b) enjoyable, (c) engaging and (d) satisfactory rating of at least 4 out of 5 • At least 50% of the shoppers would participate in the forum at least once every three months (read or send postings) • At least 80% of the potential target users would trust the website for credit card use

Table 3. Evaluation Metrics

The Design Phase

In this phase the user interface is specified, sketched, materialized, and tested. The goal is to support the identified issues during context, task and user analyses and to meet the HCI evaluation metrics requirements. The main activities are interface specification and formative evaluations. *Interface specification* includes semantic understanding of the information needs to support HCI analysis results, and syntactical and lexical decisions including metaphor, media, dialogue, and presentation designs.

Metaphor and visualization design helps the user develop a mental model of the system. For e-gourmet, a virtual store map can be used as the metaphor, in which certain areas indicate "shelves" with foods into categories, other areas for posting and checking recipes, discussing with other shoppers (the forum), and checkout with purchases. Media design is concerned with selecting the appropriate media for meeting the specific needs. For e-gourmet, photos of the master cooked dishes with great presentation may represent dishes. Certain ingredients may also be shown in realistic photos. Dialogue design focuses on how information is provided to and captured from users during a specific task. Dialogues are analogous to a conversation between two people. Many existing interaction styles, such as menus, form-fill-ins, natural languages, dialog boxes, and direct manipulation, can be used. Presentation design concerns the decisions on display layout and incorporation of metaphors, media, and dialog designs with the rest of the displays.

Formative evaluations identify defects in usability and user experience designs thus inform design iterations and refinements. A variety of different formative evaluations can occur several times during the design stage of an information system.

The Implementation Phase

HCI development in this phase includes (1) prototyping that is also part of SA&D, (2) summative evaluation before system release and (3) use evaluation after the system is installed and being used by targeted users for a period of time. *Summative evaluation* takes place after the system is developed to confirm whether the evaluation metrics or other industry standards are met. *Use evaluation* collects feedback in understanding the actual behavior toward system use. This understanding helps in developing new versions or other similar systems.

CONCLUSION

Methods and techniques in both the SA&D field and the usability engineering field matured over the years and are used for education, training, and guiding practice. However, little effort has been put on providing integrated methodologies for developing human-centered information systems that consider both organizational and user needs. This lack of integration is problematic to our students who often take different courses with different emphases. The same problem applies to

information systems developers who are responsible for delivering both organizationally effective and human-centric systems but often find reference books with one emphasis or the other. Diverse approaches with different perspectives may help to isolate different issues but they do not help with overall effectiveness and efficiency of systems development. The result of this situation is that developed information systems often either lack well-defined systems requirements to support organizational needs and thus are low in usefulness, or lack human understanding and thus are frustrating to use.

The proposed human-centered SDLC model in this paper is an integrated methodology that emphasizes human-centeredness and considers HCI issues together with SA&D issues throughout the entire system development life cycle. The methodology takes the parsimony of the SDLC model that is helpful from the project management perspective. It lays out the connections and differences between SA&D and HCI tasks and provides a step-by-step procedure for transformations between tasks at different stages. This methodology can be used for courses about human-centered information systems analysis and design (the whole methodology), HCI and user interface design (the HCI development part of the methodology), and even IS project management courses where all factors including human factors in IS development should be considered. We hope that the methodology presented will be instrumental in providing more successful information systems and thus more successful businesses.

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