Personalized, Mediated Human-Computer Interaction

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ABSTRACT

This paper discuss recent technological advances which provide opportunities for increasingly complex and fruitful interactions between users and information and communications technologies. It examines the need for personalization of interactions and the barriers to achieving this goal. A new paradigm of mediated interaction is introduced as a possible means of facilitating interactions with ubiquitous computing devices, in a manner which supports continuous usability evaluations and effective, user-controlled personalization of interactions. Details are provided regarding proposed research on this topic.

Keywords: personalized, mediated, human-computer interaction, hand-held devices

INTRODUCTION

At the current pace of growth and innovation in forms of interaction with information and communications technologies it is increasingly difficult to give users the feeling of personal and directed service. Hence, aspects such as content management, usability mining and personalization constitute key areas for research and development (Badii, 2000b; Badii et al., 2001).
To cope with the massive rates of information exchange required by the new knowledge economy, the emergent personal and business computing environment will need to be able to rely on efficient contextually-aware information retrieval and transaction systems for a wide variety of social and business needs such as life-long e-learning, e-commerce and general e-foraging for leisure, pleasure and cultural interests[1]. Currently, access to information systems such as the World Wide Web (WWW) is often associated with high levels of cognitive overload, with attendant frustration, confusion and inefficiencies for all types of users.

Although improved user interface design is clearly part of the solution, the wide diversity of the user community, which for example can access a WWW site, will mean that computationally efficient information systems have to be devised to elicit, track and update usability and personalization data. This is likely to be an increasingly critical requirement in the face of continuing changes in users' life styles and information and communication needs. A dynamic usability data intelligence technology is thus a vital requirement if user interfaces are to remain contextually-aware in the face of continuous shifts in user's focus and interests and the requirements for multi-modality, multi-lingual capability and seamless cross-cultural inter-operation (Badii 2000a;b; Turk, 2000).

New paradigms of interaction are required to facilitate the effective use of the complex and varied opportunities afforded by new types of hardware, software and protocols. Ways need to be found to make personalization of interaction a reality rather than merely a goal. This paper explores an example paradigm which operationalises the concept of personalized, mediated interaction to meet this need.

[1]e.g. http://www.useit.com/alertbox/20010916.html ; http://www.mobiforum.org ; http://www.dcs.gla.ac.uk/~johnson/papers/mobile/HCIMD1.html

TRENDS IN HUMAN-COMPUTER INTERACTION

The nature of human-computer interaction (HCI) is changing rapidly as new hardware, software and protocols make information and communication systems more interactive, mobile and ubiquitous. The range of developments can be grouped under two headings, which indicate parallel streams of approach, i.e. "Cyborg HCI" versus "Hands-Free HCI". The principal developments in these two streams may be summarized as follows:

Cyborg HCI:

This set of 'cyborg' approaches provides for different levels of functional integration of humans and machines in a physical (bodily) way[2].

Approaches in this stream of HCI advances include:

- *Implanted Computers* - computers placed within the user's body. This is currently mostly restricted to medical applications where the computer plays some role in the management of the user's medical condition - e.g. through the monitoring of (for instance) hormone levels and the automated administration of appropriate and timely doses of medication.
- *Wearable Computers* - there is an increasing range of wearable computing devices, ranging from GPS in backpacks (for blind users) to very small computers incorporated in clothing or jewelry (Barfield and Caudell, 2001)[3].
- *Body Motion Sensors* - sensors may be attached to the user's limbs or joints so as to provide feedback regarding body position, for instance, as part of a gesture controlled interface or a virtual reality system.
- *Virtual Reality* - 'immersive' HCI systems are becoming more affordable and ergonomically appropriate. They usually entail the wearing of some sort of helmet (providing for 3D display of a virtual environment) and a data glove, or possibly a full-body suit, for the sensing of user's body motions[4].
- *Augmented Reality* - applications where one or more of the user's senses (usually sight) is augmented by the introduction of a stream of sensory data from the computer[5], e.g. airport information projected onto the visor of a pilot's helmet (Barfield and Caudell, 2001).

Hands-Free HCI:

This set of approaches separates physically the user's body and the computer hardware, indeed the user may not even be aware of the presence of the computer, nor be conscious of the interaction.

Some examples include:

- *Voice Recognition* - this technology has been around for decades and is now quite functional and is being used increasingly in word processing applications[6] and for hand-held devices such as mobile phones.
- *Eye Gaze Monitoring* - this approach has been used in the past in research and medical applications and increasingly for usability evaluations (e.g. of WWW sites[7]) (Duchowski et al, 2000). However, it is also a viable form of user input to interactive systems where the necessary equipment can be fixed to the computer and/or the user. This form of interaction can be especially useful for some disabled users.

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[2] e.g. http://www.ascusc.org/jcmc/vol3/issue2/biocca2.html
[3] e.g. http://www.wearcam.org/historical/
[4] e.g. http://atnrc.org/facilities/vr.html
[5] e.g. http://www.hitl.Washington.edu/
[6] e.g. http://www.dragonsys.com/
[7] e.g. http://www.ericainc.com/webpage.html

- *Gesture and Facial Expression Activated Interfaces* - the option of using recognition of user's facial expressions and/or gestures as input during interactions is becoming more realistic with a number of applications currently operational (Braffort et al., 1999; IEEE Computer Society, 1999; Kettebekov and Sharma, 2000).
- *Ubiquitous Computing* - increasingly, computers are embedded in our work and home environments - for instance, as surveillance systems in rooms or as 'intelligence' in everyday appliances. Some commentators see this as the 'third wave' of computing or the age of 'calm computing', where technology recedes into the background[8].

All of these developments present huge opportunities for enhanced interactions but also great challenges to the theory and practice of HCI. How are such systems to be optimized through the application of sound methodologies of HCI design and evaluation? There are also key issues for users who have to cope with a wide range of possible interaction paradigms, including both conscious and unconscious involvement with different types of devices, some of which they may not even be aware of. One option is for the user's interaction to be facilitated, or mediated, by some personal (hand-held or wearable) device specifically designed for this purpose. This approach effectively bridges (integrates) the two streams of HCI development discussed above.

MEDIATED HCI PARADIGM

In the previous section it was suggested that complex user interactions with a wide range of computing and telecommunications devices could be facilitated by some form of mediation. This would enable the user to optimize their interactions through the use of a personal intermediary device.

An example of this possible new paradigm of mediated HCI is depicted in Figure 1. It would utilize a set of computer-based devices, as follows:

- Personal Identification Device (PID) – a very small device, which is implanted in a user's body (e.g. under the skin of an arm) or worn in a watch-band, bracelet, etc. It requires no external power and can transmit over short distances (e.g. five metres) a personal identification code, which is unique to a particular individual. Such devices are already available and are cylindrical in shape, about ten millimetres long and three millimetres wide;
- Hand-Held (or wearable) Computer / Mobile Communication Device (HHD) - this device will be linked to telephone and internet services and have high memory and computing power, a small (but very high resolution) screen and a keypad. This device includes a slot for insertion of a SmartCard. It interacts with other devices via infrared (or equivalent) transmissions;
- Nominated Host Computer (NHC) (either the user’s personal computer or a stand-alone or networked computer at the user’s workplace) – nominated as the computer which will be the main alternative to the HHD for interactions and will backup software/data on the HHD;
- Other computer-based devices (CBDs), including: personal computers, computer networks; digital TV; ubiquitous/appliance computing devices (including Point of Sale (POS) devices).

[8] e.g. http://www.ubiq.com/hypertext/weiser/UbiHome.html

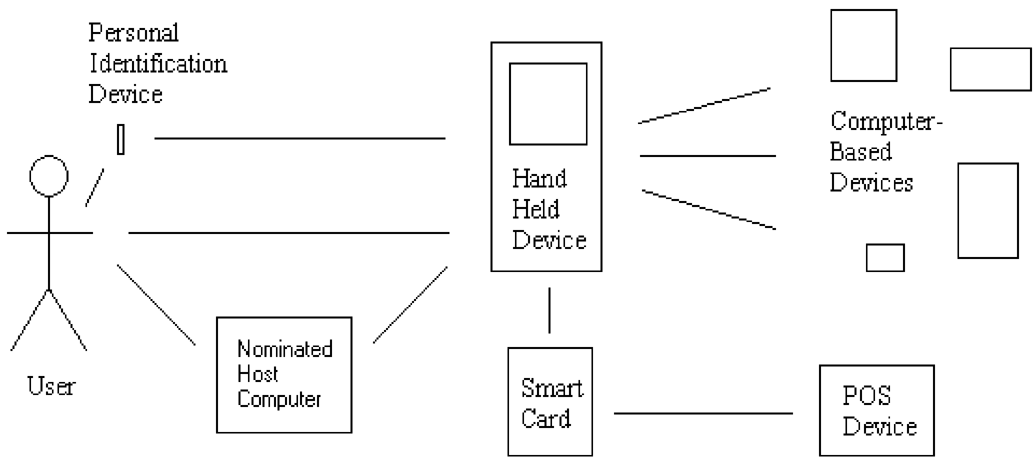

Figure 1 - Interaction Paradigm

PERSONALISATION OF HCI

Personalization of user interactions has long been a goal of HCI - what could be termed 'user intimate', rather than merely 'user friendly', interactions (Turk, 1992). Some degree of personalization is achieved in a variety of applications via intelligent, adaptive user interfaces and the use of agents. Adaptation can be either 'foreground' (the look and feel of the interface) or 'background' (within the system functionality), and either 'passive' (user selected) or 'active' (initiated by the computer system). However, such adaptation usually requires that the particular system builds up a 'model of the user', in terms of a predetermined taxonomy of significant attributes. This in turn requires that the system developer has some idea (mental model) of the nature of likely user groups and that writers of user instructions and help for the system also understand the different types of users and possible use scenarios - see Figure 2.

The whole issue of personalization has become much more difficult because of the vastly increasing range of user types and the wide variety of possible interactions, as discussed above. It is very difficult for a specific application system to be able to store all the necessary information (user model) about each potential user so as to be able to run the interface adaptation software. It is equally ineffective for the system to delay or interrupt the interaction sequence to ask a new user for detailed information so as to construct an appropriate user model for them. It may, however, be possible to implement continuous building of the required user model via analysis of patterns of user choices and by asking brief questions of the user (at key stages of the interaction) in a 'pop-up' mode that allows the user to answer the question if they wish to or have it automatically go away (Badii 2000a) However, this would still present huge difficulties if each application device needs to maintain models of every potential user.

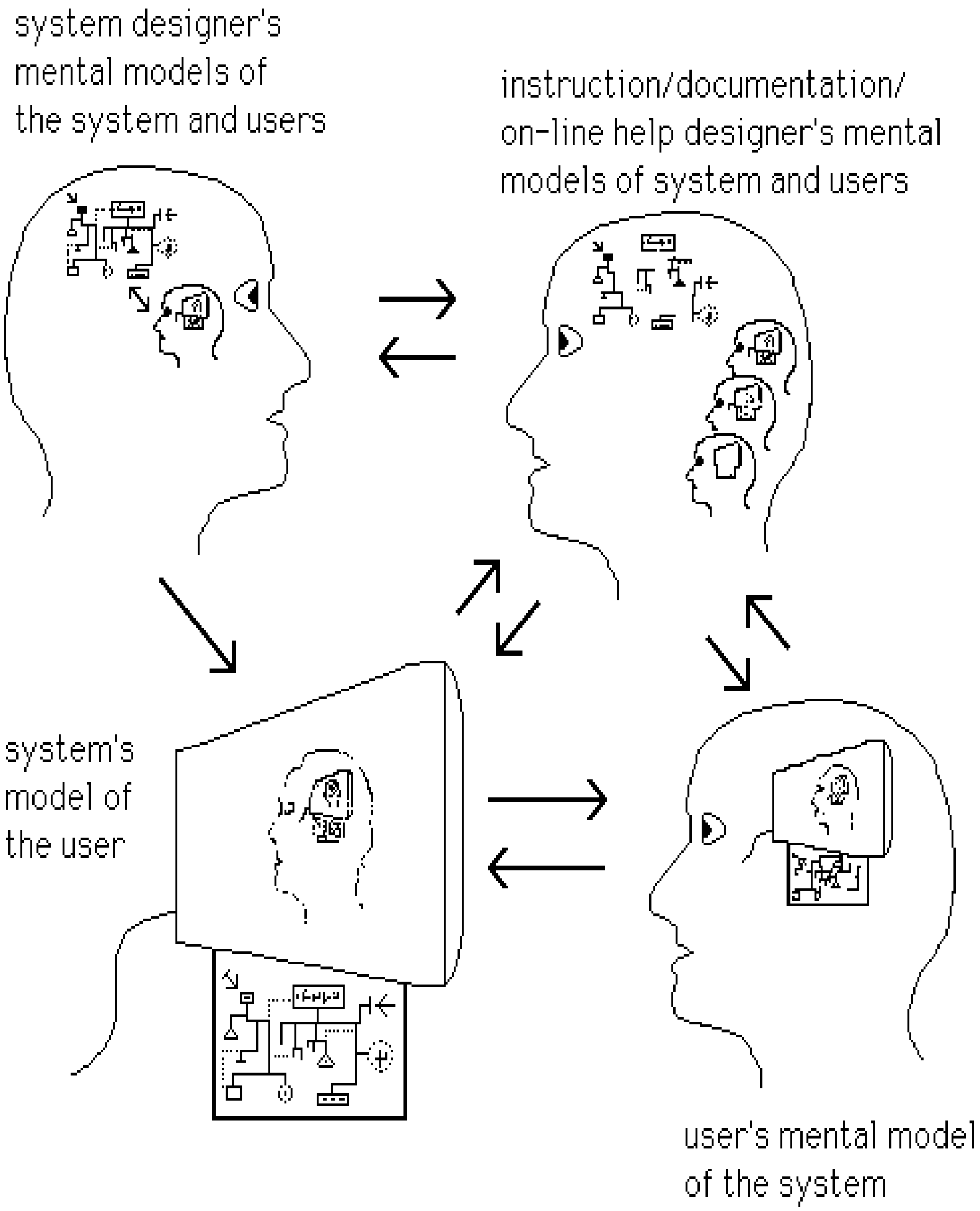

Figure 2 - Models of System and User (after Turk, 1992, Figure 9.4, p. 368)

A possible new approach to personalization of interactions is through employing such 'continuous' approaches via a mediating device. In this paradigm the mediating computer holds a set of 'personas' (Coney and Steehouder, 2000) for the user and is enabled to utilize one or more of these during interactions with other computing devices. In this way the 'user model' does not have to be held in the device carrying out the application and the personal information is always under the control of the user. This approach would also facilitate continuous evaluation of the usability of the system and create records of common usability problems for use in redesign of the system if its average level of usability, for target user groups, proved to be below some acceptable standard.

PERSONALIZED, MEDIATED INTERACTIONS

The example paradigm of personalized, mediated interactions presented below is expressed in terms of the devices described in an earlier section of this paper. It envisages that each user will have their own PID, which will be implanted in their body, or worn by them at all times, and identify them uniquely, to authorize interactions with other devices.

Each person will also have their own HHD, which will travel with them whenever they want to be able to communicate electronically with others or interact with CBDs. It will be fully enabled only while it is in close proximity to their PID, otherwise it will only provide (non-personal) basic functionality. The HHD device will interact with CBDs via wireless (e.g. infrared) connection and, in some cases (e.g. POS devices) via use of a SmartCard, which will slot into the HHD. The HHD will hold personal profile (PP) information about it's user and will control personalization and usability evaluation processes during interactions by the user with CBDs (mediated by the HHD). The user may choose to have various personas stored, e.g. one for their work activities, one for their personal financial matters and one for their home and leisure activities.

The user will also conduct interactions with the NHC (when this is more convenient than using the HHD), especially where the HHD has less than the full functionality envisaged in this paradigm. Hence, some personalization and evaluation functions performed by the HHD may be duplicated by the NHC. This will require regular transfer of information (e.g. the user's latest PP) between these devices. If there is insufficient computing power and storage capacity in the HHD, it may be appropriate for the NHC to perform the more advanced aspects of processing of personalization and evaluation. For instance, the NHC may be the preferred platform for collecting information from the user to produce (or update) their PP. It could also be the vehicle for providing feedback to application developers resulting from the usability evaluations of user interactions, after records have been down-loaded from the HHD. The NHC will also act as the back-up for the HHD.

The user will have an intimate (though unconscious) relationship with their PID, which will probably be with them always, although the user will be rarely conscious of its presence, and will not be required to initiate (or terminate) any of its interactions with the user's HHD or any CBDs. It is in effect a representation of the user's identity and a way of ensuring the unique identification of that individual and hence enabling secure interactions with other devices.

The user will also have a very close relationship (identification) with their own HHD, which will be chosen (and customized) to suit their needs and personal style. As this device is the means of the user having efficient, effective and secure interactions with other devices, it will be an extremely important part of their life, especially as unconscious interactions with ubiquitous/appliance computing devices become more common. It will also be their communication centre for input and output of text, graphics, voice/sound, video etc (increasingly rich as wireless broadband, 'always-on' facilities become available) and hence their main way of interacting via telecommunications applications with their work colleagues, family and friends.

The user's HHD will hold their PP information (at the level(s) of richness that they decide) for use in mediating/personalizing their interaction with many other devices. It will also manage usability evaluation activities which are implicit (device-device enabled) and explicit (involving input from the user), including understanding the salience of any input and its potential for updating the user's PP and refining the ways that it is used to optimize future interactions. That the locus-of-control is always with the user (in terms of updating the PP and authorizing its use) is a key element in building a relationship of trust between the user and their HHD, and hence, with applications running on other CBDs. They will be engaged with it in an ongoing 'project' of enhancing it's representation of their personas and needs/preferences, so as to continually enhance their interactions with a wide variety of CBDs.

Personalization of interaction with (the vast variety of) computer systems can take different forms, such as:

- User interaction (interface) preferences (based on, for example, cognitive style) – so that information is presented in the most effective way;
- Information needs / preferences – so that the classes of information desired by the user (and their priority) can be predicted;
- Work habits / schedules (possibly linked with a personal organizer/diary function) – so that predictions can be made regarding needs and timing to allow downloads of information before it is

likely to be used (pre-fetch, Badii 2000b) especially in 'always-on' telecommunications environments;

- Service and product preferences – so that e-business/government/entertainment relationships can be prioritized and optimized and marketing of products facilitated.

Ideally, all such aspects of personalization can be integrated so that they can be achieved via the use of one set of user data (PP), preferably located on one (hand-held) device. Personalization is primed by construction of an initial PP. It is linked to continuous (implicit and explicit) usability evaluations of interactions in order to: provide an assessment of the quality of each interaction; update the user's PP; and improve the mechanisms (software) for utilization of the PP for personalization and optimization of the efficiency and effectiveness of interactions.

Identified user preferences may be indicators of deeper attributes. The current version of a user's PP will contain information explicitly contributed by the user themselves and information inferred (by the PP management software) from their interactions. Some information (e.g. the user's gender) will be most conveniently entered explicitly by the user, while other personal attributes (e.g. cognitive style) will be best obtained via requesting that the user undertake brief elicitation exercises and/or through the monitoring of the users interactions with computer-based devices (in terms of both content and style). The interaction paradigm discussed above will maximize the user's engagement with this process and hence the amount of explicit information (and updates) which they are prepared to provide, and the implicit information gathering they are prepared to authorize, leading to higher levels of validity and utility of the PP. Different attribute sets (views/slices of the PP) will be utilized for particular personalization and/or evaluation processes, depending on the use context/scenario, application domain/software, and the particular computer-based device that the user is interacting with.

The software to implement the personalization and evaluation functions should be located (as far as possible) within the user's own (hand-held) device (along with their PP), rather than being located within specific applications/machines which they access for a variety of purposes. This requires a high level of interoperability and hence may be achieved in stages, as the required technology and protocols are developed.

The store of personal preferences for any specific user (maintained in their HHD) could contain different types of information, which would be potentially useful for different aspects of personalization and usability evaluation functions. The user could choose to enable different versions of their PP (personas) for different sorts of interactions and define the limits of information sets which could be accessed in different interaction circumstances. For instance, the user may wish his/her gender to be known in some interaction circumstances and not in others.

The range of data types could include the following:

- User attributes such as: age; gender; cognitive and learning style; personality; IT experience; etc. - which are linked through software algorithms to key aspects of personalization and/or usability evaluation (Turk, forthcoming);

- Specific (previously established) user interaction/interface preferences, such as: text/graphics preferences; desirability of speech input/output; colour preferences; etc.;

- Preference settings, preference change triggers (and thresholds) and migration patterns (Badii 2000b) established for standard interaction scenarios in key application domains and products (e.g. for specific e-commerce services);

- History of past activities, information use, stated preferences, satisfaction ratings, etc.;

- Current spheres of activities/interests - family and social groupings, career stage, type of employment, cultural and sporting interests, etc.

The functionality for managing this data would need to incorporate facilities for establishing the salience of any new data set to enable effective updating of the PP and to manage the appropriate summarizing of data, and culling of the data set to ensure that storage limits were not exceeded. The development of models and implementation of software to support this functionality is a key aspect of planned research activities.

PLANNED RESEARCH

The authors are undertaking research to examine how the proposed paradigm may be implemented. The first stage of the research program will need to be guided by taxonomies and models of: device functionality and relationships; user interactions; user attributes; personalization aspects/mechanisms; and usability evaluations. These should be at various levels of abstraction and be nested/integrated together. They will be of increasing complexity and move from being purely descriptive to being more predictive. The level and manner of formalization will enable their implementation as software. The concepts contained in the taxonomies and models will be demonstrated, implemented and evaluated through realization as software systems. These will build upon the work already undertaken in the development of PopEval and *C-ASSURE* (Badii 2000a).

In the second stage of the program, research projects will be undertaken to demonstrate how the paradigm and models operate in a selected set of use contexts/scenarios. These will be chosen so as to provide a developing level of complexity and to highlight the key aspects of the concepts. They should also be chosen for their practicality and potential for effective evaluation and use for demonstration of the utility of the concepts and software.

The space of possible use contexts can be subdivided in various ways to facilitate choice of the ones most suitable for different aspects/stages of the research program. One approach is to divide contexts in terms of the closeness of relationship between the users HHD and the CBDs with which it is interacting. This is of key significance in terms of the level of interoperability (and hence protocols) which is required and the potential for sharing of software functions (for personalization and evaluation) between the HHD and any specific CBD hardware/software combination. For instance, the earlier stages of research could investigate interactions between the user's HHD and their own PC and TV, the network at their place of work, and possibly 'appliance' type devices (e.g. an intelligent whiteboard). For such interactions, a partial (hybrid) paradigm of interaction management could be explored, where there was some degree of sharing of responsibility between the core personalized interaction and evaluation (PIE) functionality (located in the user's HHD) and application programs running on specific CBDs. Support for the PIE functions would need to be embedded within the chosen application software, running on the CBDs. Later phases could extend the exploration of the paradigm by investigating interactions with a range of CBDs (not owned by the user or their employer), where the user's HHD could (potentially) have full responsibility for operating the PIE functions.

Other approaches to choosing the use contexts could include:

- Aspects/types of personalization (listed above);
- Specific types of interaction purposes (e.g. communication; information gathering; decision making; entertainment; transactions);
- Specific (suitable) application domains (such as: business; teaching; e-government);
- Contexts of interest to sources of funding, research collaborators or industry partners.

The final phase of the research program will test the paradigm in a range of real-world situations. This will require significant developments in the PIE software and the implementation of suitable telecommunications protocols.

CONCLUSIONS

The personalized, mediated HCI paradigm introduced above implements 'user intimate' interactions – a significant step upwards from 'user friendly' computing. It also has important ethical implications regarding confidentiality of personal information.

Further research and development is required before this potential enhanced interaction paradigm can be successfully implemented. However, it does not require any significant technological developments beyond those that are already available.

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