

# CHI2000 Workshop Report

## Continuity in Human computer Interaction

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### Introduction

The CHI2000 Workshop on Continuity in Human Computer Interaction was organised by members of the European Funded Training and Mobility of Researchers (TMR) Network on Theory and Application of Continuous Interaction Techniques (TACIT) [10]. Work within the network is concerned the design challenges posed by certain novel interactive technologies for HCI, in particular those where the temporal dimension of tasks or actions becomes a significant factor.

The premise of this workshop is that the notion of “continuity” encapsulates important aspects of integrated multimodal interactive devices, especially those involving human motion [12, 13, 2, 5, 8]. Continuity in interaction has not obtained the attention it would deserve in HCI research and design methods. The purpose of the workshop is in the first place to substantiate these claims, by asking the HCI community to test their approaches on scenarios involving continuous interaction techniques.

In the second place, if these claims are found to hold water, its purpose is to map out an agenda for developing systematic HCI research and design methods capable of including notions of continuity in their account of interactive behaviour.

### Workshop participants and activities

The Workshop on Continuity in Human Computer Interaction was organised as a two days satellite workshop of the CHI2000 conference that took place

in The Hague, The Netherlands. Seventeen delegates, from both within the network and outside, attended the workshop. Seven different european countries were represented, and participants came from both the academic world and industry.

In the next sections we give a short summary of the issues that have been presented and discussed during the workshop. One of the central issues was the development of a suitable reference model for continuous interaction.

### Workshop first day

The first day of the workshop was dedicated to the presentation of two case-studies and short presentations. The participants presented their views and proposals on theory and design approaches concerning continuous interaction.

### Workshop morning session

The first session started by an informal introduction of the participants followed by the presentation of two realistic case studies identifying essential problems concerning continuity in interaction.

The first case-study was the Magic Board application developed at CLIPS-IMAG in Grenoble [7]. The Magic Board is an augmented reality application in which one or more users can use a real whiteboard and real pens in a brain storming session. A PC, a projector and a video-camera provide electronic functionalities such as copy and paste of written text and figures that have been drawn in real ink on the whiteboard. Electronic copies of text and images on the

white board can be projected in 'digital ink' on the white board.

Communication between the computing system and the users is by means of vision based gesture tracking and electronic menu's projected on the white board. The application shows an interesting mixture of continuous interaction (real-time gesture recognition) and menu-based interaction (selection of operations).

The second case-study was the Map Views application which can be characterised as a distributed real-time application for cooperative navigation involving different platforms with different interface and processing capabilities. The Map Views application is being developed at the DFKI in Saarbrücken, Germany.

The Map Views application assumes a PC user with good graphical capabilities in one place and one or more other users that are travelling in a city center and that have only a mobile telephone with a small display or a PDA and GPS facility [9]. The users can dial in into a virtual space in which they can communicate with each other. The PC user is assumed to have full access to detailed graphical information about the city where the other people are travelling and can help them to navigate through the city or to arrange a place where the other two could meet.

Continuity issues are playing a fundamental role in the Map Views application. The mobile users must be informed in time about where they should go and the kind of information that they get should be appropriate to their context (street names are not very helpful when one is travelling by bus, but indications about clearly visible landmarks could be very useful). At the same time, the PC user should be able to keep track of the continuously moving mobile users, and in which way they are travelling and where they want to go.

The presentation of the case-studies was followed by two presentations about specific usability requirements for continuous interaction. One issue is the focus of attention of people who perform a continuous activity. Often continuous activities are performed in a semi-automatic way, such as driving a car or listening to people who are speaking. This makes that people can often perform some activities at the same

time, such as driving and speaking because for driving they do not need full conscious attention all the time. This poses interesting issues on how and when people are changing their focus of attention when performing multiple tasks and to what kind of errors this may lead when using interfaces with continuous aspects.

Questions about the role of continuity in interfaces are also raised when considering the role of tangible objects in the interface. The real world around us is obviously perceived as continuous by humans. Physical parts of an interface should therefore be taken into consideration in the design and usability analysis of an interface.

## Workshop afternoon session

During the afternoon session several ideas for a reference model for continuous interaction have been presented. One proposal is based on the observation that the interchange of information between a computer system and a user is mediated by the interface of the hardware/software system and the perceptual/effector systems of the human. Direct communication between the application and the user is based on the user's perception of the rendered presentation. This implies that the user should be able to (re)construct an understanding of the execution model of the application based on the provided presentation. It has been proposed that three levels of abstraction could be used to refine the interaction model into a layered reference model. The three levels are motivated by the cognitive theory ICS [1] and would include a perceptual, structural and semantic level. These cognitive levels and their computer system counterparts are illustrated in Fig. 1 in the case of visual communication.

It is assumed that in a well designed interface the user can interact physically while their attention remains at a conceptual level, concentrating on their task. All transformations and communications necessary to realise the actual interaction are performed in a semi-automatic way by the user without requiring a shift in the focus of attention. For example, when a skilled user is moving a mouse to a target the movement of his hand operating the mouse is almost

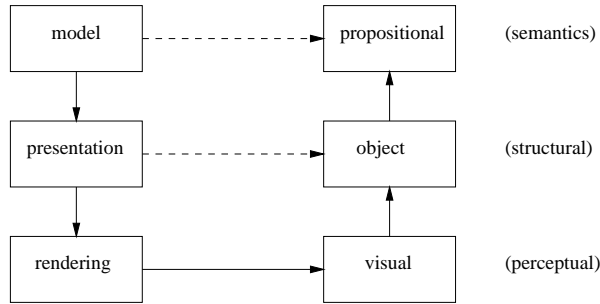


Figure 1: Visual Communication and ICS

automatic and does not require the user to interrupt his focus of attention on the model of the application at the semantic level.

In addition to a vertical division of interaction into layers describing the interaction at different levels of abstraction a horizontal division of interactivity has been proposed. Three essential constituents of interactivity were identified; turn-taking, discourse and control. Turn-taking is about the initiative in the communication process, discourse concerns the development of a dialogue between the user and the system and control refers to the feeling of the user to be in control of the system.

The last presentation before the break showed a number of techniques used in air-traffic control applications to represent continuous information. One technique used the projection of the position of aircraft in real-time on a radar screen. Even if a controller could estimate the position of an aircraft in the next three minutes by observing its change in position on a radar screen, it would require that the aircraft would be observed over a certain period of (precious) time. In order to make it possible for the controller to perform the same estimation much faster, each aircraft is presented as a short line, indicating its position in the next three minutes and five dots to indicate the speed of the aircraft.

After the break the session continued with presentations on various design methods involving continuous interaction. The importance of the use of metaphors and multiple metaphor environments have been outlined and the way in which they can sup-

port the design of continuous interfaces by integrating interactive embodiments of alternative design languages into systems exhibiting context-sensitive processing like for instance in the Map Views application.

An alternative approach to the design and analysis of continuous interaction is feedback control theory which is oriented towards continuous, dynamic tasks. In this approach the human and the system form a closed, tightly coupled loop. Feedback control theory can be linked to Fitt's law (a widely used rule relating movement time, size of target and distance to target), viewing movement towards the target as a feedback control task based on visual input with the limb as the controlled element. Importantly, relationships such as Fitt's law can be derived from feedback control models. It has been shown how this approach can be employed to perform quantitative as well as qualitative analysis of continuous aspects of interfaces in isolation.

A design model that was proposed for use at a much higher level of abstraction is that of a Dimension Space. The Dimension Space is intended to help designers to understand both the physical and virtual entities from which their systems are built, and the tradeoffs involved in both the design of the entities themselves and of the combination of these entities in a physical space. Entities are described at the level of the tasks being performed. They are characterised by six different aspects (dimensions); the attention they receive from the user, their role, manifestation, input and output capacity and informational density at any time during the interaction. To better understand the properties of and relationships between entities designers plot the significant entities composing their system in the Dimension Space. An example is presented in Figure 2.

The last presentation in this session discussed the role of continuity in haptic interaction systems and the communication capabilities of coordinated visual and haptic technologies. Haptic communication between the user and the system is bi-directional. A timed sequence of point applied forces is generated by the system and applied through some haptic device to the human's hand and/or fingers. At the same time hand or finger movements performed by the human are transformed into signals for the system by

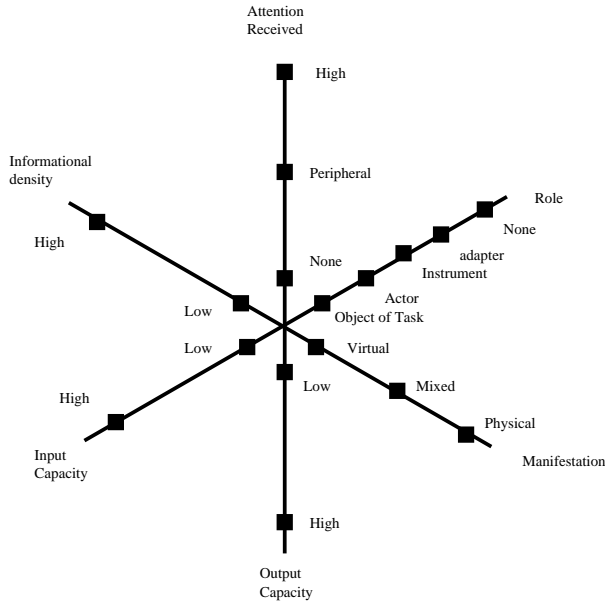


Figure 2: Dimension Space

the same haptic device. In visual haptic interaction a virtual space with 3D objects is rendered both graphically and haptically. Based on the exploration of the graphic and haptic presentation the user tries to construct a corresponding mental model starting from some hypothesis based on previous experiences. As long as the information obtained from the interface matches the expectations of the user, the interaction proceeds smoothly. But whenever an inconsistency is encountered the user's interaction is interrupted. At that point the user has to take a decision to either incorporate the unexpected information into a revised mental model, or conclude that a malfunctioning of the system was encountered, in which case the user will focus attention on a different mental model related to the functioning of the system or the interface. In the latter case the original task is clearly interrupted and replaced by another one like looking for some expert on haptic interfaces to repair the system. To illustrate this process a second layered reference model was proposed, shown in Fig. 3 that shares the human related layers with the one in Fig. 1, but

### Example: Typing text on a keyboard

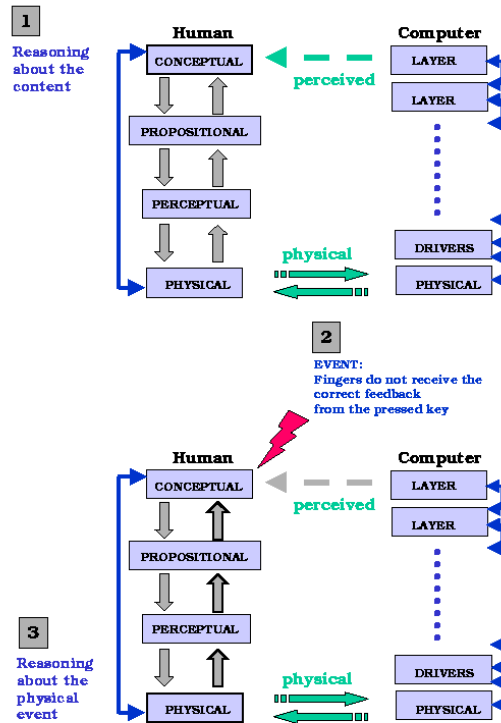


Figure 3: Layered Reference Model with physical layer

has an explicit physical layer and allows for a finer layering of the computing system model. The correspondence between the layers at the human side and those at the computing system side is left open to discussion.

### Workshop second day

The second day was used to deepen the discussion on the various approaches that were proposed to model and analyse continuous interaction. The main focus has been on the development of a general Reference Model for continuous interaction.

## Workshop morning session

The discussion during the morning session focussed on a potential reference model for continuous interaction, the possible relation between available models and the reference model and the application of the reference model on the two case studies presented on the first day of the workshop. Layered models have been used successfully as a reference model at a conceptual level or as a means for structuring in several areas of computing such as protocol design. Although there are very important differences between human to human, human to computer and computer to computer communication, some similarity may be observed between HCI and protocol design in the sense that they both deal with the design of communication and that this communication could be considered fruitfully at different, separate levels of abstraction from a conceptual point of view.

The participants of the workshop reached consensus on the idea to take a layered reference model such as presented in Fig. 4 as a starting point. The model proposed has five layers; physical, perceptual, propositional, conceptual or task layer and group layer. From a human cognition viewpoint the physical world (1) is perceived (2); the identity and referent of the percept is encoded (3); and the meaning of sequences of referents is inferred (4). The final group layer concerns issues of interaction in which more people are involved, such as turn-taking in cooperative work. The layers are intended to separate concerns on interaction without losing the relation between these concerns. In this model the solid arrows indicate the actual transformation and communication of the information exchanged between user and computing system and the dashed arrows the virtual communication at higher levels of abstraction. The model is intended to be used with a certain flexibility. The border between layers may not always be very sharp, and maybe not all layers always need to be taken into consideration.

During the discussion the model provided a sufficiently abstract framework within which it seemed possible to employ further, more detailed models such as the cognitive theory ICS, user models, architectural models such as ARCH and the Seeheim model.

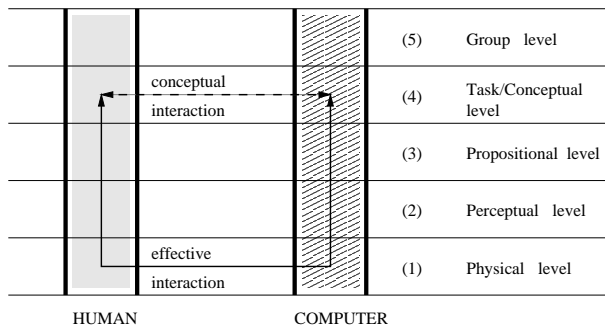


Figure 4: Layered Reference Model with 5 layers

It was quickly accepted that abstraction of goal-relevant meaning from events in the physical world could be seen as necessary in both humans and computer based systems, and that existing analytical techniques frequently included layers as a conceptual tool. On the human side, cognitive theories such as ICS centered on the notion of increasingly abstract levels of mental representation, whereby sensory information is successively transformed into high level schematic codes, and vice versa. On the system side, devices must detect changes in the world, identify them as particular instances of classes of events, associate a meaning with them relevant to the ongoing processing context, and ascertain the appropriate action to take consistent with the goals of the system.

The second half of the morning has been used to investigate how the reference model could be used to analyse the two case studies. Two separate groups were formed, each one concentrating on one of the case studies. The results of each group has been presented and discussed with the other group at the end of the morning.

Although the time was too short to perform a very detailed study of the cases at hand, a number of interesting observations were made. We highlight some of them in the following.

A first observation was that an underlying assumption of the layered model is that it is clear which systems, i.e. users, computing systems, environmental factors, have to be taken into account. It was proposed that the Design Space approach may play a

role in the identification of relevant entities and their properties.

Once a number of entities have been identified, likely communication paths can be established between the entities. It is not clear whether all entities could communicate to each other at all available levels, but certainly virtual communication at the task level takes place and physical communication at the physical level. The intermediate levels seemed to be more related to the human oriented way of information processing than to the computing system.

Specific errors during interaction could be related to the various layers. For example an interruption of the GPS information about the location of a mobile user could have physical causes (the user entered a tunnel). This has implications on the interaction at a higher level. If it is clear to the PC user that the interrupt is due to a tunnel and that communication will soon be possible again, the focus of attention can remain at task-level. If the situation is not clear, the PC user may think that the connection broke due to other factors (battery out of charge or congestion of the network) and interrupt the guiding task.

The physical layer of the model allows non-modelled entities to be included, so that their presence within the interaction environment can be recognised (in the MagicBoard scenario, the marker pens and surface of the board were such). It was realised that, having been included, they could subsequently be expanded into a layered (modelled) entity for some parts of the timespan of an interaction (if they 'burst into interactivity') and then collapsed again when they 'turned off'. This is one way in which dynamic aspects of an interface can be considered within a layered model. Fig. 4 thus illustrates a single moment in the duration of a dynamically fluid interaction, not the whole interaction. A strength of the framework is that it does not tie the analyst to any particular model for any entity; nor to any timescale; nor to any level of analysis; nor to any predefined set of entities. The models can change scope and content as is required; there is no premature commitment to an inappropriate analysis. In practice, decisions will need to be made about how best to conduct detailed modelling of the exchange of information within layers of a single entity (intra-entity modelling), and between

entities at the physical level (inter-entity modelling).

Other proposals to model dynamic aspects of interaction were the use of existing modeling techniques to model behavioural aspects of entities orthogonal to the layered model. In the discussion on the application of the reference model to the Map Views scenario it was proposed that a data flow approach could give a clear structural representation of the communication "channels" between entities. Different physical channels and representations of information communicated via these channels have to be taken into account. This is particularly the case where physical aspects of these channels (for example where they are subject to environmental noise) are of importance.

Formalisms that allow the expression of dynamic aspects of interaction, such as automata or process algebras, could be employed to detail behavioural aspects and directly support evaluation of design alternatives. In particular timed hybrid extensions of these formalisms, that can account for both discrete and continuous aspects, seemed to be worth further exploration. Work in this direction has been published in the context of the TACIT project [3, 4, 10].

## Workshop afternoon session

The afternoon session has been dedicated to the production of a poster for presentation at the CHI2000 conference. The poster is available at the TACIT web site [11]

## Conclusions

The discussion at the workshop has led to a sense of convergence of ideas about what a Reference Model for continuous interaction could look like. Progress has been made on relating a layered Reference Model to other theories that focus on different aspects of continuous interaction. These theories include cognitive, architectural and design concerns of continuous interaction.

A detailed study of the application of the proposed Reference Models on the Magic Board and MapViews and other case studies seems to be a valid way to further develop and validate them and to identify issues

on continuity in interaction in a structured way.

For more information on the workshop and follow-up activities, please contact us or see <http://kazan.cnuce.cnr.it/TACIT/Continuity>.

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## References

- [1] P. Barnard and J. May. Representing cognitive activity in complex tasks. *Human Computer Interaction*, 14, 93-158, 1999.
- [2] M. Bordegoni and M. Hemmje. A Dynamic Gesture Language and Graphical Feedback for Interaction in a 3D User Interface. In: *Proceedings of Eurographics'93*, NCC Blackwell, Cambridge, UK, 1-9, 1993.
- [3] G. Doherty and M. Massink. Continuous interaction and human control. In J. Alty, editor, *XVIII European Annual Conference on Human Decision Making and Manual Control*. Group D Publications, 2000. ISBN 1-874152-08-X.
- [4] G. Doherty, M. Massink, and G. Faconti. Using hybrid automata to support human factors analysis in a critical system. In S. Gnesi and D. Latella, editors, *Proceedings of the 4th workshop on Formal Methods for Industrial Critical Systems, Trento*. S.T.A.R. - CNR, Pisa, July 1999. ISBN 88-7958-009-4.
- [5] J. Encarnacao, J. Foley et al. Research Issues in Perception and User Interfaces. *IEEE Computer Graphics and Applications*, 14(2), pp. 67-69, 1994.
- [6] G. Faconti, M. Massink, M. Bordegoni, F. De Angelis, and S. Booth. Haptic cues for image disambiguation. *Computer Graphics Forum. Blackwell*, 2000. (To appear).
- [7] Magic Board web site: <http://iihm.imag.fr/demos/magicboard/>
- [8] L. Nigay and J. Coutaz. A generic platform for addressing the multi-modal challenge. CHI'95, ACM New York, Denver, pp. 98-105, 1995.
- [9] T. Rist and M. Huether. Adaptive Generation of Graphical Information Presentations in a Heterogeneous Telecooperation Environment. In: H.-J. Bullinger & J. Ziegler (Eds.), *Human-Computer Interaction*, Vol. 1: Ergonomics and User Interfaces. Mahwah, NJ: Lawrence Erlbaum, pp. 331-335.
- [10] S. Smith, D. Duke, and M. Massink. The hybrid world of virtual environments. *Computer Graphics Forum. Blackwell*, 18(3):C-297-C-307, 1999.
- [11] TACIT web site, <http://kazan.cnuce.cnr.it/TACIT/TACITHome.html>
- [12] C. Trevarthen. Form, Significance and Psychological Potential of Hand Gestures of Infants. In: *The Biological Foundations of Gestures: Motor and Semiotic Aspects*, Lawrence Erlbaum Associates, Hillsdale, New Jersey, pp. 149-202, 1986.
- [13] M. Srinivasan. Haptic Interactions in the Real and Virtual Worlds. In: *Proceedings of DSV-IS'99*, 1999.

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