A Scenario for the CHI2000 Workshop *Continuity in Human Computer Interaction* : The Magic Board, an Augmented Reality Interactive Device Based on Computer Vision

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The CHI2000 Workshop on Continuity in Human Computer Interaction has been organized by members of the EU TACIT TMR Network, for whom this topic is of central concern. It seeks to expose some of the design challenges posed by certain novel interactive technologies for HCI. The premise of this workshop is that the notion of "continuity" encapsulates important aspects of integrated multimodal interactive devices, especially those involving human motion. It further supposes that continuity has not been addressed to date by HCI research and design methods. Thus 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.

Interacting with computationally augmented physical artefacts in a physical space

A simplistic conception of HCI design casts it as a matter of creating useful and usable interfaces for computer systems that sit on office desktops. The growth of mobile devices, whether originating from telephony technologies or instruments for field engineers, has focused HCI design efforts on new ways of interacting with computers that are sensitive to these new settings. One of the central design aspects of these new forms of human-computer interaction concerns the dynamic spatio-temporal characteristics of their physical context. These characteristics require consideration in terms of coping with non-discrete information channels from both device and perceptual viewpoints.

This is but one reason amongst many responsible for a blurring of the distinction between the physical world and digital devices. Most every-day consumer goods incorporate microprocessors and do so increasingly to support interaction. Green and Benyon have described these as technologized information artefacts, existing on a continuum of structure and usage from even ‘dumb’ devices, such as the conventional paper diary, to the kinds of knowledge-intensive interactive systems more usually associated with HCI (Green & Benyon, 1996). All artefacts created with the storage or conveyance of information in mind, they argue, are the proper concern of designers of information technologies. Wellner, MacKay and Gold (1993) made a strong case for making efforts to integrate interactive computer systems with, rather than divorce them from, the physical world. Ishii and Ullmer (1997) suggest that there are benefits for capitalizing on the physical properties of objects in the world to control digital objects in computer systems. Müller-Tomfelde and Reischl (1998) have reported work that capitalizes on sensors for registering physical position and orientation of objects in an interaction space. HCI design should be able to take into account the continuous aspects of real-world settings. This workshop presents HCI professionals with the opportunity to demonstrate that it can.

This document presents a scenario based on the use of a new kind of electronic whiteboard, called the Magic Board. It provides a useful exemplar of continuous interaction techniques, for the purposes of this workshop, as it exposes continuity as a multi-dimensional and multi-layered phenomenon. That is, continuity presents itself as a property of interaction in non-discrete time and space, in terms of the devices used to support or mediate interaction, the level of task description and in terms of collaborative involvement in the interaction. The scenario should help participants to identify some properties of interface technologies and usability requirements for perception of continuity in terms of system behaviour and "production space". More specifically, Magic Board uses a physical space, comprising a conventional whiteboard and the area around it, that is explicitly shared between the physical productions of real ink on the whiteboard and the simultaneous projection of "digital ink" on the same surface.

Large-scale free-hand production surfaces

Experimental and emerging technologies are already beginning to incorporate physical objects into their model of interaction. Large-scale, free-hand production surfaces, such as whiteboards, have been a relatively active design area of relevance to this direction for interactive technologies. These "e-boards" are of particular interest as several have made it out of the labs and into the commercial market place. The main claims of "e-boards" are to offer the advantages of digital storage, manipulation and replication with quick-and-easy production on a scale physically large enough to support group use at a single generation point. They represent primarily a same-place, same-time groupware resource. In other words, a number of people can gather around a board, read and understand one anothers' productions at the board surface and save, retrieve or otherwise reuse such productions. Retrieval means that they may also be considered same- or different-place, different-time groupware technologies. They may additionally allow different-place, same-time work but such remote synchronous functions are in the main poorly realized and highly dependent on other supporting technologies (including at least an audio link).

A number of implementations have been suggested for realizing e-boards. All recognize that conventional marker pens have been specially and successfully designed to perform their function of producing fast, legible, precise, removable markings. These implementations include using an electro-static matrix on a special surface that can be used with conventional markers (Smart Board, http://www.smartboard.co.uk/contents.html),
infra-red lasers to read barcodes on conventional markers
(SoftBoard, http://www.micg.com/whatisit/index.html)

and ultrasonic localization with special emitters designed to hold conventional markers
(Mimio, http://www.virtual-ink.com/ns.html).

All rely on video projection as a key component in linking a computer to a display surface as a means of producing output, and sensors on the board as a means of input. Each have strengths and weaknesses in terms of technological integrity and functionality offered.

Magic Board's Design Characteristics

Magic Board uses a video projector to output the digital version of a whiteboard’s contents and also its command interface. It uses computer vision (digital image processing) techniques to both interpret user actions and to capture the contents of a conventional physical whiteboard. It uses no hardware links between its sensor (i.e. the camera) and effector (i.e. the video projector) and hence places no physical restriction on the movements of its users about the board surface.
Mobility is a key aspect of whiteboard use and this is one of the means by which Magic Board respects this characteristic. Magic Board has been designed to be autonomous. That is, after pointing projector and camera at a whiteboard and launching the application, it performs all necessary calibrations and adjustments (based on the physical proximity of the camera to the whiteboard and incident angle of image, adjusts focus and performs necessary transformations on camera image). Magic Board requires no special production instruments (that is, tools for creating marks on the board surface or for removing marks once made). Its design has been premised on the notion of large-scale production space as usable anywhere with minimal set-up requirements, to support fast and fluid productions to a resolution as good as conventional a whiteboard, robust against variation in ambient conditions.

The following section describes the Magic Board as implemented but with some additional features that are planned for the near future. These are marked with an asterisk (*). It also exaggerates some of the problems with the current implementation in order to highlight some of the design issues we feel are important in terms of this workshop. These are marked with a dollar ($).

The scenario describes using Magic Board to merge physically rendered drawings with digital renderings, manipulating renderings and some of the real-time characteristics or sensitivities of the implementation. Each numbered section refers to a different operation with relevance for the use of Magic Board, or point of interaction breakdown. An emboldened word or phrase is used to help make clear what function or breakdown is represented. This redundant system is used so that participants may feel free to draw out design issues in the text without necessarily agreeing with the kind of relevance I attribute to them.

An Illustrative Scenario of Magic Board in Use.

1. Frank and Dave are engineers. They have a problem in working out what to do with the design of some logic circuits in a new-generation domestic appliance, the 'Roast'n'Chill' microwave fast freezer combo[1]. They talked it through several times on the phone but agreed they needed to meet up in order to solve their problem. Frank turned on his Magic Board before Dave was due to arrive, knowing that it takes ten minutes($) to run through its initialization sequence.
   (Initialization - time)
2. Dave was early. They're good friends and Dave isn't used to knocking on Frank's door before coming in. He opened the door and shouted "hey Frank" whilst coming in ready to shake Frank's hand. "Stop!" shouted Frank. The Magic Board initialization sequence requires that nothing comes between the whiteboard and video projector, or the camera and the whiteboard, or else the process fails.
   (Initialization – interposition fragility)
3. Frank's whiteboard is right next to his office door. You can't use a whiteboard if something prevents you from standing in front of it. In common with many people, Frank likes to have his desk by the window which means he had three walls to choose from to place his whiteboard, two of them are adjacent to his office door. "Sorry" said Dave "I forgot again didn't I?"
   (Initialization – spatial readjustment of activities around Magic Board)
4. Magic Board was still relatively new to Frank and Dave wasn't used to it yet. He slid along the other wall, bumped into a filing cabinet and then stretched over the projector and camera to shake Frank's hand. "Great to see you. I've got some ideas sketched out here. I think you'll like them" said Dave. He handed Frank a sheet of paper on which were drawn carefully produced, scaled and annotated electrical components.
   (Existing physical artefact - contextualization of interaction)
5. Frank looked at them, then at his own notebook, and said "Yes, I thought you meant something like that. But what's this component here. This B4 transceiver." Dave, following Frank’s gaze, replied "That's a P5 not a B4 and its just a transmitter, like you have over there". He gestured at a set of components in Frank's notebook.
   (Existing physical artefact – adding to contextualization, semantic link to first artefact, gaze awareness of co-located collaborators)
6. "Right. Well, the board's ready to go. Do you mind if I try to tell you what I mean?" Dave knew that by *tell*, Frank meant a combination of drawing components and connectors, talking and pointing. "Sure" said Dave, standing up and taking two steps to the board. He’s decided to turn his drawings into an electronic form that could be used with Magic Board. His carefully produced drawings were too small to be used effectively for his discussion with Frank. This way, he could make them bigger. He picked up a magnet from a stack on Frank's desk and slapped his sheet of paper in the center of the board, sticking it there with the magnet.
   (Initialization – complete ; physical-digital merging – adding to production space)

[1]Chill your beer in 30 seconds and then roast your popcorn in the next 60, all in the same device!

7. He reached up to the top left-hand corner of the board where a letter M in a box was projected. As his finger passed over the M, a drop-down menu appeared instantaneously. He swept his finger down the menu, each item flashing with a green border as it passed over, until he reached the item he wanted: ‘’capture’’. He paused with his finger over the item, the green border flashed twice and the menu disappeared.
   (Magic Board mode selection)
8. A message appeared on the board "Capture will start in 3 seconds". Dave stood to one side and then the timer counted down. Some lights flashed over the board surface for about 30 seconds ($) and then disappeared.
   (Magic Board function – high-quality image capture)
9. If he looked carefully, Dave could see that his paper was exactly overlaid with a projected version of his line drawings and words. He knew it was projected because it was red and he had written in black ink.
   (Magic Board function – output/command feedback)
10. "OK, its in there" said Dave as Frank walked over to the board. "We will need to see an enlarged version of the P5 component" said Frank, pulling off Dave's paper and sticking his own notes on the right edge of the board. "I'll move the small version out of the way. Is all of this stuff needed?" he asked Dave. Dave replied that it was. Frank waved his index finger over a projected green outline of a box that was displayed towards the top left-hand side of the board. As his finger left the box, a small cursor was projected as an arrow shape and the adjacent M symbol had been replaced with a STOP icon. The arrow followed his finger across the board surface. He moved his finger smoothly and swiftly to the edge of Dave's projected design.
    (Magic Board function – finger tracking)
11. As his finger reached the edge of the design, he paused for one second ($). The cursor changed shape into a cross. Immediately, Frank moved his finger across the design and watched as a projected rectangular outline expanded over the design. When all the design was enclosed by the outline, he paused again and the cursor changed back into an arrow shape, just outside of the outline. The outline remained visible. Frank knew that Magic Board now had all of the marks within the outline ‘in focus’ as a selection.
    (Magic Board function – selection)
12. Frank immediately moved his finger around so that the cursor was back inside the outline and again paused for one second ($). The cursor changed into a cross shape. He noticed that the contents of the outline had been augmented with some ‘noise’ in the form of light spots. The outline and content itself were then moving in concert with his finger. He moved his finger towards the edge of the board, the projected design following all the way, and then paused again. The outline disappeared, the arrow cursor reappeared and the projected design stayed at the edge of the board.
    (Magic Board function – move digital)
13. Frank then moved his hand up to the STOP icon and, as his hand passed through it, the cursor disappeared and the M symbol reappeared.
    (Magic Board function – stop finger tracking)
14. In total, moving the projected version of Dave's design had taken about 10 seconds. Meanwhile, Dave had picked up a green marker and started to write a list of priorities for the circuitry in the right-hand side of the board (heat dissipation, low-temperature performance, radiation shielding).
    (physical-digital merging – simultaneous production)

15. Frank then grabbed the cursor (Paragraph 10) and then selected just the component P5 (Paragraph 11). Frank went to Magic Board's menu and selected copy, in the same way that Dave had selected the original capture function (Paragraph 8). This time, the original projection was unaltered, a replica having been created. The colour and size of the marks were maintained in the replica, but a certain amount of 'noise' (random spots of light arising from reflections) came with it too. Frank then moved the cursor into the outlined copy, paused and dragged the copy into the centre of the board. It followed his moving finger continuously to the desired destination. He paused once again, thereby releasing the copied marks**.** Frank then took Magic Board out of tracking mode (Paragraph 13). **(Magic Board function – copy)**
16. Dave then tried to start finger tracking. He moved his finger swiftly into the green box to grab Magic Board's cursor. Nothing happened. ''Too fast'' said Frank. Dave tried again, much more slowly. Again, nothing happened. ''Don't tell me, now I'm too slow'' said Dave. He tried a few more times at different speeds before Magic Board displayed the arrow. **(Magic Board function – finger tracking, initialization time sensitivity)**
17. Dave moved his finger carefully across the board surface, watching as the arrow cursor jittered and dodged with every small movement of his hand. He was standing close to the board surface and paused his hand whilst stepping back to see where his P5 component was projected. The cursor changed into a cross shape. As Dave began to move his hand once more, a green square began to expand between the cross cursor and his moving finger. Frank said ''You've put it into select by mistake. Just pause and it'll go back into tracking mode''. Dave paused again and the arrow reappeared. He moved his finger again towards P5. Frank had accidentally copied of another component with the image of P5. Dave did not want to enlarge this part as well. He paused again to decide how best to start sweeping out a selection box. He knew that he couldn't stop his finger so he kept moving his hand in a circle until he decided on the best place to begin his selection before selecting just P5. Frank said ''you should know where you're going before you set off''. Dave replied ''sure but I've seen you marking time with circles before. In practice, you don't know *exactly* where to stop until you get there.''
    (Magic Board function – finger tracking and selection mode error from inadvertent pause ; 'marking time' avoidance strategy)
18. He went to select the 'capture' function to remove the noise that had been picked up with copy and move (Paragraph 8). Dave was not as used to Magic Board as Frank. He moved his finger over the M symbol and moved his finger down the projected menu items. He paused slightly too long over one of the items before 'capture', the item flashed and Magic Board performed a different command. Dave tried again and then successfully executed the capture command. This time, because capture was working on only a small selection of the board's surface, it was carried out in only 10 seconds ($)
    (Magic Board mode selection – time sensitivity ; image capture function speed of execution)

19. Dave said ‘’That’s it. Now, lets see it in detail’’. Dave selected the cleaned-up version of P5 (Paragraph 7). He then moved the arrow cursor around to one of the selection box’s grab handles (*). The cursor changed into a magnifying glass shape and Dave dragged outwards. He watched P5 expand and contract as he moved his finger back and forth. Satisfied that it was big enough, he paused again thereby fixing his enlargement.
    (Magic Board function – resizing *)
20. Dave then used a marker pen to add in some additional circuitry while Frank discussed some of the construction problems with him. Frank had a pen too and as Dave and Frank discussed their suggestions they both annotated parts of the drawing, including links around the P5 projection.
    (physical-digital merging – working in a single production space ; simultaneous productions)
21. Frank and Dave agreed that heat dissipation was solved and that they should start working on low-temperature performance. They’d been working in the center of the board and were having to crouch to use the lower part of it. Frank said ‘’I’ll get us some more room.’’ He then selected the whole of their work around P5 before using Magic Board’s capture command to create a high-resolution model of the board’s surface (Paragraph 8). ‘’Stand back Dave’’. A message to wait was displayed. Lights flashed over the board for about 60 seconds ($). Then the projected version of Frank and Dave’s work reappeared, true to the size and colour of the markings they had made He then moved it up and to the right of the physical board’s surface (*). Their top-most markings disappeared off of the board and out of the projected area (*). Frank knew they were still there in computer memory even if no longer visible in the production space.
    (physical-digital merging – differentiating the production space from the projection and digitized space)
22. Frank and Dave linked in new circuitry, combining digital versions of Frank’s notebook page, the projection of P5 and its peripherals and new physical ink. The physical ink was frequently erased with finger tips or a board eraser. Less often, digital ink was removed using a Magic Board select and command combination. It was harder to use the erase function than fingers as Magic Board could only select rectangles. Frank and Dave were designing and drawing links and components in all available spaces on the board surface. These were not always easy to select with a rectangle.
    (physical-digital merging – differentiating the semantics and manipulation of digital and physical ink productions)
23. After dealing with low temperature performance, they again moved their workings out of the centre of the board (Paragraph 22) to deal with radiation shielding. Finally satisfied, Frank reorganized all of their work so that it fitted on the board surface. Dave and Frank agreed a list of things they should go on to do, adding it to a free space on the surface. Frank then saved and printed Magic Board’s high-resolution model of the board’s contents.
    (physical-digital merging – recombining images, planning on content)

Summary of design issues

The purpose of the scenario described in this document is to try to expose some of the issues that HCI theoreticians and designers should be capable of accounting for and resolving, when interactive technologies stray beyond the bounds of the digital world. Usability consequences of uncertainty about temporal and spatial discreteness are evident as the following continuous interaction design issues:

- synchronization between physical ink and digital versions of board content. A single part of the production space that appears to contain the same content behaves differently depending on whether it includes physical, digital or both kinds of ink. Erasing with a finger tip does not remove digital ink. Erasing digital ink with the Magic Board function has no effect on physical ink. How should this difference be modelled or otherwise taken into account for designs of this kind?
- reasoning about interpositions between video projector or sensor links and board, in relation to the temporal flow of working with the production space
  (in the abstract: physical interruptions of input and output media).
- deciding on divisions in the content of the production space, whether in terms of the time-base of content creation or in terms of the spatial distribution of content
  (implementing conventions for the semantics of the marks).
- multiple parties engaging in simultaneous production at a given location (multiple continuous information streams conveyed over a single channel).
- a multimodality issue, as gesture is as a means of both command control and content creation in the production space.

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http://iihm.imag.fr/demos/magicboard/

References

Green, T. R. G. & Benyon, D. (1996). The skull beneath the skin: entity-relationship models of information artifacts. *International Journal of Human Computer Studies, 44*, 801-828.

Müller-Tomfelde, C. & Reischl, W. (1998). Communication chairs: Examples of mobile roomware components. In C. Karat & A. Lund (Eds.), *Summary proceedings of the CHI98 Conference on Human Factors in Computing Systems.* (pp. 267 - 268). New York: ACM Press.

Ishii, H. & Ullmer, B. (1997). Tangible Bits: Towards Seamless Interfaces between People, Bits and Atoms. In S. Pemberton (Eds.), *Proceedings of the CHI'97 Conference on Human Factors in Computing Systems.* (pp. 234-241). New York: ACM Press.

Wellner, P., MacKay, W. E. & Gold, R. (1993). Back to the real world. *Communications of the ACM, 7*, 24 - 27-27.