

Bridging the Gap Between Real Printouts and Digital Whiteboard

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ABSTRACT

In this paper, we describe a paper-based interface, which combines the physical (real) with the digital world: while interacting with real paper printouts, users can seamlessly work with a digital whiteboard at the same time. Users are able to send data from a real paper to the digital world by picking up the content (e.g. images) from real printouts and drop it on the digital surface. The reverse direction for transferring data from the whiteboard to the real paper is supported through printouts of the whiteboard page that are enhanced with integrated Anoto patterns. We present four different interaction techniques that show the potential of this paper and digital world combination. Moreover, we describe the workflow of our system that bridges the gap between the two worlds in detail.

Categories and Subject Descriptors

H5.2 [Information interfaces and presentation]: User Interfaces – Graphical user interfaces.

General Terms

Design, Human Factors.

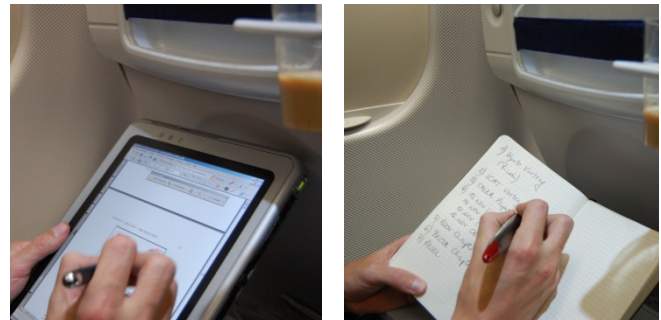
Keywords

Paper interface, digital pen, interactive paper.

1. INTRODUCTION

Designers commonly work in a studio plastered with sketches, which are either pinned on a wall or placed on flat surfaces. New drafts are designed directly on the table or a whiteboard, before creating a digital model on the computer. Many users still prefer real printouts and paper to capture rough ideas [7]. On the other hand, large interactive displays are becoming increasingly popular. Instead of replacing the current environment, we propose an approach where we integrate traditional paper into a digital environment. The support of information exchange between computer and non-computer devices seems to become more and more important. In this context, the design of solutions that seamlessly bridge the gap between these two worlds is the key factor for practical applications.

Sketching ideas and taking notes is a basic task that is performed frequently in the phase of preparing or during a meeting or presentation. For this reason, tablet PCs have been used as a good alternative to notebooks, because they allow an easy-to-use interface for sketching ideas. However, they are currently too heavy and too big to be used in different environments (e.g. people still don't like to use a tablet PC during a flight for making a quick note – instead, they still prefer pencil and paper).



(a)

(b)



(c)

Figure 1: Instead of using a tablet PC during a flight (a), users still prefer pencil and paper (b). Moreover, users can go to the meeting and present their ideas to the audience either by transferring the real ink data to the digital whiteboard or by transferring printed information of the printout to the digital whiteboard (c).

This is the reason why paper still has a lot of advantages: it is light-weight, easy to navigate, people get a fast overview, it is easy to annotate, it is socially well accepted, and it doesn't need any power.

The usage of real paper and digital information combines the advantages of paper and additionally enhances them through the possibilities of the digital world.

In this paper, we present a new paper-based interaction device which enables a seamless usage of a digital pen for manipulating real printouts and for controlling a digital whiteboard. Users can simply pick up printed items (e.g. images, text elements) from the real printout and drop them on the digital whiteboard, as proposed by Rekimoto [10].

We propose a solution where the same pen device can be used for making notes on the real printout as well as for interacting on a digital surface. From users' observations we noticed that this feature is of importance because switching input devices during a workflow affects negatively the users' experience. Using only one device for all interactions guarantees a seamless transition between real paper and digital environment.

The pen can be also used in combination with tangible objects that act as a remote controller for the digital surface. We describe three different variations of this idea in form of an acrylic palette with embedded Anoto pattern, an enhanced ID card, and active areas located at the bottom of a printout.

2. RELATED WORK

Paper-based interfaces are becoming increasingly popular. In 1993, Johnson et al. already presented a new technology, called XAX, for bridging the paper and the electronic world [6]. The system was built on a pen-based interface and demonstrates a great framework. Wellner's DigitalDesk [13] was one of the first interactive tables that combined both real and virtual paper into a single workspace environment. Wellner used computer vision technology to track user input.

Graphics tablets and clipboards for capturing the writing on the paper notebook are also becoming more and more popular. Mackay et al. propose a tablet prototype designed for biologists to write on real printouts, while the system automatically also creates an indexed and searchable on-line digital version [8]. The real ink was captured by the graphics tablet underneath the printout.

An increasing number of researchers are working with digital pens from Anoto¹. The PapierCraft application from Liao et al. demonstrates an innovative combination of real and digital content using printouts and the Anoto pen [7]. Similarly, the ButterflyNet project shows a system that integrates paper notes with information captured in the field [14]. They implemented the transfer of data over a docking station, which is connected with the PC over USB. In contrast, our implementation allows streaming data from the pen to the PC over Bluetooth (BT). Although the Anoto technology has been available for more than six years, only in the last year it became possible to use a Bluetooth connection to retrieve the pen data in real-time. With a special streaming paper, the pens can send the data (position, time, pressure value, state) to the PC with a refresh rate of 50Hz. Notice that the original SDK from Anoto just allows a single connection to the PC. In contrast, our system can handle up to seven BT-pens at once.

Signer and Norrie presented a novel way of interacting with Microsoft Powerpoint [11]. The printed Powerpoint handouts are becoming an interactive paper (PaperPoint) interface for

controlling the slides. PaperPoint was influenced by Palette, presented by Nelson et al. in 1999 [9]. While PaperPoint uses digital pens and the Anoto-tracking environment, Palette is based on a scanner technology for encoding the slide information. More paper-based interfaces are presented in the PhD thesis of Signer [12]. However, all of these demonstrations are always used isolated – thus, he never moved the data from one world to the other and vice versa. In contrast to his work, we support a seamless combination of the real and digital data. While making notes on a traditional paper/notebook, people can move the sketched information to the digital whiteboard and continue the discussion adding digital ink. The final results can again be stored and printed for continuing the discussion using real printouts.

More recently, Hull et al. presented "Paper-Based Augmented Reality", an interactive paper. Users can simply get additional information (e.g. website) on a mobile phone while the device to a real printout focusing on a printed website link. The advantage of their system is that they do not use real-time OCR for capturing the text; instead they are matching bounding boxes of the blurred text captured by the mobile phone with the bounding boxes stored in a huge database [5].

Our approach is influenced by two different research works: firstly, by Guimbretière's work, who presented a system where real notes are seamlessly transformed to the digital world, and vice versa [4]. In his system, users create digital documents and manipulate them either on a computer or on the paper using Anoto's technology. Users have to make their comments on the real printouts – once finished they can transfer the data to the computer over a USB-based docking station. Secondly, we got influenced by Rekimoto's Pick-and-Drop metaphor, where users seamlessly transferred digital data from one device to the other [10]. In contrast to his work, we postulate not to use tablet PCs or PDAs, but to use real printouts and real notebooks.

Our work is influenced by the previous work, but it is different in a number of important ways. Our system benefits from the following features:

- Seamless combination of both real and virtual data combined with augmented content; in contrast to related work, we allow a seamless switch between the digital and real data. Users can start with a sketch on a real paper, another person can add further annotations on the digital whiteboard, and in parallel the first person can continue the sketch on the real printout. Thus, we support a simultaneous, multi-user interaction in both the real and digital world,
- Users can simply drag-and-drop data from the real printout and move it to the digital environment (e.g. digital whiteboard); thus, we also use the same pen-based interface for interacting with the digital whiteboard,
- For both worlds, users can use the same input device, a digital pen with an embedded IR-camera,
- Our system allows a high degree of accuracy with approximately 670 dpi. The accuracy is independent of the shape and size (this feature is important for the digital whiteboard),
- And finally the setup is relatively inexpensive to be manufactured. One pen costs around 200 USD and the printout only has to be printed on a paper or foil.

¹ www.anoto.com

3. PAPER-BASED INTERACTION

We combine traditional input devices, such as pen & paper, with a digital environment. Designers can create imagery and notes on their real notebooks, make printouts with legacy software (e.g. Powerpoint, Excel, Firefox, etc.), and move them to the interactive wall for further discussion. The pen can be either used as inking or pointing device that allows selections on the paper document and data manipulations on the digital whiteboard. To change the mode for the pen, we integrated special control elements at the bottom of each page (see Figure 2). By clicking on them, the pen can change its mode or selected data can be sent to the whiteboard. In addition, we offer some options for defining the ink style including colors and stroke widths. Notice that by changing the color or stroke width, only the digital ink will be changed accordingly, but the real ink still has the same color or width.

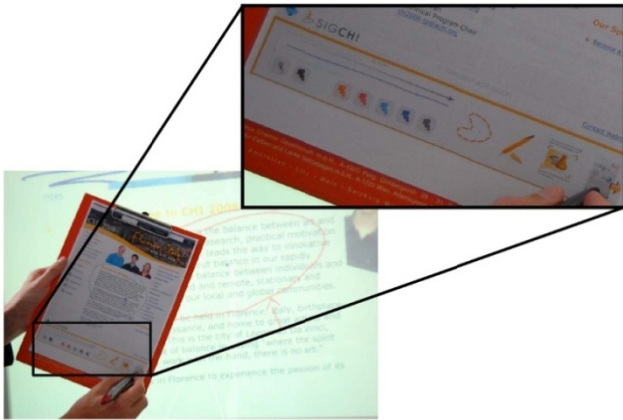


Figure 2: Special control elements printed at the bottom of the page can be used for further interaction.

The control elements at the bottom of the page are customizable by our software and allow the integration of further interaction possibilities.

Combining the real paper with control elements and the connection to the digital whiteboard offers a variety of interesting options. Our approach is characterized by the following interaction techniques:

- Pick-and-Drop,
- Remote Control,
- Sketch-and-Send, and
- Present-and-Interact.

3.1 Pick-and-Drop

Similar to Rekimoto’s Pick-and-Drop metaphor with mobile devices [10], users can pick up data from a printed document and drop it on the interactive surface, the digital whiteboard. Once in selection mode, each item of the printout becomes a selectable content and can be transferred without losing quality– since we transfer the raw data. In our scenario, users have to click with the pen on the corresponding data of the real printout. By using the digital pen, we can calculate the exact position and we can identify the according item. The data gets transferred when clicking again on the digital whiteboard (see Figure 3).

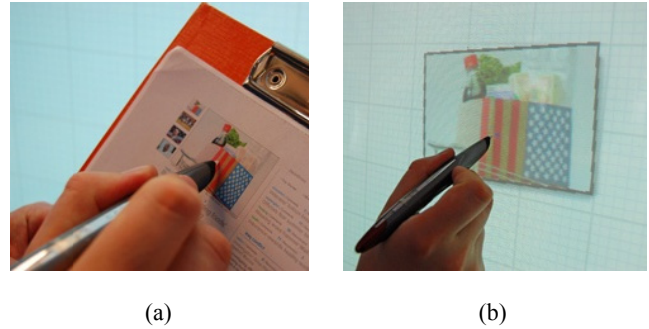


Figure 3: Users can pick up content from the real printout (a) and drop it on the digital surface (b).

Alternatively, selections on the real paper document can be sent to the digital whiteboard by clicking on the send button which is located at the bottom control panel on the paper (see Figure 2). In this case, users do not have to stand up and walk to the whiteboard to drop the selected data, but can accomplish this from their remote location.

Summarizing, users can select objects by changing the pen’s mode from inking to selecting, define the corresponding part of the page, and finally move it to the digital whiteboard by directly dropping the selection with pen or sending through the “send control” printed at the bottom of each page.

3.2 Remote Control

Influenced by the ideas of PaperPoint [11], the real printout can also be used as an alternative *input device*, where all sketched notes are sent to the digital whiteboard in real-time over BT.

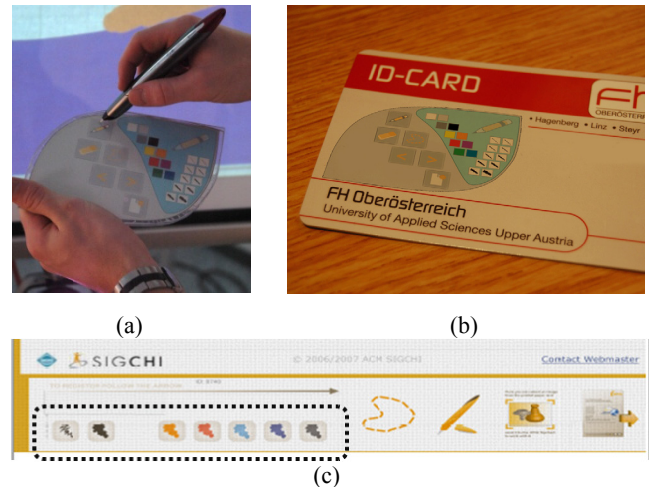


Figure 4: Different possibilities for the additional interaction. We either support a unique palette (a) or special ID cards where the additional functions are printed on the backside of each card (b). Alternatively, we also tested the same functions by placing the control elements on the bottom of each printout (c).

In addition, special printed control elements on the paper allow further operation with the digital wall (e.g. adding a new page/changing the ink color of the digital flipchart etc.). In our demonstration, we implemented different possibilities for changing the ink properties (see Figure 4).

We tested our application by using a tangible tool palette, which was either embedded in an acrylic palette (a), or by adding the functions on the back of an ID card (b). Alternatively, we also printed these functions on the bottom of each printout (c). In each scenario, we simply had to put the Anoto pattern on the corresponding surface (e.g. embed it into acrylic, or to put it on the backside of the ID card). Therefore, our solution is really cheap and does not require any additional electronic sensors.

3.3 Sketch-and-Send

Our system supports additional annotations on the real printout that can be performed with the real ink of the pen. The digital version of the ink can be either visualized in real-time on the digital whiteboard or stored on the pen's integrated memory. In both variations, all data that is entered with the pen while in inking mode is processed in one or the other way.

Real-time streaming is mainly used in scenarios, where the paper printout and the digital whiteboard are in the same location. Annotations on the paper are also immediately visible on the digital whiteboard. The data transfer is accomplished through BT streaming from the Anoto pen to the whiteboard PC. Figure 5 shows an example where a user is annotating with real ink on the paper document. The results are simultaneously visible as digital ink on the whiteboard.



Figure 5: Annotations on the real printout are immediately visible on the digital whiteboard.

In this case, the audience can immediately see all changes done on the paper by the writing person. While all manipulations on the real paper are also immediately visible on the digital whiteboard, the system does not support a visual feedback on the real printout in the case of changes on the digital whiteboard. The only possibility is to create a new printout from the sketches done on the whiteboard.

Offering remote sketching in our system allows the participants of a meeting to keep seated around a table and share their ideas by sketching with real ink directly on a paper while the digital whiteboard acts as presentation area. This means that the users have two possibilities: they can either sit at the table and work on the digital whiteboard from their place; or they can stand up, go to the flipchart but still make their comments on the paper, which also automatically get transferred to the digital whiteboard. In both cases, all sketched information is sent to the whiteboard in real-time, regardless of the user's location. In our system, multiple people (we tested the scenario with 7 participants) can interact simultaneously – independently if they are sitting or standing.

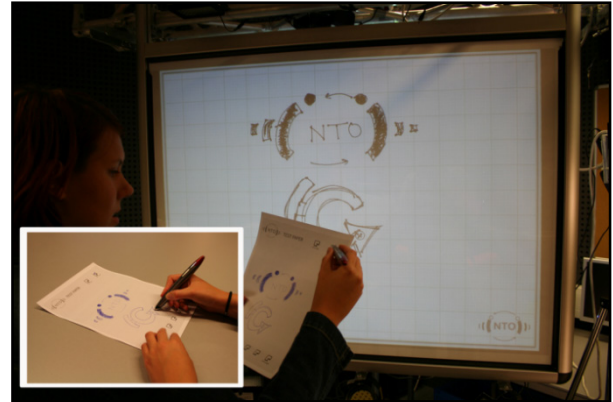


Figure 6: Users can create new sketches on the paper and send the ideas to the whiteboard for the audience for further presentation.

Working in offline mode, the sketched notes can be stored in the pen's integrated memory in advance and moved seamlessly to the whiteboard during a presentation. People can sketch offline on the real paper (e.g. during a flight as described before), come to the meeting and send all sketched data to the digital whiteboard. In this case, the pen allows to store up to 70 full-written pages. In Figure 6, we demonstrate a case where a user is preparing a sketch offline (embedded figure) and later in a meeting sends the stored data to the digital whiteboard. This whole functionality can of course also be used during a meeting to prepare sketches on the paper without displaying them in real-time on the whiteboard; presenting it to the audience can be done at any time later during the meeting.

3.4 Present-and-Interact

Finally, notes that are sent to the whiteboard can further be modified with digital ink. In addition, transferred images can be arranged and transformed on the digital surface (see Figure 7). In this scenario, we use the same pens for the interactive whiteboard as for the interaction with the real paper, so users do not have to switch to another device. Another advantage is the quality of digital data: sent data still has the same high quality as the item from the printout (e.g. the image from a website printed on the paper and sent to the digital whiteboard still has the same quality as the original image of the website).



Figure 7: The sent data (e.g. image) can be moved/rotated/scaled on the digital whiteboard.

4. THE INTERACTIVE PAPER

To capture the ink on the real printout (see Figure 8), we are using the Anoto digital pen system in combination with a Maxell pen DP-201². Sketched notes can either be stored on the pen and transferred over BT using the OBEX File Transfer Protocol or directly be streamed via BT in real-time to the digital environment. Users simply have to click special checkboxes, printed on the real paper. Each page has its own paper ID. In combination with the pen ID and the position, we can easily track each ink stroke and send them to the digital whiteboard.



Figure 8: Each printout consists of the original content (top of the page, e.g. website) and a control panel (bottom of each page) for additional interaction possibilities and commands.

Figure 9 depicts a close-up of the printout. Anoto tracking is based on the information the pen retrieves from the dot pattern printed on the paper. Since the colors of the image are changed accordingly, our system can easily track the black dots (even the dots on the black pupil of the eye can be tracked with the digital pen without any problems).

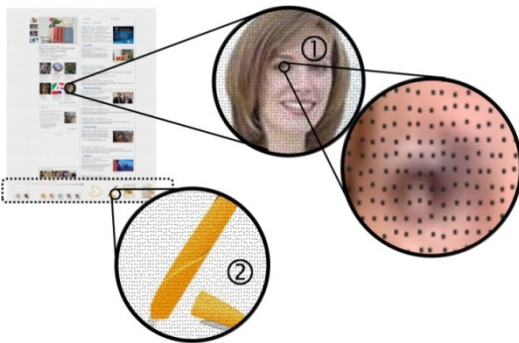


Figure 9: After exporting to an XPS file, we add an additional layer with two patterns on top of each printout for tracking the strokes with the digital pen. While the upper part of the layer (1) is used for tracking the ink strokes on the page, the lower one (2) contains a unique ID for the control elements. This pattern is equal for all pages.

We use a layer with two different kinds of pattern as overlay on the page content. The upper part of the layer contains the pattern for the “interaction” region. This pattern has to be different for each page and contains a continuous number (ID). The lower part, a unique page pattern (which is equal for all pages), is used for the special checkboxes, which are printed at the bottom of each page as depicted in Figure 8.

5. WORKFLOW

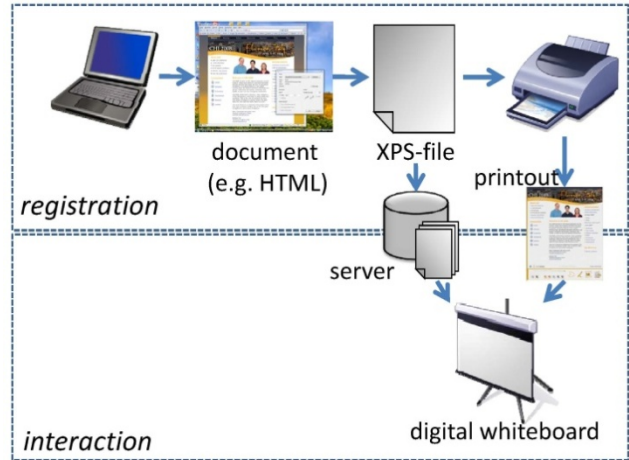


Figure 10: The document is printed with two Anoto pattern layers and also sent to the server for further interaction.

Figure 10 depicts the workflow of creating an interactive printout including a registration and an interaction phase. If users want to interact with their printout, they simply have to generate an XPS file, which is supported by all Windows applications, once the .NET Framework 3.0 is installed. This file usually contains multiple pages, which again include further content (the file can be seen as a container with different elements, such as text, images, strokes or containers again). In the next step, this file has to be printed on a color printer with our application (see Figure 11).



Figure 11: Our application can print an XPS document which automatically generates the Anoto pattern embedded in the printout. Moreover, the according page will be stored on the server.

² <http://partner.anoto.com/obj/docpart/43983a3deac3e.pdf>

In our system, we used an HP6940. As described by Guimbretière in [4], the printing process can be very complicated and time-consuming, because of the special requirements of the Anoto-based pattern. The digital pens have an embedded infrared (IR) camera. While the pattern should be printed with the black ink cartridge (which is not IR transparent and therefore visible for the IR camera), the content should be printed only with Cyan, Magenta, and Yellow (without K); the colors C, M, Y (even composed) are invisible for the IR camera. Usually, printouts contain black content and we need to find a way to make this content invisible for the IR camera. Several solutions have been discussed in [4].

Instead of removing the ink cartridge and printing the document pages twice (once with the pattern using the black ink and again with the content with C, M, Y), we propose to modify dark colors within the page, e.g. RGB (255, 255, 255) to a brighter RGB grey value, such as (169,169,169). The pages still look good and can be printed easily without any complicated hardware changes on the printer. However, the automated color management of the printer has to be switched off. Unfortunately, it is not possible to change the CMYK values directly within the XPS document.

We also store the XPS document on the server with the according ID. The server handles all documents and the corresponding pages including the page IDs used for further operation with the digital flipchart.

After the registration of the paper, users can click on the check boxes for further interaction. There are two ways of interaction: XPS content (e.g. images, paragraphs) can be easily transferred to the digital whiteboard. The objects of the corresponding XPS file are extracted and transferred accordingly. By using the XPS API, we identify digital content in the document and allow the pick-and-drop metaphor to transfer the content from the real paper to the digital world. Users can also select parts of a printed document and drop them on the digital whiteboard. Alternatively, users can make additional notes on the printout with different colors, change the stroke width, select a user-defined region, and transfer the data again to the whiteboard. For both devices, the real printout and the digital wall, we are using the pattern, which allows an easy integration of the real notebook interface. Thus, users don't have to switch the device while working with the printout or with the digital whiteboard. A closer description of the digital whiteboard can be found in [2].

6. EARLY USER FEEDBACK

In our initial pilot study we tested 6 employees from our University, who were not affiliated with this project. The overall participants' reaction was very positive. Users really liked the idea of grabbing content from the real printout and using it on a digital whiteboard. It is more convenient since people don't have to use a heavy Tablet PC. Participants also had the impression to work within *one* world.

Giving feedback on the real paper is really challenging and still a problem. The pen, used in our system, gave a vibration feedback only on errors and whenever the information has been sent successfully to the digital whiteboard. However, people asked for a better visual feedback. Especially, when they selected different ink colors, they were not sure if the system accepted their selection or not. Although the system always worked fine during the test, they expected to get a feedback. Giving feedback in the meeting room (in combination with the digital whiteboard) would be easy; in this case, we can provide audio and visual feedback on

the digital whiteboard or on an interactive table. We don't have a solution yet for users working offline. However, we also have to ask how often users would change the digital color if they can't do it with the real ink of the pen.

Participants often felt lost while working with the different modes (e.g. users didn't recognize immediately that they were in the mode of annotating the paper or that they were in the grabbing mode). One of the participants proposed to have an audio feedback or a visual feedback on the digital whiteboard since the system is mainly used in combination with the digital presentation tool. Another idea, proposed by a participant was to modify the pen with corresponding LEDs.

We used two types of pens: In a first scenario, participants worked with a digital pen that had a stylus tip, which didn't leave a real ink on the paper. Consequently, participants could also use the same pen while working with the printout and while interacting with the digital whiteboard. In the second scenario, participants worked with a ballpoint tip based digital pen, which did leave a real ink on the paper. However, using a ballpoint tip would leave ink on the flipchart. On the other side switching pens would be really cumbersome. Therefore, we propose to modify the pen where users can switch between the two modes (ballpoint tip and stylus tip). Another solution would be to use ink repellent surface on the digital whiteboard.

Finally, participants also would appreciate it to get a feedback on the real printout once they change the digital content. One solution would be to track the paper and to augment the changes accordingly on the paper. We already ran first experiments with an ARTag [3] marker applied on top of each printout (see Figure 12).

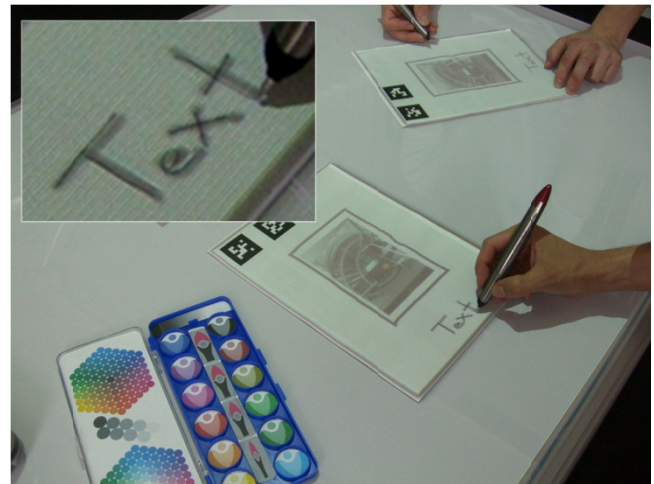


Figure 12: ARTag markers printed on each printout help to track the paper on the interactive table. However, the tracking is not accurate enough and the jittering can be cumbersome while working with the real printout. The close-up shows that the real ink of the ballpoint tip is also visible and matches with the digital ink projected from the top.

In this scenario, participants could modify the page on the digital whiteboard (e.g. embed a digital image) and the data was also visible on the real printout. Figure 12 shows that multiple users can join a session – all of them see the visualization of the same data and the printouts can be moved seamlessly on the table's surface.

Both users get the correct content visualized on the printout. We got a framerate of 30fps, which was sufficient. The markers, however, were too big. The ARTag markers are designed to track objects in 3d. In our scenario, however, we only used them to track objects which were always planar on the table's surface. We believe that we still have to spend more effort on this problem. Neither putting large markers on each page nor superimposing content on the real printout are ideal solutions for this problem.

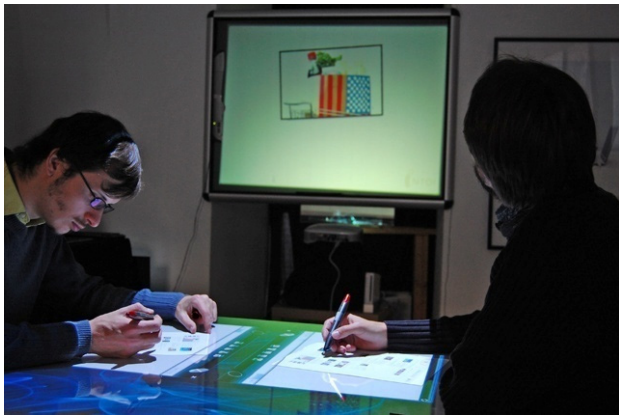


Figure 13: Users can also sit around the interactive table and interact with the digital whiteboard either through the real printout or the digital table.

An interesting observation we made was that participants discussed in a different way once they had to work together (e.g. in a brainstorming session). In a classical presentation with a flipchart or a whiteboard, where the audience is sitting around a table, the presenter is automatically the leader of the session. Usually he/she moderates the session and the audience is almost acting in the background. In our setup, however, everybody has the chance to interact immediately (see Figure 13). Everybody can send sketches, notes, and data to the digital whiteboard without standing up and going to the whiteboard. This raises the question about rights and control management, which we addressed through a social protocol in our first prototype.

7. CONCLUSION & FUTURE WORK

The integration of real notes in a digital environment seems to be a good solution for improving the performance of current digital walls and interactive tables. It combines the affordances of paper and electronic data. Related researchers found already that we will still use real printouts in the future – the myth of paperless office environment will still be true a myth in the next couple of years – in contrast, we are currently producing more paper compared to several years ago. In some domains, paper is still necessary (e.g. medical reports etc.).

Our proposed interface provides an intuitive and easy-to-use manipulation of digital information while working together on large vertical/horizontal electronic displays. Our approach is easy and inexpensive to construct and allows a scalable and multi-user environment, where simultaneous work is supported. In contrast to most related work, we use a system that allows working with the same digital pen in different situations. In this paper, we presented the usage on real printouts, on a digital rear-projected whiteboard, and on a tabletop surface.

In the future, we are further exploring the combination of real and digital paper with a special focus on how both versions can be used simultaneously.

Finally, we also have to find a better feedback for the users while working with the real printouts and find a pen-solution where the pen can be used as a stylus and as a ballpoint pen simultaneously.

A prototype video is available under

<http://organiceit.lanscene.at/~atomas/avi08/paperizer.avi>

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