

Digital and Manual Media in Design

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Although there is an important commitment to the use of Computer Aided Design (CAD) systems in the design studio, there are still technologies that are not broadly accepted as useful to the designer especially in the early design stage. This is because CAD systems use the monitor and mouse which differ from the sketch paper and pen of manual media. This presentation explores how CAD systems can be applicable and integrated to this early design stage by allowing paper as a digital medium. With this exploration, I look at some ways for bridging manual media and digital media. For accommodating this approach, this article includes the evaluation of a prototype CAD system that discusses enhancing the role of CAD systems in the early design stage and linking the realms of the two currently distinct media — manual and digital. This system allows the designer to work with computer based and paper based tools in the same conventional environment. The method provides interesting insights into the relationship between digital and manual media.

1. Introduction

The desktop metaphor presents digital media as analogous to paper. The metaphor has been successful and allows users to bring their skills with paper-based work to digital media. Computers have come closer to people and less learning is now required. However, there is still a large gap between paper and digital media, because the desktop metaphor does not fully contain enough advantages of paper-based work such as writing, reading and drawing on paper. This gap makes it difficult for users to move freely between the two media to embrace the advantages of the particular properties of each medium (Carter, 1993).

The digital medium suggests many advantages over paper, but it has not eliminated paper from the office or architectural firm. Paper has many useful properties that the digital medium lacks, for example light weight and ease of use make it ubiquitous — see for example (Weiser, 1991). It is transportable and cheap to manufacture. Despite these useful advantages, paper remains a secondary medium in the digital era because paper is also limited when compared with the valuable functions provided by digital technology such as image adjustment, digital filtering and digital collages, and so on. Furthermore, paper is passive; we have to rearrange the characters in a sentence when a new letter is inserted. Its contents cannot be automatically processed to sum numbers of words or detect misspelling (Johnson et al, 1993).

There are technologies that translate between these two media: flatbed scanners and video cameras transform paper images into digital images; printers transfer digital images onto paper, and fax machines transfer paper images into digital images or paper at a distance. Among all these tools, a video signal is the most immediate and inexpensive way to translate the conventional medium into a digital medium.

In the last few years with rapid improvements, these technologies enable the user to have the possibility of interaction with paper, yet accesses through digital devices — see example (Johnson et al, 1993; Rao et al, 1994).

The other relevant approach I explain here (Wellner, 1991; Wellner, 1993) affords a way to integrate paper and digital media into one and allows the user to interact in conventional ways with both environments. It consists of an ordinary desk, a video camera and a computer controlled projector. The video camera is mounted above the desk and connected to a system that enables the computer to track where the user is pointing, and can read documents on the desk as well. The electronic objects are displayed on the desk to give feedback from the user's interaction with the system by the projector which is also mounted above the desk. This desk space is used for both conventional and digital media. In this approach, the author argues that the computational environment is brought into the conventional work space rather than making the electronic desktop more like the physical desk — the desktop metaphor. However, the system has some problems with overhead projection. Shadows are one of the potential problem. The users can not, for

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example, lean over to have a look at the projected image more closely. Another limitation is the brightness of the room. The displayed images on the desk are unreadable by a bright desk lamp or sunlight, however it works with normal fluorescent lighting. The other is that the surface of desk has to be white to see projected images most clearly (Wellner, 1993). These overhead projection problems are related and some of them remain as the problem awaiting solution with this article as well. Moreover, Carter (1993) applies this concept to designers' working environment. She discusses the physical embodiment of the work space in supporting designers' practices and the problems of current CAD systems which are little used in the early design stage — See also (Tovey, 1989; Hyde, 1989, 1992; van Dijk, 1995; Senyapili et al, 1994). In this approach, the author suggests that new CAD systems should be designed in ways that integrate into and extend the paper-based environment. A curved mirror is used in the system in order to minimise shadows cast by the user, however it has not eliminated shadows cast completely.

In this article I will begin by describing the scope of the project, narrowing down the early stage of design process that is supported by a prototype CAD system called the Electronic Drawing Board (EDB). I will describe what kind of activity is necessary at this stage, and how CAD systems are applicable here. In the second section I describe the EDB; its physical organisation, its previous examples and its system requirements. Then, I present the evaluation of this drawing board; who tested it, how it was tested and what the results were. With this information, I can draw some conclusions about the EDB and using paper as a digital medium. This leads to new insight into the relationship between digital and manual media.

2. Design process and CAD systems

Before presenting the Electronic Drawing Board, I first describe the design procedure in order to define which part of design stages are supported by it.

In architecture the design process has been thought of in the following steps; the building program, schematic design, preliminary design, design development, contract documents, shop drawings, construction (Laseau, 1989). For the purposes of this research, the first four parts of the process were thought of as formative phases and the last three as production phases.

At each of these steps, the designer defines the problem area, develops several viable alternatives, evaluates alternative solutions to select one and finally the solution to the problem is communicated for the next stage of design.

Meanwhile, Shone and Wiggins point out that “designing is a reflective conversation with some visual medium of a design situation.” “A designer sees what is there in some representation of a site, draws in relation to it and sees what he or she has drawn, thereby in forming further designing” (Shone et al, 1992). In this process of seeing-drawing-seeing, drawing is the language of designing and discovering, and the medium of representing designer's thinking. Drawing and the designer's thinking work closely together as stimulants for developing new ideas (Laseau, 1989). In addition, drawing allows the designer to consider several alternative design ideas simultaneously (Tovey, 1989). Designers pin up their drawings on the wall and review all the ideas produced. This permits feedback and lays the groundwork for the next ideas by comparing several alternative drawings together. Drawing, moreover, has another important benefit in enabling other people to participate in the design process (Tovey, 1989). Drawing externalises the conceptual designs of the designer, thereby enabling other people to see what s/he is doing and to contribute to the design process. For this purpose, paper and pencil provide a good intuitively understood medium, which better supports the sketching that is characteristic of these early design processes.

On the one hand, in the production phases the purpose of drawing is to explain to other people the products of the designer's thinking, therefore drawing should be very precise and accurate. By contrary, *in formative phases an accurate drawing is not necessary because drawing — sketching — whose inherent ambiguity helps the designer to develop new ideas (van Dijk, 1995), and here drawing is a communication between the designer and him/herself. Although sketching also enables other people to participate in the design process,* this is different from drawing in production phases. Sketching does not provide precision like shop drawings for construction but rather aid other people to exchange data for design ideas in formative phases.

In the mean time, CAD systems mainly contribute to the production phases of design because, the beneficial aspects of the systems are two-dimensional drafting, three-dimensional modelling, surface-shaded rendering and sophisticated perspective as being part of the these phases. However, there are a few researchers attempting to utilise the CAD systems in the formative phases of design (Tovey, 1989; Hyde, 1989; van Dijk, 1995). In these researches the authors describe deficiencies of the CAD systems when applied to these phases, and the requirements of the CAD systems that support here. Tovey (1994) summarises the requirements on computer-aided formative phases of design.

- "1 Inputting geometric information must be quick
- 1 Geometry must be easy to specify
- 2 Representations must not be overly precise
- 3 Geometry must be easy to modify
- 4 Reviewing alternatives must be readily possible
- 5 Visual display quality must be adequate of evaluation
- 6 Overall interface must be user-friendly "

The EDB has been designed to adapt the computational environment to the conventional drawing board as well as intending to satisfy the requirements mentioned above that are supporting these formative phases of design.

3. The Electronic Drawing Board

The Electronic Drawing Board is a conventional drawing board with a few extra capabilities. A computer controlled video camera is located above the drawing board to translate images from paper placed on the drawing board into the computer. A computer controlled projector is placed behind a transparent drawing board, allowing the image output from the computer to be projected onto the drawing board from behind. This projector enables the system to feedback from the designers' interactions. The Electronic Drawing Board integrates the physical and the digital tools into one and allows the designers to interact in both paper and digital images in the same conventional environment (Fig. 1).

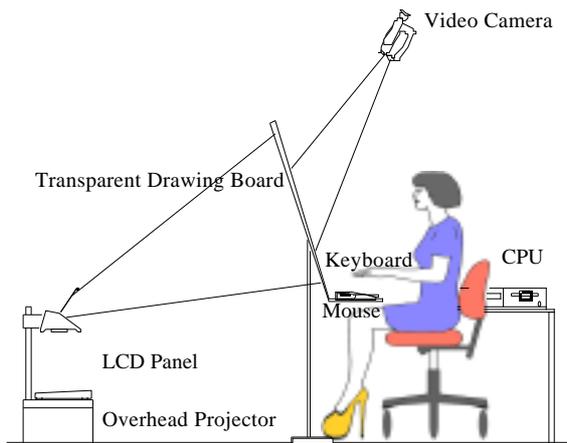


Figure 1. The Electronic Drawing Board I

This system shares some features of the Digital Drawing Board (Carter, 1993). Carter's system consists of an A1 size drawing board, above which are mounted a computer controlled video camera and projector. Carter's system also uses a curved mirror to minimise shadows cast by a designer standing in front of the drawing board. The Electronic Drawing Board differs from this system in that the image output is projected from behind, to remove shadows cast, instead of using a curved mirror. The other difference is that a surface of the drawing board is made of glass with laminated coated tracing paper. This allows the designer to use a white board marker to draw directly on the surface as well as on the paper.

The Electronic Drawing Board runs on the Macintosh AV (audiovisual) computer which contains video processing board and allows video input from any kind of video cameras and VCRs, and the projector consists of an overhead projector with a LCD panel which displays 640 x 480 pixel. The video camera is connected into the video input port on the back of the computer and it uses Video Monitor program that enables the system to display a live video image in a window on the drawing board and to capture one frame of the video image. High quality image editing and photo retouching software is also used in this system to edit transferred images from paper.

In order to evaluate this system in design process, a designer was invited and did two evaluations in our laboratory. The goals of evaluation are as follows;

1. How CAD systems can be applicable and integrated to early design stage by allowing paper as a digital medium.



Figure 2.

and eraser on a small table in front of her. A mouse and a keyboard were also placed here, being used for access to the computer environment (Fig 2).

1. What is the relationship between digital and manual media.

4. Evaluation of the EDB I

The first evaluation was an exercise to explore the Electronic Drawing Board.

A third-year architectural student was invited to come to our laboratory for one day. She has experience with Macintosh Operating System (Mac OS), AutoCAD (one of the most popular general purpose CAD system) on the Unix platform, design practice and design education. The Video Monitor program and the basic skill of Adobe Photoshop were explained beforehand. This student had skill in the CAD system that allowed her to compare traditional CAD systems with the EDB, and her experience with Mac OS helped make it easier for her to access the EDB.

Before starting the evaluation, she organised this workspace as she would at a normal drawing board. She placed her tools such as set square, scale, white board marker

The designer was intended to practise with the EDB for an hour. By taking her through a guided exercise, I made sure she practised all the functions of EDB such as capturing the video images, saving it, editing transferred images and so on. At the end of the hour she made a simple image to rehearse all functions.

4.1 Site Planing on the Physical 3 Dimensional Model

She started by taking a site image from a real model with the video camera and the Video Monitor program (Fig. 3).

The site image was stored in the pict file format and displayed in a window on the central area of the EDB by Simple Text program (Macintosh system utility). This is a similar activity to the previous actions, taping drawing to the drawing board before starting a new sketch in a traditional manner.

She started a drawing on the image of site on the laminated coated surface of EDB without placing a blank sheet of paper over the image. — Of course she can use a piece of paper over the top as well. Then, her drawing appeared in a window, which was a live video image with the Video Monitor program, on the left side of EDB (Fig. 4).

When she had finished the sketch, she captured an image to save in a pict file format on the computer with a simple gesture of pressing the Command key and C key on the keyboard. This image was edited by the paint program to enhance the resolution of it. After that, she placed the image carefully aside (the image can be saved in a folder) (Fig. 5).

Sometimes, she replaced the image on her central work area with a new image and started a sketch again.

Once in a while, she retrieved previous drawing from the folder and placed it on the board. During her working time, she often referred to these and the process was repeated.

The final step was to watch a slide show, that had just been sketched through the computer application such as JPEG View (Macintosh shareware). This allowed her to gain feedback and to refresh her ideas for new beginnings.

4.2 Elevation Sketch between the Real Buildings

Before she started a sketch she took a photo of the buildings she wanted to renovate, with a Digital Camera (Apple QuickTake 100) on the site. She brought the camera to the laboratory and simply connected it with the computer to convert the image from the camera to computer. She then placed the image on the central area of EDB and selected the building she would renovate with the mouse (Fig. 6).

She deleted the selected building with a simple stroke and started a new sketch on the blank area of the image as she did before (Fig. 7, 8).



Figure 3.



Figure 4



Figure 5.



Figure 6.

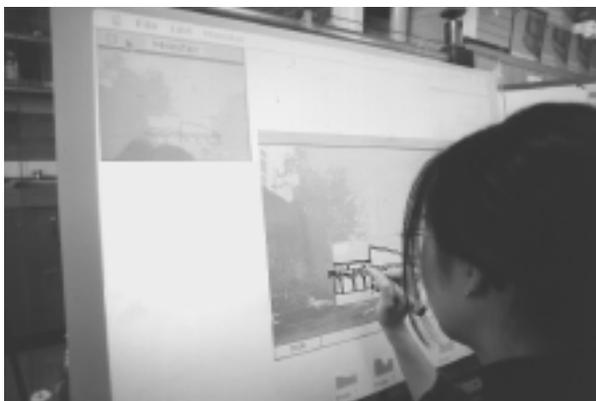


Figure 7.

The studio project is the design of a Buddhist meditation centre in the Blue Mountains, Australia, for which the student has been given a program and a site. The design project requires a masterplan which organises segregated zones for different user groups — males, females and teachers — and various buildings to be added to the existing facilities. The project then requires a developed design of a series of specific buildings.

4.3 Technical Problems of the Electronic Drawing Board

The main shortcoming with the current system is the distortion of transferred image from the video camera caused by unparalleled positioning of the camera with the drawing board. The other problem is the angle of the drawing board. The current prototype needs at least 2 m of distance between the projector and the drawing board to make an A0 size screen, therefore the angle of the board must be not less than 60 degrees. However if a high refracting lens is used in the projector, the problems might be overcome. A low angle of the board such as 15 degrees, could eliminate the distortion of the image because the video camera can be mounted over the drawing board at right angles to the board.

5. Evaluation of the EDB II

The second evaluation focused on a real project to apply in practical affairs. For the purpose of this evaluation the EDB has been developed. The principle of the system and the choice of computer application has not changed with the exceptions of variations in the arrangements of the physical environment. Two curved mirrors have been used for the system to make A1 size, low angle (12-17 degrees) drawing board which is a more practical angle than the high angle when applied to the formative phases of design process (Fig. 9).

This method is much cheaper and simpler than using the high refracting lens mentioned above. Practically, with this arrangement of using a low angle drawing board, the mouse can be placed and manoeuvred on the drawing board itself without the need for a separate table and the camera is able to be placed directly above the drawing board away from the movement range of the designers.



Figure 8.

5.1 Site Planning

The plan of the site showing the contours and the existing buildings on the site was scanned into the computer using the video camera mounted above the drawing board. The designer started the process of site planning using the captured image as the background. She was able to organise various spaces and mark circulation routes on the contour map being thoroughly aware of the location of vegetation, contours and other topographical features.

The feedback from evaluation 1 indicated that the lines from the white board marker were too thick and the pen itself felt clumsy in the hand therefore the student was given overhead projector pens to use which are also easily erasable. The following is how the designer described the process in answer to a written questionnaire.

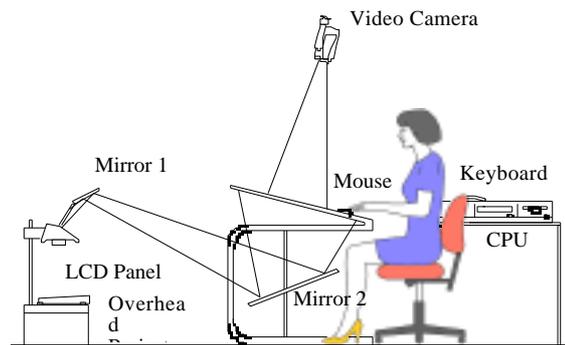


Figure 9. The Electronic Drawing Board II

I started with drawing bubble diagram sketches and arrows indicating circulation paths. The clients of the project was really fussy about getting the separate zones for males, females and teachers. I had many options of very different organisation of spaces which I could develop. I was able to draw and erase freely and compare different schemes by laying them out simultaneously. Also I had lots of different coloured pens to work with and that was really useful and the line quality of these pens was better. Being able to copy and paste images saved me a lot of effort in tracing existing drawings. The whole process was quite similar to that of using yellow trace as it was possible to overlay images and compare different schemes

It can be assumed that this process of drawing bubble diagrams and working out the circulation paths represents the beginning stage of the whole design process.

First of all, she mentions being “able to draw and erase freely”. The EDB allows the user to do freehand drawings as is possible using pen and paper. The importance of being able to think graphically using sketches and drawing at an early stage of design is an essential part of any design process (Laseau, 1989). This important process of being able to draw freely is not possible with existing CAD systems. The EDB recognises the shortcoming of existing CAD systems and tries to provide the working environment where the process of thinking and designing graphically is possible. On the other hand with paper, it is so easy to end up with a big pile of paper where less than half and very often even less than that is useful. Using the EDB, this process of storing drawings is useful in saving drawing for future referral.

She also describes that she was able to “compare different schemes simultaneously”. From experience and working with other designers, it can be seen that people often work with more

than one image available. Being able to refer to other design drawings and images allows the designer to be receptive to other options and possible ideas. Although it is functionally possible to arrange several images using a windowing system, the size of the screen means the drawings become too small and virtually unreadable to the user. The EDB in contrast provides a large working space where working in a rich environment with more than one image is possible.

Referring to the tools that were available to her, she “had a lot of colours to work with” which is a practical feature and one that can also be very useful in early stages of design such as site planning. This is another of the features that are possible using paper but has always been a shortcoming in the use of current computer screen based systems where changes of colour involves tedious processes such as selecting items and using commands.

When she says that being “able to copy and paste images saved me a lot of effort in tracing existing drawings”, she highlights an important point. How many times do we designers copy out similar drawings, wasting paper and valuable time? And yet we still insist on paper because the gap between digital medium and paper presents too many inconveniences to make use of both in the early stages of design. She is referring to a well-known useful function of computer environment. The EDB possesses these useful functions which are only possible using computer based working environment as well as recognising the essential need for designers to use paper as a design tool.

She raises the most comprehensive insight yet by saying that “the whole process was quite similar to that of using yellow trace”. This is an important aspect of the principle developed by the EDB — adopting the characteristics of paper based working environment to the digital medium in stages of design where drawing and sketching are required.

5.2 Preliminary Design

Once the site planning stage of design had progressed adequately to follow onto the next stage, the student was asked to use the EDB to develop plans of specific buildings. She gave the following account in answer to a written questionnaire.

I started by getting the approximate sizes of all the spaces required by the brief and arranging them into different organisations. Pretty rough sort of drawings really like bubble diagrams with shapes, doors and windows using the projected image of the site. Naturally there was a lot of options and it took a lot of sketches. I was constantly drawing and rubbing things out so in this respect the board and pens were good. I picked out some of the designs that I thought were worth keeping and saved them in a folder. While working on a specific drawing which I had kept at the centre of the board, I was surrounded with all the other options that I retained. I was working on the central drawing mostly but every now and then I would scribble changes on the optional design sketches or even discard some if I no longer needed them. I used the slide show at the end of the design session to review all the saved work which was good because it gave me a sense of accomplishment to see all the work on the big screen individually.

The stage of design described “getting the approximate sizes of all the spaces required by the brief and arranging them into different organisations. Pretty rough sort of drawings really like bubble diagrams and saved them in a folder.” is quite similar in principle to the site planning process discussed in the previous section.

The EDB has the ability to show more than one image at a time and the designers can interact with these images simultaneously (Fig. 10). This will contribute towards establishing a rich and productive working environment which has been a feature lacking in existing computer based systems.

She gained “ a sense of accomplishment to see all the work on the big screen individually” and furthermore this function can be used as another design tool to stimulate the designer to see the design in an alternative way. The use of a slide show, although a common function of a computer as an aid of design process, is a unique product derived from a computer based design environment (Fig. 11).



Figure 10

We attempted to develop working drawings using the environment provided by the EDB. However the EDB did not prove to be beneficial to this stage of design where accuracy and exactness is required by the drawings. Existing CAD systems are equipped to work with exact dimensions and therefore provide a better environment for working drawings.

An unexpected advantage in using the EDB is the availability of common computer tools such as alarm clocks, calculators, stickies, E-mail and so on (Fig. 12).

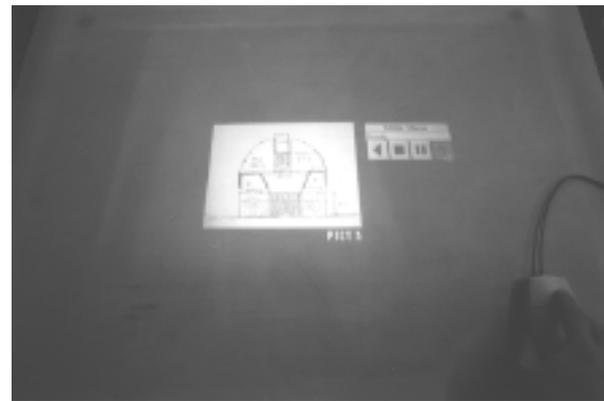


Figure 11

6. Conclusion

The achievement of the EDB is that it combines the computational image and paper to be used simultaneously in one working environment. As discussed in previous sections of this article, this results in numerous benefits derived from each of the two mediums.

Due to the inability of computers to manage anything more than numerics based procedures, the existing CAD systems can provide accurate numerical evaluation in design process but neglect other aspects of design. Therefore existing CAD systems fail to provide a method of accommodating for the needs of designers to materialise ideas through the act of drawing. This is where the EDB attempts to narrow the gap between paper and computers as mediums for design by allowing designers to engage in the act of sketching while taking advantage of the benefits that arise from using computers.

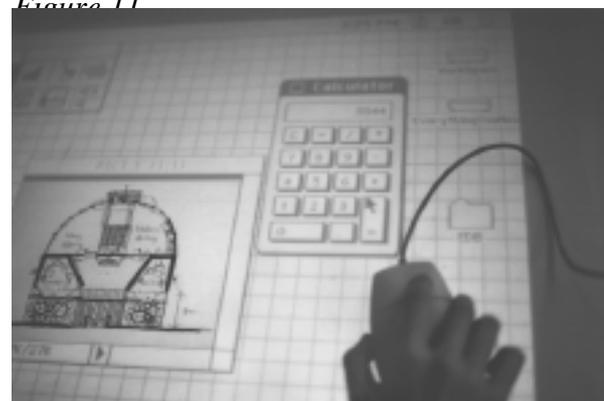


Figure 12.

In this article I have argued that the physical and digital environment have quite distinct characters which designers make use of in design. In the two evaluations, paper has been used as a digital input device. Therefore paper, in these cases, ceases to be passive. It exists between the digital and the manual working environment to interconnect the realms of the two currently distinct zones. Most importantly the EDB will help overcome the shortcomings of the digital and manual media as individual systems.

As a last word, even if the Electronic Drawing Board provides rich working environment which is allowing the designer to work with computer based and paper based tools in the same

conventional environment, it still has some drawbacks such as overhead projection problems. However, a new kind of monitor — such as the A0 size, flat, very thin, strong surface, touch screen type model like a conventional drawing board — and a integrated digital camera will make EDB more practical than it is at present.

Further research will be done concerning long distance collaborative work in which the EDB and Internet will possibly be used.

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