Taking our *knowledge* and *experience* from the previous chapters, the next step is to bring *theory*, *technology* and *practice* together in a *working prototype* called *Cabinet*.

Section 5.3 describes the design and *development process* of Cabinet. Section 5.4 and 5.5 contains the *specifications* and *evaluation* of Cabinet. These sections *justify* this research project to be *valued* as a *doctoral design* opposed to a doctoral thesis.

Cabinet addresses the two main *research questions* of this research: 1) Cabinet can be used to *gain insights* on *how* designers *use* collections of visual material in their design process, and 2) Cabinet *demonstrates how* new media tools can *support* this.

Now we can finally take the *perspective* of the *designer* and *builder* of *product* and *interaction*. The first two sections of this chapter *recapitulate* our *main findings* in the previous chapters from a *design perspective*. The findings are used to *demarcate* a playing field in which we design and develop our tool.

This work was done in the summer of 2003 and resulted in the *working prototype* of Cabinet and *many demonstrations* of it. In these demonstrations Cabinet *sparked discussions*, bearing relevance to all *three ingredients* mentioned above (*theory*, *technology* and *practice*).

ABSTRACT

This chapter presents the development of Cabinet, a tool for designers to collect and organize visual material. The development builds upon insights from our previous research in both theory and practice. Our previous experiences in making prototypes that support creative activities provided us with opportunities to apply technology and design into our tools.

Cabinet was developed in a user centred tool design process, with our users being designers themselves. The tool design process used many different methods and techniques such as translating design criteria to personas, developing storyboards and paper prototypes. The tool design process also produced many different working prototypes, which we have put through actual use scenarios.

Our final working prototype called Cabinet is a tool that is useful, stable and pleasurable enough to be exposed to the real world. By placing Cabinet into the designer's workplace we can verify the validity of Cabinet as a tool as well as gain knowledge on how designers use their collections of visual material in their design process.

The main developers of Cabinet, Aadjan van der Helm and Aldo Hoeben have contributed to many parts of this chapter.

5.1 Goal

Cabinet was developed as a tool to support designers in collecting visual material in the conceptual phase of the design process. In general, tools for this phase should empower their users to express themselves, something which computer tools often lack (Stappers & Hennessey, 2000). In solutions of computer-aided sketching, expressive and fluid ways of interacting with computers have started to emerge in research prototypes (Aliakseyeu, 2003; Gross & Do, 2000; Stappers *et al.*, 2000).

Another technique used in the early phases of design is to make collages. A collage (French for pasting) combines images to create a provoking experience, hardly expressible in words and rarely based on words (Tufte, 1997). In design these collages are used for the designers own image formation and are used to communicate the direction of a design project (Muller, 2001). Clearly the tools for making these collages should allow for expressivity, ambiguity and fluency. Yet, for making collages and moodboards, we found that designers directly resort to advanced image manipulation tools on their computers. The image manipulation tools used (most noticeably Adobe Photoshop) are powerful for the goal of making moodboards to present to clients, but the visual analysis and organization is not intrinsically supported.

Existing tool research into supporting visual material in design focuses on finding images in computer systems rather than adding and growing collections. In these research projects advances are made in using vague or visual queries (Nakakoji *et al.*, 1999; Restrepo, 2004) in existing, structured image databases. When research and software development doesn't rely on existing image databases, it usually focuses on *adding for retrieval* rather than the activity of *building a collection*, organizing and browsing it as a pleasurable task (Keller *et al.*, 2004b).

With Cabinet we aim to develop a tool to support the designer in collecting visual material over time, enabling the designer to gain new insights and find inspiration in such a collection and the interaction with it.

5.2 Design approach

In our *research through design* approach we try to integrate the theoretical constructs (described in chapter 2) and the field observations (described in chapter 4) into experiential tools. In making these tools, we use our experiences with technology. These experiences come from making and using prototypes, such as the TRI Setup (described in chapter 3) and others described in this chapter

Because we are making a tool for designers and we in turn are designers ourselves, we have to make a clear distinction in terms. Our users will be referred to as *product designers* with a *product design process,* whereas the work presented in this chapter is part of a *tool design process.*

This distinction also clarifies that we, the *tool designers,* are not designing a tool for ourselves. In design in general and human computer interaction design in specific, designing for yourself is commonly seen as a bad approach. On the other hand, it is important to empathize with and take the perspective of the end-user (Laurel, 2003). We have seen that involvement and empathy is important in design, as long as you are able to keep distance and fresh perspectives, based on solid user data (Keller *et al.*, 2004a).

5.3 Tool Design Process

The tool design process for Cabinet was highly iterative, involving user studies, prototyping, testing, evaluating and creating new prototypes (Sanders, 2004). In this chapter the tool design process is structured by the kinds of activities. This section starts out with how we involved our end-user, the product designer, in our tool design process. After that we will expand on some of our own previous experiments and prototypes that have influenced the development of Cabinet. We will end the section in a chronological report of the different prototypes that led up to the final prototype called Cabinet.

5.3.1 User involvement

The first step in involving our users was to visit them in a contextual inquiry. The main results of this contextual inquiry are described in the previous chapter and resulted in six considerations for a collecting tool. During the tool design process we used more data from the contextual inquiry and made them applicable by creating personas, scenarios, and storyboards, which will be described more detailed in the remainder of this section.

DESIGN CRITERIA FOR CABINET

In the contextual inquiry into collection use in design practice, described in the previous chapter, we found that designers take care in building and maintaining collections of visual material but hardly approach these collections with a specific question in mind. They rather visit their collections for reference and inspiration. Another important aspect found in the design practice was the huge effect of current graphically powerful computers in the design process, specifically in making collages and moodboards. All designers in our contextual inquiry made their collages directly on their computers, but none of them had specific tools for organizing and managing their source material.

The findings from the previous chapter are translated in six considerations for a collecting tool in table 1.

Table 1. Design criteria for Cabinet, with the findings on which they were based

	Findings	*Design criterium:* A tool that supports collecting should ...
1	**Active collecting**	... allow for building a collection without a predefined structure and make it easy to add material.
2	**Merger of physical and digital collection**	... merge the physical and digital collection in both interaction and value.
3	**Visual interaction**	... not force designers to verbalize their visual thinking process.
4	**Serendipitous encounters**	... allow for serendipitous encounters with digital material.
5	**Inspiration by breaking rhythm and involving the body**	... lure designers away from their desks and involve their body in visual thinking.
6	**Social aspects of visual material**	... allow designers to calmly communicate the contents of their collection to colleagues.

Apart from these six criteria, the Cabinet prototype had to function as a research tool as well. This meant that it needed to stay within the theoretical framework set out in chapter 2 and needed to provide answers to our research questions on how designers interact with collections of visual material and what new tools can do to support this. To provide these answers we needed a prototype that makes the implicit behaviour of collecting explicit, either by invoking reflection on its users or by logging the users actions.

Finally Cabinet was developed to be able to withstand real world conditions, i.e. in design practice. This means Cabinet had to be technically robust, extremely easy to use, self explanatory, focused in functionality, with a compact but complete feature set, tuned to the context of use. This also involved some practical considerations: we should be able to transport our prototype and the technology used should be available and affordable.

These considerations set the boundaries to develop and design within. However, we also needed tools to empathize with the user and make them a contributing part of the tool design process.

PERSONA

One way to translate user data into tool design parameters is the use of *Personas.* A Persona, as defined by Cooper, is a fictional archetypal user based on user research (Cooper, 1999). The technique combines the creative use of characters and playacting (Djajadiningrat *et al.*, 2000; Verplank *et al.*, 1993) without loosing sight of the actual users.

Cooper advises to define this character as real as possible and communicate this to all the members of the tool design team. By referring to

WISSE: OUTLINE OF THE MAIN CHARACTER


Wisse


Presenting


At the desk


Behind computer


Studio


Desk


Imre


Intern

1 A photo collage of the main character Wisse, what he looks like, what he does, where he works, who his colleagues are

the character all through the tool design process, this avoids trying to cater to every possible user (usually resulting in feature-rich but unusable products).

In our case the six designers visited in the contextual inquiry formed the basis of our Persona called Wisse. Figures 1 and 2 show an image of the character and context with a part of his week in a contextual scenario partly described below.

> *"Wisse is a 26-year-old male designer with three years of work experience. He works at Fris Design, a studio with 3 partners and 10 employees. He is currently working on three different projects a medical project, a packaging for candy and a conceptual scenario for subway interiors.*
> *He has received our prototype and plans to use it for the candy packaging client ...*[1]

[1] On http://studiolab.io.tudelft.nl/cabinet/wisse/ the complete scenario continues

WISSE: STORYBOARD OF THE CONTEXT OF USE

Monday: Wisse arrives at Fris Design

Sits down to check messages

Weekly meeting

2 A part of the storyboard for Wisse, illustrating the contextual scenario

The scenario continues to report a complete week and contains client contact, collaborative use and many other situations for which Cabinet may or may not be suitable.

In each step of the tool design process we evaluated our decisions by asking ourselves whether this would be relevant to Wisse and the story we had made for him and his colleagues. Early on, we also set up a reference collection of 80 images related to the fictitious company and the different clients and projects Wisse was working on. This reference collection was used to deliver suitable content in the development of Cabinet.

PAPER PROTOTYPING

To explore natural interactions and to think about how to make the digital collection more physical we used a technique known as paper prototyping (Snyder, 2003). The 80 images from the reference collection were printed on cardboard and made into 2 by 3 inch cards. These cards could easily be manipulated on a flat surface, to try out natural behaviour in organizing.

Working with these cards showed that images could be organized relatively easy by making meaningful compositions on a table. Furthermore, the use of stacks or piles (Mander *et al.*, 1992) offered a good way to represent groups.

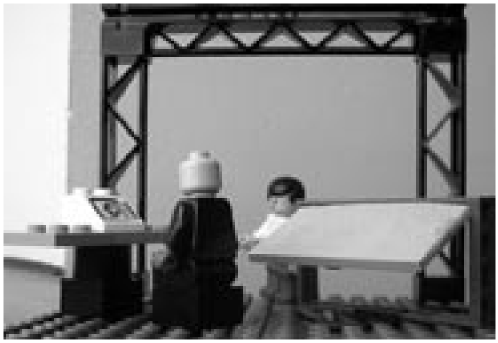
With these insights we performed a small grouping and composition experiment. We asked 12 design students to create a composition using 40 cards on a table. After completing that task they were asked to identify groups in the composition by drawing a line around them. Half of the participants were asked to select a representative for each of the groups, while the other half would get a randomly selected representative. After taking away all the images but the representatives, all participants were able to fit the right images in the right categories. There was no significant difference between the participants that could select the representative themselves and the random representative. Though this experiment didn't help in the decision of how to select a representative, it did offer confidence that designers would be able to remember the contents of a group represented by a stack using composition as the organizing principle.

PLAY-ACTING

By physically acting out different situations that were described in the contextual scenario of Wisse, we could explore the situations and interactions, using the printed cards of the reference collection of Wisse as our incarnation of the tool to be designed. Many new ideas emerged on details and interactions while acting out these new ideas, such as the way stacks would be created or how they would get *out of the way.* One important decision made in these play-acting sessions was to use a horizontal table display for both scanning and organizing (figure 3).

To explore different set-ups in the context of design studios we built different *sets* using Lego. This made us decide our tool should be more like a drawing board, opposed to a wall projection (figure 4). In later play-acting sessions we used photographs from situations and sketched prototype designs over these situations (figure 5). With these rough sketches, we were able to define the size, scale and transparency of the physical prototype in its context.

4



3

5

3 Play-acting: three colleagues are acting out the contextual scenario of Wisse, using the paper prototype

4 Lego storyboard: a situation from the scenario recreated using Lego, with Wisse at his desk and a colleague passing by

5 Play-acting with sketching: using a photo print as a background to draw on

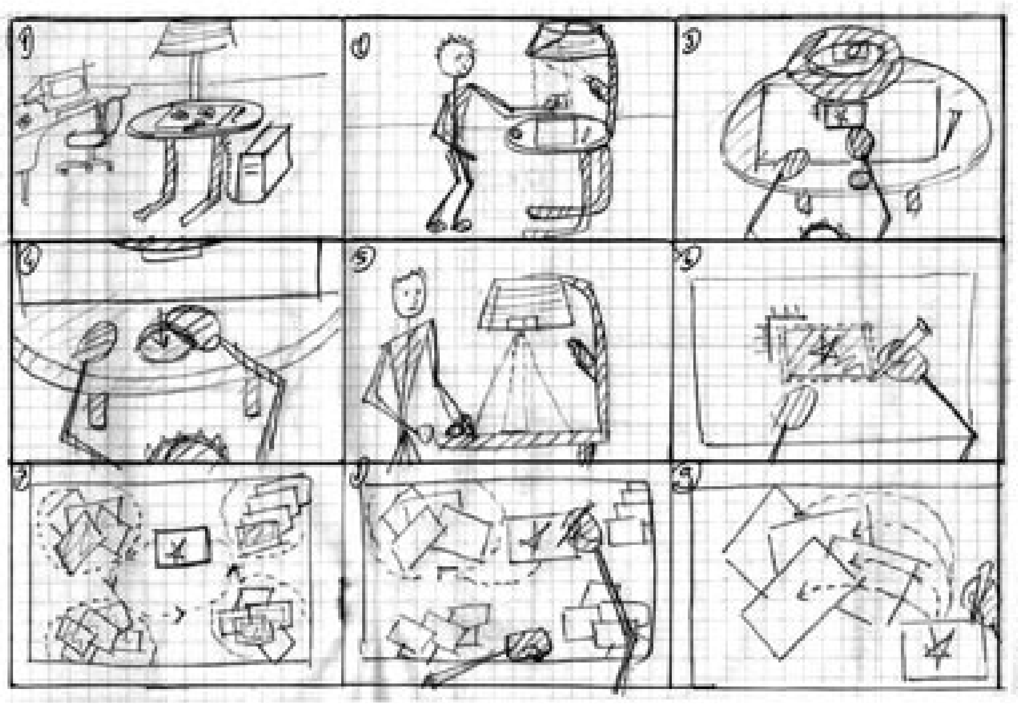
ACTION STORYBOARD

The overall scenario of Wisse, the paper prototyping and our play-acting sessions gave the team members a shared image on the direction of our solutions. To visualize the solutions in more detailed actions, a rough storyboard was generated of the interactions with the hardware and the software.

Figure 6 shows the interaction of transferring a physical photo into the digital collection organized in stacks.

5.3.2 Involvement of technology

In this chapter, we describe the tool design process from a user-centred perspective. Apart from this user perspective our previous experiences with technology also had a big influence on the tool design process. Therefore we now take a small step sideways and present our previous explorations in



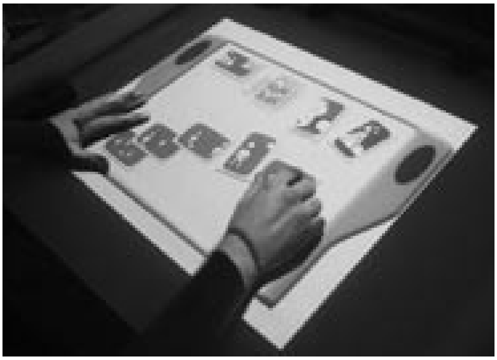
6 Storyboard of the actions the user goes through with Cabinet to scan a photo (1-6) and place it within the collection (7-9)

technology. Before entering into the actual prototype development we first present other hardware and software prototypes we developed before, and their influence on Cabinet.

TRI

A first exploration into how new media can be given sketchy interfaces was our work on the TRI Setup, explained in-depth in chapter 2. In the years before developing Cabinet we have been using the large-scale display of the TRI Setup as a library of images, which we shared with our colleagues in a smooth screensaver. The medium-scale display was used for organizing experiments and table interactions. The last years we used the projection in combination with an overhead camera to scan in hands, models and sketches and project them on the same scale and on the same place. The almost magical effect of this transformation – from the physical to the digital realm – was directly used in Cabinet and served as inspiration for a combination of digital camera and projection on a table.

7



8

7 MyPhotos: a design prototype for interacting with personal photo collections
8 ThinkTUB: an interactive prototype for a shared collage making tool

MDS-INTERACTIVE

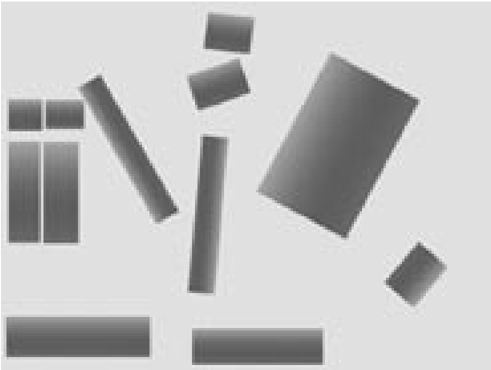
This whole research project was initiated as an opportunity for further research on the patented MDS-Interactive visual searching method (Stappers & Pasman, 1999). With MDS-Interactive users can visually explore databases by interactive visualized similarity scaling. Using a real-time Multi-Dimensional Scaling algorithm, queries can be made by selecting between samples in a composition, resulting in a new composition with optimized distances. The interactive visualization, in which the whole set looks for new stability, provides a fluent and dynamic effect.

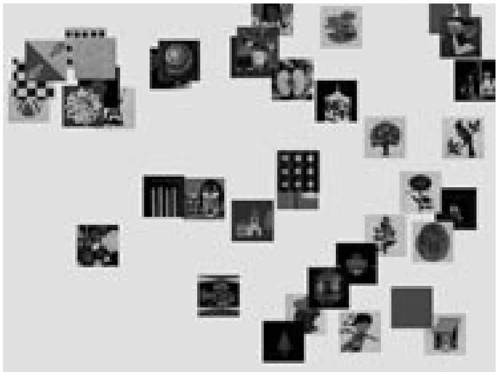
ProductWorld, a software tool developed using the MDS-interactive techniques, supports designers to get new insights from the activity of structuring visual materials (Pasman, 2003). ProductWorld offers a visual mode of interacting with a collection of images (in this case existing products in a product catalogue).

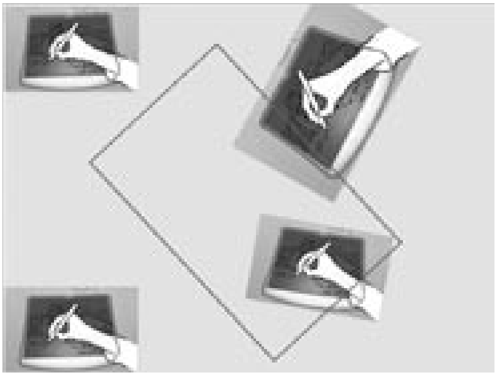
The techniques from the output of MDS-interactive and the input of ProductWorld showed great potential in supporting designers in actively collecting and structuring visual material. Cabinet uses these techniques to integrate the theoretical framework and makes it explicit in the prototype and interaction.

COLLECTION PROTOTYPE DEMONSTRATION

In a series of small design studies, students developed demonstrations of tools to support personal collections and design tools with an emphasis on inspiration. In MyPhotos (Vroegindeweij, 2003), a tabletop interaction is proposed for organizing personal photo collections. The emphasis in this design was direct manipulation of images, in a way that resembled ordering


9


11


10


12

9 An interface exploration for rotating images, using a simulated center of gravity
10 An interface prototype that allowed to both rotate and scale in one gesture
11 A gestural method of selecting and grouping thumbnail images in a sweeping gesture
12 A purely visual interface to select images for a collage, in this screen 6 images are selected and have become semi-transparent

physical photos on a kitchen table, rather than dragging thumbnails across a computer screen (figure 7).

These concepts were explored further in ThinkTUB, a tool for designers, which combined collecting images with collage making.[2] ThinkTUB used a physical interaction style with thumbnails on a wall-sized projection. Using the metaphor of gravity, users could rotate and drag the thumbnails using hand gestures. This prototype also allowed for the designers to take a picture of a physical object and add it to the collection immediately (figure 8).

[2] On http://studiolab.io.tudelft.nl/act02/project5.html ThinkTUB is presented

INTERFACE EXPLORATIONS

Using Macromedia Director we built many small experiential prototypes in which several interaction styles and solutions were explored. Some examples are illustrated in figures 9 to 12, though still pictures can hardly illustrate these explorations.

The different interface explorations were used as sketches and demonstrations for interfaces. With these different examples and some imagination we were convinced that we could make an interface that acted natural while not requiring verbal input to interact with a collection of images. In these explorations composition, orientation and minimal interfaces were the key aspects to be explored.

A separate stream of interface explorations was geared towards implementations of the MDS-interactive algorithms in growing and interacting with collections. The MDS-interactive algorithm was first tested as an input mechanism, but later in the tool design process we found it had the most potential as an output mechanism, in representing the collection in other ways to the user.

RESULTS FROM TECHNOLOGICAL EXPLORATIONS

From all these explorations the following aspects were used in the further tool design process.

1) Tangible interaction with digital images: direct manipulation and rotation;
2) Expressive possibilities of dynamic and interactive spatial visualization: MDS-interactive and other fluid visualizations;
3) Effects and possibilities of using the different ranges of body actions: lessons learned from the TRI Setup;
4) Shared use of interfaces: collaboration on the same interface.

5.3.3 Cabinet prototype development

The remainder of this description of the tool design process presents the different prototypes and the lessons learned from those. By making many different working prototypes, and putting them through actual use scenarios, we could make big decisions in a relatively short time. Early on we accepted to design and build our prototypes quickly, making it easier to throw them away if things did not suffice. In software development, Brooks describes throwing away prototypes as an efficient process (Brooks, 1975), we applied these same rules to physical prototype development.

In each of these prototypes we always based our decisions on whether our solution was good enough for Wisse, instead of being led by what was technologically possible. With knowledge of what is technically possible,

13 Collage for the possible direction of the tool. From lef to right: the current situation for collecting, the technical components used for a collecting tool, and three directions of overall appearance of the prototype – professional, playful or flexible

it is always tempting to opt for the highest resolutions or fastest computers. Instead of aiming for the best technology available, we decided on stable and proven technological solutions, allowing us to take big steps on the user side.

TOOL COLLAGE

The tool design process for a tool that supports making collages should include at least some collages. We made many intermediate collages of situations, characters and such, but for the development of prototypes we made a collage shown in figure 13. It depicts what we are trying to replace or improve in the current situation at design practices with cupboards, what technical components we use to achieve an improvement, and different directions for the overall appearance of such a tool.

FIRST TECHNICAL PROTOTYPE

To bridge the gap between the physical and digital world we needed a smooth way of digitizing visual material. Meanwhile consumer digital cameras had become powerful tools for capturing static images. At the ID-StudioLab it was common practice to archive our student's big-sized collages by laying them on the floor and taking a snapshot with a digital camera from above.

With this routine in mind, we took a repro camera (figure 14), used in reprographic studios to capture pages and other 2D graphics, to transform it into a smooth and efficient grabbing mechanism.


14


15

16

14 The first technical prototype using a standard repro camera
15 The first technical prototype with projection on the medium range of the TRI Setup
16 Image taken with the prototype using a webcam

In our first technical prototype we wanted to see what possibilities such a repro camera combined with a digital camera could deliver. The repro camera was connected to custom software on the medium range of the TRI Setup (figure 15) and different cameras and lighting conditions were tried to explore image quality, speed and interaction.

Our initial attempts, using USB web cams to capture images, offered direct feedback, but the image quality of the stills were not good enough to be used by designers (figure 16). The digital cameras tested offered better image quality, but without the direct feedback, and some of them required external lighting or the use of flash. Especially glossy material would suffer from these external light sources so we finally opted for an indirect light source in combination with a digital camera that offered optimal conditions.

FIRST TECHNICAL PROTOTYPE / INTERNAL TESTING

To find out if the workflow and quality worked for other people as well, we created a feature-focused application that allowed users to take a picture of a composition made on the table. After taking the picture the image was projected on the medium-range surface of the TRI Setup and by using a combined rotation and crop utility a selection of the picture could be made. This selection was automatically uploaded to our research lab website and could be placed on people's personal web pages on the ID-StudioLab website.[3] We invited our colleagues to try out this tool and many of them were eager to try out such a simple way of adding images to their web pages.

FIRST TECHNICAL PROTOTYPE / RESULTS

In the internal test we found that we didn't need the amount of control delivered by the repro camera stand with its levers and measurement grid. Most of all the colleagues reported problems with finding what area was captured and especially the orientation of the compositions captured. Transferring the image to the medium-scale of the TRI Setup was too much of a mental transformation for its users. For further development we looked for ways to strengthen the relationship between the capture mechanism and display and interaction.

IGS

The first working prototype of a collecting tool was called the Image Generation Station (IGS in short). With IGS we built a prototype that could do all the things described in our scenarios and storyboards. IGS took the experience in capturing physical material by using a digital camera. With IGS the projection of the result was done over the original in the same size and location.

To make the prototype more compact, we used mirrors to project the collection on a table from a digital projector. In these tests we found a solution in which we could use a mirror that could rotate 45 degrees providing both a wall projection (figure 17) and a table projection (figure 18) in one solution. Though this feature seemed rather tempting, we finally ended up not using this solution because it would make the mechanisms unnecessary complex and would result in two interaction modes. Moreover, we expected tabletop interaction would elicit collaborative behaviour more easily than a wall projection (Scott *et al.*, 2003). Though wall projections (if you can find any clear walls in a design studio) would enhance serendipitous encounters, it would also elicit situations with one presenter and other people passively watching.

[3] On http://studiolab.io.tudelft.nl/cabinet/webscan are some examples of the results


17


19


18


20

17 Testing a wall projection using a mirror
18 Rotating the mirror 45 degrees for table projection
19 IGS Construction made of alumunium
20 Close-up image of projected interface and input devices

IGS / IMAGE GENERATION STATION

The IGS could handle both physical material and digital images. Using a USB flash drive, digital images could be added to the collection. The collection was projected on a digitizer board, on which users could directly interact using a special digital pen. The collection was organized using composition and stacks. The compositions with their separate originals could be exported to the USB flash drive to be used on the designer's personal computers.

The IGS is constructed from aluminium square tubes (figure 19), with all the cables and technical components connected to the aluminium construction. A mirror on top of the frame reflects the image produced by a digital projector (figure 20). The image is projected on an A2 Wacom digitizer tablet. The interaction takes place using a digital pen with 4 buttons. A digital camera is connected to the top of the aluminium frame facing downwards to the centre of the table. On the side of the frame a 500-Watt halogen light is attached to provide a light source on the surface. A numeric keypad and a special USB button provide further input. A laptop computer controls all the components.

IGS / INTERACTING WITH IGS

IGS enables the designer to capture physical material, to add and export digital images and to organize by making compositions and groups. A physical object can be captured by laying it on the table and clicking the special USB button. The halogen light source illuminates the table for 20 seconds and the camera takes a picture from above. After the light is turned off, the image is projected over the original. The selection can be cropped by dragging a rectangle directly on the image on the table and the selection is accepted by clicking the special USB button. The new image automatically appears as a thumbnail, rotating in the centre of the composition, waiting for the user to give them a place.

Digital images can also be added by copying them to a USB flash drive. If the USB flash drive is connected to a cable and the zero-key on the external numeric keypad is pressed, the images are transferred to the collection and represented as thumbnails, rotating in the centre of the composition.

The user can directly interact with the thumbnails using the digital pen. Touching and dragging a thumbnail in the centre moves the thumbnail, touching and dragging an image on the side rotates the thumbnail.

To make a group or stack of thumbnails, the user holds a button on the side of the digital pen and selects each of the thumbnails in that group. By clicking twice on one of these thumbnails they become a group represented by that image. The interface makes no visible distinction between thumbnails representing an image or a stack. To take an image out of a stack the user can click the thumbnails with the backside of the pen. The thumbnail would start to rotate in the middle of the screen, similar to new images in the collection. These rotating thumbnails follow the user around while navigating the collection.

The user navigates into stacks by double clicking the representative of that group. The other thumbnails disappear and the images in the group appear. By clicking on the enter-key on the numeric keyboard, the user returns to the *top-level* of the collection.

IGS / PILOT TEST

To find out if the prototype also works for designers we performed a long-term pilot test in the office of a designer and research colleague Marieke Sonneveld (figures 21 and 22). She used the IGS for three weeks to digitize and structure

21

22

21 IGS in the pilot test at the office of Marieke Sonneveld
22 Physical and digital piles at the desk during the pilot test

her collection of pictures related to tactile aesthetics in product design. During the pilot she kept notes and provided a lot of feedback on both the IGS prototype and how it affected her thinking and working with visual material.

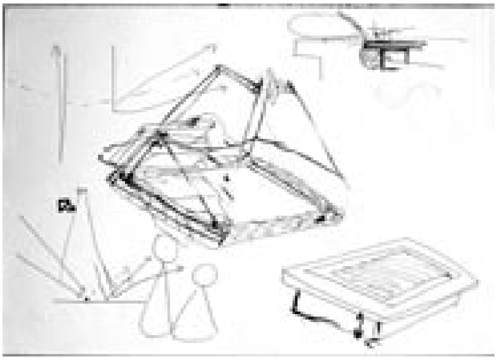
IGS / CONCLUSIONS

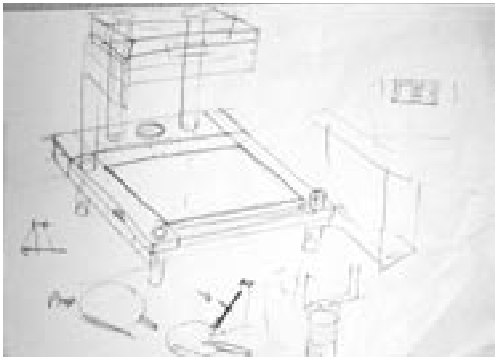
Clearly the prototype was not a finished product, but it technically performed all the things it intended to do. During the pilot Marieke Sonneveld built a collection of 333 images.[4] She wasn't able to finish organizing all the images but she was happy with the first overall result.

In her evaluation, Marieke reported having problems with the image quality and the overwhelming effect of the external light source on her desk. Furthermore the complex interactions with the numeric keypad, the buttons on the side and the back of the pen proved to be too complex and ambiguous.

Critical evaluation made us decide the IGS prototype was not yet suitable for the design practice. In all aspects, software, hardware, interface and

[4] On the DVD accompanying this book, an interactive working demo of this collection can be tried out





23 Sketches for the hardware design of Cabinet, three people collaborated on this sketch
24 Final solution by Onno van Nierop resulting in a table-like design using wood and tubes

features of the IGS prototype came close to all the considerations, yet improvement was needed on all aspects.

Therefore we decided to do extensive tweaking, that came close to completely rewriting the software and rebuilding the hardware. For our next prototype, the following changes were identified.

1) A higher resolution, more light sensitive digital camera;
2) No external light source;
3) No cables or technical components visible on the prototype;
4) Only one button on the whole prototype;
5) Pen input device would only afford clicking and dragging (no extra buttons used on the side or double-clicking);
6) Fluent dragging of thumbnails;
7) Improve creating and navigating stacks.

BUILDING CABINET

Knowing we were so close yet so far away, the whole team started redoing their own parts in such a way that the elegance and smoothness would be integrated in a whole concept. It took less then two months to do a drastic rewrite of the software and rebuild of the physical prototype.

Because the feature set was taken directly from the IGS prototype and the software was already there, it was possible to distribute tasks. We used a web logging system that was available on our ID-StudioLab website to communicate results to each other and this worked effectively over this short period of time.

25


26


25 Building the table construction of Cabinet

26 Finished construction of Cabinet, with tools in the background

Ideas on the hardware design were first sketched out in sessions with different people from the ID-StudioLab, discussing overall looks, room for components, light reflection, ergonomics and user interaction (figure 23). The final hardware design incorporated many ideas and solutions from different sketches in one solution (figure 24).

The exact measurements were specified according to the sketches and the technical components. The hardware for Cabinet was built in a period of three weeks (figure 25), partly in the workshop of the TU Delft faculty, and partly at home (figure 26).

During the development of this final prototype a new name was decided upon: *Cabinet.*

The name refers to its definition, a cupboard for storing and displaying articles, and to the *cabinets of curiosities* that the well-to-do of the 16th and 17th centuries used to keep collections of strange and foreign objects in.

27

28

29

27 Cabinet: scanning in a physical packaging design

28 Cabinet: moving and rotating a thumbnail

29 Cabinet: selecting images for a group

5.4 Cabinet specifications

Cabinet (figure 27) is a tool for product designers to build up and organize their collections of visual material in their work environment. To achieve this Cabinet offers the following features.[5]

1) **Dragging.** With the pointer, the user can directly manipulate projected thumbnails in both orientation and position (figure 28), allowing the creation of meaningful compositions.
2) **Enlarging.** By touching a thumbnail, it is enlarged to a full-screen image.
3) **Grouping.** By drawing a (red) line around a number of thumbnails of images and stacks, they can be selected for grouping (figure 29). The selected thumbnails will start pulsating and the user can assign the representing image by clicking on its thumbnail. The thumbnails will then move together into a stack.
4) **Navigating.** By clicking on a stack, the group will open up pushing all the other stacks and thumbnails to the sides of the table. Within these stacks all the features are available that were available before. The user can close a stack by clicking the right or left sides of the screens where the other stacks have moved while opening up the stack.
5) **Organizing.** Stacks and thumbnails can be moved into and out of stacks, by respectively moving and holding them above a stack or moving and holding them to the right or left side of the composition. The selected thumbnail will disappear from the current composition, and when moving out of the stack the thumbnails will appear spinning in the centre of their new location in the collection.
6) **Adding physical material.** Any image, object or composition put on the table surface of Cabinet can be added to the collection by pushing the (only available) button on the side of the table. The camera gets activated and an image is taken from above. The digital image is projected over the physical original providing a smooth transformation from physical to digital. The image can be cropped by dragging a rectangle using the special pointer. The selected image is then added to the collection spinning in the centre of the last active composition.
7) **Adding digital material.** When a special USB flash stick is inserted into Cabinet's USB slot, all the JPG images that are stored in its *to Cabinet* folder are automatically added to the collection, with a thumbnail of that image spinning in the centre of the last active composition.

[5] On the DVD accompanying this book these features are demonstrated in a movie and can be explored interactively in a working demo

8) **Taking out digital material.** When the USB flash disk is inserted, it also automatically exports the current active composition, together with all the original images, and transfers it as a HTML file with clickable image map into the *from Cabinet* folder.
9) **Searching images.** When Cabinet is not touched for 90 seconds, it automatically starts displaying three random thumbnails from the collection based on the MDS-interactive algorithm. The relative distances between the thumbnails are based on the sum of the distances between the thumbnails in the compositions in different stacks. Images can be queried by selecting anywhere between or outside of the composition. The image that fits best the selected location will be displayed in the composition. The thumbnails are continuously looking for a new stability with dynamic, fluid aesthetics.
10) **Show images.** When Cabinet is not touched for another 5 minutes, it will automatically start displaying thumbnails in a circular grid. All the images will keep an even distance and every 20 seconds the next image in the database will be displayed, resulting in a circular grid.

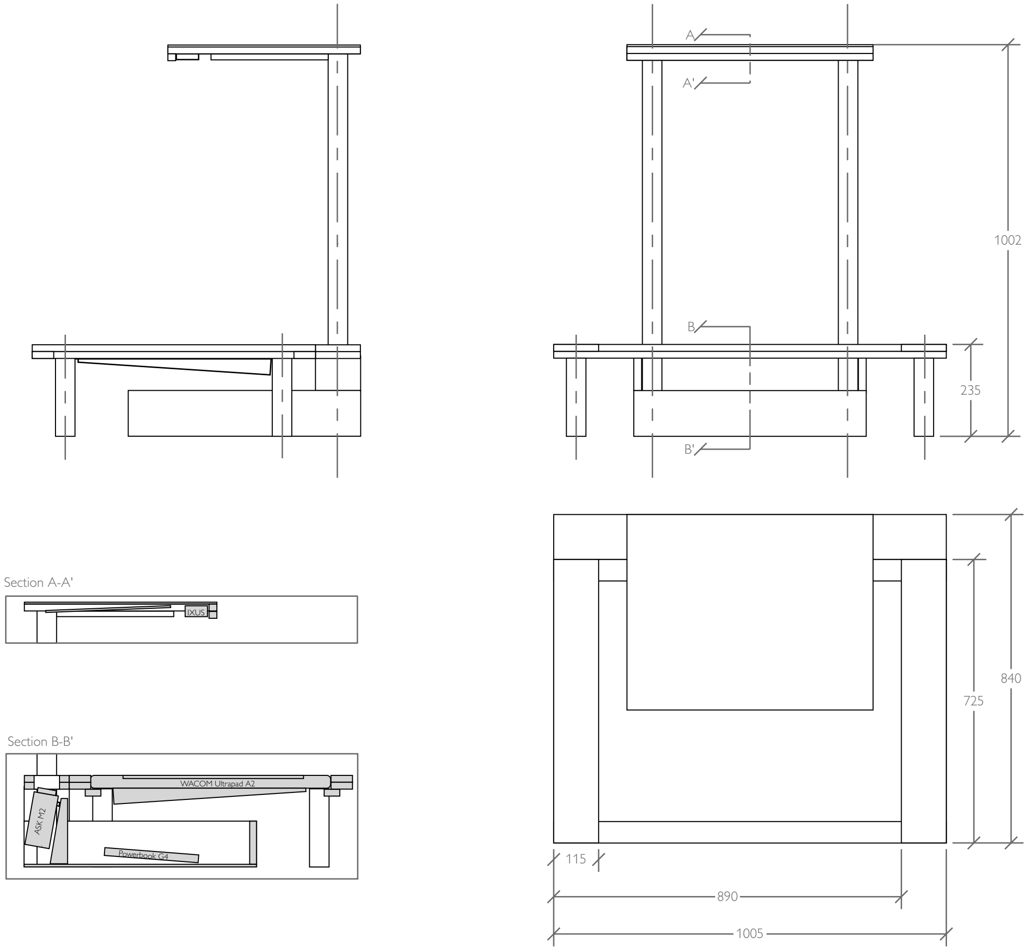
Overall, Cabinet uses the notion of thumbnails to represent images, stacks to represent groups and composition to represent organization. The features explained above are demonstrated on the DVD accompanying this book.

5.4.1 Physical specification

Cabinet is a device that can be placed on an office desk. It is built up from three structural components: 1) the table surface on which the user interacts directly, 2) the technical box below the table containing all the components, cables and the projector, and 3) the overhead construction holding the camera and the mirror that reflects the projected image on the table. For transportation and maintenance Cabinet can be separated in these three structural components.

The footprint of Cabinet is 1050 mm wide by 840 mm deep; the table surface is elevated 240 mm from the desk to allow use while standing. The overall height of Cabinet with overhead construction is 1050 mm (figure 30).

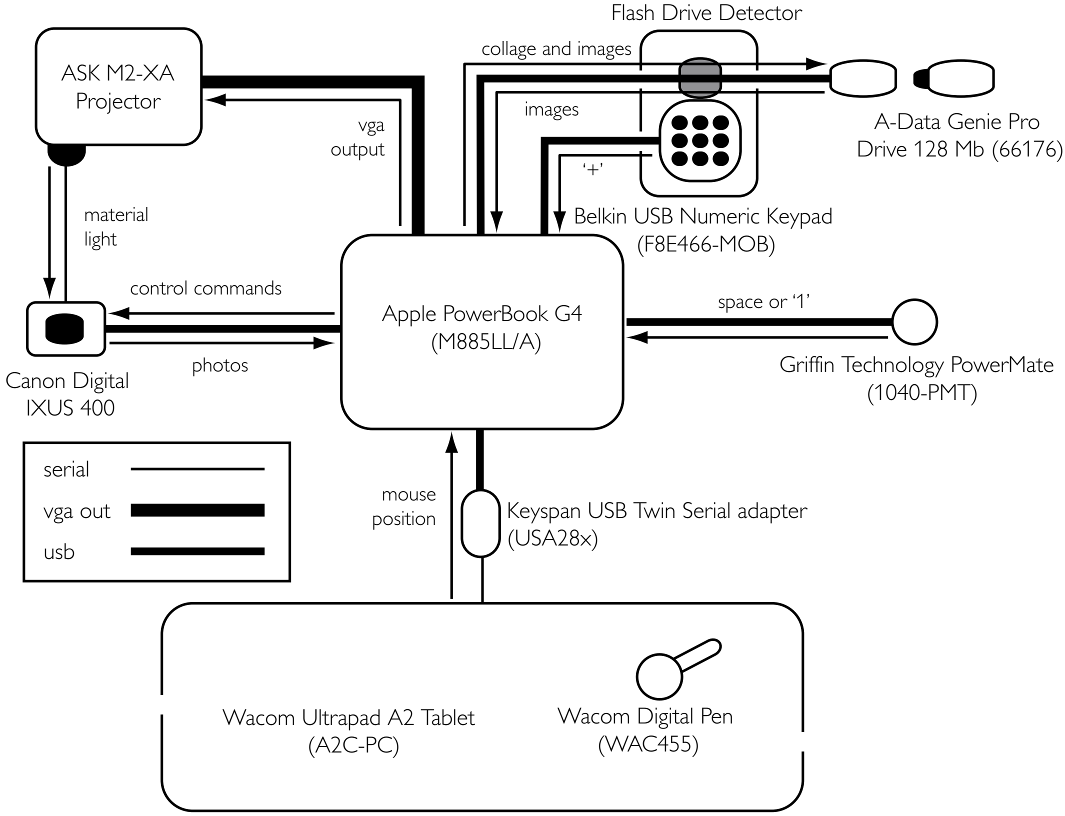
The wooden parts of Cabinet are made of 18 mm thick multiplex, the same material used for construction in the building of our department. The visible construction parts are made of a double thickness of this multiplex, providing a solid, rugged yet natural look and feel. Both the table surface and the overhead construction are elevated with an aluminium tube construction with a radius of 50 mm. The table surface has 4 legs to resemble a table design. The overhead construction is supported by two tubes, allowing an open construction on the front side.



30 Technical drawing of Cabinet with two cross-sections

The wooden parts in the construction have a transparent acrylic finish. The aluminium tubes are blasted with glass pearls to give them a matte appearance.

The table surface is covered with an acrylic board that has the Cabinet logo, ID-StudioLab logo and contact information on a business card printed on it. Also the interface outlines are printed on the surface: the active surface is kept white (for maximum contrast), while the outside area is a light blue. The active right and left side of the table are printed with a white to yellow to light blue gradient. The design of the print supports a smooth transition between the physical and the projected interface.



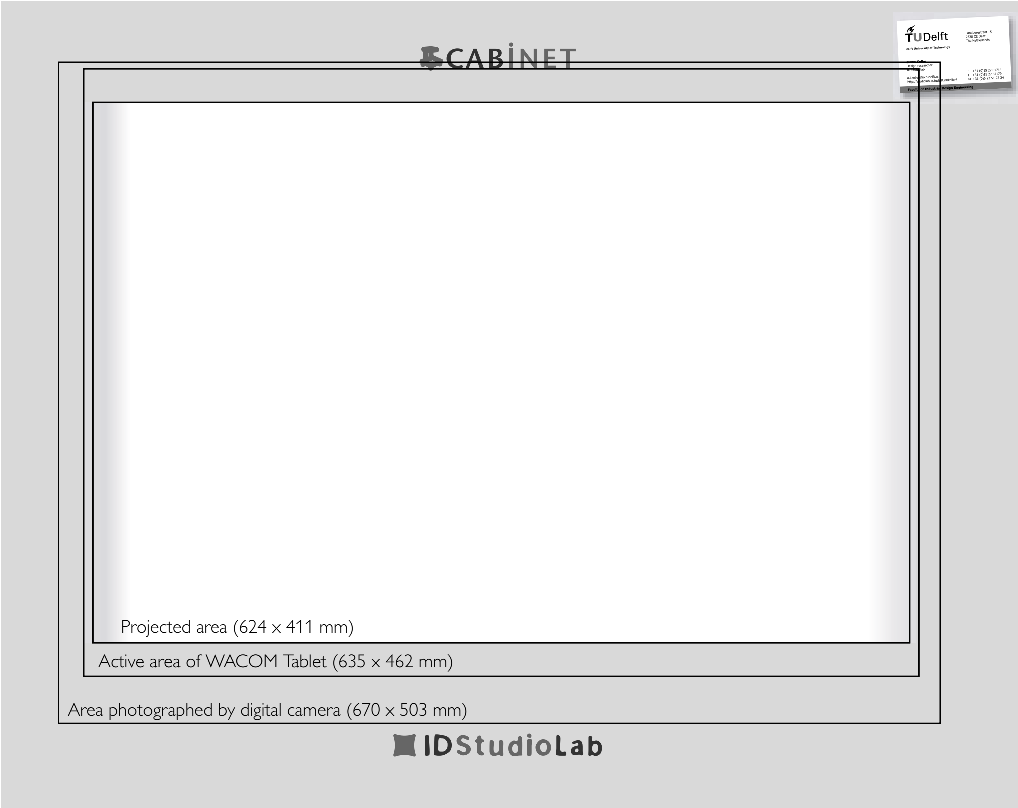
31 Schematics of technical components, cables and information flows in Cabinet

5.4.2 Technical components

Cabinet relies for the most part on proven technological components. The components are visualized schematically in figure 31 and in a cutaway diagram in figure 32. Cabinet is controlled by a compact portable computer which connects all the components and runs the software for the collection. The computer display is sent to a digital video projector. A digital camera is used for capturing the originals on the table. The Flash Drive Detector senses if a USB Flash drive is connected, to allow for digital images to be imported and exported to the collection. The user interacts with all these components through one button and a digitizer tablet with digital pen.

32 Cutaway diagram of Cabinet with the technical components. On the left of the table the big button is visible; on the right lies the pen input device, connector and flash drive. The first cutout layer reveals the digitizer tablet below the printed acrylic board. Below the table the technical box is visible containing the digital projector and the computer. The diagram also displays how the light is projected via the mirror on the table. On the overhead construction the lens of the digital camera is also visible

All but one of the technical components and cables used in Cabinet are standard commercial solutions and standard cables without adaptations. The only custom-made component is the Flash Drive Detector. It consists of a circuit board – developed by Rob Luxen – that measures the power throughput in the USB cable and sends a signal to the '+' key in a USB numeric keypad logic board. This key-press is sent to the software notifying the system that a USB drive is connected.

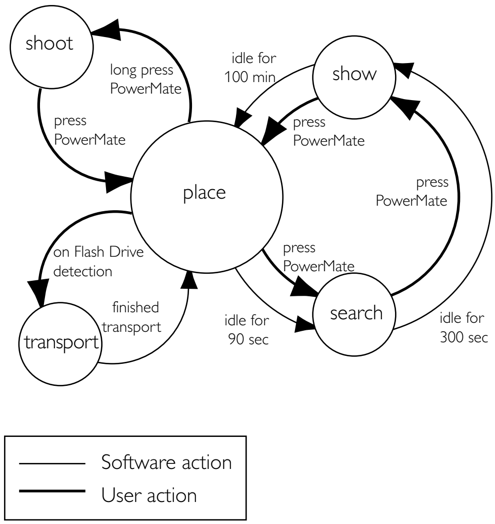


33 Interface surface with active and used areas

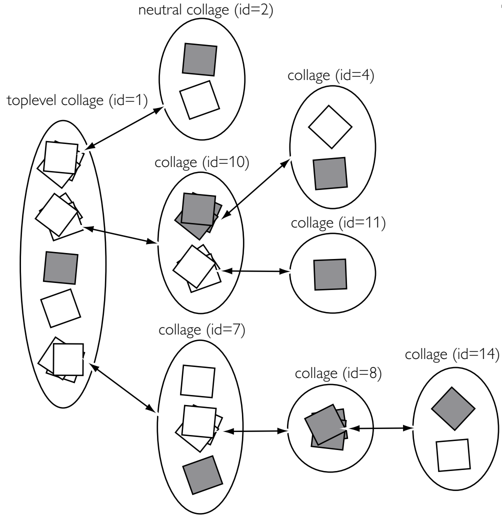
5.4.3 Interaction surface

All the user's interactions with Cabinet and the collection take place on the table surface (figure 33). The digital video projector projects the interface at a size of 624 x 411 mm. The active area of the digitizer tablet (i.e. sensitive to pen input) is slightly larger at 635 x 462 mm. The camera mounted above captures an area that is larger than both at 670 x 503 mm.

The interaction surface can be calibrated in three steps to fine-tune the alignment of the projected image, the camera and the digitizer tablet. First step in the procedure is to align the corners of the projected image to four printed markers (cornered lines) on the display surface. Alignment is done manually, adjusting the mirror and the digital projector to visual accuracy. Second step is to adjust the tablet's active area to match the image, which is performed in software by tuning the driver. Third step is to adjust the image grabbed by the camera to match the displayed image. To do this, an image of the display surface with contents is made and projected back on the surface.



34



35

34 State diagram of Cabinet software

35 Diagram of the data structure of the collection in Cabinet with examples of different collages. Collages are sequentially given an id when they are created. Collages can consist of only one (id = 11) or more images (id = 2, id = 4, id = 14). Collages can contain only stacks (id = 10) or only one stack (id = 8). Finally, collages can contain a combination of images and stacks (id = 1, id = 7)

Using a temporarily attached keyboard, the image can be panned and scaled using the cursor keys. Again, the calibration is done visually.

In practice only steps 1 and 3 are needed after Cabinet has been transported. Most of the times calibration only provides fine-tuning (to approximately 1 mm), while uncalibrated, the accuracy is quite acceptable of working (approximately 3 mm). In the experiments reported in the next chapter, calibration was performed only once for each visit. It was not part of the user experience.

5.4.4 Software

All the software for Cabinet is written in Macromedia Director. The software controls the digital camera using third party extensions (Xtras). In a similar way the software communicates with the Flash Drive and other input devices.

The software on Cabinet has five different states (figure 34) in which different features of Cabinet are supported. These states are not communicated as such in the interface and most users will not even notice them. The central state is the *place* state in which the user can organize thumbnails, navigate the collection and make stacks. From this state the software can switch to the *shoot* state in which the camera is controlled and images of physical material can be added to the collection. The *transport* mode starts automatically when a flash drive is connected and enables importing and exporting images to and from the collection. The other two states, *search* and *show*, start automatically after respectively 90 and 300 seconds idle time, and show the images in the collection in different visualizations based on the MDS algorithms.

The user interacts with the collection through interaction with stacks and images. The organization of the collection is organized in a tree-like structure (illustrated in figure 35) of collages (compositions), stacks (groups) and images (thumbnails). All the images, collages and stacks have a unique serial number. And all the collages have an image or stack in them that represents the group (the grey images in figure 35). This image or stack is displayed at the top of that stack, with the other images layered below them.

The collages are connected with bidirectional links, allowing the user to navigate up and down the tree structure, while maintaining the flexibility to reorganize the collages and tree structure. The first two collages in the collection stand aside; the first collage (id = 1) is the top-level collage from which the tree structure starts. The second collage (id = 2) is the neutral collage, which allows the user to get erroneously imported images out of the way. The images in the neutral collage are still in the collection, but will never be presented in the *show* or *search* state. Most users interpret this neutral collage as the *"trash can"* from the desktop metaphor. Because the capacity or performance is not an issue, we chose not to support deleting images, instead images can be ignored by putting them in the neutral collage.

5.4.5 Performance

As shown previously in figure 33, the active display area of Cabinet is 624 by 411 mm, with a display resolution of 42 dpi. On this size and distance, the projector provides a brightness of 1002 nits (cd/m2), which in theory should provide a sunlight-readable display. In this calculation the mirror used in the projection and the reflective properties of the projection surface are not taken into account and the display is not used to read text, but only to judge colour and visual expressions. In practice, the thumbnails and interface can be properly viewed in a normally lit office environment (400 lux).

The camera captures the active display area at 2076 by 1378 pixels. The resolution of images captured by Cabinet is 86 dpi (pixels/inch), more than double the size of the display resolution. When the scan is projected over the original, it is slightly displaced over the original, up to 2 mm on a flat image and more on thicker originals, caused by the slight displacement of

Table 2. Design criteria for Cabinet with the findings on which they were based

Activity	*Conditions and measurements*	*Duration*
Take picture	From pushing the button to shooting the picture	6.8 s
Display image	From shooting the picture to displaying it over the original	14.5 s
Add to collection	From cropping an A4-sized image to appearance on Cabinet	3.2 s
Add digital image	From inserting the flash drive (with 300Kb image) to appearance on Cabinet	9.1 s
Export image	From inserting the flash drive to taking it out (with 2 images copied, 700 kB)	15.0 s
Enlarge image	From clicking the thumbnail to displaying the original image (of 240 Kb)	1.6 s
Open stack	From clicking a stack to displaying the opened stack	2.3 s
Close stack	From clicking the sides to displaying the upper collage	1.6 s
Change state	From *search* state to *place* state	1,3 s

the camera and projector. Most viewers perceive this displacement not as an error but as a shadow effect.

The performance of Cabinet is best demonstrated in its speed and responsiveness. Cabinet is always on, readily available for use. A physical object or image can be scanned in and added to the collection in less than half a minute. Adding a digital image to the collection takes under 10 seconds. For more details and other performance data, see table 2. During most of these activities the user can see the activities, such as opening or closing stacks or enlarging an image, happening on the screen.

The speed and performance of Cabinet is enhanced by the smoothness and low attention needed for these activities. A physical object can be added while passing by, and the animations make the interaction seem natural.

5.5 Evaluation

Cabinet has been evaluated on different aspects and in different ways. First we look if Cabinet fits the design considerations we formulated in table 1.

Secondly we look at the things we might have wanted to change, add or develop further. This could be an endless list, but we are aware of the dangers in adding more features than needed, therefore we give a short overview of opportunities for further development or improvement.

Apart from our own evaluation, we also base our observations on its use by colleagues and on the reactions of peers and visitors during many demonstrations. Finally we will look forward to the evaluation of both the prototype and its impact on our research questions at design companies, described in the next chapter.

5.5.1 Design criteria

As we stated in the beginning of this chapter in table 1, a tool that supports collecting should:

1) *Cabinet should allow for building a collection without a predefined structure and make it easy to add material.* Cabinet does this by offering groups and compositions based on *what is present on the table*. The user has to give the images a place, but these are not based on predefinition. Adding both physical and digital images is easy and smooth activities with a low cognitive load, especially because Cabinet is meant to be readily available: always on and present in the design environment.
2) *Cabinet should merge the physical and digital collection in both interaction and value.* Cabinet does this by making the interaction with digital images more physical, and by stimulating the user to add physical material to the collection. The value of digital material for inspiration rises, whereas the value of physical material for use in collages rises as well.
3) *Cabinet should not force designers to verbalize their visual thinking process.* Cabinet uses no words at all in any part of the interface. Words, when scanned in, also become visual material in the collection.
4) *Cabinet should allow for serendipitous encounters with digital materials.* Cabinet continuously displays visual material from the collection in different ways. These displays allow for interaction but can also be just noticed while passing by. Serendipitous encounters do require Cabinet to be placed in a strategic position in the work environment, e.g. near the door, printer or bookshelves.
5) *Cabinet should lure designers away from their desks and involve their body in visual thinking.* The mere size and scale of Cabinet forces the designer to stand up and walk to Cabinet. Cabinet's interaction involves rough gestures using the whole arm, opposed to precise interaction requiring concentrated eye-hand coordination.
6) *Cabinet should allow designers to calmly communicate the contents of their collection to colleagues.* The table size and scale of Cabinet are automatically associated with collaborative work. It is easy and inviting for a colleague to stand next to the designer and look over his shoulder. Furthermore, the serendipitous encounters described in design criterium 4 also allow colleagues to stumble on the images.

We also set out practical criteria in the beginning of this chapter, such as transportable, self-explanatory and stable. Cabinet turns out to be a practical and stable tool; transportation is easy, e.g. we have been able to take apart and set up Cabinet in less than 30 minutes.

5.5.2 Good enough to be criticized

Cabinet was built as a one-off prototype that was good enough to be set out in the field and to be evaluated by designers as described in the next chapter. On the one hand it has a complete set of features, which makes it look and feel like a working and stable product. On the other hand, it is not so polished, that it would stifle critical evaluation or raise the expectations of a *real* product. From our research towards sketching and *sketchy* tools (Stappers et al., 2000) and in the experiences with paper prototyping (Snyder, 2003) it was found that a completely polished sketch or visualization can get in the way of valuable criticism.

Having said that, there certainly are features and implementations that could be improved upon or added if time and technology would permit it.

1) **Pen input device.** Though we chose a proven method for pen input, the digitizer tablet, we found that the operating system still can be erratic in tracking the cursor and clicks. The pen input device allows for sudden clicks from one end of the screen to the other, making thumbnails appear to stick to the pen. In practice we found that – after a short training – our users could avoid these situations and didn't find it problematic.
2) **Picture taking performance.** Though adding physical material with Cabinet is efficient as compared to a flatbed scanner, it is not instantaneous. The camera has to be activated, it has to do some adjustments and the picture has to be transferred from the camera to the computer. In all, this takes about 30 seconds, but some users tend to take away their source material too quickly. Besides optimizing the speed and performance in technology, a better feedback mechanism could also solve this problem.
3) **Centred spinning of new image.** To support active collecting, we decided to never automatically place new images, but force the user to give these images a place in the collection. This was fine, but our implementation of a *spinning* thumbnail in the *centre* of the screen attracts too much attention and makes users compose their collages with an empty centre. A more subtle and location-independent solution might have been a better choice.
4) **Spring-loaded stacks.** Currently the user can drop a thumbnail on a stack and it will disappear from the current collage. Taking cues from the Mac OS (Apple Computer, 2005), the idea of spring-loaded stacks, which would open when the drag action hovers over a stack, may be a useful added feature.

5) **MDS-Interactive search.** The way to search or explore the collection using the MDS-Interactive algorithm looks and feels good, but doesn't provide a useful search mechanism, yet. It is both not random enough and not specific enough, because the algorithm requires a weighing method based on knowledge of the collection. On the other hand, the automatic display of images works quite well for exploration by simply glancing at it when passing by.
6) **Wall-projection.** The option of rotating the mirror (explored in figure 17 and 18) to project both on the table and on the wall, could enhance the social use of visual material in a studio environment, especially when combined with the MDS-Interactive displays.

Apart from these points we came up with numerous ideas, features and solutions, which we wisely kept outside the scope of this project or put off for later. Given our criticism, we believe we have built a working prototype that in the words of Alan Kay is *"good enough to be criticized"* (Laurel, 1990).

5.5.3 Living with the prototype

As described in the design process, we involved our colleagues in the ID-StudioLab actively in the development of all the prototypes. We have lived actively with Cabinet for three months before setting it out in practice.

During this period twelve colleagues actively used Cabinet. Nine colleagues approached Cabinet by their own initiative. We have never presented or promoted the use of Cabinet actively, but word-of-mouth referral made many colleagues come over to see if it met their needs. All of the colleagues were positive on their use of Cabinet, though many of them had suggestions for improvements, alternative uses or added capabilities.

From living with Cabinet we found the value of the USB flash drive for social use of digital imagery. Colleagues enjoyed taking away a physical carrier to transport their digital images from their computer and back. Colleagues perceived borrowing the USB flash drive itself as a social act (Miller, 2004). We originally opted for this solution over using a networked solution, to avoid problems of network security at different design studios, but this was an unexpected positive side effect.

Our own use of Cabinet has continued for over a year now and the prototype supports our own collections of visual material. Many of the figures in this thesis are made and collected using Cabinet.


37


38


36


39

36 Usability guru Donald Norman trying out Cabinet
37 Demonstrating Cabinet to the Dean of Industrial Design at TU/e
38 Presenting Cabinet to interaction designers of SigCHI.nl
39 Demonstrating Cabinet to other researchers from Luleå University of Technology

5.5.4 Demonstrating Cabinet

Both during and after the development we demonstrated Cabinet to many visitors of the ID-StudioLab (figures 36 to 39). These visitors represent a mix of valuable peers in research, design and commercial practice. During these presentations we found that Cabinet was a good carrier of discussions on the subject of designers collecting visual material.

The discussions would sometimes focus on the relevance of such a tool in practice, and on commercial viabilities, or they would focus on the theory on being inspired by visual material. On most of these occasions the discussions would focus on tools in general and the impact of such a tool in other fields or other applications.[6]

5.5.5 Cabinet in practice

After all these demonstrations, feedback from colleagues, first-hand experience by using Cabinet over a longer period, we are confident of the value of its design. Yet a product can only be valued if it has been used in a realistic setting by real users. Therefore in the next chapter, Cabinet is set out in design studios, to get a better insight on the tool itself and to find out more on how designers actually use their collections of visual material in their design process.

5.6 Conclusion

The goal of Cabinet was to develop a tool suitable for use in real practice and for a realistic task. Developing such a tool makes it tempting to add features that may appeal to designers, but have no relevance to phenomena you are researching. Our previous research in both theory and practice allowed us to focus on the phenomena, without loosing its relevance to designers.

To keep this focus we used techniques that allowed us to keep the end user in mind and keep ourselves as users out of the tool design process. We are designers ourselves, yet we are not the designers for which this tool is meant.

We developed Cabinet as a means for technology to support our findings from theory and practice. By developing working prototypes quickly, we could try out and experience the results and decide how to further develop them. We built each of these prototypes with the intent to develop them into the final prototype, yet we kept an open mind and easily threw out any solution that didn't work. For each new prototype we took out the aspects that didn't work and kept the things that were good.

Considering all the techniques used in the tool design process, ranging from sketching, storyboarding to play acting and paper prototyping, the most important technique is demonstrating a tool with a working prototype. Bringing something real to the table is the best way to convince yourself and others of its value.

[6] On http://studiolab.io.tudelft.nl/cabinet/quotes/ all the visitors with their remarks on Cabinet are accumulated

LITERATURE REFERENCES 5

Aliakseyeu, D. (2003) *A computer support tool for the early stages of architectural design.* Doctoral Dissertation, Eindhoven: TU/e.

Apple Computer. (2005) *Apple human interface guidelines*. Cupertino, CA: Apple Computer.

Brooks, F.P. (1975) *The Mythical Man-Month: Essays on Software Engineering.* Reading, MA: Addison-Wesley.

Cooper, A. (1999) *The inmates are running the asylum*. Indianapolis, IN: SAMS.

Djajadiningrat, J.P., Gaver, W.W., & Frens, J.W. (2000) *Interaction relabelling and extreme characters: Methods for exploring aesthetic interactions.* Proceedings of DIS 2000, New York City, NY, pp.66-71.

Gross, M.D., & Do, E.Y.-L. (2000) Drawing on the back of an envelope: A framework for interacting with application programs by freehand drawing. *Computers and Graphics Journal, 24* (5), pp.835-849.

Keller, A.I., Hoog, W. van der, & Stappers, P.J. (2004a) Gust of me: Reconnecting mother and son. *IEEE Pervasive Computing, 3* (1), pp.22-28.

Keller, A.I., Stappers, P.J., & Vroegindeweij, S. (2004b) *Supporting informal collections of digital images: Organizing browsing and sharing.* Proceedings of the conference on Dutch directions in HCI, Amsterdam, p.17.

Laurel, B. (Ed.) (1990) *The Art of Human-Computer Interface Design*. Menlo Park, CA: Addison-Wesley.

Laurel, B. (Ed.) (2003) *Design research: Methods and perspectives*. Cambridge, MA: MIT Press.

Mander, R., Salomon, G., & Wong, Y.Y. (1992) *A "pile" metaphor for supporting casual organization of information.* Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, Monterey, CA, pp.627-634.

Miller, K. (2004) Anti-social networking. *Plug In Magazine,* pp.15-16.

Muller, W. (2001) *Order and meaning in design*. Utrecht: Lemma.

Nakakoji, K., Yamamoto, Y., & Ohira, M. (1999) *A framework that supports collective creativity in design using visual images.* Proceedings of the Third conference on Creativity & cognition, Loughborough, UK, pp.166-173.

Pasman, G. (2003) *Designing with precedents.* Doctoral dissertation, Delft: TU Delft.

Restrepo, J. (2004) *Information processing in design.* Doctoral dissertation, Delft: TU Delft.

Sanders, E.B.-N. (2004) *Design and the empowerment of everyday people.* Presented at a lecture at TU Delft.

Scott, S.D., Grant, K.D., & Mandryk, R.L. (2003) *System Guidelines for Co-located, Collaborative Work on a Tabletop Display.* Proceedings of ECSCW 2003, pp.159-178.

Snyder, C. (2003) *Paper prototyping.* San Francisco, CA: Morgan Kaufmann.

Stappers, P.J., & Hennessey, J. (2000) *Beyond the electronic beermat: Digital devices for discussing design drawings.* Adjunct proceedings of Codesigning 2000, Coventry: Coventry University, pp.143.

Stappers, P.J., Keller, A.I., & Hoeben, A. (2000) Aesthetics, interaction, and usability in 'sketchy' design tools. *Exchange Online Journal, 1* (1).

Stappers, P.J., & Pasman, G. (1999) *Exploring a database through interactive visualised similarity scaling.* Proceedings of CHI '99 Human Factors in Computer Systems, Pittsburgh, PA, pp.184-185.

Tufte, E. (1997) *Visual explanations: Images and Quantities, Evidence and Narrative.* Cheshire, CT: Graphics Press.

Verplank, W., Fulton, J., & Moggridge, W. (1993) *Observation and invention: The use of scenarios in interaction design.* Proceedings of CHI '93 Conference on Human Factors in Computing Systems.

Vroegindeweij, S. (2003) *My pictures: Informal image collections.* Internal report No. HPL-2002-72, Bristol, UK: HP Laboratories.