

# COMPUTER SUPPORT USING DESIGN PRECEDENTS



This chapter presents the actual design and implementation of the visual database concept that was introduced in chapter 4. More specifically, the design of the user interface, which mediates between the designer and the content of the database, is described and evaluated. The chapter starts in section 6.1 with a review of design support systems, which make use of product examples. In section 6.2 a number of design criteria are listed, which guided the development of the user interface of the visual database. Taking these criteria into account, a new method of interacting with large information structures, called MDS-Interactive, was developed. This method is described in section 6.3, along with a number of prototypes, which were built to demonstrate and evaluate the new method. With a few modifications MDS-Interactive then provided the basis for the design of the visual database, which was named ProductWorld.

The main functionalities of ProductWorld are indexing design precedents into the database, and retrieving design precedents from the database. Indexing involves the formation of design knowledge structures by spatially arranging product samples relative to each other on various similarity criteria. Retrieving design precedents is conducted through a dynamic, small, and interactive set of product samples. Both are described in section 6.4. Finally, ProductWorld is evaluated in an educational setting, to determine its value as a design support tool. This evaluation is described in section 6.5. The chapter ends with a discussion of the results in section 6.6.

## 6.1 Precedent databases in design

The idea of using existing examples as building blocks in constructing organized bodies of knowledge, is not new to the field of design. Especially in the domain of architecture, several systems have been developed to assist the architect during the design process, substituting for or adding to traditional resources such as reference books and magazines. While some of them are merely electronic catalogues, offering a large amount of information which can be searched and browsed, other systems even incorporate advanced artificial intelligence techniques, which even enable them to take over part of the design task.

Oxman (1993) describes a system called MEMORABILIA, a precedent-based design aid in which significant architectural designs can be browsed through cross-contextual indexing. The knowledge embodied by the stored designs is formalized by means of "design stories", which are textual statements highlighting those aspects of the designs which are meaningful in a particular design task. Such stories could be extracted from descriptions of the precedents in architecture magazines and books. Performing a content analysis on these stories results in the formation of a concept vocabulary of keywords. The designer can then use these keywords to retrieve relevant precedents from the database. However, because its indexing system is based on architectural literature, it will probably serve historians and critics better than practicing architects, since the latter use a different vocabulary than the first.

In the Software Environment to Support Early Building Design (SEED), described by Flemming and Aygen (2001), architectural precedents are used as prototypes and cases. A prototype has standard properties, that can be applied across projects, while a case represents a specific solution for a given set of requirements. This distinction enables the construction of a hybrid memory model, consisting of a semantic memory, made up of prototypes, and an episodic memory, made up of cases. The developers of SEED claim that queries can use an inference mechanism, which operates on the prototype description, in coordination with a matching mechanism, which operates on the cases. In this way connections between general and specific design precedents would be established.

The development of systems such as these is, however, heavily directed from an information processing perspective. Instead of facilitating and nurturing the reasoning process within the designer's mind, their aim seems primarily to be to mimic this process within a computer environment. Thus the design knowledge they contain is decomposed, by the system developers, not its users, into fragments that fit the requirements of this computer environment. The emphasis in the development is completely directed towards the internal functioning of the system; how the user might interact with it, remains to be an issue.

Two examples of systems that focus more specifically on the shared aspects of design are EDAT (Akin et al., 1997a) and DYNAMO (Heylighen and Neuckermans, 2000). EDAT (Electronic Design Assistance Tool) was designed to provide students with a central environment in which they could store the documentation they gathered in the early stages of design. Thus a database of previous work that can be consulted in the design process, would get established by its users,. Students would have the responsibility to organize the structure of their designs within the constraints of the database. EDAT also would incorporate a presentation tool for students' electronically produced design documents. It remains unclear, however, what exactly the added value of EDAT is compared to a collection of records, as in a traditional database. Its interface follows Microsoft Windows GUI conventions, with its emphasis on windows, scrollable lists and text. Although this probably ensures a high level of familiarity for its users, it also lacks any expressiveness or inspirational qualities, which might stimulate the designer in the generation of new ideas.

DYNAMO is a web-based design assistant for student-architects, taking entire building designs as its cases. Similar to EDAT, it puts the responsibility of representing and indexing cases with its users. An important characteristic of DYNAMO is that it considers design to be a social process, in which several kinds of interaction (between designer and computer, between designers, between designs, between practice and education) are to be supported by the system. Thus the goal of DYNAMO is to provide a platform for these interactions in various context and different levels of experience. Because of the web-based approach various media such as text, images, video and sound, can be stored into the database. Case submission as well as case retrieval is, however, still a linguistic

process, involving the selection of keywords. Results of a query are presented in a sequential way and the interface is constrained by the standards of the browser.

Two systems which stress the inspirational qualities of images in the design process, are IAM-eMMA and EVIDII (Nakakoji et al., 1999), both developed within the domain of product design. The IAM-emMa system uses knowledge-based rules to help designers retrieve images from a large image library given vague initial requirements. These requirements are expressed in terms of aspect-value pairs. For example, the aspect *Atmosphere* has as possible values *cheerful*, *warm*, *cold* etc. Rules between these aspect-value pairs and image features are then used to present the designer with suggestive sample images. By selecting one of these samples and giving value to its corresponding features, the designer can further specify his query. This process can be repeated until the designer finds images that are useful for the creative design task.

The EVIDII system allows designers to conduct surveys on image associations, such as "warm" or "pretty". These associations have been attributed to the images previously by other designers. Thus the three elements of person, image and word are used to create association spaces. The results of a survey are presented in two- or three-dimensional lay-outs, which the designer can explore to identify who thinks of what images in what ways. The main goal of EVIDII is therefore to allow designers to experience how other designers 'see' visual images. Designers can also construct their own 'maps' by positioning words or images in a two-dimensional space in relation to each other. User studies of both systems showed designers to prefer EVIDII to IAM-eMMA, because it did not impose any rational framework upon its users. Designers felt the inference by the IAM-eMMA system on the underlying association from a selected image to be intruding on their own thinking process. They considered it to be their core task to identify the commonalities between an interesting image and the design task at hand.

Nakakoji et al. end their study with the following important conclusions:

- *Computer systems can help designers in their creative design by using visual images.*
- *Delivery of images is helpful as long as the delivery is based on the 'rationale' that the designers considered meaningful.*
- *Mechanisms for supporting collective creativity need to be carefully designed so*

*that they will not deprive designers of the feeling of doing the design activity themselves.*

## 6.2 Design criteria

The evaluation of these precedent-based support systems provides valuable input for the development of a tool, which uses existing products as sources of design knowledge that can be applied in the generation and development of new product forms. Candy and Edmonds (1997) suggest that the development of computer systems for such creative tasks should be criteria-based, instead of task-based, because the latter form is not suited to fully describe the loosely and dynamically structured creative process. Interactions with computer systems should be considered in terms of how they influence their users' thinking, rather than in terms of their specific output. Interaction designers involved in the design of such computer support systems should therefore use design criteria as a tool that steers their design process rather than a method that can guarantee the generation of good solutions. Thus a number of design criteria for the development of the visual database were drawn up.

First, from section 6.1 the following criteria were derived:

- **Don't patronize**

Let the designer do the designing. Meaningful support is highly valuable, but is only appreciated when the designer stays in control of the creative act. Attention should be primarily directed towards the visual aspects of the embedded products, which have to be organized and presented in a meaningful way, without imposing any absolute consequences on to the designer.

- **Provide for an Expressive Interface**

A system which should support creative tasks, should have in its look and feel a high degree of expressiveness, as opposed to the rigidity found in the most common user interface standards. At the same time, however, the interface should also be reserved, so as not to distract too much attention from the samples that are displayed.

Secondly, in chapter 2 a number of considerations for designing a computer environment to support conceptualizing by designers were formulated. These will now be discussed with regard to their implications for the design of the visual database.

- **Afford a Personalized Environment**

Designers work in an information-rich and highly individualistic environment. A supportive computer environment should therefore allow a high degree of individuality and freedom of organization. For the interface of the database this implies that it should offer possibilities to be tailored to the designer's personal preferences.

- **Support the Rapid and Rough Capturing of Ideas.**

The database is intended to be used by the designer together with other tools, such as pencil and paper, that do allow a rapid and fluent recording of possible design solutions. Therefore the database itself will not offer any functionalities for quickly capturing design ideas. Its interface should, however, not constrain the designer with technical limitations or performance constraints, which might hamper the constant flow of creative ideas. The designer should be able to focus his attention almost entirely on the visually presented products, to assess their similarities, differences and relationships, in order to extract and apply the embedded design knowledge into new design situations. Since the relevant features of these products can not be determined 'a priori' for each new situation, the elements of the interface should be neutral in terms of shape and color so they don't extract any unnecessary attention. Furthermore, the interface should allow a flexible and fluent dialogue with the content of the database, thus enabling dynamic queries which support the designer's rapidly fluctuating trains of thought.

- **Use Rich Information Resources**

The ubiquitous presence of visual material in the design process calls for an image-intensive computer environment which should offer the designer many possibilities to easily store, retrieve, manipulate and display large collections of images of various kinds. In a nutshell this exactly describes the functionality of

the visual database. Its interface should therefore possess a highly visual appearance, enabling the designer to fully concentrate on the visual characteristics of the products, which make up the content of the database. Indexing and retrieving products, the two main functionalities of the database, should exhibit a prominently visual character, reducing linguistic elements to a minimum, to support both visual and verbal thinking. Also the presentation of the results of a query should not possess the rigid and static character of the interfaces currently applied to databases.

- **Enable a High Level of Communicability**

The need to communicate ideas, thoughts and views to others is present throughout the form-creation phase. Presenting sketches, models or other design representations offers designers a means for acquiring valuable feedback from others regarding their designed concepts. A computer environment should therefore support these acts of communication by offering possibilities for collaborative work. For the database's interface this would imply facilitating multi-user interactions, so that designers can compare each other's arrangements or discuss the querying process together with a client or co-designer.

- **Support Individualistic Styles**

In time, each designer has developed a personal 'design style', which is reflected in his sketching and presentation habits, his affinity for certain tools and techniques, his preferences for certain shapes and materials etc. In the database this style would express itself in the organization of products into product types. Although the results of chapter 5 showed that designers reflect a considerable degree of agreement when classifying products, it is probably in the subtle differences between these classifications that the personal preferences of the designers are expressed. This calls for an interface that supports these differences without intruding on the idiosyncrasies of an individual designer's style of working. It should afford the same continuous and immediate control the designer has when organizing visual material in a non-computer environment, while at the same time extending this with the new possibilities which a computer environment has to offer.

- **Afford a Smooth Shifting of Activities**

Throughout the form-creation phase the designer frequently changes activities, presentation modes, tools and projects. A computer environment should therefore afford a high degree of flexibility of changing between functionalities. Since the indexing and retrieving of products are the two main functionalities of the database, it's user interface should enable a fluid shifting between these two activities, as well as between browsing and searching. Thus a high level of involvement is maintained, with the user constantly interacting on both a verbal and visual level.

- **Support Motor Skills**

Designing is not just a cognitive process, it is a bodily experience as well. While conceptualizing the designer uses various body postures to get a better overview or to enable more direct actions. The organizing of visual materials, such as in collage making, also brings with it various physical actions such as tearing, cutting, shoving etc. Somehow the interface of the database should reflect the freedom and space these actions acquire in it's design, e.g. by presenting a sufficient surface for arranging of presenting the images.

Candy and Edmonds (1997) list the following key features a software system should have, for it's user to achieve a truly knowledge-intensive form of interaction:

- **Knowledge modification and evolution**

The user should be provided with accessible and powerful tools to modify the knowledge base to his likings. It should be possible to add new knowledge or to alter existing knowledge. The database should therefore offer functionalities for indexing new products as well as changing the index of existing products. The interface should provide a natural way of interaction for both functionalities.

- **Evaluation of evolving knowledge**

Support for evaluating the knowledge provided by the system should be given, expressed in domain-specific terms that are meaningful for designers. The



interface should therefore give its user enough information to interpret the relevance and meaning of the presented knowledge.

- **Comparative evaluation of knowledge.**

Support for comparative evaluation of the knowledge in the system should be available. Thus the user should be able to perform quick and easy comparisons of different compositions of the knowledge in the system. The interface has to allow the user to carry out such comparisons without interference, a functionality which is in line with the typological approach.

Schneiderman (2000) suggest eight activities which creativity support tools should offer. Of these eight activities, two which fit in very well with the design of the visual database will be presented here:

- **Searching and browsing digital libraries**

The tools supporting this activity should enable effective exploration through rapid browsing, similar to what people do in bookstores and physical libraries. Overviews should be presented in arrangements meaningful to the user. This clearly indicates the value of a database system.

- **Visualizing data and processes**

Information visualization supports creative work by enabling users to find relevant information resources in digital libraries, identify desired items in a set, or discover patterns in a collection. User interfaces should therefore make extensive use of information visualization techniques to make the information more accessible and meaningful.

Using these criteria as reference points in the design process, attention was first concentrated on how to retrieve and visualize the design knowledge which is represented in the visual database, in a way meaningful to and applicable for designers.

## 6.3 Information retrieval

With the emergence of multimedia technologies, large digital storage capability and high-bandwidth computer networks, the need for efficient retrieval of information from large visual databases has increased rapidly in the past decade. Although text-based search engines allow users to specify any desired combinations of features, their emphasis on linguistic input makes them unsuitable for visual data, where these features are often difficult or impossible to exactly describe in words. In the development of new interaction paradigms to search for visual information, content-based retrieval has turned out to be one of the more active ones (Djeraba, 2002). In content-based retrieval, visual elements which are part of the data such as color, texture, shape or spatial relationships, are used to retrieve data with similar content. The interaction paradigm of querying by 2D visual examples requires users to provide an example image as a reference.

Several techniques of querying by 2d examples have been developed (Assfalg and Pala, 2000):

- **Iconic querying**

In this process the relevant objects and features of an image are represented by means of icons. An icon is a simplified image of a function of the system or an object in the real world. The icons are then used for manipulating the system. Systems using this technique are SCORE (Aslandogan et al., 1995) and IconicBrowser (Tsuda et al., 1989), which both allow the user to retrieve objects from an image database by means of icons.

- **Querying by sketching**

Used to retrieve images that are similar to the exemplar. Sketches can be manually created by the user or traced from an existing image, following an objects' contours. Examples of systems incorporating this technique are the Electronic Cocktail Napkin (Gross, 1995, 1996), which uses diagrams drawn by a designer to index and retrieve information from an architectural database; and the Artistic Design System for Industrial Product Image Retrieval (Suzuki, 2002).

- **Querying by image**

Images from a sample set or from a previous query are used as inputs for a new query. This technique is especially suited for global features, such as overall color and appearance or texture similarity. Examples using this technique are IBM's QBIC system (Flickner et al., 1995) and MIT's Photobook (Pentland et al., 1994).

The query-by-example paradigm does have some obvious benefits for the proposed visual database. Conducting a query by means of visual examples relieves a user from the cognitive load of translating visual features into database-specific textual jargon. It also opens up the possibility of establishing a completely visual dialogue through the content of the system, in which the user can fully concentrate on the similarities and differences of the presented examples. However, query-by-example also has its drawbacks (Assflag and Pala, 2000). In systems which require user-made query examples, such as in querying by sketch, users often find it difficult to create such examples because they lack the acquired sketching skills or the ability to specify the salient features of the content they are looking for. Choosing from existing examples forces the user to pick from a pre-determined selection the example that best matches their query, even if the example barely represents the desired qualities. The challenge was therefore to develop an interaction technique which builds on the strengths of query-by-example and at the same time tries to overcome its limitations.

## Information visualization

This development started from the observation that similarity with respect to products' overall appearances constitutes the main organization principle of the database. Products are organized into product types based on the salient features of their appearances regarding function, form and meaning. To present the design knowledge resulting from this organization in a meaningful way to its users, the system's interface should concentrate on visualizing the similarities and differences between products on a variety of dimensions. To achieve this, the technique of Multi-Dimensional Scaling was applied. Multi-Dimensional Scaling (MDS) is a statistical technique for visualizing similarity relationships between objects. It generates a 2D, 3D, or even higher-dimensional, arrangement of

objects based only on information about the amount of similarity between object pairs. In an MDS-display, objects are arranged in a layout in such a way that the distances between pairs of objects express their (dis)similarities. Thus 'landscapes of objects' are created, in which similar objects appear closely together, and dissimilar ones far apart.

MDS is often used in marketing to identify key dimensions underlying consumer evaluations of products, in which it has proven to be remarkably robust and insightful (Malhorta, 1999). Thus MDS has been applied in a variety of areas, such as image measurement, in which perceptions of a company by consumers and non-consumers are compared with the company's perceptions of itself; new product development, in which gaps in the MDS-display are considered as potential opportunities for positioning new products; and market segmentation, in which brands and consumers are positioned in the same display to identify groups of consumers with similar perceptions.

As an example figure 6.1 shows an MDS-display, which resulted from a survey in which consumers were asked to rank-order all the possible pairs of 10 brands of soft drinks in terms of their similarity (Green et al., 1989). Based on other information from the survey, the horizontal axis was labeled as "cola flavor" and the vertical axis as "dietness". The arrangements of objects in an MDS-display often reveal aspects of the structure of a collection that weren't noticed before. Thus the figure shows that Pepsi and Coke Classic were perceived as being similar, while the same thing can be said of Diet Pepsi, Diet Coke and Tab.

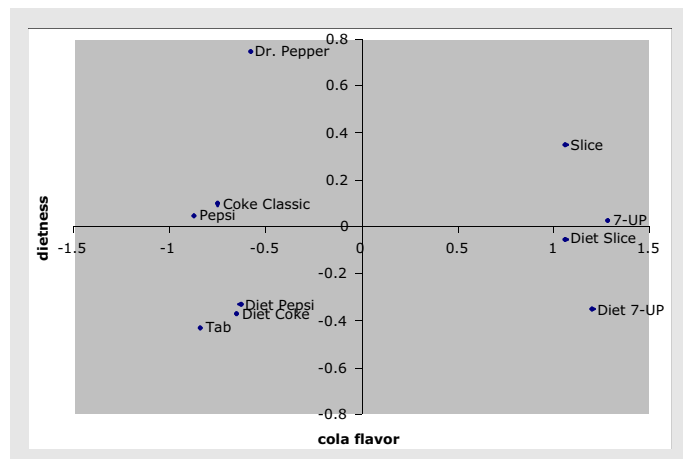


Figure 6.1 MDS-display of 10 brands of soft drinks, showing the competitive structure of the soft drink market. (Green et al., 1989)

Dr. Pepper, however, is considered to be relatively dissimilar to the other brands.

MDS techniques have been used before to produce lay-outs showing the relations between objects of a database according to a similarity criterion. In the system by MacCuish et al. (1996) all objects in the collection are presented as a cloud of points on a display, allowing users to gather information on an object by clicking these points. In ZASH (Orimo and Koike, 1999), a browsing system for a movie database, MDS is used to make layouts of titles and commentators. In the "El Niño" Image Database System (Santini and Jain, 1999) two-dimensional as well as three-dimensional display spaces are used, in which the distance between images reflect as well as possible the distance with respect to the current similarity measure used by the database. In these systems the displayed MDS-arrangement is static, calculated previously because of the large number of objects that was presented at one time.

There are several dynamic query systems, however, which show the relations between objects in an ever changing context. Examples of such tools are the AquaBrowser™ ([www.aquabrowser.nl](http://www.aquabrowser.nl)), TouchGraph ([www.touchgraph.com](http://www.touchgraph.com)) and Thinkmap™ ([www.thinkmap.com](http://www.thinkmap.com)). In the AquaBrowser the results of a query into large amounts of information from different sources will not only include direct hits, but also a 'knowledge cloud' of related keywords. For example, entering "pancake" will also return linked terms, such as crepe and pizza, contextual terms (breakfast, syrup) and direct relations, such as flower and butter. Figure 6.2 shows an application of the AquaBrowser developed for the

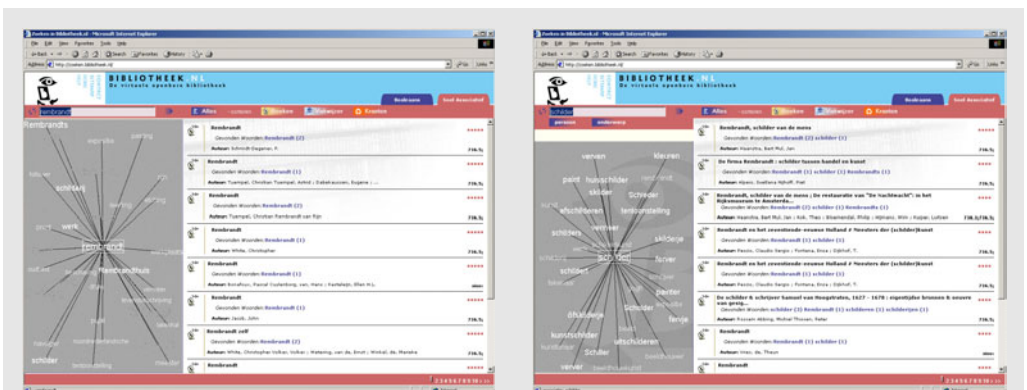


Figure 6.2 Example of a query in the AquaBrowser™ interface of the Dutch public library. ([zoeken.bibliotheek.nl](http://zoeken.bibliotheek.nl))

Dutch public library, in which typing in the term "Rembrandt" brings up a display of related terms, among which the term "schilder" (Dutch for "painter") is further selected, resulting in terms such as "paint", "exhibition" and "Vermeer".

In TouchGraph networks of interrelated information are visualized as interactive graphs. The user can explore different ways of arranging the network's components on the screen, thus navigating through large information clusters. Since this is inherently a dynamic process, the graph is kept as static as possible to provide the user with a feeling of stability and control. Figure 6.3 shows two screenshots of an application called TGGoogleBrowser, which shows a graph of related web-pages as determined by Google's "similar-page" function. Two graphs are presented, one of the faculty of Industrial Design Engineering and one for the Delft University of Technology.

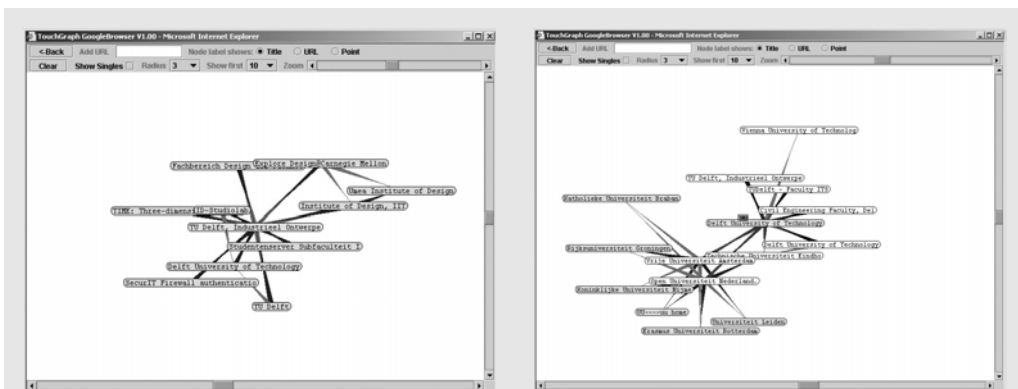


Figure 6.3 Example of a query in the TGGoogleBrowser interface. ([www.touchgraph.com](http://www.touchgraph.com))

Thinkmap provides developers of information systems with tools to present data in ways that make both data and the interconnections between data visible. Thus data is put in context and opportunities to navigate dynamically through interconnected data are created. The developers of Thinkmap themselves refer to 'visually captivating theaters of information' that promote learning and encourage learning. An example of an application of Thinkmap is the Visual Thesaurus ([www.visualthesaurus.com](http://www.visualthesaurus.com)). Its interface consist of a single word at the center of a spider configuration made up of words related to the center word (figure 6.4). By clicking on one of these related words, it becomes the new center of the Thinkmap, creating a new configuration of related words, a process which is



items simply means that they are related, the length of the line gives no information on the strength of this relationship. The configuration of the related items as well as differences in font size, boldness and transparency seems to result from functional considerations, such as readability and overview, or aesthetic considerations, in that it is more pleasing to the eye.

## MDS-Interactive

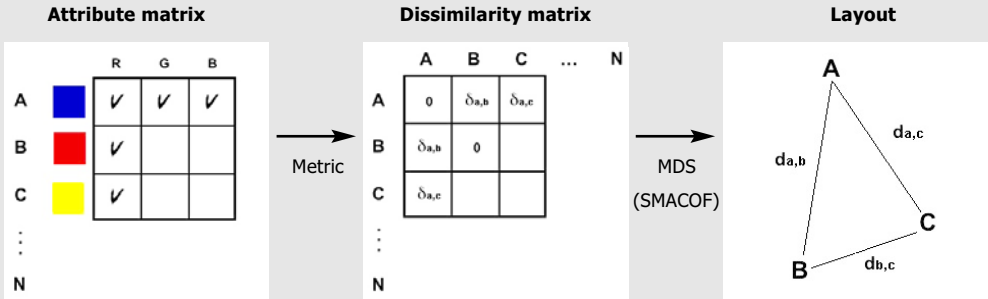
To overcome both the rigidity of the static display techniques and the lack of overview and limitedness of the meaning depicted in the current dynamic systems, a new interaction technique was developed by Pieter Jan Stappers at the ID-StudioLab. This technique, called MDS-Interactive, is the core around which the interface of the visual database will be designed. In MDS-Interactive, the user browses a large database of objects by interacting with a small set of sample objects, which are shown in an MDS-layout expressing the similarities between the objects. The main interactions are removing samples which have little meaning for the user, adjusting the weight of the similarity criterion, and calling up new samples from the database. While performing these actions, the layout is continuously adjusted to best reflect the similarity relations in the sample set. Box 6.1 gives a short description of the technical principle of MDS-Interactive.

The algorithm which is used to calculate the new layout was developed by Patrick Groenen of the Econometric Institute at the Erasmus University Rotterdam (Borg and Groenen, 1997). By keeping the number of samples limited to about 15 to 20, the user preserves the necessary overview. At the same time this number is small enough for the MDS-algorithm to keep updating the new positions of the samples in real-time. Thus the way the samples move in the display resembles a system of magnets or springs, in which the internal dynamics of fast and slow movements between the samples conveys information about the strength of their mutual relations.

The robustness of the MDS algorithm is such that if a single sample is removed from the set, the arrangement of the whole does not change much. If this reasoning is turned around, this opens up the possibility to make the removed sample reappear based on the information of its position relative to the



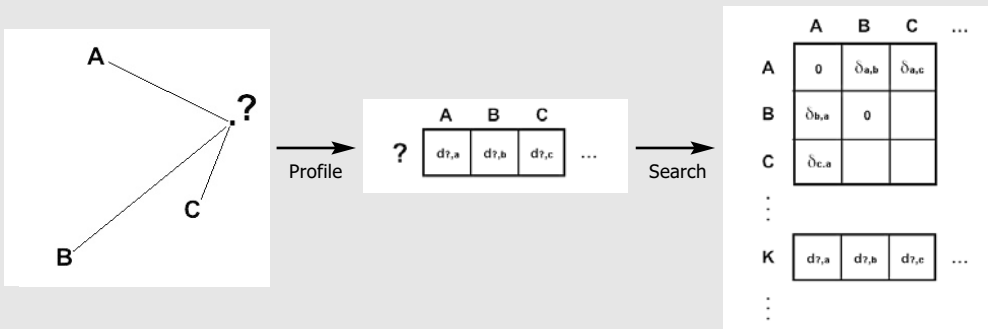
Box 6.1 Description of the technical principle of MDS-Interactive.



Multi-dimensional scaling algorithms start with a matrix of dissimilarities between the objects to be displayed. Dissimilarities can be measured directly, as in psychological experiments, or derived from a list of features using a metric function. Different metrics are used for different data types, e.g. nominal, ordinal, or interval. Also, the different features can be given different weights, e.g. when one is considered more important than the others. Metrics can be made with high sophistication, especially when a theoretical model of the features is known. Often, however, crude modeling and judicious use of initial weight factors suffices for producing expressive, meaningful MDS

layouts. The example shows a set of colors, each color having three features, representing the red, green and blue coordinates, and using the Euclidian metric to determine the dissimilarities.

From the dissimilarity matrix, MDS algorithms produce a spatial layout for the objects. The SMACOF algorithm (Borg and Groenen, 1997) is an iterative method, which can start from a random layout, and gradually, yet quickly (usually in three to four steps) improves this to an optimized layout. When new samples are added, or existing samples are removed, the iterations produce a subtle animation effect, akin to the relative motions of charged particles.



A crucial step is bringing in a new object into the sample set. The MDS-Interactive search mechanism starts from the existing layout. When the user places a query (by clicking between samples), a profile of the distances between the mouse pointer and each of the

displayed samples is calculated. This distance profile is then compared to the rows of the dissimilarity matrix. The 'resulting' sample is the best fit, the one whose dissimilarities to the samples differ the least from the distances in the profile.

set. In this interpretation, any position in the MDS layout specifies a query for the database to find a sample which relates to the ones shown on the screen as indicated by its position. This understanding led to a key innovation of MDS-Interactive, for which a Dutch patent was granted and an international patent applied (Stappers, 1998): its ability to use the 'negative' space between the samples for user input.

By indicating a position in the display, the user can request a new sample that 'belongs' in that position. So by clicking close to an existing sample in the display, a new sample will be retrieved from the database which is very similar to the existing one in terms of the relevant similarity criteria. Likewise, clicking far away from an existing sample will return a new sample which is very different from it. In these queries, spatial relations between all other samples are simultaneously taken into account.

It falls outside the scope of this thesis to describe in detail the technical principle of how MDS-Interactive works. Advanced aspects of MDS, such as data normalizations and iterative procedures require a profound statistical treatment, for which the reader is referred to Borg and Groenen (1997).

## Prototypes

In accordance with the 'research through design' philosophy of the ID-StudioLab, which was described in section 1.3 of this thesis, a number of working prototypes were built in which the MDS-Interactive technique was applied. Macromedia Director™ was used as the prototyping environment because of its capacity to quickly integrate various media types and elements into a dynamic and coherent production, and because of its familiarity to both researchers and students. Furthermore, Director does not impose many explicit restrictions on its interface elements, which allows for more aesthetic designs.

To properly test the new query technique, all prototypes were built with a high degree of interactivity in them. This would implicitly encourage their users to get actively engaged with the prototypes, requiring an intense level of active involvement. It is believed that the value of such a system is not directly in the physical or tangible output, but much more in the insights the user develops

while using it. The spatial arrangements would encourage users to explain proximities, to generate hypotheses, and to search for explanations. Three different prototypes will be discussed here: a consumer information system for roller skates, a selection tool for whiskey lovers, and a color selection tool. The first of these prototypes will be presented in detail, to show how the MDS-Interactive technique is implemented in a realistic application.

The prototype consisted of an interface to a database of roller skates, from which a potential user might select a model according to his likings. To build up the database, 70 different models of roller skates were collected, which together represented a cross-section of the current market. Each model was then catalogued on 21 properties, which were classified into three main categories considered to be relevant for consumers in their buying process: design, quality, and activity. In the design category differences in laces or buckles, color, and boot height were taken into account. The range of quality properties included the type of ball-bearings, boot material and a host of technical properties. Finally, the activities category included fitness, off-road, hockey etc. The graphic design of the interface was done by student Bram van den Nouweland. Great care was given to the design of the interface's aesthetics to make it appealing and readily understood, as well as fitting to the young and sporty charisma of the product class. Figures 6.5 to 6.12 shows the interface, depicted in various stages of a fictitious user scenario.

The other two prototypes are variations of the roller-skate database in terms of content and graphics. The colors prototype provides access to a database of 109 color samples, which have been categorized according to their RGB-values and HSV-values. Interacting with the database proceeds in a manner similar to the roller-skate database. The inner circle on the screen shows a graduated field of matching colors, while the outer circle shows which colors differ most from the made selection. By clicking on a color sample, the user can change the color of the couch, which is depicted in the insert on the lower left corner of the screen. Below the couch the name of the color is displayed. Such an application might conceivably be used in an interior design shop, to view the colors of a preferred couch in the context of a living room. Figure 6.13 shows that by moving the slider in the RGB-triangle all the way to the "Green" corner,



Figure 6.5 A query might start with randomly retrieving a few roller skates from the database, to get an impression of its content. This can be achieved by clicking on the "random" button. The samples, in this case four, are then shown as thumbnails in a multi-dimensional arrangement in the general view on the left. The top right-hand corner shows a large image of the last retrieved model, or from the one activated in the general view. Additional information on brand, price etc. is given in keywords below the image.

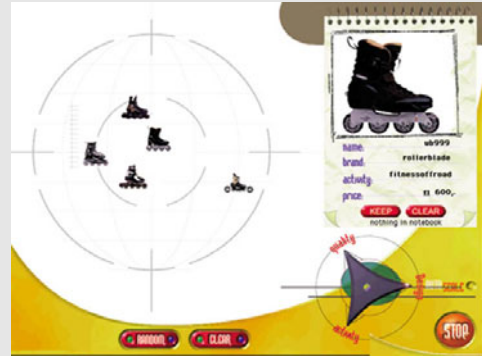


Figure 6.6. The dialogue between the user and the database now consists of removing and inserting samples in the general view. When a user clicks in this (see the arrow in figure 6.5), the database looks for the model that forms the best match for that location, by comparing the properties stored in the database with the samples already depicted on the screen. The resulting five samples rearrange themselves dynamically in real-time into their new MDS configuration, while the new model and its properties get displayed in the top right-hand corner.



Figure 6.7 An unwanted model can be removed from the selection by dragging it off the screen. The remaining models will then regroup into a new area-filling composition. Clicking the "clear" button removes all samples from the screen, so a new query can be started.



Figure 6.8 The selection triangle (bottom right) can be used to increase the weight given to either quality, design or activity. By moving the selection slider to the lower right-hand point of the triangle, the user gives more value to "activity" in the MDS procedure. This causes skates, which are suited for a similar activity, to be grouped closer together, and further away from the other types.



Figure 6.9 By changing the emphasis to "design", an entirely new arrangement is obtained. In this way the user can distinguish those samples which have the sought after design qualities, and eliminate the ones that don't from the selection process.



Figure 6.10 Again, when a new roller skate is retrieved, the skates in the general view are rearranged to accommodate the newcomer in the right spot. If no new model appears in the proximity of the clicked position, everything in that area has already been retrieved from the database.



Figure 6.11 When the weight is on "design", queries also focus on design. In this way the user can distinguish those samples which have the design qualities searched for, and eliminate the ones that don't from the selection process.



Figure 6.12 Interesting models can be stored, or removed from a notebook by using the "keep" and "clear" buttons below the textual descriptions. The selection process continues until the user finds the best model(s) to suit his preferences.

importance is given exclusively to the green-value of the colors in the overall judgment. Thus the colors rearrange themselves on a straight line, because only the (difference in) green-value is now used in the MDS-algorithm. This model most clearly explains the mathematical workings of MDS-Interactive and was not designed to be a new color selecting tool.

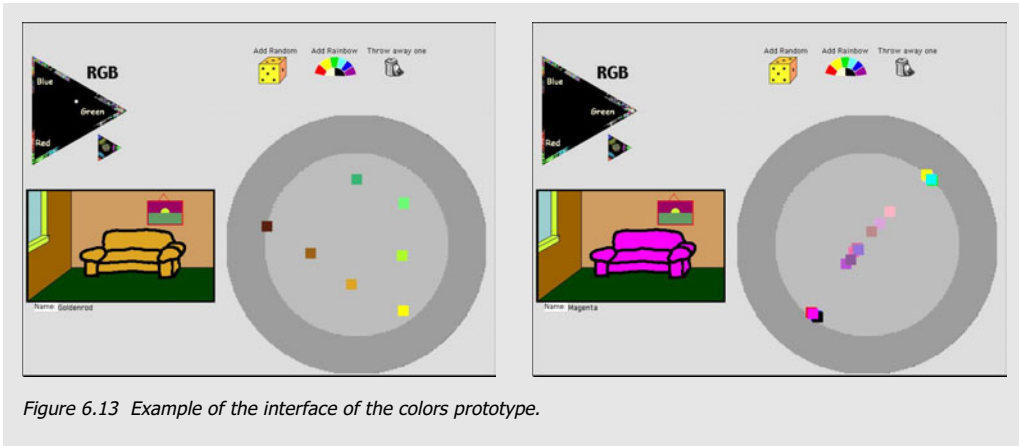


Figure 6.13 Example of the interface of the colors prototype.

The whiskey database, designed by student Arvid Smit, contained 50 whiskies, which were sorted according to price, sweetness and peatiness, the latter two being important taste parameters for whiskey. Each whiskey was represented by its label. The prototype (figure 6.14) showed that the database content need not be limited to purely technical or physical parameters, but can also be fed the results of 'tastings'. However, although the display shows at a glance to what extent the various whiskies differ, it doesn't tell exactly how they differ, for instance which ones are more or less sweet. To infer this from the database additional information is necessary, for example through textual statements such as in the skates database.

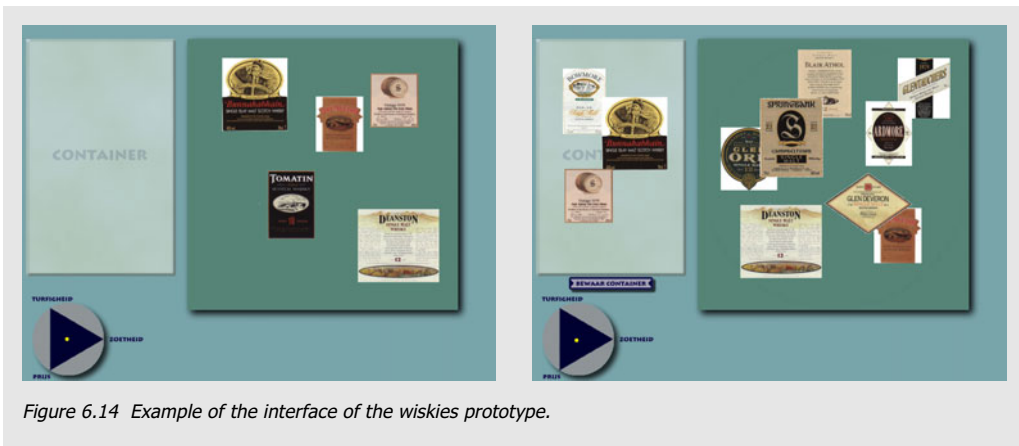


Figure 6.14 Example of the interface of the whiskies prototype.

## Evaluation

The skates database was evaluated in a small explorative user test. Twelve design students participated; six individually, the other six in pairs. Before trying out the system for themselves, they were given a one-minute demonstration. After that they received the instruction to find those skates that best fitted their own interest. During the interaction with the system they were observed and their behavior was noted. After using the system the subjects answered a number of questions regarding the ease of use of the system, their satisfaction with their search results, and their opinion about this way of working.

Both the observations and the given answers revealed that the subjects did not meet any major complications in working with the system and that they enjoyed using it. However, some details of the user interface design did cause some confusion. The configuration of the three nested circles was considered misleading, in that it suggested that the 'best' sample ought to appear in the smallest circle. In a similar way, some subjects thought that the samples which appeared at the top of the circles would represent the 'best' ones. The MDS-algorithm is, however, rotation-independent, which implies that the orientation of the samples has no meaning attached to it. The weighting triangle was sometimes incorrectly perceived as a filter. Two subjects did set it all the way to 'quality' with the expectation that only high quality skates would be shown. However, giving full weight to 'quality' merely implies that this criterion is getting more value in the grouping process. Removing samples by dragging them off the screen was found to be somewhat cumbersome, while having two buttons with the label "clear" was perceived as confusing. Finally, instead of the notebook in which individual samples are stored, it was suggested to offer the possibility to store meaningful organizations of samples.

Observations of the subjects working in pairs showed that, because of the interface's visual simplicity, both subjects could be equally involved in the interaction process. This in contrast to text-based search engines, where one user is usually typing in the keywords, thus controlling the query. The subjects also reported learning from the system. Being unfamiliar with all of the various types of skates, some of the subjects did not know of the existence of 'off-road' skates. They learned, however, when one of the displayed samples appeared to have the

value 'off' road' for the attribute 'activity'. By moving the weight to 'activity' and subsequently clicking close to this particular sample, they could call up other off-road skates and study their appearances.

## Conclusions

MDS-Interactive shows potential as an interaction method for accessing large information collections. Its visual and dynamic qualities have an intuitive and intriguing appeal, while its dialogue proceeds through tentative suggestions rather than hard prescriptions. By interacting with the system the user creates 'landscapes of meaning', with points or areas in these landscapes becoming suggestions for new queries. By showing the changes in relationships between samples, the characteristics of these relationships are transmitted to the user in an implicit way. When two samples move far away from each other when changing the weight of an attribute, this directly conveys the message that these samples are dissimilar when it comes to this attribute.

However, experiences with the whiskies database made clear that additional information in the form of attribute values may be necessary to completely understand the message. Also, in the three prototypes that were discussed previously, indexing the samples into the databases was still done in a traditional way, and not by the user: by attaching keywords or attribute values to each sample individually, in a sequential manner, based on an independent assessment, without making comparisons between samples. This is contrasting with the typological approach, which advocates the organization of product examples into groups called product types, which involves mutual and parallel comparisons between these examples. Therefore, to fully turn MDS-Interactive into a design support tool for the form-creation phase, a method has to be developed which integrates the holistic perspective of the typological approach with the querying qualities of MDS-Interactive.

## 6.4 ProductWorld

Chapter 5 of this thesis studied how designers organized design precedents. They were asked to arrange, group and name collections of product samples. The



results from this study established a two-step procedure, in which a collection is first spatially divided into smaller groups, which subsequently are given names, as a natural and efficient way of organizing. The logical next step was then to integrate this two-step procedure, as a way of indexing the product samples into the database, with the MDS-Interactive technique, as a way to retrieve them from the database, into a new tool.

This new tool was named ProductWorld (Pasman and Stappers, 2001). Its development was directed from the perspective of the designer as an active 'organizer, retriever and reviewer' of products. The remainder of this section will describe the main two functionalities of ProductWorld. First it will be shown how precedents designs are indexed, followed by a description of their retrieval.

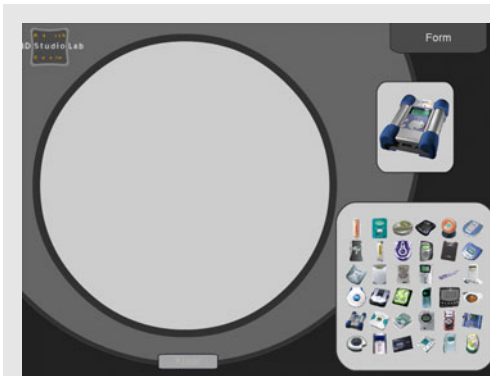
## Indexing design precedents

With the volumes of image data to be stored becoming larger and larger, the need for quickly indexing these images has increased in the past years. This has resulted in several techniques to automatically extract relevant features from image data (Rui et al., 1999). The most widely used of these features are color (Panchanatahan et al. 2000, Lin et al., 2001), texture (Patrice and Konik, 2000) and shape (Adoram and Lew, 1999, Gagaudakis and Rosin, 2001). Although such techniques could be beneficial for a database of products, they have not been incorporated into ProductWorld. A practical reason for this is that their construction and implementation is a research field on its own, which falls outside the scope of this thesis. Also their scope is still limited. For many aesthetic properties, such as style, no complete descriptive frameworks yet exist. More importantly, however, as stated before, the act of classifying products is considered to be a substantial part of the knowledge acquisition process of the designer while using the database. Moreover, the observations from the organizing task showed a large variety between designers in how they classify products. Automating this part would thus remove the possibility for designers to create their own personal organizations.

A fully functional prototype of ProductWorld has been developed in Macromedia Director™. The goal of this prototype was to generate a 'proof of concept' which would show how the ideas brought forward in this thesis could be

implemented in a computer environment. Prototyping therefore concentrated on creating a working demo, which would demonstrate how the main functionalities of ProductWorld were translated into interactive concepts. ProductWorld's interface incorporates several elements from the MDS-Interactive prototypes, although a number of adaptations have been made based on the results of the previous evaluations. The large circle, which from now will be referred to as the "interaction circle", still represents the main interaction area. However, any inner circles as well as the cross-hair in the center have been removed, to avoid giving more importance to certain areas. All interface elements were made in grayscale, to achieve a neutral and general purpose look, which would accommodate a variety of products without interfering with their appearances.

How products can be indexed into ProductWorld is illustrated in figures 6.15 through 6.18, which describes a scenario of a designer organizing a collection of MP3 players.



*Figure 6.15 The light gray field in the lower right corner contains a set of samples of MP3 players, which has been collected by the designer and is now to be indexed into the database. These samples might be imported from the designer's hard drive, from the Internet, or from other resources. In the upper right corner a similarity criterion is displayed, on which the products are to be assessed. Clicking on one of the thumbnails shows a larger image in the center field on the right.*



*Figure 6.16 Indexing is primarily based on visual assessments. Using drag-and-drop actions, the samples are to be positioned into the interaction circle in such a way that their relative positions express their perceived similarities regarding the selected criterion, here "form". The designer thus positions similar samples closely together, and dissimilar ones far apart.*



Figure 6.17 By putting samples into the interaction circle, mutual relationships between them are being established, without having to attach keywords to each sample separately. When the designer is satisfied with his arrangement, clicking the "Done" button the system calculates and stores the distance between each pair of samples.



Figure 6.18 Subsequently, he can identify each group of samples by a textual label, which typifies the characteristics of the group. Selecting all samples which constitute a group, followed by clicking the "New label" button, brings up a textbox in which the name can be typed. Clicking the "Assign label" button assigns this name to each sample in the group. Thus this two-step process results in the classification of the total set of samples on the selected similarity criterion. The user can then decide to repeat the process with the same set of samples on a different criterion, with a different set of samples on the same criterion or with a different set of samples on a different criterion.

## Retrieving design precedents

Retrieving samples from ProductWorld proceeds through a dialogue, which is for the most part similar to that of the skates database. The interaction circle now functions as an interactive area, through which the user conducts a dialogue with the database.

## 6.5 Evaluating ProductWorld

To determine the value of ProductWorld in its present form as a design support tool, it was evaluated within the setting of an actual design course. A group of students, who were to design a MP3 player, used a prototype of ProductWorld at the start of their design process to construct a small database of existing MP3 players. Subsequently they could use this database for the remainder of the

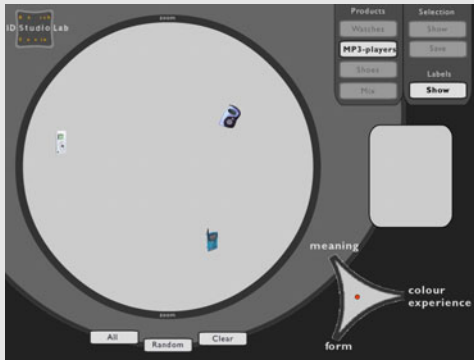


Figure 6.19 When selecting a new product class, the system retrieves three random samples from the collection and depicts them in the interaction circle. Thus an initial selection is created, from which the designer can start his exploration. A sample can be removed from the current selection by clicking on it, while holding down the Ctrl-key (Win) or Option-key (Mac). Clicking the "Clear" button removes the whole selection.

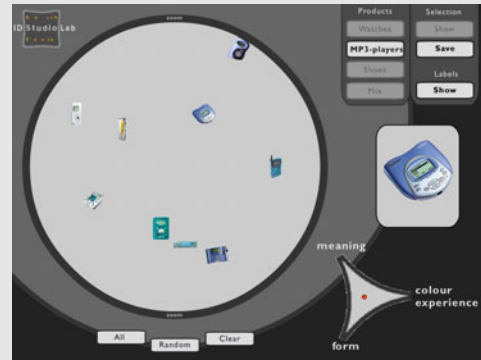


Figure 6.20 Samples can subsequently be retrieved from the system by clicking on a position in the interaction circle, by clicking on the "Random" button, or by clicking on the "All" button, which retrieves all samples in the selected product class from the database.

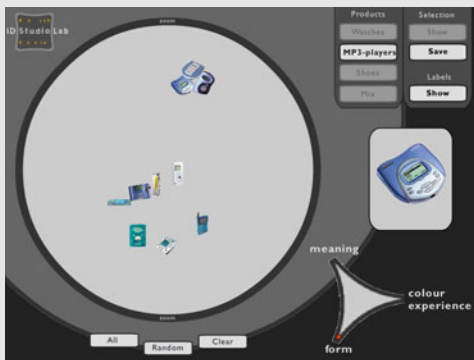


Figure 6.21 By moving the small dot in the triangle, the designer can set the weight that is assigned in the MDS-algorithm to each criterion. Changing the weight makes the samples in the interaction circle move onto their new configuration. By clicking on the criterion itself, the weight is set completely to this criterion. Here all samples have rearranged themselves according to their form similarities, with the small dot placed in the lowest point of the triangle.



Figure 6.22 The names that have been assigned to each sample in the input-module can be made visible by clicking the "Show" button. For each similarity criterion the corresponding label is then displayed below the large image of the selected sample. Clicking the "Hide" button will remove the names again from the display.

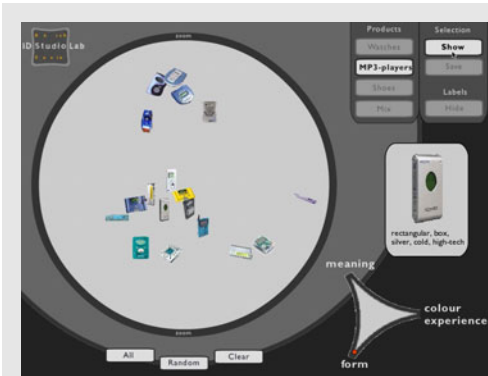


Figure 6.23 A selection can temporarily be stored by clicking on the "Save" button. The designer can then add samples to or remove samples from the selection, or set the weight to different positions in the triangle. By clicking the "Show" button the stored selection is again displayed in the interaction circle, complete with the corresponding setting of the weight.



Figure 6.24 Clicking on one of the other product class buttons removes all samples from the interaction circle, and places three random samples from the selected product class into the circle.

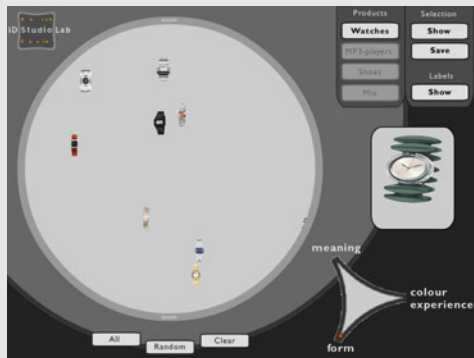


Figure 6.25 The designer can zoom in on the displayed samples by clicking on the dark border of the interaction circle. This increases the scale with which the samples are positioned relative to each other. Clicking on the border while holding down the Ctrl-key (Win) or Option-key (Mac) zooms out, decreasing the scale.

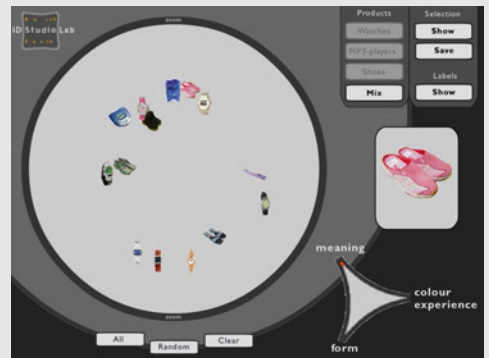


Figure 6.26 Clicking on the "Mixed" button, retrieves samples from all three product classes from the database. However, only samples that have been indexed simultaneously will be retrieved, since the distances between samples are relative.

course. Exploring it through ProductWorld's interface allowed them to study the relationships between the products, to compare the ways they organized the product themselves with an organization made by their design tutors, or to evaluate their own design concepts with the qualities of already existing products.

Their experiences provided important feedback on the value of ProductWorld as a design support tool.

## Setting

The evaluation took place as an integral part of the course *Ontwerpen 3* (*Designing 3*), which runs in the second year of the Industrial Design Engineering program and is obligatory for all students. The course, in which each year approximately 250 student participate, is part of a series of six design courses, which run as a common thread throughout the whole five-year program. All of them aim at the integration of aesthetic, ergonomic, engineering and marketing aspects into the product design process, with each course zooming in on certain specific elements.

*Ontwerpen 3* focuses on the conceptual phase of the product design process. The type of product to be designed is a series- or mass-producible 'hand-held' product with a plastic housing, which contains the electronic components. The students, who carry out most of the work individually, first have to develop a 'vision', which is not a concrete representation of the product, but an expression of the context the product will be used in, the needs it has to fulfill, the moods it has to arouse etc. With this vision, which is presented by means of collages and textual statements, as a reference, the generation of form concepts starts. Besides through sketches, each concept has to presented by means of foam models, to acquire insights into the dimensions, construction and handling of the product.

To structure the concept generation process, the so-called 'Fish-trap' model is applied (Muller, 2001). This model is a method for generating and developing a form concept for a product up to the sketch plan, and consists of a series of diverging and converging sub phases. In a diverging sub phase a large quantity and variety of possible alternatives are generated, without judging their quality and feasibility. In the subsequent converging phase these alternatives are then categorized into types, in which the previously discussed product typologies serve as 'templates', directing the categorization. The resulting types, which represent possible directions for further development, are then arranged in order of suitability and the most promising one is then further developed in the next

diverging sub phase. Thus, starting from a basic structure of the functional components (structural concept), through a first overall materialization of this structure (formal concept), the initial ideas finally get developed into a rather detailed, materialized form (material concept). The integration of the typological approach, with the activity of organizing products already embedded into it, makes this design course therefore a suitable setting to evaluate ProductWorld.

## Procedure

The evaluation started in the third week of the course. By this time the students had familiarized themselves with the design problem through associative techniques such as brainstorming and mind mapping. Thirteen students, all working on the design of a portable MP3 player, participated in the session. At the start they received a verbal introduction by their design instructor, in which the background and the purpose of the session were briefly explained to them, followed by a short demonstration of the grouping and naming of products in ProductWorld. After this introduction the students were each assigned to a computer, on which a copy of the ProductWorld prototype was running. They were then asked to group and name a set of 36 MP3 players, which was collected by their design tutor, on the criteria "Form", "Meaning" and "Color experience". Appendix F shows the complete set of MP3 players.

Each criterion was preceded by a short description, which listed the main aspects the students had to take into account while organizing the products. When the grouping and naming was completed for one criterion, a screen dump of the resulting organization was made and for each of the 36 samples the screen coordinates, as well as the names attached, were written to a text file. After completing the last criterion, the session ended with a short questionnaire, in which the students were asked for their opinion regarding the tasks and the use of ProductWorld. Figures 6.26 shows students while performing the task.

After this indexing session a personal database was created for each student from the data in the text file. After consulting the design tutor, it was decided that the database would not only contain the student's own organization, but an organization made by the design tutor as well. It was thought that the similarities and discrepancies between both organizations would facilitate the



Figure 6.26 Students grouping and naming MP3 players in ProductWorld.

discussion between student and tutor on the relationships between the products.

The prototype of ProductWorld as described in section 6.4 was slightly modified for this occasion, the adaptations concerning only the retrieval mode. The possibility to select different product classes was removed, since only the product class of MP3 players was used, and the possibility to switch between a student’s own organization and the organization made by the design staff, was added. Figure 6.27 shows the modified interface.

In the week following the session each student was given a CD-ROM, containing a personal copy of ProductWorld, which provided access to their own organization



Figure 6.27 Interface of ProductWorld modified for Ontwerpen 3



as well as to the organization made by their tutor. During the remainder of the course they were free in their use of the program.

Finally, at the end of the course, four students were selected by the design tutor to participate in a small group discussion, in which they were asked about their experiences using ProductWorld. The discussion was facilitated not by the author, but by Ianus Keller, a member of the ID-Studiolab, to avoid a possible bias in the interpretation of the comments given by the students. To structure the interview a set of questions was used, which addressed different aspects of the use of ProductWorld.

## Results

### *Observations*

No major problems were encountered during the indexing session. All students seemed to be comfortable while interacting with the program. Some of them in the beginning needed a bit more explanation on the tasks, and the aspects that had to be taken into consideration, especially for the criterion "Meaning". After receiving this explanation, however, they completed the tasks without further difficulties. While performing the tasks, the subjects showed a high degree of concentration and dedication, which indicated that they perceived the tasks to be valuable and meaningful. Everybody reacted enthusiastic on the qualities of the program, although some remarks were made about lacking certain flexibilities in the indexing procedure. Especially the fact that no more changes could be made in the groupings once the names had to be attached to them, was reported by some subjects as being annoying. Figure 6.28 shows two examples of the organizations made by one subject.

### *Questionnaire*

The short questionnaire which the students had to fill in after the organizing session, consisted of four questions, which addressed the organizing task and the use of the ProductWorld prototype. Each of these questions will now be discussed. Because of the small number of subjects (N=13) the results are mainly indicative. Box 6.2 shows the questionnaire, while table 6.1 presents the scores of the subjects on the four questions.



Figure 6.28 Two organizations made by one subject in the indexing session. On the left the organization regarding "Form", on the right the organization regarding "Meaning".

**Box 6.2 Questionnaire Indexing session**

*Question 1: How familiar are you with the presented MP3 players?*

Very unfamiliar	1	2	3	4	5	6	7	Very familiar
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*Question 2: How difficult did you find grouping the MP3 players?*

Very easy	1	2	3	4	5	6	7	Very difficult
-----------	---	---	---	---	---	---	---	----------------

*Question 3: How difficult did you find naming the product groups?*

Very easy	1	2	3	4	5	6	7	Very difficult
-----------	---	---	---	---	---	---	---	----------------

*Question 4: How difficult did you find using the program?*

Very easy	1	2	3	4	5	6	7	Very difficult
-----------	---	---	---	---	---	---	---	----------------

Table 6.1  
Scores of the  
subjects (N=13)  
on the four  
questions in  
absolute  
numbers

	1	2	3	4	5	6	7
<b>Q1</b>	1	4	1	1	1	4	1
<b>Q2</b>	0	1	2	1	8	1	0
<b>Q3</b>	2	2	2	3	2	1	1
<b>Q4</b>	6	7	0	0	0	0	0

The results indicate a split into a group of subjects, who reported to be familiar with the presented MP3 players, and a equally large group who indicated to be unfamiliar with the presented samples. It is not clear whether or not this also had any influence on their organizations. The majority of the subjects did find the

grouping of the MP3 players to be somewhat, though not very difficult. One subject reported the grouping to be easy, while three subject were indifferent about the difficulty of this task. Overall, the grouping task was considered to be rather difficult. The difficulty of the naming task showed a more scattered image. Four subjects found the naming to be easy, two subjects reported it to be difficult, while the rest of the subjects took up a middle position. Finally, for the usability of the program an univocal picture emerged, with all 13 subject finding the use of the program to be easy.

### *Group discussion*

At the end of the course four students, three female and one male, participated in a group discussion, which lasted about 45 minutes. It concentrated specifically on the use of ProductWorld for retrieving and evaluating the previously made organizations, although sometimes statements about the organizing session were also made. On average the four subjects used the program four times during the course, mainly in the first quarter in which they had to generate concepts. They indicated that use in the second quarter was limited due to lack of time. The reasons for using the program varied from comparing organizations to determine a direction for further development, looking at products to get fresh ideas, or presenting it to others to explain certain aspects of MP3 players. In most cases the program was used individually. The collection of MP3 players was seen as sufficiently broad, giving a good impression of the total product class. The fact that no indications of the dimensions of the samples were given, was perceived by some as a disadvantage for comparing them to each other.

Operating the program presented no major problems. However, making corrections to earlier made selections as well as deleting samples was considered too be cumbersome, a simple undo-function would be a nice improvement here. The fact that the retrieval process started with three random samples was perceived by some as too loose, they would rather make this initial selection themselves. These subjects reported therefore to start their process by clicking the "All" button, which would present the whole collection to them, and subsequently reduce this collection by removing samples. The movement of the samples to their new position was perceived as being too fast to provide insight.

However, it was found to be attractive and meaningful and should therefore be supplemented with the possibility to control the speed of movement. The zooming function was valued as positive, though it should also be possible to zoom in and out on the samples themselves as well. A printing facility, which would make a screen dump of just the interaction circle and the weighting triangle was also suggested as a possible additional functionality. Finally, all subjects would welcome some sort of history, which would keep track of all the actions and offer possibilities to return to previous selections.

With respect to the design value of using the output mode of ProductWorld, the subjects reported that they did not had acquired more insight into the product class "MP3 players". However, they indicated that they already gained this by doing the grouping and naming task during the indexing session. Moreover, they did report to have acquired a better understanding of the relationships between form, meaning and color experience, although especially the relation form-meaning was considered by all to be very difficult. The possibility to compare their own organizations with the ones made by the design tutor, was not regarded as being very useful, although the names given by the tutor to the groups were seen as informative.

All subjects reported to have applied insights acquired from using the program into their own design process. One subject based the selection of the material for her own design on some of the samples, another used the samples to set a direction for the further development of her concept, a third found the names especially helpful in thinking about possible solutions, while the last subject mainly used the samples as a reference of what his own design should not represent. However, they all did not consider the use of the program to be of influence in making their design decisions. They attributed this to the fact that specific evaluation techniques such as checklists and Harris profiles were prescribed in the course.

The overall look of the program did elicit mixed responses. One subject thought it was boring, with its reserved color scheme, while another perceived it as nice. The other two subjects considered it to be neutral and non-distracting from the actual product samples. Finally, the subjects did see a commercial application for the program, once it would be developed to the extent that the

user could easily add his own samples, select and add his own criteria, store his own organizations etc. In all, the subjects did perceive the total use of ProductWorld, including the indexing session, as valuable to their design process. Providing that certain improvements and additions are made to the program, they all recommended its use as an integral part in future sessions of Ontwerpen 3.

### *Design tutor*

The design tutor who supervised the students in the course, also reacted positive to the use of ProductWorld as a design tool. In his opinion the program motivated and assisted the students to map and analyze the current solution space, thus helping them to identify certain 'blank spots' in this space where they might position their own designs. It also provide him with a means to discuss and explain certain aspects of existing products, the relationships between these aspects as well the relationships with the students' designs. He did find it difficult for the students to interpret the organizations into meaningful information for their design process, but also considered it an important functionality of the program to train them in this ability. In addition to product samples, he suggested that similar organizations could be made using color samples of material samples. In all, he regarded the use of ProductWorld to be a valuable addition to the course.

### Conclusions

Reviewing the results of this evaluation, it should be taken into consideration that the subjects were only in their second year of study, having had not much training yet in assessing products. Thus they have little of the judgment and knowledge needed to classify products on a sub-ordinate level, have no extensive design vocabulary in place to name the groups, as well as no experience of integrating the results of such a classification into their own design process. Training them in these abilities is therefore one of the goals of the Ontwerpen 3 course.

The evaluation clearly showed that ProductWorld can support and enrich this training. The tasks in the indexing session were performed by all subject with dedication and enthusiasm. They were considered as insightful and valuable for

the design process. The implementation of them in a interactive computer environment seems to facilitate their acceptance as meaningful design techniques. Exploring the self-made organizations through ProductWorld's interface was considered to be engaging and inspiring, but also as difficult to interpret. The specific design character of ProductWorld, with its emphasis on interactivity, aesthetics and usability, was highly appreciated and certainly contributed to its acceptance.

However, in its current state ProductWorld is still just a prototype. Its design and level of functionality has been highly influenced by the research settings in which it was used and evaluated. So, although it effectively incorporates and demonstrates the most important functionalities of the database, more functions will have to be added and implemented to make it a mature or even commercial product. For example, it should be possible to easily import product pictures, which can differ in quality, size, orientation etc. from various sources and index them subsequently. The indexing itself should also be more flexible, with possibilities for making adjustments when new products are added. The three product typologies could be integrated into the database as templates, offering possible indexing criteria as well as suggestions for relevant product types. Besides making designers acquainted with the typologies, such a common structure would also facilitate the use of the database by more than one designer. However, it should also be possible for the individual designer to personalize the database by adding his own criteria, types, names etc.

On the output side the number and the kind of criteria used in the retrieval process should be adjustable. More facilities for saving interesting organizations should be offered, maybe complemented with a history which keeps track of the retrieval process. The dynamic character of the interface, in which the movement of the samples is displayed in real-time, turned out to be an important factor in getting designers interested and engaged in the product. However, it can also impose a drawback in that, when the number of samples in the interaction circle increases, too much action can be taking place. With multiple samples moving at the same time, it quickly becomes too hard to follow all the changes that occur. This has as a negative side-effect that the interpretation of the relationships between the samples, which are the core

information of the database, imposes too much of a cognitive load on the user. The samples are moving, so the relationships between them change, but how exactly? Moreover, the 'fit' of the MDS algorithm quickly decreases when more samples have to be taken into account. Therefore, besides keeping the number of samples small (experiences showed 4 to 5 to be the most efficient), it should also be possible to show the movements of the samples to their new positions in discrete, controllable steps or to turn it off completely.

Finally, ProductWorld is currently no more than a front-end, offering no storage facilities for a large number of products yet. To turn it into a full-fledged product archive its interface has to be 'fitted' to an actual database, which offers the capabilities needed for storing and retrieving large amounts of data.

## 6.6 Discussion

ProductWorld was designed with the intention to create an interactive environment, in which a designer can build up and explore a design knowledge base in accordance with the ideas and conclusions, that have been put forward in this thesis. It offers its users full control over the organization of the database, as well as a new and dynamic way of browsing through its content. By basing both indexing and retrieval techniques mainly on visual assessments, maximum attention was directed to the appearances of the displayed product samples. The use of spatial arrangements as a means of indexing products into the database gives the designer full freedom to organize products to his precise taste, without being forced into categories that have been determined a priori. One of the key principles underlying the design of ProductWorld was the notion that by visibly showing the dynamics of the relationships between the samples, as well as how these are being influenced by the various similarity criteria, the designer implicitly builds up a better understanding of the design knowledge that is contained in the database.

The use of ProductWorld in an educational setting demonstrated its potential as a design support tool. Its high degree of interaction implicitly encouraged design students to get actively engaged with the material, thus requesting the same intense level of active involvement as traditional design

techniques, such as sketching, collage-making and model making. This involvement is considered to be essential: Through it the designer creates, evaluates and modifies different kind of representations, which enable him to deepen his understanding of the design problem at hand. Fundamental to this is the notion that the value of such techniques is not directly in their physical and tangible output, but much more in the knowledge the designer acquires through them.

How then does ProductWorld in its current form reflect the design criteria, which were listed in section 6.2? It is intended as an open environment which facilitates the organization of a collection of products by a designer. No automatic classification or intelligent reasoning techniques have been used, which gives the designer full control over the organization and the interpretation of the design knowledge stored in the database. In terms of expressiveness, the movements of the products in relation to each other, convey the strengths of their mutual relations and suggest a feeling of dynamics and looseness rather than of hard boundaries and prescriptions. Although the interface itself does not yet offer possibilities for personalization, a future version might incorporate such possibilities by allowing designers to add and select their own similarity criteria, to control the speed of the movements of the products etc.

As the tool has been designed with the intention to support the process of generating and developing of new concepts, it does not offer any direct possibilities for externalizing these concepts. It should therefore preferably be used in combination with other tools, such as pencil and paper, that do allow a rapid and fluent recording of possible design solutions. Furthermore, the interface facilitates and stimulates communication and discussion through its interactive, visual and open character. Individuality can be expressed, although limited, through the organizations made, which could become reflections of a designer's personal style in the same way as his sketches, collages or models. Shifting between indexing and retrieving is not implemented in the current prototype, but will certainly be added to a next version.

Finally, although ProductWorld does not prominently support motor skills, the act of indexing products by positioning them relative to each other does involve small-scale movements. Currently a version of ProductWorld is running in



the ID-Studiolab on the TRI-setup which is a body scaled interactive medium through which users can interact with their environment on three different scales: A large scale, used to create a sense of presence; a medium scale, used for organization, presentation and discussion of ideas; and a small scale, used for visualizing ideas. The large scale consists of a vertical projection area, the medium scale of a horizontal table projection and the small scale of a Wacom sketching tablet with an integrated screen. Interacting with ProductWorld is done on the medium scale, which involves virtually moving and arranging the product samples on the table, thus mimicking to a considerable extent the bodily activities of making collages in the real world. The results of the interactions are also displayed on the large scale to create an atmosphere and to present them to others. Further experience is needed, however, to determine the added value of using ProductWorld on such a setup.

*In the final chapter...*

the overall results of the thesis are combined and discussed on a more general level. Possible applications and implications, as well as directions for future research, are discussed for four areas of interest: design education, design practice, design methodology and design support systems.

