Multiple voices in the graphic design of a visual information system

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ABSTRACT
This paper describes the work of a multi-disciplinary team developing the visual interface of an interactive, freely navigable 3D world. The focus is on working methods: searching for visual examples, sketching, formulating design principles, prototyping, testing and developing guidelines for scene composition. Practices of aligning multiple voices, the different roles of architect, 3D designer, and computer graphic specialist, as well as the power of visualizations are discussed. At the core of this analysis is the notion of innovative design as 'oscillating between precision and fuzziness'.

Keywords
Interactive 3D world, graphic design, visualization strategies, design methodology

INTRODUCTION
This paper explores the case of a team of systems developers, computer graphic specialists, architects, a 3D design specialist, and a graphic designer developing the visual interface to a navigable, interactive 3D world. The *Wunderkammer* is a visual environment in which multimedia inspirational materials can be placed, stored, encountered, found, displayed, and integrated with the flow of the work. It is created interactively. We have written elsewhere about the concept of *Wunderkammer*, which is grounded in fieldwork within an architectural office and a studio of landscape architects, which is part of European Research Project DESARTE [1] Here we look at a stage in the design process, which focuses on the graphic design of the 3D visual interface.

From the point of view of participatory design this is a particularly interesting phase, for various reasons. First, it is in the nature of the design task that visual material, metaphor, and association play a major role in how the participants communicate ideas, define positions, and create representations. Secondly, the complexity and novelty of the task requires to

conduct and align several professional discourses at the same time:

- Architects' approach to defining and visualizing space and their experiences with using computer tools

- Computer scientists' experiences with the design of 3D user interfaces and with the problems of rendering highly complex 3D worlds in 'real time'

- A 3D designer's approach to constructing visual interfaces

- The ideas of use which place emphasis on different visual features of the *Wunderkammer*.

Complexity and the multiplicity of voices require an open, non-linear mode of developing as well as rich forms of communicating. One way of bringing these multiple worlds together is through shared tools and procedures, another way is through imagery, metaphors, and descriptions which can translate between different views of the product to be developed.

In this paper we, firstly, describe some of our working methods – user 'experiments', searching for visual examples, sketching, formulating 'design principles', prototyping, testing, and developing guidelines for scene composition.

We then analyse how the designer team members' multi-disciplinary resources – professional knowledges, visual cultures, presentation techniques, etc. - were used for creating common representations of the 3D world, in a process of in a process of "combining and contradictory combining, of discovering and inventing'.

THE IDEA
The challenges we face are partly to do with our notion of *Wunderkammer*. It is grounded in the need for imprecise, fluent forms of categorizing inspirational objects as observed in our fieldwork of architectural practice. The nature and sources of such inspirational material - images, models, samples, and other objects - are varied and so are the ways of collecting them. As association objects they assist the architects in their effort to form, develop, and communicate design concepts. Currently, such objects are stored or kept mainly

within the physical space of the office, and they are categorized and archived in a fairly static yet relatively broad, sweeping way. Current practice also makes little provision for aesthetic or conceptual categorization and retrieval.

The *Wunderkammer* is envisaged as a visual association space. Users should be able to intuitively insert an object in a particular *Wunderkammer* place, which fits his/her range of associations with this image. A place should be 'knowable' to support the meaningful placings of objects and sufficiently open to invite different associations. We talk about this placing of inspirational objects in fuzzy but culturally connoted places as 'weak indexing' [2]. A place should also attract the attention of the traveler and collector, who encounters the artfully placed images, selects some, and combines them in surprising, contradictory ways. The emphasis is on combinations of visual material that stimulate users' associations.
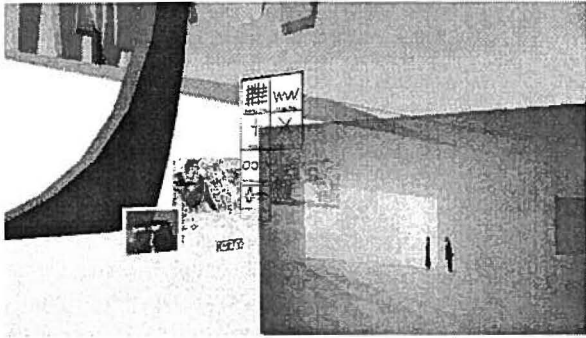

Fig. 1: Encountering inspirational objects in the desert

The architects imagined this inspiration space of *Wunderkammer* as a 'pars pro toto' of the world. The process of defining the world has been described elsewhere in more detail [3]. Its composition reflects architects' professional categorization schemes on the one hand, the contents of their work and their association material on the other hand. Inspirational material from current projects was used in discussion of places that might invite architects to place materials and to search for them, like 'large sculptures in urban space', stone formations (to be placed in a mountain area or in a quarry), 'stealth bomber' (close to an airport), 'transmission lines' (near a highway), paintings (for the art gallery), and many more. The current 'pars pro toto' world is a construction site, with two modules - *Skyscraper City* and *Desert/Ocean* - and 'place-holders' for additional areas of significance for architects' work and the materials they collect.

The 3D *Wunderkammer* is an interactive, freely navigable real time world. The places in this world do not resemble any 'real' place. They are 'mis-en-scène' for inviting the placing of inspirational objects and for stimulating contradictory associations. A sufficiently rich association space requires providing a significant number of places. This makes the *Wunderkammer* world large and extended. Users should not only be able to identify these places from a distance, but also know where they are when navigating through an area.

Hence, recognizable and stimulating vistas of all places need to be displayed. Each of the *Wunderkammer* places is complexly designed, satisfying architects' aesthetic judgment. Designing such a world is an aesthetically and technically challenging task.

THE HISTORY

Developing the visual interface of the *Wunderkammer* world was done in several steps, with different versions reflecting changing priorities and insights.
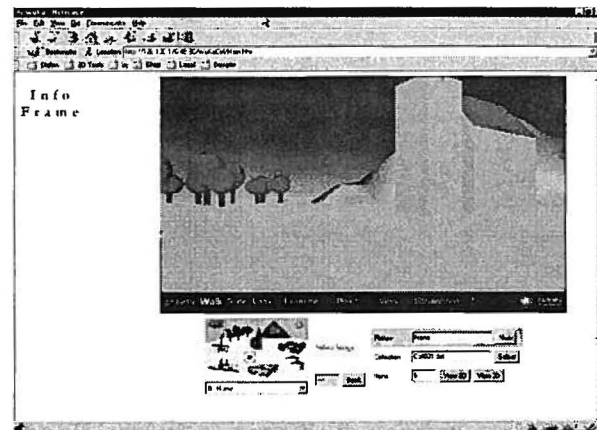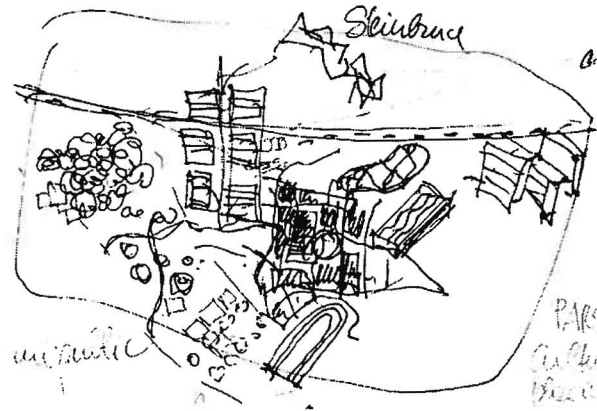

Fig.2: The architect's first sketch of the *Wunderkammer* world and its translation into 3D

The first version was a simple symbolic ,village' with a few significant and easily recognizable places. While simple, it already supported the basic operations. Users could navigate in this space and explore it. They could place inspirational objects (images), and manipulate them (turning, enlarging, re-positioning them). They also could collect images and place them in an exhibition space. The graphic design was a system developer's quite literal translation of the architect's first sketch into a 3D environment, using a series of simple and compact objects with clear contours. The first users of this world 'knew' where they placed their images.
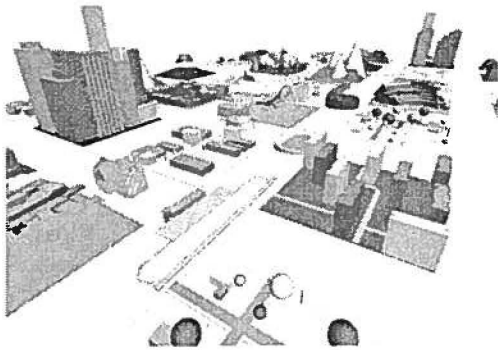
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Fig.3: The first Collage City/Landscape

A more elaborate assemblage of types of city and landscape – a *Collage City*/Landscape [4] - replaced this version. This 3D world was directly inspired by the architects' approach to urban planning, which aims at creating specific spatial qualities on the one hand, leaving space for unforeseen uses on the other hand. Hence the idea of a user-definable plug-in-world, based on a neutral grid.

The first version of this world was still predominantly symbolic. It contained a series of significant objects – amphitheatre, museum, highway, bridge, etc., which were placed in-between the different areas. This world offered interesting views, in particular from bird-view, when flying over. The approach was architectural 3D modeling with an emphasis on structural elements. To be imported into a real-time 3D environment, the AutoCAD files had to be converted into VRML files and assembled into the plug-in-world. This produced serious performance problems. Needs of the traveler of this world for orientation were simply not considered at this stage.

The next step was to focus on navigability and performance. The architects switched to 3D Studio, a modeling tool with better 3D compatibility. The symbolic-iconographic language was replaced by a structural approach. Each place was architecturally constructed as containers for pictorial material to be filled in. The screenshot of *Industry* captures some of the qualities of this world. Its language is abstract, focusing on building structure, but naturalistic.
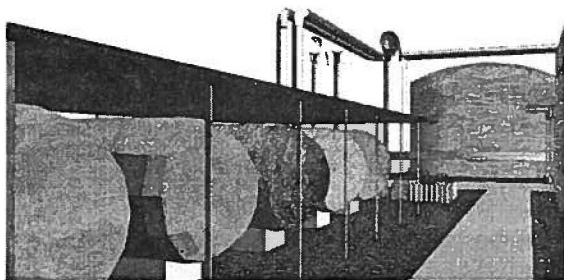

Fig.4: An architecturally constructed world - screenshot of *Industry*

As there were still performance problems with these quite complex constructs, the architects reduced the detailedness of their designs, by removing significant objects. They started experimenting with textures, including scans of materials and vegetation, which also had to be simplified step-by-step. The result was a quite monotonous world, which lacked in stimulating detail and atmosphere.

RE-DESIGNING THE WUNDERKAMMER

The current re-design builds on experiences with these different versions. A working prototype with well-developed functionalities is now available[1].

The following sections are based on observations of numerous joint prototyping sessions as well as in-depth interviews with the different participants. The working method is an iterative process in several steps:

- Users explore the *Wunderkammer*, travelling, discovering and placing inspirational objects.

- The user-architects, in intense conversations with the other team members, describe parts of the world, define atmospheric qualities and structure, collect and discuss visual examples, produce sketches, formulate 'design principles'.

- The 3D design specialist, in consultations with the computer graphic specialists and the graphic designer, translates these multi-media descriptions into 3D designs.

- The whole team views each design, navigating through it, making comments and suggestions, providing additional visual material.

- The computer graphic specialists test the performance of the design and its navigability; they apply various post-production techniques, and define guidelines for scene composition.

Experiences of use

The modes of traveling and seeing the *Wunderkammer*, of placing and collecting images, and displaying them are informed by our ethnographic work and the cooperation with practitioners. Each prototyping session is an opportunity for the participating architects to explore the *Wunderkammer* from the point of view of use. We also conduct short design sessions of about 90 minutes with additional architect-users, asking them to explore the *Wunderkammer*, traveling, discovering, and placing inspirational objects. Some of these people bring their own set of scanned images to these ses-

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[1] The 3D *Wunderkammer* runs in a web-browser. The program is a set of Java Applets, and uses the Cosmo Player plug-in to display VRML files. The prototype version runs in Netscape Communicator V 4.5, and uses Cosmo Player V 2.1. Communication with the VRML scene is carried out via the External Authoring Interface. The program requires the host computer to be set up as a Java RMI Server with database access (JDBC-ODBC bridge), and uses an Access relational database. All the data is accessed via HTTP.

sions. They comment on the changes to the prototype and, in particular, on the visual-aesthetic quality of the 3D designs.

One of users' preoccupations is with the feeling of travelling within the *Wunderkammer* world and the ease with which this can be done. Movement requires and is supported by elements such as paths, in-between spaces, elevators, and doors. The traveller may want to see interesting detail, be helped to change level or invited to turn around a corner, be able to walk through a wall or fence, etc. Some modules are simply not well enough designed for this purpose. Volumes invite the traveller to enter through doors or look through a window. There is the need for some interior spaces, which can be furnished with inspirational objects.

Another relevant issue of use is the legibility of *Wunderkammer* places. A place should be intuitively knowable, provide visual associations for primarily visual materials. While some places are easily recognizable from a distance, others are difficult to identify.

Users make clear statements about atmospheric qualities. Some places, such as the city are expected to be lively –

> B (in *Skyscraper City*):" this is missing, the liveliness – people, glitter, light, colour, advertisement – this is a ghost city – "
>
> E (in the Forest):"…you feel very lonely, I would like to meet someone – ah, someone is collecting mushrooms here – it should not be so deserted – ".

Qualities such as dense, hectic, peaceful, irregular, unexpected, etc. are evoked (and not always experienced) when talking about *Wunderkammer* places. And there is a connection between graphic design and mode of movement, places being encountered differently, depending on the speed and smoothness of movement.
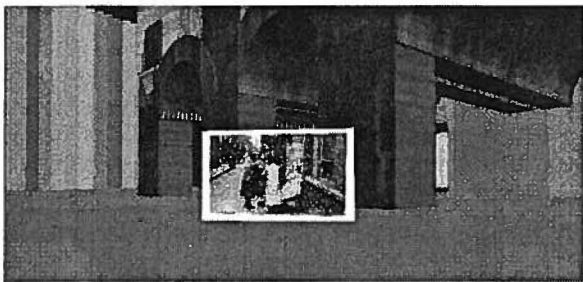

Fig. 5: Users' experience of atmospheric qualities

In general users found too much neutrality and too little specificity. However, none of the users expected 'realism'. To the right of Fig. 5 is an example of what one of the architect-users described as 'density' – "combining the abstract (the volumes of columns) with the literal (the image of 'chattering women')". From this perspective, detail is something, which should be sparsely used, if at all, more as a signifier than as a pervading feature.

Another issue is to do with the relationships between the *Wunderkammer* world and the inspirational materials users

place in it. Currently, some of these images are difficult to spot (e.g. in the forest) or they are scattered rather randomly across spacious areas (e.g. on roads or other openings). The *Wunderkammer* needs focal points for placing inspirational objects such as paths (river, railway, etc.), clearings (e.g. in the forest), squares, or poster walls. At the same time qualities such as encountering images 'on the road', being able to fly through, have them suddenly appear at the periphery and grow big in an instance, should be preserved.

As our users are architects, they want to *do* something with the *Wunderkammer* world – rearrange, add detail, construct – and eventually design their own modules:

> O: "I find these textures irritating – because they introduce a particular scale – I would like an unscaled world, what I am looking for is much more open (talks about his own design practice) – bringing in particular qualities such as dim, shiny, etc., is the next step – I would like to be able to do this as a user – "
>
> W: "I discover particular qualities – as an architect I want to be able to experiment with them, for example to build a relationship between an object and the surrounding architecture – ".

One of the special aspects of our project is that architects are users of the *Wunderkammer* and co-designers at the same time. As users they are confronted with the merits and the shortcomings of their own visual culture with respect to the design of navigable 3D worlds. They ask questions such as: where am I, how do I get back to where I was, what do I see? Furthermore, architects' experiences reflect the tensions between different modes of use. As travelers in the *Wunderkammer* they are looking for surprising combinations of materials. At the same time they want to use it as an archive of dedicated materials, such as textures, stones, chairs, etc., easy to retrieve. There is a need for both, ambiguous and open, and well-defined places.

Defining the qualities of places

As already mentioned, the overall design of the *Wunderkammer* was directly inspired by the architects' approach to urban planning. At its core is the idea to provide a 'solution space' rather than a 'masterplan' that specifies areas and objects in great detail.

A common starting point in urban planning is a neutral grid [5], which can be filled with places of different qualities, with volumes and voids, some of them dense and compact, touching each other, others light, spread out, with spaces in-between. Architects have developed a way of 'talking' about qualities, which is rich in metaphorical language, images, and associations.

In our joint work, the architects use examples such as this urban planning project, to communicate this approach to defining the qualities of places. One of the places in this project was conceived as mediating between the base of four old *Gasometer* buildings in Vienna and a building under construction – between 'harsh nature' on the one hand, and 'transparent walls, impregnated with light and color' on the

other hand. The architects expressed the qualities of this 'art space' through metaphors and a series of inspirational objects (Fig. 6): *Artificial Nature* (a painting by Mario Merz), *The Big Wall* (a painting by Richard Serra) and *Chartres* [6]. Sketches, drawings and stories were created around each of these themes or qualities. The growing, metamorphosing idea of 'art space' was represented in the material that was collected and produced, including the talk around it.
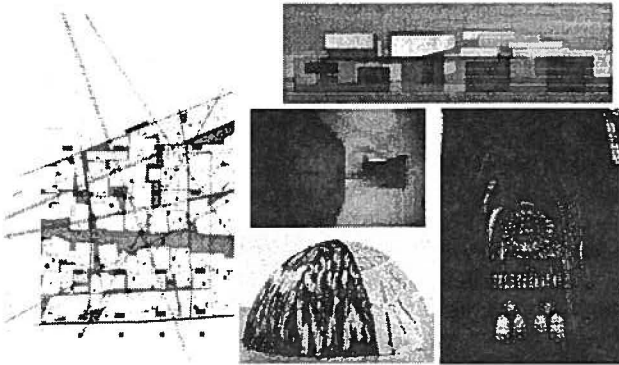

Fig.6: Defining the qualities of an urban place

This method is applied to characterizing *Wunderkammer* places. Rather than specifying 'how a place should look like', its qualities are described. So is for example *Skyscraper City* imagined as a part of the world, which the architects portray as "anonymous, closed, hermetic, glamorous, glittering, fashionable, noisy and fast, with islands of high culture and consumerism, intimacy and tranquility, but also with permeable boundaries to the derelict, dirty areas of inner cities".

An advantage of a digital 3D environment is the freedom to vary scale and density. A place, which in reality might be extended and sparsely populated, can be compressed so as to intensify some of its qualities. The idea of *Skyscraper City* can be condensed in a set of significant buildings around a plaza, which are packed with glitter, rich decoration, and icons of fashionable life. Another strategy is to place contrasting environments next to each other, emphasizing contradictions such as between glamorous and neglected, artificial and natural, transparent and solid (Fig. 7).
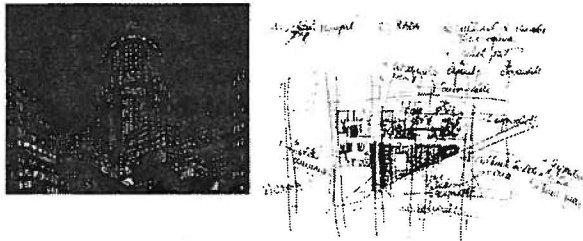

Fig.7: Compressing space – image and sketch

Exploring visualization strategies

The next step consists in finding an adequate visual language for expressing these qualities. Metaphorical descriptions of a place are interwoven with visual material, like in this exam-

ple, of assemblies of different formations of desert, mountains, and ocean into a highly compressed space (Fig. 8):

> "The Ocean, first a zone of stormy waters with high waves, like in Japanese wood engravings, followed by a zone of idyllic water, painted, populated by boats, then a peninsula with one of its sides cliffy, with a coral reef, on the other side a resort place. From the coast, which offers a natural path several, entrances into the desert area, first a rocky part with valleys, an archaeological site, oasis, then a zone of dunes, which ends in a volcano".

While describing his notion of *Ocean/Desert*, the architect produces a sketch, which is arranged, together with visual examples copied from art books, into a rich visual representation of the area.
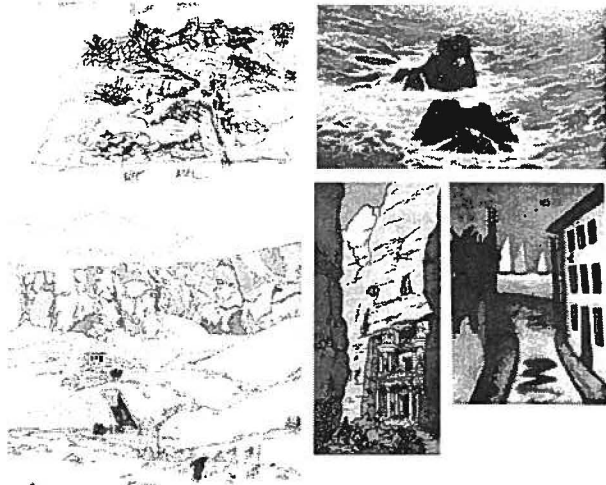

Fig. 8: Assembling sketch and visual examples

Intense discussion of these visual examples leads to the formulation of 'design principles', among them:

- To stress the iconographic aspect of objects such as shapes of roofs, towers, sails, etc. or to reduce objects to strong edges (using a thick brush), openings, etc. (like in the Beckmann painting, Fig.8)

- To use combinations of visualization methods, e.g. collage with painting, linear structures with movement, rendered objects with sketches, mapped textures or images with exact drawings, etc.

- To use light (reflections, shadows, etc.) as well as unobtrusive forms of object animation whenever this helps to enliven a place (the lights of passing cars, moving water or leaves).

Translating 'text-image' into 3D designs

The 3D designer takes all this material to his workplace and starts developing a prototypal realization, which is then intensely discussed. Here is an example of viewing one of the first designs of *Skyscraper City*. Central issues in this session are structuring space and creating atmosphere. One of the architect's concerns is how to create signifiers – 'identification

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objects' - for different parts of city. He stresses the need to create a differentiated topography, by compressing, widening, introducing different levels. He also suggests to experiment with different ground level zones, from open and inviting, to closed and rejecting. An idea from urban planning is introduced - to leave the ground floor entirely open and to implant sets of displays in this space, e.g. fashionable shops. Here depth is created through layers and partial openings.
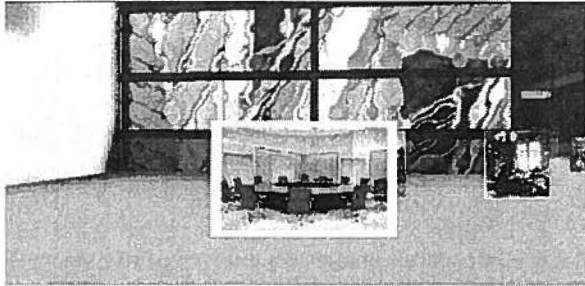

Fig. 9: Discussing the design of *Skyscraper City*

Another concern is how to differentiate and intensify atmospheric qualities, using colour (from 'golden and glittering' for the fashionable areas, to 'gray' for the business zone, and 'yellowish' for the more derelict parts). The graphic designer is asked to provide textures for the façades that help introduce specificity.

A special concern is the navigability of the world, which is partly to do with its legibility, partly with performance. The legibility of an area depends on its structural aspects on the one hand, on the use of detail and a significant visual language on the other hand. Detail is used here in an exemplary way to help users identify and interpret the place, like in this first prototype of Ocean/Desert, where significant objects – volcano, lighthouse, Bedouin tent, oasis, caravan, desert monument, etc. – create recognizable places.

Here the viewpoint of the computer graphic specialists is introduced as complementary to the architect's and the graphic designer's experiences. They, for example, propose to use different textures, depending on the user's distance from a place. While the skyline with buildings with windows painted in black looks good from a distance, different, more detailed textures are needed when the user comes closer. This suggests a technique like the one used for comics where detail increases with nearness. A 'stage sets' technique is discussed for objects such as trees, a caravan, the skyline, the set of mountain scenes surrounding the desert, etc. While in the theatre the spectator is usually not allowed to enter the stage set, s/he may pass through a set in the 3D world or the set may move with the spectator, as do the trees in Skyscraper City, with tiny birds or butterflies emerging.
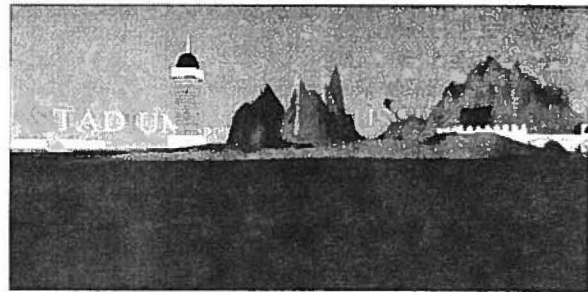

Fig. 10: Discussing the design of *Ocean/Desert*

A 3D environment lives from a sense of depth and of the possibilities of travel. The design of structures and objects in our physical environment is tied to 'practical grammars of perception' and it may be useful to build on these when designing a 3D environment such as the *Wunderkammer.* An important source of knowledge is Kevin Lynch's work [7], which has been widely referred to in user interface design, showing that the spatial ordering of artefacts shapes the legibility of urban spaces.

Research suggests that people readily apply and adjust the metaphor of urban space or landscape to a digital environment, even if this abstracts from reality [8]. The role of the graphic designer here is to introduce visual elements that make use of 'practical grammars of perception' in everyday life.

Guidelines for scene composition

It is a well-known fact that rendering 3D worlds in 'real time' so that users can navigate through them with ease and explore them is a task that is challenging the hardware and software configuration of the machine. The main goal of real-time graphics is not to render scenes as close to real world scenes as possible, but to render the scenes as fast as possible, still giving the observer recognizable representations of the real world. If the 3D designer wants his scenes to be rendered in real-time, he has to take a few simple rules into account. Viewing and discussing the design with the computer graphic specialists helps understand and apply these rules.

Some effort was needed to adapt these rules for scene composition to the specific problems of the *Wunderkammer* design and to make them practicable. They developed these guidelines in an empirical way from testing the 3D designs. A 'handbook' was produced, discussing *Wunderkammer* scenes and suggesting practical ways to improve performance.

Scene designers should be aware of real time rendering need all the time when they are designing new worlds. This will make the scene simpler, without any loss in visual quality. One of computer graphic specialists' concerns is grouping objects so as to optimize their spatial arrangement from the point of view of rendering in order to increase rendering speed Another question is how to avoid too complex modeling. They for example simplified landscape meshes, decreasing polygon count between 50% and 80%, with no visible

difference between original and objects with reduced mesh (Fig. 11). Furthermore, there should be no unnecessary modeled details, like interior modeling that can never be seen. All objects should be modeled as simple as possible, using VRML primitives whenever this makes sense. Also textures may help in achieving the same impression using reduced rendering time.
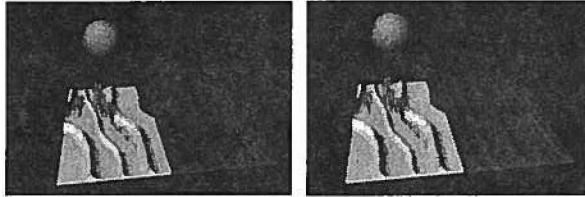

Fig. 11: Guidelines for scene composition

If the modeling is done in a non-VRML modeler (like 3D Studio), and the final scene is converted to VRML, some post-production is almost always needed. If the scene designer tries to keep the world simple during the design, the postproduction will be easier, and can produce better (which means, easier to render) scenes at the end.

The prototyping sessions are used for developing, discussing and refining both, guidelines for scene composition and post-production methods. Rather than being kept separate as a 'computer graphics research issues', they are interwoven with the ongoing design work.

DISCUSSION
When looking at these examples of cooperatively imagining and designing a set of navigable 3D worlds from a participatory design perspective, several issues stand out:

- The alignment of multiple professional perspectives in ways that help solve a highly specialized design problem that cuts across disciplinary boundaries

- The role of visualizations in expressing, developing, detailing, communicating, and presenting the evolving design concept

- The *Wunderkammer* as a 'placeholder' and 'meandering' as a working method.

Multiple perspectives
In a series of case studies on the work of systems designers we have identified heterogeneity as an intricate part of design work [9]. We used the notion of 'boundaries', analyzing how software teams managed membership in multiple worlds. From this point of view we can look at the visual interface of *Wunderkammer* as a 'boundary object', which is both, flexible, shapeable and open for a variety of activities and forms of expression, and sufficiently defined for allowing the development of particular forms of perception and use [10].

The need for such multidisciplinary cooperation grew out of our experiences with the first versions of the *Wunderkammer* world. These versions showed some of the strengths but also

the limitations of an architecturally constructed 3D world. Architects construct 2D and 3D representations that allow the 'immutable transfer' of information [11]. Their visualizations are detailed, optically consist scale-constructions of worlds to be built. In this sense they are 'real' and at the same time highly abstract, lacking the kind of rich and 'telling' detail necessary for conveying highly differentiated content. Architects' main field of experience is to do with structure, topography, the qualities of space, with light as a space-generating element, and with the effects of combinations of materials in the real world. When producing 3D visualizations of objects, architects tend to focus on ease of construction and optimal image quality. The images are used as 'stills' to be plotted out or merged into vivid realistic bitmap animations.

The graphic designer's professional world is the traditional visual media of posters, book illustrations, etc., and increasingly also includes multi-media displays as may be used in an exhibition. Their main contribution to the design of a navigable 3D world is their experience with textures. In so far they are specialists in making the 3D world legible, providing pictorial elements which may act as signifiers. These elements may be figuratively loaded (such as images of façades) or abstract (such as signs that provide orientation).

Computer graphic specialists have the ability to navigate through a 3D world, knowing how it is mathematically constructed. This helps them identify critical spots in this world such as too complex objects, disadvantageous object groupings, etc. They have developed the art of smoothening out, simplifying, and playing with optical illusion, without diminishing the visual qualities of the design. In doing so they have to combine their technical knowledge with aesthetic judgments, absorbing, reflecting and translating what they learn from the architect and the graphic designer.

Interestingly, the pooling of these diverse and complementary experiences in itself is not sufficient to develop 3D designs that satisfy all the requirements we have set ourselves for the *Wunderkammer*. While the exact scale-constructions of architects do not cope well with the extension of such a world, video and comic are inapt to cope with 'coming very near'. The 3D designer's role is to assimilate all those voices in his work. When entering the project, his approach was shaped by the experience of comics, video, and computer games. This was useful, but also a constraint. Game designers do not only have the benefit of specialized hardware. They are used to working with fixed viewpoints and paths. This makes them less concerned with rendering speed. The 3D designer's task is to find a balance between the different visual languages – of architectural constructions on the one hand, the language of film and comics on the other hand.

The multiplicity of perspectives reflects differences of visual cultures. The question in our project was how to align these for creating 'novel' visualizations strategies that appropriately take account of the affordances and limitations of an interactive, navigable 3D world. Norman, O'Brien and Rodden

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[12] refer to the visual arts – namely cubism, futurism, and suprematism – as a source of inspiration for designing 3D environments. They point to the aptitude of 'abstract' art to communicate spatial depth and dynamics. Our approach here is to experiment with a wide range of visual languages, from painting, comics, and woodcuttings to letter-buildings and constructivist stage designs, mixing them and using their strengths in complementary ways.

For example, stage sets as implantations in an architecturally constructed world acquire some of the in-between qualities we are looking for. The 3D designer's special role here is to make use of the whole repertoire of visualizations and to literally 'compose' the worlds in great detail, deciding when the user sees what, from whole objects to detailed textures.

Working with visualizations

One of the main aspects of our work is the central role of visualizations in expressing, developing, detailing, communicating, and presenting the evolving design concept. This is partly to do with the intensely visual character of the world to be designed, partly with the professional culture of the people involved in it.

Visual examples are used all the time. Their sources are manifold. The graphic designer looks through his large digital library of visual materials. Images from art books and journals are scanned, printed out, and arranged on a pin wall. While working, the 3D designer places significant visual material on his desk.

Lynch [13] emphasizes the 'eidetic' properties of visualizations. An image may synthesize the generalized or idealized version of an object rather than be literal representation of it. Many of the visual examples (see Fig. 7) are a source of inspiration, portraying some of the envisioned qualities of e.g. atmosphere, as present in colour or a special stroke. They serve as association objects rather than instructing the 3D designer in a direct way of how to proceed. Some of the material is also used directly in the form of textures.
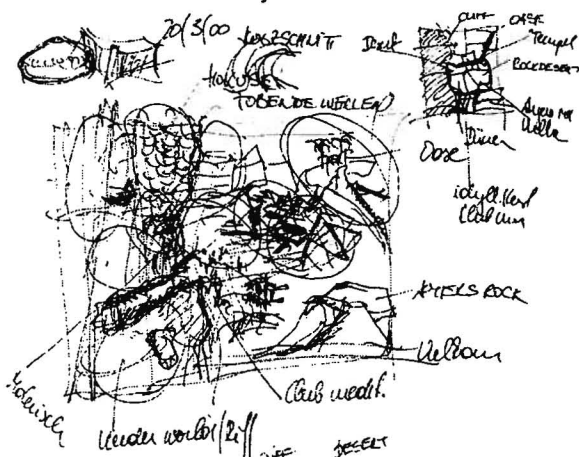

Fig. 12: Visualizations as 'network organizing devices'

One achievement of visualizations is that they are 'network-organizing-devices', individual and interactive thinking tools, organizers of interdisciplinary communication [14]. As has been described elsewhere, sketching and explaining ideas are tightly interwoven activities [15]. While producing this sketch (Fig. 12), the architect was thinking aloud, listening to questions and suggestions, and simultaneously visualizing his idea of places with different qualities in *Ocean/Desert*. A common understanding of the idea was created. Talking about *Ocean/Desert* was facilitated by being able to point to the sketch, re-reading the textual annotations, and connecting them with other visual materials.

A related achievement of visualizations is that they support the dynamic interplay of images, metaphors, and analogies. Typical of our prototyping sessions is the intermingling of visual material with text. The visualizations are used and created as part of talk. Many of them contain text as well as visual elements [16]. These types of visual-verbal relationships are crucial for many design disciplines. As Mitchell argues: " ... all arts are 'composite' art (both text and image); all media are mixed media, combining different codes, discursive connections, channels, sensory and cognitive modes "[17, p. 95]. So is writing in its graphic form inseparable from the visual. Conversely, stories are created around visual materials. The growing, metamorphosing idea of *Ocean/Desert* is represented in the material that is collected and produced, including the talk around it.

Most importantly for the joint prototyping work, the visual materials serve as tools for mobilizing heterogeneous resources, which are open to diverse levels of interpretation and understanding, and invite 'contradictory (or surprising) combinations'. This is to do with our notion of innovative design as oscillating between 'precision and fuzziness' [18]. A good example in this respect is the prototypal 3D designs, visualizations themselves. They are resonant of multiple voices, inviting participants to project their imagination onto the *Wunderkammer* world. They are incomplete and preliminary, yet very concrete. While their concreteness allows evaluating what has been achieved on the one hand, their openness stimulates ideas of what to change, how to develop further, etc., including alternative or novel ideas of how to approach the design of *Wunderkammer* places

The *Wunderkammer* as a 'placeholder'

In a previous paper we discussed the notion of 'placeholder' and its relevance for architectural as well as for systems design [19]. A placeholder stands for something which is in formation. Working with placeholders for an element or a design feature rather than with a full specification of it, requires holding things at a stage of incompletion.

Designing the visual interface of the *Wunderkammer* is a perfect example of this strategy. In the beginning of the project, the *Wunderkammer* was imagined in talking about architectural practice and the need for ready access to a wide range of inspirational objects in this process. It mainly existed as

an expression of users' fantasies, which were visualized in a series of sketches, the metaphorical language the architects used in talking about it, and in their collections of association images. Step by step prototypal realizations were created and with them more and more detailed scenarios of use. The envisaged interactivity was implemented technically, more and more functionalities were developed, and the working prototype was stabilized. Still, the architects continued to perceive the (changing) visual interface as preliminary. Even in the current prototyping work the emphasis is often on 'design principles' rather than on the appearance of the Wunderkammer places. 'Fixing' a design is defined as a preliminary closure of something which has to be held open.

A danger of this approach is that the emergent products tend to 'slip away'. A whole archive of 3D designs is being created in this process. An important aspect of the design work is to maintain these examples present as part of a solution space and to refer to them in ways that we described as 'meandering' [18]. Meandering means that the possibility to suspend a design decision or to re-open it even at a rather late stage of the planning process should be preserved. It should be possible to go back to an earlier stage of a project, to images, associations, possible solutions that have not been pursued at an earlier point. Each 3D design combines parameters that have been fixed with open parameters.

This working method does not only allow accounting for the complexity of the objects to be designed. It is an important element of the process of listening to and aligning different voices.

CONCLUSION
In this paper we discussed how representatives from different professional communities cooperate in the design of navigable 3D worlds. While this is one of many cases of participatory design that have been reported, it is also special in some ways. The story of *Wunderkammer* helps highlight issues such as:

- The pooling of diverse, partly complementary knowledges and visual cultures into 'novel' visualizations strategies, and the 'intermediary' role of the 3D designer in this process

- The uses of visual materials – sketches, art work, the evolving 3D designs - as 'intermediaries' [20] in expressing, detailing, and communicating design ideas

- The interwovenness of technical and aesthetical judgments and the different viewpoints each profession takes on these

- The openness of the design process, which is partly to do with the technical and aesthetic complexity of the product itself, partly with the method, which we described as 'working with placeholders' and as 'meandering'.

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