DRAFTED VIRTUAL REALITY

A new paradigm to design with computers

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Abstract. This paper proposes a new technique for designing spaces, called Drafted Virtual Reality (DVR), to be used in interior, architectural or industrial design. It proposes the construction of virtual panoramic environments through the QuickTime VR (QTVR) Panorama platform (Apple), starting from sketches made by hand using traditional pen-on-paper techniques. To construct these drawings, the designer uses the computer to build a graphic panoramic template. Using this technique, the designer takes advantage of both approaches, the capacities and possibilities of the computer using VR (3D environments, interaction and real-time), and those of free-hand sketches (abstraction, inaccuracy and ambiguity). These last elements are essential for the first steps of the design process in contrast to the conventional techniques of 3D modeling interacting with mouse and menus. In the development of design computer solutions, it is important to know the user well. However, most researchers propose systems very different than how designers actually work. The DVR doesn't try to simulate analog tools by computers (digital pens), but takes advantage of hand drawn sketches created using analog techniques that are already known by designers and improved by VR visualization. A review of the implication of this technique on the design process. Not only is the technique fast and easy to learn, the results show that the designer can express their individuality and the idiosyncrasies of their personal sketches; important elements hard to achieve with conventional 3D modeling techniques. Finally, this technique can be perceived as a new paradigm in the way we work with computers in design. The limitations of interfaces and usage of current technology are seen when the designer outputs information from the system to process using other analog techniques. The proposed solution marries the existing competencies and techniques of the designer with the advantages of the computer processing. The

quality of the virtual experience of this technique is consistent with current designer's intentions within the traditional design process.

1. Two histories

Architectural representation and computer graphics represent two histories concerned with paradigms relating to 3D information processing. Comparing the two histories we can say that they are both challenged by Virtual Reality (VR).

In the antiquity of architectural representation it seems that plans (2D documents) weren't use to build. The artist or project manager, as the architect did not yet exist as a profession at this time, made wood scaled model mock-ups, featuring all the details including interiors, textures, windows, etc., and was the only tool to process the design information and the only media to present and visualize the design for clients. It was time consuming to construct these models, some times even taking years as the concept for the building was developed in parallel to the making of the model. The model *was* the conceptual tool of the time. During the Renaissance's cultural revolution and with the goal of representing and understand classical architecture, F. Brunelleschi proposes perspective as another tool to represent buildings and urban landscapes in a realistic way. The changing design tools combined with the specific knowledge to create 2D drawings (plans and perspectives), defined architecture as a profession. Until now, this vision of the architect has remained, and the plans, mock-ups, and perspectives remain the principal tools and hallmarks of the profession. However, beginning in the 1980's this set of tools was enriched by a new one: the computer. Let's review its history.

In 1833 Charles Babbage proposes the mechanic computer to treat numeric information. During the Second World War, Alan Turing advances the idea that the computer can process symbols and logic and not only numbers. Later, Ivan Sutherland (1963) develops a system called "Sketchpad: A Man-machine Graphical Communication System" where the user communicates with the computer graphically. From this point onwards the computer's evolution develops rapidly, specifically in the field of interfaces. The result of this evolution is the processing of information graphically through easy-to-use interfaces, creating new ways to work for numerous disciplines including Architecture.

At the beginning the computer was a best and faster way of drawing plans in architecture and other disciplines related to design resulting in the creation of CAD software. Due to the time involved in making the perspectives by hand, the computer began to be used to assemble perspectives, taking advantages its ability to calculate. Based on these representations, the

computer is used again to build 3D animations and walkthroughs. Finally a new interface is added in lieu of the traditional computer screen: the direct interaction with 3D graphics in an immersive way through head-mounted-displays (VR). Slowly the computer invades other traditional design tools proposing digital ones, asking old skills and experiences already acquired by the user to be retired and requiring new ones to be developed.

2. One Common Point

Observing these two histories and considering the evolution of paradigms concerning information processing as a consequence of changing tools and knowledge, we can say there is a common point: the way we communicate information. In architecture at the beginning the mock-up represented the building well, but some problems still existed: the construction of these models was labor intensive and the reduced scale was a significant problem to visualizing and feeling the space well. The client and the designer visualized the information transmitted by the mock-up through a "Gulliver" effect (Porter, 1979), as giants observing a tiny building resulting from the very reduced scale and the human angle of vision that is not adapted to it. Additionally, the plans and perspectives present other problems: the abstraction of 3D information that needed to be "codified" in 2D information on paper (plans), and the creation of the perspective that took a long time to be calculated and finished and in addition was static. These problems limited a good understanding of the shapes, spaces and proportions of the project.

A new challenge for computer graphics aside from technical problems was proposed: how to communicate the information between the user and the machine (the interface). The mechanical computer interface consisted of cranks and levers; then perforated cards; later groups of interrupters defined the program to execute; eventually command lines that needed to be written without syntax errors until Ivan Sutherland's proposal to communicate graphically with the machine, opening the door to the interactivity. The foundation for this type of computing was at XEROX Parc "1972-1980" where the direct manipulation of a graphical user interface (windows and icons) using a mouse was proposed. Douglas Englebart invented this device in 1965 (Rheingold, 1991). At the same time, Sutherland (1965; 1968) develops the head-mounted-display preparing the foundation for the development of human computer interaction in virtual 3D environments (VR).

One of the bigger challenges for this kind computer graphics is to give the users the sense of presence inside another environment. Work in VR suggest different proposition to offer this experience through different techniques including interactive panoramas. This goal doesn't come from the

last century but from the XVIII century. The first panoramic environment was designed 200 years ago in Scotland. Robert Baker (Wright, 2000; Oettermann, 1997) developed a technique for the "virtual" visualization of Edinburgh using a big panoramic painting (360°) to be placed in a large circular building. The solution would allow a group of people to share the experience of being in that city without really being there.

It is at this point in time that the two histories converge. In architecture, this ultimate way to process and perceive visual information (3D) is presented as the ideal one, because the project is essentially in 3D and because it is possible to design directly in a 3D virtual world without the coding and decoding of plans. In computer graphics, due to the intuitive interaction without abstraction, only with body movement, can limit errors in communication of information. However, some problems remain in the way technology developers propose VR systems.

3. Some contradictions

With the exception of some software programs and hardware systems the architect and the designer often take a passive position regarding the advancement in computer graphics due to their professional education and professional practice. They accept the proposed changes of this tool without appropriating them. Most of the time, computer scientists or programmers impose hardware and software solutions on the designer without taking in account all the aspects of the practice of design.

VR computer scientists and programmers have presented fundamental contradictions concerning how to work with VR 3D interfaces. On one hand, they approach VR as an addition of sophisticated devices and not as an experience to the user. On the other hand, they have privileged the VR development in terms of total immersion of the user in the 3D space, forgetting other types of more accessible VR such as non-immersive VR. Immersive strategies have been proposed as a response to this vicious technological circle, (Mine, 1996), which in turn have led to other contradictions. Some of the strategies are:

3.1. SKETCHING IN THE VIRTUAL SPACE

It is true that the designer during the creative process is used to expressing himself by drawing free-hand sketches intuitively on paper (2D). The free hand drawing is a fundamental representation tool for the architect. Within techniques to work immersed in VR, the immersive virtual space 3D sketch is proposed as an evolution of the traditional 2D sketch (Donath, et al., 1995; 1996). This technique proposes a new type of "sketch" where the arms and

even all the body are employed to generate it creating a situation that the designer has never had to deal with before. Totally different from traditional sketching this approach creates new problems in addition to those of the 2D sketch. Those problems are: control of proportions in perspective view, accuracy in the 3D space, scale of the designer in the 3D sketch, manipulation and interaction with a new media interface, problems of configuring expensive and sophisticated equipment, and other physiological problems created by the immersion (Travis, et al., 1994).

Moreover, other propositions exist to sketch inside the virtual space in a non-immersive approach (Achten, et al., 2000; Do, 2000; Do, 2001; Jung, et al., 2001). One again, it is not the traditional sketch but another technique based on the control of gestures through the interface of a digital pen or mouse. In these examples the computer media that does not entirely simulate the benefits of free-hand drawings directly on paper limits the sketch.

3.2. MINIATURE WORLDS

Due to the difficulties of designing spaces and objects at the user scale inside the immersion, actions have been proposed to select, edit and move objects within the virtual world. One of these actions are "streams" that goes from the virtual user hands to select and translate objects. Another strategy is to give "handlers" to the objects to allow the modification and ease of movement. Taking in account the difficulties to work in an accurate and efficient way with these techniques and considering also the difficulties to select objects often hidden by others, one solution is proposed: to make a miniature world placed accessible and manipulated by the user's virtual hand in order to help him build the virtual world (Stoackly, et al., 1995).

This miniature world is presented as a mock-up to the user in the immersion. But, what happens with the problems related to the mock-ups already known to architects? ("Gulliver" effect). The users view this time a "Virtual Gulliver" facing a tiny mock-up, also virtual. What a contradiction: to have to use a virtual mock-up to deal with the space inside the immersive VR, considering it was proposed as the solution for resolving the problems of physical mock-ups! The contradictions inherent to the physical model are replicated in the virtual realm.

In addition to these errors, the computer scientists neglected the analog tools that are used in the design of physical environments: pens, airbrush, clay, boards, etc. Also, within VR the hands of the designer are used but it is difficult to represent them graphically (virtual hands) and to manage their movements within the space. Another point was to decline the drawing and the hand expressions on paper inside the creative process. It is like we are going far a way of the Sutherland "Sketchpad" proposition, where the user drawn directly on the screen.

It is here where the designer can intervene in the development of VR and even in the way we work with computers (at least in design related disciplines). Humans have the ability to interact with a real 3D world. VR exploits this capacity to interact intuitively with 3D information. Therefore, it should be the designer, with their expert knowledge in the design of real 3D spaces and objects that takes advantage of computer technologies to enrich and improve VR applications. In addition, with his experience in the use of traditional tools he can contribute ways in which to represent 3D.

4. Virtual Reality

Even as VR is the product of technological evolution, in order to really understand VR we need to analyze it from the point of view of that it is a specific experience and not just a question of hardware (Stuer, 1995). Participating in these simulations and being inside these virtual worlds force us to experience sensations. The key to define VR in terms of a human experience and not as a technology is the concept of presence. Presence is defined as the sensation of being in a 3D environment. It is obtained mainly by the user viewpoint control and his direct interaction in real time (Zeltzer, 1992). VR is categorized in two ways:

1. Immersive VR: the goal is to place the user inside a 3D environment that can be manipulated directly. The idea is that the users believe that they are interacting not with the computer but intuitively with a 3D environment. To achieve this, the users employ sophisticated equipment such as head-mounted-displays, projection environments as the CAVE (Cruz-Neira, et al., 1993) or the Panoscope (Courchesne, 2000), cockpits, etc., in order to obtain a total visual immersion allowing movement and the direct manipulation of the six axes.

2. Non-immersive VR: it is presented as an accessible alternative to the immersive VR. With the use of very complicated equipment, the VR is always associated to the immersion. However, the sensation of presence in a virtual world can be achieved using a conventional workstation (screen, keyboard and mouse). This is called non-immersive VR (Robertson, et al., 1993). In the non-immersive approach, the scene is showed with the same characteristics to achieve the 3D factor used in the immersive VR: perspective view, hidden faces, colors, textures, lighting and shadows. In the immersive approach, the navigation and the simulation are controlled by the system feedbacks of the user interaction. In the non-immersive VR, the computer screen becomes a window on the virtual world.

5. The Sketch and The Design Process

For the architect drawing free-hand sketches is a media of communication. Through Euclidian representations to achieve accurate plans, and projections to obtain perspectives, the architect makes a mental comparison between a group of hypothesis and possible solutions expressing them directly by hand (Lebahar, 1983). Lockard argues that the act of free-hand drawing allows the mind to "see, understand and respond" to the information (Lockard, 1973). Hebert advanced that the sketches are the principal signification of designer thinking (Hebert, 1993). Analyzing architects' sketches, Schön proposes that they are "a thought in action" (Schön, 1985). Graphically representing the real world is a practice of that knowledge. In this way, the world is interpreted through a language specially designed to be transformed (Viollet-le-Duc, 1978). Sketches are essential in architectural design and serve as a reference to be used, transformed or re-used during a later work (Graves, 1977). Compared to detailed and "coded" architectural drawings (plans), sketches represent the architects thinking and deliberations during the first steps of the process (Dirk, et al., 1995).

Sketch drawings are a fast and intuitive visualization tool. Goel (1994) proposed that the representation sketch supports the designer's cognition in a better way than finished and accurate shapes. The sketch allows the exploration and communication of 3D geometrical ideas. Traditionally, the designer approaches the conceptual design with pen-on-paper techniques and not with the computer, even if it offers multiple advantages. This is due to the simplicity of the interface (the pen). Also, it is not necessary to have a spatial knowledge to draw. The changes are easily obtained and accuracy is not required to express ideas (Zeleznik, et al., 1996).

The general characteristics of free-hand sketches are that they are abstract, ambiguous and inaccurate (Gross, et al, 1996). Abstraction delays detail specification and encourages replacing detail representations for abstract elements. The ambiguity also helps the designer to develop new ideas (Park, 1996). Inaccuracies also delay decisions related to the positioning or exact dimensions of elements. These characteristics provide flexibility and a visually explicit place for the solutions that need to be resolved assuring that certain decisions are kept open for the designer. The computer can express these qualities through an interactive behavioral interface.

An interactive psychomotor behavior is proposed by Furness (1987) with the third type of visualization, within the framework of "Visual Thinking". It is here where the transfer of the user visual image makes the connection with the psychomotor functioning, producing in this way a physical image: the drawing. According to Furness, the creative process is improved while all three processes (visual, mental and psychomotor) are active. The visual

image becomes stronger while the results of a psychomotor activity are integrated with those of a visual observation.

Moreover, the sketches allow the discovery of new graphical and visual ideas in unexpected ways (Suwa, et al., 1999). These discoveries are driven by combining many anterior sketches that weren't see together by observing the design from a different point of view. While we show a photorealistic image to a client, he often gets a bad reaction thinking the design is already completed. Despite certain design rules the sketch expresses a high level of the designers own idiosyncrasies (Gross, et al., 1996).

J.C. Lebehar (1983) analyzed the role of the sketch in the architectural design process. He divides the design process into three steps, signaling the second as the most important: finding the object through graphical simulation. This step is developed by improving the graphic base established during the first step (architectural diagnosis). Here the sketch appears as a graphical simulation system. It permits the creation and representation of facts, placing and moving, rebuilding, deciding and determining the building dimensions. This simulation gives the designer the power to transform the environments "in the mind" before it will be built in physical reality. As the finding is closer to the object, the designer knowledge augments in quantity and in accuracy. The drawings will be completed when all the necessary defining information concerning the objects are present. Later, the process will be finished with the plans during the last step (establishment of a building model).

6. VR issues

Despite its advantages, VR still has problems that affect the design process especially in the first steps of the design process: a compulsorily accurate work, the non-ambiguity of the representation, and the loss of interaction with the graphical representation itself. Additionally, the computing requirements, even for the non-immersive VR, limit the designer in detail modeling, slowing down the real time, and diluted the experience of presence (Funkhouser, et al., 1996). The comment usually made regarding sketches prepared with computers is that sketches and work done with CAD systems is slower than man's imagination. Creativity is dependent on the speed and the ease-of-use of the system (Klercker, 1995). Furthermore, the structured interaction of the mouse with the menu forces the designer to make premature decisions, demanding an inappropriate accuracy compared to pen-on-paper techniques (Gross, et al. 1996).

7. Drafted Virtual Reality

A new technique is proposed as a solution for current VR systems adapted to the early steps of the design process. It uses the QTVR Panorama technique which generates, with the help of the computer, a 2D panoramic (360˚) graphic base on which the designer makes free-hand drawings. This image is then scanned and viewed through a QTVR Panorama creation software. Combining computer computational power with the advantages of sketched drawings, it is then possible to experience a new type of VR: Drafted Virtual Reality (DVR).

QuickTime VR software (Apple) is a non-immersive VR technique. It is based on a panoramic image of a virtual space (made by computer) of real a space (through a group of real photos of the space stitched together). The image is based around the user point of view that allows the user to interactively decide the direction of the line of sight (moving the image by clicking on it). The panoramic view deforms the perspective to adapt it to the central point of view (a cylinder) around the user. Once the cylinder is closed, the user observes multiples of corrected perspectives (not deformed). The QTVR technique allows fast visualization without the limits of machine calculations because pre-calculated images are used and not 3D geometries that depend on computer power to display each frame in real-time. The quality of the image is therefore improved because it is possible to invest more time calculating visual effects, shadows, reflections and textures.

The DVR is developed following these steps:

A) PANORAMIC TEMPLATE

3D modeling software that permits 360˚ representation of a scene in a panoramic view is used (i.e. form•Z, from autodessys). First, basic 3D shapes are generated to serve as graphical references for the space (walls and ceiling). It is also possible to add certain details and predefined volumes (furniture, trees, etc.). Once the observer's height and position are configured, then the representation of the panorama mode is changed in order to print the scene in wire-frame. The objects and the space may also be meshed to have polygons as reference lines in the panoramic template (Figure 1).
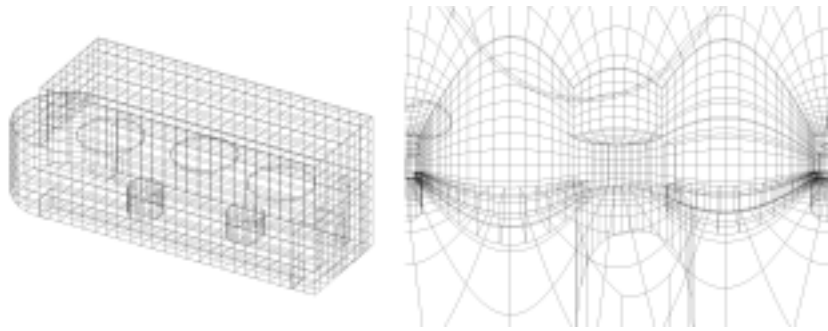
Figure 1. Panoramic template for the DVR.

B) SKETCHING

Once the template is printed, the designer returns to the drawing table to complete the panoramic view by hand enriching it with any 2D graphic technique (airbrush, markers, pastel, etc.). It is possible to cut and paste people or other 2D elements from photos. The designer uses the reference lines of the basic modeled shapes in the printed panoramic template in order to guide and control the proportions and the projection of the drawing (Figure 2).
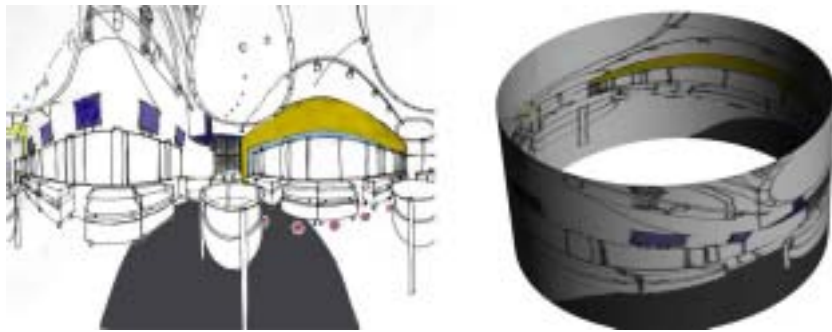

Figure 2. Scanned sketch and construction of the QTVR.

C) IMAGE EDITION

The image is then scanned. The panoramic view is presented as a matrix 2D file that can be processed with other image composing software. It is at this stage that lighting effects or other elements are added. Lastly, the file format is set according to the QTVR Panorama creation software.

D) QTVR PANORAMA CREATION

Finally, the QTVR creation software is used (i.e. QTVR Make Panorama, from Apple) and the QTVR file is created taking in account the angles, the proximity of the user point of view and the video compression (if needed) (Figure 3).
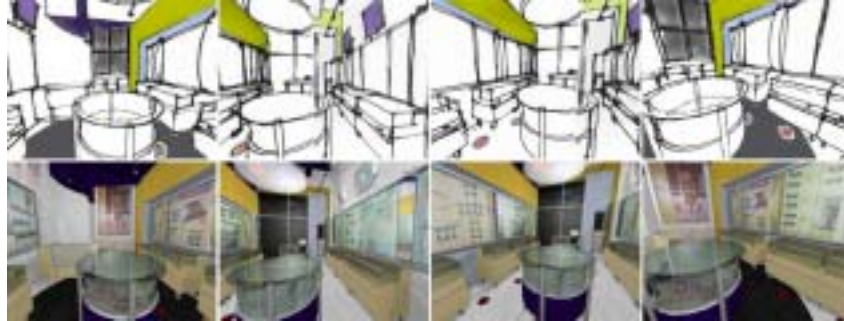

Figure 3. DVR views and traditional QTVR views.

8. One panorama = multiples perspectives

This type of VR has multiple advantages in comparison to traditional QTVR Panorama or other sketching tools:

1) The traditional perspective creates many problems: the execution time to obtain one view of the object, the fact it is static, and the possibility to have construction errors which create impossible proportions and effects. With DVR the designer develops a panoramic view that once processed by the machine is converted into multiple dynamic perspectives. Using the computer to generate the printed template, the designer is assisted to generate a view without errors or deformations. This is helpful in drawing projections of non-orthogonal objects.

2) The VR is enriched by a 3D sketching technique that is closely resembles traditional 2D perspective, developed by pen-on-paper.

3) Scale problems of the mock-up are bypassed because the DVR experience is at the user scale. It can be immersive using glasses or with projection systems.

4) This technique takes advantage of free-hand sketches in the first steps of the design process. Additionally, it takes advantage of the expertise and capacities of the designers' personal graphical expression, replacing those of traditional computer renderings.

9. DVR and Current Computer Graphics Approach

With DVR the projects ideas and characteristic are represented by graphical objects. By manipulating these objects, the designer discovers the solution by graphical simulation inside this DVR. As related to CAD systems, the traditional VR is nearer to the last step of the Lebahar's design process (establishment of the construction model), than sketches, taking into account the accuracy and the non-ambiguity of the representation. Using DVR we are no trying to simulate real sketches by digital ones, or translating them to accurate 3D models (Do, 2001). Regarding the sketch, traditional VR can distract the designer with the complexity of the modeling commands during the design process. The sketch augmented by DVR can better communicate 3D information of complex spaces than traditional static sketches. The global perception of the space and its implications can be better and more easily explored.

The free-hand representation expresses personal and subtle interpretations of the projects designer. In most cases traditional computer graphics homogenize the representation of the project with photorealistic renderings and accurate models. According to initial results (Figure 4) personal expression and characteristics of the designer are transmitted well by the DVR.

Figure 4. Samples of panoramic DVR sketches.

According to Lansdown (1994), the problems of the sketch to generate 3D objects are: impossibility to feel the space and inhabit it; we can't avoid spatial abstractions to understand shapes and complex 3D relationship; inaccuracy of the 3D representation (unconscious cheating over the object proportions); and disregard for human scale and vision observer angle.

DVR resolves all these problems. It places the designer in the middle of the virtual space that is displayed in 3D without information decoding. This technique permits ambiguity while respecting scale and vision angles.

10. Extended multimedia

In computer graphics, the term multimedia identifies a fusion of different information medias, all processed with the computer. Usually, the fusion is made between text, animations, sound and images. Furthermore, with hypermedia, it is possible to navigate through a universe of multimedia information without limits, thanks to only one tool: the computer. However, others have proposed integrating in the design process designers' knowledge of how to use analog and digital tools (Bermudez, et al., 1998). We designate "extended multimedia" as the association of the computer with other analog tools, allowing information processing not only by the computer but by other tools, allowing for the integration of digital and analog techniques in design. The importance of the significant processing power of the computer is acknowledge. However, there are existing analog tools in which the designer is already an expert in their use. Extended multimedia is oriented towards restoring the advantages of both operational modes breaking away from the one-way path leading exclusively towards to the digital mode.

11. Considerations for DVR

Certainly this technique has other problems such as the challenge of drawing over a panoramic template where the reference lines are deformed and the wait time to obtain an interactive experience of the space inside the VR. However, the time taken to develop a traditional VR 3D model or traditional QTVRs is time better used for creative activity using the sketch. It is frustrating to see a designer with advanced sketching skills forced to wait for the 3D model to be rendered by the computer.

DVR is proposed as an example of a new approach of extended multimedia that can contain all analog tools and enrich them with the computer without being integrated with it. The creative activity of the designer can't be imitated either by technology or sophisticated equipment. In addition the ephemeral personality of the designer represented by the sketch needs to be preserved.

12. A new paradigm to design with computers

Centering the design with the designer as the user of the system facing the problem of information processing this technique fuses the computer with other tools without replacing or imitating them. According to Norman (1998), the computer as it is today must disappear from the workspace. Meaning, applying the computers strength when useful while allowing the traditional

use of tools already mastered by the designer. In this way the computer evolves towards being an agent that unifies different tools, processing the information without becoming a funnel. We must stop replacing traditional tools with its digital equivalent but try to enrich them or improve them with the information processing of the computer.

At the moment when the designer reaches the computers limitations, he returns to the traditional design tools he has already mastered. Once the limitations are overcome he reenters the digital mode. Most importantly the approach does not impose new methods but is based on existing users capacities and skills (McCullough, 1996).

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