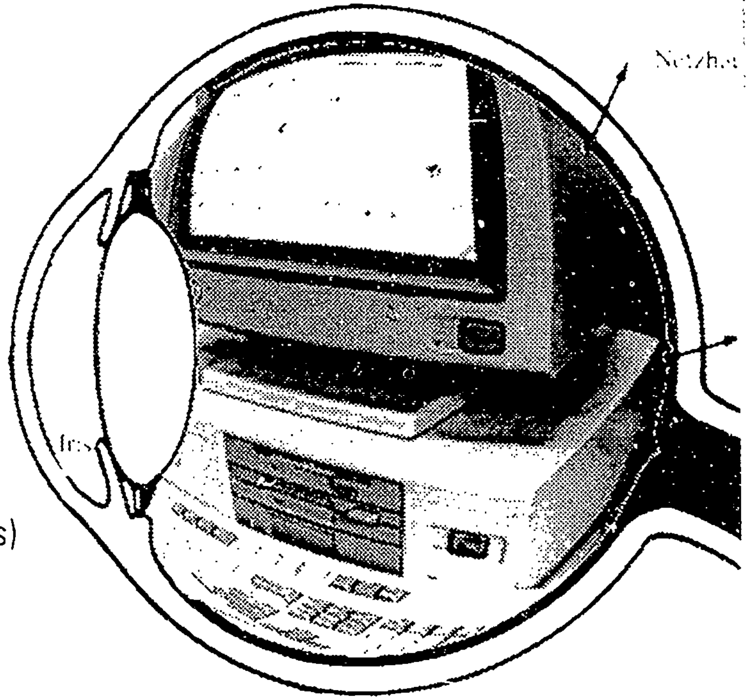
Principles and tools for instructional visualisation



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Conceptual Metaphors for the Visualisation in Interactive Learning

Piet Kommers

Abstract

With the arrival of the full spectrum of presentation modes in computer-based learning resources, it becomes urgent to review already existing theories about visualisation and animation as defined for paper-based publication, movie and video.

One of the differences between traditional media and hypermedia is that the first ones take the user along in a consistent sequence of episodes that refers to a lay-out, story or scenario that can be understood and in some way or another 'be predicted' from cultural experience and prior knowledge. Hypermedia in contrary allows the user to jump away from a current piece of information to a certain aspect which is only an arbitrary detail of the previous scope. Text-based hypermedia (called hypertext) allows the user to browse via concept identity. This means that a term in an explanation can be exploded by clicking the location of this term (called hot spot). The same term will appear at the top of the exploded view, and will also be the key issue its content. The concept identity is the fact that the term in the clicked hot spot is identical to the subject of the exposition in the exploded view. Browsing through pictures, video and sound elements allows the user to zoom in on details. However it is quite complicated to guarantee some kind of concept identity in the transition from one picture element to another. The reason is that picture elements are less self-contained than words in a text. The context dependency of visual elements causes surprise and confusion in the user. One way to solve this problem is to enclose meta-information with the visual representation which links different views with concepts that are present at both sides of the link.

Hypertext links can be visualised in a concept network, where the nodes stand for concepts. The concept node represents the identity between hot spot and the key issue in the subsequent exploded view. Generalising the concept network to picture transitions can be done by prompting clusters of elements and labelling them with a concept term. The choice of clusters and the term will orient the user to the type of digression he/she may expect after clicking a certain hot spot.

Conceptual overlays in audio and video segments presuppose a moderate level of granularity; The overlay should remain valid for a minimum time span so that the user can anticipate his browsing direction while seeing the next fragment. This can be done by having the hot spot elements at static positions in the screen, while the moving elements settle the context situation in which critical concepts arise. The conceptual metaphor for effective use of hypermedia constitutes schematic representations which is an accentuation of the meaningful elements the user should be aware of while browsing through unknown information. At the same time it might function as an epistemic analysis for the hypermedia designer who needs an explicit content description in the design phase.

Introduction

Computer-based learning programs have triggered again the basic discussion on didactic strategies, styles in learning dialogues and the design of information elements like text , visual images and sound. The key element in this revived debate is the notion of 'self-control' for the student versus the attempts to facilitate learning by regulating the learning process by pacing and sequencing information elements and systematic remediation of evolved misconceptions in the student's mind. Hypermedia and multi-media were quite welcome after twenty years of high expectations of 'advanced programmed instruction', 'intelligent tutoring' and 'student model-driven dialogues' Rather than stimulating the traditional opposition between student- versus system control its seems more productive now to unify them by asserting that hypermedia explorations might serve complementary stages in learning and instruction. Initial stages of learning in which pre-cognitive levels of expertise and intuition in the student are mobilized, versus the need for a more controlled instruction facilitating a later, more operational stage of learning in which correct task performance plays an important role. This chapter presents the merits of recent visualisation techniques in pre cognitive learning stages while using hypermedia. Essential for the cognitive benefits in this stage are the so-called metacognitive effects; Balajthy, E., 1990 and Cates, W., 1992.

The availability of pictures, sounds and video in electronic learning material brings the opportunity to confront the student with flexible realistic views in a certain domain. Especially as competing media programs like television commercials with astonishing video clips, animations and highly suggestive and condensed social episodes penetrate, it is quite urgent to make interactive learning programs as expressive as possible to elicit emotions and keep the attention of the user.

The user flexibility of hypermedia gives full control on sequence, focus and perspective to the learner. While hypertext browsing has become popular quite quickly, hypermedia browsing is still rare. One reason for it is the amount of effort to prepare the numerous transitions and necessary visual consequences that should be anticipated. Another important complexity is in the inconsistencies that may arise when allowing the user to browse between visuals, sounds and video fragments. The chosen solution to overcome ambiguous transitions between pictorial elements is to superpone conceptual structures on the candidate hot spots. Before going into the techniques of concept representation, - metaphors and interaction procedures, let's review already existing theories about visualisation and animation as defined for paper-based publication, movie and video.

Words, Images and the Level of Abstraction.

'Words and images cannot be derived from each other, ...' Foucault, 1966. It stresses the uniqueness of human senses. Quite typical prehistoric tribes reflected their desires and fears in pictographic images. After centuries however they moved to more abstract cryptic symbols representing objects but also feelings and reflections These symbols did not necessarily resemble the objects they referred to: A separation between reality and mental representation Words like symbols do not necessarily refer to one concrete object or situation, it may also point to a more general unity of things Words like 'cattle' or 'agriculture' are typical generalised concepts in the sense that they 'pack' a set of more specific concepts like 'cow', 'deer' etc.

Figure 1

Figure 2

The typical difference between word and image is that words do typically tend to express generality and tend to neglect individual perceptions, while images do defacto point to specific elements of reality. The trade-off for hypermedia designers is to take the advantage of words, tending to tell the most general impact of their meaning, or images which se- -ce the user to the uniqueness of a certain element. General concepts like 'inflation', responsibility', 'entropy' or 'inertia' are difficult to express in static images. If we try to do so as they can hardly express conditions like 'sometimes', 'only if ....' etc. and it brings the user in the danger of picking up irrelevant or even uncorrect attributes in the visualisation of the key concepts. At the other hand images can sketch a typical situation quite rapidly by triggering perceptive templates that we as users know from past experiences Above the so-called 'scheme-activation', images, sound and video have a strong appeal to the imagination of the perceiver. Spatial and episodic consequences of the scenery can be generated and remembered for a long time. Conflicts in pictures can be detected quite easily, as the human eye has been trained for many years. One could even say that the human brain is especially equipped to interpret reality from social and visual messages. The picture with the bed scene in figure 3 is ambiguous in many senses, but several hypotheses can be rejected by the observer immediately The perceptive and interpretative effects are quite dependent from conflict elements in the image. Archetypical features in the outlook and character of actors make it easier to arrange a conflict in the scene. Conflicts arise emotions in the spectator and makes it easier to catch the attention for a longer time. Learning effects will only take place if the arranged conflict is anticipated by a question or open interest in the user. The first of the two next pictures will hence evoke a longer attention from the viewer and will also be processed at a deeper level. As a consequence it may be expected that the picture in figure 4 will be remembered for a longer time, compared with the picture in figure 5 which causes less arousal at the spectator.

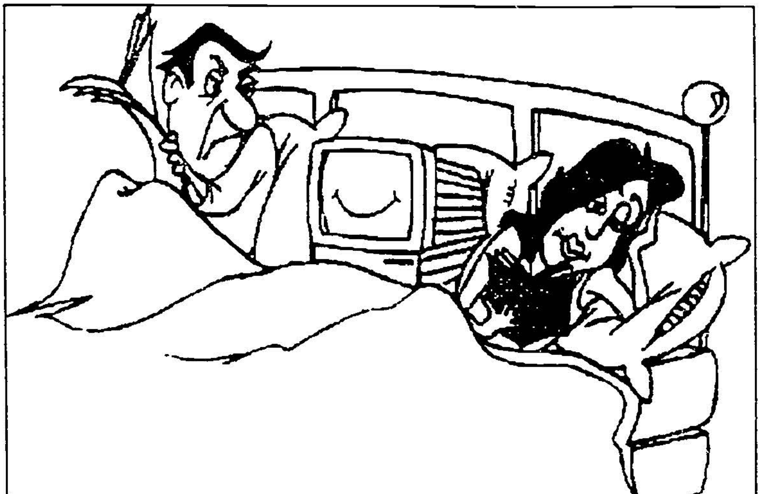


Figure 3

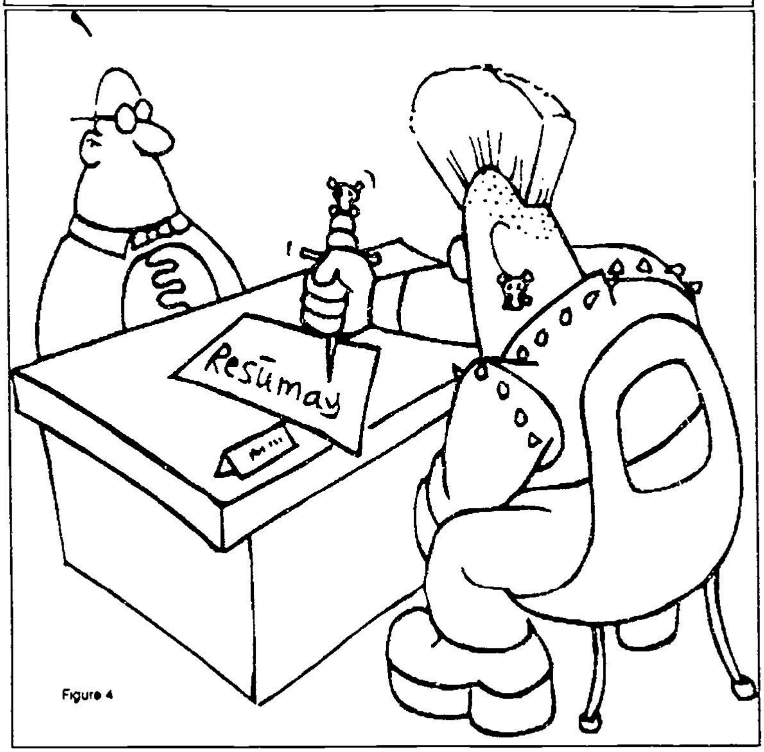


Figure 4

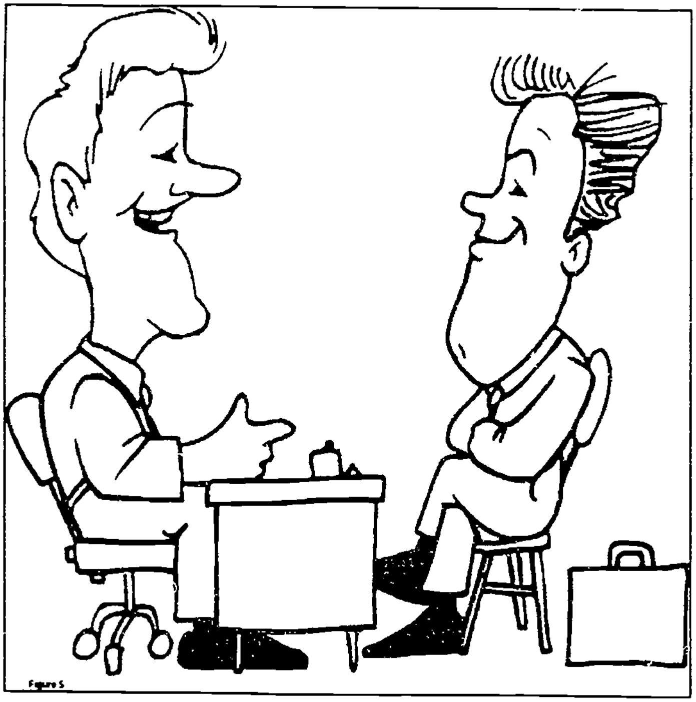


Figure 5

As one tries to explain the difference in examining figures 4 and 5 it makes sense to distinguish between 'understanding' (coping with the meaning of a certain impression) and 'remembering'. It is generally assumed that meaningful processing facilitates remembering. Semantic processing for instance is assumed to be more effective than formal processing; (Jenkins, 1974). Increasing the 'depth' of processing will produce better memory (Craik and Lockhart, 1972; Craik and Tulving, 1975). The key issue is to arrange the images so that they actually trigger emotions, imagination and personal experiences from the past. As culture changes quickly, and persons differ quite a lot, it is hard to find overall guidelines. The urgence to chose the right elements in visuals is clearly demonstrated in the effort given to commercials.

Trade off Between Abstraction and Concreteness in Presentation.

So far the global distinction between visuals and audio (perceptual) at one side and verbal or written information (conceptual) at the other side has been made. While hypermedia designers are steadily improving the flexibility and expressiveness of browsing, the more fundamental question arises to what extend we might expect beneficial cognitive effects for the user. A dominant criterion so far is the level of excitement and entertainment: The more exuberant presentations, inclusively three-dimensional impressions and direct manipulation in space, the more is the appeal to the user.

Besides the alertness on cost-effectiveness it becomes important to find a rationale for the learning criterion that might decide upon presentation richness. Edgar Dale took up the concept of 'realism' of Hoban and Zissman (1937), and laid it down in his 'Cone of

Experience'. Dale's ambition is to adapt the realism and the level of user interaction during media presentations to the momentary user's level of cognitive development and competence. The trade off has to be made between the conciseness of information, which is typically appropriate if the student can read and understand scientific expressions, mathematical formulas and pictographic symbols at one side, and more elaborate experiential situations which cost more time and instructional effort, but which will compensate lacks of prior knowledge and which will allow the student to learn by experience before any formal instruction takes place.

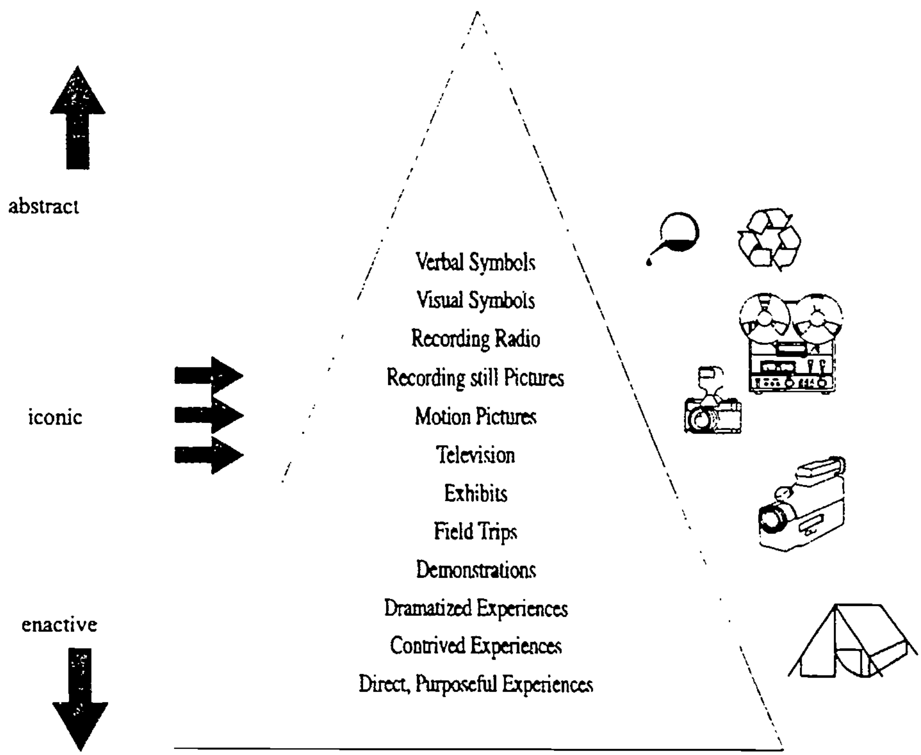


Figure 6

Dale's notion on levels of presentation goes beyond the question how to visualise. In fact it addresses the issue of interaction style and instructional strategy. For hypermedia design we can use Dale's cone to decide upon when to invest in full motion video, still video, sketches, the combinations with audio, or visual and verbal symbols only. As many student characteristics are hard to assess during or even more difficult before a learning session, hypermedia presentations might be superior to prepacked CBL sessions as they leave essential choices about the modality of information to the user. Based on cognitive style, prior knowledge or momentary interest the student may ask for presentations at a lower (more concrete) level. It may even be the case that the student at a certain moment wishes to interrupt the presentation and asks for a confrontation with a simulation environment in which so-called 'what-if' experiments can be done

Concepts, Objects and Visual Representation.

The idea that one can think in images is not as strange it sounds Of course its validity is quite dependent upon our definition of 'thinking'. Many of the human actions are directly based on what we see, hear and smell; The resulting behaviour at those mentioned moments is controlled by a very fast cycle between perceptions, emotions and testing our feelings by taking a perspective for new impressions again. Abstractions, reasoning and conceptual change occurs hardly in those situations. This is the very reason why certain social behaviour and emotional reactions are hard to change. It is this pre-cognitive aspect that plays an important role in the effects of visualisations. At one hand we should be aware that images and sounds trigger a fundamental layer in the user/learner, while at the other hand we know from research that they are most effective to consolidate the process of knowledge acquisition and conceptual change. The user of a hypermedia system may benefit from a flexible access to different visual representations so that we might describe this browsing behaviour as operating a camera: Panoramic view, zooming in, zooming out, filtering, jumping back etc. If the information nodes and links via hotspots have been defined from a didactic perspective however, we might expect that these perceptual transitions finally promote mental views which are more or less congruent those of the experts who prepared them. The central discussion about hypermedia as learning resources is to what extent explicit conceptual arguments should be added to the browsing space, before effective learning takes place. This discussion is both relevant for optimising hypermedia for the pre-cognitive stage of learning, and for the integration of hypermedia in more controlled instructional episodes as well.

Let's imagine the domain of combustive engines and see how visuals may facilitate cognitive stages in understanding, generalisation and problem solving. It's hard to imagine how difficult it would be to teach the typical characteristics of a diesel motor to someone who never saw, smelled and felt the movements of a running diesel engine. Not knowing the physical and mechanical principles of a combustive engine, one will still derive quite important aspects of the combustive mechanism by seeing, hearing the effects of such an engine built in a car, boat or train. Having observed the starting process of combustive engines gives already the notion that certain conditions must be met before the process starts running. E.g. the effect of temperature, the speed of the rotation and the degree of choking and giving throttle.

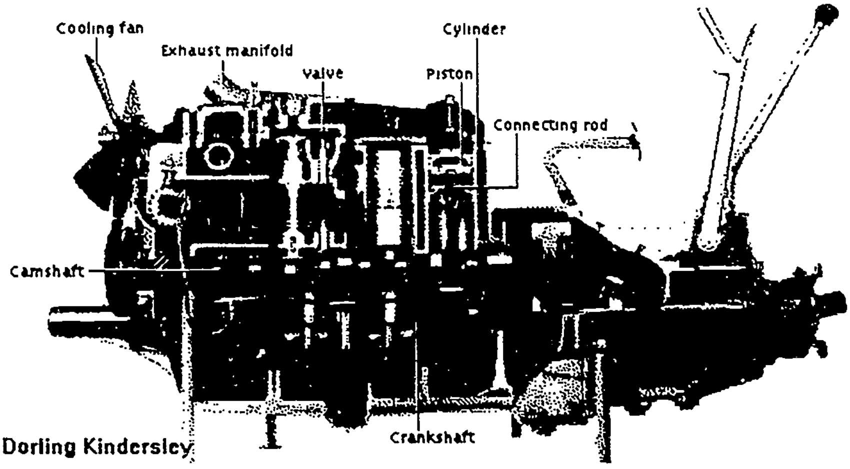
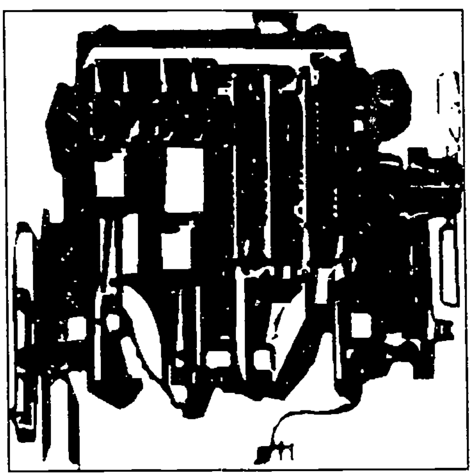
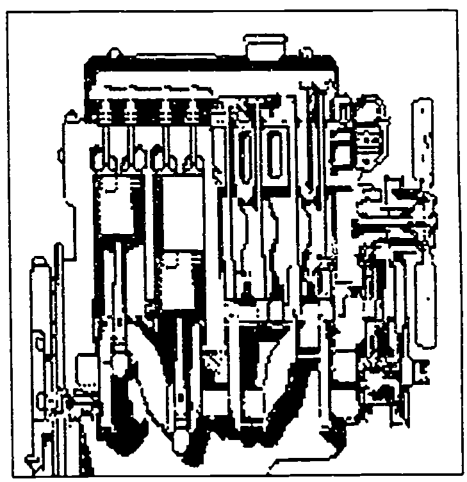


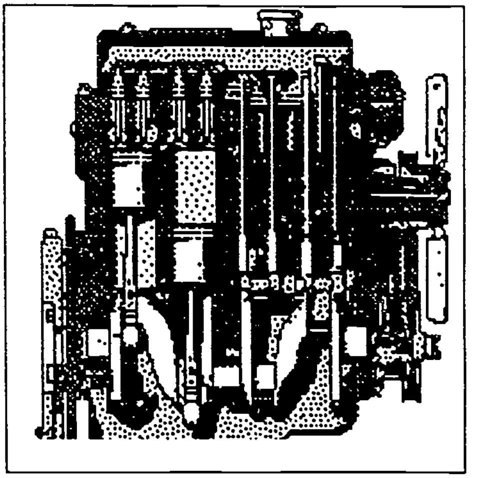
Figure 7

However most of the even very successful car drivers do not know any formal aspect of the combustive mechanism. Even after many years driving, these perceptions and experiences are not sufficient at all to build up a correct idea what happens in the motor itself. To acquire such knowledge is exactly the typical task for education and training. In terms of Dale's cone of experience it is the question then to migrate tactically from perceptual confrontations with the phenomenon of combustive engine up to more conceptual representations so that flexible knowledge may evolve.


Otto Engine Figure 8


Otto Engine Figure 9

The three images and caption text of the combustion engine are clipped from Microsoft's Encarta Encyclopaedia on CD-ROM.



Early Internal-Combustion Engine
One of the most important inventions of the mid- to late- 1800s, the internal-combustion engine generated mechanical energy by burning fuel in a combustion chamber. The introduction of the new engine led almost immediately to the development of the automobile, which had been largely unfeasible with the unwieldy steam engine. Shown here is a 1925 Morris engine, the basic unit for a family car. It features four in-line cylinders with aluminium pistons. The valves are opened by push rods operated by a camshaft and closed by springs. Power is transmitted by means of the crankshaft to the gearbox. (By: Dorling Kindersley) Otto Engine Figure 10

The displayed opened engine takes place in an animation sequence to illustrate different periods in the Otto-cycle engine, named after its inventor, the German technician Nikolaus August Otto (1832-91). It is the familiar gasoline engine used in automobiles and aeroplanes. The diesel engine, named after the French-born German engineer Rudolf Christian Karl Diesel, operates on a different principle and usually uses oil as a fuel.

The first image (Otto Engine Figure 1) gives quite a global impression of the overall shape and is quite close to a pictographic representation; The global components are visible, only to attend global positions of the crankshaft and two of the pistons. To illustrate the interrelated positions of the crankshaft, piston rod, piston and valves, the front view is more appropriate as it gives a natural argument to display only the constellation in one of the four cylinders.

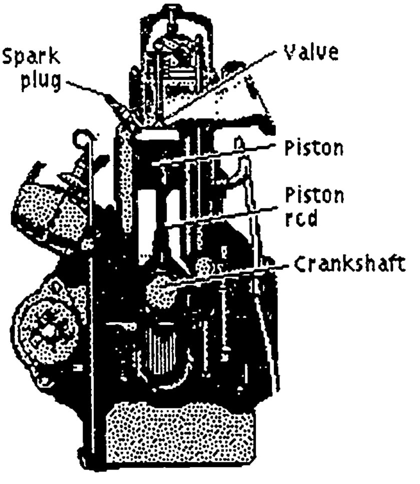


Figure 11 **Front view**

Figures 8 to 10 displaying the Otto Engine with an increasing level of detail illustrate the capability of current drawing facilities in graphical user interfaces to prune away successive levels of details, even in bit-mapped images. The potential opportunity of these various smudging levels in hypermedia presentation is that we might confront students with pictures that are automatically filtered from details just above to the level of understanding at that moment.

Computer-based Adaptation of Visual Images

As more tools for image processing become available, it becomes easier and challenging for courseware engineers to prescribe adaptive levels of detail in didactic images. The next two pictures of arch fences start quite differenct reactions in perception, interpretation, generalisation and retention for the user. Figure 13 has been derived from figure 12 by means of Corel Draw's 'tracing' facility.

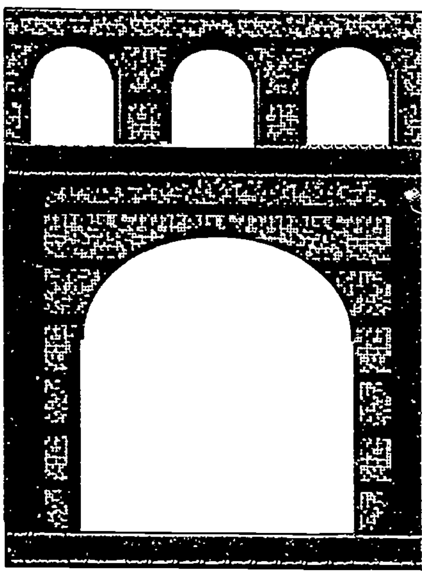


Figure 12

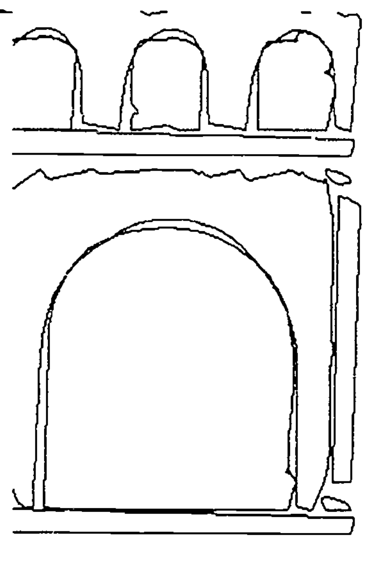
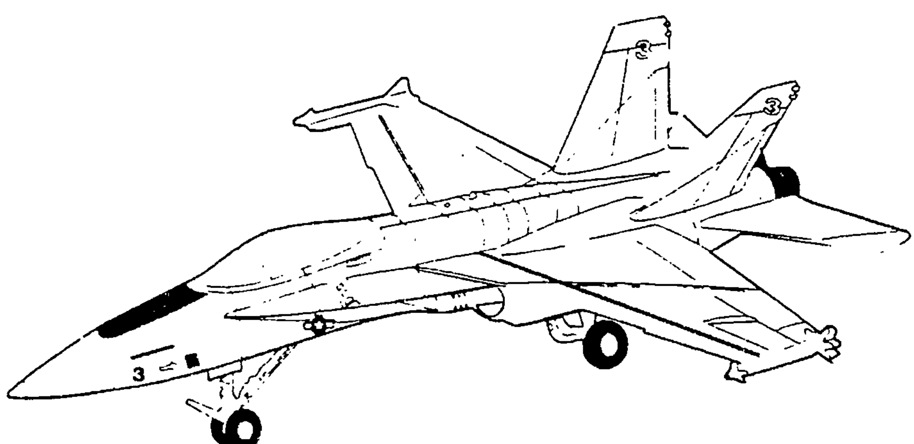


Figure 13

To illustrate the technique as used to change Otto Engine Figure 10 into 9 and finally into 8, the bitmap image of the three arches above is used to trace its contours and finally drawing the attention of the user to its major components, hiding the structure of the bricks the fall of the light etc. Essential however is that the final trace image



keeps the impression of a real object, with small vividness in its lines so that it activates the imagination of the spectator. Visuals, composed of purely geometric elements miss this suggestion and though they suggest more exactness, they lack the appeal to the human mind. Finally the contour image in figure 13 costs only 200 times less storage space and can be drawn in a fraction of the time compaired to figure 12. In fact this contour sketch can be handled as an object image, which is easy to colour or to rescale based on an actual presentation or instructional arguments. In terms of Dale's dimension of contrived versus real experience it is obvious that the contour image is situated more closely to the symbolic level, however it keeps a stronger reminiscence to the perceptual image of the photograph by its suggestive details.

Bit mapped images are difficult to manipulate in a meaningful way, as there is no information about its components. Object images can be filtered, cropped and distorted based on semantic criteria as long as the names of its labelled parts are compatible with the descriptions of its functions and relations to the presentation arguments like speed impression, articulation of perspective etc.

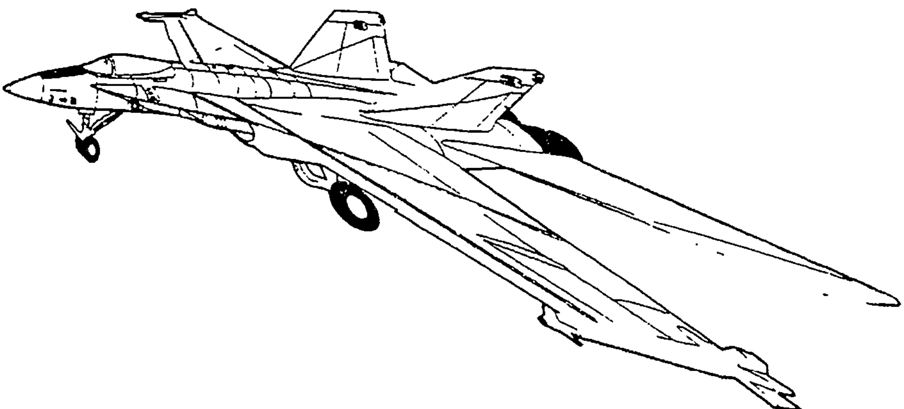


Figure 15

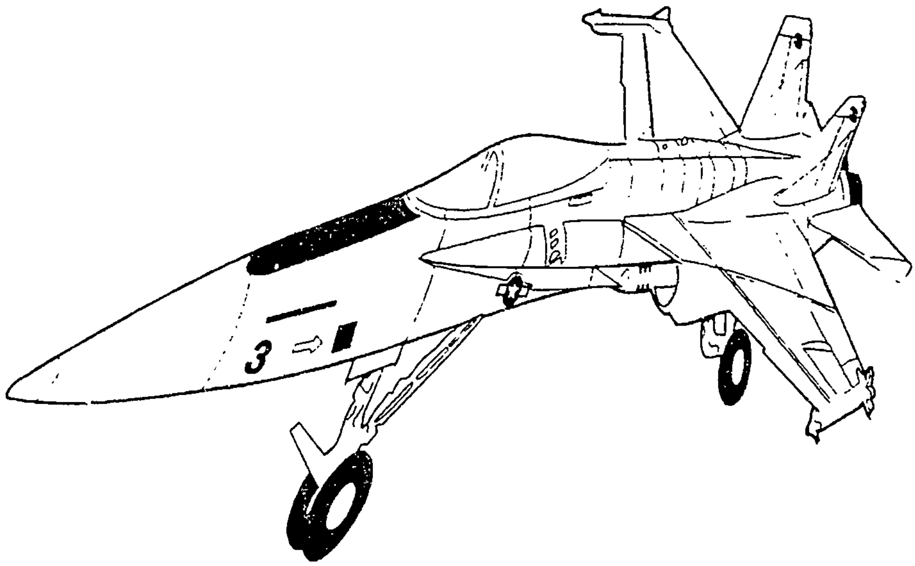
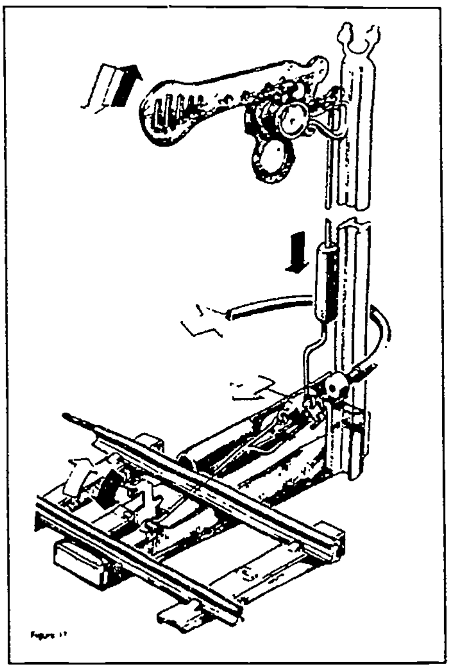


Figure 16

Object oriented visualisations permit the hypermedia designer to be more expressive in



the functionality of certain objects and to change easily between certain cognitive perspectives elicited by display arguments as shown before. The display of the pneumatic train semaphore (figure 17) gives a rudimentary impression of its working. The human eye however needs a longer time to detect the mechanistic elements like the airtubes, the cylinder, the piston and the final drive mechanism of the switch staves.

The help of arrows to indicate the direction of movements and the cut and opened parts ask quite an effort of the visual designer to reduce the complexity while keeping the picture appropriate for different levels of expertise in users. Changing the function of the display in the explanation chain needs a laborious redrawing, and of course it cannot be generated automatically by a computer program. Is easy to see that one of the major options in using object-oriented pictures is in the pick-and-mix facilities, enabling hypermedia designers to include precisely defined elements of other pictures in new ones

Let's focus on technical drawings like those to explain maintenance personnel where to find certain elements or to prompt them in which order procedures should be performed. These drawings need sufficient details in certain parts while they may be global in the peripheral zone. Good examples can be found in repair manuals for the car dealers.

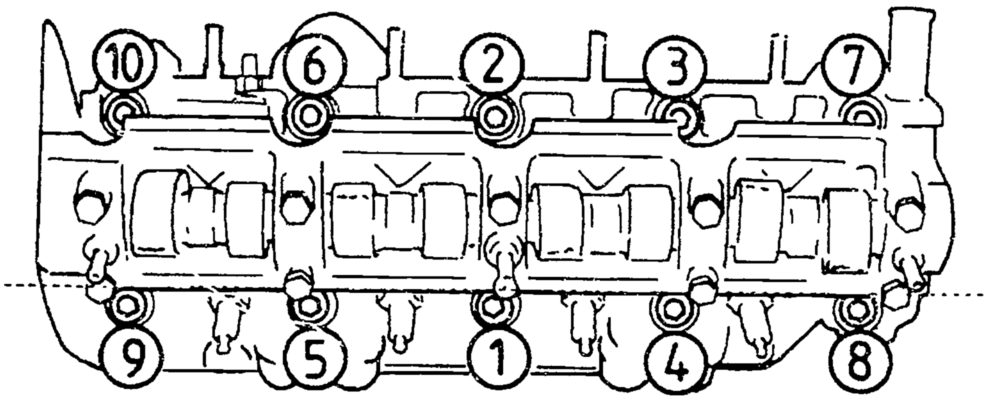


Figure 18

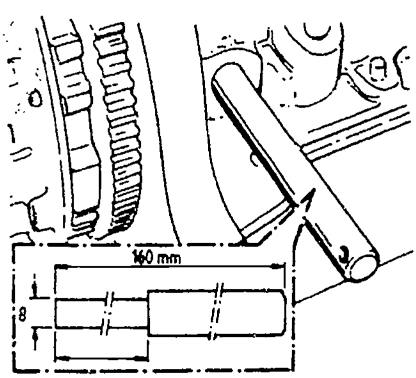


Figure 19

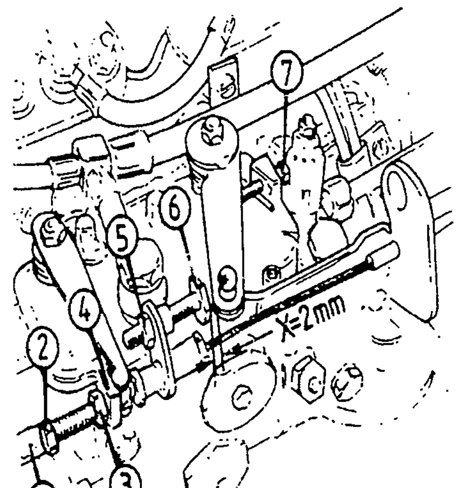


Figure 20

Within the scope of a certain assembly action like tightening the bolts through the cylinder head (figure 18), a drawing is made so that it servers as a direct orientation for the operation to be performed. The location and relative positions of the bolts have been drawn quite precisely, while the surface of the motor head is only suggested vague. A more delicate action to be expressed is the adjustment of parts, as shown in figures 19 and 20 Especially in the last two examples it it obvious that one has to find a balance between the clearness and convenience of overview at one side and the wish to combine different actions in one picture at the other side

Concept exploration by visual negotiations

Visual images may play an important role in concept formation, especially if the application domain is visual. If the concept space is more abstract, concept mapping techniques can be useful to express global entities as a framework for elaborations later on. Concept mapping has become popular in learning, design and problem solving The underlying idea is that the schematic representations give the user a greater flexibility while searching for creative solutions. Graphic representations rather than oral and written words enable to express the simultaneity of ideas in one stroke. Concept maps are mostly drawn in twodimensional space. For more dense networks, a third dimension may help, especially to distinguish between fore- and background. The negotiation metaphor is well known for learning purposes and says that students should not simply be receptive for new information, but they should be placed in the position of a stakeholder who faces the trade-off between changing him/her self (by internalising the new concepts) or by analysing the new ideas for their structure and reformulate them so that they fit in their actual state of knowledge. The first approach asks for a better memory while the second heavily relies on reasoning and detecting analogies. The concept mapping technique as a negotiation tool for evaluating these two strategies can be intensified by introducing 'spatial impossibilities' like present in the well-known paintings of Esscher. The two images below place the spectator in a mental conflict. He/she has to decide upon fore- / background positions based on the content in the nodes (placed on the edges of the figure).

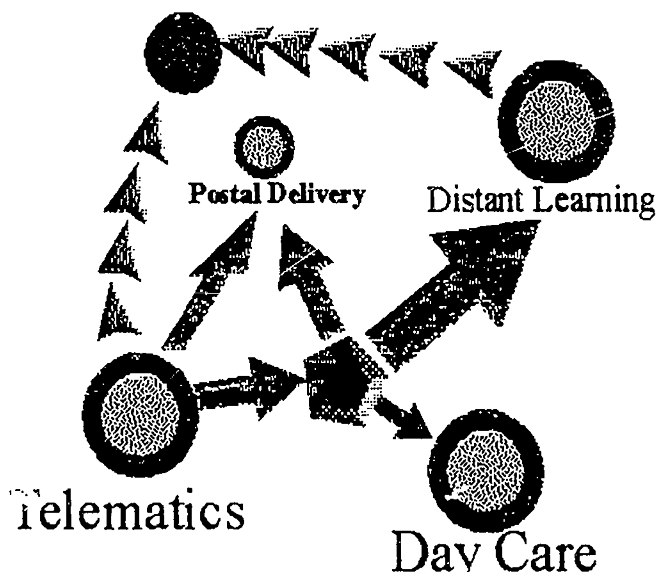


Figure 21

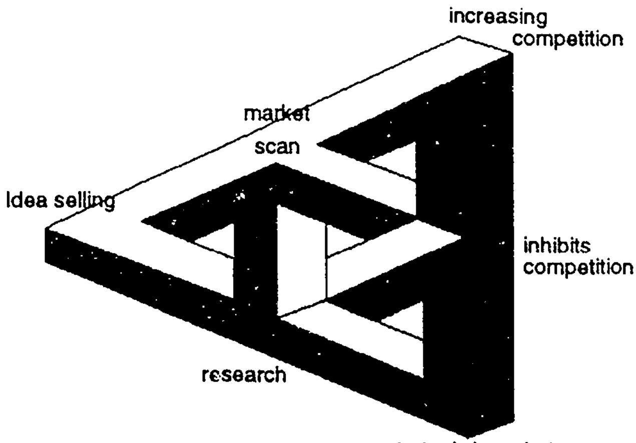


Figure 22a

The choice should be effectuated in dragging the concept terms so that he spatial connotation looses ambiguity and reflects the semantic implication as well. The cognitve benefits of provoked mental conflicts will only emerge if the student is trained and motivated for a certain level of cognitive flexibility. If we regard the typical atmosphere and discipline in educational and training setting we see the opposite tendency: Students are trained to assimilate prestructured views and opinions. However many students face massive uncertainty if they meet realistic problems they have to solve, because they don't have fitting solutions ready to apply in their memory. So for creative jobs like design, human managment, boundary spanner and trouble shooter it is obvious that cognitve flexibility is a defacto attitute, that should have been stimulated in the early phases of learning.

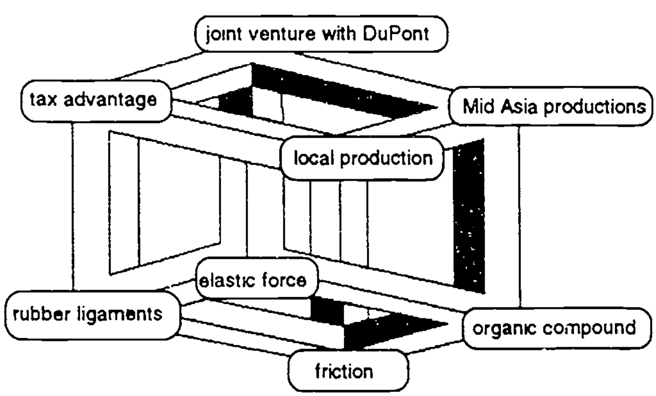


Figure 22b

Spatial connotations of concept relations have been worked out by researchers quite intensively so far The basic assumption is that human knowledge cannot only be scaffolded by verbal concepts, but need a more perceptual and experiential representation for several reasons Computers may help in realising the manipulation and reconciliation between the user and his/her conflicting mental perspectives. In fact the visualisation here works as a provocation to the user who will strive for equilibrity between knowing, feeling and seeing. The perceptual conflict as demonstrated above can also be extrapolated to an operational one, in which the user has to compete against 'primitive' intuitions how to achieve a certain spatial effect. Let's take a simple spatial, conflictless design tool for concentric objects before going into an example which may illustrate provocational situations for travellers through concept space.

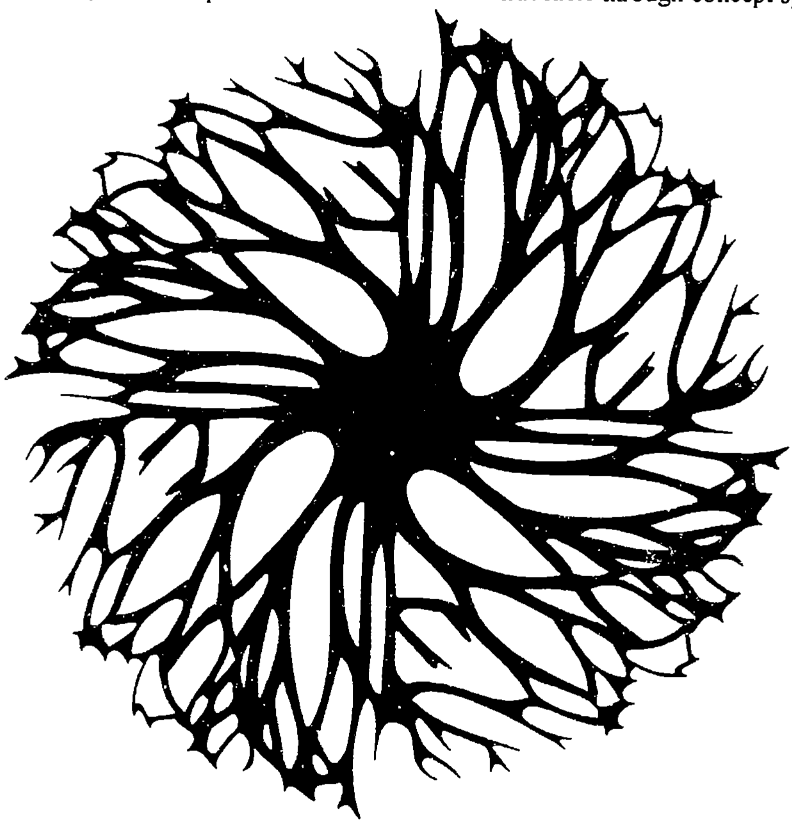


Figure 23

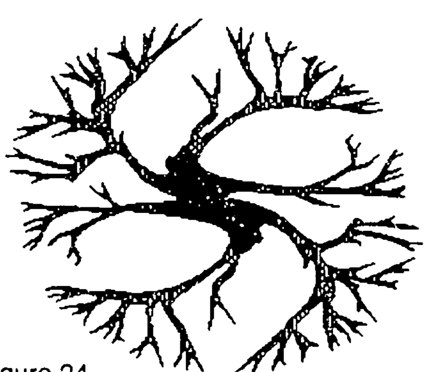
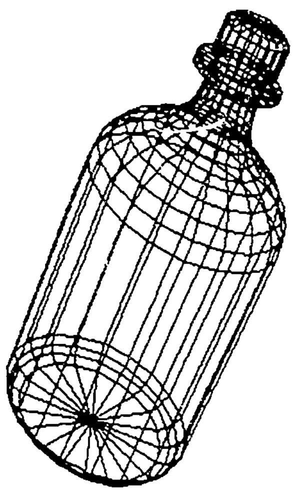


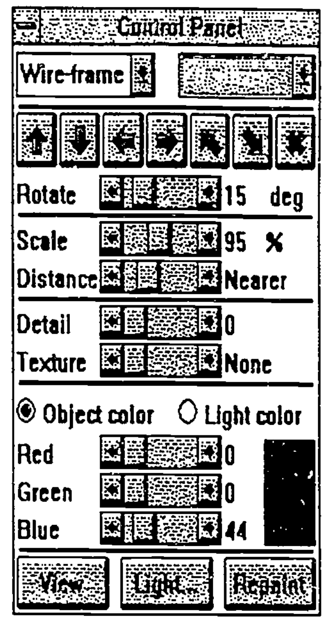
Figure 24

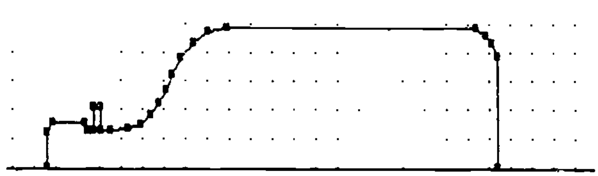
To show how we as perceivers are bound to 'common views' try to identify the next image. Where can you find this object? If you have problems finding the answer, try to make assumptions about the genetic element of this object: How did this shape evolve from the centre part? Why is the density of smaller elements higher at the outside of the object?

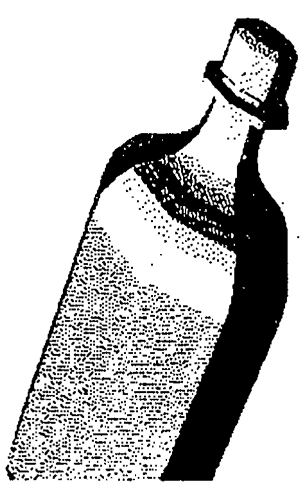
If you still have problems, please study some of its substructure in the next picture

Probably the organic structure in the centre of the figure acknowledges your initial idea that it has to do with a tree. However the trunk fails. If I ask you: "O.K. it is a tree, but where can you find such a strange shape of a tree?" You might start some reasoning and find out it must be the top view of a tree. This is correct. This puzzle illustrates that the third dimension can easily confuse your normal reference to reality if not appearing in conventional situations or from conventional angles. This weak part of human perception can be used to amplify cognitive uncertainties which are very important in thinking, learning, decision making and design. Just like perceptual tasks, cognition needs exploratory situations where we can discover the constancy in our relation to reality by experiments. For instance it is a good practice to imagine cutting planes if you like to become aware of complex shapes.

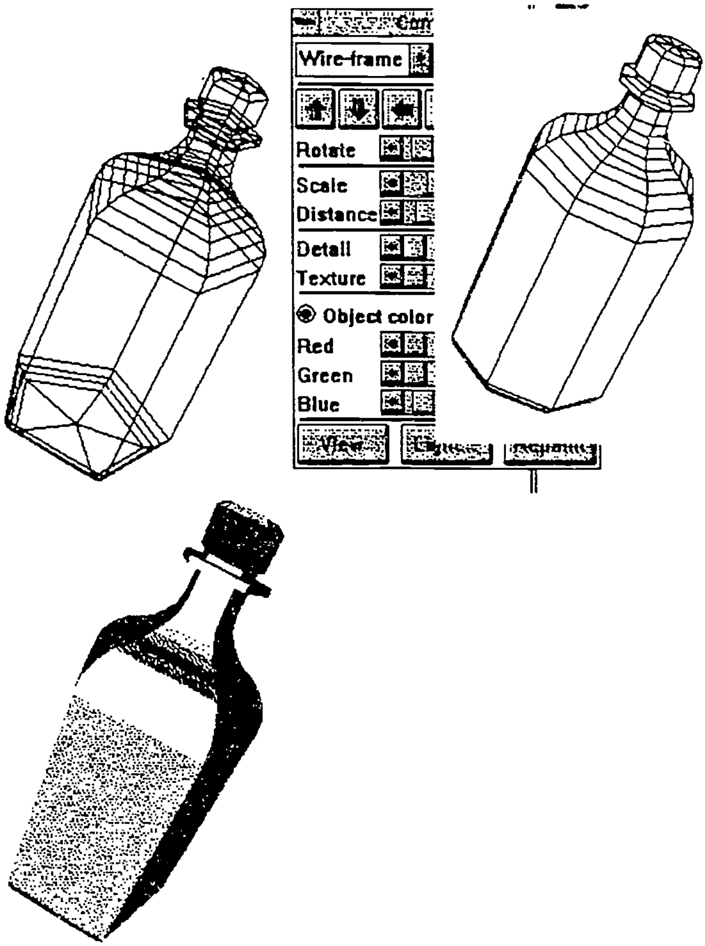








µLathe (MicroLathe) is an easy to use modelling tool that allows you to create three dimensional objects using the metaphor of the carpenter's lathe. The number of slices may be chosen and one of
the display methods as well. the wire-frame is the most rudimentary one. Hidden, constant and Gouraud give an increasing level of spatial and light-reflective realism.



The different outlooks of the lathing procedure can immediately be viewed and controlled for certain conditions of light and rotation. The lathing metaphor enables the user to explore the relation between lathing curve and its final effect in 3D space. It illustrates perfectly the functionality of CADD technology (Computer Assisted Draft and Design). It is not only effective for the designer of visuals but especially adequate for students who use it as an exploratory tool for spatial awareness.

Conclusions

This chapter has raised some didactical opportunities which may benefit from graphical and spatial manipulations by the student. Browsing through visual images in interactive learning material until now is restricted to simple actions like panning and zooming like present in current CAD and drawing packages. Visual representations in computer systems allow the user to explore spatial perspectives in order to acquire a better understanding of physical objects, machinery and constructions like architecture and design

Before flexible and meaningful visual transformations become possible it is important that pictures are vectorized along at least three dimensions The fourth dimension (time axis) becomes important if it concerns an animated process, like important in explaining the four strokes of a combustive engine.
Adding semantic relations between the components in a visualized constellation like an engine, electronic device, or an organic body can will even allow the student to explore its functionality as he/she changes the position, the size or even the shape of elements, after which the consequences in functionality will be displayed, like e.g. the temperature, current, concentration, speed, friction etc.
The ultimate benefit from interactive visuals might even go beyond the spatial and mechanistic orientation. The given examples of 'impossible figures' as carriers for concept maps show that spatial conflicts in pictures can be used to elicit pre cognitive ideas and hypotheses from the student at the beginning of learning sessions in order to provoke an optimal receptive mind for new ideas. Crucial issue in visualisation for learning purposes is the possibility to manipulate, change, combine by the student while the consequences can be seen immediately from the same picture.

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