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Art from the Screen

Those among the constructivists who used the first mechanical plotters for the realization of their concepts 25 years ago, were much impressed by the exact programming technique. This technique not only provided them with the possibility of a precise representation of graphic elements but also, for the first time, with the chance to include more complicated objects in their performance. With the emergence of the versatile scanning devices, this method was somewhat forgotten. Today, one prefers the spectacular photo-realistic pictures from the computer. In connection with these latter pictures, however, the mathematical method, also for artistic purposes, has regained importance, not so much for the production of works of art themselves, but for the preparation of systems designed to facilitate the work of future generations.

The tasks in this field do not concern the problems of "hardware", of the instruments, but the increasingly important "software"—i. e. everything dealing with the organization of calculation and logical processes, with the conversion of data. These activities are an integral part of graphics, too. Undoubtedly, the development of effective output-units is of great importance; at the same time, the inclusion of graphic instruction into the procedure-oriented languages is indispensable for utilizing this very equipment. In the course of time, entirely new ideas were developed that have their impact on application. Here one has mention the so-called "rubber band graphic" by Ivan E. Sutherland who has, apart from other pioneer achievements in the field of computer design systems, introduced the following seemingly simple principle: with a sort of pencil the user is able to draw straight lines at their endpoints all over the screen; a similarly practical device is a procedure to fix the exact position of points; all you need to do is to designate, with the pencil, to the computer a certain point on the tableau, near the exact position; then, the computer will determine the exact coordinates on the basis of general data such as that the point ought to lie on a given screen or at the cross-point of two lines; the computer chooses the nearest point to which the given data apply.

Step into the Third Dimension

In the field of software we have witnessed an important step similar to the one taken with the transition from the plotter to the scope screen. This innovation is the progress from the two-dimensional to the three-dimensional. At an early stage, computer designers had found out that their systems were not only suitable for the graphic representation of data lists but also for the production of autonomous graphic documents. Thus, they turned to circuit diagrams, maps and architectural horizontal and vertical projections. All these are limited to the two-dimensional sphere—the architectural example suggesting to produce pictures in perspective apart from the mere projections. In principle, a three-dimensional configuration is sufficiently determined by horizontal and vertical projections, thus making a drawing in perspective a mere matter of routine. Here, certain mathematical methods are needed that do not pose any basic difficulties, that would, however, were they carried out by hand, take up so much time that the architect prefers to use a three-dimensional model in order to give a notion of the completed building. The fast computer manages calculations like these in no time, a fact that brought about a gradual transition from the second to the third dimension.

With high-capacity systems, the calculation is carried out within fractions of seconds, as a result of which one can calculate the views of permanently changing perspectives at such speed that the sequence of images equals a tour around the building or the turn of a camera to the building or—if so desired—into the interior of the building. This method, CAD (computer-aided design), was developed for the purposes of tool making and mechanical engineering. Frequently, one restricts oneself to a schematic drawing in which only the edges of the envisaged object are shown, to a so-called "net-graphic". Such objects are transparent and have the disadvantage that one cannot easily determine which parts are in the foreground and which in the background. But this problem, too, can be solved mathematically. It is possible to incorporate routines into the programs that determine, on the basis of given data, which parts of the surface have to be covered, thus producing far more realistic images. While previously having had to deal with a network, a transparent skeleton, the graphic image with covered surfaces is no longer a structure of edges but a structure of planes. This, however, raises a new problem, the problem of illumination, of shadows. Again, we need mathematics—on the one hand in order to calculate those parts lying in the shadow, and on the other hand to determine the so-called "lightness of the plane". Here, one uses optic laws according to which one can calculate what part of the light resorting from the source and reflected by planes of differing inclination, will reach the viewer. This calculation is extremely complicated as it has to be carried out for every single point of the image.

Even at this stage we have still not reached full reality, as the objects with which we are confronted, are normally not defined by level planes like those of a polished diamond. The images resulting from net-graphics are therefore only an approximation to the real form, reached by gradually reducing the size of the plane-parts to such an extent that we get a simulation of a continuous process, a surface curvature. It is unnecessary to stress the fact that the calculation of this kind of design in perspective takes very much time.

In the fields of science, technology and architecture one can manage with schematic images that differ substantially from a realistic representation. Here, one has arrived at the limit that is decisive for practical use. Any improvement of quality beyond this limit leads into the sphere of aesthetic tasks, in no way to be understood as purely artistic ones—the necessary means are hardly available—but foremost those of the so-called applied arts such as commercial design, illustration, etc. The costs for production increase dramatically if one does not limit oneself to single images but wishes to have sequences of images, films; in this case, the calculation work described above has to be repeated 25 times a second. In order to solve problems like these, one needs the largest computers in the world, and even they do not manage to perform them in real-time. The necessary calculating time lies far above the required 25th part of a second. Therefore, the material for films is being delivered in single images that are being put together like in former-day trick films. The necessary funds can be raised by wealthy institutions only. Therefore, this method has up to now been primarily used in fantastic science fiction films and in advertising. The explanation is simple: fantastic films show scenes that do not exist in reality—figures from fairy tales, landscapes of science fiction; computer-animation in photo-realistic representation has created an unbelievable semblance of reality in the fantastic film and explains its considerable prosperity. Advertising, especially in the American "commercials", has similar tasks. Often, a product has to be introduced that has just gone into production and is therefore not available for filming. Here, the method of computer design is able, on the basis of construction plans, to produce images of an object that the viewer cannot detect has having been created by the computer.

The high cost for the production of scenes like that is caused—as indicated above—by the demand for photo-realistic reproduction. The costs for the procedure can be lowered substantially if one is satisfied with the solution of approximation. A possible form of application is simulation, for example in the training of astronauts, pilots or engine drivers. For these purposes, one uses cabins in which the cockpits are reproduced true to nature, only the windows are replaced by screens. And it needs a computer system that registers all the trainee's actions and calculates images that could be seen through the windows if the maneuvers were carried out correctly. As one cannot foresee whether the learner will act correctly, the system has also to react to unforeseeable orders; and here one needs real-time.

Consequently, simulator images are still rather schematic, partly because of the lack of details and the abandonment of the exact calculation of optic reflection.

The users of calculating systems who try to solve new tasks with them have a two-fold function: on the one hand, they dedicate themselves to their very special problem that they will have to bring into an adequate form for processing by the computer, e. g. by translating it into a programming language. On the other hand, they do pioneer work by determining with these programs the general outlines of a software that will be available to future users. Once the method has been sufficiently elaborated its application becomes routine, the task is reduced to the scientific, technical or artistic topics. In the field of the two-dimensional graphics this process is well advanced. There even exists a more or less official norm, the so-called GKS (graphisches Kernsystem—graphic core system), choosing of a multitude of principally available possibilities a certain number of possibilities offering the best prerequisites for graphic work with the computer. No norms have as yet been set up for three-dimensional graphics, certain methods have, however, already emerged that will facilitate their use. One of these methods is the construction of stereoscopic objects from simple elements the forms of which are so highly sophisticated that by their combination and by additive or subtractive overlapping a variety of forms becomes presentable. By multiple application of this method, especially by splitting up into ever smaller units, one can achieve an optional approximation to any given real form.

Even possible movements are already pre-conceived in specific systems. Thus, it is possible to achieve the rotation of a three-dimensional object in perspective in real time, by means of a manual operation; a suitable input-instrument is the so-called roll-ball. It can be sunk into a table top with only a small part, adapted to the size of the hand, protruding. The ball is mobile and can be moved along any chosen axis of rotation. The system can be established in a manner that allows the drawing on the screen to rotate in the described way, thus becoming visible from different angles. This movement can also be understood in the sense of the viewer or the camera going round the object. Furthermore, it is possible to change the viewing-point to any other position; as with rotation, the computer has to carry out certain transformations in real-time, in order to simulate a continuous sequence of movements. These pre-conceived routine modes of viewing offer interesting aspects for artistic use. Among them are unusual perspectives such as viewing buildings from below, and last but not least spectacular moves of a camera that would be impossible in reality. A sequence for a film in the series "Startrek", produced by the computer institute of the Lucas Film Company caused some excitement: the strip shows an approach from space to a planet, passing on to a flight over a relief of mountains and lakes and finally—view back to the planet falling behind—leading back into space.

Expensive calculating methods have to be applied in order to achieve an effect of reality. Apart from methods serving an improvement of the quality of pictures not to be described in detail here, it is a question of perspectives, overlappings, shadows and the distribution of light. The necessary programs are partly developed by institutions that also produce the image sequences, being primarily available to them only. Beside the already mentioned group of Lucas Film—they have in the meantime established an independent firm, PIXAR—one has to make special reference to two university institutes associated to enterprises: one of them is the Laboratory of Computer Graphics at the New York Institute of Technology, NYIT, the other one the Institute of Computer Graphics of the Ohio State University in Ohio, under the direction of Charles Csuri. The affiliated enterprises are responsible for the commercial distribution of the systems after testing.

We can suppose that problems of computer graphics related to geometric questions have been generally solved. Today, the main efforts in development are to be found in the representation of certain structures, one might say they have shifted to the sphere of semantics. With the help of Computer Aided Design it has become possible to produce photo-realistic images of all technically produced objects, machines, vehicles, buildings, etc. A curious problem arises when using CAD in the field of art: Everything appearing on the screen is as perfectly clean and faultless as would hardly be the case in reality. So, if such objects were to appear for example in realistic films, one would have to "age" them by some special programming method. As far as we know, experts up to now have evaded this question as it seems to be fairly easy to produce rust stains or scratches if required. At the moment there remains a sufficient number of complex problems raising fundamental questions and demanding the application of new methods. This is the case when natural formations are to be depicted, such as the surface of planets or the reliefs of mountain ranges with valleys in between. Yet, here one is still concerned with solid unchangeable objects to which one can readily apply the routines of geometrical optics. A different question is according to which points of view a mountain landscape ought to be composed. Certainly it is no problem to construct a specific mountain or even a specific landscape by means of computer design. However, the experts of the institutes intend something else: they wish to find a generally applicable method for the routine representation of such surface forms. In this context it seems desirable that the basic formulas contain parameters by which it is possible to describe characteristic features of the objects. Take the example of a mountain range—such parameters might be the average altitude above zero level, the average inclination of the slopes, the degree of cleavage, etc. With this task an important step is being taken towards a scope of propositions that are no longer technically but predominantly aesthetically oriented. While there are differing technical as well as artistic applications of the various procedures of the three-dimensional representation, the programs for the set-up of landscapes, of clouds, water, plants and animals are only important in the fields of applied and "pure" arts.

Once again—they are aesthetically oriented tasks, the means of their solution, however, are to be found in mathematics and programming techniques. Strangely enough, this involves mathematical principles that hardly ever are applied in technology but seem to be especially adapted to natural processes. Apart from any artists goals, this opens up a multitude of fascinating questions connected to the structural principles of mountain formation, growth processes and similar phenomena.

Random Distributions and Fractals

Closely related to this, we find a principle that has been tendered by computer software ever since the very beginnings of computer design, i.e. the principle of randomness. This seems a contradiction in itself, considering the computer as a machine for the generation of order, whereas randomness is characterized by the very absence of any order. In fact, it is not real randomness that is being provided in the framework of various programming languages but a so-called pseudo-randomness. This is to say that in spite of an outward appearance of chaotic distribution, combination of color, etc. there does exist a hidden principle of order. One might take this as a starting point for discussions on the differences between random and pseudo-random, involving interesting mathematical and also philosophical considerations. As for the application in art, however, the only thing that matters is the fact that those who deal with the product, possibly a work of art, are unable to detect any order in the multitude of forms that count. In this connection one might raise a number of very interesting questions of information psychology and perception theory with a view to aesthetic effects that will, however, not be dealt with in this paper.

Be it random, be it pseudo-random—there are only few applications in science and technology, eg. for the various tasks of simulation; on the other hand, the first artistically interested programmers already used this phenomenon by incorporating not only the computer-inherent order but also the elements of randomness produced by it. An entirely different aspect gave new actuality to the element of randomness in our days, in connection with the reproduction of forms of nature. For natural structures such as fir needles spread on the ground, stones littering the seashore, the pattern of raindrops on a window pane, it is not important whether they are distributions of randomness or pseudo-randomness but only whether one is able to achieve a seemingly correct reproduction by means of "random instruction" established for this purpose. In many cases this is possible, in even more cases one comes up with so-called "stochastic" processes: with processes that can be characterized as "partially subject to randomness". By clever combination of order and randomness, by setting certain focal points, by fixing average quantities and by establishing "interference factors" one can reproduce an even greater number of natural textures. Some examples of stochastic distributions: logs floating on water, leaping flames, sparks flashing from red-hot metal. In all these cases there is a certain given direction to which, however, the elements do not stick exactly, they are said to be dispersed around an average value.

In recent years, a new focal topic of mathematics has unexpectedly led to a variety of groupings in photo-realistic computer design, i.e. the "fractals" defined by Benoit B. Mandelbrot; numerous mathematical papers and several books have been recently written on this topic. It is astonishing that these structures have also aroused the attention of artistically interested circles and become subject of several exhibitions, amongst them an international event organized by the German Goethe Institut. The only thing to be said here about the nature of the fractals is the fact that they can be made visible with the help of lines that are—as their name indicates—"multiple refracted". And these refracted parts, e.g. edges interrupting the course of a curve, are not only to be found in macroscopic viewing; this principle of refraction repeats itself into the very smallest spheres.

We know of regularly structured fractals, of which the "snowflake curve" is a well-known example. We can imagine this as a regular hexagon whose collateral lines are interrupted by prongs. These prongs are composed of line elements that again are interrupted by prongs of the same geometry, reduced in size accordingly. In addition, there are also irregular fractals, composed on the basis of a principle of randomness. They, too, show this "endlessly refracted" character, with the distinction, however, that here the formation of prongs, interruptions and corners is not subject to fixed propositions but that they change from one step of reduction to the other.

When Mandelbrot confronted the public with his fractals, his colleagues were fascinated by the originality of the idea, they were at the same time certain that they were a synthetic product of thought with no counterpart in reality. To everybody's surprise the character of the fractals has in the meantime proved to have become part of the principles of natural structures. Finally, it ought to be mentioned that we have been informed of the first practical application of fractals to the solution of the tasks of computer design; it was Loren Carpenter who had used the fractals for the construction of a mountain range relief. This idea is obvious: from an overall view, a mountain range does not only seem to be irregularly structured as to the situation of elevations and valleys, but also consists of smaller valleys in the various mountains and smaller elevations in the valleys in which we find further hills—this structure could be continued into the microscopic sphere. And this is a typical characteristic of fractals.

Mountain ranges composed of fractals have since become part of the everyday appearance of the computer simulation of landscapes; what once used to seem so logical has started to meet with renewed criticism. The Swiss Martin Heller, for example, proposes a completely different method—he believes that one should, when modelling an alpine landscape, depart from realistic preconditions, from a given tectonic of plateaus, and carry out the changes according to the model of erosive processes as they happen in reality. Heller being an informatics expert specialized in computerized geological cartography, one might consider his objection as the exaggerated postulate of a scientist. But he is also a renowned computer artist and reasons with aesthetic arguments in favour of his proposal. He feels that his method would not only offer a closer proximity to the real processes but also safeguard a greater variety and thus aesthetic improvement. Doubtlessly, his opinion should not be left unheeded. Fractal mountain ranges will suffice for short-term scenic backgrounds. However, if a strange landscape in itself is to be subject of a computerized animation sequence, the "scientific" method will offer far more impressive possibilities of forms. Thus, one could replace the notion of real terrestrial conditions and postulate a mountain formation that does not exist on our planet. The wealth of pictorial forms that could evolve from this basis would be, also from an aesthetic point of view, a "better reality" even though it does not exist in nature.

Modelling of Life

Similar considerations could be attached to various other tasks of modern computer design and computer animation; we shall, however, restrict ourselves here to mentioning the most important problems only. Among them are other structures that one was able to come by with the aid of fractals—e.g. the distribution of clouds. The representation of moving water, such as the surface of a lake or of the sea, was an even more difficult task. One of the first to dedicate themselves to this goal was the computer designer Nelson Max from Lawrence Livermoore Laboratory in California. The problem of simulating the motion of waves in a physically correct manner proved to be very difficult. Simple cases such as the wave movement resorting from the centre of a circular container are easy to handle, but nature confronts us with irregular coastlines from which refraction starts out, which in turn is overlapped by the primary wave motion. This task cannot be solved exactly; therefore, the author's quality is illustrated more by his capacity to take into account all the substantial characteristic parts and leave out everything that would surpass the framework of his task or to replace it by a random motion.

Bill Beeves of the PIXAR group has been concerned in recent years with various examples of textures for which he found common valid logarithms of representation. Among them, there are licking flames, as well as waving cornfields. Plant structures, grass, woods and individual trees, too, were subjects of research by Bill Reeves and his colleagues.

Finally, the treatment of living creatures brings forth entirely new aspects. In some cases, such as the famous commercial strip "Sexy Robot" by Mssrs. Robert Abel, Hollywood, the task was solved by hiring a human model and fixing lamps to shoulders, knees and other prominent parts of the body, thereby studying the process of movement envisaged for the animation sequence. In other, more research-oriented institutes such as Ohio State University and New York Tech, one has tried to tackle the problem at the roots. As one could not expect the very first attempt at a true-to-life representation of known animal species to be successful, one started out with fantastic beings. In Columbus, it was a beast of prey, similar to a tiger, in Long Island, the headquarters of NYIT, the experts worked with an ant-like robot-being in the framework of a planned science fiction film. In these cases, the reproduction of movement was not achieved by plane projection as it is done in painting or film, but by a method that reminds us more of the construction of a machine than of a process of imaging. The designer starts out from the three-dimensional structure of the skeleton (that need not be true to nature as long as it functions with regard to the joints) and develops—e. g. by fixing the limiting value of the angular motion—the changes of form that result from running, jumping, turning of the head, etc.

With a view to the complexity of the task, requiring fully qualified programmers, it is evident that this method has not yet been applied in pure art. But it does open up remarkable perspectives, modes of procedure that have nothing in common with the traditional forms of painting or with the three-dimensional classical sculpture that mainly take into account the surfaces. The term "creative" in the true sense of the word seems adequate for the construction that proves essential here—because the work of the designer comes far closer to a creation than to an image.

While we are here dealing with activities the consequences of which for artistic processes are to be expected for the future, the same goes for the most complicated problem of all, i.e. the computerized modelling of man. One of the reasons for the difficulties encountered is to be seen in the fact that the human body, the human face is so familiar to us that even the slightest deviation irritates us. Nevertheless, some programmers are tackling this problem and especially that of the face and its changing expressions. For the purposes of feature films the main problem is the movement of lips synchronous to the language and—a connected problem—the facial expression suited to the content. We have still a long way to go before we will achieve a physiognomy close to real life, we have, however, succeeded in simulating the human face so that it has become animated, although in a puppet-like manner. The movement of the eyes, the lifting of brows, the changing form of lips—all those suggest human sentiments that, however, seem very strange because of the metallic smoothness of surface forms. Representations like that are especially odd because the faces are not framed by hair, thus giving the impression of animated masks. The reason is to be seen in the fact that up to now nobody has been successful—or maybe nobody has really tried—to image human hair on the computer screen.

Modes of Alienation

The next years will probably bring about an increase of the number of structures that can be handled by computer design and computer animation and used by means of user-software. This will be the moment when this method will be freely available to those users who are not interested in the development of graphic software but only in design.

Certain critics have objected that the simulation of reality and its translation into program instructions could not be considered an artistic or creative act and had nothing to do with art. In this extreme formulation the argument is certainly not valid. However, the problem of imaging in the classic way now shifts to a task of synthesis in the sense of a technical construction. This comprises the entire variety of our world in realistic presentation of all natural and man-made forms. There are various reasons why this kind of painting is no longer appreciated in our days; they need not be dealt with in detail. It is not a question whether applications are finally to be expected in the field of the "pure" or the applied arts, or whether works like that meet with the approval or disapproval of critics. It is, however, the question of finding a general solution to a problem and the fact that a new approximation has been found. Experiences have shown that results of this kind have proved to be important impulses for art, too, possibly as starting points for entirely new tasks.

According to wide-spread opinion, the imitation of reality is no artistic achievement, from a work of art one expects some kind of alienation, frequently called "heightening"; this means that an effect utilized at random is not considered sufficient, one expects an underlying formative meaning, such as a clarification by reduction to the essential or a dissolution of familiar forms for the stimulation of associative processes. Both the representatives of real-simulation and their critics are aware of the fact that profane reality is not so important in art than in the task mentioned above. The representatives of real-simulation think it desirable to master the representation of reality before turning to alienation. But why take the complicated way of realistic representation when there is a far simpler access to the interesting effects of alienation?—that is to say the way of limiting oneself to the approximation methods in simulation, thus automatically achieving deviations from the naturalistic image.

In fact, certain artistic works in the field of computer design simply resulted from the application of inadequate methods of imaging. Some of the occurring effects are known in traditional art as well as in experimental photography, for example the reduction to contour lines, the dissolution into rough courses, the attribution of wrong colours. However, many of the occurring phenomena are new. Produced images of unusual charm doubtlessly enrich the spectrum of representational possibilities. From an aesthetic point of view it might be of interest to study these effects as to their applicability to specific goals.

The film TRON may serve us a good example. Although it was produced only a few years ago, the methods of computerized graphic representation have made such progress since then that the images shown in this "classic" might be considered inadequate by today's standards. Regrettably, this film as a rather commonplace plot in the form of a primitive action-spectacle. On the other hand, the film shows fascinating, up to then unknown pictures that might be the vision of a fantastic city of the future. They were produced with a method of computerized design that had no aspirations to photorealism but used deviation from the usual as an element of style. This is justified by a clever trick in the plot's concept: The scene is set in an imaginary world situated in the sphere of adventurous computer games. By a trick, the hero is banned to this place—and this gives the opportunity to demonstrate transparent buildings resisting the power of gravity, utopian vehicles racing around corners with breathtaking speed, fantastic machines and a exceptionally elegant craft, a hovering aircraft propelled by sun-sails.

It might be suspected that alienation effects based on inadequate processing might lose their attraction after some time and that the better, because more general method is the reduction of achieved reality. Here, the artist himself can truly determine his own kind of alienation and adapt it to his own purposes. There is yet another way of achieving unusual image innovation on the basis of the representation of reality. It is up to the artist to make use of all means of real-simulation and to stick to the created impression but to deviate from reality in his concept insofar as he himself invents certain objects, creatures and landscapes by figuring non-existent objects in a realistic presentation—even using optical effects of refraction and diffraction. This style is known in classical art by the term of surrealism. This style is limited by the simple fact that it is technically laborious to abide strictly to the laws of geometry and optics and to work with the multitude of details of an assumed reality. In the field of static images this method has been applied frequently, having, however, raised the question whether the precise consideration of the laws of geometry and the exact positioning of lights has anything to do with art; the creative act should be seen in the conceived vision.

A very important additional element is the fact that the computer animation is also able to present these pictures, scenes and visions in motion; here, the borderline has been crossed within which visual concepts that can be realized by manual means are enclosed. Up to now, there are only few short scenes giving an indication of what will once be possible, also in the field of arts; and even these few examples are mostly packed away in banal science fiction action so that earnest critics do not think them worth mentioning.

This, too, leads to a shifting of the artistic act of creation from a depicting activity, generally taking into account geometrical projective points of view, to the elaboration of visionary concepts. What is expected from the artist by far surpasses the creation of a single image. When he has to deal with sequences of pictures, with processes, they all have to be tuned to one another. To be exact, it needs a conception of an imaginary world with its own multitude of forms and its own laws. For the user of computer-animation is by no means confined to the known laws of nature—he can change them at random, something that has already been demonstrated in the film TRON with the racing bicycles that can go around corners without time delay. It is certainly up to the artist to decide which formations to chose, how to conceive a utopian or fantastic scenery. The critical viewer, however, will soon notice whether the artist's concept is homogenous or faulty. There is nothing to be said against showing a world of dissolving clocks—following an idea of Salvador Dali; contrary to the work of the famous surrealist, the production of an instantaneous picture is not enough, it will prove indispensable to reflect on the rules governing dissolving objects.

Interactive Art

In art, the transition to motion is a consequential step, for the traditionally educated painters as well as for the graphic artist who will be utilizing this method in the future. This does by no means exhaust the possibilities offered by the computer technology. An additional, fundamentally important element that can only be realized with the help of the electronic method is that of interactivity. Up to now, talking of image sequences meant film sequences, linear series determined in their logical succession. This limitation complies with the conventional mode of thinking oriented towards film and television. If it is possible to describe an entire series of pictures by means of a computer program, it is also possible to run the series in any order of succession. Computer supported design offers one simple example: here, the viewer can choose any desired point of vision by means of the roll-ball. A similar case are the simulation programs that need not necessarily be regarded as linked to a learning process. The same program principle makes it possible to fly over the given landscape forms in any chosen direction and—as an additional effect—to go into low level flight at places of special interest: the mouth of a river, a bridge, a city. In fact, there already exist programs like that for game purposes (derived from more sophisticated models) to be operated on small computers. It goes without saying that this implies a limitation to considerable simplifications. Let us mention a third case: the Massachusetts Institute of Technology has developed a program based on the highly detailed mapping of a village. It lets the user stroll through the streets and regard any chosen point. A program like this might, for example, serve the purpose of acquainting a group of special agents with a location they could not enter before the planned action.

Applications of this kind are undoubtedly practice-oriented, up to now they have hardly ever been used for artistic purposes but they nevertheless indicate surprising expansions of the known method of dealing with images that might be of special interest to the artist. This links up to the method of constructing surrealistic sceneries that was described above, pre-supposing that it is the artist who determines the manner in which they present themselves, in which way and with which speed the viewer moves through them. Now, there are indications that the viewer, or better the "user", might become able to make his own decisions. The artist offers him the world designed by him and the user takes it up, no longer in a position of passive viewer but of active scrutinizer.

In spite of all the improvements to be expected in the future, the storage capacity of computers will remain a limited one; one could therefore suppose that the worlds designed by the artists have to remain restricted to a segment—a three-dimensional segment. But this does not necessarily have to be the case. A method can be conceived—and has already been practiced tentatively—that would only need limited storage capacity and would nevertheless offer an unlimited "world". This can be achieved in the following manner: the computer constructs the region that the viewer wishes to visit in the very moment in which the relevant direction is being chosen and thus the intention being expressed (this goes unnoticed because of the high speed of calculation). As, on the other hand, the artist is unable to fill an infinite space with objects, he is forced to design his world as a mere concept, that is to say he has to set rules for the formation of landscapes, for the growth of plants, the appearance of animals, etc. Today, the limited calculating capacities prevent a process like this; it will certainly take another ten or twenty years of technical progress before the methods described will become applicable. The artist will be expected to demonstrate an even higher degree of creativity for he will have to construct a world not of individual objects but according to all-encompassing rules that are in conformity with our laws of nature.

The development of such methods can also progress in a different direction: not with the aim of creating immense spaces but with a view to simulating complex interhuman relations. Although this possibility may seem utopian to us today, there is no reason against its possible realization in the future; and that is why it should be mentioned briefly. It is not unrealistic to imagine that in the next century it will be possible to conceive human characters in a manner that they will not only be visible on screens or projection walls but that they will form societies in which action goes on, communication takes place and conflicts are being settled. With regards to an interactive representation the viewer will not have to remain excluded—it seems possible to attribute him a certain role in the event so that he becomes a co-actor. These forms of "event games" can be supported by transition from the close limits of the screen to the larger projection walls and finally to panorama projection. The user then finds himself right in the middle of a world that is modelled to such perfection that it comes very close to reality. It goes without saying that sound effects will be integrated into this kind of representations so that the connection with music can be as close as desired. Another, even more remarkable effect is that there will also be a connection to narrative literature—the concept of action spheres in which the user will make his artistic experiences, not only visual creativity but also the art of narration is attributed to the authors.

After having made this excursion into the not too far future and into the imaginary worlds of the computer, it is certainly necessary to recall that we are today still at the very beginning of this development. Compared to the classical arts, computer art is still in statu nascendi. It is therefore understandable that the majority of endeavors dedicated to it takes place in the field of instruments whereas truly artistic application is still the exception, not least because of the horrendous costs of the necessary systems. There are many indications that this situation will change in coming years—only then a development set in vehement that will be governed by creative artists more than by inventors of technologies. Today's products of primitive apparatus will therefore hardly do justice to higher esthetical criteria. In some few video and computer created image sequences, however, we are able to get glimpses of the artistic possibilities that can be expected from the future; that is why some people who are interested in the development of contemporary society and especially in the development of art, consider these very strips to be more remarkable than most of what is to be found in our museums as testimonials of ripe classical art.