Physical models for the visualization of animated images ”from the physical model to the eye”

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"FROM THE PHYSICAL MODEL TO THE EYE"

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I. THE PROBLEM: General presentation and an overview of the already existing concepts and techniques

The creation of animated images consists of working on both movement and image itself . This paper falls within the framework of a reflection on the properties of image and its creation processes within the double context of animation and artistic creation. The first part of this paper is a general presentation of the problem and the different research questionings that it raises. The following part is a presentation of the first studies that we have carried out on these subjects.

We will briefly examine the situation of image synthesis today in order to propose image creation modalities that be better suited to artistic creation than those that are usually used for realistic visualization.

In the case of animated images, the properties inherent in motion and those inherent in each image reinforce or cancel each other depending on each individual case . Consequently, we must study the properties of images when it is meant to support motion.

Realistic rendering techniques as a neutral level of digital visualization : a pre-artistic stage

Today, image synthesis consists of a digital modeling of objects. It yields what could be named a "digital prototype" of the objects or scene that is to be represented. This prototype tends to reproduce as faithfully as possible the shape of the reference object or scene, its behavior towards light or its movements.

Next this prototype is given to be seen by a projection on a visulization screen . This is realistic visualization. Thus the various existing visualization techniques tend to restore this prototype as if it were directly present before the observer's eyes. This is a representation level that can be termed neutral. In this sense, we consider that image synthesis is in a pre-articistic stage.

From the object to the eye : a set of representation strata

We know clearly that the modeling of physical objects implies representation processes that demand explicit questioning when it is a matter of artistic creation. In quite the same way, passing from the prototype to its visualization implies representation and interpretations of this prototype for the eye (whose "neutrality" is only a first stage insufficient for artists.)

Besides, visualization is a new term in arts (as it is for the other fields for that matter). Does a painter make any difference between modeling and visualization ? Between the mental model and the eye stand the canvas and the brush, the frame and the film, that all belong fully to the tool of creation and leave their mark in the whole work.

In our previous works, on physical modeling and gestural control (Cf [1] [2] [3] [4] [6]) we have developed concepts and techniques for the modeling of objects in motion. At present, we must go beyond the neutral level of realistic visualization in order to think of the models and tools with which we can render these movements.

Models for the creation of static images

The comparison with painting and sculpture is fruitful. Image creation implies a questioning on the creation tools. Obviously between the painter's model and the viewer's eyes stand not merely a neutral marker or a neutral support but a brush and a canvas. In quite the same way, between the digital model of the object and the viewer's eyes must be added a creation tool for images, in which a sort of modeled and simulated marker interprets and inscribes this model on a modeled and simulated support.

Note that the point is not to copy already existing markers and supports, and pretend that image synthesis can produce paintings or charcoal. Our work consists of thinking basically about the purpose that this layer of model interpretation must fulfil, by the eyes and for the eyes.

II. Elements of answer

From the previous analyses two studies must be carried out within the framework of the theme : "From the physical object to the eye"

II.1.The modeling of the object that is to be visualized

The role of this sequence in the creation of the final animated image is the same as the role of the sketch that, in the creation of a drawing fixes the proportions and the balances . This scene is to be visually interpreted in the same way as the drawer, starting from the sketch, erases, adds, evokes clearly expresses, stresses or forgets certain strokes.

This is why a new object with specific properties is to be defined, a *clothing* that on one hand would fit the underlying physical structure, and on the other hand would support the visualization.

The simplest case of clothing is the simple outline. Physical modeling models natural objects in terms of matter rather that in terms of outline.

The outline is the object's exterior whose function is to support what will be seen . For instance in the case of the marionette, this clothing can trivially result in a humanoid shape.

However it is far more interesting to generalize our concern by thinking of what we actually wish to show. Thus rather than a trivial outline, a few lines or tension zones judiciously chosen, may be sufficient to evoke the object in motion. The clothing would be a new shape that would reveal or perhaps more or less conceal the underlying physical structure. It does not necessarily or trivially stick to this structure and the very distance between these two representations is the subject of a true creation work.

In order to illustrate what we mean by clothing

let us mention a process that is sometimes used in hand animation. For example in a dynamic sequence animating a character, only a part of the character is drawn on each image. It is from snatches that the observer restores the character in the course of its movement . The choice of these snatches is fully an artistic work.

Furthermore these snatches are painted and therefore have their own life within their relief. Thus what is shown is not a mere character but an artistic being in which are combined, the character's movement, the painting's life, and a representation of ephemera, since the subject never appears wholly and nevertheless has a clear and great presence.

The nature of clothing and the relation with the physical structure

Thus the clothing is one more shape dynamically controlled by the underlying physical structure. It can be physical, graphical, geometrical or mathematical depending on different cases that have to be specified. The link with the physical structure can also be physical or not, through points or control structures. Moreover, since clothing is visually much richer than the DPO. This raises the problem of its computational cost and its insertion into the creation protocol : how are the sketch and the final object to be articulated within the creation time.

II.2. The modeling of the visualization support

After the two stages (i) models for motions (ii) from the support shape to visualization, we have an animation that can be visualized. As we introduced it previously, the visualization support must be modeled in terms of intrinsic properties, that do not depend on the objects' properties but define the conditions of its perception. The support, according to its very definition, is what receives the visible trace of what is to be seen.

This support is defined by a basic model and properties :

a. The 3D pixel, the basic model of the support

The basic model of the support is composed of a surface of simulated discrete 3D pixels. One model example is the pin screen that is a sort of a discrete carving plate on which the 3D objects to be visualized carve and thus render volume sensations.

b. The geometrical and physical properties of the 3D pixel

-- grain and texture

The geometrical and physical properties of the 3D pixel that is, the arrangement of the pins on the surface of the screen, the shape and the size of each pin and the lighting would model the textured grain of the support.

-- Remanence

The drawer's paper as well as the photographer's film are a sort of permanent memory. With the use of computer simulation, other supports can be envisaged for which the traces' lifetime would be a parameter. More or less fleeting traces as on paper, on sand, or even on liquid surfaces (!) ...

The remanence of the trace can be controlled by the attribution of a physical behavior to the 3D pixels.

– Dynamic behavior

By establishing physical interactions between the simulated 3D pixels, it becomes possible to model dynamic properties such as diffusion, absorption, (blotting paper effect, static blur effect) delayed impression (development effect) and propagation effect (wake effect, dynamic blur effect)

III Our first works

III.1 Clothing models

** Physical clothing in physical interaction with the underlying physical structure*

In the sequel, we will study the necessary and sufficient physical object for the achievement of a given dynamic behavior and we will call this structure the "Underlying Physical Object" or the "Deeper Physical Object" (DPO)

The DPO is described and simulated in accordance with the principles of Cordis-Anima (Cf [1] [2] [3] [4] [6]) . It is moved by the physical action of either a human operator or a synthesis command signal. To this first physical structure is added a kind of "skin" also described physically, and linked physically to the object.

Consequently

(i) the clothing has its own dynamic behavior (a deformable skin for example)

(ii) the clothing's movement depends on the DPO's movement and the operator's action

(iii) this dependance is reciprocal the clothing will influence the movement of the DPO.

The example chosen in this case is a visco-elasto-plastic modeling clay.

Figure 1 displays two images taken from a physical simulation sequence. In each figure, both images correspond to the same image of the same sequence, but on one, the DPO is still visible whereas on the other one it is not.

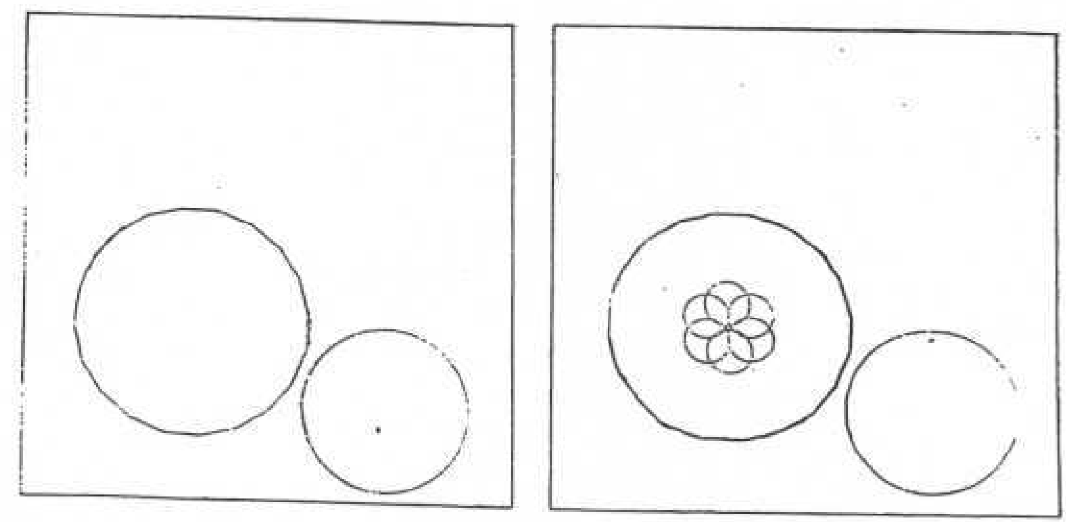

Figure 1.a

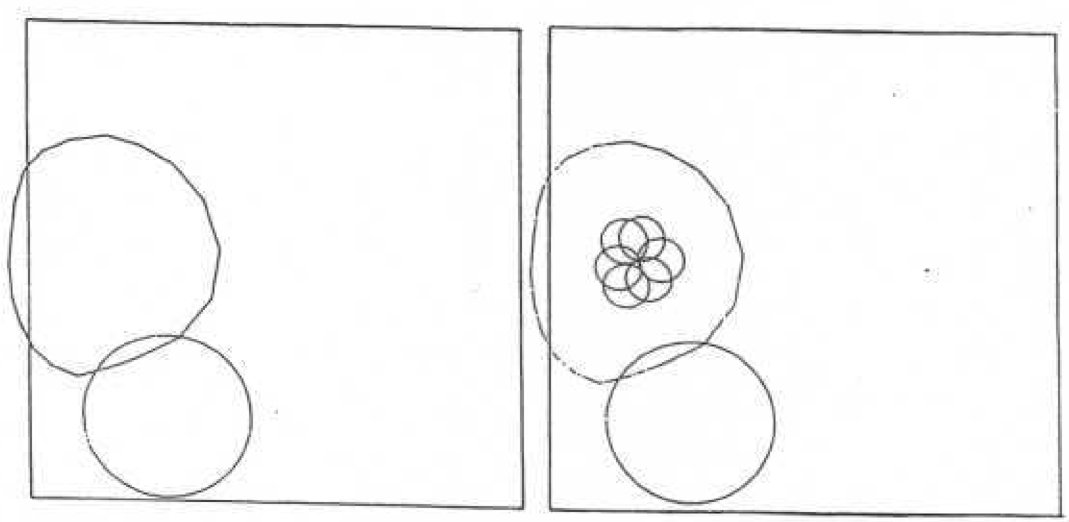

Figure 1.b

Figure 1.a shows the clothed object resting and figure 1.b. shows the plasticity of the skin, its resistance and its influence on the DPO's shape.

* *Physical clothing in non physical interaction with the DPO*

Clearly it is important that the clothing should have its own dynamic behavior and that it should follow the DPO's movements. However it is rarely necessary for the clothing to influence the DPO's motion in return. In this case, the clothing remains physical but will simply be controlled by the DPO.

So in a first step, we carry out a real-time simulation of the DPO. This first sequence is memorized. In a second stage, certain points of the DPO are associated with certain points of the clothing. These points will receive force or postion command signals from the associated DPO points memorized in the first stage. Then we can carry out the physical simulation of the physical clothing. The interaction between the DPO and the clothing goes through signals assigned to control points.

Separating the clothing and the DPO in this way makes it possible not to simulate the clothing in real-time and in this way to achieve more complex objects while keeping the qualities of physical simulation for the DPO and the clothing.

The example chosen for this case is a marionette model. The physical clothing is composed of six masses linked to the DPO by damped spring type links. Figure 2.a shows the marionette alone (the DPO) and figure 2.b the marionette with six masses attached to it.

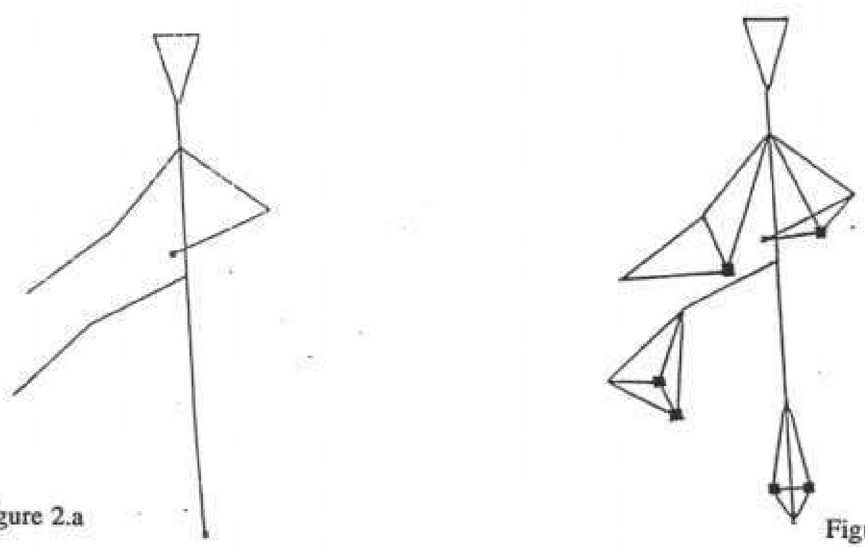

Figure 2.a

Figure 2.b

** Non-physical clothing*

The complexity up to which it is possible to go (for example in terms of number of points) in the previous stages is not always sufficient for visualization . Moreover any physical model is much more limiting (in terms of number of points) than any other model (geometrical, graphical or mathematical) since the masses are necessarily linked by a still greater number of interactions. (Between O(n) and $O(n^2)$).
So it must be possible to put a non-physical mathematical or geometrical clothing on one of the objects of the previous stages. The simplest case is that of mathematical interpolation between physical points. This clothing layer does not add any dynamic behavior of its own. It simply adds spatial properties. This stage was tested by B-spline interpolation applied on each of the previous stages. We will observe and analyze the visual differences produced

Figures 3 and 4 display examples of this process in the case of the marionette. On figure 3 the interpolations were carried out on the DPO itself. The DPO is on figure 3.a. The result of the interpolation is on figure 3.c. Figure 3.b. displays a superposition of the previous objects in order to show the change from the DPO to the clothed object. On figure 4, the interpolation was carried out on the points of the physically clothed marionette. (fig. 2.b)

In fact in this case we have two clothing layers : a deeper physical layer first. and an outer geometrical layer next. Figure 4.b shows the change from the one to the other.

III. A physical model of visualization support

In accordance with the principles mentionned in the previous section (§II.2) we have elaborated a physical model of visualization support based on the principle of the pin-screen. A pin-screen is composed of a white plate with a great number of pins (in the region of a hundred thousand) that are driven through the plate and can be completely pushed in or pulled out by various objects (markers). This *screen* must be properly lighted.

When the pins are all pushed in, they have no shadow on the screen. Thus the screen appears as a white surface. When they are all out, the shadows cover the screen and it appears as a black suface, and when a marker object runs over the screen, pushing more or less the pins underneath, the resulting image with its gradations between black and white renders the shape of the marker.

This principle was implemented with a topological model, a geometrical model, a lighting model and a physical model.

-- The topological model

determines the pins' arrangement on the screen. Different types of discretization can be thought of : rectangular, hexagonal, anisotropic etc...

-- The geometrical model defines

(i) the size of each mesh (the absolute positions of the pins on the screen)

(ii) the relative values of the distance between two neighboring pins and the length of each pin.

(iii) the geometrical shape of the pins that determine the shape of the shadows.

-- The lighting model

defines the number of shadows for each pin, their direction and maximal size. The final image is monochrome.

-- The physical model of the pins

assigns to each pin a mass that is attached to the screen with a damped spring. This 1D mass moves perpendicularly to the screen and undergoes the physical action of the marker. The physical parameters mass, stiffness and viscosity determine the dynamic behavior of the pin. Thus the return of the pins to the neutral balance position and the phrasing of this return can be controlled. Between permanent remanence and zero remanence all the intermediate situations can be simulated.

-- In the physical model of the screen

each pin is linked to its neighbors by visco-elastic physical interactions. In this implementation only the 2, 4, or 8 closest adjoining pins are linked. In this way when a given pin is pushed in, the neighboring pins tend to follow it and are more or less pushed in, with a speed that depends on the specified interactions between the pins. This enables the simulation of propagation phenomena or blur effects depending on the chosen physical parameters.

The simulation goes through two stages:

(i) physical or geometrical simulation (this consists in the calculation of the Z of each pin, i.e. the length of its emergent part)

(ii) displaying the shadows of all the pins.

With the geometric model of the screen, the Z of a given pin is obtained by calculating the intersection between the line that is perpendicular to the screen and goes through the pin's basis on one hand, and a point of the marker (a geometrical sphere) on the other hand.

The pins have a balance position corresponding to Z=Z0. This is a threshold for the calculation of the pins' Z : any intersection point above this threshold level is ignored and the corresponding pin will be set to the balance position. For all other cases, the Z of the pin will be the Z of the intersection point.

With the physical model of the screen, the Z of a given pin is calculated in two stages

(i) the calculation of the interaction forces between the pin and the marker object, the screen and the neighboring pins.

(ii) the calculation of the vertical movement of each pin during the sampling period, in terms of the pin's mass and the forces that it undergoes. Figure 5 displays an example of pinscreen visualization. The represented object is an agglomerate. On figure 5.a is displayed an agglomerate visualized by a non-physical model of the pin. Figure 5.b is an enlargement of figure 5.a showing the shape of each individual pin. This shape does not depend on the type of the pin's model (physical or geometrical) Figure 5.c represents the same agglomerate visualized by a physical model of the screen. In this case were modeled the remanence and the blur phenomena.

III.2. Animation examples

A demonstration video will illustrate the different cases that we have studied. Why prefer an animation tool rather than the reference mechanical pinscreen made by A. Alexeieff ? Because the simulated screen has dynamical properties. The simplest (and certainly the most necessary for animation) is the self-erasing property. In order to animate an object in movement, mechanical pin screen animators have to push in the pins with a marker and pull them back out after the object's passage, while precisely controlling the phrasing of this return. In the simulated model the mastering of all the physical properties of the screen enables the control of this phrasing, as well as the propagation, diffusion and blur effects and still others ... yet to be discovered.

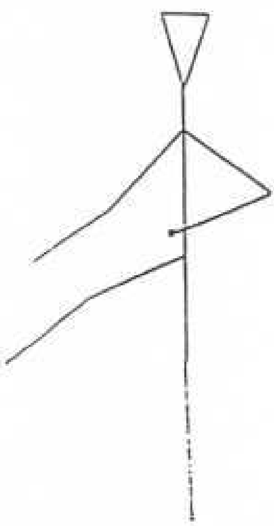

Figure3.a

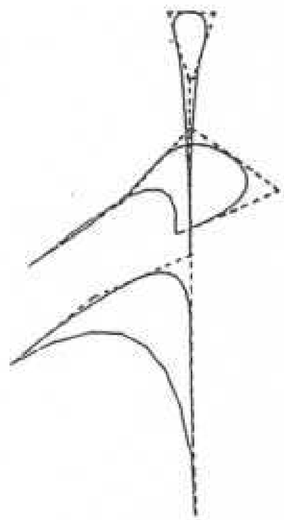

Figure3.b

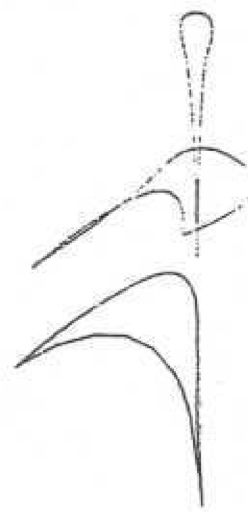

Figure 3.c

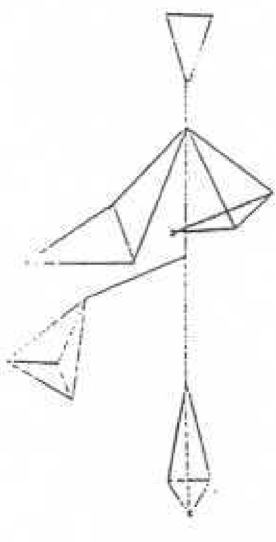

Figure 4.a

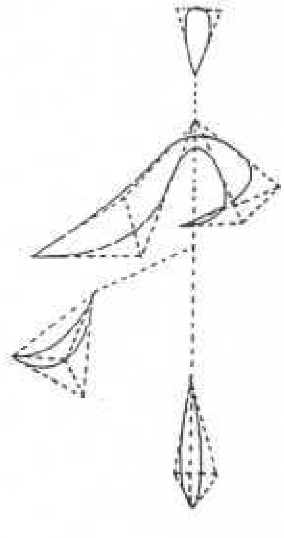

Figure 4.b

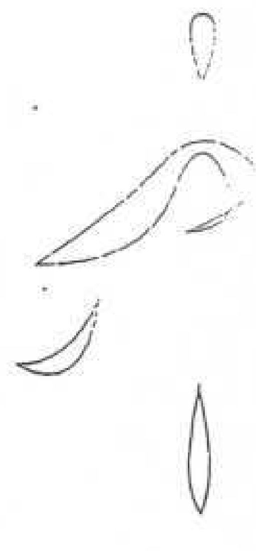

Figure 4.c

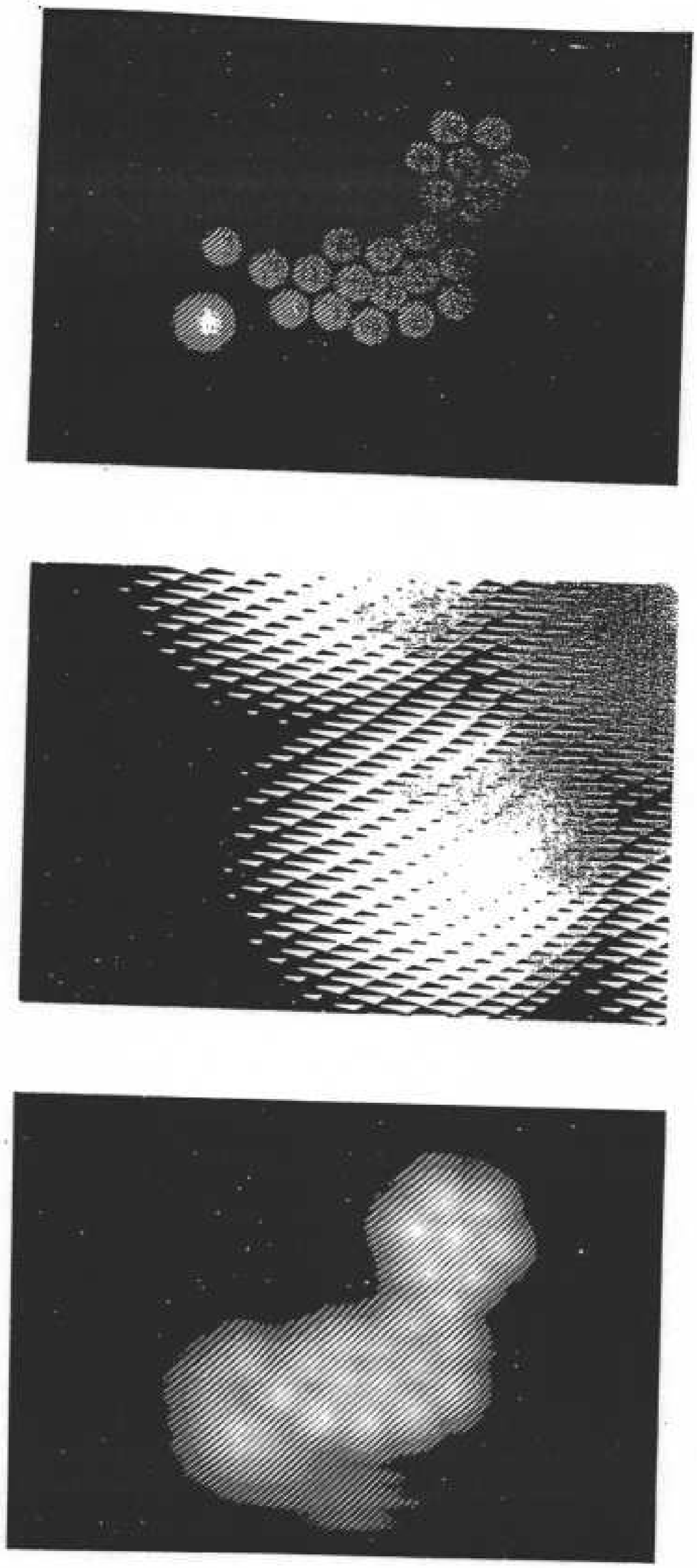

Figure 5 - A model of visualization support

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