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"Computers and Beauty"

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1-18-17, Syoan Suginami-ku, Tokyo 167, JAPAN

In this article we consider beauty and simple methods of its realization by a computer. Here, by the beauty we do not mean such beauty as of logic or of love but mean artistic beauty appealing to the human's aesthetic sense.

In order to realize the beauty systematically by a computer, we need the concept of beauty to be defined suitably for programming. In searching for such a definition, we first note a very simple and very typical example: the "golden section," i.e., the most *beautiful* sectioning of a finite line into two parts. It is impressive that the ratio giving the golden section is not far from 1:1. If the ratio was 1:10, say, then the corresponding section would not appeal to our aesthetic sense. One of other typical examples is music; a beautiful melody would be an ugly one if the arrangement of notes in the music were bad. We can suppose from these examples an *essential* element of beauty; we may call it harmony. A thing being lacking in harmony will make the human's feeling unstable and cause an antipathy in his mind. Saying this from the viewpoint of beauty, we can say that it is not beautiful. On the other hand, we also note that the ratio giving the golden section is not exactly 1:1. We may describe this as that variety is necessary for the object being *more* beautiful. Let us illustrate this by cooking: cooking must contain the nutriment, but even the nutrimental cooking is not a better one if it tastes bad! Thus variety is an *additional* element of beauty. In this sense, an object which is full of variety but lacking in harmony, say a picture drawn by utilizing only random numbers, will not be beautiful. Therefore, one can adopt *the representation of harmony and variety* as a simple definition of beauty. It should be noted that both harmony and variety are conceptually much less abstract than beauty itself and suitable for computer programming because they can be converted into numerical relations rather easily. In the following we shall consider actual methods of realization of beauty through a computer by taking up the drawing as a concrete example.

For the sake of explanatory convenience, we classify the pictorial beauty into i) mathematical beauty, ii) natural beauty, and iii) creative beauty. By these terms we mean, respectively, that i) beauty found in figures easily expressible in terms of mathematical functions, ii) beauty found in nature, and iii) beauty being dependent mainly on the human's creative powers. Many of the actual drawings may, of course, contain two or all of these types of beauty. We are not sure that above classification covers all types of the pictorial beauty, but the reader will see that it is very adequate for the computer drawing.

i) We often experience that simple mathematical functions enable us to make excellently beautiful drawings. Most functions commonly used in applied mathematics represent continuous changes of one dependent variable with respect to changes of other independent variables under some definite rules. These rules maintain the balance of the resulting drawing as a whole, and continuity of the functions prevents the local configurations of the drawing from becoming too various. Thus we may say that most mathematical functions are harmonic. (The functions called harmonic in mathematics are solutions of

the Laplace's differential equation. We are using the term "harmonic" in wider meaning here.) Perhaps the mathematical functions are best suited for expressing harmony simply. What we should care for in this case is how to represent variety. Fortunately, variety is also contained in the functions to some extent, and mathematics provides us with random numbers. Hence, we may be able to represent variety sufficiently in terms of mathematics. Many works of the computer art up to the present are based on the mathematical beauty. This beauty is so popular to computer artists and so easy to realize by a computer that we do not discuss it anymore.

ii) Most people will agree with an opinion that nature is full of variety. But we can also find a great many kinds of harmony in nature; e.g., figures of flowers, butterflies, fishes, mountains, etc., etc. We think this is because that laws in physics, biology, etc. govern the nature and make it be harmonic: matters are built from atoms systematically, only evolved and selected beings are surviving and they are balanced as a whole due to the struggle for existence, and even the nonliving things are balanced. We can hence represent harmony as well as variety by imitating the natural objects. Further the natural objects can also cause through our memory many psychological effects which are no more contained in the category of beauty. The important points in representing beauty by natural objects are that the resulting drawing should not become too complicated and that each object drawn in the drawing should be easily identified. The reason is that natural objects themselves are sufficiently various. For example, suppose we are drawing many flowers on a paper. If we only outline the flowers the drawing would not be so beautiful. If the overlapped and invisible parts are also drawn, the resulting drawing will be too complicated and may even be ugly. In this case, therefore, more complicated programs or peripheral systems are necessary than in the previous case. Some examples are an image reader and a picture recording system, but here we explain our simple program by showing illustrations. Figure 1 shows an input drawing for our system. The drawing showing three flowers

in Fig. 2 is rather ugly because it is too complicated; even to identify it as representing three flowers is not so easy. Invisible parts are eliminated in Fig. 3. In Fig. 4 insides of the flowers are "painted" with assigned patterns. The resulting drawing is much more beautiful than that shown in Fig. 2. In this way, we can see that we can well represent beauty by imitating natural objects and processing them through even a simple system. We should of course design many systems in order to raise the computer art to higher positions. But, since nature is full of variety, we can conceive many possibilities. In particular, since we know beauty of the mathematical beauty and easiness of its handling, we have a good possibility in creating a new type of beauty which has not been well considered so far, by synthesizing the mathematical and the natural beauties.

iii) It is very common that artists raise aesthetic effects of their pictures by emphasizing the principal parts, changing color tones, modifying and distorting the figures to be drawn, and so on. Further artists often make pictures by using mainly their inspiration and imagination. The beauty represented in these cases is created by the human's creative powers. Therefore, in order to treat it systematically and automatically we

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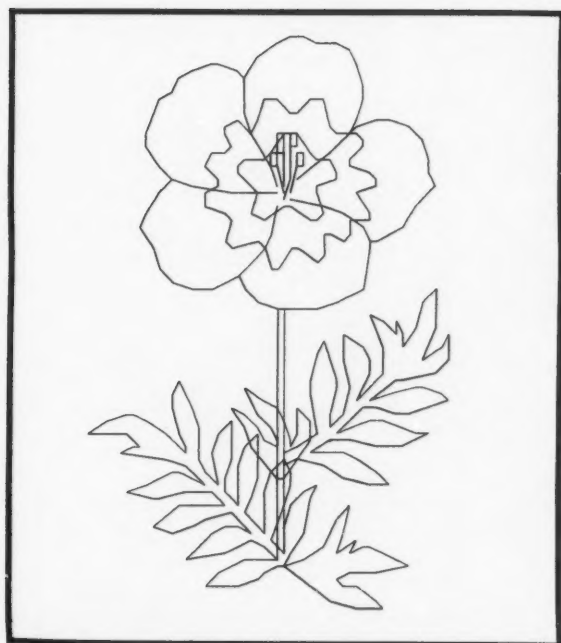


Fig. 1



Fig. 2



Fig. 3

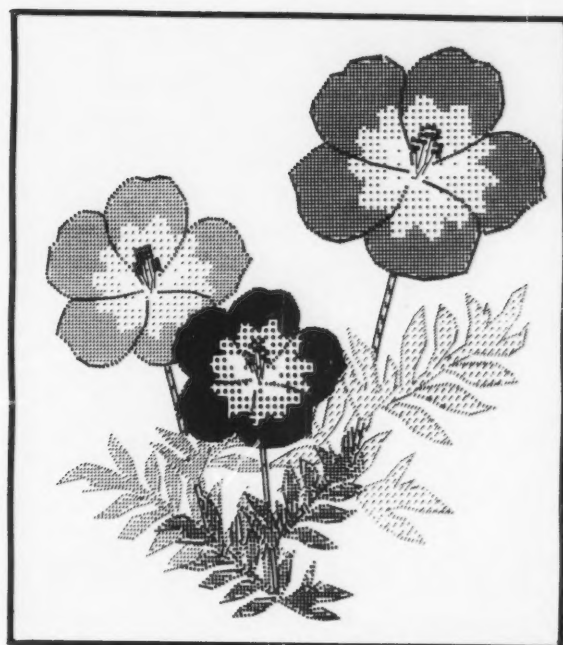


Fig. 4

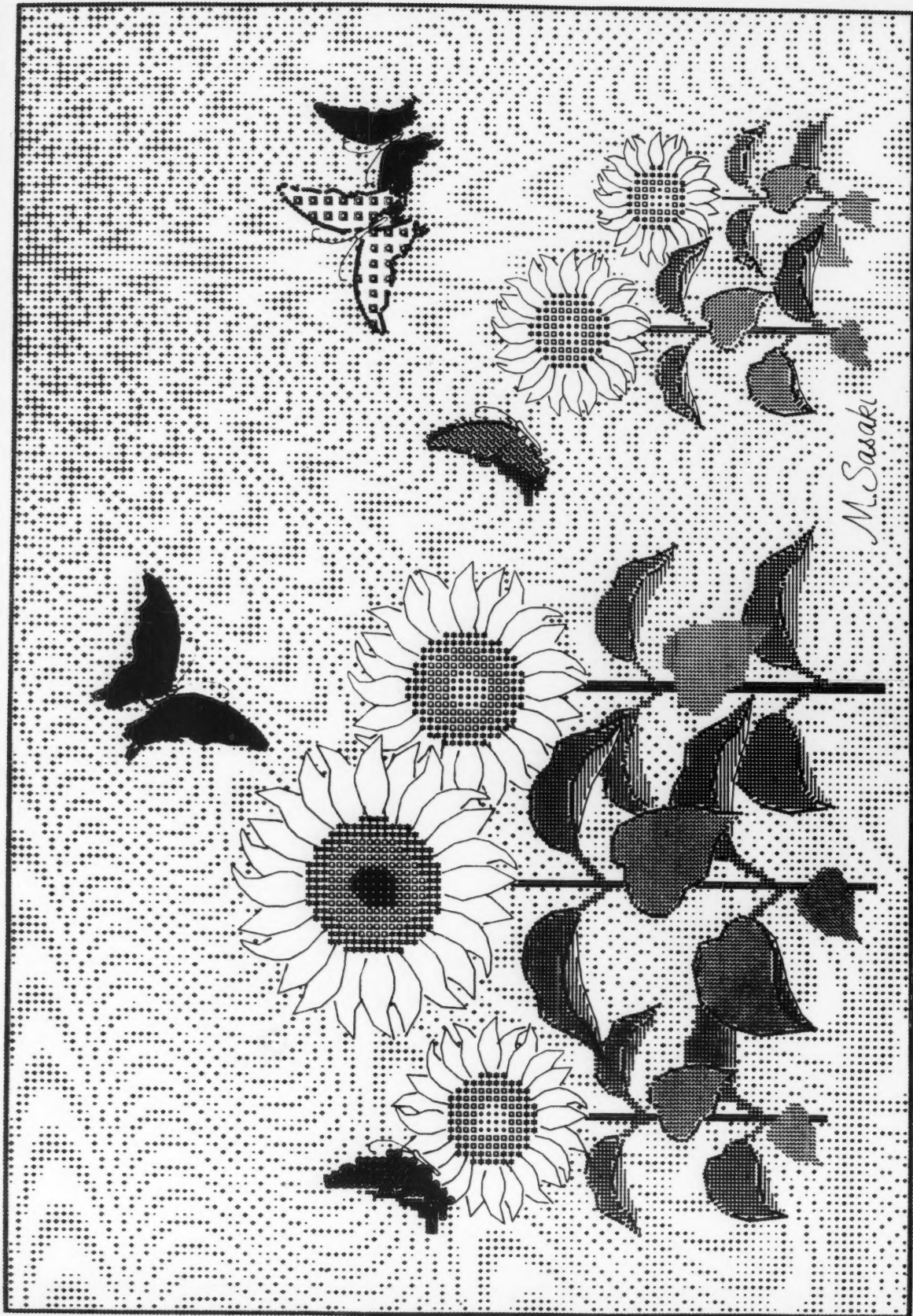
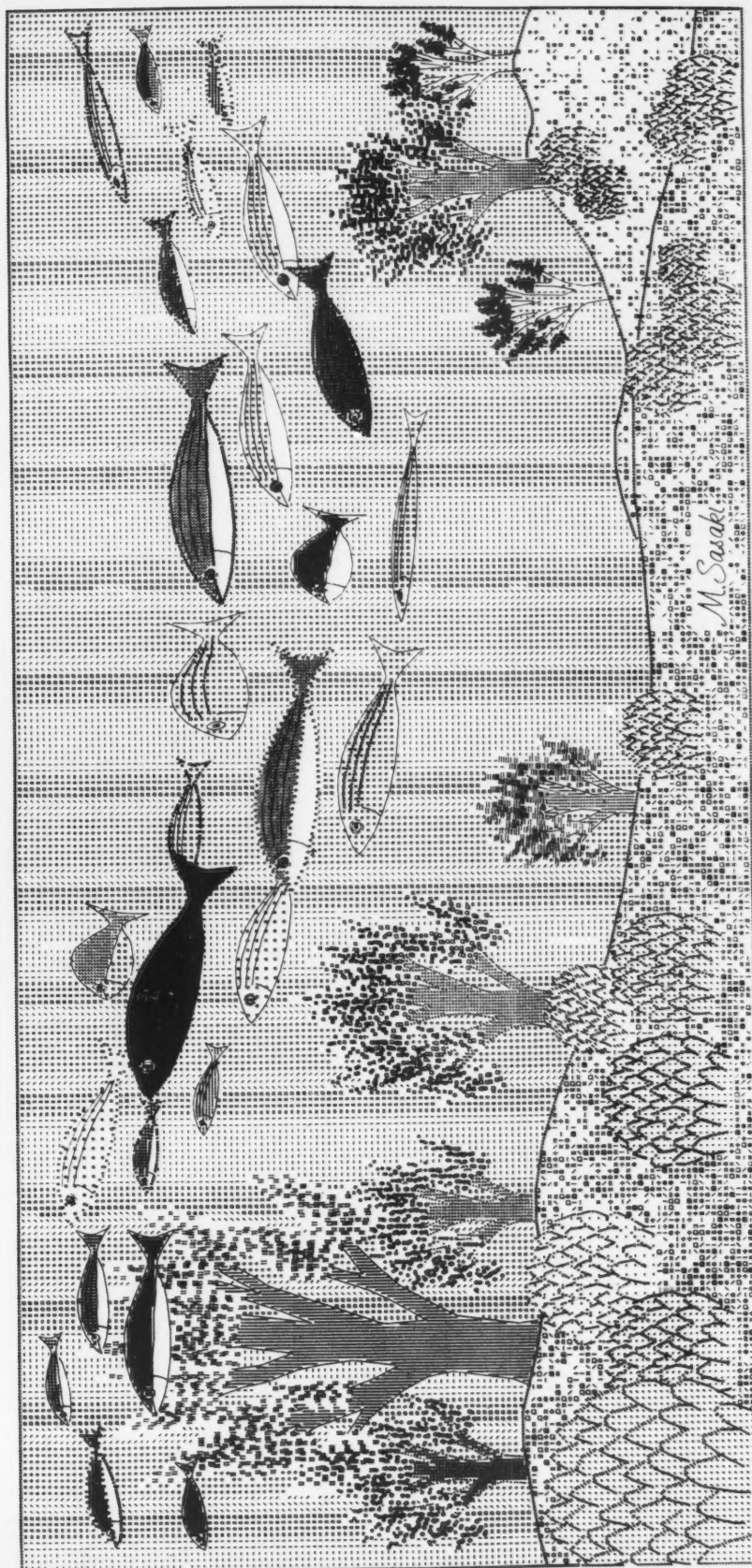


Fig. 5: "Hollow Sunflowers, II." Original size 24 x 34 cm². Computer execution time 48 sec on a FACOM 230-75.



Perhaps we will have to educate and train the computer so that it can appreciate beauty.

must implement, more or less, the creative powers to computers. This is a very important task, because the creative powers are so much widely required in almost all of the art works; even in handling mathematical functions we encounter many problems whose solutions require the creative powers, such as how to use the functions in the drawing. On the other hand, the implementation is certainly a difficult task. We must investigate many things: What procedures are effective in creating beauty? How can we realize them by a computer? And so on. Perhaps we will have to educate and train the computer so that it can appreciate beauty, by making trials and errors. An important strategy which we would like to propose here is to ease the difficulty by adopting our definition of beauty and considering all things from this viewpoint. We have seen that the definition is persuasive and useful for the previous two types of beauty. We think it is also useful enough for the creative beauty. For example, the artist's techniques mentioned at the beginning of this section can be explained in part as that artists recover harmony from otherwise excess of variety. Of course there are many ways in representing harmony and variety, and much more detailed investigations are necessary in the actual programming. But above example seems to show usefulness of our strategy clearly. We can not say much about the realization of creative beauty through a computer at present, because we have not considered it yet. A few years later we will surely be able to say much about it.

Finally we show our recent works in Figs. 5, 6, and 7. They were produced by our system for computer art named ART-3, whose main functions are i) transformation of the input figures, ii) elimination of the invisible parts, and iii) to paint the surfaces by various patterns. ART-3 contains more than fifty mathematical functions for the figure transformation and the pattern generation. We can see from these figures how ART-3 works and how mathematical and natural beauties are united by it.



Fig. 7: "Surmarine walk, II." Original size 24 x 50 cm². Computer execution time 83 sec on a FACOM 230-75.

Figure 6 appears on the cover.