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Paper: **EDUCATIONAL SYSTEM OF SCIENCE ART FOR STUDENTS OF ART AND DESIGN**

Topic: Teaching Theory of Science Art

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Abstract:
The science art is defined here as a kind of art created with strong scientific mind. There are two kinds of science art; one is an art created with a scientific method which is being developed, and the other is an art expressing a scientific concept. The generative art occupies the major part of the first kind.
The present author, after the career of many years as a physicist, began in 2004 to establish an educational system of science art for graduate students of art and design at Kobe Design University, Japan.
In my course of the University students observe natural (physical, chemical and biological) phenomena or their simulations with brief introductions of their mechanisms. After that they are encouraged to create artworks based on their impressions which they have had during the observation. Although they have no training of scientific activity, they are eager to observe real phenomena, and try to create artworks based on what they have felt in the observation. The important point in developing this educational system is to choose suitable natural phenomena.
In the presentation of this paper total system of the education is introduced, and some examples of artworks created with definite algorithms are shown (see figures below). Although students follow processes of the algorithms, they prefer deforming their results or combining them with other images by arbitrary manipulations.
The present author believes that the artworks created by algorithms, which simulate natural phenomena, should be attractive in principle, because we have grown up while observing natural phenomena around us. Therefore, it is a good strategy to apply such algorithms to production of art and design.

Left: Relief of snow crystal by N. Nagahama (2007), created by following an algorithm of crystal growth mechanism.
Middle: Rheo-art by S. Tomioka (1998), which shows deformation of a spherical dyed part in a viscous fluid owing to two rotating cylinders. The deformed part is expressed as a transparent material with ray-tracing.
Right: River branching system by T. Yamashita (2007), created by die throwing and merging principle of streams.

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Educational System of Science Art for Students of Art and Design

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Abstract

The author's trial to establish an educational system of art and design based on scientific experiences of students is introduced. The basic concept of this system is that our senses of beauty and preference are constructed through observing the nature from childhood, hence a good strategy for creative activities will be developed by applying mechanisms of natural phenomena. In this paper the framework of this educational system is explained briefly, and some examples of particular topics are illustrated with students' works as outcomes of this system. In addition a recent trial of creating animation movie is introduced, which is created by the use of natural signals extracted from video image of natural scene. A question is put in the last section on what an attractive art is.

1. Introduction

The term "science art" is defined in this paper as an art which is created with a scientific mind. It is realized in the two cases, first when an art is produced with a method which is newly developed by the artist, secondly when the art expresses a scientific concept clearly. It is noted here that development of a new method necessarily stimulates a scientific mind and affects the content of the art.

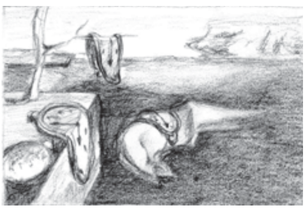


Fig.1 Garden design by N.Nagahama (2007), and "The Persistence of Memory"

An example of the first category is shown in Fig.1 left, which is a model of garden by a teacher of garden design at Kobe Design University. He drew a set of sunflower spirals exactly according to a certain algorithm and applied it to this design. A good example of the second category would be the painting by Salvador Dali, “The Persistence of Memory” (Fig. 1 right, sketch by Takaki). It is believed that Dali expressed his idea about the relativity theory.

The present author, after a long career as a physicist, began in 2004 to establish an educational method of the science art for students of art and design. Although the students are not familiar to mathematics or scientific thinking, they are eager to observe natural phenomena and to express their impressions as art and design works. Based on this experience the present author began to have an idea about the relation between the science and the art, as explained below.

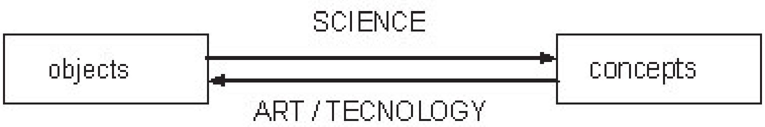


Fig. 2 Relation between the science and the art/technology.

Both science and art (including design) are products of human activity, and make a bridge between real objects and concepts. Here, the concepts mean what appear in human brain, such as natural laws, social needs and personal desires. The role of science is to make up concepts about nature, while the role of art and design is to produce real objects based on the concepts. Technologies belong to the side of art, because their roles are to produce useful objects based on scientific concepts. Thus, the major difference between science and art is that of the directions of creation processes, as shown in Fig. 2.

In the course of education students have experiences of both these directions. They observe natural objects and phenomena and study basic mechanisms of those phenomena, so that they can have some concepts about the nature, then they are encouraged to create artworks as home works according to these concepts. The topics treated in this course are classified into five groups arranged as a hierarchy shown in Fig. 3. Each topic is associated with a lecture, workshops of observation of phenomena or hand works to understand mechanisms of phenomena within three hours.

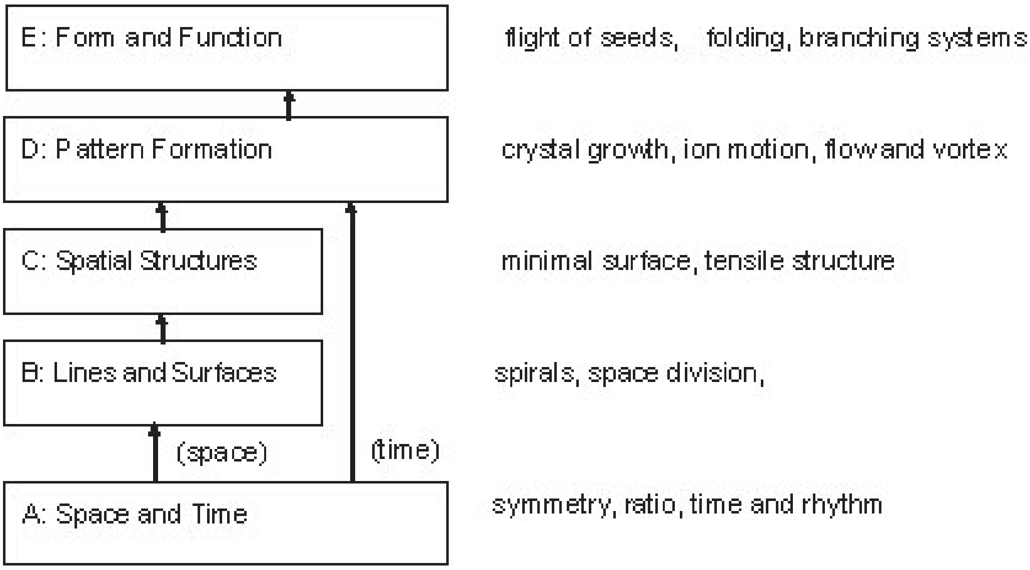


Fig. 3 Framework of the educational system of science art with topics

Results of this activity were reported in an international meeting called ISIS Symmetry [1], and also introduced in a monograph published in Ukraine [2]. An English report of the course was issued from Kobe Design University in 2006 [3]. In the following sections three examples of topics are explained, and some results of students' activities are shown.

2. Topic: Growth of snow crystal

The snow crystals grow slowly from small seeds. The variety of their shapes is understood by the so-called Kobayashi diagram (Fig. 4), which determines one growth mode according to the climate condition, i.e. the temperature and the humidity (degree of over-saturation of vapour). This diagram is an improved version of the Nakaya diagram, and Dr. U. Nakaya was a Japanese scientist who produced a snow crystal in the laboratory first in the world. While a snow flake falls down, it encounters variety of the climates, hence the flake grows at each stage with respective growth mode.

In the class, after introduction of the mechanism of crystal growth, students have a workshop to draw a snow crystal by pencil on a sheet of section paper with oblique grid lines. They make snow crystals grow on the section paper according to a fixed rule, which is a simplification of the real growth mechanism.

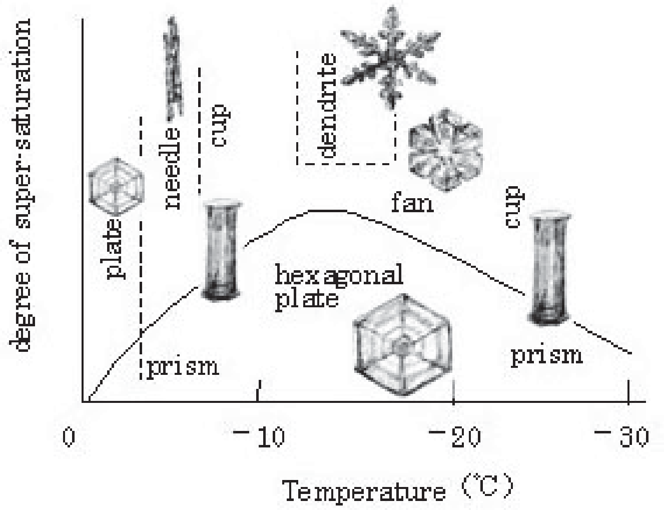


Fig. 4 Kobayashi diagram for growth of snow crystal. The growth mode depends on the temperature and the degree of super-saturation (sketches by Takaki)

This rule is composed of the three types of growth modes, the hexagonal growth and two kinds of dendrite growth. At each time step students throw a dye and choose one of the three growth modes, which is a modelling of the situation that a falling snow flake meets various climates randomly. According to the dice they add small growing parts in the following way:

(1) Hexagonal plate mode: add a layer of outer envelope around the crystal. Note that the crystal shape asymptotes to a hexagon If this process is repeated.
(2) Simple dendrite mode: the ends of all branches are extended by a certain length.
(3) Complex dendrite mode: the ends of all branches are extended by a certain length and new side branches are added.

An example of resulting crystal shapes is shown in Fig. 5(a). This crystal began with a hexagonal plate, then made a simple dendrite growth and finally made a complex dendrite growth. Owing to the simplified rule this crystal shape is not very realistic, but students can understand how various shapes appear in the nature. An exhibition is made at the end of each semester, where group works including those of crystal growth are exhibited. Two of such works are shown in Fig. 5(b), (c).

The mechanism of crystal growth is a good topic for students to become familiar to natural phenomena, because the mechanism of crystal formation is understood easily through the growth algorithm given above. Moreover, they can enjoy producing crystal shapes not arbitrary way but with a fixed algorithm.

(a) (b) (c)

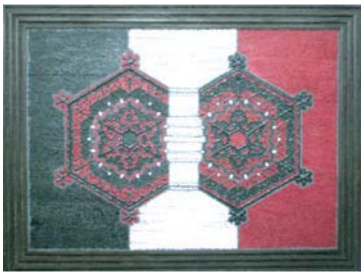
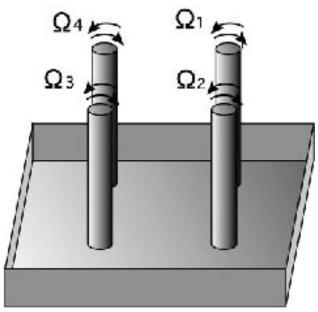


Fig. 5 Examples of produced snow crystals. (a) Pencil drawing by K. Ishida (2005), (b) oil painting by H. Wang and C.-N. Chang (2005), (c) crystals pasted on a plastic plate by J. Xu. et al (2006)

3. Topic: Rheo-art - chaotic pattern in viscous flow

The chaotic behaviour of viscous fluid under a shearing motion is discussed by many scientists in physics and fluid dynamics. It is a deterministic flow showing chaotic nature and is different from the turbulence containing randomness. Good introductions of this phenomenon are given by a monograph and a review by Ottino [4, 5]. The present author has been interested in this phenomenon because he considers that it might be a powerful method for creation of artworks. Based on this idea he made some researches and published a few papers [6, 7]. The following example illustrates the process of chaos formation in a viscous fluid.



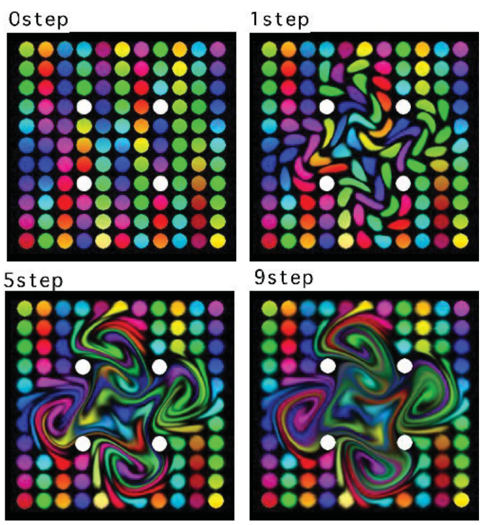


Fig. 6 Mixing chaos in the two-dimensional case. Right: Rotations of four cylinders, left: deformations of dyed parts after several steps of cylinder rotations.

Suppose four cylinders are inserted vertically and given rotations with angles Ω_1-Ω_4, not simultaneously but in turn as shown in Fig. 6(a). The rotation of cylinder produces a fluid motion around the cylinder with speed inversely proportional to the distance from the cylinder. After rotations of four cylinders, they are given rotations in turn in the opposite directions with the same angles as before. These processes as a whole result in mixing the fluid, which is called 1 step of mixing. In order to visualize this mixing, many parts of the viscous fluid have been dyed beforehand with various colours, as shown in Fig. 6(b) upper-left (0-step), where the four white circles are not dyed parts but the cylinders. Deformations of the dyed parts were obtained by computer for the case $\Omega_1=\Omega_2=\Omega_3=\Omega_4=180°$ as shown in Fig. 6(b). Since these deformations are not random but deterministic, this phenomenon is called a mixing chaos. Repetition of this mixing process produces more complicated patterns. Note that arbitrary paintings by artists can not create this kind of patterns.

This process is possible also in the three-dimensional configuration of cylinders. Let two cylinders be placed in a twisted configuration as shown in Fig. 7(a). They were rotated with the same angle 180° (opposite rotations are not given). Then, a spherical part of the fluid between the two cylinders deforms at each step, as shown in Fig. 7(b). A solid model of the three-dimensional shape at 9-step was produced by a sculptor, as shown in the left of Fig. 7(c). At that time he did not like this model. Therefore, the author asked him to produce one more model by deforming the shape at 9-step arbitrarily, which is shown in the right of Fig. 7(c).

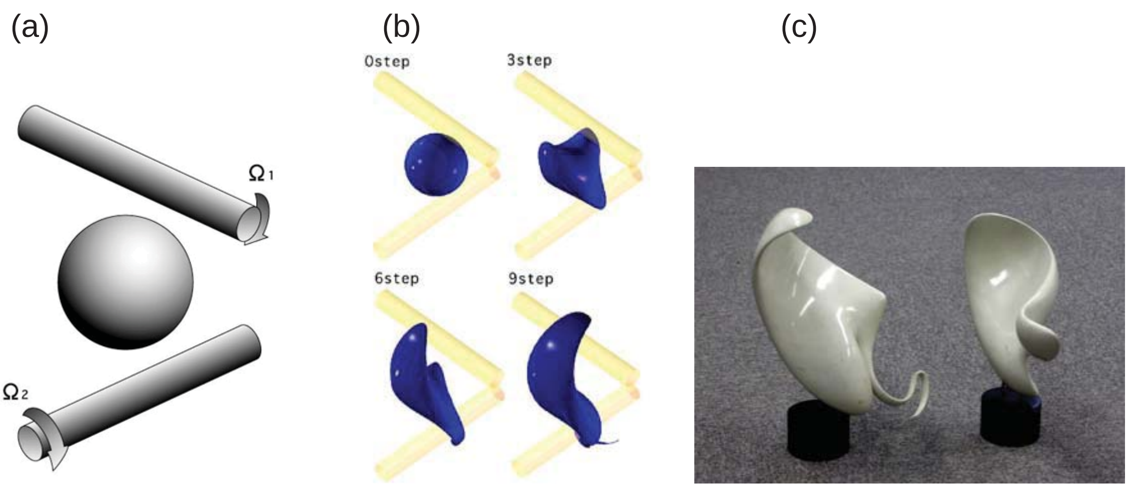


Fig. 7 Mixing chaos in the three-dimensional case. (a) Configuration of two cylinders, (b) deformations of dyed part at the 0, 3, 6, and 9-steps, (c) left: solid model of the 9-step, right: solid model by a sculptor with arbitrary deformation of the 9-step.

It is interesting to compare these two solid models. The left is a shape faithful to calculation (i.e. a generative art), while the right includes arbitrariness just as in traditional arts. The present author often showed both of these to students in the university class and audiences in conferences, and asked them which they liked better. In most cases they liked the right one. However, the fraction of those supporting the left is recently increasing.

One can point out two fundamental differences between these models. First, the left one has a shape of developable surface, while the right one has a shape like a spherical surface. Secondly, the thickness of the surface of the left one decreases monotonically as approaching to the edge, while the right one has swelling parts near the edge. These properties in the right one are seen at many parts in human body, which might be a reason why people like the right one. At the same time the recent tendency towards the left one might show an interest in non-humanistic objects.

Recently, a group including the present author produced a simple computer program to create arts of chaotic mixing in two-dimensional space and used it in the workshop for students of Kobe design University. Students prepare images and operate the program by arranging cylinders and giving angles of their rotations. Some examples of students' works are shown in Fig. 8.

Fig. 8 Rheo-arts by cylinder rotations inserted into a viscous fluid. Left: by T. Zhou (2006), middle: by N. Endo (2007), right: M Liu (2006). The program is developed by S. Sasada, K. Ishigaki and R. Takaki in 2004.

4. Topic: Computer animations by the use of natural signals

The natural signals, such as sounds from water waves coming to the coast, often have the so-called 1/f spectrum, i.e. the intensity is inversely proportional to the frequency f. This type of spectrum is considered to have a healing effect. Then, there is a possibility that computer animations become more attractive, if the objects in the animation are given motions which are determined by the use of natural signals. This idea was pursued by the present author and his collaborators, and some results were presented at an international meeting in 2010 [8].

In the university course, however, the creation of animation is not made, because it takes much time and needs a special technique. Instead of that students are asked to obtain spectra of images, such as natural sceneries and human bodies, which students choose arbitrarily. The images are scanned in the horizontal direction and changed to one-dimensional signals, from which spectra are obtained by a computer program. This program is produced by an author’s colleague, K. Ouchi. This activity belongs to the topic “rhythm” in the framework shown in Fig. 3. Two examples of images and spectra are shown in Fig. 9.

(a)

(b)

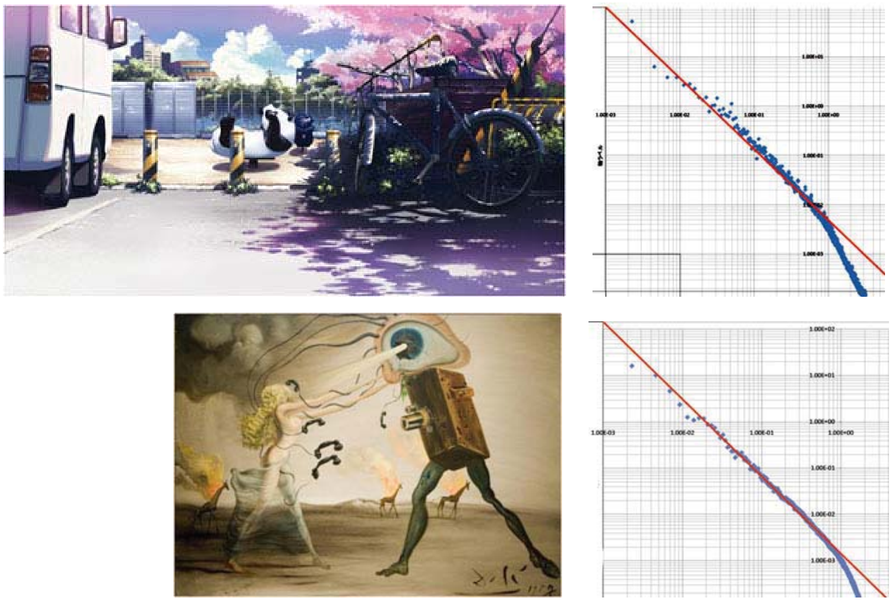


Fig. 9 Images and spectra (plotted in logarithmic scales) obtained by students. (a) A scene in the town and its spectrum ($1/f^{1.43}$) by M. Urbanowicz (2011), (b) a graphic of two characters and its spectrum ($1/f^{1.59}$) by Soraya (2011)

Both of these examples have spectra of $1/f^n$. This type of spectra means that the images contain high frequency noise, but it intensity decreases rapidly with frequency. Through this workshop students are expected to understand the meaning of spectra obtained from images. After that we show them the animations created by the use of natural signals.

The method to produce the animation is shown in Fig. 10. Before producing an animation, a video movie of natural scene are obtained, such as the waves near coast or the shaking of branches in the wind. It is also possible to catch a natural scene while producing the animation. Next, characters or objects to appear in the animation are produced by hand or CG, and are input into computer. Their initial positions in the 3D space are given randomly.

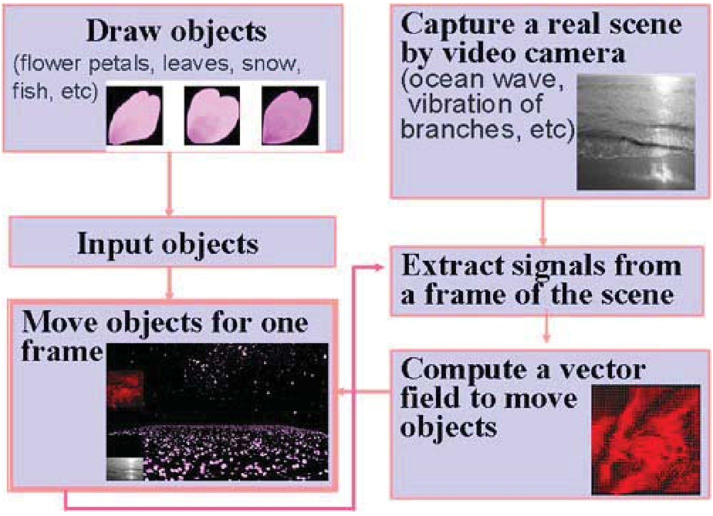


Fig. 10 Flowchart of production of animation. A vector field to drive objects is constructed based on one frame of a movie of natural scene within 1/30 second.

In creating animation the motions of objects in each frame are determined by a 3D vector field, which is constructed from each frame of a movie of natural scene. The 3D vector field is constructed in a clever way from 2D movie frame in real time, i.e. within 1/30 second.

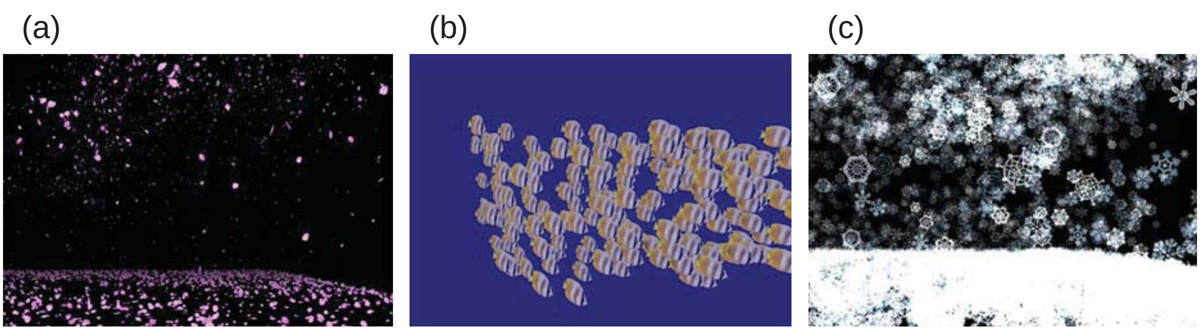
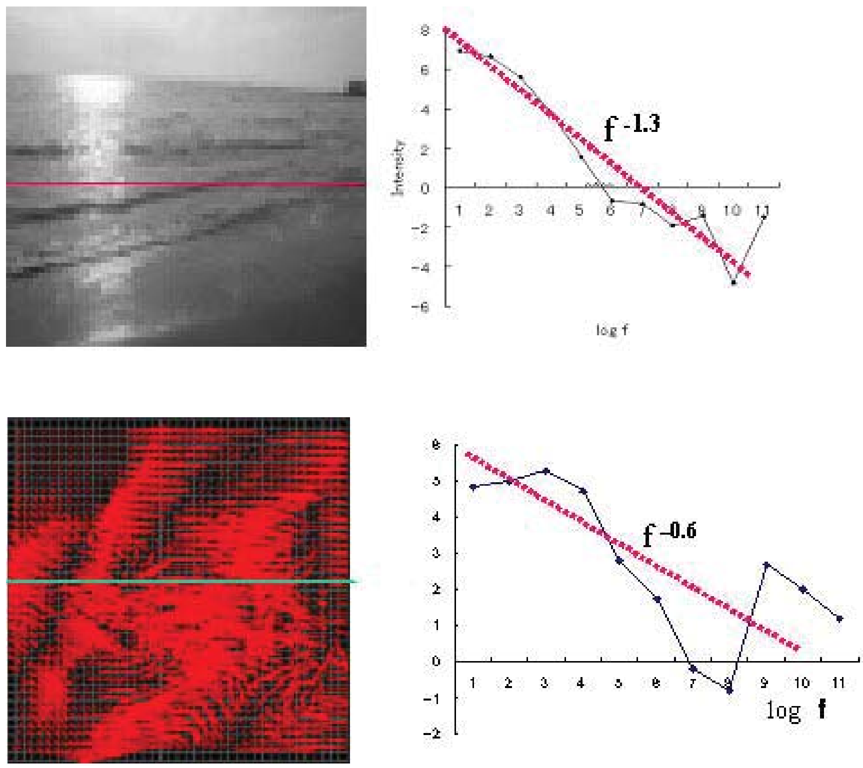


Fig. 11 Shots from computer animations of (from left to right) fall of cherry petals, swimming of fish and snow fall.

Some shots of produced animations are shown in Fig. 11. Figure 11(a) shows a scene of fall of cherry petals, where each petal has fluctuations of speed and direction in 3D space. These fluctuations are controlled by a video movie of waves at a sea shore. Figure 11(b) is a scene of swimming of fish, where their directions and speeds of swimming are uniform but they fluctuate with time. These fluctuations are controlled by a video movie of shaking tree branches in the wind. Figure 11(c) is a scene of falling snow flakes, whose motions are controlled by a video movie of water waves. In this animation, the falling objects can be chosen from two options, realistic snow flakes and hexagonal crystals (the latter is shown in Fig. 11(c)), by pushing the space bar of computer while producing the animation.

The present author had several chances to show these animations in the university classes and conferences. People seemed to be impressed by the animations. The reason is considered to exist in the process of producing animations, i.e. to use natural signals in controlling motions of objects.



(a)

(b)

Fig. 12 (a) Image of natural scene (water waves) and its spectrum of signal on a horizontal line, (b) a vector field obtained from the natural signal and its spectrum.

Fig. 12(a) shows one shot of water waves and a spectrum (shown in logarithmic scales) of the brightness signal on a horizontal line at the central level (a line in the image). It has a spectrum type of $1/f^n$. Fig. 12(b) shows one shot of vector field constituted from an image of water waves, whose spectrum of horizontal components of vectors on a horizontal line seems to have also the type of $1/f^n$. Although these spectrum curves deviate from the simple $1/f^n$ type, it will converge to this type if spectra along many horizontal lines in these images are averaged.

In conclusion, the use of natural signals to control motions of characters or objects is considered to be a powerful method in order to produce animations which look quite natural and give strong impression to observers. However, this method is yet not developed enough, and the present author welcomes the offers of cooperative work.

5. Concluding remarks

In this paper some results of the trial to construct an educational system are reported, along with works of students and the present author. Here, a comment is given on the problem of “What is art?” In section 1 it is claimed that the art is an expression of a concept as a real object. Hence, everything produced by humans can be an art, if it is an outcome of some concept. Then, a meaningful question for fruitful discussion is not “What is art?”, but is “How an attractive art is created?” This question is almost equivalent to “What kind of objects or phenomena is attractive for humans?”

Most of humans have grown up while absorbing much from natural and social environments. Experiences in these environments should have affected in forming their senses of beauty. Then, the arts created by methods or algorithms which match to these experiences should be attractive. It was a motivation of the present author to produce an animation movie based on natural signals. However, there will be many other ways to create attractive arts. It seems to be the most important question for the present author what kinds of methods or algorithms match to experiences in our lives. The present author would like to hear opinions from others who are conscious of this kind of problem.

The present author would like to express his thanks to the organizer of GA2011 for inviting him to this meeting, and to the collaborators, especially Mr. S. Sasada, Mr. K. Ishigaki and Dr. K. Ouchi. He also thanks to students in my course for their cooperation with establishing this educational system.

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