Basic Sketch Learning Environment with Adaptive Advice

Saeko Takagi Noriyuki Matsuda Masato Soga Hirokazu Taki Fujiichi Yoshimoto
Faculty of Systems Engineering, Wakayama University
930 Sakaedani, Wakayama, Wakayama 640-8510, JAPAN
Email: {saeko, matsuda, soga, taki, fuji}@sys.wakayama-u.ac.jp

Abstract—Support to make a picture is one of important research subjects in order to make our life spiritually rich. Most studies on pictures, however, only propose some substitute functions of actual materials for drawing and painting. There is no system that evaluates images made by novices and gives advice. We have been proposing a support system for basic sketch learning. The proposed system deals with novices’ pencil drawings. The system receives a subject (motif) data set and an image of user’s sketch and returns advice to the user. We developed and experimented with a prototype system. As a result, the validity of the proposed system was confirmed.

I. INTRODUCTION

Many people like drawing and painting since they know the activities are good for their relaxation, refreshment, mental health, etc. Support to make a picture is one of important research subjects in order to make our life spiritually rich.

There are many studies related to generating artistic computer graphics. In the field of non-photorealistic rendering, including a historic work by Haeberli [1], a lot of drawing or painting algorithms were proposed [2]. Current systems let us generate high quality images interactively with a pen-type digitizer or a haptic device [3], [4]. Most studies in this field, however, only propose some substitute functions of actual materials for drawing and painting. In the design fields, some assistant systems were proposed. Although these systems aid users in making a certain design such as posters [5], [6], they do not teach us how to draw what we see.

Analysis of actual pictures, in particular famous pictures by great painters, is also a common research subject. There are several studies on use of analysis results to edit an input image. Kasao et al. extracted some features from actual sketches which could be categorized into several types and converted an input image into other expression types [7]. Tanaka et al. provided a tool that analyzed the composition of pictures and supported editing the composition of an input image [8]. Chang et al. proposed a new approach to stylize the colors of an image by using a reference image [9]. This lets us edit an image to make better harmonized colors. Although these functions by using reference pictures are useful for editing images, the quality of the result image depends on the user’s sense of beauty. There is no study on evaluating images made by novices in order to give advice.

We have been observing novices’ sketches and instructor’s advice in several sessions for basic sketching intermittently over five years. There were many mistakes in sketches drawn by novices, because they could not draw precisely what they saw. Novices did not notice their own mistakes usually. In addition, although the instructor pointed out the mistakes to them, common novices were not able to correct the mistakes by themselves. Most novices need concrete advice on their mistakes. Problems to take lessons in sketch are time restriction and a shortage of instructors. People can also learn sketch from books. However, if a motif (subject) printed on a textbook is not the same one that a learner tries to draw, it is difficult for the learner to understand the advice in the textbook.

We have been developing a system for basic sketch learning [10]–[14]. Because basic sketching is considered as training for realistic representation, we consider that novices’ sketches can be evaluated with comparison of the sketch and the portrayed objects. Basically the proposed system aids users in learning a basic sketch using real pencils and drawing paper. We adopted the three step method of sketching: drawing outline, drawing half tone, and drawing three grades of light and shade. The system deals with a (nearly) finished sketch in each step. The system receives a motif data set and an image of user’s sketch, diagnoses the sketch, and gives advice to the user. We are also developing real time advice functions [15]. The proposed system would be useful not only for the support of self-educated novices but also for the auxiliary role of teachers in mass schooling.

The rest of this paper is organized as follows. In Section II, the overview of the proposed system is described. In Section III, based on the latest prototype system, the details of the proposed system are explained. In Section IV, we report some experiments. In Section V, investigation for giving real time advice is described. Section VI contains concluding remarks.

II. OVERVIEW OF THE PROPOSED SYSTEM

Figure 1 shows the outline of our system. The input to the system is a user’s sketch data and corresponding motif data. Sketch data is an image taken by a digital camera or scanner. There are several types of motif data used in the system according to motif and the phase of sketching.

In the process to recognize images, essential features for diagnosis of a sketch are extracted from both of sketch and motif data. A part of motif features is used in order to extract sketch features. The features used in the system were decided based on which advice would be presented from the system.
The diagnosis & advice process receives the feature values. Basically, the differences between motif and sketch feature values are regarded as error. Each error is identified among the error database (EDB). Every error in EDB has a link to a piece of advice in the advice database (ADB). An adaptive advice in ADB is selected through the link, and presented by several types of media. EDB and ADB are prepared in advance according to analysis of actual sketches and advice.

There are many methods of drawing sketches. In our system, a learner makes a sketch according to the three-step procedure: outline, half tone, and three grades of light and shade. First, draw outlines of the motif as shown in Figure 2(b). At this point, the lines are thick and clear. The lines become pale during the third step. Second, cover the whole of the motif and shadow area with a uniform shade as shown in Figure 2(c). The uniform shade is called "half tone" since it becomes the middle density in the total tones. Third, using a pencil and eraser, make lighter and darker parts than half tone. Adding a middle tone between two tones repeatedly, five or more grades of light and shade are depicted as shown in Figure 2(d).

We chose a set of a glass and a plate as the first motif since the set was simple still life, including the basics of sketching. It is actually used in continuing education of sketching. We developed a prototype system from outline sketches [10]–[12] to shading sketches [13], [14] where the motif was the set of a glass and a plate. We are currently trying to deal with a fruit motif as the next target. One or two apples and a bunch of bananas, such as shown in Figure 3, are used as the second motif. In the previous system, we used a definite motif, which was a known shape and placed in a certain arrangement [13], [14]. This time, each motif has an individual difference and is placed at any arrangement. In addition, the advice provided from the previous system is only for the motif of a glass and a plate. It cannot be used for fruit motifs. Therefore, although the basic design concept of the system is the same as the previous one, the details of each processing are different mostly.

III. OBJECTIVE ADVICE AND FOUR SUBSYSTEMS OF THE PROPOSED SYSTEM

The latest prototype system can deal with outline sketches of the fruit motif. The following are the details of the four subsystems according to the latest prototype.

A. Objective Advice

From the observation of lessons for eight hours in total, the following sentences of advice were selected for planning the system:

1) The top part of the drawn apple looks like a tomato. / The top part of an apple should be different from the top part of a tomato.
2) The position of the drawn objects is too high. / The objects should be a little below.
3) Right and left margins should be the same intervals.
4) The objects should be drawn a little bigger according to the size of drawing paper.
5) A general apple is wider in the upper part and narrower in the lower part than the middle part.
6) The stem of an apple should be at the center of the apple.
7) The ratio of the sizes between the apple(s) and the bananas is somewhat out of order.
8) The arrangement of the apple(s) and the bananas is somewhat out of order.

This is the order based on the frequency in the actual lessons. The above sentences, 2), 3), and 4), affect the whole composition. The sentences, 1), 5), and 6), concern the shape of an apple. The sentences, 7) and 8), are about the relation between the apple(s) and the bananas.

B. Extraction of Motif Features

Because the arrangement of the fruit motif is unrestricted, the fruit motif data cannot be held in advance like the previous system [13], [14]. A learner takes pictures of the motif that the learner arranged, and the motif features are extracted from the taken images. The system requires two images. One is taken at the learner's point of view and the other is over the motif.

We use mean-shift image segmentation [16] to decompose a motif image into homogeneous small regions. By using the color information and merging adjacent regions, the apple region(s) and banana region are detected. Several values, e.g. the center of gravity, width of margin, the coordinates of the vertex, etc., are calculated from each region of fruits, and circumscribed rectangle around the fruit regions in the image taken from the learner’s point of view. The image taken over the motif is used for decision of the depth of each object. Figure 4 shows an example of a motif image from a learner's point of view and its mask image with the circumscribed rectangle lines shown in the system window.

C. Extraction of Sketch Features

By the same way in the previous system [14], the region marked with round colored stickers is automatically cropped as the drawing paper region from the input sketch image. The pencil drawn area is extracted from the paper region and the thinning algorithm [17] is performed to the drawn area. The obtained skeleton lines are single pixel wide. These series of processing is performed by the same manner as the previous system [11], [12]. Figure 5 shows (a) a sketch image, (b) its drawn area, and (c) the skeleton lines.

It is difficult to know from only the sketch image where the apple(s) and bananas are drawn in the paper region, since the arrangement of the motif is not predefined. Therefore we use the mask image made in the subsystem of extracting motif features. A circumscribed rectangle covering all the fruit regions is set on the mask image of the motif. A circumscribed rectangle covering all the skeleton lines is also set on the sketch image. The rectangle of the fruit regions is scaled and translated according to the rectangle of the skeleton lines. Each fruit region in the rectangle of the fruit regions is scaled by the same ratio and translated by the same quantity. The skeleton area which overlaps with each fruit region of the motif is classified into a fruit region. Skeleton lines in Figure 5 (c) are classified into lines in Figure 5 (d) by using the mask image shown in Figure 4 (b).

The feature values extracted from the sketch image are: widths of margins, the center gravity of each fruit region, size of each fruit region, width at several positions of the apple, etc.

D. Error Identification

Errors are identified by using the feature values obtained from the feature extraction subsystems of both the motif and the sketch. The following eight errors corresponding to the advice are judged:

1) Errors in the hollow of the apple.
2) Errors in the vertical position of the whole composition.
3) Errors in the width of the whole composition.
4) Errors in the balance of the sizes between the drawn region and the drawing paper.
5) Errors in the shape of the apple.
6) Errors in the stem of the apple.
7) Errors in the ratio of the sizes between the fruits.
8) Errors in the position between the fruits.

Basically, the differences between motif and sketch features values are regarded as error. Each error is identified among the error database (EDB). Specifically the subsystem decides kind of the error, place of the error, and size of the error. The values in EDB were prepared according to analysis of various
TABLE I
ERROR IDENTIFICATION BY THE SYSTEM AND INSTRUCTOR

<table>
<thead>
<tr>
<th>Errors</th>
<th>System</th>
<th>Instructor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) the hollow of the apple.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2) the vertical position of the whole composition.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3) the width of the whole composition.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4) the balance of the sizes between the drawn region and the drawing paper.</td>
<td>error</td>
<td>error</td>
</tr>
<tr>
<td>5) the shape of the apple.</td>
<td>error</td>
<td>error</td>
</tr>
<tr>
<td>6) the stem of the apple.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>7) the ratio of the sizes between the fruits.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>8) the position between the fruits.</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

TABLE II
SUCCESS RATE OF FEATURE EXTRACTION FROM SKETCH IMAGES

<table>
<thead>
<tr>
<th>Features Corresponding to Errors</th>
<th>Success Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) the hollow of the apple.</td>
<td>18/18 (100%)</td>
</tr>
<tr>
<td>2) the vertical position of the whole composition.</td>
<td>18/18 (100%)</td>
</tr>
<tr>
<td>3) the width of the whole composition.</td>
<td>18/18 (100%)</td>
</tr>
<tr>
<td>4) the balance of the sizes between the drawn region and the drawing paper.</td>
<td>18/18 (100%)</td>
</tr>
<tr>
<td>5) the shape of the apple.</td>
<td>12/18 (83.3%)</td>
</tr>
<tr>
<td>6) the stem of the apple.</td>
<td>12/18 (66.6%)</td>
</tr>
<tr>
<td>7) the ratio of the sizes between the fruits.</td>
<td>15/18 (83.3%)</td>
</tr>
<tr>
<td>8) the position between the fruits.</td>
<td>15/18 (83.3%)</td>
</tr>
</tbody>
</table>

sketch errors from actual sketches. Every error in EDB has a link to a piece of advice in the advice database (ADB).

E. Advice Decision

ADB is also prepared in advance according to analysis of actual advice about sketches. The system provides four types of advice: pointing the error out; an explanation of physical principles; an explanation of drawing techniques; and a good movement of the hand, wrist, and arm. Most novices fail to realize errors in their sketches. To learn sketching, they need adequate advice. An adaptive advice in ADB is selected through the link of EDB and presented to the learner.

Figure 6 shows two snapshots of the system window. The window shows: the sketch image taken by the learner; the list of errors; a space to show an example of the errors corresponding to the selected item in the error list; and a sentence of advice to modify the sketch. Although the advice should be provided via multiple ways, e.g. a speaking agent, error visualization by 3D models, etc., like the previous system [14] as shown in Figure 7, the current prototype system unfortunately provides only text and 2D images as advice about fruit outline sketches. From our previous investigation, we know that it is important to show where the mistake exists and how a instructor draws. Therefore we are going to improve the interface about the above two points at least.

IV. EXPERIMENTAL RESULTS

We have experimented with the developed prototype system to verify the validity of the proposed system. Eighteen sketches drawn by novices in a certain art class and university students were used as the input images.

The learner’s sketch shown in Figure 6(b) is one of the input images and Table I shows the result of error identification by the system and a instructor. In this image, the system can identify the same errors as the instructor.

Table II gives the success rate of feature extraction from the eighteen sketch images. When the system was successful in classification of each fruit region, the right values were extracted in all the items except the stem of the apple. The series of processes about the stem of the apple, e.g. the features used for error identification, the algorithms of calculating the feature values, the rules for error identification, and the rules for advice decision, requires more consideration, since some of them are not enough robust. In identification of errors in the ratio of the size between the fruits and the position between the fruits, as the apple(s) and bananas were overlapped in a large area, the feature values were not extracted correctly. In the instructor’s judgment, when error identification is successful, suitable advice was provided in all the sketches.

In this experiment, learners did not touch the prototype system. After improving the system interface, we will perform a user study.

V. INVESTIGATION FOR REAL TIME ADVICE

Both the previous system [10]–[14] and the system described in this paper can not provide real time advice. This
causes learners’ inconvenience. For example, a learner cannot modify the sketch easily because the system diagnoses not on the way but after drawing. The preceding system may not offer suitable advice sometimes, since the system cannot specify cause of errors. To solve former problem, the system needs to offer advice to learners on their way in sketching. To solve latter problem, the system needs to diagnose a learner’s arm motion on their way in drawing sketch.

A. Three Kinds of Immaturity

Generally three kinds of immaturity are considered as cause errors: (a) immaturity in recognition; (b) immaturity in interaction planning; and (c) immaturity in action [18]. It is important to diagnose the cause of the error in order to give more adaptive advice to the learner. As for immaturity (a), it is quite difficult to diagnose immaturity in recognition, since recognition is behavior in the learner’s brain. In sketching, tracking eye motion by using an eye-mark recorder will be helpful to estimate the behavior for recognition. As for immaturity (b), interaction planning means to select adaptive action based on results of recognition. To diagnose this immaturity, both results of immaturity (a) and (c) are required. As for immaturity (c), immaturity in action is caused by immaturity of muscles, immaturity of muscles control, immaturity behavior, etc. In sketching, action is to grip a pencil and draw on paper and diagnosis would become better by using a pen tablet for capturing the position of drawing and a sensor for capturing the arm motion.

B. Analysis of Eye Motion

We are planning to develop a real time advice system. As a part of the plan, we are analyzing eye motion during sketching by using an eye-mark recorder. In order to find differences between novices and experts in sketching, we made subjects sketch three motifs wearing an eye-mark recorder. The subjects were five novices and five experts in sketching. The motifs were a set of a glass and a plate, a bunch of bananas, and a flower pot. From the analysis of the experiments, when drawing unknown objects, experts took relatively longer time to observe the objects before starting to draw than novices. Other experts’ characteristics are to capture the rough outline and observe the details, and to compare one object with the surrounding very well. On the other hand, novices took longer time to observe simple motif (like a glass and a plate) than complicated motif (like bananas), since common geometrical shapes are not familiar to them. However, although they thought they knew bananas well, each banana had an individual difference, and the drawn bananas did not resemble the bananas which they saw. To make use of the results for designing the advice system, a further analysis is necessary for the data.

C. Capturing Drawn Position and Arm Motion

As for capturing learner’s motion and giving real time advice, we are developing a real time advice system by using a pen tablet and a 3D position sensor [15]. It has two subsystems for area-dependent advice and hand & arm motion advice. The area-dependent advice subsystem obtains learner’s drawing position data with a pen tablet. It infers a figure
that the learner is drawing and offers advice about the figure. The subsystem is designed for the motif of a set of a glass and a plate. Since the arrangement and the size of the motif are not limited, several values of the length and distance are required to input. A 3D motif model is generated in the system and a sketch area map is also generated by rendering the 3D model. The sketch area map has several regions which are divided according to the feature of the motif. While the learner is drawing a sketch with a pen tablet, the subsystem keeps on calculating where the drawn area is, what should be drawn in the current area, and which advice will be useful for the learner. The advice provided currently is only general knowledge, e.g. a way to draw an ellipse, a general process to draw something, etc.

The other subsystem is the hand & arm motion advice subsystem that obtains learner’s arm motion data by using 3D position sensors installed in the shoulder, elbow and wrist. According to the learner’s motion, a 3D arm model is moved. The learner can monitor the motion in real time from any point of view as shown in Figure 8. Learners can confirm the motion of their arm and the correct motion of instructor’s arm stored in the system. The motion which can be compared is currently limited to simple motions since it is difficult to infer all motions.

Both subsystems do not consider the condition of the learner’s sketch yet. As we mentioned in Section I, most novices need concrete advice on their mistakes. Even if all learners watch the video clips before sketching, it is impossible that nobody make any mistake. To infer detailed motions, it is necessary to consider what the learner is drawing at all times. These real time subsystems should be merged together the preceding system, then each advantage will become more effective.

VI. CONCLUSION

We have been proposing a support system for basic sketch learning. The objective sketches of the proposed system progressed from outline sketches of a glass and a plate through shading sketches of a glass and a plate to outline sketches of fruits. In the system for sketches of fruit motifs, although the basic design concept was the same as the previous systems for sketches of a glass and a plate, the details of each processing were different mostly. Especially, because fruit motifs had individual differences and there was no limitation in the position of each object, two images of the motif were used to obtain the motif features and to classify the sketch segments. We developed a prototype system and confirmed the system gave suitable advice when the line segmentation of sketches were successful and the correct values of features were extracted.

In the future, we are interested in the diagnosis of the shaded and colored sketches of fruit motifs. Another area of interest is to provide real time advice on sketches under drawing. Finally, we will tackle the problem to infer learner’s recognition skill, and the total support to learn sketching will be provided.

ACKNOWLEDGMENT

The authors would like to thank Mr. Takashi Shima for him help as an instructor of art. We are also grateful to the students in the art classes of Mr. Takashi Shima for their acceptance of our activities in their classes. This research is partly supported by the Grant-in-Aid for Scientific Research (B) No. 16300069, Japan Society for the Promotion of Science.

REFERENCES