Development of Sketch Learning Support Environment Using Augmented Reality and Step-by-Step Drawing

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Abstract: We developed a new sketch learning support environment. The new system inherited the feature of free composition by a learner with using augmented reality. Furthermore, the new system considered step-by- step drawing. Thereby the new system can offer advice in real-time on three kinds of information, the closest part, direction and distance to a correct bounding rectangle or correct contour of a motif, when a learner put the tip of a pen on a paper on the pen-tablet. We have evaluated the new system by an experiment.

Keywords: Augmented reality, learning support environment, drawing, sketch, skill

Introduction

Various tools and software have been produced to support drawing of pictures and diagrams on a virtual plane in computers. For example, Bill Baxter et. al. have developed a system to draw pictures on a virtual canvas by operating a paintbrush in virtual space. It uses a force feedback display device, a Phantom, as the interface and operates a stylus pen as the paintbrush [1]. The system can be positioned at the highest point in conventional painting tools. However, the system provides only tools sufficient for drawing pictures within a virtual space and does not support learning for drawing skill. In General, there are several means of sketch learning as follows.

- To go to painting school
- To use Internet and take distance learning
- To buy a book of painting and learn painting by self-learning

However, these study methods had some problems in terms of monetary and learning effect issues. Therefore, our research group launched a project that intended to support sketch learning for beginners about 10 years ago, and there were no other project that develops learning support environment for drawing skill. Developed learning support environments are intended to improve sketch skill of beginners.

1. Previous studies

1.1 Previous systems in our research group

Our research group has developed some systems for supporting sketch learning by various perspectives. They were evaluated as an unparalleled. Then, we briefly introduce our previous systems which were developed by our project.

First, the system diagnoses learner's sketch after he/she finished drawing sketch. Then, the system offers some advice for correcting mistakes. First, learner sits down on a chair and input data of height of learner's eyes from desk. Furthermore, motif must be located in a position which is decided in advance. Then, system calculates correct apparent contours of motif from learner's viewpoint. After that, the system offer optimal advice for the learner that quote from advice database by comparing the learner's sketch with correct apparent contours [2][3].

However, this system has a problem. The system can offer advice only after having finished drawing sketch. Therefore, system can't offer advice during drawing sketch. If there are some errors in the sketch, the learner must re-draw sketch again from the beginning. This problem has caused learner's reluctance.

Second system can offer advice during drawing a sketch by a learner. A Learner fixes a paper on a pen-tablet, and draws a sketch by accessory pen which tip was replaced with a pencil lead. Therefore, the system can obtain position of the tip of the pen. Then, the system can offer advice during drawing the sketch and prevent the learner from making great mistakes.

However, this system also has a problem. A learner must draw contours of motifs from the beginning. Therefore, it is difficult for a learner to recognize the whole balance of motif composition and to reflect it in the sketch.

Third system introduced step-by-step drawing from rough shape to detailed shape. First, this system induces to draw bounding rectangle of whole motif shape. After that, the system offers advice on the bounding rectangle, and encourages the learner to fix errors of the bounding rectangle. At the end, system induces to draw contours of each motif [4].

Although these three systems have been improved as described above, these three systems still have a common problem. A learner must use motifs which sizes and shapes are well-known by the system in advance and must set correct layout of the motif that is also known by the system in advance, because systems must compare learner's sketch with correct contours calculated from learner's viewpoint. This problem is due to using real motifs for drawing a sketch. Therefore, system can offer only a few patterns of correct layout that was prepared in advance.

To solve these problems, the fourth system used augmented reality. Real motifs were replaced with virtual motifs by augmented reality. The system can calculate correct contours with any layout of motifs and with any viewpoint due to augmented reality. Therefore, degrees of freedom of motif composition that a learner can decide increase dramatically [5].

1.2 Proposal draft for improvement

We set three goals to develop a new system.

(1) To achieve both using augmented reality and considering step-by-step drawing with real-time advice during drawing a sketch.

(2) To offer advanced advice that includes information on the closest parts, directions and distances of gaps between learner's pen position and correct contours. Here, a part means a part of a drawing object, such as a side of a bounding rectangle or a part of contour of a motif.

(3) Improvement of user interface.

Previous system that used augmented reality didn't consider step-by-step drawing. Therefore, we re-construct the system. New system has all advantage of previous systems. Moreover, workflow of the system is divided into four stages for considering step-by-step drawing. Advice by previous system offers only information on parts of gaps between learner's input pen position and correct contours. The new system offers advice on parts, directions and distances of gaps between learner's input pen position and correct contours.

(1) Closest part: It is a part of the correct bounding rectangle or the correct contour of a motif, which is located in the closest position from a learner's input position.
(2) Gap direction: It is either x component or y component of a directional vector from a learner's input position to the closest part.
(3) Gap distance: It is a distance from a learner's input position to a gap part along the gap direction.

Each previous system has used a keyboard to control an interface, but it was not easy for a learner to do it. Therefore, we use a Wii remote controller in the new system instead of a keyboard.

2. System configuration and flow of process

2.1 System configuration

The system comprises of PC, head mounted display (HMD), Web camera, pen tablet and Wii remote controller. In addition, two AR markers are used. One marker shows a virtual dish, while the other marker shows a virtual cup. Motif of a sketch is a combination of the dish and the cup. A learner uses the system like Figure 1. The learner can arrange composition of the motif by arranging the layout of the two markers and his/her viewpoint. In other words, a composition of a sketch is decided by both layout of two makers and learner's viewpoint.

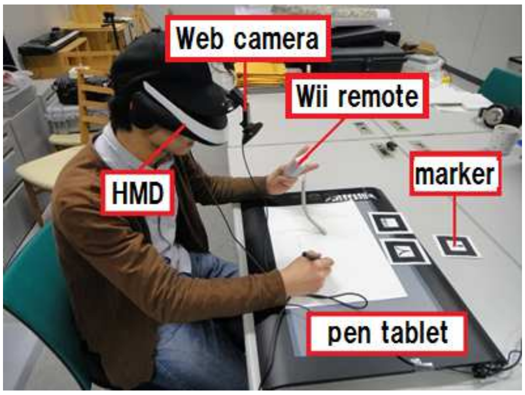

Figure1. System configuration

2.2 Extraction of the coordinate values of feature points

The system extracts information of vertices of motif models automatically when the system started, which were made by using Metasequoia (It is software for CG modeling). The system needs to calculate feature points on contours of the motif, because contours were represented by feature points. We classified contours into two types as follows.

- Edge type
- Surface type

Edge type contour is a folding line or a contour in model's development diagram. Surface type contour is a part of surface of the model that appears as a contour depending on a viewpoint. The system extracts feature points on contours from vertices and feature points on surfaces by different ways for each type of contour. Detail of the extraction algorithm is the same as our previous system [5].

3. Functions

3.1 Drawing guidance

To consider the induction of step-by-step drawing from rough shape to detailed shape, we divided system workflow into four modes.
(1) Initial mode
(2) Whole bounding rectangle mode
(3) Bounding rectangle of each motif mode
(4) Contour of each motif mode
A learner needs drawing in accordance with this order. First, the system is in "Initial mode" when it is immediately after starting the system.

"Whole bounding rectangle mode" **"Bounding rectangle of each motif mode"**
"Contour of each motif mode"
Figure 2. Upper: Indicated visual information, Lower: drawn sketch in each mode

Next, the system moves to "Whole bounding rectangle mode" after a learner decided composition and pushed button of decision. Whole bounding rectangle means the rectangle which includes both a dish and a cup. The upper left picture of figure 2 shows the whole bounding rectangle indicated by the system and the lower left picture of figure 2 shows a whole bounding rectangle drawn on a paper by a learner.

After the learner drew whole bounding rectangle correctly, the learner moves to “Bounding rectangle of each motif mode.” In this mode, bounding rectangle of the dish and bounding rectangle of the cup can be indicated by the system as middle picture of figure 2, if the learner needs. The lower middle picture of figure 2 shows bounding rectangle of each motif drawn on a paper by a learner.

Finally, the learner moves to “Contour of each motif mode”. In this mode, contours of the dish and the cup are shown with red color as shown upper right picture of figure 2. The lower right picture of figure 2 shows contour of each motif drawn on a paper by a learner. Learner can draw contours of motifs eventually if follow to order that system instructs. Transition from a mode to next mode can be controlled by a learner by any timing.

3.2 Offered advice

The system can offer three kinds of information in real time as follows.

- Bounding rectangle or contours to draw
- Position of the pen on the pen-tablet
- Gap between learner’s input (pen position) and correct position on a correct contour

First, the system displays bounding rectangle or contour with red color in each mode of system. This means that a learner currently must draw the red bounding rectangle or contour. For example, system displays virtual motif like middle picture of Figure 2 in “Bounding rectangle of each motif” mode.

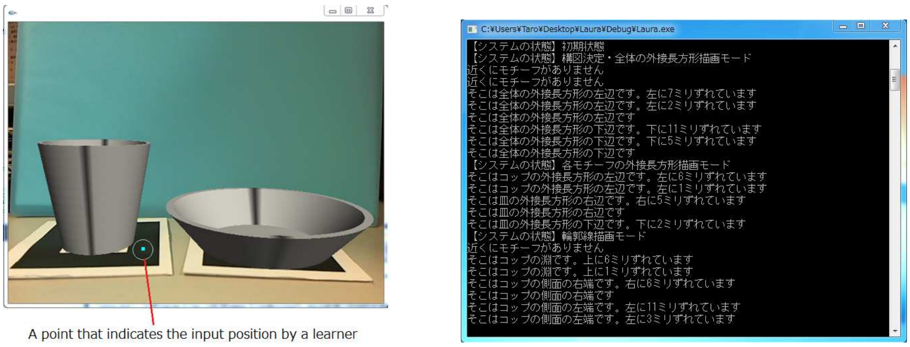

Figure 3. Left: Indication of learner’s input position, Right: advice on a gap

Second, the system displays learner’s input (pen position) by dots with light blue color when the learner touches a pen-tablet with tip of the pen like left picture of figure 3. The learner can grasp how far his/her pen position from correct position of correct contour visually.

Third, the system calculates information of gap by comparing learner’s pen position with feature points on the correct contours. After that, the system generates advice based on calculated gap information, and the system offers the advice with text and voice as shown right picture of figure 3. Vocal advice is put out by “LaLaVoice” It is application software produced by Toshiba corporation, which reads text data aloud. The learner can grasp a gap not only visually but also auditorily. A learner can switch on or off for displaying support information at any time.

3.3 Generation of advice

The system generates advice by three kinds of information, such as mode of the system, motif composition decided by a learner and input by the learner. The system selects a set of feature points that must be searched depending on a mode of the system when an input by the learner is accepted. There are three sets of feature points, which are whole bounding rectangle, bounding rectangle of each motif and contours of each motif. After that, the system searches a feature point that has smallest distance by comparing the input point and each feature point. Then, the system calculates gap's direction which is largest distance as seen from the feature point to the input point. Finally, the system generates advice based on calculated information.

4. Evaluation experiment

4.1 Flow of experiment and analysis

We performed an experiment to verify the effectiveness of the system. 24 subjects were divided into two groups, which were an experimental group and a control group. Each subject drew sketches five times. First drawing was pre-test, in which subjects in both groups drew sketches with real motif (a dish and a cup) in the same condition without the system. Second, third and fourth drawing were training, in which subjects in experimental group drew sketches with virtual motif using the system, while subjects in control group drew sketches with real motif without the system. Fifth drawing was post-test, in which subjects in both groups drew sketches with real motif in the same condition without the system as well as the pre-test.

We evaluated subjects' sketches of pre-test and post-test for each subject by checking eight evaluation items. Then, we compared error degrees of the sketches between the pre-test and the post-test for each subject. Specifically, we defined "degree of progress (DOP)" for each evaluation item.

$$DOP = E_{pre} - E_{post}$$

where E_{pre} represents error degree of pre-test, and E_{post} represents error degree of post-test. If an error degree decreased, DOP is positive value. Therefore, if DOP is positive value, it means that the subject's drawing skill was enhanced for that evaluation item. Eight evaluation items are as follows.

(i) Width of bounding rectangle of the dish
(ii) Height of bounding rectangle of the dish
(iii) Height of bounding rectangle of the apparent ellipse of the dish edge
(iv) Position of center of gravity of the bounding rectangle of the dish
(v) Width of bounding rectangle of the cup
(vi) Height of bounding rectangle of the cup
(vii) Height of bounding rectangle of the apertural apparent ellipse of the cup
(viii) Position of center of gravity of the bounding rectangle of the cup

4.2 Results of the experiment

Table1 shows DOP of each item for each subject and average value of DOP for comparison between experimental group and control group.

Table 1. DOP of each item for each subject

Evaluation item / Subject		Dish				Cup			
		(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)
Exp. group	A	0.6	−1.4	−0.3	1.6	−0.9	−0.5	0.3	0.7
	B	2.0	1.3	0.6	0.5	0.0	0.5	0.9	1.5
	C	−0.9	1.6	1.7	−0.2	0.1	−0.7	0.6	1.4
	D	0.1	0.3	−0.8	1.1	0.2	0.2	−1.0	0.4
	E	1.1	−0.4	1.2	0.4	−1.3	−0.4	1.0	2.2
	F	0.9	0.8	0.4	0.2	−0.5	0.6	−0.4	2.2
	G	1.8	1.4	0.8	−1.8	−0.9	0.1	0.6	1.4
	H	0.2	−2.0	−0.9	−0.7	0.0	−0.4	−1.0	−1.7
	I	3.6	−1.0	−0.7	3.8	0.2	−0.2	−0.7	1.9
	J	1.9	0.0	0.3	0.0	1.6	0.0	0.5	1.2
	K	0.5	0.7	−0.2	1.4	2.0	1.3	−0.7	1.9
	L	2.1	0.9	0.1	2.5	−0.1	−0.4	−1.1	1.1
	Ave.	1.16	0.18	0,18	0.73	0.03	0.01	−0.08	1.18
Cont. group	M	−1.8	2.8	2.8	−1.1	0.2	−0.5	−0.6	1.4
	N	−0.1	−1.1	−0.7	2.8	1.5	2.2	−0.6	2.3
	O	0.8	1.3	2.3	−1.3	−2.7	−1.2	−1.9	−2.3
	P	−0.2	−0.5	−1.3	−0.1	1.2	0.4	−0.7	−0.5
	Q	0.7	−0.4	0.5	0.7	0.7	0.3	−0.7	−1.3
	R	0.6	−0.8	−1.4	1.4	0.9	0.3	0.7	−1.5
	S	−0.4	0.8	0.7	−0.7	−1.2	−0.2	−0.4	−2.6
	T	0.2	−0.3	−0.1	−2.1	0.2	−0.4	0.8	−0.4
	U	1.5	−2.2	−2.0	3.0	−0.3	−2.8	−1.4	1.0
	V	4.2	−4.3	−4.0	0.6	0.2	1.0	−1.4	−0.8
	W	0.1	−4.6	−2.8	1.3	−3.4	−3.7	−0.5	1.1
	X	−0.1	−1.4	−1.5	0.6	0.7	−0.8	−0.1	0.2
	Ave.	0.46	−0.89	−0.63	0.43	−0.17	−0.45	−0.57	−0.28

Result of experiment indicated effectiveness of system. Average values of “degree of progress” of experimental group were more than control group. However, we could not confirm significant difference by t-test. We also performed a questionnaire survey in the end of the experiment. Each subject selected one of 5 selections (5:really think so 4:think so 3:neither 2:not think so 1:not really think so) for each sentence from ① to ⑩. Table 2 shows the result of the questionnaire survey. 10 sentences are as follows.

① It is useful to draw auxiliary lines before drawing contours of motifs.
② It is useful to divide system workflow into three steps, whole motif, each motif and contours.
③ It was easy to understand the information by voice and text?
④ It is better to be able to get information by voice.
⑤ Presented information was easily understandable and concrete.
⑥ Learning by the system is better than reading the book about sketch.
⑦ I can continue sketch learning by self-study if I use this system.
⑧ I didn’t feel any discomfort for drawing by use pen tablet.
⑨ I didn’t feel any discomfort for drawing by use HMD.
⑩ I think it easy to control the system by Wii-remote.

Many subjects agreed with the sentences①②⑩, many subjects didn't agreed with ⑨.

Table 2. Result of questionnaire survey

	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩
A	5	4	1	3	4	3	2	4	2	3
B	4	4	5	5	5	4	4	3	3	5
C	5	5	3	4	4	5	3	4	2	5
D	5	5	3	2	3	4	3	2	2	5
E	5	4	1	2	2	2	3	4	2	3
F	5	5	4	4	4	4	4	3	2	4
G	4	4	3	2	4	3	4	5	2	5
H	4	5	3	4	2	3	4	2	1	4
I	5	4	3	3	4	3	3	4	2	3
J	5	4	3	3	3	3	2	2	2	2
K	5	5	3	4	2	4	3	4	2	4
L	2	2	4	4	5	3	4	2	1	5
Ave.	4.50	4.25	3.00	3.33	3.50	3.42	3.25	3.25	1.92	4.00

5. Conclusion

In this paper, we described a new sketch skill learning support environment which improve preceding research of our project. A learner can decide a composition freely because the system uses AR technology which is inherited from previous system. In addition, the system guide the learner by step-by-step drawing from rough sketch to detailed sketch, which is also inherited from another preceding system.

We have evaluated the new system and the results indicated an inclination of effectiveness, but unfortunately we could not confirm significant difference by t-test. This might derive from the fact that the training is too short to show the significant difference. In general, skill learning needs long period. A learner needs to repeat training every day. We have to verify the learning effect by conducting an experiment with a longer term.

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