On Effects of Cooperation with the Machine in Human-Computer Co-Drawing

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Premise

This paper proposes a system model for studying the effects of computers cooperating with humans in drawing a subject together on the same canvas. We present our hypotheses, partly drawn from a preliminary experiment with ten subjects. It is a part of our plan in wider experiments on the subjects. We propose two questions; (1) "How does the drawing style of the computer affect the users performance?" and (2) "How does the distance between strokes drawn by computer and human affect the users performance?" We are pursuing the answers through more experiments in which the computer draws with two parameters, imitation rate of drawing style and spatial interference rate. The effects of the rates are investigated by assigning a variety of probability distributions of occurrence for each rate.

1. Introduction

The doodle is a play drawing with paper and pen. Wide people, from small children to the elderly enjoy it. In addition, it is also generic and highly scalable play. It expands to graffiti on the walls, the drawing on the screen using the projector, and so on. Traditionally, creative activities such as doodle, has been considered as the act only human do, so only human can collaborate on creative activity. However, computers those perform autonomously and creatively have begun to be accepted by people, recently. Artificial intelligence artist AARON [1] is a typical example. Along with these creative computer, the possibility of human-computer collaboration on doodle has begun appear.

In fact, there already have been computers that aim to collaborate with human. There are two examples of the studies; SHIZUKA [2] is a computer system which draws picture interactively by associating next drawings from human drawings, and another system aims to mix own creativity and human's [3]. In the aspects of human-computer interaction, *human-computer doodle* is one of the "collaborative interactions of which primary aim are spending a fun time together [4]".

Yamamoto et al. argued that one of factors that bring fun to humans on such as collaborative interactions is "itself that thinks partner is human" [5]. Therefore, it has been said that it is difficult to make human fun by such human-computer interaction. However, Yamamoto et al. also pointed out that; might humans can enjoy human-computer interaction itself, if computer's behavior achieve the level in which human can empathy with it or can superimpose psychological state on it.

When humans doodle together, they tend to care what the partner is drawing and how it is possibly going on. In this study, we consider that the computer which human empathies with or superimposes psychological state onto gives the partner feelings of "the computer cares me" and "I'm caring the computer". Further more, we assume such computer promotes human-computer interaction spending a fun time together.

In human-computer doodle, the computer reaction that gives the partner the feelings of "the computer cares me" and "I also care the computer" have not been much studied. In addition, the creative computers are not suitable for verification of computer interaction, because these computers are not yet adequate to "doodle together with".

In this study, we develop the Co-Drawing System (CDS) which doodles a presented image based on a teaching data together with human, and propose two assumptions to give human feelings that "the computer cares me" and the Co-Drawing System TOMMY (CDST) which is the system to investigate these assumptions. These assumptions were induced based on our preliminary observation using CDS.

As a result of the human-computer drawing observation using the CDS, we assumed two hypotheses; 1. Human is easily aware of the drawing style, and feels easily "the computer cares me" if the computer imitate the person's drawing style, 2. Human is easily aware of the spatial interference of strokes, and feels easily "the computer cares me" through the spatial interaction with the computer.

To investigate these two hypotheses more deeply, we propose the CDST that can set imitation rate of drawing style and spatial interference rate and change behavior of the system.

2. CDS Overview

2.1 System doodling together with human

Figure 1 shows the schematic diagram of the CDS. CDS is software running on a PC, and it doodles an imitated figure of the image presented by an experimenter together with a person on a single canvas shared between them. The CDS does not only doodle on its own, but also do together with a person. If the person doodles a stroke on the canvas using a pointing device such as a mouse, the CDS detects it, and acquires information of drawn strokes. In addition, the person sees how strokes are drawn during the CDS is doodling the strokes on the canvas in real time.

The CDS doodles in accordance with the teaching data obtained by converting the presented image to interpretable form. Figure 2 shows the flow of processes to doodle in accordance with the teaching data, with acquiring strokes drawn by the person. Until the teaching data exhausted, the CDS repeatedly selects a stroke from the data and acquires information of a stroke drawn by the person if it detects the person drawing strokes on the canvas.

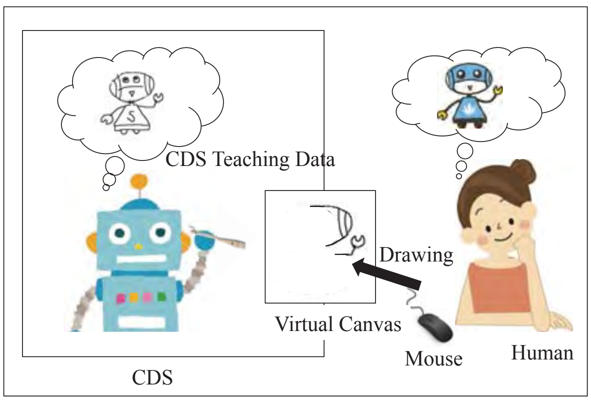

Figure 1. Schematic diagram of the Co-Drawing System.

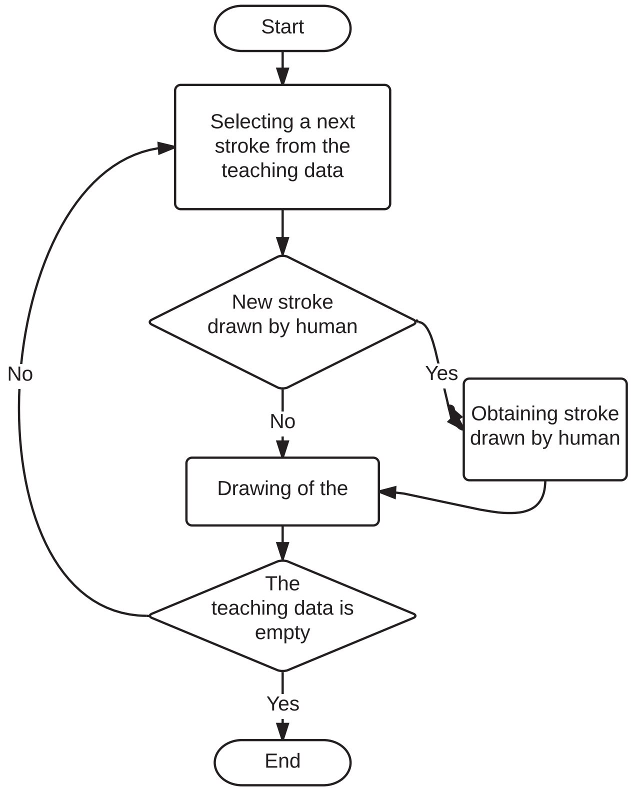

Figure 2. The flow of processing to doodle drawings with acquiring strokes drawn by the person.

2.2 Creation of teaching data

Teaching data is obtained by converting a presented image to a recognizable form of the CDS, and a hand of man converts the presented image. First, a person doodles the presented image on the canvas using a mouse. Next, the CDS gets boundary of each stroke, absolute coordinates of the stroke, and drawing speed of the stroke from the drawn data. Finally, the presented image is converted to the teaching data. At that time, beginning and end of each stroke are obtained by detecting the moment the mouse is pressed or released, and each strokes is obtained as a set of points. The points are taken at predetermined time intervals, so if a distance between points is long the drawing speed of the stroke is quickly, and if the distance is short the speed is slow.

When the CDS doodles on own, it can faithfully reproduce strokes forms of the teaching data and the drawing speeds of the strokes.
However, draw order is not recorded.

3. Outlook of the factors that affect human

3.1 Observation of human-computer doodle by CDS

In this experiment, the CDS operates according to the following three policies, in order to hold the act of doodle together.

- Do not draw a stroke on the stroke drawn by human.
- Select a stroke from the teaching data, with priority the furthest from the stroke

drawn by human.

- The stroke of teaching data, which is not yet drawn, is considered that it is already drawn, if the stroke is close to a stroke drawn by human.

These policies realize human-computer doodle sharing, separating the area to draw strokes.

Below we describe the conditions of the experiment.

- At first, the subjects are informed the partner of doodle is a person.
- Drawing speed of the CDS is based on the teaching data (it is same as the teaching data creator).
- It seems that the CDS draws strokes at random order from a person who doodle together with the CDS, because it chooses a stroke from teaching data in favor of distant stroke from the strokes drawn by the person.

In this experiment, we asked some questions to subjects; whether felt that "doodle together with", whether felt that drawing speed of a computer is adequate, whether felt that the computer doodled drawings at adequate order, and so on.

3.2 Observation results

Subjects were ten university students, and of which eight people answered that "I felt drawing together with the computer", but other two people did not feel so. The computer / the person supported the other, or they succeed to share the canvas to complete drawing the presented image, these are the reasons why the eight people felt drawing together with the computer.

On the other hand, as the reasons why they did not feel so, the two people mentioned that the computer drawing speed was too unlike their own. About feeling of computer drawing speed and feeling of computer drawing order, we prepared some choices.

For the drawing speed, there were slow, somewhat slow, normal, somewhat fast, and fast choices. For drawing order, there were unnatural, somewhat unnatural, neither unnatural nor natural, somewhat natural, and natural choices. While a half of subjects answered the drawing speed is normal, seven subjects answered the drawing order is unnatural or somewhat unnatural. Despite the computer's drawing order is unnatural, nobody mentioned about it at free impressions. To the contrary, some subjects mentioned about the drawing speed.

3.3 Hypothetical factors affecting human

First, we considered that there are conscious factor and unaware factor, in human-computer doodle. From a result 3.2, we regard the drawing speed and each other's drawing area as conscious factors. To contrary, the drawing order is seemed to be unaware factor.

The drawing speed is not fixed while a stroke is drawn, and it is closely related to how to draw the stroke. Thus, we considered that humans imitate other party each other, and assumed that the person feels easily "the computer cares me", if the computer imitates person strokes.

Therefore, we devised the system which the experimenter can change how much imitate and how much interference to strokes drawn by human. This system extends the CDS, and it is called Co-Drawing System TOMMY (CDST).

4. Imitation of how to draw strokes

In this study, we define the drawing style, which represents how to draw strokes using the drawing speed, and CDST imitates the style using "imitation rate" which CDST has. Using the system CDST, we investigate the change in human impression due to increase or decrease of imitation rate. Then, we will verify the relationship between imitation of the drawing style and whether the person feels that "the computer cares me".

4.1 Style of how to draw the stroke

Each stroke has own style of how to draw strokes, and each style is represented using the three factors.

The first factor is the average drawing speed to draw the stroke. The average drawing speed V_{ave} is the number of the stroke length divided by the number N of points contained in the stroke, and it is expressed by following equation.

$$V_{ave} = \frac{\sum_{k=1}^{N-1} D_{k,k+1}}{N} \qquad (1)$$

where $D_{t,t+1}$ is distance between point P_t and next point P_{t+1}.

Second factor is the drawing speed ratios arranged in order from the first section to the last section. It is prepared to express a habit of how to draw such as initially slow gradually faster. Figure 3 shows an example of the habit of how to draw in the graph. When the drawing speed ratio in the vertical axis is 1, drawing speed of the section equals the average drawing speed of the stroke. Therefore, figure 3 shows the change of drawing speed; the start drawing speed is slow, but it is gradually faster, and it again gets slow at the end of drawing. The drawing speed ratio R_t of section S_t is expressed following equation.

$$R_t = \frac{D_{t,t+1}}{V_{ave}} \qquad (2)$$

where, section S_t is between the point P_t and next point P_{t+1} on the stroke, and the drawing speed of section S_t is distance $D_{t,t+1}$. Such drawing speed ratios R_i arranged in order from the first section S_1 to the last section S_{N-1} is treated as a habit of how to draw which the stroke has.

Third factor is the waiting time from time finished previous drawing to time beginning current drawing. The previous two factors can be calculated only from the current stroke, but the third factor needs to measure the time continued from the stroke drawn previous.

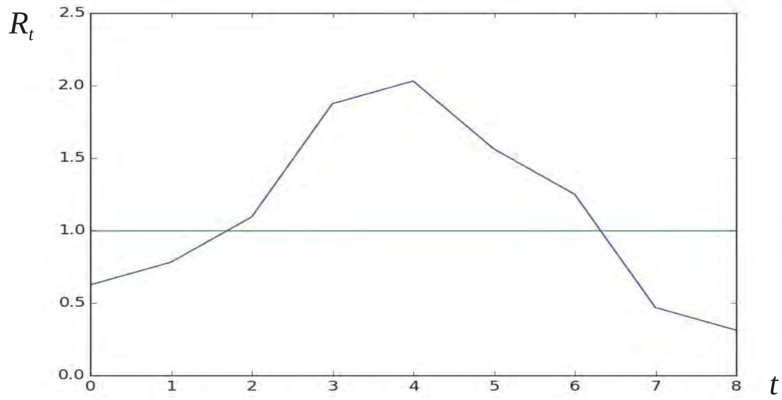

Figure 3. An example of habit of how to draw

4.2 Acquisition and imitation of drawing style by person

If CDST detects a stroke drawn by person, it acquires the stroke, and calculates the drawing style using representation of 4.2. When CDST draws a stroke L_c chosen from teaching data, it imitate human drawing style using own imitation rate. That means it calculates drawing speed V_t used to draw the point P_t on the stroke L_c by own drawing style and acquired human drawing style. When the imitation rate is high, the calculated drawing style close to human drawing style, but it is close to the CDST drawing style if the rate is low. Imitation rate takes the real number of 0 or more 1 or less.

Now, we assume CDST draws a stroke L_c with imitation of human drawing style acquired from stroke L_h. When imitation rate is M, the drawing speed V_t of section S_t on stroke L_c is expressed following equation.

$$V_t = (1 - M)R_{ct}V_{\bar{c}} + MR_{ht}V_{\bar{h}} \quad (3)$$

where R_{ct}, R_{ht}, respectively, refers to the habit of the CDST's drawing and humans at point P_t and point P_{ht}, and V_c, V_h, respectively, refers to average drawing speed of the CDST's stroke and humans. The point P_t is on stroke L_c, and the point P_{ht} is on stroke L_h and corresponding to the point P_t. Figure 4 shows the correspondence of point P_t on stroke L_c and point P_{ht} on stroke L_h.

Finally, the waiting time d until choosing next stroke from teaching data and starting drawing is expressed following equation.

$$d = (1 - M)d_c + Md_h \quad (4)$$

Here, d_c, d_h, respectively, are the CDST's waiting time and the human waiting time.

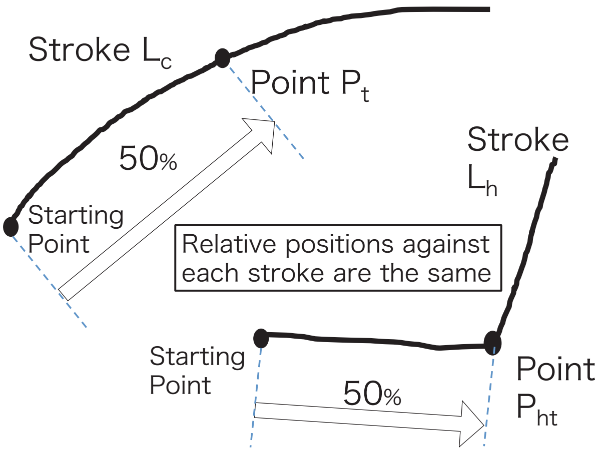

Figure 4. The correspondence of point P_t on stroke L_c and point P_{ht} on stroke L_h.

5. Spatial interference

The CDST adjusts by interference rate the distance between human previous stroke and the stroke chosen from teaching data, in order to observe the impact of spatial interference among strokes.

First, get strokes which are included in the teaching data and have not yet drawn, to sort that in the order of proximity to the stroke drawn by human. The distance between a stroke drawn by human and a stroke gotten from teaching data is regarded as the distance of which the combination of most closer points. Then regard 100 * (1 - interference rate) as the percentile value, and choose appropriate stroke from sorted strokes.

In other words, when there is the interference rate I $(0 < I \leq 1)$, the chosen stroke L_n is located n_{th} of sorted strokes counting from 0, then, the n is given by the following equation.

$$n = \lfloor (1 - I)N \rfloor \tag{5}$$

where N is the number of strokes which included the teaching data and not yet drawn. Therefore, when the interference rate is high, the CDST draws in favor of close stroke from strokes drawn by human, and when it is low, draws in favor of distant stroke from strokes drawn by human.

However, because selectable strokes gradually become less, the CDST can draw distant stroke from strokes drawn by human despite the interference rate is high, and it also can draw close stroke despite the rate is low.

6. Occurrence probability and combination of imitation rate and interference rate

When a human does something, it is difficult to repeat the same thing exactly like computer. In order to provide some fluctuations in the behavior of computer, the spatial interference rate and the imitation rate are updated with a random number according to a triangular distribution on the each time to draw a stroke.

Triangular distribution of the probability density function *f(x)* is given by following equation.

$$f(x) = \begin{cases} \frac{2(x-a)}{(b-a)(c-a)} & (x < c) \\ \frac{2(b-x)}{(b-a)(b-c)} & (x \geq c) \end{cases} \tag{6}$$

Here, a, b, c denote respectively, the lower limit of the distribution, the upper limit, and the mode value. Table 1 shows values of experimentally used three distributions.

Imitation rate in the 0 to 1 inclusive of the real number, and spatial interference rate is greater than 0 to 1 or less of the real number. Figure 5 shows the probability density function of the triangular distribution using values in table 1.

The horizontal axis expresses the value of imitation rate and interference rate. In Figure 5, as distribution of imitation rate goes from (1) to (3), the CDST often imitates drawing style of the person a lot. In interference rate, as distribution goes from (1) to (3), the CDST often disturbs human strokes.

The behavior of the CDST varies by the combination of the shape of the imitation rate distribution and the shape of the interference rate distribution. Because the imitation rate and the interference rate have respectively three shapes of distribution, the CDST have nine behaviors.

	a	b	c
(1)	0.0	0.5	0.2
(2)	1.25	0.75	0.5
(3)	0.5	1.0	0.8

Table 1. Values of distributions.

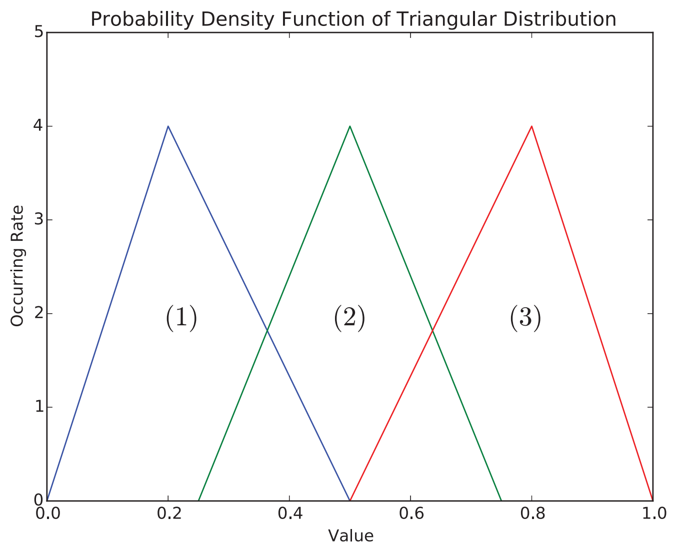

Figure 5. Probability density function of triangular distribution.

7. Conclusions

In this study, we assumed the two hypotheses; 1. When the computer imitates the style of drawing by the person, the person feels that "the computer cares me", 2. If there are appropriate spatial interferences, the person feels easily that "the computer cares me".

These hypotheses are based on the prediction that there are possibility of which human feels a fun through human-computer interaction itself, if a computer reaches the level in which human empathies with and superposes psychological state onto. In addition, to investigate the two hypotheses, we proposed the Co-Drawing System (CDS), which can doodle together with human, and Co-Drawing System TOMMY (CDST) which can adjust degree of imitation of drawing style and degree of spatial interference.

Then, we show that the CDST behaviors are changed by combination of imitation rate and interference rate, in the other words, varying the distribution of imitation rate and spatial interference rate.

In the future work, we will conduct the verification of the hypothesis throughout the experiment.

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