Development of an interactive digital signage based on F-formation system

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Abstract: In this research, we propose a position determination algorithm for an interactive digital signage system using Kinect sensor and a lifelike agent. This system detects the spatial relationship of a display and spectators in real time, and provides an effective interaction between the lifelike agent and spectators based on the F-formation system, which is an analysis concept of the dynamics of a conversational place.

1 Introduction

Signboards have been changing from electric signboards that are difficult and costly to update to digital signage, which is easy and inexpensive to update. Digital signage is an electronic display that connects to a network and distributes information to locations such as retail stores, public spaces, and transportation spaces. This definition comes from the Digital Signage Consortium established by communications companies, manufacturers and advertising companies, and so on [1]. Interactive digital signage is gaining interest for use in many locations, such as roadways, shopping mall and museum, and so on.

Even if a digital signage is very large and displays attractive content, the digital signage tends to interact with only one spectator. If other spectators enable to join the interaction, then the digital signage is able to provide information to more spectators. We define this state as one-to-many interaction.

In this research, we develop an interactive digital signage with Kinect sensor [2] and a lifelike agent. Kinect sensor always measures position and height of a user by using the provided software. It automatically calibrates the yaw angle of the body position of Kinect sensor to adjust for the best motion recognition. We propose a position determination algorithm for a lifelike agent. The algorithm is based on the F-formation system, which is an analysis concept of the dynamics of a conversational place. The algorithm enables to change from one-to-one interaction to one-to-many interaction.

Lifelike agents that act with awareness of spatial body arrangement have been developed as avatars in a metaverse [3][4][5]. Some studies have been investigated lifelike agents with an awareness of spatial body arrangement interacting with users in actual space. Nishimura et al. focused on the distance between a lifelike agent and a participant [6]. Another study verified a participant's spatial body arrangement when a participant joins a conversation between lifelike agents [7]. However, no experiment has been conducted on a participant's spatial body arrangement and participant's evaluation of impression for the lifelike agent when the participant joins the conversation between the lifelike agent and an experimental cooperation as far as we know.

In this research, we carry out an experiment on a human's spatial body arrangement and the impression when participant joins the conversation between the lifelike agent and experiment cooperation.

2 Unit of Analysis for Position Determination

In this section, for the position determination algorithm, we introduce some analysis concepts that allow us to verify a conversation between humans.

2.1 F-formation System

We adapt the F-formation system [8] as an analysis concept of conversation detection to construct the position determination algorithm. F-formation explains the phenomenon of space that is constructed by face-to-face interaction when two or more people come

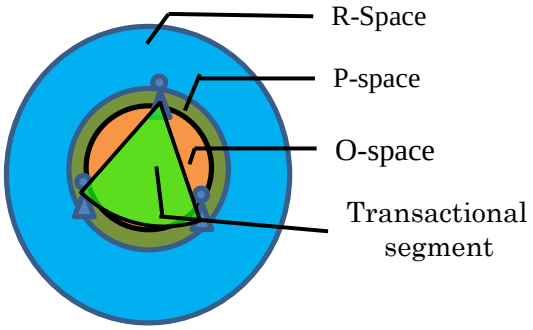

Fig. 1. F-formation

together. It is an analysis concept for the whole interaction, including the environment surrounding the conversation.

As shown in Figure 1, the F-formation system verifies the conversation space by dividing the space into a transactional segment, O-space, P-space, and R-space.

The transactional segment is the space in front of an individual's body. The transactional segment of an individual is aware of others as well as him/herself. Whenever two or more people talk, an O-space is formed by their overlapping transactional segments. These "participants" who are talking maintain the space physically. The area occupied by the participants themselves is called the P-space and the area outside the P-space is called the R-space. The R-space is a spatial buffer, where someone who wishes to join the grouping will be positioned, until the formation reconfigures to include him.

2.2 Hall's Proxemics

When the lifelike agent interacts with only the F-formation system, the conversation is unnatural, because concept of distance is not considered on F-formation system. According to Kendon [9], the F-formation focuses on the spatial arrangement of physical behavior. For this reason, we need to provide distance constraints for the lifelike agent.

In this research, we refer to the distance of the lifelike agent and human as Hall's proxemics [10]. The distance is divided into four ranges, intimate, personal, social, and public, and each range has a close phase and a far phase, as shown in Figure 2. We feel uncomfortable when getting closer. When the distance is between 2.0 m and 1.2 m, this range is the close phase of social space.

2.3 Procedure for Participation Conversation

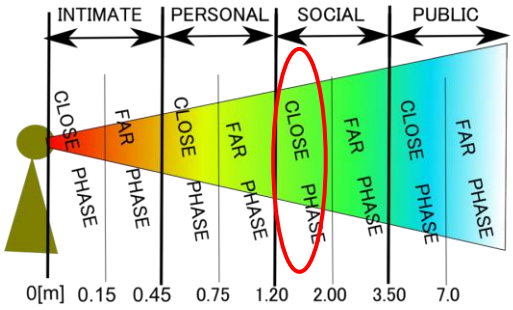

Fig. 2. Hall's proxemics

Bono et al. [11] described the general procedures that are common to face-to-face participation in terms of the participation structure of conversation. According to [12], a person starts as a "non-participant." When a non-participant moves closer to the conversation field, a non-participant begins to be conscious of the conversation. By doing so, non-participant becomes a "bystander." A bystander becomes a "participant near" by being aware of the presence of an existing participant. A "participant near" becomes the "addressee" by receiving utterance by the current speaker.

In this research, a lifelike agent makes a non-participant clearly conscious of the lifelike agent, so that the non-participant changes to a participant nearby exhibiting behavior such as making eye contact and walking close to the lifelike agent. The participant becomes the addressee when the lifelike agent begins to talk. We think, by repeating this procedure, a lifelike agent is able to convey information to more units.

3 Define Behavior for Interaction with Lifelike Agent

In this section, we define the typical pattern of human behavior and lifelike agent placement of interactive digital signage (IDS) by using a lifelike agent. Many external factors must be considered like location, degree of congestion of people, and others. However, we focus on the impact of human behavior and the resulting placement of the lifelike agent in the description information. Because we think the implications of actions and body placement when a participant joins in the conversation with the lifelike agent and human are important

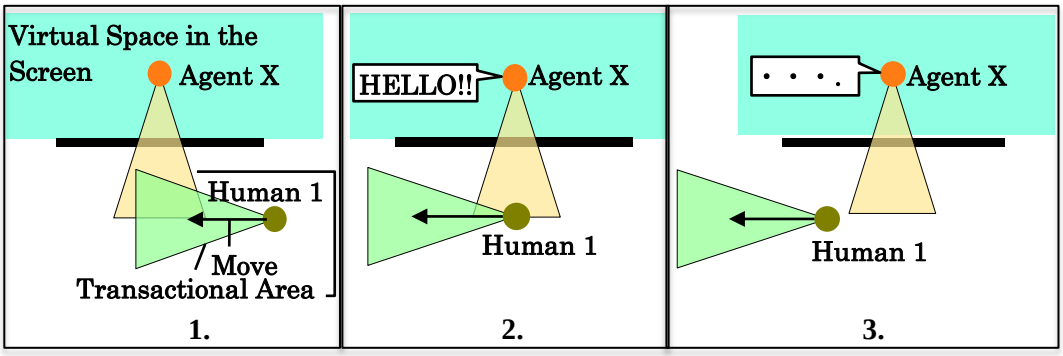

Fig. 3.Wait continuation pattern

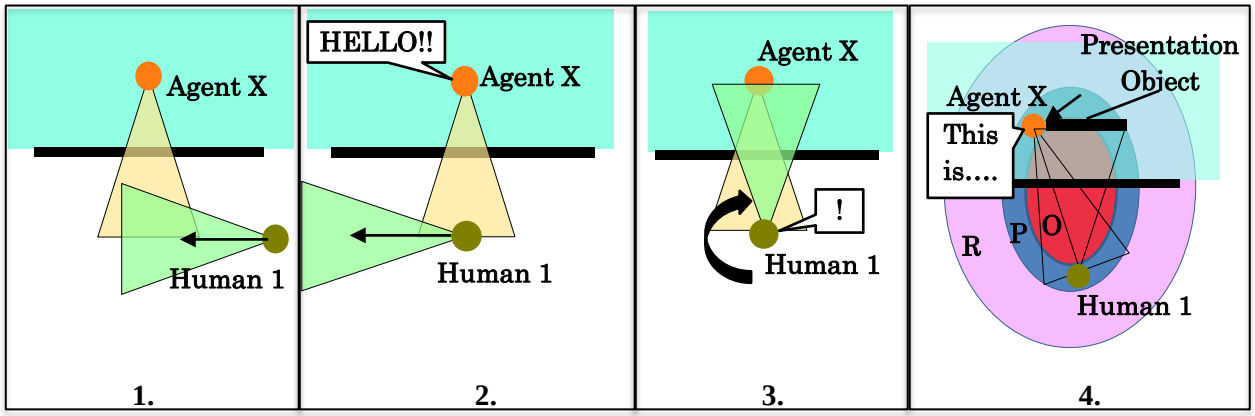

Fig. 4. Starting one-to-one explanation pattern

We predict that a lifelike agent is able to convey information to more units when someone approaching the R-space is incorporated into the P-space, formed by a lifelike agent talking with people. We define the distance between a human and a lifelike agent which is the close phase of social space as a talking phase.

First, we define two patterns starting from the agent beginning the conversation with Human_1 (Fig. 3. and Fig. 4.). And more, we define two patterns of behavior when Human_2 appeared in the R-space made by the conversation of the agent and Human_1 (Fig. 5. and Fig. 6.).

The following describes the four patterns.

3.1 Wait Continuation Pattern (Fig.3.)

The wait continuation pattern is shown in Figure 3. On wait continuation pattern, even if the lifelike agent (X) talks to a non-participant (Human_1), the participant passes by the IDS because non-participant is not interested in what the lifelike agent is explaining.

1. The non-participant passes through the transactional area of the lifelike agent.
2. The lifelike agent advertises with a short talk.
3. The non-participant passes by the IDS.

3.2 Starting One-to-one Description Pattern (Fig. 4.)

The starting one-to-one description is a pattern in which the non-participant is interested in the lifelike agent or what the lifelike agent is explaining, and stops his/her walking, as shown in Figure 4.

1. The non-participant passes through the transactional area of the lifelike agent.
2. The lifelike agent advertises with a short talk.
3. The non-participant directs the transactional area to the lifelike agent.
4. The non-participant becomes an addressee.

3.3 Continuing One-to-one Description Pattern (Fig. 5.)

Thereafter, we explain the state after the end of starting one-to-one description pattern. This is a pattern in which the non-participant (Human_2) enters the R-space and leaves there with the addressee and the

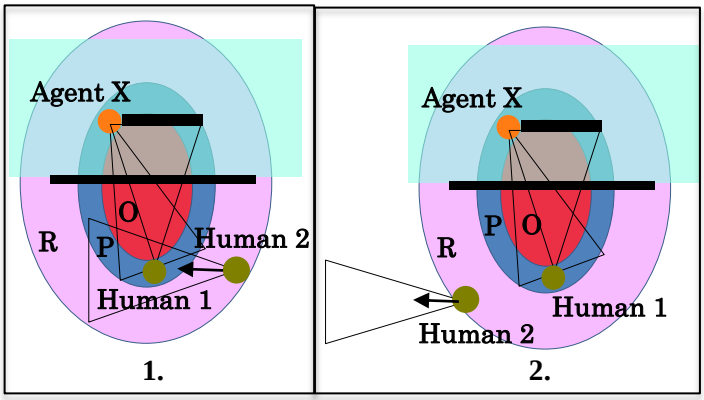

Fig. 5. Continuation of one-to-one description pattern

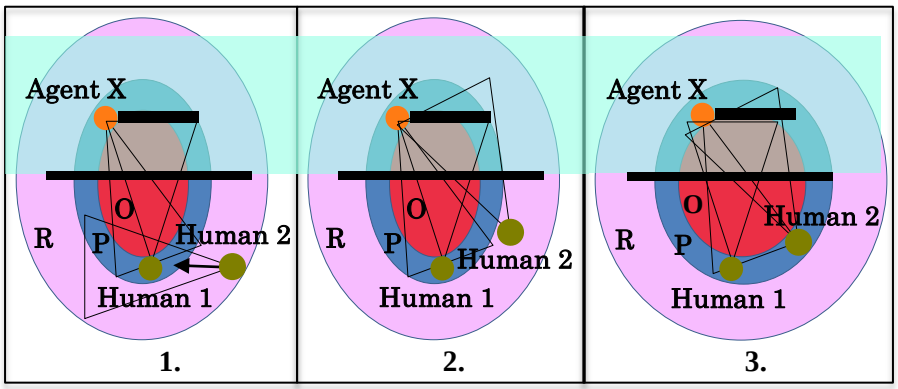

Fig. 6. Starting one-to-many description pattern

lifelike agent, to interact as shown in Figure 5.

1. The non-participant enters the R-space.
2. The non-participant leaves the R-space.

3.4 Starting One-to-many Description Pattern (Fig. 6.)

In this pattern, the non-participant enters and stops in the R-space, and starts an interaction with the lifelike agent and addressee, as shown in Figure 6.

1. The non-participant enters the R-space.
2. The non-participant stops there and becomes a bystander who listens to the lifelike agent's conversation.
3. The lifelike agent makes the bystander an addressee by the conscious behavior of talking. The O-, P-, R-spaces spread as the number of people in the F-formation increases.

4 Position Determination Algorithm

In this section, we propose an algorithm based on Section III. This algorithm was designed to lead to starting one-to-many description pattern of the previous section.

1. If no people are in front of a display device, the lifelike agent calls.
2. When the lifelike agent detects a non-participant, the agent faces the non-participant.
3. The lifelike agent gives an overview of the presentation contents in detail following the movement of the non-participant.
4. When the non-participant stops, the lifelike agent increases the distance between the non-participant and himself.
5. The lifelike agent provides the information of the presentation contents
6. In the middle of step 5, when the lifelike agent detects another non-participant, the lifelike agent moves to the front of the body to include them in its transactional area.
7. By continuing this procedure, many participants interact.

5 Verification of the Effect of the Lifelike Agent by the Proposed Method

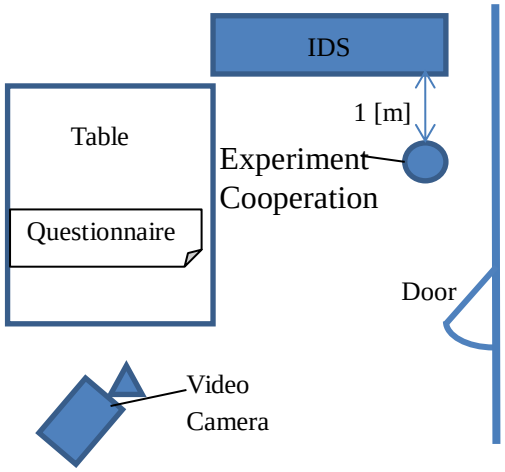

Fig. 7. Setup of the room used in the experiment

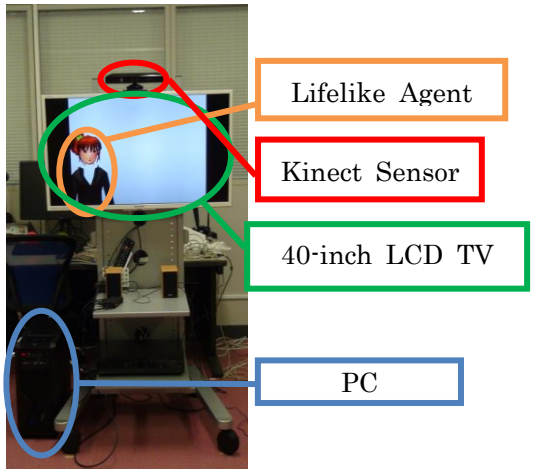

Fig. 8. IDS used on this experiment

5.1 Purpose of the Experiment

We verify whether the proposed IDS which is interacting with an experimental cooperation is taken any notice by participants. And a proposed lifelike agent is too.

5.2 Experimental Setup

Figure 7 shows the room setup used in the experiment. This room is imitated the situation of 5. Chapter4.

A participant enters the room after he/she has received some instruction. An experiment cooperation stands on the side door of the display device, 1 [m] away from the display device. The participant listens to what the lifelike agent is explaining.

The device used in this experiment is shown in Figure 8. We obtained the Kinect sensor movement trajectory of the participant in this environment. The sensor mounted on the display device is at an optimal view for setting the height of sensor on the program for experiment. We can observe actual movement of a participant by the video capture of the camera.

We use a 40-inch LCD TV as a display device. The TV, connected to a PC, displays the lifelike agent.

The number of participants was 26, with a mean age of 22.0 years. All were engineering college students.

5.3 Experimental Procedure

The following shows an experimental procedure.

1. The lifelike agent talks about prepared trivia with 3 slides towards the front of the body in the experiment cooperation.
2. The participant receives the instruction paper: "there is a display in the room. Please listen to the explanation about a trivia. Please listen constantly while moving to the position that is easy to hear. Please answer the questionnaire on the table after the end of the description. After you understand the above, please return this paper and enter the room."
3. After the participant returns the instruction paper, the participant enters the room with digital signage by opening the door.
4. The lifelike agent interrupts the description after a certain period of time. Then, the lifelike agent says "Hello. Let me explain it again because there is another new person." The lifelike agent moves for each condition. After that, the lifelike agent starts explaining from the beginning.
5. The participant responds to the questionnaire after the lifelike agent has finished.

The 7 point scales semantic differential method was performed of the questionnaire, which included questions of memory, attention and interest of AIDMA model [11] properties on an adjective scale [13].

5.4 Introduced Content Settings to be Used in IDS

The introduced content that was used in the experiment is trivia lasting for 1 minute 19 seconds. The lifelike agent interrupts the utter after a certain period of time and moving participants were under the conditions for using the lifelike agent. We made the lifelike agent a moving and utterance after the agent explains the first slide of the three slides.

5.5 Experimental Conditions

This section describes each condition of the experiment.

1) Lifelike agent in proposed method condition (positive direction condition)

The lifelike agent is standing in front of an experimental cooperation and explains an experimental cooperation at the beginning. According to the experimental procedure, the agent approaches the participant and resumes the explanation from the beginning. This condition is imitated the situation of 6. Chapter 4.

2) Condition lifelike agent moves uncomfortably (negative direction condition)

The lifelike agent is standing on the opposite side of an experimental cooperation and explains an experimental cooperation at the beginning. According to the experimental procedure, the agent approaches the experimental cooperation and resumes the explanation from the beginning. This condition is the agent do not try to talk with the participant.

3) Slide condition

In the same way of general digital signage, this condition is a condition that the device explains the trivia with slides without the agent. In particular, the device doesn't act procedure 4 of the experimental procedure.

5.5 Experimental Result

The movement locus [m] of each experimental condition is shown in Figure 9. Origin O is the center of the display, and (1.5, -2.5) is located in the vicinity of the door. Table I shows the average of the total travel distances of each locus.

As a result of testing at a 1% level of significance in the t-test assuming a distributed equivalent between sliding conditions and the conditions where the lifelike agent moves in the negative direction and positive direction for the average total distance traveled (T <= t) to one side, P = 0.008. A significant difference was found. Therefore, we should say that the effect of using the lifelike agent is strong.

We decided to give a definition for each behavior from the trajectory. We show the definitions below.

Behavior 1) Behavior closer to the display than to the experiment cooperation

This is behavior that was closer to 0 than to the Y coordinate of the experiment cooperation.

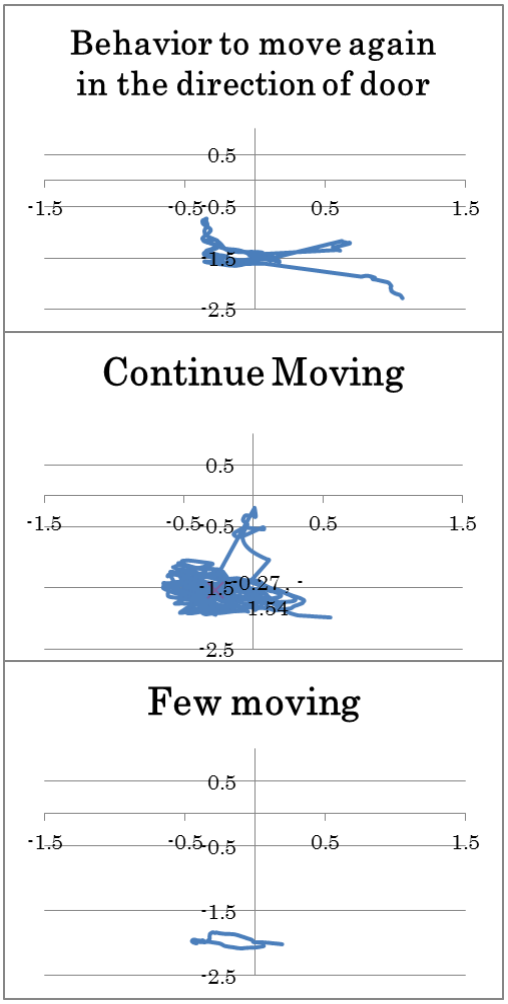

Fig. 9. Locus obtained by experiment

Table 1. Travel Distance of Each Movement Locus [m]

	Positive	Negative	Slide
1	4.3	2.0	18.7
2	2.5	1.5	18
3	9.3	1.6	2.7
4	2.5	7.7	39
5	5.8	3.1	46.2
6	3.1	15.7	7.4
7	16.9	1.9	8.1
8	—	2.2	6.9
9	—	—	5.7
10	—	—	11.6
11	—	—	6.1
Average	**6.3**	**4.5**	**15.5**

Behavior 2) Behavior to move again in the direction of door

Behavior is a trajectory that exceeds more than twice the Y axis on the graph.

Behavior 3) Continue behavior movement

The total travel distance of further behavior is 3 m.

Table II shows the results expressed as a percentage of the observed trajectory corresponding to the behaviors defined above. We think that there is the effect is also easy to see by looking at other suitable distances from the display of the audience from the verification results of Behavior 1).

The highest numbers are the slide conditions of definition Behavior 2). We think the results show that the lifelike agent continues to move without being aware of the position relationship.

When we compare the conditions in the negative direction and the positive direction, the positive direction condition is more than the negative direction condition for Behavior 2). We think the given impression is that the lifelike agent has to react to the movement of the participants.

Figure 10 shows the averages of the survey results under the three conditions. We found that the lifelike agent of a positive direction condition gave the impression of being cheeky, regally and sociable. In the t-test at the 5% significance level, equal variances were found for the three items of attention, interest, and memory under the two conditions, using the lifelike agent and the slide. As the result, there is a significant difference only on the item of attention.

Table 2. The Result in Percent[%]

	Positive (7 results)	Negative (8 results)	Slide (11 results)
Behavior 1)	28.57	12.50	90.90
Behavior 2)	42.86	25.00	90.90
Behavior 3)	71.43	25.00	90.91

6 Conclusion

The present study constructed a position determination algorithm to expand the scope of information transfer by a lifelike agent in an IDS from one-to-one to many-to-one. We built an IDS to actually evaluate the interaction.

The lifelike agent was eye-catching, and we found that the movement of people was highly effective for interacting with the lifelike agent.

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