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Tabletop dish recommendation system for social dining: Group FDT design based on the investigations of dish recommendation

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Abstract: A tabletop dish recommendation system for multiple users dining together, called Group FDT (Future Dining Table), is presented. The system continually assesses the dining status of users, and recommends dishes in a timely manner. The recommendation timing and displayed position of recommended dishes are based on research on real dining, extant literature, and experimental results. Thus, the system is expected to be useful in addressing staff shortages in the food service industry such as Japanese pubs which often receive additional dish orders.

Keywords: social dining, dish recommendation, interactive system

1. Introduction

Dining is clearly indispensable to our lives and closely connected to feelings of happiness and the quality of life. Recently, as the significance of dining in our lives has been noticed, more attention has been paid to the topic of dining. Lately information and communication technologies have been constructively applied and promoted in almost all fields, however, their potential contribution to the pursuit of pleasant dining has not been sufficiently investigated; the dining environment has experienced little change.

In this paper, we propose a tabletop dish recommendation system for multiple participants dining together, called the Group FDT (Future Dining Table). Given the present state and future prospects of labor supply shortage, it will become more difficult to keep employees capable of recommending another dish which suits the dining status of the customers. The Group FDT is expected to be useful as a substitute for a food server in such situations.

The following is a summary of the present study. The proposal and design of the system is outlined in Section 2. System implementation is described in Section 3. Accuracy of the recognition of the dining is shown in Section 4. The recommendation style for the proposed system is outlined in Section 5, followed by a description of the recommendation timing for the proposed system in Section 6. Based on Section 5 and Section 6, the recommendation rule for the proposed system is mentioned in Section 7. The evaluation experiment is outlined in Section 8. The related research is described in Section 9, and the conclusion follows in Section 10.

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2. System Proposal and Design

2.1 System Proposal

In comparison with more standard restaurants, fine dining establishments offer a high level of service catering to customers' demands. The staff in such restaurants is trained such that they can recommend dishes and drinks gracefully according to customers' conversational atmosphere, facial expression, dining status, and numerous other elements. Skillful recommendations made by experienced staffs typically increase customer satisfaction because the dining situation and dining habits of the customers are taken carefully into consideration [1]. To maximize customer satisfaction, the timing of service is essential [2], [3], [4]. For example serving dessert soon after dishes are completed is important [3], [5]. Presenting recommendation is also important factor in inducing positive customer response [10].

Lately, labor shortages are making it increasingly difficult to provide such high quality recommendation services. We thus propose the Group FDT, a tabletop dish recommendation system for multiple participants dining together. We believe the system enhances user satisfaction while dining. The target environment for the system would be dining establishments in which additional orders are common. (e.g., a bar, Japanese Izakaya).

2.2 System Design

To achieve the system's goal of substituting for trained service staff;
1) The system must be capable of making timely recommendations.
2) The system must be capable of making recommendations that match existing dishes.
3) The system must be capable of presenting a recommendation

Fig. 1 Appearance of the system in use.

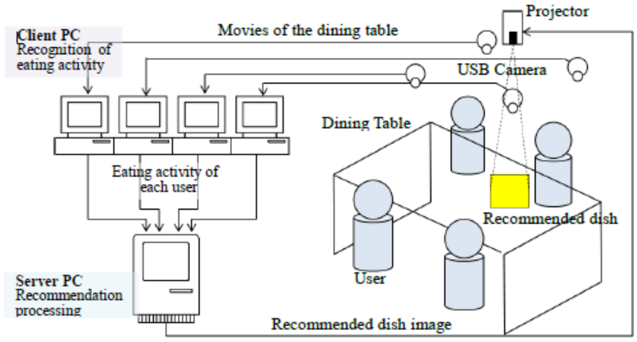

Fig. 2 System architecture.

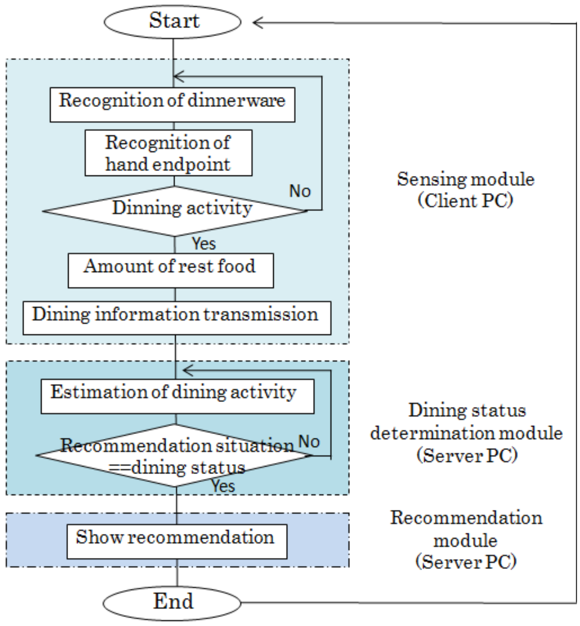

Fig. 3 System software procedures.

attractively.

To achieve 1) and 2), the system must constantly recognize the dining status of the users. To assess dining status accurately, the user's dining activity is monitored and the resulting is stored. The history includes information such as who ate the dish, what dish was eaten, and when the dish was eaten. To confirm the dining progress, the amount of food left in each dish is monitored. Since the dining activity is monitored from a USB camera placed over the dining table, it is not necessary for the user to wear any sensors, which would be uncomfortable when dining.

Another important factor is the attractiveness of the dish recommendation. To achieve 3), the display positions of the recommendation on the table are based on the investigation of attractive dish arrangements [10].

The appearance of the Group FDT system in use is shown in **Fig. 1**. The recommendations are displayed on the table surface.

3. System Implementation

To monitor the dining status of multiple users, 4 USB cameras (resolution 640*480 pixels) are set 125 cm above from the dining table. By this setup, the USB camera monitors the dishes without taking the image of user's face, which protects user's privacy. The data collected by the 4 cameras are handled by each Client PC then sent to a Server PC as dining information. A projector with XGA is set up 165 cm above the dining table and used for showing recommended dish images.

The system software includes 3 modules; a sensing module (Client PC), a dining status determination module (Server PC) and a recommendation displaying module (Server PC). **Figure 2** shows the system architecture and **Fig. 3** shows the system software procedures.

3.1 Sensing Module

The sensing module is responsible for integrating the users' dining data provided by each camera. Regarding the center of the dining table as the origin, the table is divided into four areas, and each camera covers one quarter of the dining table and records one user's data. The resolution of each camera is 640*480 pixels, and the dining table is rendered with resolution of 1280*960 pixels. The size of the table is 120*90 cm, so that each pixel represents an area of 0.094 cm on the table.

After the camera captures the image of the table, the tableware and user's hand are recognized, and then the distance between dishes and user's hand is calculated. The eating activity is estimated based on the distance. When the dining activity is completed, the remaining amount of food is computed, and the data including dining status and rest food amount, is sent to the server PC. The real time image processing is implemented with OpenCV. OpenCV is an open source computer vision library originally developed by Intel. Each sensing module process is composed as follows.

3.1.1 Recognition of Dishes

Dishes are equipped with different colored rims for recognition purposes [6], [7], [8]. The system extracts the respective color of each dish rim through labeling process. Labeling is used for selecting the area that is larger than a certain value, in order to reduce image noise. The maximum and minimum values on the X and Y of the extracted area (dish area) are used to calculate the midpoint of the dish. Cups are recognized by the respective color equipped on the handle. **Figure 4** shows the sample of table wares and the extractions.

3.1.2 Recognition of the User's Hand

During dining, the user's hand moves to and from the dishes. Thus, in Group FDT, the distance between a dish and the user's

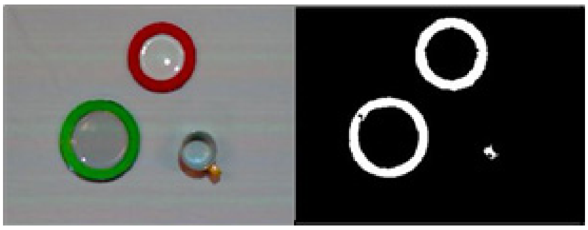

Fig. 4 Sample tableware colors (left), with the extractions (right).

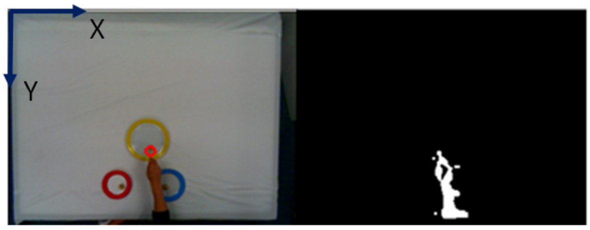

Fig. 5 The recognized user's arm area. Captured hand by camera (left). Extracted arm image (right).

hand is used as the basis for confirming eating behavior [6].

The recognition of the endpoint of the user's hand is processed with OpenCV background subtraction. The image of the table is captured first as the background. To cope with the gradual changes in shooting conditions, each frame is combined with the background at a rate of 0.01. And, to cope with regarding the movement of dishes and projection of the recommendation as the background change, the background is updated by replacing it with the foreground image when the foreground remains the same in 25 consecutive frames. Then, the dynamic area on the table is subtracted from the background image. **Figure 5** shows the subtracted arm area. If this area is larger than a defined area (2,000 pixels), it is regarded as the user's arm area. In this user's arm area, the closest point from the dish (the smallest point of the y-value) is recognized as the user's hand. In this process, then, the endpoint of the area including the chopsticks and user's hand is recognized as user's hand.

3.1.3 Recognition of Eating Behavior

The system recognizes the eating behavior based on the distance between the dish and the endpoint of the user's hand and on the time that the hand stays in the dish area [6]. When this distance is less than the dish radius, the user is considered to be taking the food. However, sometimes the endpoint of the user's hand cannot be recognized because the angle or thickness of the hand is varying. To solve this problem, if the distance is as less than (dish radius+ 20 pixels) (about 2 cm), and this situation lasts for at least 3 frames (about 0.3 second), then the eating behavior is recognized.

In the current system, eating behavior done by one hand could be recognized. In the case of recognition of eating behavior done by both hands such as using a knife and fork, the recognition will be realized considering that one eating behavior has done when both hands are staying on the same dish at the same time.

The recognition of drinking behavior is roughly the same; if the distance between the finger endpoint and the cup handle is close enough, and lasts for at least 3 frames (about 0.3 second), then the user is regarded as drinking.

3.1.4 Calculation of Remaining Amount of Food and Drink

The remaining amount of food left in the dish could be known by calculating the food area in the plate [6]. The radius and midpoint of the dish are computed based on the dish recognition procedure. The total pixel number of the dish is first determined. And the none-white area is regarded as the food area. The pixel number of the food area in the plate is computed using the HSV model and this enables the calculation of the amount of user's food consumption. The food area in the first captured image is considered as 100%, and the percentage of remaining food is continually computed through the dining event. In the case of white food such as plain rice, the system can't distinguish the food area and plate area using this recognition method. This will be the future modification. However, since the range of pure white food is limited we do not perceive this as a serious limitation of the system.

In addition, it is difficult for the camera to recognize how much the beverage left in the cup. However, if the typical number of sips needed to finish a cup of beverage is known, how much remains in the cup can be easily estimated. We set the total sips for a given beverage, the system recognizes how many times the user has sipped, and the remainder will determine the remaining drink amount.

3.1.5 Transmission of Dining Activity Information

User's dining information is transmitted to the server PC using socket communication (Winsock). The information sent to Server PC includes the user ID, eating time, eaten dish NO., remaining amount of food, and the coordinate of dishes on the table. User ID is the IP address of the PC, so that each user may be recognized by their distinct IP address. Eating time is the time when dining behavior is recognized.

All this information is stored for the dining status determination module. The coordinates of dishes are used when presenting recommendations in the recommendation displaying module.

3.2 Dining Status Determination Module

The dining status determination module determines user's dining status on the basis of dining activity information from the sensing module, and stores the dining history. This module estimates the kind of dish user eats, how much food remains and how often user eats particular dishes.

After determination of dining status, it checks if the current dining status matches the recommendation rules mentioned in Section 7.

3.3 Recommendation Displaying Module

The recommendation displaying module determines the position of the recommended dish image on the table, and thus the dish coordinates are necessary here. The system is able to change the image position automatically according to the real-time dish positions on the table. With the dish position information provided by the sensing module, the space without dishes and attractive dish position is determined in preparation for the recommendation presentation. The recommendation position is determined by the distance between dishes and the location of the tableware [10].

When we have a meal together, usually we have our own personal dish near our hands, and share large dishes in the centre of the table. So a personal dish for recommendation is displayed beside use's hands, and large shared dishes for recommendation are displayed in the center of the table.

4. The Recognition Accuracy

We conducted an evaluation experiment on the accuracy of recognition of the eating behavior and the remaining amount of food.

4.1 The Accuracy of Recognition of the Eating Behavior

We recruited 4 participants (3 males, 1 female), with an average age of 21.7. We asked them to pick snacks with chopsticks using the Group FDT. We placed three dishes on the table. Two dishes were placed in front of each participant. One more dish was put behind the two dishes. Each dish had 8 snack pieces on it. The participants sit down at the table and freely pick the snacks with chopsticks and move all of them (24 snacks) to an empty dish one by one. We asked them to repeat the same task 10 times, which means each participant moved snacks 240 times in total. Their behavior was recorded by a video camera throughout the experiment. We verified the correspondence of the behavior between the log data collected by the system and the recorded video.

Statistically, the F-score is a measure of a test's accuracy. It considers both precision and recall. Precision is a measure indicating the accuracy of achieving a designated result, while recall indicates completeness. The F-score is the harmonic average of the two. We used these measures to compute accuracy of recognition of the eating behavior. Here, the precision was determined by dividing the total number of the eating behaviors recognized correctly by the total number of the recognized eating behaviors. And, recall was determined by dividing the total number of the eating behaviors recognized correctly by the number of the eating behaviors that are supposed to be performed in picking all the snack pieces (24times = 8snacks*3dishes). We computed these average scores among 10 tasks for each participant, and the results are shown in **Table 1**.

The average F-score was 0.868 and this was considered high enough to indicate accurate recognition of the eating behavior.

Table 1 The results of the accuracy of recognition of the eating behavior.

Participant	Precision	Recall	F-score
A	0.978	0.875	0.922
B	0.903	0.720	0.799
C	0.967	0.874	0.918
D	0.925	0.761	0.833
Average	0.944	0.808	0.868

4.2 The Accuracy of Recognition of the Remaining Amount of Dish

We think that the manner of selecting food from a dish would vary with individual, and this would affect the results of the experiment. Therefore, we recruited 5 participants (4 males, 1 female), with an average age of 23.2 for this experiment.

We asked the participants to pick green soybeans using the Group FDT. We placed one dish filled with the green soybeans (70 g) on the table in front of the participant. The participants sit down at the table and pick the green soybeans piece by piece and move them to an empty dish on the table. During their performance of this task, we stopped them temporarily at the points when the system recognized the remaining amount in the dish was "75%", "50%", "25%" and "5%", and weighed the remaining amount of the food with a weigh scale. After weighing, we asked participants to continue moving the soybeans. The task ended after weighing the amount when the system recognizes the remaining as 5%. We asked participants to repeat the same task 10 times.

Table 2 The result of the recognition accuracy of the remaining amount of food.

	75%	50%	25%	5%
A	67.1%	45.8%	24.0%	7.5%
B	69.4%	50.5%	28.4%	6.8%
C	62.7%	48.0%	27.1%	12.1%
D	60.2%	41.5%	27.1%	12.2%
E	58.5%	42.2%	22.5%	10.8%
Average	63.6%	45.6%	25.8%	9.9%
Error	11.4%	4.4%	0.8%	4.9%

We verified the accuracy of the recognition by comparing the recognized amount to the actual amount, computing the average of the actual amount among the 10 tasks for each participant. The results are shown in **Table 2**. We found that the accuracy increased with decreasing amount of food remaining in the dish, and attribute this to the increased ability of the camera to distinguish changes in food area with lesser amounts of food remaining. However, even when a large percentage of food remained (75%), the error was 11.4%, and thus we consider the accuracy of recognition practicable in this respect.

5. Investigation of Recommendation Style for the Dish Recommendation System

It is thought that there are typically two kinds of recommendation styles. One is the one time recommendation and the other is the sequential recommendation. The one time recommendation is that all dishes are recommended once, at the beginning of dining, and the sequential recommendation is that some dishes are recommended sequentially at specific points in dining. We conducted an experiment to determine which recommendations are more appropriate for the Group FDT.

In the experiment we created a hypothetical dining situation and asked participants to order dishes. 17 males and 13 females were invited, off the street, to participate in the experiment. The average age was 29.5, and their ages ranged from 18 years old to 60 years old.

We asked participants to order dishes in the following manner;

1. to order their dishes once, at the beginning
2. to order their dishes as often and whenever they pleased

Before the experiment, we asked participants to sit at a table and instructed them to imagine they were in an actual restaurant, passed a food menu to them so that they could order dishes. Then, we instructed them to order dishes. After this, we gave them a questionnaire and asked them to answer three questions using Likert scale below:

Q1. Was there enough food to choose from in the menu?
Q2. Did you like the manner of ordering dishes once at the beginning?
Q3. Did you like the manner of ordering dishes as many times as you wanted?

Regarding Q1, 70% answered that there was enough food to select from in the menu, 27% answered that there was a just enough food to select from and only 3% answered that there was not enough food to select from. Thus, we consider that the menu presented to the participants was sufficient for food selection.

Regarding Q2 and Q3, we assigned specific scores according to 5-point Likert scale (Strongly disagree = 1, Disagree = 2, Neutral = 3, Agree = 4, Strongly agree = 5). The average was 2.6 for Q2 and 5.0 for Q3. A Wilcoxon signed ranks test showed there was a significant difference between the two ($N = 30$, $p < 0.001$). From these result, we conclude that customers are more likely to order whenever they wish, than to order once at the beginning of a meal, and that, therefore, sequential recommendation while dining would be more appropriate for the Group FDT.

6. Investigation of the Recommendation Timing for the Dish Recommendation System

As noted Section 5, sequential recommendation is more suitable for users of the dish recommendation system. We then investigated the optimal recommendation timing for the sequential recommendation.

6.1 Investigation Procedure

Here, we established seven distinct dining situations, depending on the progress of meal.

1. The time to order dishes
2. First ordered dishes are ready, but have not yet been eaten
3. The remaining food amount is more than 50%
4. The remaining food amount is more than 25%
5. The remaining food amount is more than 5%
6. Dishes are fully consumed (remaining food amount is 0%)
7. Dining is completed and empty dishes are taken away

A total of 12 participants were recruited for the experiment and answered a questionnaire. We instructed them to imagine an actual dining environment, including the pictures of dishes that are shown in **Fig. 6** and **Fig. 7**. These pictures were used for presentation to participants and were different from the dishes used in testing the Group FDT. Using the pictures, we conducted the dish recommendation. After the pictures of a recommended dish were presented, we asked participants to answer two questions.

Q1. Would you like to order the recommended dish?
Q2. Did you feel annoyed by the recommendation?

Participants were requested to answer each question according to a Likert scale. The ordered dishes here are Salisbury steak set menu (Salisbury steak 200 g, rice, Miso soup), Fig. 6 shows the food amount status at different stages in the dinning process. The vanilla ice cream shown in Fig. 7 was recommended dish because it is the most frequently ordered dessert, and also suitable for the Salisbury steak set menu.

Fig. 6 Pictures of dishes presented to participants (Salisbury steak 200 g, rice, miso soup).

Fig. 7 Picture of recommendation dish presented to participants.

6.2 Investigation Results

The two questions, asked at each dining status stage, were assessed according to a 5-point Likert scales (Strongly disagree = 1, Disagree = 2, Neutral = 3, Agree = 4, Strongly agree = 5), with a specific value assigned. We scored points from the questionnaire and make the 2 graphs shown as the **Fig. 8** and **Fig. 9**.

Figure 8 clearly shows that the median value and average value under the "First Order" and "100%" conditions are much lower than the other conditions. At this point, the recommendation dish is not expected to be ordered when the dining begins, and the order of recommendation dish is highly needed as the dining continues. Using multiple comparisons based on the Turkey-kramer method, a significant difference was notable between the "First Order" and "25%" conditions ($p = 0.001$) and between "First Order" and "5%" conditions ($p = 0.002$). And for "100%" and "50%" a significant difference was also seen. These results suggest that the recommendation dish would not be expected to be ordered under either "First Order" or "100%" conditions, that is, when dining has just begun. However, though the probability of ordering the recommendation dish is highest when the progress of dining is from "25%" to "5%", the optimal recommendation timing was not statistically evident.

The average values in Fig. 9 are all below 3 point except for

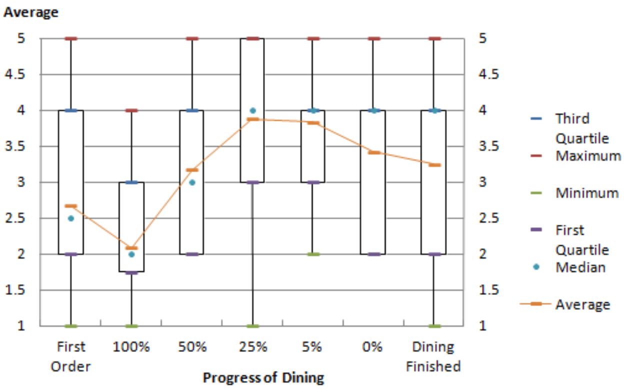

Fig. 8 The result of Q1: Would you like to order the recommended dish?

Fig. 9 The result of Q2: Did you feel annoyed by the recommendation?

the "100%" condition, suggesting that, beyond this condition, there is little confusion concerning the timing of dish recommendation during dining. Due to the multiple comparisons of the Turkey-kramer method, a significant difference was seen between "100%" and "25%" conditions and between "100%" and "5%" conditions. There was also a significant difference between "100%" and "0%" conditions. In comparison with other conditions, the "100%" condition of dining progress typically involves more confusion, while the recommendation under "25%" and "5" conditions are perceived to be acceptable.

Combining the results of Fig. 8 and Fig. 9, we see that, during the first half part of dining, it would not be a proper time for recommendation, especially when the progress of dining is [100%]. Moreover, the best time of recommendation is when the progress of dining is [25%] and [50%], that is, before the food is fully consumed. During this period, the user is more willing to accept the recommended dishes. We thus regard these two timings as the optimal recommendation timing.

7. Recommendation Rule for the Dish Recommendation System

We created a recommendation rule based on the results of Section 6, and applied this rule to the Group FDT.

7.1 Dish Recommendation Rule

Table 3 shows the rule for food recommendation. For the recommendation condition, based on the investigation for the recommendation timing mentioned in Section 6, we adopted the times when remaining amount of food becomes less than 25% and 5% as acceptable recommendation times. And, we have roughly two types of dish; a large shared dish and an individual dish while dining with multiple people. We think this should be reflected in the recommendation target. Therefore, regarding the individual dish, the system generates recommendations individually and regarding the large shared dish, the system generates recommendation to the part of participants who are sharing the dish. Also, the system generates recommendation to all participants depending on the whole remaining amount of dishes. As for the actual recommended dish, we performed an experiment to determine what sort of dish should be recommended next. Here, we recruited 30 people (17 males, 13 females, average age: 29.5) off the street, and asked to order food in the way they do at bar, presenting them an actual food menu used in an actual bar. We asked participants to imagine they were dining on food they had ordered, and to further order as much additional food as they wanted. As a result of this experiment, Ochazuke and vanilla ice cream are preferred to be ordered at the end of the meal. Also, ordering dumplings after Caesar salad, and fried potato after Karaage are preferred to be ordered. It is known that young soybean is commonly ordered while drinking beer.

Table 3 Rule for food recommendation.

Condition	Recommendation target	Dish of recommendation
All dishes are less than 25%	All	Ochazuke
All dishes are less than 5%	All	Vanilla ice cream
Caesar salad in big dish is less than 25%	Part	Dumpling
Caesar salad in individual dish is less than 25%	Individual	Dumpling
More than 3 consecutive bites of Karaage	Individual	Fried potato
More than 7 swallows of beer in the recent 10 bites	Individual	Young soybean
Others	None	None

Table 4 Rule for drink recommendation.

Condition	Number of cups drunk	Dish of recommendation
Dining begins	1st glass	Beer
Drink is less than 25%	2nd glass	Chūhai
Drink is less than 25%	3rd glass	Wine, Sake
More than 2 orders of beer	After 4th glass	Chūhai
More than 2 orders of cocktail	After 4th glass	Shōchū, Sake
All dishes are less than 5%	None	Soft drink

7.2 Drink Recommendation Rule

Table 4 shows the rule for the drink recommendation based on research regarding alcoholic consumption by Macromill, Inc [11]. The study involved a total of 533 men and women, aged 20 or over, who had drunk an alcoholic beverage in the past three months. According to the results, customers prefer beer as their first order, chuhai as the second, and wine as the third. We followed this rule in establishing the recommended drinks up to third glass. Regarding the recommendation from the fourth glass, the drink that hasn't drunk frequently so far will be recommended according to the user's specific dining history. Regarding the drink recommendation for when dining is completed, Oolong tea is known as the frequently ordered beverage after alcoholic drinks.

8. Evaluative Experiment

We then conducted an evaluative experiment on the Group FDT system's effectiveness in facilitating user satisfaction in dining.

8.1 Participants

We recruited 8 participants (7 males, 1 female). They were undergraduate students and graduate students with an average age of 22.7.

8.2 Conditions

We asked participants to have a meal under two different conditions:

1. The Group FDT condition

2. The random condition

The Group FDT condition means that the recommendation is done based on the rule in Section 7, while the random condition means that the recommendation is done randomly (the controlled condition).

Participants began dining with Caesar salad served in a large shared dish, Karaage served in another large shared dish and oolong tea served in each individual glass.

In the FDT condition, dumplings are recommended as the dish following Caesar salad, and fried potatoes are recommended as the dish following Karaage, when the remaining amount of the current dish (Caesar salad and Karaage) is 25%. In addition, vanilla ice cream is recommended, when the whole amount of dishes is 5%. The recommendation is displayed on the table surface in an area where there are no dishes.

In the random condition, three dishes for recommendation are chosen randomly from a typical Japanese bar (izakaya) menu and recommended at random time. Under this condition, the position of the recommendation on the table surface is also decided randomly.

In this experiment, 8 participants were divided into 2 groups of 4 members and, each group participated under both conditions. To reduce the effect of the sequence according to which the two conditions were experienced, one group participated in the Group FDT condition first and then the random condition next, while the other group participated in the random condition first and the FDT condition next.

8.3 Procedure

The 4 participants were invited to sit at the table, and requested to have a normal meal. The dish recommendation was performed three times during their dining, and stopped their dining temporarily when each recommendation had been done to ask them to fill in a questionnaire concerning the recommendation. After the participants answered the questionnaire, they were asked to continue dining until the final recommendation was made.

8.4 Questionnaire

We designed the questionnaire to determine if the recommendation timing was proper, if the recommended dishes were proper, if the recommendation table position was proper and if they liked the recommendation.

The questions were:

Q1. Do you think the dish was recommended at a proper time?

Q2. Do you think the recommended dish was suitable for you?

Q3. Do you think that the recommendation was presented in a proper position?

Q4. Would you like to order the recommended dish?

8.5 Result

We assigned specific scores according to 7-points Likert scale (Strongly disagree = 1, Disagree = 2, Disagree somewhat = 3, Neutral = 4, Agree somewhat = 5, Agree = 6, Strongly agree = 7).

We computed the average score for each question among the 8 participants. In the experiment, three recommendations were performed in under both conditions. **Table 5** shows the averaged results of the three recommendations. The averaged scores for all the questions under the Group FDT condition are higher than those under random condition. The Wilcoxon signed ranks test shows there were significant difference between the two conditions in Q2 (p = 0.020), Q3 (p = 0.015) and Q4 (p = 0.011).

Q1 assesses the timing of the recommendation. No significant difference was seen here between the two conditions, which may be because under random condition, some of the acceptable recommendation timings (40%, 10%) among total six recommendations were chosen randomly.

Q2 assesses the suitability of the recommended dish. Here, some participants reported that under random condition, same type of dish was recommended as the one they were dining on, and the recommendation was therefore uninteresting. Also, some reported that they were very pleased when their favorite food was recommended. It is thought that what the sort of food being dined upon is highly significant for recommendation, and the Group FDT system carefully could incorporate this consideration. Personalizing the system by integrating user's dietary preferences

Table 5 The result of the rating from participants (N = 8).

Question	FDT		Random		P Value
	Mean	Std dev	Mean	Std dev	
Q1(Timing)	5.4	1.1	4.6	0.3	0.126
Q2(Recommended Dish)	5.7	0.6	4.7	0.9	0.02
Q3(Position)	4.4	1.5	3.3	0.9	0.015
Q4(Feeling like to order)	5.7	0.8	4.4	1	0.011

represents an important future task.

Q3 assesses the recommendation position. Under random condition, some recommendations were displayed on the existing dishes. Participants reported that this overlapping made it difficult to see the recommendation clearly. It is thought that the overlapping the recommendation with the existing dishes is problematic and the Group FDT could consider this point well.

Q4 assesses participants' inclination to order the recommended dish. We could see a tendency on the part of those who gave a high score to Q1 and Q2 to also score Q4 highly. It appears that the recommendation timing and the recommended dish are closely related to the level of inclination to order the respective dish. This relationship deserves careful analysis in the future.

We think that in order to get more precise evaluation results more participants are needed, but the effectiveness of the Group FDT system had been shown in this experiment.

9. Related Research

The Another Dish Recommender system, the first FDT, recognized dining activity by the visual markers attached to user's hands and the bottom of dishes [7], [8]. This made it difficult for the user to properly focus on the meal itself. Furthermore, a hand in use may alter the angle of the visual marker attached, which sometimes results in inaccurate recognition. Moreover the acrylic dining table had to be transparent in order for the markers and dining activity to be easily recognized from the bottom surface. This made users see their own feet and the facilities installed there, which may well impair the pleasure in dining. Finally the remaining amount of food was estimated from counting eating activity, which was not very accurate.

In response, recognition method, including the remaining amount of food was altered to incorporate image processing with a camera placed above the dining table [6]. This system, however, was designed only for a single participant, whereas we usually have a meal with others rather than alone in a restaurant. The system here proposed is similar in its recommendation of dishes based on the recognition of dining status, but novel in its suitability for multiple users dining together, and more nuanced in its incorporation of considerations regarding recommendation style and the timing.

Chang's dining monitoring system uses dishes with RFID tags and a food tray with an RFID reader, a load meter and pressure sensors [12]. It can faithfully measure every step of weight reductions in food. Moreover, what and how much has been consumed can be recognized. But the system is expensive and does not incorporate the behavior of the user. The system here requires monitoring only by a USB camera.

Recognition of video-recorded dining behavior has been proposed by Qing [13]. Hand movement is detected and dining is recognized in video of a dining room by utilizing Conditional Random Field method. Qing's system recognizes only drinking activity, while our system recognizes both dining and drinking.

To recognize consecutive the dining activity, such as seizing food with chopsticks and putting it into mouth, Miyawaki installed an acceleration sensor on the user's wrist to detect his/her wrist movement and elbow twist [14]. However, the user is then burdened with the acceleration sensor during dining, whereas the present system's recognition of dining activity is made by cameras only with no burden or distraction for users.

In welfare and medical care, such as that studied in Takeda's research [15], meals have been recorded for the management of health. The record is typically a written memorandum showing the given menu and sometimes the remains of meal. However, since making a written meal record is time consuming and is not easy when there are many clients, the automatic recording of meals has been researched as part of studies in welfare information technology.

There have been many studies concerned with supporting dining scenes, including interpersonal communication. Mori has developed a system involving visual decorations and storytelling for dishes [16]. The visual decorations and stories of dishes provided by the cooker adapt to user's dining status. To recognize the dining activity in Mori's research, dish recognition, dish location detection, and the remaining amount of food, are implemented by image processing. Our system not only recognizes these elements, but in addition, detects other elements of dining status, such as who ate the dish, which dish is eaten, and when the dish is eaten, and then recommends dishes according to the full dining status history.

"Sixth dish" by Amano is a system to support interpersonal communication during dining [17]. The system projects pictures on vacant dishes from above so that pictures give trigger to facilitate conversation. The system enhances meal times in terms of communication but does not corporate dining status or a users' behavior during dining.

An agent system to support interpersonal communication during dining has been developed [18], while the Group FDT presented in this paper is for dining support.

10. Conclusion

We developed an automatic dish recommendation system that is called the Group FDT. The system recognizes multiple users' real-time dining activity, stores it as dining history, and provides dish recommendations based on the dining status estimated from this dining history. The system recommends the additional dishes by displaying their images on the table surface, with consideration of the most attractive display position. We conducted the experiment for verifying an accuracy of the recognition of dining, which showed that the accuracy was practicable.

And we also conducted an experiment to investigate suitable recommendation style and the optimal recommendation timing for the Group FDT system. As the results it is thought that sequential recommendation is suitable, and the remaining dish amount from 25% to 5% is likely to be more acceptable for recommendation timing. Based on the investigation we created a recommendation rule and applied it to the Group FDT.

We conducted an evaluation experiment of the proposed system comparing Group FDT recommendation condition and random recommendation condition.

The Group FDT is expected to be useful as a substitute for a food server in a restaurant where additional dishes are often ordered and contribute to customer's satisfaction while eating. The system will be extended to better support dining activity including interpersonal communication in the future.

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