Making Meals Both Appealing and Healthy: A Food Presentation Simulation System

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"You eat with your eyes first." Marcus Gavius Apicius, the insightful first-century Roman gourmand, stated. Although arranging foods in attractive ways can increase one's appetite, creating an aesthetic food presentation is challenging. For instance, users have to cut ingredients into pieces of specific shapes and sizes, while imagining the overall appearance of their desired composition. To overcome such challenges, we introduce a system that assists users to arrange ingredients to present appealing patterns in meals. The system enables them to perform a process of trial-and-error in the simulation prior to creating a real food presentation. Due to machines' high computing power, our automatic simulation provides users with a variety of food presentation results and inspires their creativity accordingly. It also computes the nutritional composition of each simulated food presentation so that both visual quality and health are considered simultaneously. Results demonstrate that the simulated food presentations are visually appealing and could be physically created. Participants who joined the user study also favored our food presentation simulation system.

CCS Concepts: • **Human-centered computing → Human computer interaction (HCI)**; **Interactive systems and tools**.

Additional Key Words and Phrases: Food presentation, simulation, nutrition, interaction

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1 INTRODUCTION

A good dining experience involves not only taste, but also vision, especially as the world's standard of living rises. Indeed, people tend to choose meals that both taste and look appetizing [13]. To enhance aesthetic appeal, chefs modify, process, arrange, and decorate ingredients based on their creativity. Among the ways of food presentation, Japanese

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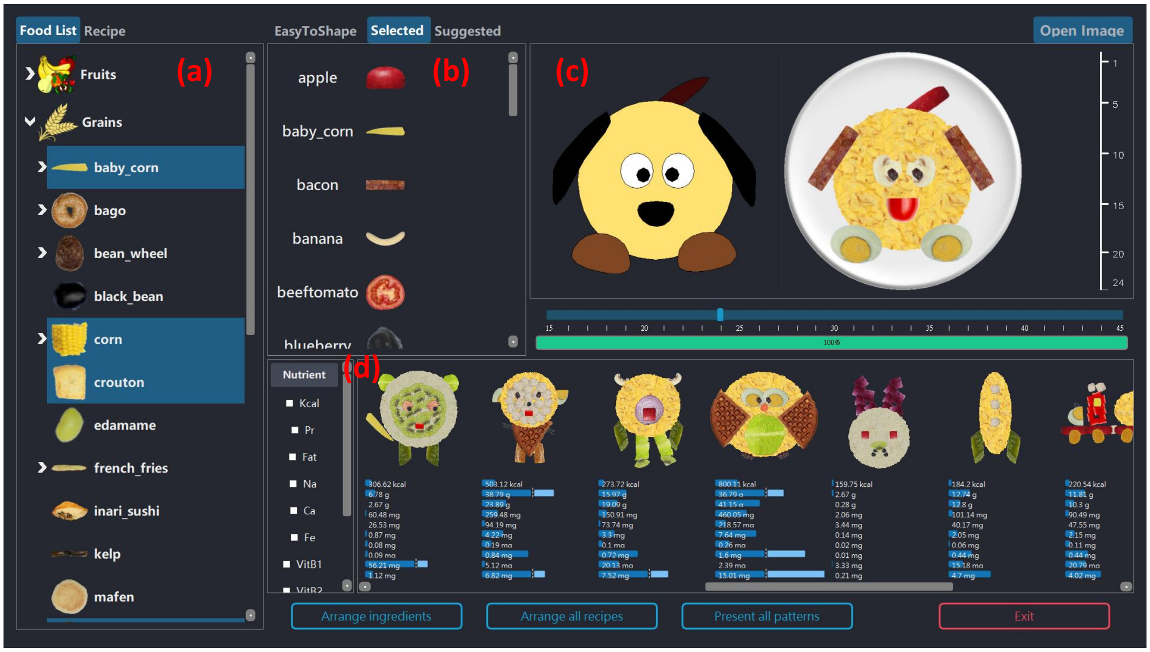


Fig. 1. The user interface of our system. (a) The ingredients are listed based on their groups, such as grains, proteins, vegetables, and fruits. Users can select the ingredients available at home or choose a recipe in this view. (b) The ingredients that will be used in the current food presentation. (c) The visual pattern and the food presentation. (d) The current and previously simulated food presentations. The presentations can be sorted based on visual quality or each type of nutritional composition.

bento box is a classic type, where ingredients are arranged to appear as a cartoon character[1]. Bento boxes are often made by parents to encourage their children to eat nutritious diets. In this study, we focus on this specific type of food presentation and implement a system to help amateur chefs create inventive bento boxes.

Many of the cooks, especially home cooks, focus on the taste of meals but seldom pay attention to food presentation. One major reason for this is that, in order to make a creative and eye-catching food presentation, it is necessary to design patterns, select recipes, cut ingredients into pieces of different shapes and sizes, and arrange those pieces accordingly. This process, especially when it involves repeated trial-and-error until satisfactory results are obtained, is both time-consuming and food-wasting. To reduce these efforts, some people seek existing examples of food presentations online. Such examples, however, are generally not customizable and may not be appealing to all people due to personal preferences and tastes. Moreover, ingredients used in the examples may not always be available at home. To address these limitations, we present a simulation system to assist people to create their own attractive food presentations.

To simulate an attractive food presentation, users of the system can specify the available ingredients, the plate size, and a pattern that they wish to create. Our system then finds the optimal combination and arrangement of ingredient pieces to achieve the pattern. It also estimates the presentation's nutritional composition. Users are allowed to edit the presentation if needed. For example, they can drag an ingredient from the list and then drop it on one of the pattern contours. The arrangement, such as orientation and number of ingredient pieces, will be automatically determined. Specifically, if the ingredient and the contour are similar in size, the system determines the ingredient's position and

[1]https://en.wikipedia.org/wiki/Food_presentation

orientation to present the contour. Otherwise, it fills the contour by using multiple ingredient pieces and packs them neatly to fit the contour.

The implementation of our system comprises ingredient data collection and algorithm design. To build the ingredient database, we purchased various ingredients from a supermarket, cut them into commonly seen pieces, placed them on a white background, and then took photos of them. The photos' white backgrounds are then removed by image matting techniques. We also measure the weight and area of each ingredient piece. By integrating the measurements and the nutrition obtained from the Taiwan Food and Drug Administration, we can estimate the food presentations' nutritional composition. Regarding the algorithm design, we decompose a visual pattern into closed contours. Under this formulation, the food presentation problem can be solved by presenting each contour with ingredient pieces. Specifically, for each contour on the visual pattern, we check all ingredient pieces in the database, and assess if any of them can present the contour well. A fitness function is introduced to evaluate the visual quality of the simulation. By default, we sort the simulated food presentations based on visual quality. Users can also sort the presentations based on preferred nutritional characteristics.

We have implemented the system to assist users to present foods in eye-catching ways. To evaluate whether the system is helpful, we conducted a user study with 22 participants who cooked at least five days per week. We asked them to accomplish two different tasks by using our system. Both the quantitative results and qualitative feedback from these participants showed that our system was helpful in creating attractive food presentations with ingredient flexibility, desired nutritional characteristics, and required only a short amount of time.

2 RELATED WORKS

Extant literature has demonstrated that sensations are elicited by physical stimuli, and can be influenced by numerous factors. How people interpret a particular sensation can determine what they see and what they hear. Certain established examples, such as the rabbit-duck illusion [1], Müller-Lyer illusion [15], Kanizsa Triangle [8], and McGurk effect [11], show how one's visual and auditory perceptions can deviate from physical reality. Experiments also show that visual cues can alter the perception of the taste, odor, and flavor of a food or a beverage. For instance, adding food coloring to a white wine could change the terms that people used to describe the wine's flavor [14] and its sweetness ratings [16]. Altering the shape of the glass used to present a wine could also change the perception of the wine's flavor [4].

Since visual stimuli can alter the perception of taste, smell and flavor [5, 19–21, 23], this strategy has been utilized to improve the dining experience. For instance, Michel et al. [13] presented a salad on a dish in three ways: simply-plated, art-inspired, and a neat manner. It was found that participants preferred, and were willing to pay more for, the art-inspired presentation. In fact, they even gave higher tastiness ratings to the art-inspired presentation than they did to the others. Subsequently, Michel et al. [12] conducted an experiment in a naturalistic dining context, in which two groups of diners were given the same menu, but the ingredients were presented in dissimilar ways. The results showed that the diners were willing to pay more for an appetizer if it was arranged in an artistically-inspired manner. The diners were also willing to pay more for the main course if the culinary elements were placed in the center of the plate, rather than off to one side. Moreover, studies introduced by Zellner et al. [26] indicated that people prefer foods that are arranged neatly over those that are arranged messily. It was further found that participants judged that foods that were arranged neatly were served in good restaurants and prepared with comparably more care. Afterwards, in Zellner et al.'s experiment [25], a restaurant served the same meal, but in different presentations, to diners on two different nights. Although the presentations were assessed as having the same neatness, subjects reported that they liked the food on the plate more when it was arranged attractively. Furthermore, Zampollo et al. [24] tested the factors that influence children's and adults' food-plating preferences. The experiment revealed that children preferred more food items and colors, than adults did, on their plates.

Food presentation can be considered as a type of collage: the creation of a visual pattern by assembling objects of different forms. Several methods have been developed to create collage artworks automatically [6, 7, 17]. In addition, Cho et al. presented a system for users to generate food images based on sketches [3]. However, none of them target arranging foods to present a visual pattern. To the best of our knowledge, our simulation system is the first to assist users to create food presentations. It saves both time and food in the process.

3 SYSTEM DESIGN

Since our goal is to create bento box food presentations to encourage children to eat nutritious diets, the target users of our system are parents. In this section, we describe why and how we design our system.

3.1 Pilot Study

We conducted an informal interview with participants at the early stage of our system implementation. These participants were recruited from the Internet, and the inclusion criterion was that he or she must cook at least five days per week. To know whether they had experience in creating food presentations, and enable them to share their feedback with us, we presented a prototype to the participants, which could arrange ingredients automatically to present visual patterns. Compared to our current system, this version did not allow user interaction and did not provide nutritional information.

Participants stated that creating an attractive food presentation was both difficult and time-consuming. They especially disliked the inefficient trial-and-error process because of the amount of food that was wasted. Normally, they would imitate food presentations that were publicly available on the Internet if they were not busy rather than creating their own. Therefore, the system was inherently interesting to the participants because the automatic simulation solved these problems. They expected that the system could create a variety of food presentations. However, participants were disappointed by the absence of user interaction. One of the participants mentioned that she felt that she was watching a food presentation animation, but was not actively contributing to it. Participants informed us that changing the ingredients of a simulated food presentation was important because it was likely that they did not possess the exact ingredients used in the simulation. As a consequence, they would like to know whether there were acceptable replacements for those ingredients. Participants also suggested that those ingredients should be specified by the user. Overall, they indicated that they preferred to create food presentations based on the ingredients that they have at home.

3.2 Design Philosophy and System Overview

We designed a system that assists users to create attractive food presentations in a manner that addresses the above-mentioned issues. The goal is to first allow users to engage in a process of trial and error regarding the arrangement of food ingredients in the system. After they are satisfied with the simulated result, they make the real food presentation. Considering that users may not be able to cut ingredients into complex and attractive-looking pieces, the simulation uses only natural and commonly-seen ingredient pieces that can be achieved without requiring advanced cutting skills. In addition, since most home cooks care about providing proper nutrition in their meals, we also estimate each food presentation's nutritional composition and display the corresponding facts in the system.

Figure 1 shows the system interface. We provide users with semi-automatic and fully-automatic modes. Under semi-automatic mode, users drag an item from the ingredient list and drop it on a contour. The system then computes the ingredient's optimal orientation to present the contour or duplicates the ingredient a sufficient number of times to fill the contour. If users do not know what ingredients they desire to present for the contour, they can click on the contour itself. Our system then shows suggested ingredients by considering the contour's shape and size. The suggestions also update whenever users change the plate's size (Figure 2). In contrast, fully-automatic mode simulates many food presentations under specific constraints. Precisely, users specify the available ingredients and let the system simulate all visual patterns in the database. They can also specify the pattern that they prefer and allow the system to simulate the pattern by testing all ingredients or recipes. Afterwards, in both modes, users can browse the list of food presentations and check their nutritional compositions (Figure 3).

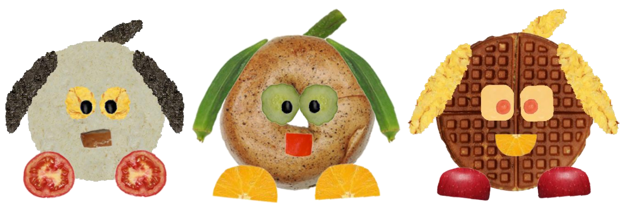


Fig. 2. Our system can simulate different food presentations according to given plate sizes. The plate size from left to right are 15 cm, 18 cm, and 29 cm, respectively.

Presentation

Kcal	22.718 cal
Pr	0.6442 g
Fat	0.0622 g
Na	6.658 mg
Ca	20.554 mg
Fe	0.1886 mg
VitB1	0.02928 mg
VitB2	0.02368 mg
VitC	10.7208 mg
VitE	0.09164 mg

Fig. 3. (Left) The name of an ingredient is shown when the mouse cursor is placed above it. (Right) Nutritional composition is estimated for each simulated food presentation.

4 METHODOLOGY

We assume that a visual pattern is composed of several disjoint and closed contours. Consequently, we present each contour by a kind of ingredient for achieving the food presentation. The input to our system is vector graphics, in which vertex positions on each contour and the order of vertices are available. If the visual pattern is represented by bitmap images, users can apply well-known image processing methods [9, 22] or commercial software, such as Adobe Illustrator, to transform the bitmap images into vector graphics. Concerning the ingredient images, the contours can be obtained by alpha map segmentation. To reduce computational cost, we down-sample the contours, in which the distances between consecutive vertices are approximately 0.5 cm. Furthermore, contour vertices in counterclockwise order are flipped to be in clockwise order. We also compare the similarity of contours in each visual pattern using the iterative closest points (ICP) method [18]. Highly similar contours are detected, and are represented by the same kind of ingredients to achieve a visually symmetric appearance.

Properties of ingredients play an essential role in food presentation. Some ingredients, for example, are easy to shape, such as rice and laver. Certain other ingredient pieces are planar on two sides, such as lemon slices and pancakes, which are suitable to be placed at the bottom of a food presentation because other ingredient pieces placed on such planar pieces do not tend to collapse. We term these two properties, *easy-to-shape* and *planar*, respectively, and manually label the properties of each ingredient piece as one or the other. In general, easy-to-shape ingredients are also planar because they can be shaped to have two planar sides.

The goal of food presentation in our system is to show each visual contour using an ingredient. Easy-to-shape ingredients can be used to fulfill this requirement easily. Regarding other ingredients, it is necessary to consider their size. Specifically, if the contour and an ingredient piece are similar in size, we represent the contour by using the piece.

If the ingredient piece is much larger than the contour, however, it is not suitable. Finally, if the ingredient piece is much smaller than the contour, we pack multiple pieces to present the contour. Accordingly, we introduce three methods to handle the three ingredient-contour relations: (1) easy-to-shape ingredients; (2) contours and ingredients that are similar in size; and (3) ingredients that are much smaller than the contours. We describe the details of these three methods in the following sections.

4.1 Easy-to-Shape Ingredients

Considering easy-to-shape properties, we evenly filled the white background using the ingredients, and then took photos of them. The weight and the area of each ingredient were measured for estimation of nutritional composition. To present a visual contour using such ingredients, we cut the image to fit the contour. Because a perfect cut may tear the structure of ingredient elements, such as grains of rice, and result in unrealistic food presentations, we applied the graph-cut algorithm to cut the ingredient image. The goal is to find a path that can pass through pixels with low color variations while simultaneously being close to the expected contour. Let $\partial \mathbf{B}_I$ and $\partial \mathbf{B}_O$ be the inner and the outer boundaries, respectively, which are obtained by shrinking and expanding the contour of the visual pattern. Also let f_p be the label of pixel p. We expect $f_p = 1$ if $p \in \partial \mathbf{B}_I$ and $f_p = 0$ if $p \in \partial \mathbf{B}_O$ because $\partial \mathbf{B}_I$ and $\partial \mathbf{B}_O$ are considered foregrounds and backgrounds, respectively. Moreover, while neighboring pixels $\{p, q\} \in \mathbf{N}$ are given different labels, the gradient magnitude between them g_{pq} should be low. Specifically, we minimize $E_{data}(f) + E_{smooth}(f)$, where

$$E_{data}(f) = \sum_{p \in \partial \mathbf{B}_I} 1 - f_p + \sum_{p \in \partial \mathbf{B}_O} f_p, \quad and \quad E_{smooth}(f) = \sum_{\{p,q\} \in N} g_{pq} \cdot T(f_p \neq f_q), \tag{1}$$

T is an indicator function that will output 1 if the condition is true. We refer readers to the work of [2] for details.

4.2 Contours and Ingredients that are Similar in Size

In this case, we use an ingredient piece to present a visual contour. Since an ingredient piece can be represented by a contour as well, we apply the ICP method [18] to compute a rigid transformation (i.e., rotation + translation) that can best align them. The quality of the alignment is then evaluated by the deviation of vertices on the contours. Specifically, for each vertex i on the ingredient contour, we find a vertex j on the visual contour that is closest to vertex i, and compute their distance. The computation is bi-directional, i.e., we also consider each vertex k on the ingredient contour that is closest to vertex j. Note that vertices i and k can be different. The mean distance of the vertices is used for quality evaluation.

4.3 Ingredients that are Much Smaller than the Contour

We pack multiple ingredient pieces to present a visual contour in this case. There are three steps to achieve this goal.

Approximating the contour boundary. We present the boundary of a visual contour using the long boundary of each ingredient. To arrange the first ingredient, we extract half of its contour, denoted as $S^f_{i \to j}$, where i and j are the indexes of the start and the end vertices, respectively. We then compare $S^f_{i \to j}$ to each segment of the visual contour $S^v_{m \to n}$. These two sub-contours are the same in length and have a one-to-one correspondence. We compute a rigid transformation to align the two sub-contours and then estimate the deviation of corresponding vertices. To obtain the optimal arrangement of the first ingredient, we test all combinations of the sub-contours. Although the brute-force strategy is adopted, the computation is efficient because of the small ingredient and the fixed contour length.

After the first ingredient is arranged, we position the other ingredients sequentially along the visual contour in a similar manner. Specifically, we fix the ingredient contour $S^f_{i \to j}$ while updating the visual contour by $S^v_{m+k \to n+k}$ during the arrangement, where $k < |S^f_{i \to j}|$ is the unknown distance between adjacent ingredients. We find an optimal k that can minimize the contour deviation. In addition, we prevent overlapping of ingredients if they are not labeled as planar. If the ingredients are planar, we also prevent the overlapping area from being larger than 20% of an ingredient. The process repeats until the ingredients can present the whole visual boundary.

Filling the inner space. The second step is to fill the interior space of a visual contour. To achieve consistency, we set the ingredients' orientation by the averaged orientation of the ingredients used to present the contour boundary. These ingredients are aligned from left to right and from top to bottom to fill the space. The overlapping criteria of the ingredients are considered, as well.

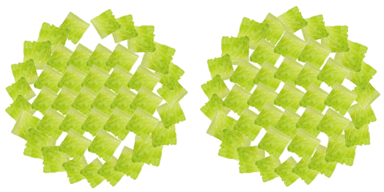


Fig. 4. (Left) Filling a space by rigid objects inevitably results in gaps. (Right) We fine-tune each ingredient's position.

Fine-tuning the ingredients' positions. Finally, we fine-tune the ingredients' positions using a force-directed graph and make the ingredients evenly distributed (Figure 4). To implement this idea, we generate a graph, in which the nodes are the ingredients' centroids, and edges are created if two ingredients are adjacent. We give each edge a repulsive force to push adjacent ingredients away, while retaining the boundary ingredients unmovable and fulfilling overlapping conditions. The ingredient positions iteratively update until the system converges.

4.4 Quality Metric

Presenting a visual pattern by arranging different ingredient pieces results in dissimilar qualities. The automatic mode of our system can simulate many food presentations by testing a recipe on many visual patterns or many recipes on a specific pattern. Since there are many combinations, sorting and showing users high-quality simulated results are needed. We therefore compute

$$E = E_c + E_s + E_a \tag{2}$$

to evaluate the quality of a food presentation simulation. Specifically, E_c estimates the mean color difference between the ingredient and the visual contour; E_s determines whether an ingredient matches a visual contour; and E_a measures how well ingredients cover the visual pattern. The results are displayed in ascending order of metric sum. To determine E_c, we first compute the mean color difference under the Lab color space, and then normalize the error to the range of [0, 1]. To compute E_s, we measure the mean contour distance between the visual pattern and the ingredient. Precisely, for each vertex i on a pattern contour, we find a vertex j on the ingredient that is closest to i and compute the distance between vertices i and j. All of the vertices on the visual pattern are considered, and the mean distance is computed. Finally, to obtain E_a, the union and the intersection areas of the visual pattern and the ingredients are estimated. Let π^v and π^f be areas of the visual pattern and the ingredients, respectively. We compute

$$E_a = \sqrt{\frac{(\pi^v \cup \pi^f) - (\pi^v \cap \pi^f)}{\pi^v}} \tag{3}$$

to measure the coverage of the visual pattern by ingredients.

Fig. 5. The visual patterns (top) and the simulated food presentations (bottom). Below, we show the ingredients used in each presentation. Flower: onion, green pepper, okra, and bamboo. Bird: waffle, hash brown, taro, baby corn, toast, edamame, and black bean. Dog: scrambled eggs, okra, bacon, mushroom, rice, and black bean. Lion: cucumber, green pepper, pumpkin, red pepper, black bean, baby corn, rice, and crouton. Girl: carrot, green pepper, bacon, tomato, and baby corn. Train: kiwi, red pepper, apple, waffle, banana, and blueberry.

Fig. 6. Food presentations simulated using our system.

5 RESULTS

We have implemented the system and run it on a desktop PC with a Core i7 3.0 GHz CPU. The semi-automatic mode of our system achieves interactive performance so that users can perform a process of trial-and-error on a variety of food presentations. Although automatic mode takes some time to present visual contours, it considers ingredients in many recipes and filters the simulation results according to quality. Users can continue fine-tuning the results by changing ingredients on a presentation if needed. Figures 5 and 6 show a variety of food presentations simulated by our system, which are visually appealing. In addition, the patterns can be easily recognized. It is also worth noting that our system does not use smashed ingredients to present visual patterns because smashing ingredients easily leads to nutrient loss.

To elucidate the gap between simulation and reality, we physically created food presentations by following the simulated results. The photos are presented in Figure 7. During the creation, we found that the main issue was not difficulty, but rather labor-intensity. When simulating a food presentation, users tended to use many ingredients to present visual patterns because they needed to perform clicking and dragging with the mouse. However, when creating a real food presentation, they had to cook and cut many ingredients to realize the simulated result. Furthermore, the cut ingredients could have various shapes and sizes. For example, carrots are cone-shaped, and their slices are circles with different radii. Selecting the proper size of a carrot slice is needed when packing it on the plate, the process of which could be tedious. We also found that the manner of cooking could alter the color of certain ingredients (e.g., eggplants). Indeed, novice cooks needed to take more care in the food preparation. However, once the ingredients were prepared, packing them was not challenging.

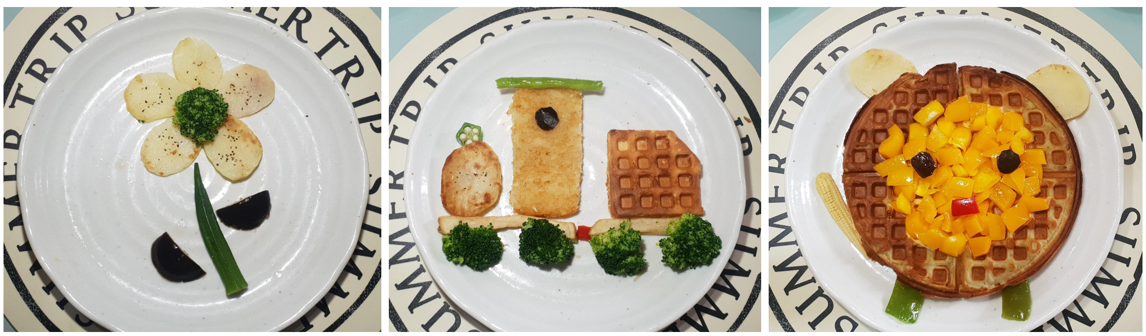


Fig. 7. Real ingredients were arranged on a plate based on the results simulated by our system.

6 USER STUDY

We conducted a user study to evaluate the feasibility and user experience of the system. Participants were asked to use our system, accomplish tasks, and provide us with quantitative and qualitative feedback at the conclusion of the study.

6.1 Participants

We recruited participants by posting advertisements on social media pages and distributing flyers to users on our university campus. One participant who joined a food presentation club in the LINE messenger [2] also helped us to share the recruitment message in that club. Our recruitment focused on users who cooked at least five days per week. We finally recruited a total of *22* participants. Among them, three were male, and nineteen were female. Their ages ranged from *30* to *58* (M = *39.8*, SD = *6.6*). Approximately half of the participants reported that they had previously attempted to create food presentations.

6.2 Study Tasks

The participants were asked to accomplish tasks in two scenarios. In the *Recipe* scenario, they created a food presentation according to a recipe with specified ingredients. Moreover, there was no pattern limitation. This scenario simulated the circumstance in which users create food presentations using only available ingredients. In the *Pattern* scenario,

[2]https://line.me/en/

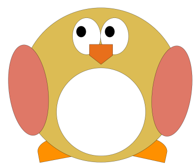
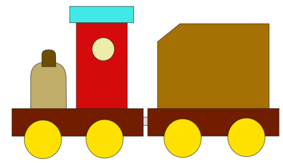
Task set A	Task set B
 Vegetable set: lettuce, onion, apple, green pepper, gherkin, baby corn, mushroom	 Pumpkin rice: rice, pumpkin, mushroom, onion, green pepper, baby corn, egg, carrot.

Fig. 8. Two task sets were used in the user study.

they were given a visual pattern and had to arrange the ingredients to approximate the appearance of that pattern. There was also no ingredient limitation. The scenario simulated the circumstance in which users attempt to present a specific pattern, and are willing to prepare the used ingredients. In addition to the two scenarios, participants were asked to accomplish the tasks by using the semi-automatic mode (*Semi*) and both the semi- and fully- automatic modes (*Semi+Fully*) of our system. To prevent bias, we designed two task sets, *A* and *B*, which were of similar difficulty, for the participants, as shown in Figure 8. The task had no time limit. The participants were allowed to operate the system and simulate as many food presentations as they wanted to. When they were finished, they showed us the result that they preferred the most. We collected the number of actions and the time that the participants used to accomplish the tasks.

6.3 Study Procedure

We first introduced the study to the participants, including our motivation for creating the system, the experiment procedure, and the way in which we collected and encrypted their data. They provided written informed consent, and continued the study if they agreed to participate. Subsequently, we gave them a tutorial about the user interface of our system, and all of the functionalities that could be used to simulate food presentations. After the tutorial, the participants practiced and were allowed to freely use the system until they were fluent in its operation. Once the study commenced, they were asked to accomplish the tasks in the *Recipe* and the *Pattern* scenarios, respectively, by using our system. They were also asked to think-aloud during the task, which was recorded by the research team. In addition to observing how well the system assisted the participants to create good presentations, we also wanted to examine whether *Semi+Fully* allowed the participants to create food presentations easier and quicker than in *Semi* mode alone. For this comparison, we randomly and evenly separated the participants into two groups. The first group was asked to solve task set *A* using *Semi* and task set *B* using the *Semi+Fully*. The second group had the opposite setting. We randomized the order of *Semi* and *Semi+Fully* in the study. After accomplishing the tasks, the participants filled out a post-study system usability questionnaire (PSSUQ) [10], and were interviewed to determine their experience in the tasks, as well as their feedback about the system. We have included the PSSUQ in our Supplemental Material.

We recorded the number of actions taken by the participants to accomplish each of the tasks. Actions that were recorded included dragging an ingredient and dropping it onto a contour, clicking a button for automatic arrangements of ingredients, and seeking an ingredient suggested by the system.

6.4 Study Results

Number of Actions and Spending Time. The participants took significantly fewer actions to simulate food presentations when using *Semi+Fully* (*Pattern: 219*, *Recipe: 185*) than when using *Semi* (*Pattern: 351*, *Recipe: 329*). The t-test shows that the difference was statistically significant (*t(21)=3.54 p = 0.0013*). However, no significant difference was found in the amount of time spent on creating food presentations between using *Semi* (*249* seconds) and *Semi+Fully* (*214* seconds) according to the t-test (*t(21)=0.83*, *p=0.25*). One major reason for this was that *Semi+Fully* demanded system computation time to automatically arrange ingredients, while *Semi* did not. We also observed that the participants spent a substantial amount of time exploring the results simulated by *Semi+Fully*.

Quality. To evaluate the food presentations created by the participants between using *Semi* and *Semi+Fully*, we recruited another five voters to evaluate the results. Food presentations created from the same task (i.e., *Pattern* or *Recipe*), but from different modes, were compared side by side on the screen. The voters selected the one that they considered to be better. The order of the comparison and the position of the food presentations were randomly determined to prevent an order effect. We also asked the voters to ignore their own food preferences and focus on the visual quality of the food presentations. In each scenario, we obtained $11 \times 11 \times 5 = 605$ votes for each pattern/recipe.

In the *Pattern* scenario, food presentations created via *Semi* and *Semi+Fully* were of similar quality, according to the votes. Although *Semi+Fully* obtained slightly more votes (*Semi*: *582*, *Semi+Fully*: *628*), the results were not statistically significant (*t(21)=0.63*, *p=0.54*). In the *Recipe* scenario, food presentations created via *Semi+Fully* (Vegetable set: *419*, Pumpkin rice: *319*) obtained more votes than those created via *Semi* (Vegetable set: *186*, Pumpkin rice: *286*). The result of the t-test indicated that the difference was statistically significant (*t(21)=4.52*, *p < 0.001*). It was also found that, in the *Recipe* scenario, participants were more unsure of the patterns that they wanted to present when using *Semi*. They tended to present simple patterns, such as a flower or a butterfly. In contrast, when the participants used *Semi+Fully*, most of the participants tested the recipe on all of the patterns in the beginning. Subsequently, they explored the results, selected the one that they most preferred, and then refined the presentations by trying out different ingredients. The simulated food presentations seemed to inspire their creativity. As a consequence, many of their food presentations exhibited complex patterns, such as a tank, girl, and owl.

The PSSUQ scores of using *Semi* and *Semi+Fully* are presented in Table 1. Overall, participants preferred *Semi+Fully* over *Semi*, with a particularly high perception of the usefulness of the automatic arrangement feature.

	Semi	*Semi+Fully*	*t-test*
Overall satisfaction	*M = 4.22*	*M = 4.43*	*t(21) = 3.70*, *p < 0.001*
System usefulness	*M = 4.37*	*M = 4.64*	*t(21) = 3.25*, *p < 0.002*
Information quality	*M = 4.23*	*M = 4.36*	*t(21) = 1.35*, *p = 0.178*
Interface quality	*M = 3.97*	*M = 4.24*	*t(21) = 2.07*, *p = 0.040*

Table 1. Participants preferred *Semi+Fully* over *Semi*. The difference was statistically significant.

6.5 Qualitative Feedback

We conducted an interview with participants after the experiments, in which they shared their experiences in creating the food presentations and thoughts about our system.

Overall Thoughts. Participants who had previous experience with food presentations mentioned that, in most cases, they used ingredients they had at home to create the food presentations. Limited by the availability of ingredients, they often did not know what pattern to create or had to spend a substantial amount of time to cut and arrange the ingredients. To solve this problem, P8 applied silicone molds to shape mashed vegetables into patterns, and P5 cut fruit using a food cutter. Therefore, they were pleased with our system. P6 stated, *"The system is helpful. In the past, I had to imagine the appearance of the food presentation. But now I can see what it will actually look like. It's like buying clothes. Sometimes, you think that a piece of clothing is beautiful, but you have to wear it. Otherwise, you cannot be sure."* P11 said, *"The system is inspiring. I can use it when I feel tired creatively."* Most of the participants liked the combination of *Semi* and *Fully*. They preferred altering ingredients based on automatically generated results over creating patterns from scratch. However, a few participants who had extensive experience in food presentation preferred *Semi* more than *Semi+Fully*. For instance, P15 reported, *"I have created food presentations for six years. I don't think I need an automatic system. But I would try it when I need inspiration."* Several participants informed us that they would be more willing to create food presentations if they had our system. P2 stated, *"Many Moms like to cook because they gain satisfaction from cooking. It can get people interested in creating food presentations."*

Nutrition. Although almost all participants agreed that nutrition is an essential issue, interestingly, they did not consider the daily amount of needed nutrition. Instead, they cared about whether their families eat grains, meats, and vegetables in a meal. P10 reported, *"... When creating food presentations, I try to use several categories of ingredients. But it's difficult to know what kind of nutrition an ingredient has and how much it contains."* Therefore, they appreciated the feature of nutritional composition estimation. P15 also said, *"Sorting results according to the amount of nutrition is good. Without this function, I have to check the nutrition facts of each ingredient and then calculate by myself."* Several participants paid attention to sodium because it can cause cardiovascular disease, and is frequently added to pre-processed foods. However, not all participants cared about nutritional composition. P5 stated, *"Visual quality is the most important thing for food presentation. ... As long as the foods we eat are diverse, nutrition should not be a problem."*

Suggestions. Despite the major benefits that the system provides, a few participants proposed relevant suggestions for our system, for example, including more kinds of ingredients. P3 said, *"... I didn't see ingredients that are healthy but taste awful, such as balsam pear."* Other participants wished that the system would include other ways to process the ingredients, as P1 remarked, *"Besides slicing ingredients, you can shred or dice them."* Regarding system usability, participants desired several functions that were not supported by our current system. For example, they wanted the ability to input or draw patterns, change plates, undo actions, and fine-tune the position/orientation of each ingredient. P18 said, *"The plate is a part of food presentation. If I present a fish pattern, I need a rectangular plate."* P13 stated, *"Kids may be allergic to some kinds of food. I would like to specify this condition in the system and prevent those foods from being used."* Finally, our system was implemented and run on a PC, and several participants expected to use it on a mobile device so that they could use it conveniently whenever they have leisure time.

7 CONCLUSIONS

We presented a simulation system to assist users to create food presentations. By using our system, users can perform a process of trial-and-error in the simulation before they arrange real ingredients on a plate. The simulation saves both time and food, while simultaneously enabling users to create high-quality food presentations. The results and the user study's feedback verified that our system was beneficial and could motivate participants to arrange foods in creative ways. In addition to visual quality, by reading the nutritional composition estimated by our system, users can determine whether each nutritional element is being over- or under-consumed in each meal. In other words, the created food presentations are not only visually appealing, but also healthy.

Although participants considered our system to be highly beneficial, they provided certain pertinent suggestions. Moreover, they identified several functions that they desired but not provided in the current system. In the future, we will attempt to include such suggestions and functions in the system, and test their effectiveness. We will also conduct research that aims to improve the system's usability. Furthermore, considering that many children are relatively selective eaters compared to adults, we will consider representing well-known cartoon characters with healthy foods and then encourage the children to eat those foods. We also plan to consider taste as a factor when simulating food presentations. In this way, we hope that our system will help children to try new foods that they previously refused to eat, and develop the habit of eating a wider variety of healthy foods.

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