Shadow Cooking: Situated Guidance for a Fluid Cooking Experience

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Abstract. Cooking is one of the most popular activities at home; however, preparing a new dish by reading a recipe is not a trivial task. People might lose their current position in the recipe, misunderstand the required amount of ingredients, and generally become confused by the step that should be followed next. Shadow Cooking guides users with situated, step-by-step information projected on a kitchen counter. It consists of a depth camera and a projector, which are installed above the kitchen counter. Shadow Cooking instructs the user on the steps to follow by projecting information directly onto the utensils and ingredients. The system also integrates a digital kitchen scale with the recipe such that the user is automatically prompted with the required weight based on the ingredient currently being measured. In addition, we have connected the system with remote locations in order to enable a user to communicate with other cooks easily.

Keywords: Accessibility of Smart Environments, cooking, AR, kitchen, measuring.

1 Introduction

Cooking is a staple domestic activity around the world. Such activity provides a feeling of sufficiency; therefore, cooking is important beyond just providing nourishment. However, there are many steps involved in cooking and it requires some knowledge, which makes cooking difficult, especially for beginners. Even people with experience are likely to make mistakes when preparing a recipe for the first time.

Cooking by following a recipe is not a trivial task. A cook has to be aware of the steps that have been completed, and be equally aware of the steps that follow next. However, different cooking books will frequently list several steps within one sentence or one block of text, such that the cook can sometimes lose their place in the recipe. Meanwhile, the cook might attempt to simultaneously focus on their current activity and try to understand what to do next. This type of balancing can cause mistakes, such as missing steps or inadvertently using the wrong amount of an ingredient.

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Given that cooking is a real-time task, excessive efforts to understand the recipe can interrupt the cooking activity itself, which could result in an improperly cooked dish.

The other problem with current recipes is measurement. If the weight of an available ingredient (for example, meat) is different from the weight specified on a recipe, the amount of all the other ingredients must be recalculated accordingly. However, recalculating ingredients is an extremely cumbersome task that can cause mistakes when done incorrectly.

We conducted a pilot study to observe the mistakes that are most likely to occur with common written recipes. We used a muffin recipe, and both beginners and experienced cooks participated. We found that beginners were not familiar with measuring units, such as grams, cups, spoons, and milliliters, and as a result, they often made mistakes by using the wrong measuring tools. Beginners were also confused as to which utensil to use when the recipe only indicated to "mix" and used a spatula when a whisk was more appropriate. Both beginners and experienced cooks became confused with units such as "tablespoon" and "teaspoon," or inadvertently missed steps, such as forgetting to use flour where the recipe indicated to "…mix sugar, flour, baking powder and oil…" These results illustrated to us that the current style of recipes commonly used at homes can easily cause users to make mistakes.

In this paper, we propose a system that guides cooks by displaying a single step directly onto the cooking environment; the step displayed varies according to the user's progress. This enables users to recognize immediately the step to follow, thus helping the user to avoid mistakes and cook smoothly.

2 Related Work

Recently, several experimental systems have been developed to enhance the kitchen.

The method of integrating a recipe with a real kitchen is used in several systems [1, 2, 3, 4, 5]. CounterActive [1] projects a recipe to a kitchen counter that the user can operate by touching the counter. Panavi [4] is a sensor-embedded frying pan that manages user by recognizing the temperature of the frying pan. However, with these systems, users are still required to read instructions and be aware of their current step in the recipe and the following step. Kitchen of the Future [6] installed several monitors, cameras, and foot switches in an entire kitchen such that users were not required to see a recipe from a distance location. However, Kitchen of the Future does not recognize user's action. Cooking Navi [7] and Video CooKing [8] synthesize multimedia such as videos and photographs in order to make text-based recipes more understandable. These systems help users know detailed information. Some systems specialize in recognizing user's activities and objects within the kitchen [10, 11, 12]. Adding depth images to normal images enables such systems to recognize fine-grain kitchen activities, such as mixing and the number of spoonful ingredients that have been poured into a cooking implement [11].

In contrast to these systems, our system is more focused on supporting the entire cooking process according to the context of cooking, rather than merely recognizing cooking activities.

Fig. 1. An operation scene from the Shadow Cooking system. Cooking instructions are directly projected onto the kitchen counter and cooking objects. The instructions move forward according to the user's progress.

3 Shadow Cooking

As explained in the previous sections, the problem with written recipes lies in the separation of the real cooking workspace and the recipe itself. Previous works that merged the kitchen with recipes did not attempt to solve this problem, and a cook is still required to read the recipe, or the user must decide when to proceed to the next step; therefore, it is still possible for the cook to commit mistakes. Our research supports a merged kitchen and recipes, and it guides users according to their situation. Our system aims to decrease the possible mistakes and confusion in cooking in order to facilitate a fluid cooking experience.

Our proposed system, called Shadow Cooking, is a system that projects a guide directly onto the work surface, in accordance with a real-time situation (Fig. 1). The system recognizes the user's current progress in the recipe and guides the next action step-by-step. The real environment and the recipe are integrated in two ways. One is spatial (i.e., information is projected onto the position of actual ingredients) and the other is chronological (i.e., instruction information is projected according to the current progress of actual cooking). Thus, we expect the cooking activity to proceed uninterrupted, without the necessity to read a recipe. Our system aims to allow users to place their full attention on the cooking activity.

3.1 System Configuration

Shadow Cooking consists of a computer, a depth camera, a projector, and a digital kitchen scale (Fig. 2). The depth camera and the projector are installed above the kitchen counter to detect objects and project a visual guide directly onto the ingredients and utensils. A kitchen scale is installed with a Bluetooth chip that sends weight information to the computer in real time. After a recipe is selected, a step-by-step guide is projected onto the objects according to the user's current status in the recipe.

Fig. 2. Configuration of the system. The wireless digital kitchen scale tracks the quantity of an ingredient that the user has poured into the scale.

3.2 Recognition of the User's Cooking Context

The depth camera recognizes the existence of objects at specific locations on the kitchen counter in order to determine whether the user is following the instructions. The recognition is based on depth; therefore, once the user has placed an object on the specified place and the depth has been recorded, the system would not fail to recognize objects because of hands moving over them. To distinguish objects, we set the lower and higher height of each object; the system then recognizes the existence of the objects when the depth value is within these two thresholds at the designated position on the kitchen counter. This is an extremely simple method, but it can effectively detect typical incorrect situations, such as incorrectly placing a milk carton instead of butter.

Fig. 3-(2) shows the recognition screen from the depth camera. The blue lines indicate that an object exists in its designated position. Further, the digital kitchen scale is used to recognize the currently used amount of ingredients. Steps move forward by tracking the movement of objects and the currently used weight. For steps that cannot be determined through these two actions, the user can simply place a hand over the hand outline in order to move to the next step (Fig. 4-(2)).

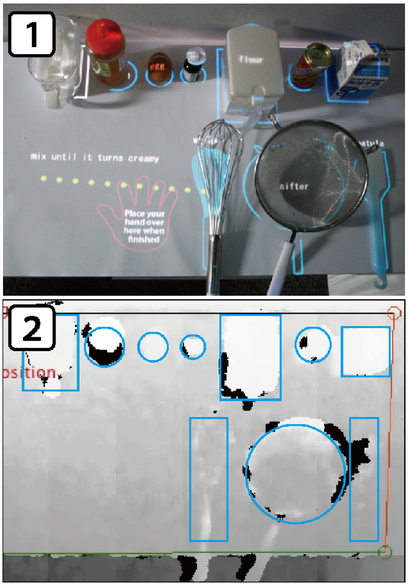

Fig. 3. (1) A real scene from a kitchen counter, (2) a corresponding depth image for recognition

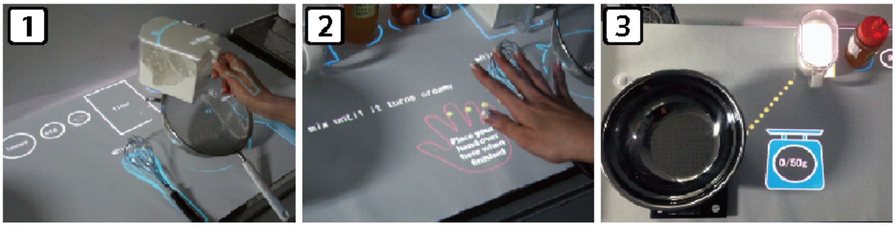

Fig. 4. Operation steps. (1) The user sets all the ingredients and utensils onto the projection. (2) The steps move forward by detecting the movement of objects and the scale amount, or by placing hands over an image as shown. (3) The user follows the instructions visualized with lines and some words. In this figure, the system is instructing the user to place 50 grams of sugar into a bowl.

3.3 System Usage

The system follows the steps indicated in this section to guide the user.

Step 1: Preparation. After selecting a recipe, the user sets all the ingredients and utensils onto the shadows as shown in Fig. 4-(1). After placing all the ingredients, the system will automatically proceed to the next step in the recipe.

Step 2: Adjustment (Optional). Optionally, the user can adjust the quantity of the recipe according to the specific weight of an ingredient. To adjust, the user would pick up the ingredient from the counter and place it on the scale; the amounts for the remaining ingredients are adjusted automatically.

Step 3: Cooking Along with Shadow Cooking. After step 2, the user can place a hand over the hand outline to start cooking. The user cooks based on arrows, numbers, and short instructions to progress. Steps proceed according to the movements of objects. For example, if the step is to "Put 50 grams of flour into a bowl," an arrow is directed from the flour to the bowl and a circle image shows the remaining amount that needs to be added and the amount that has been added already, as shown in Fig. 4-(3). When the user picks up the wrong ingredient or adds too much, an alert is displayed. When an ingredient is not needed anymore, its shadow disappears from the counter, or the user is guided to wash the utensil to use it again.

3.4 Trial

We conducted a trial to observe the performance of the system and to verify whether the user interface is appropriate. Two subjects (a male and a female) used the system to cook muffins. The male subject did not have any experience in cooking pastries; the female subject cooks several times a year. We explained only the usage of a standard digital kitchen scale: it has two buttons, one is to power the apparatus on and off; the other is to reset to zero grams any object on the scale. We did not explain how to use the system. Moreover, we recorded videos from a camera above the kitchen counter and to the side in order to observe the participants' handling of the utensils. Additionally, we interviewed the subjects after the test.

Consequently, both subjects did not make any mistakes and both answered that there was no difficulty understanding the instructions. However, the female participant responded that when the instructions indicated to "Mix well," she felt unsure as to how well to mix. In addition, both subjects had an inclination to pour more liquid, such as milk, than was necessary.

4 Remote Instruction

Novice cooks have a poor knowledge regarding cooking, and the information provided in recipes is frequently inadequate to guide beginners; for example, generally, recipes have no indication as to the proper heat level at which to cook certain dishes, or how to cut ingredients. Further, beginners might be unaware of how to manage unexpected circumstances, such as overheating, or a mixture not appearing as expected. On the other hand, experienced cooks, who cook daily, have sufficient knowledge such that they can arrange recipes in their own way, and adjust the heat level and taste according to their experience. Novice cooks cannot perform such changes without experience, and experienced cooks lack the opportunity to share their knowledge and sense of cooking.

With Shadow Cooking, we present another feature: experienced cooks can advise other cooks who are cooking in real time and from remote locations. A USB camera is attached to the ceiling of a cook's kitchen, and the adviser can observe the actions of the cook through video displayed from a touchscreen tablet (Fig. 5). The adviser can then guide the cook in two ways: (1) through voice chat, and (2) through annotation of hand-written messages using a conductive pen. For (1), users can simply chat about cooking; for (2), when the adviser writes a message directly on the video using the tablet, the written contents are projected immediately onto the same position on the cook's kitchen counter. This annotation enables users to communicate directly, and even demonstrate instructions that might be difficult to express using words only. Moreover, the adviser can ensure that the cook is following instructions correctly. We expect this feature to help novice cooks in acquiring more cooking knowledge than their present experience. We also expect this feature to aid users in inheriting home cooking skills; for example, a mother can teach a child who lives away from home.

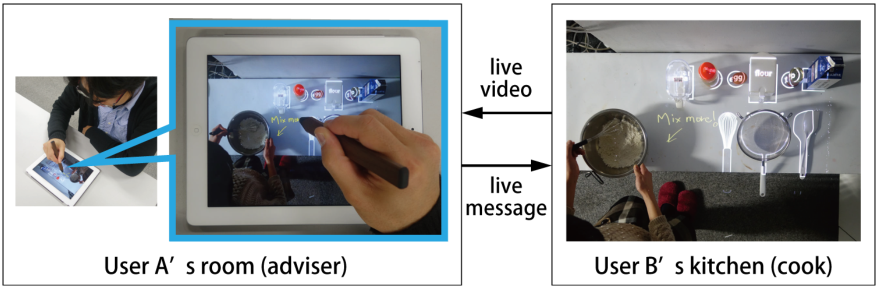

Fig. 5. An adviser from a remote location advises a cook using live video from the camera placed at the ceiling of the cook's kitchen. The adviser can then speak and write instructions; the written messages are then projected directly onto the kitchen counter.

5 Discussions

In this section, we discuss present problems and future work.

5.1 Supporting Other Cooking Processes

Our work assists the complete flow of cooking using weights and depth changes. For the trial, we used a recipe for muffins, which mainly consisted of measuring and mixing ingredients. There are several other processes involved in cooking, such as frying, steaming, and cutting. The processes that necessitate heat require temperature management; however, it is difficult to determine the appropriate temperature, and the process cannot be reversed once a given dish has been overcooked. We consider that previous studies, which visualize heat temperature by numerical methods [4] or heat maps [14], are valid and users can evaluate visually whether they are applying the correct temperature. The process of cutting is also difficult, especially for novice cooks, because there are several methods for cutting ingredients, for example, chopping, slicing, and mincing; moreover, cutting requires practice. We consider that it is effective to combine a video database, similar to the database that VideoCooking [8] incorporates into its system, or videos recorded by other cooks, such as CookTab [15].

5.2 Combination of Other Measuring Tools

In the trial, we observed that the subjects poured too much liquid because pouring speed is fast and it is difficult to control small amounts, compared with flour. The authors of this work have previously developed a system called “smoon” [13], a measuring spoon that automatically adjusts its capacity according to recipe data (Fig. 6). We consider that this type of measuring tool is more suitable for liquids.

Fig. 6. Our previous work developed a utensil called “smoon,” which is a measuring spoon that automatically adjusts its capacity according to recipe data

5.3 Miniaturizing the System and Applying to Other Activities

The current system requires the installation of several devices in the kitchen. Recently, USB cameras, projectors, and depth cameras can be miniaturized and can be connected to a tablet. If the entire system is miniaturized and becomes portable, it can be used for other situations, for example, to perform other activities on a table, such as knitting, sewing, and soldering circuits.

6 Conclusion

In this paper, we proposed a cooking support system called “Shadow Cooking” that aims to integrate recipes with real-time cooking. Because the recipe steps are progressively shown, and the position of ingredients and utensils spatially correspond to real ingredients and utensils placed on a kitchen counter, a user can concentrate on the activity of cooking, instead of diverting their attention on attempting to understand the recipe. Our user evaluation confirmed that this system helps users, and both beginner as well as experienced cooks can prepare a dish equally correctly, without any prior knowledge of the recipe.

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