International Journal of Innovative
Computing, Information and Control
Volume **9**, Number **12**, December **2013**

ICIC International ©2013 ISSN 1349-4198
pp. 4753–4763

COOKING SUPPORT WITH INFORMATION PROJECTION OVER INGREDIENT

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Received August 2012; revised January 2013

Abstract. *Recipes once only appearing in cookbooks are being digitalized, now accessible through PCs and on mobile devices, including smart phones. Researchers endeavor to provide details of the cooking processes in these computerized recipes; however, cooking support systems tailored to novice cooks remain a matter of research. In this research, we discussed weakness of current cooking support and developed a cooking support system that compensates for the weakness. Our system has three features. First, the system provides concrete instructions for cooking by superimposing a cutting line and a knife CG over ingredients. Second, the system recognizes the position and direction of ingredients that are put on the cooking table. Based on the recognition, the system provides suitable instructions for the situation at that moment. In addition, the system equips a conversational robot "Phyno" that provides additional verbal and gestural support. The system not only provides detailed visual support for cooking novices, but also contributes to enhancement of the safety of those novice cooks. This paper explores the advantages and drawbacks of our system and reflects on its adequacy based on trial evidence.*
Keywords: Human robot interaction, Recipe presentation, Visual and acoustic instructions

1. **Introduction.** Numerous researchers in the Human Computer Interaction (HCI) field are actively working to create future living environments. Our research groups suppose that a lot of sensors and computers will be embedded throughout houses and computerized houses will become mainstream. Therefore, we have been conducting various researches in our experimental house. In particular, we focus on the kitchen as one of life supports in the future living environment.

Cooks often cook with a recipe on cookbooks or web pages when they make a first-time meal. Cooks who have some cooking experiments can make it with only the texts and pictures on the recipe. However, cooking novices cannot do the same because only the texts and pictures are not enough explanations for them. This is because the cooking novices cannot imagine the correct way to cook due to the lack of cooking experiences. A lot of videos that illustrate how to cook are also posted online for easier instruction for cooking novices. However, instructions with a video are not easy enough for them. Current cooking supports like cookbooks or online recipes include three weaknesses as follows.

- **Memory load**
  Cooks must memorize a certain chunk of explanations from a book or a video before starting cooking. They must repeatedly do it until the final step.

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- **Gaps between contexts**
  It is sometimes difficult for cooking novices to correctly understand how to cook from pictures and videos on the recipe because most of them are recorded from the viewpoint of an outsider.
- **Interaction**
  Interactions are needed for turning a page of a cookbook or for controlling a video to browse a cooking process that cooks want. However, interaction during cooking is not easy.

This research aims to overcome the three weaknesses and develop a cooking novices-friendly cooking support system. While a lot of researches have been conducted previously, some challenges still remain. In this research, we developed a cooking support system with three novel approaches for the challenges: overlaying cooking instructions over an ingredient, recognizing the position and direction of an ingredient, and interaction with a conversational robot. First of all, this paper introduces the design and the example of our cooking support. Next, we describe the implementation of the system and discuss the system based on a trial use of the system. Our main contributions are to propose novel instruction approaches for three weaknesses and to indicate the potential of our framework for intelligent user assistance.

2. Design of Cooking Support System.

This research aims to overcome the three weaknesses mentioned in Section 1 to develop a cooking-novices-friendly cooking support system. Our challenges are to develop an instruction technique with less memory load, to present cooking instructions suitable for the context, and to realize easier interaction. We describe our approaches for each challenge as follows.

2.1. Overlaying the cooking instruction over an ingredient.

Cooks must memorize a certain chunk of explanations from a book or a video before starting cooking, and cook while tracing their memory. In some recipes like cakes, cooking time and the order of cooking process are very important. Therefore, cooks must memorize the correct cooking process and spend less the wasted time. However, it is difficult for cooking novices who do not know the fundamental way to cook to memorize them correctly.

Therefore, we adopted an approach overlaying cooking instructions over an ingredient and a cooking table. The types of guiding images can be broken down into three categories: process instruction images, procedural images, and progression images. Process instruction images include those that show how to cut an item, such as computer graphics (CG) cutting line, accompanied with an image of a moving knife that demonstrates how to maneuver the knife. Procedural images provide text or graphics, such as arrows that show the steps in preparing an item, such as turning an ingredient over. Progression images link steps in a recipe. If it is necessary for an item to be transferred to a dish for instance, text will appear instructing the cook to do so.

Overlaying the cooking instructions provides cooks with two advantages, in addition to the reduction of memory load. First, the system can visually show the cooking instructions in a comprehensible way. Cooks can easily understand the instructions compared with the cookbooks and the videos because it overlays more concrete instructions over the ingredient and the cooking table with a CG, a text and an arrow. With such detailed instruction, even a novice cook can successfully complete a recipe from start to finish with ease. Second, the system improves the safety of cooks. By providing superimposed images in the cooking area, the cook can keep their attention on the cooking process. When vertically-placed LCD interfaces are utilized in cooking support systems, the cook must divert their gaze between the cooking table and the LCD to receive directions.

Unlike these systems, our system allows the cook to stay focused and concentrate on the task at hand. When using a vertically-placed LCD like previous researches, the cook has to move his/her gaze between the cooking table and the LCD many times. On the other hand, the system improves the safety because it decreases the gaze movement and lets the cook concentrate on his/her works. In addition, our system encourages the cook to properly use cutting tools without injury. With interfaces that use video to demonstrate how to cut ingredients, we have found that novices tend to focus more on the object they are cutting rather than proper and safe use of the cooking implements, potentially leading to injury. On the other hand, novices with this system can acquire the skills to use knives safely, thereby enhancing the safety of the cook and preventing injury.

2.2. **Recognition of the position and the direction of an ingredient.** A lot of existing cooking support systems do not reflect the cooking situation at the time. When using a cooking support with a video, cooks must understand the situation in the video and then reconstruct the situation to fit the real world. For instance, when cutting an ingredient, the suitable way to cut depends on the position and the direction of the ingredient. However, most of the existing systems do not care about this. In addition, pictures and movies on a cookbook or a cooking video are often recorded from the viewpoint of an outsider. Therefore, cooks sometimes must imagine the viewpoint of the cook. Thus, cooks must fit the provided information into the cooking situation at hand.

On the other hand, our system presents suitable cooking instructions depending on the cooking situation at the time. The system automatically recognizes the position and the direction of an ingredient and then presents a suitable instruction for the situation. This enables the cook to freely put the ingredient and proceed with the cooking as s/he likes.

This could be apprehended that the system becomes to do a context transformation, which cooks used to do. In general, less context transformation by a user improves the usability of a support system. Our proposed technique can be applied to a lot of systems and contributes to improving the usability of them.

2.3. **Interaction using a conversational robot.** Interaction with a computer is still a large challenge in the research for the kitchen. This is because current interfaces such as mice and keyboards are not always suitable for the usage in the kitchen, which is widely different from a desktop environment. Therefore, some approaches like using foot switches [8] or the line of sight [2] have been proposed. In this research, we use audio-based interaction with a conversational robot. There are other two reasons why we adopted the robot for interaction.

One of the authors of this paper previously conducted research in installing a cooking support system in an experimental home using a conventional robot [10] that was referred to as "ubiquitous home" at the National Institute for Computer Technology (NICT). In the NICT project, it was found that the robot successfully allowed users to proceed through the cooking process without the necessity of a mouse or keyboard. The robot also significantly decreased the amount of mistakes that users made during cooking process as well. Finally, when a user made a mistake while cooking, the robot could pinpoint the mistake by having a conversation with the user. In addition, it displayed a recording of the user cooking to compare against a pre-installed video showing how to cook so that the user could discover where they made a mistake during the process. Due to the successes of this project, we decided to adopt a robot in our cooking system.

Another reason we decided to utilize an interactive robot in the cooking system is because of the potential for a robot to serve as a cooperative partner. While spoken interaction between a user and cooking support system can be achieved through the use of a speaker and microphone, this leaves the user feeling detached. Recently, new role of the robot has been proposed; the role of the robot shifts from "human-like interaction partner" to a social entity which stimulates constructive, cooperative activities between people and improves the quality of their interpersonal interactions [1]. We believe that introducing the conversational robot into a cooking support system allows to achieve conversation without empty feeling and to stimulate the cooking activity.

3. The Kitchen Environment and the Robot.

To realize overlaying the cooking instruction over an ingredient, recognition of the position and the direction of the ingredient and interaction with a robot, we used an IT kitchen in which projectors, cameras and various sensors are embedded, and a conversational robot.

3.1. Kitchen environment.

The kitchen illustrated in Figure 1 is equipped with a sink cabinet (user's left), cooking table (center), and stove with a hood (user's right). Two cameras and three projectors have been installed in the ceiling in addition to lighting equipment. The camera and projector have been strategically placed so that footage of the entire kitchen, except for the hooded-stove, can be captured. We used high-speed cameras in order to record the quick movements of the kitchen users. For safety purposes, the kitchen is always kept highly illuminated. We use high-power projectors so that fine picture detail can be provided in the bright kitchen environment.

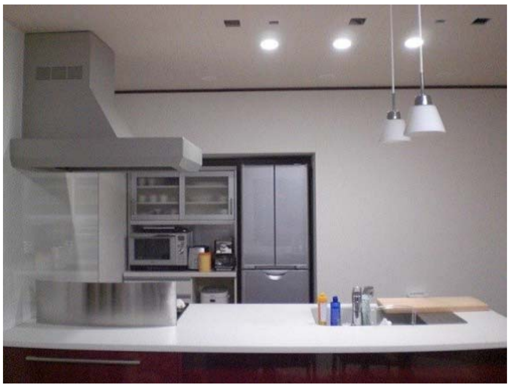


Figure 1. Photograph of entire kitchen facility

Figure 2. Appearance of a conversational robot Phyno

3.2. Conversational robot "Phyno".

We installed a Phyno robot, a small conversational robot in the kitchen (Figure 2). Measuring 260mm × 210mm × 340mm and weighing 3kg, it is placed on a control box containing computer. Phyno does not move but has a degree of freedom (DOF) totaling to five – 3 DOF in its head and 1 DOF in the arms and torso respectively. Phyno can record images with the movement of its eyes, as well as sounds, because its head is equipped with a camera and microphone. Phyno is controlled by a computer via RS-232C on the control box.

With the purpose of capturing the cook's speech, even in the noisy kitchen environment, we installed a separate speaker and microphone. With the speaker and microphone, the cook and Phyno can hear each other. We placed Phyno at the back of the cooking table so as not to interfere with the cooking work. We used an open-source large vocabulary CSR engine Julius [6] to recognize the cook's speech.

4. **Cooking Support for Filleting a Fish.** We introduce a cooking support for filleting a fish as a concrete application of the system that we proposed. From the viewpoint of a novice, filleting a fish requires some complicated techniques. In addition, most of processes need overlaying the instruction over the ingredient, recognizing the position and the direction of the ingredient and audio-based interaction with a robot. Therefore, this example can indicate the effectiveness and the value in the practical usage of our system.

4.1. **Cooking process.** The cooking support system instructs cooks through projected CG, speech, and the Phyno. CG is projected on the cooking table and speech is outputted by the external speaker. The following details the steps for filleting a fish provided by the cooking system.

Step 1: Starting cooking. The system instructs the cook to put a fish on the cutting board through speech commands of Phyno and CG projections. After detecting the fish on the cutting board, the system displays a CG and announces in speech "Let us start cooking. Good luck!" to encourage the cook. At this point, a bounding box appears around the fish to demonstrate to the cook that the system has properly detected the fish.

Step 2: Removing scales. The system instructs the cook on how to remove the scales utilizing CGs.

Step 3: Flipping the fish. The system instructs the cook to flip the fish in order to remove scales on both sides of the fish. In addition to speech, a CG of an arrow is shown on the fish. This allows the cook to easily understand the process. After the fish is flipped, the instructions from Step 2 are repeated so that both sides of the fish are scaled.

Step 4: Removing the offal. The system instructs the cook to remove the internal organs. The system projects a CG of a cutting line and demonstrates how to move the knife, providing detailed instruction on how to remove the entrails from the fish, as illustrated in Figure 3(a), to facilitate a novice in this potentially complicated task.

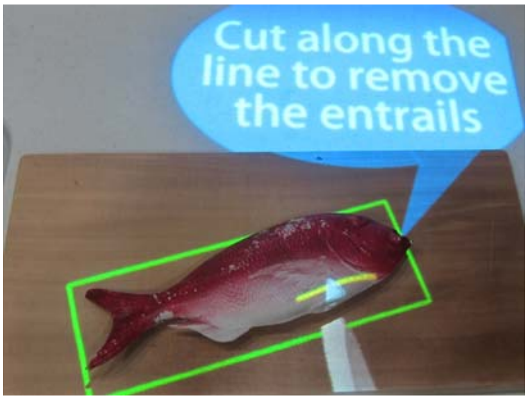
Step 5: Removing remaining offal. The system instructs the cook to wash the fish in the sink to remove the remaining offal. In this case, speech is used instead of a CG projection because it is difficult to maintain a CG on the fish when it is being moved to the sink.

Step 6: Cutting off the head of the fish. The system instructs the cook to cut off the head of the fish. The system projects CG of a cutting line and knife onto the fish for cutting off the head of the fish.

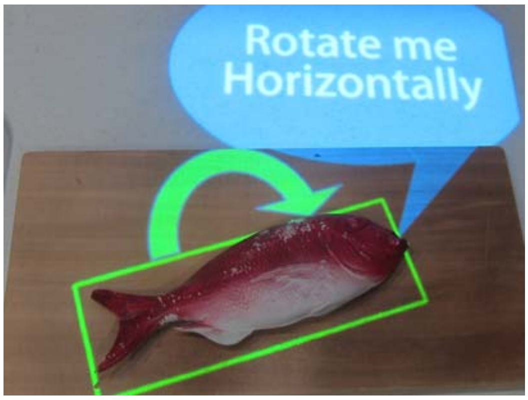
Step 7: Inserting the knife into the abdomen. We adopted a cooking technique for effectively removing the flesh from the fish that requires a knife to be inserted into both the abdomen and back of the fish. First, the system instructs the cook to insert the knife into the abdomen of the fish by projecting onto the fish a CG of a cutting line and image showing how to maneuver the knife.

Step 8: Rotating the fish horizontally. To maintain the safety of the cook, the system instructs the cook to rotate the fish 180 degrees in the horizontal direction. Then, the system projects a CG of an arrow around the fish (Figure 3(b)) so that the cook can easily understand this step.

Step 9: Inserting the knife into the back of the fish. In order to cut off all of the flesh from the fish properly, the system instructs the cook to insert the knife into the back of the fish by projecting a CG cutting line and showing how to move the knife.



(a) Projection of a cutting line and movement of the knife over the fish



(b) Captured image when just finishing a process

FIGURE 3. Arrow projected over the fish instructing to rotate it

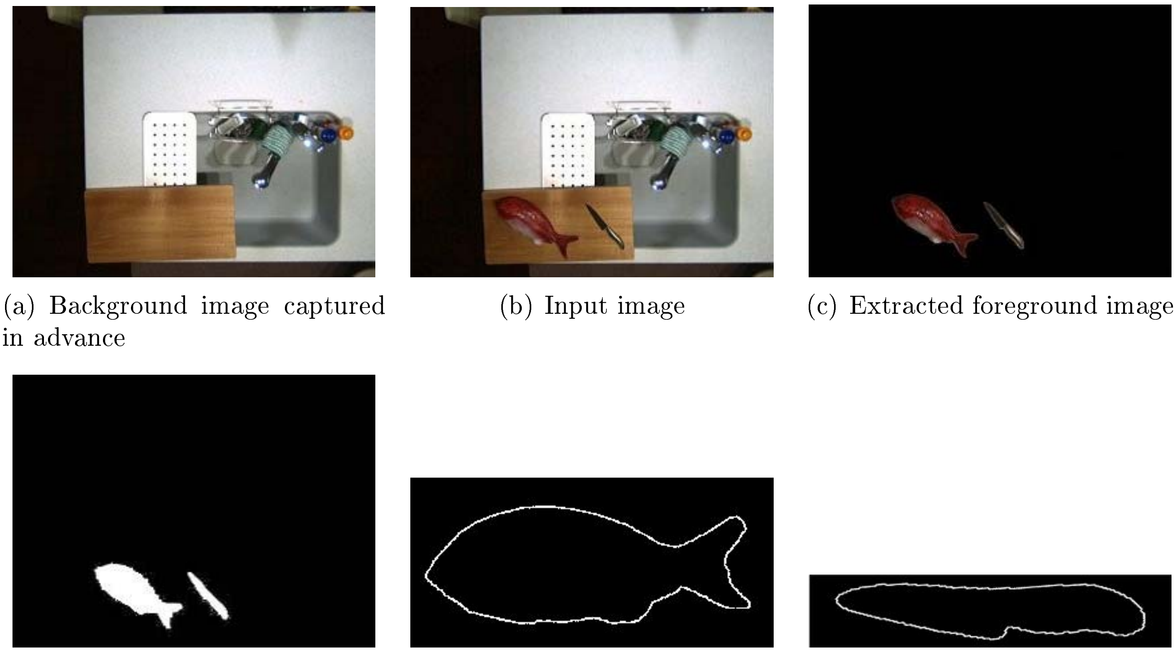
Step 10: Finishing cooking. After all of the steps are complete, the system announced through both speech and a CG, "Completed. Well done.".

4.2. **Implementation.** In order to determine whether a step in the cooking process has been completed or not, we have installed functions into the system to both recognize the fish and judge whether or not a step has been completed. Detecting the fish is also important so that the CG projections, such as cutting lines, can be properly calibrated. The system can use a cue from the cook as the judgment because it can recognize the cook's speech. However, cooking novices are worried about whether they have proceeded the cooking process well or not if putting the judgment in the cook's hand. Therefore, the system eliminates the concern by asking the cook whether s/he finished the process or not. The judgment has to be implemented to achieve this. While cooking processes may vary with fish of different sizes or species, currently the system is only equipped to handle certain fish.

4.2.1. *Fish recognition.* The system utilizes two computer-vision techniques: a background-differencing technique and a pattern-matching method.

First, the system detects objects on the cooking table using a background-differencing technique. Prior to cooking, it captures an image of the cooking table to use as a background image (Figure 4(a)). The system then takes another photo when something is put on the table at the start of cooking to use as an input image (Figure 4(b)). With background-differencing, it extracts a foreground image (Figure 4(c)) from the background image to isolate the input image. Then, labeling (Figure 4(d)) is done to detect multiple objects included in the foreground image. The system extracts object images after detecting the contour definition of each detective object by analyzing their rotation on the smallest rectangle. The rotational angle is used to determine the direction of the fish.

Next, to identify whether previously extracted objects (Figures 4(e) and 4(f)) are fish or not, the system utilizes a template matching technique. The system tries to match the extracted image with a template image of a fish stored in the system in advance (Figure 5(a)). While the system is successful in distinguishing between a knife and a fish, it has difficulties discriminating between the cooks' hands (Figure 5(b)) and fish because the shape of the hands is similar to the shape of fish. We have developed a technique that divides captured images into right and left parts (i.e., head and tail of fish) and then respectively matches them with images stored in the system (Figure 5(c)). Consequently,



(a) Background image captured in advance (b) Input image (c) Extracted foreground image

(d) Labeling and contour definition (e) Extracted object image (1) (f) Extracted object image (2)

FIGURE 4. How to detect objects put on the cooking table

(a) Template image of a fish (b) Hand image caused false identification (c) Object (fish) image divided into right and left

FIGURE 5. Images using in template matching

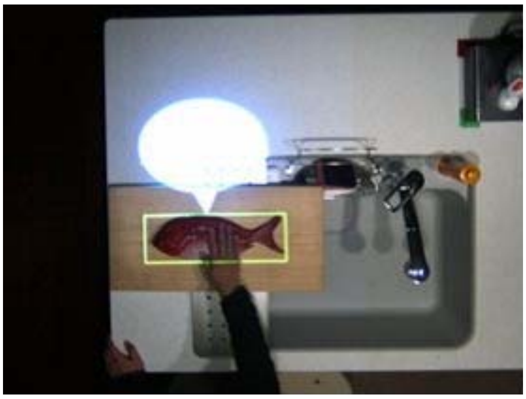
we succeeded in decreasing the incidence of misidentification of items and increasing the recognition rate of the system higher than simpler methods employed in the past.

The system temporarily halts the CG projection when the camera is capturing images as projected images can complicate the recognition result. Since the detection process is relatively quick, the cook can continue cooking without difficulties.

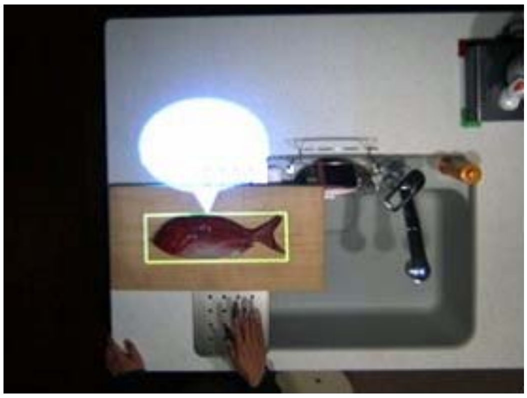
The recognition of the object and its position and direction enables the system to directly present suitable instructions on the suitable position. It is one of the technical contributions in this research to develop such an image processing technique and a projection technique.

4.2.2. *Determining the completion of cooking processes.* Some judgment techniques [5] have been explored. However, it is difficult to automatically judge all steps. Therefore, we have developed a hybrid technique that combines image processing and speech recognition.

This technique is completed in two steps. First, the system implements image processing to determine if a cook is touching an ingredient or not. The system detects the ingredient and its state by the background differencing technique in the same way as the fish recognition. The system judges as during cooking when the cook is touching on the



(a) Captured image during cooking



(b) Captured image when just finishing a process

Figure 6. The judgment whether a cooking process is done or not by image processing

ingredient (Figure 6(a)). On the other hand, it judges as finished when finishing touching on the ingredient (Figure 6(b)).

The second step utilizes speech interaction. Phyno prompts the cook for a response by asking, "Have you finished this step?" once it has judged through image processing that the cook is no longer touching the ingredient. If the cook answers "Yes.", the system will judge as the process is finished. If s/he answers "Not yet.", the system will start again from the first judgment.

This two-step judging technique improves the efficiency of the cooking system in determining the completion of cooking steps. Furthermore, cook anxiety can be relieved through communication with the Phyno.

Thus, the hybrid technique that combines image processing and speech recognition improves the reliability and the robustness for recognizing cooking processes. In addition, it also has a good influence on cooks. These are also one of the technical contributions in this research.

5. **Discussion.** After taking the cooking support system on a trial run, we found that a user was able to successfully complete all of the steps of the cooking process. While three approaches were effective for supporting cooking novices, we found some problems. First, overlaying the cooking instructions received a high evaluation and users had interest in the system. We found that overlaying the instructions over the ingredient at hand could provide cooks with correct way to cook. On the other hand, the system still lacked the detailed support needed for novices at certain points in the cooking process. Specifically, the user was uncertain of how to proceed with the removal of the offal because there were no CG but only speech. Second, the recognizing the position and the direction of the ingredient enables cooks to freely proceed with cooking processes. Therefore, cooks did not have to care about the cooking situation and finished cooking only by following the instruction. On the other hand, it revealed that some users did not understand how to hold the ingredient. This is because our system does not provide how to do it. Therefore, it seems difficult for some users who tried to use a knife in the same way as the knife CG with wrong hand positions to cut an ingredient. We found that it was important to not only recognize the position and the direction but also present a cook's hand position. Third, it revealed that audio-based interaction and the embodiment of a robot were suitable for the cooking support. In particular, actions that the robot points at an ingredient with the arm made the instructions much easier. In addition, we found that the embodiment provided

cooks with a sense of affinity. The combination of the recognition of the ingredient and interaction with the robot enabled to let cooks particularly know the cooking situation, and to personalize the system with higher level than existing systems. On the other hand, it also revealed that the system could not instruct advanced cooking methods. For instance, when removing the flesh from the fish, the cook has to cut it by relying on a haptic sense generated by a knife and the bones of the fish. However, our system does not have the ability to provide this kind of detail instruction. Such advanced cooking methods sometimes need to correctly cook. Therefore, this must be a big challenge for this research field in the near future.

Our system requires a projector, a camera and a conversational robot in the kitchen. At this moment, few kitchens equip such devices in ordinary houses. However, the houses have become to computerization step by step. Therefore, we expect that the kitchen also will be computerized in the near future. In addition, the robot will be put in every house because researches on human-robot-interaction have been conducted actively. In such a future house and kitchen, the combination of overlaying information over the real world, the recognition of a context and interaction with a robot has possibilities to provide inhabitant with an effective support without physical and psychic load. This combination will be able to be utilized for researches on living environment as one of the most ideal way of support. For instance, elderly people sometimes cannot recognize the surrounding environment and take suitable actions because of physical declination. However, our framework enables them to take suitable actions because a house with our framework automatically recognizes an inhabitant and its context. Such a support must be necessary for developed countries that have aging society. For instance, a system recognizes elderly person's slipper and stick, and presents the way to them on the hallway by a projector. Thus, the framework of an intuitive interface that recognizes the context, projects information and interact with a robot can be applied to a lot of cases. As an application for inhabitants, this framework can effectively support changing a battery or repair of home electronics in addition to the cooking support. This support can eliminate the concern about breaking them by accident because the system visually instructs how to do it step by step. In addition, the system might be able to prevent injures by incorrect usage of home electronics. We expect that our research output can be utilized and applied to a lot of situations in daily life.

Our cooking support system focused on supporting cooking novices. By using this system, the novices will be able to cook by themselves and bad cooks will improve their cooking skills. We expect that this system can not only increase the cooking population but also fuel the spark of imagination for cooking. In addition, we hope that this research contributes to the development of researches on cooking and living environment and our output is utilized as a fundamental technology of future houses.

6. **Related Work.** The three weaknesses mentioned in Section 1 have been cared in a lot of researches. As researches for weakness of memory load, Siio et al. [8] developed a system that presents shortly-divided cooking videos step by step according to the actual cooking process. They aimed to support cooks' understanding by making full use of multimedia technology. Hamada et al. [3] developed a cooking support system that both cooking videos and texts. Since these researches combine multimedia to cover each weakness, cooks get to be able to easily memorize the cooking processes. Personal Trainer Cooking, which is an off-the-shelf software for Nintendo DS, does not include too many instructions in one cooking process. We thought that this software also considered the memory load. On the other hand, in this software a cook can easily obtain a detail cooking instruction with a simple operation. Thus, previous systems also proposed the

way to present cooking instructions that cooks can easily understand. However, most of them present the instruction with a flat display. In this research, we proposed a technique overlaying the cooking instructions over the ingredient and cooking table. Since, in our technique the instructions are presented in the real world, cooks can cut out the need of understating the context. Therefore, cooks can proceed with cooking processes by only following the instructions at hand.

As researches for weakness of the context, Miyawaki et al. [7] developed a cooking navigation system that recognizes a cooking process from multiple sensors put on the kitchen and synchronizes with cooks. Hashimoto et al. [4] tried to control cooking processes by detecting the position of ingredients and the motion of a cook's hands. Their system can track the ingredients even if their appearances change. From these research outputs, we thought that understanding the cooking situation is effective for the suitable cooking support. Therefore, our system also presents the instruction depending on the context. We implemented this mechanism by recognizing the position and the direction of the ingredient with image processing techniques. In addition, by combining the image recognition and robot interaction, the context detection became more robust.

A lot of researchers have tried to resolve the weakness of the interaction. Siio et al. [8] proposed an interaction technique with foot. They installed four foot switches in the lower part of the kitchen counter. A cook can operate the system only by kicking switches according to the instructions presented on a display. The foot switches are used for switching between cameras and displays for remote communication and controlling the multimedia contents such as cooking recipes. In addition, eyeCook [2] enables a cook to follow a recipe through eye gaze and speech. One of authors of this paper developed a variety of input devices in a previous research [9]. His research group thought that the situations of a cook frequently change because the cook has to do many kinds of works. They developed suitable input devices for different cooking situations and examined their suitability. Personal Trainer Cooking equips two interaction methods: a touch panel and audio interaction. A cook can use both of them or either of them. Thus, previous researches proposed interaction with foots or eyes or cook's available actions during cooking. They also reported that such interaction techniques had effects on the weakness. In this research, we proposed an audio-based interaction technique with a robot. By using the robot, the system is able to not only benefit from the audio-based interaction but also give the instruction with the embodiment of the robot. For instance, pointing at an ingredient with the robot's arm enables cooks to easily understand the instruction. Thus, we indicate that the robot in the cooking support system has a lot of possibilities.

7. **Conclusions.** We have proposed a new framework for intelligent user assistance that combines a video camera and a video projector and a robot. As an example of the application, we developed a cooking support system with a projector, a camera and a conversational robot, and indicated the feasibility of the framework. The system has three key concepts: overlaying the cooking instructions, recognition of the ingredient and interaction with a robot. Overlaying the cooking instructions enables to present the correct way to cook in a comprehensible way. Recognition of the ingredient enables cooks to freely proceed with the cooking processes. Interaction with a robot enables to provide cooks with not only audio-based operations but also instructions with the embodiment of the robot. In addition, we expect that the embodiment of the robot provides cooks with a sense of affinity and triggers cook's creativity. The combination of the recognition of the ingredient and interaction with the robot enabled to let cooks particularly know the cooking situation, and to personalize the system with higher level than existing systems.

The three approaches we proposed in this paper have possibilities to provide inhabitants with effective supports without physical and psychic load. As our future work, we will use this framework for not only the cooking support in the kitchen but also the inhabitant support in the house.

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