

# panavi: Recipe Medium with a Sensors-Embedded Pan for Domestic Users to Master Professional Culinary Arts

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## ABSTRACT

“*panavi*,” a recipe medium, supports cooking experience for domestic users to master professional culinary arts in their kitchens by managing temperature and pan movement properly. Utilizing a sensors-embedded frying pan—providing projected images, LED indications, and vibration—wirelessly connected with a computer system that shows text messages with sounds, the *panavi* system analyzes sensors’ data, recognizes users’ conditions, and provides the users with situated instructions. Describing our vision, design process, implementation, and user study that outlines experience of challenging professional cooking, this paper introduces a design framework model of this recipe medium for domestic usage. Throughout revealing the design process—from ideation to the finished research artifact as a whole cooking support system—this research suggests how to design interactive systems responding to human situated actions, for use as daily commodities enriching domestic user experience.

## Author Keywords

Cooking; Kitchen; Interaction Design; Situated Actions; Ubiquitous Computing; Research through Design

## ACM Classification Keywords

H.5.2 User Interfaces: Interaction styles

## General Terms

Design

## INTRODUCTION

A famous American chef named Julia Child debuted on the TV program “The French Chef” in 1963, what can now be considered the pioneering cooking show. In contrast to her high level of French cooking skills that she had accumulated over years of practice, the humorous show consisted of general cooking instructions. Throughout the show, she discussed and commented contextually regarding what she was doing. When making an omelet, for example, she stirred

the eggs, put them in the pan, and roughly shook the pan while heating it. Her cooking show, translating traditional print or verbal recipe sharing to the medium of video or TV, was a great hit with domestic audiences in the US.

Cooking medium has entered a transitional period with regards to HCI. Cooking instruction systems based on new digital platforms such as iPhone or Nintendo DS have already become commonplace [1, 17]. Vita Craft released an automatic temperature control cooking pan that works with a special IH cooking heater in Japan [19]. ThinkGeek also released a temperature sensor embedded frying pan [3]. Highly-smart kitchens provide new experiences such as remote communication through cooking [20], prevention of memory loss [24], or making invisible information visible using augmented reality [5, 6]. Although computerized kitchens and utensils have provided us with convenience, domestic users still have limited means to utilize professional culinary arts, such as proper temperature management or proper handling of the pan, especially when following a recipe that is not easy to understand. To cook quickly, smartly, and beautifully like professionals, one has to apprentice for years which may be as difficult as training to become champion athletes.

This paper introduces “*panavi*” (Figure 1), a recipe medium for domestic users to master professional cooking culinary arts, normally inherited through life-long training experience under apprenticeship of other chefs. ‘*panavi*,’ its name deriving from the combination of frying-‘pan’ and ‘navi’gation, guides users to control the fire, move the pan properly, and cook sequentially with the instructions via sound, light, vibration, projection of the pan, and also the monitor display. Users inspect current temperature and follow the instructions projected on the pan as shown in Figure 4-a, b. The system analyzes the embedded motion-sensor’s degree of tilt, recognizes the users’ cooking condition, and provides text instructions on the display with audible alerts. The *panavi* system, a package of these technical functions, is designed as a recipe medium suitable for usage in domestic kitchens enabling users to master professional method, approach, and technique for cooking.

Our initial prototype of *panavi* described in this paper is a “*Research Artifact*” [26] produced to conduct interaction design research in domestic environments, especially kitchens. Activities in kitchens cannot be planned as a static model, be-

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Figure 1. Cooking the Recipe of Carbonara Mediated by “panavi”

cause it seldom causes uncertain troubles due to users’ activities basically based on situated actions [21]. Therefore this research attempts to obtain ways of designing computer mediated artifacts that support uncertain domestic environments.

This paper follows Zimmerman’s principles for “*Research through Design*” that evaluates how a Research Artifact could contribute to the HCI community; *Process*, *Invention*, *Relevance*, and *Extensibility* [26]. Firstly, this paper contextualizes this work in previous researches and also defines contributions to the HCI community (*Relevance*, *Invention*). Secondly, it describes our design process: what our initial motivation and hypotheses is, how we developed the panavi system in several iteration processes through hardware sketching with “trial and error” cooking, a preliminary user study to find deficiencies of design, and the design of our first prototype (*Process*). Thirdly, it presents the design and architecture of panavi with instructions of how to use this system (*Invention*). Fourthly, revealing user experience of this new recipe medium, we describe a user study of three groups including four persons actually challenging to cook the recipe for spaghetti *Carbonara* as instructed by the panavi system (*Invention* and defining *Extensibility*). Finally, this paper defines two ways the HCI research community can leverage on this research (*Extensibility*); 1) A consideration about how to make an interactive system supporting users’ situated actions [21], especially how it supports the difference in skill between users, 2) A model of interactive artifact design supporting domestic everyday affairs, consisting of basic technological framework and a design methodology for interaction designers: how to design a smart device with communication functionality for the real home environment.

## RELATED STUDIES

In the latter of 1980’s, Winograd [25] suggested to design computer systems as tools for human lives rather than the “perfect” Artificial Intelligence (AI) as if another human being. At the same period, Suchman [21] criticized applying AI for designing HCI systems by ethnographically surveying the usability of the Xerox copy machine. In Suchman’s

description, examinees cannot easily utilize the machine, since the programmed instructions do not support their situated actions: the errors and problems they actually face are not expected by the system. Traditional media formats for recipes basically describe steps toward a perfect completion of cooking in text, which is usually difficult for non-professional users to reproduce the taste of meals.

Cooking support systems corresponding to users’ situated actions have been considered in HCI context since nobody is able to cook by going ahead with planned actions. Bradbury et al [7] designed an interactive cookbook supporting situated actions using eye-tracking and speech recognition technologies. Olivier et al [18] realized a situated coaching system by integrating projection systems, RFID, accelerometers, and under-floor pressure sensing technologies. Hamada et al [13] designed a cooking assistant system enabling users to cook several menus at the same time, recognizing the procedure and managing/keeping the time. While, Chi et al [9] designed a kitchen providing real-time feedback, tracking the number of calories in food ingredients.

Providing situated suggestions by real-time sensing and giving feedback, our system embeds the sensors in the physical pan wirelessly connected with the computer system. The combination of the pan and the interactive recipe application does not mean just a technical innovation, but provides a new user experience enabling users to enjoy daily cooking with trials and errors rather than skill-improving or automation-cooking. Mennicken et al [16] designed a very creative kitchen experience as if users can cook with a professional chef. Our work also suggests a new user experience to challenge a difficult recipe with situated assistances by following the video of chef’s cooking.

Furthermore, the panavi system integrates various technological aspects the previous works have used; using image, video, and sound instead of traditional text based recipes [11, 20], designing situated navigations by monitoring and recording conditions in videos and image [4, 24], or replacing everything related with cooking with a cooking agent robot [22]. Augmented Reality visualization using the projector compensates user’s senses by showing invisible things [5, 6] or provides efficient information for cooking such [14]. The sensor embedded knife [15] distinguishes what ingredients the user slices. The sensor embedded pan [3] monitors the current temperature on the LCD display in its handle. A consumer product [19] enables automated cooking by integrating a sensors embedded pan with a special IH cooking machine.

This research contributes to the HCI community firstly to provide a medium for recipes as a whole cooking support system, and secondly to suggest how to design an interactive system responding to human situated actions, for use as daily commodity to enrich the user experience in domestic life. This paper’s contribution is neither technical innovations nor scientific theory, as the technical element of the current prototype already has been used in both the research and the consumer product field. Main contribution of this prototype is integrating each technical element as a medium, analyzing the sensors data from the pan and suggesting to users what to do,

depending on each condition. This combination of analysis and feedback demonstrates a solution to human situated actions. The cooking process in the kitchen is generally tricky to deal with as it involves high temperature, water, cooking ingredients, kitchen utensils, and the unique experience of each user; meaning that there is no way to perfectly calculate the plan of the dishes ahead of time, and that the user must handle situated actions. Our design process case study from ideation to finished research artifact gives the CHI design community knowledge to develop smart daily commodities supporting domestic life.

## DESIGN PROCESS

panavi system was designed through an iterative process that consists of hardware sketching, software sketching, and small tests that the authors actually use for an ‘imperfect’ prototype. Before arriving to our first prototype described in this paper, we went through three phases; 1) the iterative sketching cycle—making three hardware prototypes with software sketching and conducting experiments four or five times by the authors using the prototypes, 2) a preliminary user study of the basic prototype with two persons, 3) implementation by designing a robust hardware prototype and re-configuring the software.

### Vision

Firstly, we focused on temperature control or maintaining the fire. Although temperature control is one of the most important skills for cooking, descriptions about it written in the cooking book are very ambiguous; low heat, medium heat, or high heat. It is said that some professional chefs can sense the temperature of pan, ingredients, or oil by physical sensation. Some touch the pan and feel the heated oil to sense the temperature, while others listen to the sound of water in the heated pan to gauge temperature as well. However, it is very challenging for domestic amateurs to practice these physical sensation, therefore we decided to develop a system providing real-time temperature sensing and feedback.

### Model Recipe

Prior to the sketching, we chose a recipe of Italian pasta Roman-styled *Carbonara* as an initial menu, because this recipe requires some cooking ways including sensitive temperature control, which is difficult to master. We quoted a recipe of Tsutomu Ochiai [2] a famous Japanese chef of Italian cuisines who sometimes appears in TV. After a trial and error process as described below, we formed an original cooking sequence for this system by arranging his recipe, referring to his texts and video tutorials.

### Iterative Hardware Sketching Process

Lower-fidelity iterative sketching process such as paper prototyping, drawing scenarios, or making videos has been required before designing the actual hardware when designers create an interactive artifact [8]. However, the kitchen is complex environment where accidents frequently occur. There are constraints to ensure the design through the lower-fidelity sketching for developing the tools used in the kitchen. Therefore we adopted an iterative hardware sketching cycle from the beginning of our prototyping.

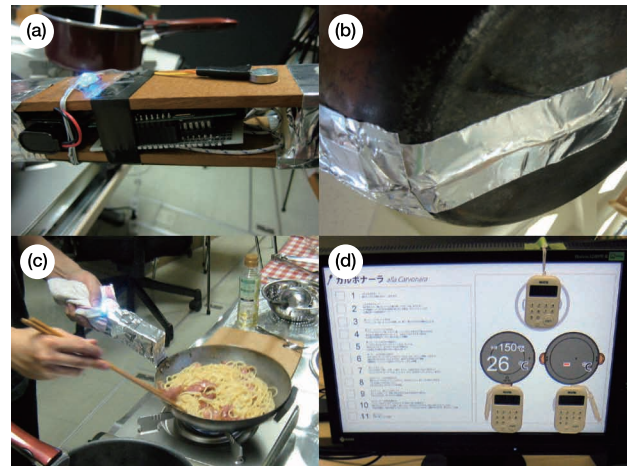


Figure 2. Initial Hardware Sketching; (a) Circuit, (b) Thermocouple Probe, (c) Experimental Cooking Using the Pan, (d) Display

Our iterative hardware sketching process consists of 1) making a trial hardware and software sketch, 2) test cooking using the sketch; the authors actually attempted to make *Carbonara* using the trial hardware and software, 3) finding problems and considering an improved plan, and 4) making a new prototype. At the initial stage, an iron-made pan with the thermocouple probe attached with aluminum tape, whose handle embedded a “MOXA” prototyping circuit with wireless communication function [23] and a full color LED, was crafted. The members of our developing team attempted experimental cooking several times, referring to the paper recipe and using this prototype (See, Figure 2). Through these trials, we found problems; the LED cannot be seen under concentration, the temperature sensor cannot measure correct temperature, and the assumed temperature settings were not suitable for actual use. Hence, we adopted a new idea projecting temperature value on the pan’s surface, changed the position of the temperature sensor, and also configured temperature settings at each point on the recipe.

### Preliminary User Study

After a basic prototype shown in Figure 3 was designed through the iterative sketching process, we conducted a preliminary user study with two amateur users, attempting to cook using the prototype in the domestic kitchen. In this study, users cooked *Carbonara* using the pan integrated with projection of temperature value, LED indications corresponding to proper temperature settings, and the embedded temperature sensor. During cooking, the users were required to coordinate the fire to keep the proper temperature which the system indicated, referring to the text recipe sequence displayed on the monitor and viewing current temperature’s degree shown on the monitor or the projection.

### Reflection toward the Final Prototype

From this user study, we observed that users had difficulty making a satisfying dish. Even if the users can keep the proper temperature control, the *Carbonara* sauce may be baked without physical actions such as stirring ingredients and shaking the pan. Hence, we added onscreen navigations



Figure 3. Left: The Prototype Used in the Preliminary User Study, Right: Setting of the Preliminary Study

in the form of stirring, shaking and moving by embedding an accelerometer in the handle of the pan that senses the pan's moves. In addition, we decided to provide video instructions to support text recipes on the navigation display. After this trial and error process, the current design of the system described in the following section was finalized.

## DESIGN: FUNCTIONS AND INSTRUCTIONS

### Special Frying-Pan

The special frying-pan (Figure 4-a) that can be used to cook ingredients over the heated stove, provides some instructions via LED lamps, vibration, and projection images. Five color LED lamps indicate temperature conditions and a vibration motor moves when the users' temperature control is good, which are embedded within the handle of the pan. The instructional graphics by the projection can also be checked on the display monitor to support the recognition of the projection when the pan is removed from the stove or when the projection cannot be recognized since there is much ingredient on the pan. If part of the system fails, other parts could still help the user (i.e. if the projector fails, the display and the LED indication work). See, Table 1. The temperature color changes from white to blue, green, yellow, and red, depending on the value, which also synchronizes with the LEDs. White is the default color or indicates when the condition temperature is too low, blue indicates 5-10 degrees lower than the proper temperature setting, green indicates when it is at the proper temperature within 5 degrees, yellow indicates 5-10 degrees higher, and red indicates over 15

TEMP (°C)	A	- 149	150 - 159	160 - 169	170 - 179	180 -
	B	- 0	54 - 64	65 - 74	75 - 84	85 -
	C	- 69	70 - 79	80 - 89	90 - 99	100 -
Color	White	Blue	Green	Yellow	Red	
Sound	—	the second hand of a clock	the second hand of a clock	the second hand of a clock	warning tone	
Vibration	—	—	ON	ON	ON	

Table 1. Parameters to Cook the Carvonara Programed in the System.

degrees to high. When the pan is being heated, the system makes a sound like the second hand of a clock at 1-sec intervals. When the color is red, it makes a warning tone. The user is required to stay within the green zone by controlling the stove by turning it off or cooling the pan. In addition, the instructions about actions such as shaking or stirring appear. When the pan should be shaken, an animation of an arrow will be displayed on the surface as shown in Figure 4-b. At the same time, the user is required to observe the specific instruction by referring to the texts on the display.

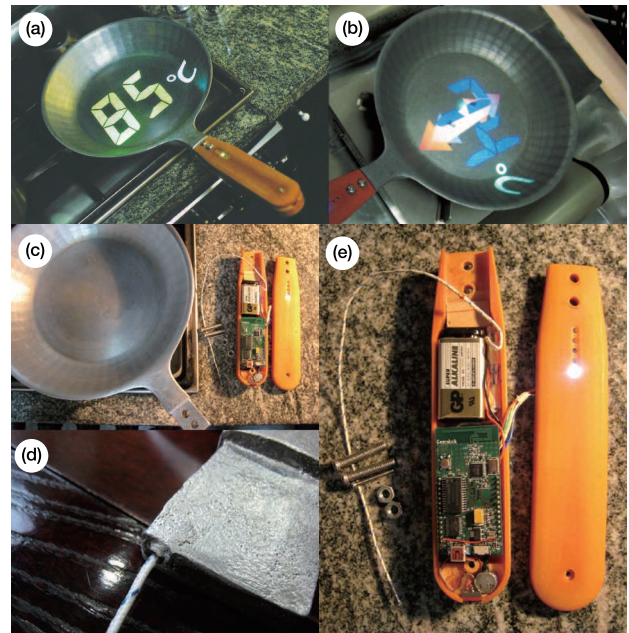
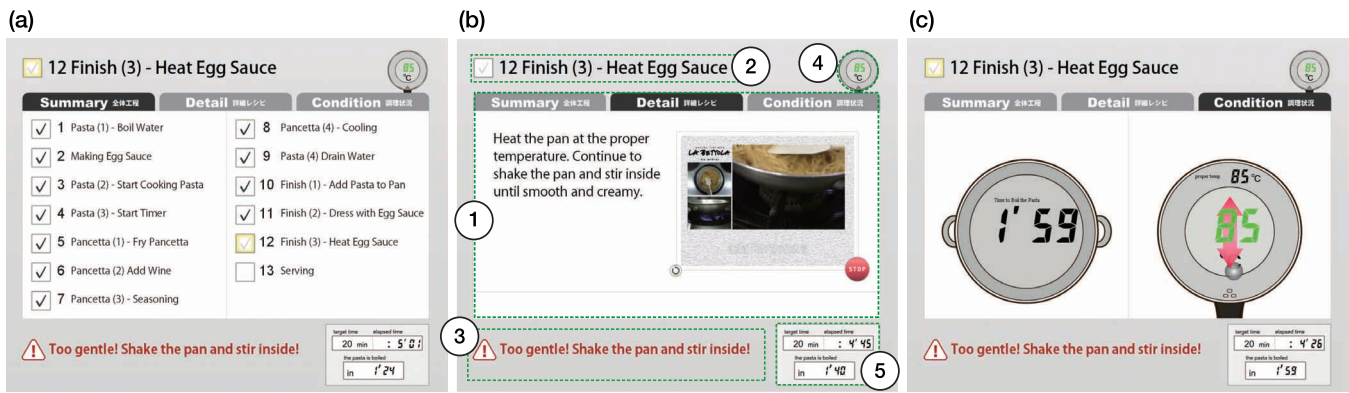


Figure 4. Special Fry-ing Pan; (a) Current Temperature is Projected, (b) Temperature and Action are Indicated, (c) Separated the Body and the Handle, (d) Stainless Made Small Pipe, (e) Inner Circuit of the Handle

### Display

There are three modes displayed on the main panel (Figure 5-b-1) that are loadable by touching a particular tab, which are 'Summary,' 'Detail,' and 'Condition' at anytime. The Summary mode (Figure 5-a) displays an overview of the text recipes and current progress. Detail mode (Figure 5-b) displays a detailed culinary art of the text recipe with video instructions, Condition (Figure 5-c) displays the boiling time, current temperature and the pan's movement like the dashboard of a car.

The current Step Panel and Checkbox (Figure 5-b-2) displays the title of each step (Table 2) and the check box that manages the procedure. The user touches the box when the current step's tasks are completed and the system recognizes it and loads the new navigation setting as the next step. Comment Panel (Figure 5-b-3) indicates the instruction messages including advice, caution, or alert texts depending on the current condition, which the user should notice continuously during the cooking process. Temperature Panel (Figure 5-b-4) is an auxiliary tab used when the user wants to check the temperature not referring Condition mode. Timer Panel (Figure 5-b-5), displays the target time to finish cooking, the

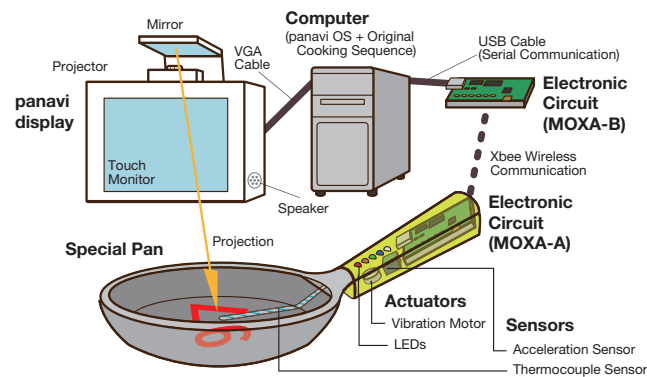


**Figure 5. Three Kinds of Setting Displayed in the Monitor; (a) Summary, (b) Detail, (c) Condition / Name of each Area [See, (b)]; (b-1) Main Panel, (b-2) Current Step Panel and Checkbox, (b-3) Comment Panel, (b-4) Temperature Panel, (b-5) Timer Panel**

elapsed time, and the timer of boiling the pasta, which is also a supplemental function to Condition mode.

### IMPLEMENTATION & ARCHITECTURE

panavi system mainly consists of three parts; the special kitchen utensil (frying-pan) with embedded sensors and actuators, the display system connecting the computer with the touch monitor and the projection system, and the software system showing cooking sequence information (Figure 6).



**Figure 6. System Architecture**

#### Special Pan

The main body of the pan is formed of cast aluminum, with a handle made of Bakelite that can be clamped to the body (Figure 4-c, e). The pan is embedded with two sensors. One is the J-type thermocouple sensor measuring the current temperature with a fast response speed that can sense the temperature shift continuously. A small, stainless steel pipe is implanted in the pan from one end of the handle to the center of the pan in order to embed the sensor. Another is the acceleration sensor also embedded in the handle sensing the movement of the pan. A MOXA [23] (MOXA-A in Figure 6) is embedded in the pan's handle, which wirelessly communicates with the computer system by sending the sensors' value to another MOXA (MOXA-B in Figure 6) connected with the computer as a server client. On the surface of the pan, the proper temperature and the instructions regarding movements are displayed from

the projector. Actuators, LEDs and vibration motors are embedded in the handle, controlled by the signals from the computer system via MOXA-B.

#### Display and Computer

The computer is connected with 'panavi display' packaging touch panel monitor and projector, and 'panavi OS' with the 'Original Cooking Sequence' works as an Adobe Flash application on the computer (as shown in Figure 6). The panavi OS displays the instructions by analyzing the sensors' degrees against parameters programmed in the system.

#### Original Cooking Sequence

The original cooking sequence models the recipe of *Carbonara*, consisting of videos and photos in addition to the general text recipes. For the panavi OS, this cooking sequence was reconstructed by the development team and its procedure is divided into 13 steps (as shown in Table 2). Each step is programmed with settings; temperature, sounds, and vibrations settings etc. (as shown in Table 1).

**Preparing Pasta (Table 2, Step 1-4)** When the checkbox of the Step 1 is touched, the elapse time counter from the beginning (See, Figure 5-5) starts. The normal cooking time is set to 20 minutes. When Step 4 is checked, the pasta timer shown in the Detail mode starts. The user should complete cooking the pancetta by the end of the time limit. The boiling time for the pasta is set to 6 minutes.

**Frying Pancetta (Table 2, Step 5-7)** At the Step 5, the temperature setting A (Figure 1-A, 165°C) is applied. In the Comment Panel (Figure 5-3) the instruction message is displayed; "Stop Heating" if the current temperature is too high, "A little hotter" if slightly higher, "Keep at this temperature" if it is on the proper setting, or "Heat up a little more" if it is slightly lower. The user is required to follow the instructions and keep the proper temperature.

**Cooling Down (Table 2, Step 8-9)** From the Steps 8 to 11, the temperature setting B (Figure 1-B, 70°C) is applied, because this setting is optimized to cool the pan. The instruction messages are displayed as follows; "Cool the pan on the wet washcloth" if the current temperature is higher than the proper temperature or "Go to the next step" if lower.

**Finishing (Table 2, Step 10-12)** On the Step 10 and 11, the instruction messages are displayed as follows; “*Cool the pan on the wet washcloth*” if the current temperature is much higher than the proper temperature, “*Wait a moment till the temperature drops*” if slightly higher than the proper temperature, or “*Put the egg sauce*” if lower. The users are urged to follow the instructions because the sauce will burn if the temperature is too high. After the Step 12 begins, the temperature setting C (Figure 1-B, 85 °C) is applied, which is optimized to heat the egg sauce with the pasta. This step models “*Stirring the sauce constantly until it comes to a boil and has thickened with shaking and swinging the pan,*” which is required for high level skills. The instruction messages are displayed as follows; “*Remove the pan from fire and shake*” if the temperature is higher than the proper degree or “*Heat up a little more*” if lower. In addition, the messages also have instructions about movements fed from the acceleration sensor; “*Shake the pan and stir inside*” when the pan is not shaken. The user must keep the temperature to 85 °C stirring the sauce very quickly.

## USER STUDY

This section describes the user experience of cooking using the panavi system. In order to earn detailed user experiences, we observed how the system effects the users’ behavior while cooking, verified the usability of the current prototype, and found its problems. The user study was conducted in an environment specially constructed in our research laboratory similar to the kitchen, as shown in Figure 7 and Figure 8-A. Total of four beginner or intermediate level persons in three groups without experience of making *Carbonara* were selected, because experts or professional chefs are able to cook without the system.

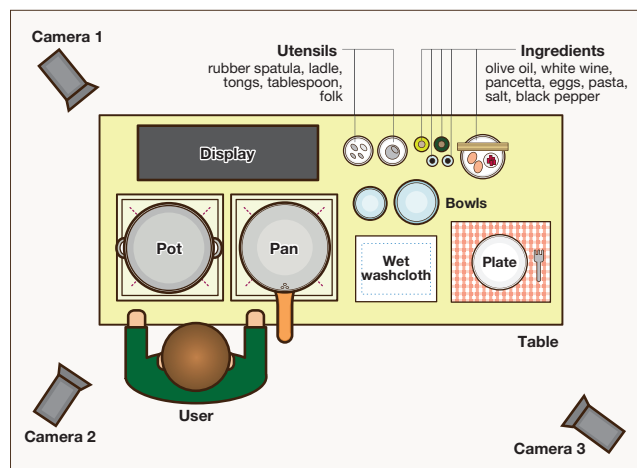


Figure 7. Layout of the User Study

In this study, we consider not only general or common findings but also each user’s originality; their respective backgrounds, and experiences about cooking. Not only does it improve the users’ skills but it provides fruitful experiences such as challenging to difficult recipes, enjoying cooking actions, and tasting delicious dishes even at home. Design researchers should not only evaluate the

### Step 1. Pasta (1) - Boil Water

Boil 8 cups of water in the pot.

### Step 2. Making Egg Sauce

Beat a whole egg with an extra egg-yolk in a bowl. Then add 15 grams of grated cheese and small amount of freshly-ground black pepper, and beat them well again.

### Step 3. Pasta (2) - Start Cooking Pasta

Put one and a third of tablespoons of salt and 70 grams of pasta into the pot.

### Step 4. Pasta (3) - Start Timer

Start the timer for boiling pasta. (Keep boiling for 6 minutes.)

### Step 5. Pancetta (1) - Fry Pancetta

Heat a teaspoon of olive oil in a pan. Add 30 grams of diced pancetta and fry over high heat to the proper temperature. Keep cooking until crispy and brown.

### Step 6. Pancetta (2) Add Wine

Turn off the stove temporarily and add 10ml of white wine. Heat it again at the proper temperature until almost no liquid remains in the pan.

### Step 7. Pancetta (3) - Seasoning

Turn off the stove and move the pan onto a wet washcloth. Add 50ml of boiled water from pasta pot to the pan along with a table spoon of fresh water. Shake the pan until oil and water are mixed well.

### Step 8. Pancetta (4) - Cooling

Keep the pan under the proper temperature.

### Step 9. Pasta (4) - Drain Water

After the pasta timer rung, drain the water from pasta well.

### Step 10. Finish (1) - Add Pasta to Pan

Add pasta and mix it to be dressed with the pancetta.

### Step 11. Finish (2) - Dress with Egg Sauce

Add the egg sauce into the pan. Stir with a spatula about 15 seconds until the yellow and the white of the egg uniformly combined.

### Step 12. Finish (3) - Heat Egg Sauce

Heat the pan at the proper temperature. Continue to shake the pan and stir inside until smooth and creamy.

### Step 13. Serve

Serve immediately to avoid after heat.

Table 2. Original Cooking Sequence’s Texts Displayed in the Main Panel (Figure 5-b-1) of the Detail Mode (Figure 5-b).

effectiveness of the system itself, but they must verify real experience of users with systems [12]. Because our work is not a scientific experiment system, we considered that quantitatively measuring user experience and effectiveness is not suitable, therefore focused on how each user’s experience has changed from their everyday cooking lives. This report describes the detailed experience including the user’s own context and differences among individuals; each user’s characters, previous experiences, and creative impressions through the user studies.

## Method

The user study was conducted in the following sequence. At first, the authors interviewed each user about his/her cooking experience, home environment, and other related things about cooking and diet in 5 - 10 minutes as a prior interview. Before starting the cooking, we introduced how to use this system in about 5 minutes and then gave the user about 5 minutes to learn the functions of panavi, actually heating the pan and showing the changes of the temperature’s degree, and touching the display to operate the system. In addition, we explained what the end goal of the process is by showing the photo of completed *Carbonara*, Figure 8-a. During the cooking, we did not help the user in all tasks except when troubles such as system errors occurred. After the cooking,

we interviewed the user in about 60 minutes as the posterior interview. The users were required to specifically explain intentions and impressions about each action, activity, and process of cooking, watching a video of his/her cooking.

This study was video-recorded in 90 minutes per group, total about 270 minutes. The scene when the user did the cooking was recorded by three video cameras each set at different locations as shown in Figure 7; Camera 1 is to capture the user's actions, Camera 2 is to capture the display, and Camera 3 is to capture the pan and actions on the kitchen table. During the prior interview, we recorded the user's face and voices using one camera. The posterior interview was recorded by one camera when the user talks, watching the monitor showing the video taken during the cooking activity.

Our user study method is constructed by arranging "video-cued recall method" Costello et al. [10] adopted to verify their media art works. The method is a way to interview the user watching the video of when he/she experienced the work in order to reveal the detailed user experience of the artwork. Moreover, it prevents ambiguous answers based on the user's objective interpretation comparing to the way to depend on the user's recollections. This method intends to restress the user, because the user can experience the work in a natural situation. In the case of our study, we did not interrupt nor ask the user about intentions or impression during the cooking sequence. To understand detailed feedback at each point during cooking and make thick descriptions about user experience, this method is highly efficient.

## Users

For this user study, we asked four persons in their twenties to use this system because we assumed they would be potential users if this future work becomes commercialized. Recipe books, cooking schools, and digital recipe contents are frequently engaged with young persons in their twenties in Japan. Therefore we considered to earn the user experience as our first user study.

User A, an attendee of Study 1, is a 23 years old male with little experience in cooking. He has an experience of living on his own for a brief time, but lives with his parents now. Although he has tried to do basic cooking such as fried rice or miso soup, he could not make them well. As a result, he does not do any cooking recently.

User B, an attendee of Study 2, is a 24 years old female undergoing simple cooking once or twice a week. She lives with her parents and gives some help to the parents' cooking ever since she was young. Her parents have interests in food and cooking, and hold their own home garden. Raised in such a family environment, she has basic knowledge of cooking, but has not had a chance to challenge authentic menus.

Study 3 was designed to see two persons co-cooking in the domestic kitchen, so two attendees were selected; User C, a 24 years old male, and User D, a 22 years old female. They are colleagues at the same graduate school. User C lives with his parents and brothers, having a wide experience as a Boy Scout member when he was young and in part-time jobs at a restaurant when he was an undergraduate student. He has

basic cooking knowledge and does cooking 3 or 4 times a week. User D lives on her own for 5 years and has a habit of cooking. After starting to be the single life, she mastered the recipe book for beginners her mother gave her, and utilizes web sites in order to expand her cooking repertoire.

## Results

### Study 1, User A

Since User A did not have much knowledge about cooking, he could not understand instructions and as a result, spent a lot of time cooking. Despite this, he followed each step carefully and completed his *Carbonara*; although the pasta was too soft. We describe highlighted scenes from the sequence (Table 2) in the following paragraphs.

While the Step 5, he started to cook after reading the recipe texts. In the posterior interview, he explained that he could not understand the detailed instructions for example "*Cold the pan put on the wet washcloth*"; he had no idea such as stopping the heating or using the washcloth after heating.

During the Step 7, even though the alert bell was ringing to announce the boiled time has passed, he did not seem like he was in a rush. After the cooking, he said "*I could not understand how the pasta will be affected by not carrying out the procedures quickly.*"

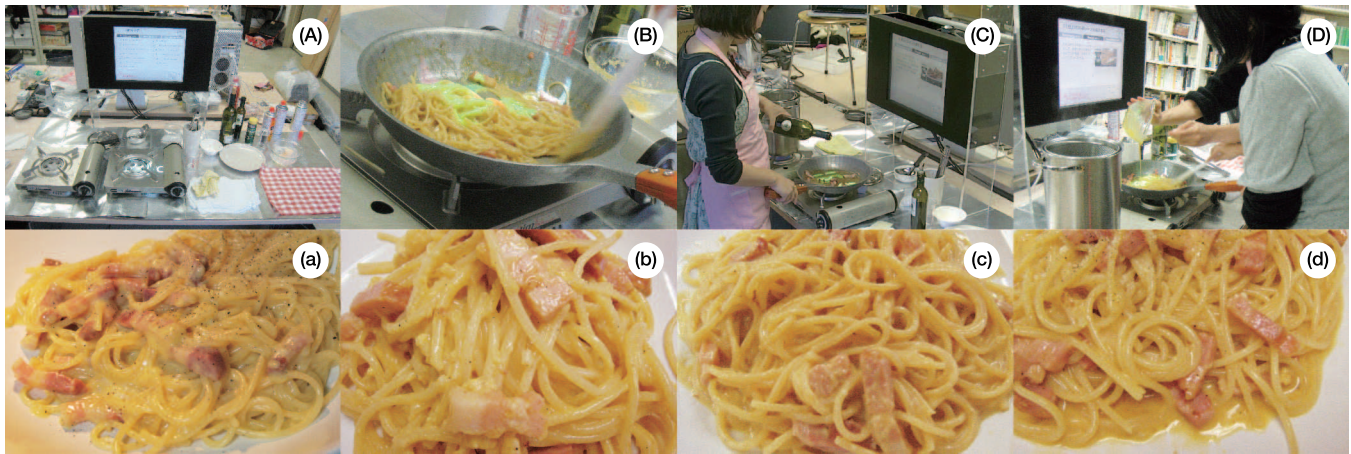
On the Step 11, he was about to turn on the stove even though the system says "*Keep the fire off.*" Then, he checked the monitor again, noticed his misunderstanding, and stopped to turn on the fire without minding the time. After the cooking, he said "*I was so anxious to re-read the Main Panel of the Detail mode many times.*"

Finally, on the Step 12, he finished heating the egg sauce with pasta very well in 2 minutes, by checking the video and the projection images on the pan and preventing 'red' or 'yellow' temperature indication (Figure 8-B). However, he could not stop heating the pan even after the sauce was thick and creamy. As a result, his *Carbonara* sauce was slightly baked compared to the perfect example (Figure 8-b). After the cooking, he said "*I could not image the completion, because I had never eaten this menu.*" Eventually, all of his cooking was finished in 32 minutes, which is over 10 minutes later than the normal cooking time.

In the posterior interview, he discussed some aspects of the design. For example, he said "*I could not judge between the important steps and the omissible ones throughout the all steps, because it was too much information for me to understand and follow. If I cook while talking to my mother on the phone, I can do it well as she comments directly. In case of using this system, it is challenging for me to think about all things.*" He also commented "*I would not like to use this system when my girlfriend comes to my home, because it does not look smart to depend on the machine like this. I like to use this system as a practice in private.*"

### Study 2, User B

User B, having a habit of cooking, had conducted most steps without difficulty. Rather, she seemed to enjoy the process



**Figure 8.** (A) Setting of the User Study (a), Carbonara the Author Cooked, (B) User A Heated the Egg Sauce Very Well., (b) Carbonara Sauce was Slightly Baked., (C) User B Poured the Wine in the Pan with Imitating the Chef's Action., (c) Carbonara User B Cooked., (D) User C Put the Egg Sauce into the Pan while User D Grasped the Pan and Stirred the Ingredient Using a Rubber Spatula., (d) Their Carbonara was Slightly Sloppy.

of cooking like playing a game, and completed a delicious *Carbonara* except it was slightly scorched at the end.

She easily finished the steps following the instructions until the Step 4. She was amazed to the visualized temperature degree at the navigation on the Step 5. When the temperature reached to the proper setting, she sensed the vibration from the handle of the pan and lowered the heat. Furthermore, when the system indicated the “yellow” temperature, she kept the pan away from on the stove and waited until it returned back to “green.” She speedily finished this step in 210 seconds from the beginning, when the ingredients have been baked slightly.

While the Step 6, she poured the wine in the pan imitating the chef's action shown in the video after checking the video two or three times, (Figure 8-C). After that, she turned on the fire and heated the pan until water evaporated. In the posterior interview, she said “*At first, I could not understand the meaning of the task on this step. It was difficult so I tried carefully, different from the previous steps.*”

During the Step 7, the alert bell for the pasta rang. After the cooking, she said “*At this time, I thought to improve my cooking's speed, being aware of time.*”

On the Step 12, she started the tasks after checking how to cook by reading the recipe texts aloud. The chef Ochiai [2] in the video said “*Don't turn the heat on high,*” she also repeated this sentence. When the arrowed line was displayed on the surface of the pan, she immediately responded to the signal and stirred the ingredients. She had completed the entire cooking sequence in 18 minutes, which is 2 minutes shorter than the normal cooking time.

She was engaged in the process with swinging tempo, sometimes reading the texts aloud and speaking to herself. In the posterior interview, she said “*I am very satisfied to make a delicious menu (Figure 8-c). I have felt the process was easier than I had imagined. But I might fail something to do without using the panavi.*” She has really enjoyed the cooking with the panavi.

### *Study 3, User C & D*

User C and D conducted the steps by dividing the tasks flexibly. Firstly, in the early steps, they enjoyed talking with one another, but in the latter part of the process they talked less and seemed to be concentrating on the work. Although they completed the dish perfectly before Step 12, their *Carbonara* was undercooked on the last step and were disappointed with the result.

On the Step 2, while User D made the egg sauce, User C provided the instructions to her by referring to the video. After that, they divided the tasks in several scenes, which had not been decided before the cooking. This division was conducted flexibly on a case-by-case basis, according to the posterior interview.

While the Step 5, User D took the pan and turned on the fire, and then User C measured oil using a spoon and poured it in the pan. After that, they continued to cook at low heat for a while, but the pan's temperature was not close to the proper degree (165 °C). Then, User C turned the fire up after viewing the monitor of the Condition mode and checking how far the current temperature was from the proper degree.

As a result of their collaboration, they completed the cooking with time to spare until the Step 7. When starting the Step 8, User C saw the Condition and checked the proper temperature for this step (70 °C). When the pan's temperature had been lowered to the proper degree, the alert bell for the pasta rang.

At first on the Step 11, User C put the egg sauce in the pan while User D grasped the pan and stirred the ingredients using a rubber spatula (Figure 8-D). However on the Step 12, she exchanged places with him and began to adjust the fire standing on his side, because User D was not able to shake the pan well. After a short time, User C removed the pan from the fire and put it on the wet washcloth, because the temperature had been too high. From the posterior interview, User C said “*I checked if it is suitable for the finish, but I judged it needs to be more time heated and put it on the stove again.*” After a while, he checked it again and arranged the pasta on a



plate. They have completed the cooking in about 15 minutes and 30 seconds, which was the fastest time among 3 groups. However, in the interview, we noticed User C worried about what the dish would be like if it was heated a little longer. As a result, their *Carbonara* was slightly sloppy (Figure 8-d).

Throughout the cooking, User C frequently checked the proper temperature referring to the Main Panel of the Condition mode, while User D read the recipe texts many times. The videos were rarely used and they cooked relying on their experiences. But from the interview, User C said “*We’d forgotten about watching the video.*” Since they had not seen the videos, as a result, they could finish the cooking very quickly. Both User C and D said “*I want to cook it again using the system,*” because they were disappointed in quality of the pasta sauce.

### Reflections

This study revealed the difference between the understandings of instructions for each group, because the users had distinctive prior knowledge and skills about cooking. User A, the beginner, repeated the same video at least twice or three times on each step, and also tried to faithfully follow the all of instructions. As a result, he ran over the normal time substantially. In contrast, User B finished the cooking quickly without watching the videos and depended on her own experience, except when she was dealing with the steps she thought was difficult. User C and D also used their own ways and completed the steps sometimes without checking the navigation.

We perceived the main feature of this system (the combination of sensing, analyzing, and navigation supporting users’ situated actions) took care each user’s differences, even for beginner users. Although User A had little knowledge about cooking and stumbled throughout many steps, he eventually succeeded on the Step 12, which requires a high skill level. The other two groups also controlled the temperature and moved the pan well at this point.

On the other hand, however, the system sometimes could not respond to the users’ situated actions because the instructions by texts and video tutorials are fixed and not changeable. For example, User C and D skipped to check the video tutorials since they understood basic ways to cook only when referring to the text tutorials, but they regretted not to see the videos at Step 12. If the system could suggest the users to inspect this navigation, they may not fail this process.

The current system is able to support cooking conditions such as the temperature or movements but does not support any other contexts. This is because the system cannot recognize if the user understands the tutorials, forgets to check, or is worrying about what to do. Regarding these aspects, HCI systems, especially cooking support media, should not only sense users’ conditions but also understand what the users need under some contexts and provide proper directions considering the individual experience and skills.

Furthermore, as a technical issue, the current system cannot navigate the timing of judging when the heating should be stopped especially on the Step 5 and 12. It would not judge when the heating should be stopped, because the system

cannot recognize some changes; how the pancetta is fried on the Step 5, how the moisture of the egg sauce is evaporated, and how long the sauce is heated to be creamy and not baked on the Step 12. The possibility of adding other functions to the system (e.g. measuring water amount, multiple-sensing temperatures, etc.) to solve this issue should be discussed.

### CONCLUSION

#### *Designing Smart Daily Commodities*

This paper described panavi, a new recipe medium format utilizing a special pan that analyzes sensors data, recognizes users’ conditions, and provides the users suitable navigation messages based on each situations. It consisted of an iterative sketching and prototyping process, an implementation for the initial menu *Carbonara* that requires specific temperature and movement control, and a user study of three groups.

Throughout the design process and the user study, we developed the system in the temporal kitchen set in our research place, and obtained a model for designing daily commodities (e.g. kitchen utensils) as smart objects enriching our everyday life experiences. This model consists of a technical framework and a methodology. The technical framework is the integration of sensor-embedded tool(s), wireless communication modules, and operating system; sensing and analyzing users’ state, and generating feedback suitable for each user’s situations. But this framework itself is not an innovative aspect. Rather, the methodology is important; the integrated technical elements should be designed as a whole system through the prototyping process in real domestic environments. In our case, panavi has been designed in the mock kitchen environment, not in a scientific research lab. This process is a way of designing user experience instead of ‘usability evaluation oriented researches’ Greenberg [12] strongly criticized. It is also an example of how to design artifacts supporting Suchman’s situated actions [21]. If (HCI) designers challenge to develop a new system for domestic users, they will be able to apply this basic model in a certain domestic context.

The basic design model of the panavi system—the sensor embedded daily commodities communicating wirelessly with computer system—enables the users to concentrate in cooking without noticing if it is a computing device. The appearance and usability of the pan seems the same as normal consumer products. Furthermore, the wireless communicative sensor-embedded tools are needless of any massive equipment to construct the system. Integrated systems based on HCI technologies, focusing on cooking support (e.g. [6, 7, 9, 16, 18, 20]), require complex or ambitious architecture, however, this design model is simple but sufficient and easy to set in current domestic kitchens.

#### *Future Visions*

This recipe medium may be applied to other menus. For example, French chefs skillfully move the pan with a high temperature in a minute when making an omelet, Japanese chefs season ingredients into tasty soup by sensitively controlling its temperature and osmotic pressure, or Chinese chefs dynamically move the pan to cook fried rice. As future works, we would like to measure and model chefs’ cooking

ways such as temperature and movement controls, and apply these data to navigation, and produce various kinds of recipe working on future prototype.

The design model of the sensor-embedded frying pan may also be applied to other kitchen utensils such as small and large pods, bowls, knives and chopping blocks [15], and etc. If multiple “smart” utensils may be integrated in a navigation application, this system will support various scenes; for more challenging and sophisticated menus, and multiple food preparations at the same time [13].

Developing the panavi system challenged us to design computer artifacts to be used in an extreme environment, the kitchen that is always associated with water and fire. Moving towards Ubiquitous Computing environments, HCI design is required to adapt with usages in uncertain but exciting everyday life. We will proceed to develop and improve this system to be more suitable for real domestic contexts and encourage people’s daily cooking to become more enjoyable.

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