Thermal Visualization on Cooking

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Abstract

Sensors for cooking such as a thermometer provide us essential clues for a better result. However, they only sense temperature on a certain point and the user's reaction is slow. Thermal cameras are capable of getting thermal images of a cooking pan, but it is difficult to utilize those images because the user has to rapidly shift their eye focus from the screen to the cooking pan, and vice versa while cooking. In this paper we propose a visualization technique that applies thermal information on cooking. The system enables users to acquire thermal information from the surface of the food on a cooking pan, using a thermal camera and a projection based Augmented Reality (AR) environment. The main contribution of this paper is to provide a technique to overlap thermal clues on the cooking pan without occluding the important information on cooking. We conducted a user study and discussed the potential applications of our technique.

Keywords: Visualization, AR, cooking, Augmented Kitchen.

1 Introduction

While we cook, we utilize visual, olfaction, and audio information to recognize the state of food on the cooking process. However, if we can use further information like thermal information which we can't assess from the vision that we gain with our own eyes, the result would be better. Nowadays, advances on sensors enable us to obtain such information about ingredients while cooking.

For example, thermometer provides accurate temperature measurement that is not available with our limited perceptions. Even a thermometer is capable of measuring the temperature, it only provides sensor value in numbers, which requires users to read.

With an advance of thermometer, thermal camera is available to obtain and analyze spacial temperature clues on cooking. The camera captures the surface temperature of the food and the user see a heat map on a display. This is a typical way to measure the temperature in an experimental cooking, or to analyze the cooking process in molecular gastronomy [8]. However, in this case, users have to understand the spacial relationship between the thermal image and the heating pan (Figure 2a). These reading and recognition process are obstacles for cooking.

On a heating process, such reading burdens are not only obstacles, but also results in failures of heat management such as overcooked or half-baked eggs. To address this issue, we explored a thermal visualization technique and developed an AR environment that provides easily recognizable thermal information.

One of the advantages of AR use on cooking [5] is that they reduce the reading burden of sensor values by mapping annotations directly onto the actual cooking space. However, they often clutter and occlude the main object of interests (e.g. food's color) with projected annotations. For example, projected annotations may hide the color of yolk.

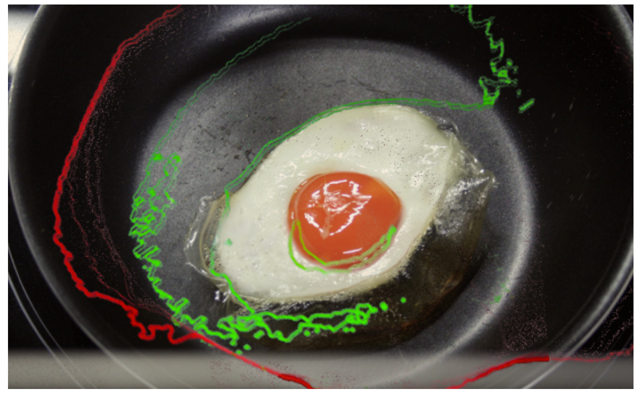

Figure 1: A visualized thermal image: the green line indicates 65℃ which is the congealing point of protein, and the red line indicates 145℃ which is the ideal temperature for cooking. Users can see both the temperature lines and the surface of the food at the same time.

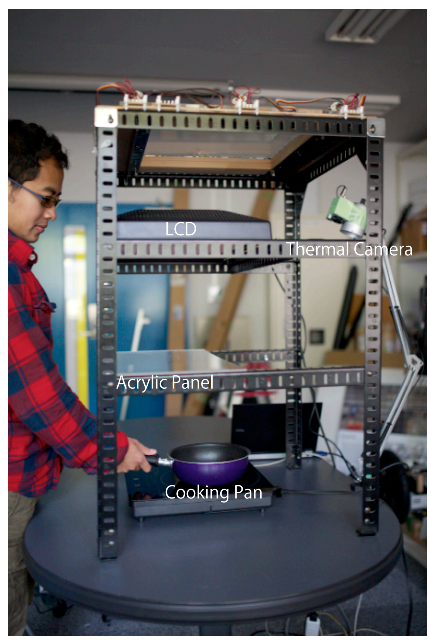

Figure 2: The system setup: the user can see the illusion image created by the LCD through the acrylic panel. The user sees an image as if the screen is arranged on the surface of the heater.

The contribution of this paper is to realize an AR environment that provides thermal images without disturbing or hiding important objects in the actual workspace (Figure 1).

2 Configuration

Our current prototype is described in Figure 2. The system consists of a thermal camera, acrylic panel, LCD display, IH cooking heater and computer. Our system's configuration is

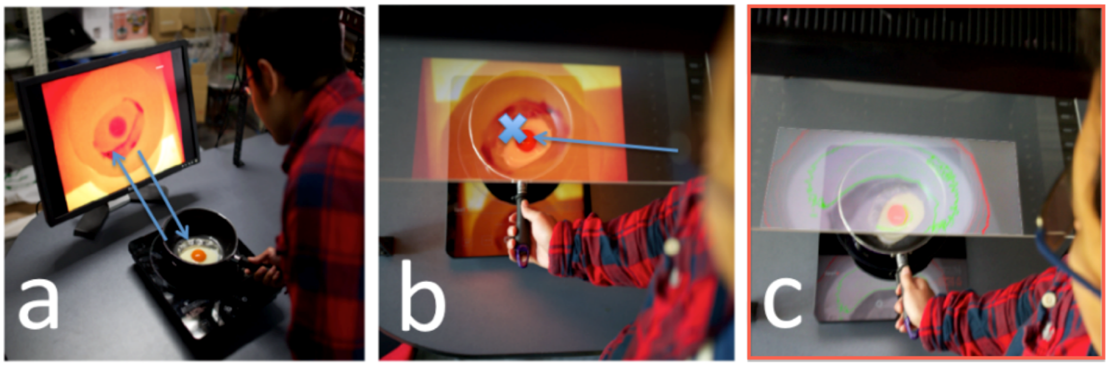

Figure 3: a) Thermal image on a screen makes the user understand the relationship between the image and the workspace by rapidly shifting his focus. b) Thermal image using AR environment: although the users can intuitively see the temperature of the workspace, it occludes the workspace for the user, and s/he miss important food surface changes. c) Our approach: contours indicate important temperatures for cooking. With this method, the user can obtain the thermal information without disturbing the workspace.

similar to Holodesk [2], which represents a simple but effective AR environment. In this configuration, users can see virtual images created by the LCD display through the acrylic panel. The user can see optically correct image, i.e., the user can see thermal images on the surface of the heater as if a screen is arranged on the surface of the heater.

Contours are generated as below. The server software of the thermal camera (provided by OptrisPI200 [6]) sends gray scale images (Lowest temperature as black, highest as white) to an image processing software. Then the image processing software generates contours on the configured threshold (the pixel value that is corresponding to the focused temperature, 65℃ in the case of omelet). Then, warps and adjusts it to optically fit the contours onto the bottom of the pan.

We used the OptrisPI200 [6] for the thermal camera. The measurement range is between 0 and 250 Celsius. The resolution is 160 x 120 with the frame rate of 128 Hz. The measurement error is within 2%.

We considered several possible methods to visualize the surface temperature of the cooking pan. The simplest configuration is to simply show thermal images on an independent screen (Figure 3a). This configuration requires users to understand the relationship between the thermal image and the actual workspace. As a result, the user has to rapidly shift his/her eye focus between the screen and the cooking pan.

Figure 3b shows an AR environment that simply overlaps the thermal image on the workspace. In this case, the user can see the thermal image without shifting the eye focus between the two spaces. However, in this case, the thermal image occludes the surface of the food itself. This is unsuitable for a practical cooking support because the food surface information such as reflection or color of the food is important for cooking.

The consideration of the two cases (Figure 3a and b) suggests an AR limitation of providing information about an object without occluding the object itself, as [3] suggested.

To address this issue, our system adopts the visualization of enclosing the area with similar temperature (Figure 3c). To minimize the hidden area of the workspace, the contours are limited within the important values involved on cooking: 65℃ (congealing point of protein) and 140℃ (ideal temperature for cooking). This configuration effectively visualizes the thermal information without occluding the workspace.

3 User Study

To confirm the feasibility of the system, we conducted a user study.

There are several recipes that require heat management. For example, boiling (e.g. stew) or frying requires careful heat management to heat the food sufficiently, or avoid over cooking. Although these recipes are suitable to evaluate the system in some cases, we used omelet recipe to evaluate the system by following reasons:

First, as the previous work shows, to evaluate a cooking support system, the recipe of the user study should be popular [4]. This is because distinctive prior knowledge and skills about cooking of participants make it difficult to evaluate the system itself. We considered omelet is suitable to evaluate the system because all participants have similar experience of cooking omelet.

The omelet is thin (we used only one egg for each omelet), and it requires rapid and accurate heat management compared to other recipes. We considered this difficulty makes it easier to evaluate the system limitation.

Our user study setup and procedures are described in the following:

- Our system visualizes the thermal information of the surface of the cooking pan as well as the foods on it.
- The contours indicate the temperature of congealing point for protein (65℃) while cooking.
- Participants are asked to bring the pan out of the heater if the contours are all disappeared (at this point, all proteins are just cooked and the egg is neither overcooked nor half-cooked).

We recruited two males (A, C) and one female (B). Participants were asked to cook an omelet with and without the system, one time for each. Every participant cooks 2 to 3 times in a week.

Professionals are not included, and they cook at home in their daily life. Participants were also asked to use the same type of heater prior to the user study. This is because the type of heater can be a strong factor of the result, and different types of heater requires a few times of exercise to get used to it.

Participant A is 27 years old, male. He lives with his family. He lived by himself for four years. He cooked for himself about once a week when he was living by himself. His brother and father are working for food-related companies, and he has advanced knowledge about food and cooking. He also cooks with his family using foods from his family's garden. He has own cooking pan for omelet, and he prefers better eggs.

Participant B is 25 years old, female. She lived by herself for four years. Currently, she lives with her family, and she often cooks with her family. Her mother is good at cooking, and she said she learned cooking by looking her mother. She is especially good at cooking Japanese foods. She also has skills and knowledge about sweets cooking, and she cooks sweets such as muffins and cookies about once a month with her mother.

Participant C is 24 years old, male. He lived by himself four years, cooks about twice in a week. His family lives near his house, and he often comes backs and cooks with his family. He likes Japanese and Chinese food. He also cooks using a cooking pan and used to it.

Participant A and B cooked an omelet with the system first, and C cooked an omelet without the system first.

3.1 Result

Figure 4 shows the result of omelet cooked with the system (left) and without the system (right). The result shows that the omelets cooked with the system are evenly heated and tender, while omelets cooked without the system are unevenly heated and overcooked or not half-baked.

We asked the participants about the results and the usability of the system. All participants answered that the omelets cooked with the system are more preferable compared to those cooked without the system.

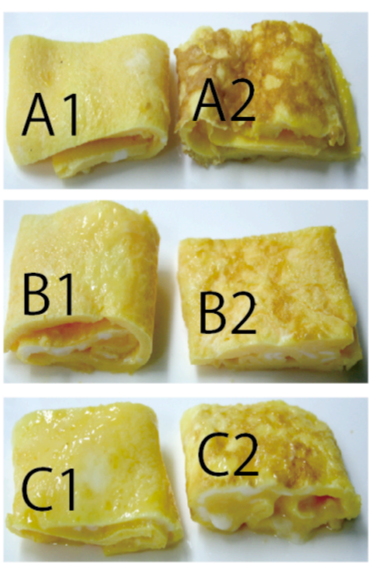

Figure 4: Results of omelet cooked with the system (left, 1), and without the system (right, 2) by participant A, B and C. Although each participant has different cooking skills, there was a significant difference between results 1 and results 2. Omelets cooked with the system (A1, B1 and C1) are smooth and tender while these cooked without the system are overcooked (A1) or half raw (C2).

In addition to the user's comment, we asked another five people to decide which do they prefer (We showed the real omelet of Figure 4), and four out of five preferred the omelets cooked with the system.

Participant A had difficulties on cooking with the pan, because he usually cooks omelets with specialized cooking pan. He also argued that the acrylic panel could be an obstacle for cooking.

4 Discussion

We consider that one of the reasons of this significant result is because we are not capable to see the denaturation of protein: when we bake eggs, visible changes of egg surface begin on 68-70℃, while egg's protein will be congealed with 65℃.

Using the system, users are able to see the congealing point of protein by the contours that indicate the 65℃ line and thus help to perform better heat management. All participants also answered that the contours were thin enough, and they felt no difficulty on cooking referring the contours and see the surface of the omelet at the same time.

Participant A commented that he usually estimate the temperature of the cooking pan according to his experience, but using the system, he could grasp the temperature, and also felt easiness because the system shows important temperature for cooking an omelet.

Participant B also answered that she was thinking that she cannot cook well in an unfamiliar kitchen environment because she uses lots of tools for cooking in her kitchen. On the contrary of her concern, she commented she could cook well because all she could focus on checking the important information in stead of relaying her experience.

Participant C commented that he has confident both of the omelet (omelets cooked with/without the system). However, he also commented that using the system reduced his work to check and estimate the temperature of the pan while cooking, and it made him to cook omelet easier.

These comments suggest that participants can manage the temperature of the pan using the thermal information without being disturbed by it. They also suggest that the system reduce their work to estimate the temperature of the pan. This is useful to help users to cook multiple foods simultaneously.

While minimum contours are enough for cooking an omelet, contours can be obstacles when the user needs to monitor several different temperatures. In this case, our visualization technique is not sufficient to provide thermal information to the user without disturbing the workspace.

5 Future work

This visualization is efficient for users to know if s/he has heated the foods enough. However, it is inefficient for them to find cooler area and smoothly correct the unevenness of heating, because the visualization only shows the temperature on the line, and it is not clear which side of the line is higher (Figure 5a). By providing thinner auxiliary lines around the main line (Figure 5b), the system can indicates heat information to the users. They are useful for the users to correct the unevenness of heating by moving the cooking pan on the heater.

In addition to the occlusion problem, AR fails when colors are mixed into the initial view. For example, the configuration for omelet (note that we manually used green and red contours for yellow omelet) is not applicable for Chinese food that often contains red or green food because the AR indication will be mixed into the colors of the view.

One of the simple solutions for this issue is to setup a camera to capture the color of the view, and color the indication in high contrast colors. However, it requires additional camera settings to AR systems that use non-camera information for AR (e.g. location information). In addition, it requires the camera to share the view with the user.

Our visualization technique will also support human perception in various situations (Figure 6). For example, on surgery, cutting a thick blood vessel causes extra bleeding which will be a crucial visual obstacle for a successful operation. Using our visualization technique, the surgeon can ware a lightweight AR devices such as Google Glass[1]. Based on the thermal information on the part of operation, the system can visualize important blood vessels, maintaining the workspace that contains complex issues, at the same time.

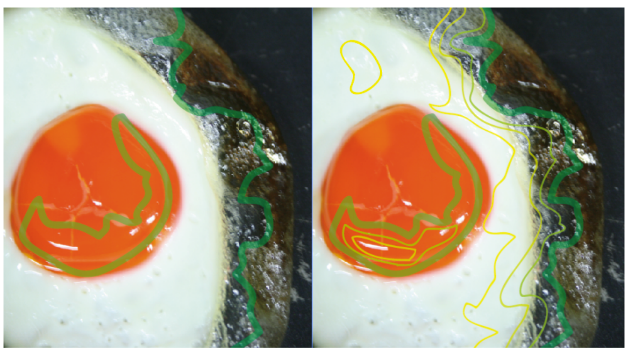

Figure 5: Contours indicate the important temperature without occluding the workspace (left). However, contours are often insufficient for users to know which side of the contour is the higher side. This makes users confused especially when they want to correct the unevenness of heating. Our system indicates the higher side by providing thinner lines around the main line (right).

Another possible application is air condition designing for architectures. Architects would be able to explore and inspect functional defects of the air conditioning on the architectures, at the same time confirming materials of walls or windows.

Recent studies show practical and low-cost implementation for gaze tracking [7]. They are useful to analyze where and what people tend to see in the workspace.
Analysis of the gaze tendency would reveal the important area where people frequently see. By using this data, the thermal information can be arranged more effectively to avoid the important area, and appear where people less frequently see. For example, by tracking chefs' gazing area during cooking process, the system finds areas where chefs less frequently see, and arrange the thermal information visualization.

6 Related work

Previous works focusing on cooking activities have been proposed: Panavi [4] supports professional cooking at home using video instruction or thermal sensor attached on the pan. As far as we know, Panavi is the first experiment that utilized thermal information of a pan for real time feedback. Although it supports brief thermal information, and thus the system cannot measure the temperature of cooking ingredients.

Bonnani et al proposes a graphically enhanced kitchen environment. Counter Intelligence [5] is a system to provide an AR environment in a conventional kitchen. Their focus is to coordinate between multiple tasks and increase confidence in the system with the projection of information onto the surfaces of objects in the kitchen or cookware. Counter Intelligence includes five discrete systems. HeatSink and RangeFinder provide techniques to provide temperature information in the kitchen.

HeatSink is a thermal information display that colorizes cold water as blue, and hot water as red. Although their thermal visualization of water is simple and effective display, the application is limited in transparent water.

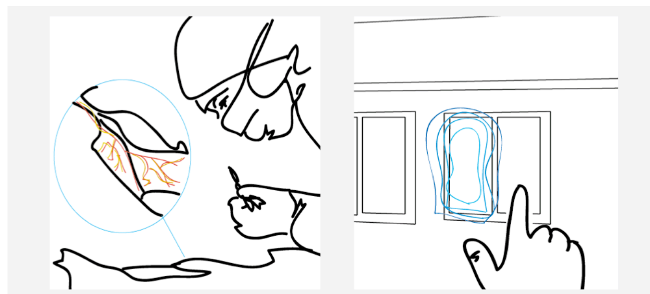

Figure 6: The system can visualize important blood vessels to the surgeon without disturbing the workspace that contains complex issues (left). Another possible application is air condition designing for architectures. Architects would be able to explore and inspect functional defects of the air conditioning, at the same time confirming other conditions such as materials of walls or windows (right).

RangeFinder [5] measures the surface temperature of the food while cooking using a remote infrared thermometer, and projects useful information directory onto the cookware or food itself. For example, it determines when food reaches a desired temperature (for example, when water boils), and time the duration of the state.

The difference between CounterIntelligence and our system is that our system provides detailed information without occluding the workspace while CounterIntelligence is based on projections. In this configuration, detailed information projected around the workspace confuses the busy user because users have to shift their focus between the information and the workspace. For a more suitable visual support, the information should be visualized on the workspace to reduce user's focus shift. In this case, projections are unsuitable because projections on foods make both colors undistinguishable. Our system provides a practical visualization technique and AR environment for the temperature control without confusing the temperature information and the workspace.

7 Conclusion

This paper proposes a visualization technique of thermal information in cooking environment using a thermal camera and simple AR environment.

Our contribution is to provide thermal information without disturbing the cooking workflow. Our system visualizes contours which indicate important temperature to avoid overlapping thermal information onto the workspace.

We conducted a user study and demonstrated the utility of our approach where participants advanced their skill in cooking an omelet. We conclude this paper by discussing limitations and potential applications.

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