Digitally Enhanced Utensils: Designing Dynamic Gustation

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Abstract. While modern cuisine uses various materials such as powder, oil and chemical materials, time-sensitive materials such as bubbles or temperature are still not considered as part of the design of cuisine, due to their temporal nature. Although these time-sensitive gustation play an important role in cuisine, it is difficult to serve them with human hands and static utensils. In this paper, we will introduce sensing and actuation mechanisms to maintain and enhance time-sensitive gustation. We will explore the design space of digitally enhanced utensils through three research prototypes.

Keywords: food, utensil, cutlery, kitchen, cooking, cuisine, dining, wet materials.

1 Introduction

The history of cuisine is also the history of the discovery of tools and technology. For example, fire enables humans to make raw foods edible, and yeast is essential for breads or fermented food. Novel tools of cuisine were also developed as the industry has been grown. Motors contribute to affordable mousse or whipped cream, and stainless steel is necessary for modern tools in cuisine. In this sense, the development of cuisine emerged from the development of technology. On the other hand, the history of cuisine is also based on heuristic process, and scientific knowledge on cuisine's methods or reasons for recipes has not been explored. Absence of scientific viewpoint and technology for metrology is one of the reasons of this. In fact, French cuisine had been focusing on only the ingredients for a long time before chefs began to indicate the amount of ingredients.

Molecular Gastronomy

Recently, science has begun to explore these little-understood parts of cuisine [17]. This field, called molecular gastronomy [9][10], investigates the physical and chemical transformations that ingredients undergo while cooking. Knowledge based on this investigation not only unveils the cooking process, but also contributes new cooking methods. With the development of a scientific point of view on cooking, chefs began to use digitally augmented cuisine methods. One example is sous-vide. Sous-vide is a

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cooking method for heating foods with accurate heat management. It uses thermostat chambers to heat ingredients evenly [17]. For example, when cooking meat with sous-vide, by heating meat in oil heated 70 Celsius, the lowest pasteurization temperature, chefs can cook the meat rarer than possible with other cooking methods. As another example, when chefs extract the flavor from herbs, they must be careful of the time and temperature, because one degree or one second of error produces bitterness Thus, chefs can control physical parameters to maximize the quality of the food in the kitchen.

Food in Dining

However, the quality of foods is out of the chef's control when they are served from kitchen to the diner (Fig 1). As time passes, the temperature or taste changes, or ingredients are mixed when the guest eats them, and the food changes into something which is far from what the chef intended. This means that foods are not as designed when they are on the table, even though the chef prepares them carefully in the kitchen. The quality of dishes decreases as time passes. For example, protein and oils in meat get hard and it loses its juicy flavor as the steam escapes. Clam soup or sherbet also loses its quality because of temperature changes. Some methods use heated utensils to maintain the quality of food. For example, while the temperature of steak starts to get lower when it is served, by serving it on a heated iron plate, chefs can prevent the decrease of temperature to some extent. Another example is using cooled glasses to prevent cold drinks from lose their quality as the temperature rises.

However, heated iron plate is not effective when it is not hot is not enough, and the foods are overcooked when the temperature is too high. Cooled utensils have same problem. The way of eating is also another problem that changes the taste of food which chefs cannot control. This means that the act of eating is not the part of the design of cuisine, even though careful and precise design is possible in the kitchen.

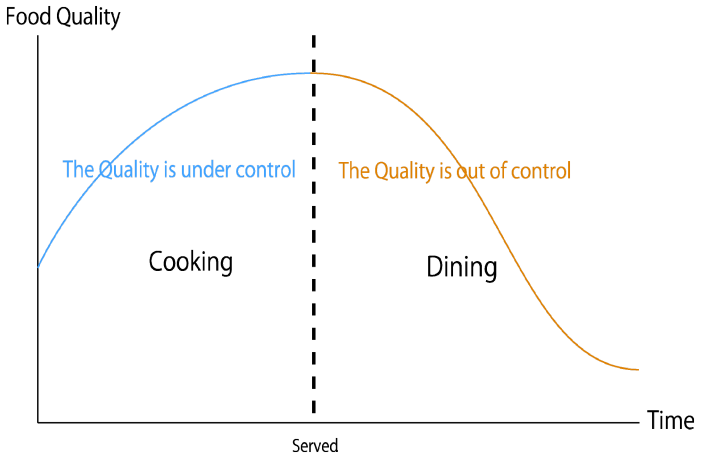

Fig. 1. Food quality after serving dishes: while the food quality is carefully and precisely controlled in kitchen, they are losing quality after serving and out of the control while dining

Thus, while dining, the quality of food and taste is difficult to maintain, and often the food is far from what chef has designed in the kitchen. This paper introduces digitally enhanced utensils that actuate ingredients to make the consumption of foods part of their design. We introduce three prototypes and discuss how sensing and actuation mechanisms can contribute to cuisine design.

2 Related Work

HCI and Food

Dinning Presenter [14] is a system that augments dining experience. This system shows images or changes the color of food. SpotLight [1] is a system implemented in a desk light to enhance the quality of food from its visual and sound aspect. These systems that use projector in dining context is effective only on its visuals and not on the gustation. One of the advantages of these systems is that they can be implemented in distant place by using roofs or lighting devices that naturally exist around the normal dining. On the other hand, distant from chemical materials of foods, they are not useful for augmentation of the gustation itself.

Some studies leverages physiological aspects of gustation. The gustation is composed by multiple senses such as visuals, sounds or texture. MetaCookie [12] modifies the gustation of cookie by augmenting its visuals using HMD and providing scent using an olfactory display. Another system changes the texture of food by providing the chewing sound when the user is eating food of another texture [4]. These systems can change the gustation of food, but they require large-scale devices that are often difficult to be accepted in the current dining setup.

Thus, existing studies for augmenting gustation has two divided research approach: one is fine for the dining context with less effects, and the other uses large scale devices with effective augmentation on the gustation.

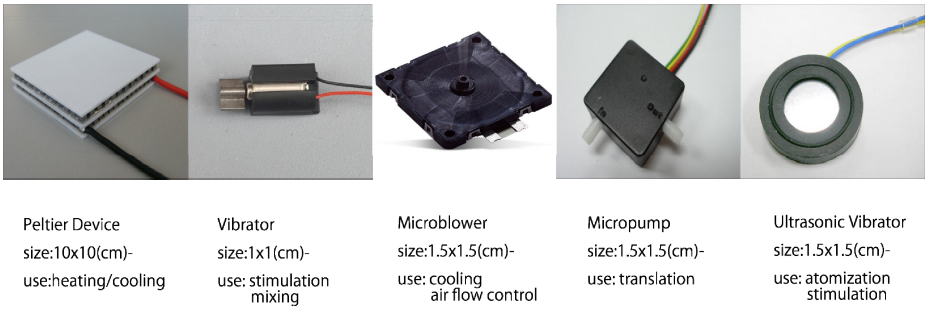

Fig. 2. Novel actuators for foods: actuation to food is difficult because the essential of food is based on chemical materials

Novel Actuators for Food

One of the disadvantages of existing research products for food augmentation is that they requires large scale devices to actuate food itself including the chemical

materials in the ingredients. To overcome this difficulty and design devices that effectively augment food with minimum complexity and smaller system, we surveyed actuators available for food augmentation. In this section, we explore the actuators that can effect to chemical materials or structures of food (Fig 2).

Peltier device can create a heat flux that is useful for cooling or heating materials attached on the device. It requires heat sink because it does not create heat itself but move heat from one part to the other part.

Vibrator is one of the smallest devices that can effects on foods. The taste changes not only by its temperature but also by mixing ingredients.

Microblower is useful when quiet and small blow is required. This device is used as one kind of fans in a small space. Using this device, chefs can control the flow of aroma or dry and cool the food.

Pumps are also effective to change the food's situation. They are not only available for moving ingredients, but also create a dynamic gustation changes while eating.

Ultrasonic vibrator can mix ingredients as the normal vibrators. In addition, it is effective for chemical changes without sound, in some cases. For example, when using ultrasonic vibrators for liquid materials, it can atomize the liquid, in other words turns liquid into mist. This is useful to change gustation without large-scale devices.

We designed three prototypes based on this survey, considering its size, effects on food and its cost. Actuators used in the prototypes are smaller than the quarter size of a normal dish for one guest, effect directly on the chemical materials and cost lower than one normal dish.

3 Research Prototypes

3.1 Heat

Temperature is one of the most important elements that create the gustation of food. Heating food is effective to make rising aroma and soft texture of foods especially they contain fat. HEAT is our first prototype designed to maintain the temperature of the food. For example, it maintains the temperature of meat just lower than its melting point, serving soft putty.

Mechanism

Heat consists of Peltier device, thermo sensor, and microcontroller under a stainless plate. The Peltier device heats the plate when the temperature of plate gets lower than the setting temperature. The sensors and switches of Peltier device are contoled by the microcontroller, and it also records the temperature changes while eating. The Peltier device can not only heat, but also cool the plate. The amount of the device is dependent on the plate, so the system can provide heated food and cooled heat on the same plate maintaining each temperature.

Evaluation

To confirm the effectiveness of HEAT, we conducted a study. In this study, we used cooked pork and used HEAT to maintain the temperature of pork. We measured the

temperature of pork with and without the device. In both measurements, we set the temperature of the air around the pork (room's temperature) and other conditions that may effect to the result. The desired temperature is 30 Celsius, and the temperature of the room is 25 Celsius. We repeated the measurement for five times.
The graph (Fig 3. (d)) shows the average of the results. It shows the pork on HEAT keeps around the 30 Celsius that is the desired temperature, while the pork without the system gets 25 Celsius in 10 minutes. The over shoot was with in 3 Celsius.

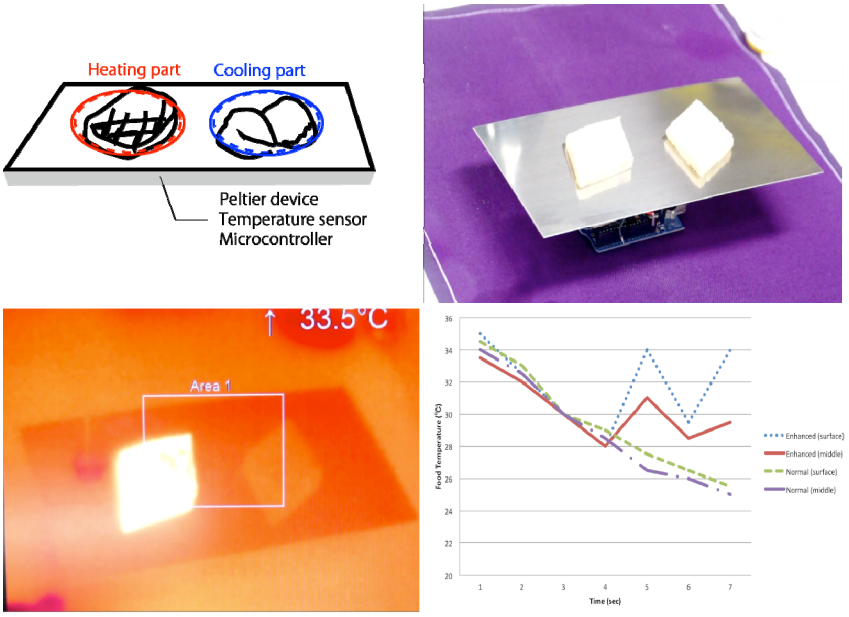

Fig. 3. HEAT: a) HEAT can provide heating and cooling part on one plate. b) Appearance of the device. c) Thermal image of HEAT. d) Evaluation of heat transition.

3.2 Pafuma

Stimulation by vibration
While bubbles in Champagne carries its aroma [6], 80% of them are disappearing to the air. PAFUMA serves bubbles before they are lost while we are just holding the glass. PAFUAM with vibrator stimulate the beverage and enhance the aroma of champagne. It stimulates the beverage just before the guest approaches to the glass when drinking.

Transformation by atomization
Aroma emerges from the surface of liquid material. PAFUMA with atomization device actuate the beverage and transforms it into moist and strengthen the aroma. It uses ultrasonic vibrator to atomize the liquid when the guest approaches to the glass when drinking.

Mechanism

A photo reflector was provided on the edge of the glass works as a proximity sensor. As the guest drinks the beverage and approaches the sensor, it detects the drink action and turns on the vibration or atomization. The time and power of actuator are programmed in the microcontroller in advance.

Evaluation

We conducted a study to investigate the effect of atomization device. In this investigation wine was used as the example of beverage. We used wine because it has strong and complex aroma. Complex aroma is useful to investigate detailed effects on the aroma.

We approximated the flow of aroma to the alcohol because the airflow is the strongest factor for each material. We used TGS2450 [8] as the sensor to investigate the density of the aroma. This sensor detects several gases including alcohol. We measured the density of alcohol in the air while user drinks 100ml wine using the sensor attached on the edge of a wine glass. We measured the density with and without the device. The sensor on the edge is located where the user's nose approaches when drinking wine to investigate the air the guest actually smells.

The figure (Fig 4. (e)) shows the result. It shows the density of alcohol has been enhanced when with the device. The waves seen in the graph is because of the airflow around the glass.

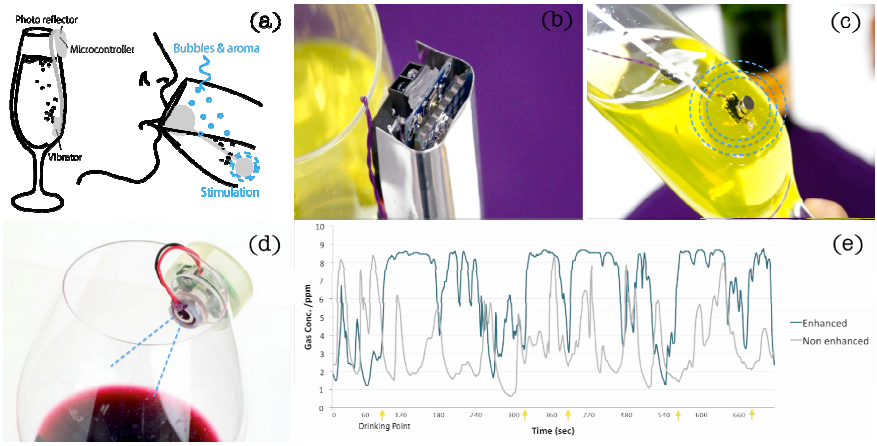

Fig. 4. PAFUMA: (a) PAFUMA stimulate/atomize liquid in the glass and enhance the aroma when drinking. (b) Approximate sensor and microcontroller. (c) A vibrator attached with magnet (d) Atomization device with ultrasonic vibrator. (e) Evaluation result.

3.3 Midas Spoon

In French cuisine, course is a normal way of serving dishes. The course can design the order of the gustation by limiting the edible foods for guest. It usually serves appetizer first, and desert last to provide satiety.

This is a technique of restaurant to design the gustation while dining invented by Escoffier, a French chef. Before the invention of course, appetizer and desert had been provided at the same time, and the dining was chaos of gustation. However, even with this technique, chefs cannot design the gustation changes on one dish. The order, amount and the changes of gustation are dependent on the gust.

MIDAS SPOON is an augmented spoon to control the changes of gustation while cooking. It changes the taste of food by adding seasoning while eating by pumping flavored sources for each bite.

Mechanism

The system consists of seasoning pumps, nozzles from pumps and shooting needle to shot the seasonings. The needle is also a touching sensor and shots seasonings as it detects the eating gestures. The types and amount of seasonings are programmed in advance and the system changes them referring the eating process detected by a weight sensor provided under the dish. GUI to program the timing and amount of seasonings are provided for chefs. The GUI consists of icons that represent the seasonings, and a programming field which consist eating process in the horizontal axis and the amount of the seasonings in the vertical axis. Chefs can program the types and the amount of seasoning by putting icons on the field. The program can be installed in the microcontroller. The microcontroller actuate the seasoning pumps according to the eating sensor and the eating process. As the microcontroller actuate the pump, the needle shot the seasonings through the nozzles. The seasoning can be done in the guest's mouse.

Fig. 5. MIDAS SPOON changes the gustation while eating by shooting seasoning when the guest eat food and touch the needles

4 User Study

To confirm the effect of each device on the gustation, we conducted user studies for each device. The user study has two parts: one is to investigate if guests prefer foods

enhanced with the device for HEAT and PAFUMA, and the other is to investigate the detailed changes by atomization of food for PAFUMA. For the first part, 3 males and 2 females were recruited. No professional for food (e.g. sommelier) was included. Participants were asked to eat lunch 3 hours before the user study to eliminate the effect of satiety. They were encouraged to be relaxed to eliminate the effect of the metal condition.

The user study for HEAT is to investigate the effect of the gustation changes when the food is heated from the bottom by the Peltier device. Participants were asked to eat two pieces of pancake. Temperature of one piece was maintained 30 Celsius, and other was provided without the temperature management (as served naturally on the plate). We asked participants to comment on the device as an eating utensil, and asked to eat and compare the taste, then decide more preferable one. The order of eating two pancakes was randomized for each participant to eliminate the effect of after tastes.

The appearance of PAFUMA is more complex and thus unnatural compared with ordinal eating utensils or HEAT. So we tried to investigate the effect of the visual aspect of the device. The hearing process of user study is same as HEAT, although we encouraged participants to comment on the visual aspect of the device.

The study of PAFUMA has two parts because PAFUMA has two different actuations: vibration and atomization. For vibration, participants were asked to compare the taste of the aroma with and without the device, and for atomization, more detailed changes of aroma (including how it changed) was investigated.

To evaluate the stimulation, participants were asked to compare the taste of champagne with and without the vibration, and decide more preferable one. The order in the comparison was randomized for each participant. To evaluate the atomization, participants were asked to drink wine with and without the device and compare the taste, and decide which is more preferable. In addition to the evaluation, we investigated detailed aroma changes by the device. We used LIEDEL's evaluation sheet and asked participants to evaluate 5 elements that creates the complex aroma of wine in the range from 1 to 9. For comparison of evaluation of 5 elements, we prepared normal wine and decantaged (enriched by mixing air) wine in addition to the atomized wine. Participants were asked to compare the three wines with blind and fill the evaluation sheet.

Result

The result shows that both of the devices have certain effect on the gustation of food. On HEAT, the result shows significant effect and 4 in 5 participants preferred the piece with temperature was managed with the device. Visual aspect was also confirmed to be acceptable. All participants did not feel uncomfortable or it is unnatural as an eating utensil. Some participants were not even aware of the device under the plate although the height of the device is much higher than the ordinal eating utensils.

On PAFUMA, as for vibration, 4 in 5 participants preferred the champagne with the device. As for atomization, while all participants felt that the aroma was strengthened with the device, some participants commented that the aroma smelled different. In other words, the aroma was not simply strengthened by atomization but some particular parts of the aroma were enhanced.

According to the comments by participants, the large-scale devices can discomfort the user even with the size of the prototype. This is because the current ordinal utensils are so sophisticated in its visual aspects and most of them are simple on the contrary that the prototypes that include microcontroller or sensing mechanisms are not.

In HEAT, which consists all complex mechanism under one simple stainless plate, has been accepted naturally for the participants. In this sense, PAFUMA can be improved in the visual aspect, by implementing the device in the bottom of the glass.

On the other hand, MIDAS SPOON which is a directory digitally enhanced eating utensil, requires materials or shapes which is usually not used in the dining and makes participants uncomfortable. This is because the texture of surface is different from the eating utensils used in the ordinal dining. Surface covering with another material can be help to overcome this problem.

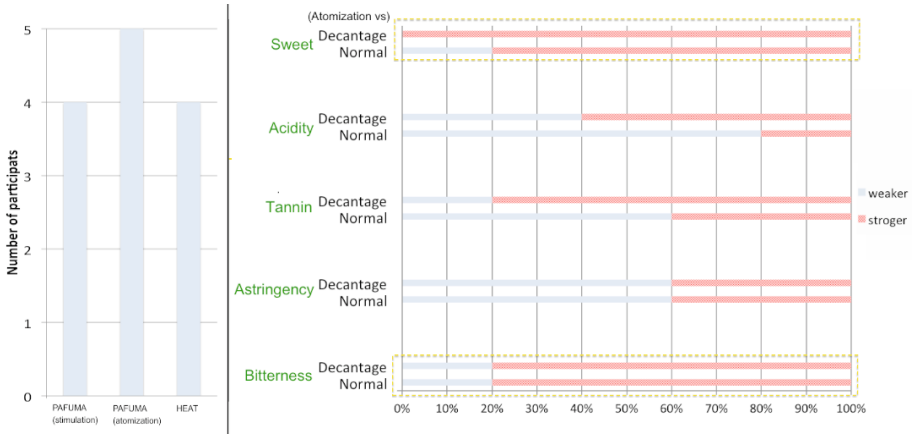

Fig. 6. Result of the user study. Over half participants preferred food supported with each device (left). We investigated detailed response to PAFUMA of atomization (right). The result shows sweet and bitterness gets stronger with atomization.

5 Discussion

Recent science reviles the relationships between the shapes or materials of utensils that effects the gustation of food. In the study, scientists found that the taste of foods differs when participants eat with different shape of spoon. They also investigated the effects of colors of eating utensils. Some eating utensils are carefully designed so that the shape of them maximizes the food quality. Glasses for wine, for example, are designed for the type of wine. In this case, for some type of wine, the glasses are designed so that it maintains the aroma in the body of glass. Glasses that maintains aroma in the body are developed for some types.

However, the design is still heuristic, and the viewpoint of metrology has not been provided as in the industrial design (e.g. automobile). In this sense, it is possible to introduce the viewpoint of metrology by investigating the food or gustation changes

that differs in the shape of eating utensils. Simulation and sensing techniques are useful to design the effective shape of eating utensils. In this case, the computation works the background of the design of eating utensils thus the results consists only with the materials that are used in the ordinary dining.

6 Conclusion

Three prototypes are introduced and evaluated as the digitally enhanced utensils. The evaluation proved actuations for foods are effective to augment quality of food, although the visual complexity affects negatively on the gustation. We discussed the possibility of computation, sensing and actuation mechanisms on designing eating utensils to enrich food.

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