Enabling Nutrition-Aware Cooking in a Smart Kitchen

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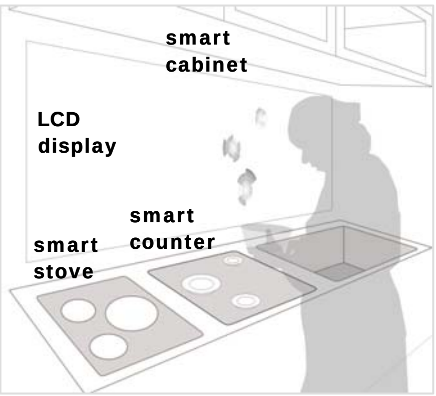

figure 1. Smart Kitchen promotes healthy cooking awareness and cooking interaction to the cook.

Abstract
We present a smart kitchen that can enhance the traditional meal preparation and cooking process by raising awareness of the nutrition facts in food ingredients that go into a meal. The goal is to promote healthy cooking. Our smart kitchen is augmented with sensors to detect cooking activities and provides digital feedbacks to users about nutritional information on the used food ingredients. We have created a preliminary prototype for evaluation, and the result is promising.

Keywords
Context-Aware Computing, Ubiquitous Computing / Smart Environments, Home Computing, Interaction Design, Kitchen, Nutrition

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction
A kitchen at home is a place to prepare and cook meals for a whole family. Food preparation can be considered as an act of caring for family members. Through cooking healthy foods for their beloved family members, they receive self-satisfaction in promoting health and reduce risks of chronic diseases in the family. For example, if a

Chili with Beans

Nutrition Facts	
Serving Size: 1 cup (253 g) Servings per container: 2	
Amount per Serving:	
Calories 260	Calories from Fat 72
	% Daily Value
Total Fat 8g	13%
Saturated Fat 3g	17%
Cholesterol 130mg	44%
Sodium 1010mg	42%
Total Carbohydrate 22g	7%
Dietary Fiber 9g	36%
Sugars 4g	
Protein 25g	

figure 2. Sample nutrition facts on the package of foods.

family member is diabetic, special cares should be given to prepare meals with lower fat, protein, and sodium [1]. However, studies [11] have shown that average family cooks may not know how much nutrition goes into their cooked meals and whether the used food ingredients are considered healthy for each of their family members. Although most packaged foods in grocery stores list nutritional information on the package, a.k.a. Nutrition Facts (Figure 2) [10], it is rather difficult for the cook to calculate overall nutrition after cooking and mixing many ingredients together.

Therefore, we aim to promote healthy cooking to the average family cooks by raising awareness of healthy food ingredients and their nutrition facts. Our kitchen is augmented with sensors to detect cooking activities during the cooking process. Then it can infer how well these activities conform to healthy cooking, and provide corresponding digital media feedbacks to raise healthy cooking awareness. For example, while a user is making a spaghetti alla carbonara, our kitchen can detect when he/she is adding too much whipped cream (high calorie) or bacon (high saturated fat). By showing the large amount of calories (saturated fat) from the whipped cream (bacon), an average family cook can choose to adjust the amount of food ingredients for healthy cooking.

Related Work

Many research efforts [3,4,5,6,7,8] have focused on augmenting kitchens with a variety of digital media to create rich, interactive experiences for users cooking in the kitchen. Some work has focused on providing awareness to support multi-tasking activities in the kitchen. For example, Counter Intelligence project from MIT [3] has augmented a kitchen with ambient interfaces to improve usability of a physical environment. Their augmented reality kitchen can assist users in determining temperatures, finding things, following recipes, and timing intermediate steps during meal preparation. Other work has focused on capturing or using digital interactive recipes that can guide users through a step-by-step cooking process. For example, Siio *et al.* [4] automates the creation of web-ready multimedia recipes in a kitchen. By operating one of the foot-switches, a user can capture images of the cooking workplace with voice memos and organize into a multimedia recipe. Such digital recipes can provide a more interactive experience than that from reading a paper-based recipe book. The CounterActive project [5] utilizes digital recipe to teach people how to cook by projecting multimedia recipes onto a touch panel-like interactive kitchen counter. Also, the Intelligent Kitchen project [7] proposes a human activity recognition system in the kitchen, using data mining approach to infer next human action by considering the past human behaviors.

Rather than augmenting kitchens with a variety of digital media to create interactive cooking experiences, our smart kitchen is focused on promoting healthy cooking by *raising nutritional awareness* during the cooking process, while leaving the decision about how to cook to users.

Design Concept

A kitchen, as in any part of home, is not a machine from which we live in and operate it. In other words, there should be no standard procedures and manuals telling users how to operate various tools in a kitchen to produce meals. Instead, users should be allowed to freely choose whatever tools and methods they are comfortable with to produce healthy and delicious meals. In our design concept, we want to avoid using digital technologies that exert control on or create distractions and interruptions to the users' natural cooking habits. Our interaction design simply provides easy-to-understand feedbacks that raise awareness on the nutritional facts of the used food ingredients. There are no instructions or steps to learn or follow when using our system. If it is not needed, users can choose to ignore our nutritional awareness feedback.

Preliminary Prototype

To test its feasibility, we have created a preliminary prototype of a smart kitchen show in Figure 3.

Weighing sensor deployment and space layout of smart counter (the upper line) and smart cabinet (the lower line)

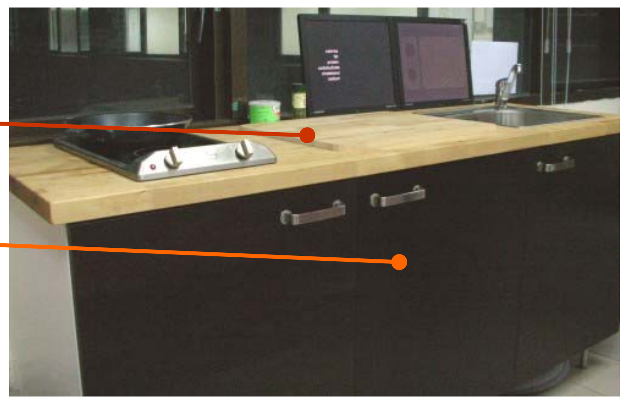

figure 3. Overview of our Smart Kitchen system, which includes a LCD display, a smart counter, a smart stove, and a smart cabinet with weighing sensors.

Our prototype contains two main modules. The first module is a sensor infrastructure to detect and recognize cooking activities. The second module is digital feedbacks to bring healthy cooking awareness to users. To recognize cooking activities, the first module must first identify cooking elements and their weights in the system, i.e. food ingredients and containers, so that nutrition facts can be displayed by the second module to promote healthy cooking.

This first module of the smart kitchen is composed of the following three components: a counter, a stove, and a cabinet.

Smart Counter – main activity

Through observation, we have found main food preparation activities are taking place primarily on the kitchen counter, such as transferring foods among containers, cutting foods, mixing, etc. Our system needs to accurately recognize and track the amounts of ingredients being added to every dish in order to calculate its nutritional information. In our prototype, we have adopted the design from the load sensing table [9] by installing 4 weighing sensors in the four corners underneath the kitchen counter (see Figure 3 annotation). This enables our smart counter to track the position of each container placed over the countertop and its weight of food ingredients within.

Smart Stove – cooking actions

Our stove has two burners – one in the front and one in the back. Underneath each burner is a weighing sensor to detect if any new ingredients are added to a pot above the burner.

Smart Cabinet – preserving foods and containers

In the kitchen, containers are stored in the cabinet, like dishes, bowls, plates, etc. Our smart cabinet also has weighing sensors to detect weight changes.

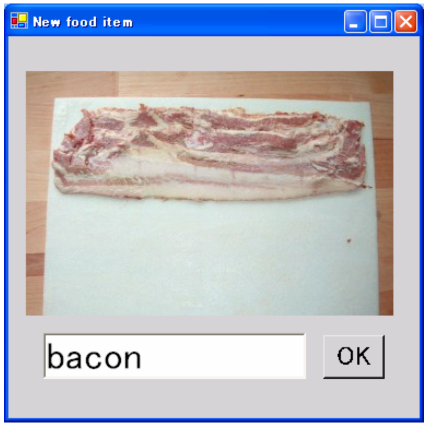

figure 4. Dialog window for asking input the name of new food item in the system.

For every container in the system, the interface shows weight information about food ingredients the container has.

To simulate food ingredient recognition, we currently rely on a human observer to manually type in the name of the food ingredient appearing in the system for the first time. When the system detects new weight increase on the counter, the image of new ingredient is taken from an overhead camera and then shown to the human observer for input (shown in Figure 4). We are currently testing other possible methods for automated or manual food ingredient recognition: (1) a voice dialog-system, (2) RFID tags/reader, (3) computer vision recognition.

After the sensor infrastructure detects low-level cooking elements and weights, our system can apply an inference rule engine to infer high level food ingredient transfer activities described as follows.

Food ingredients transfer Recognition
This involves tracking the *path* of each food ingredient from a starting container (e.g., taken from a fridge and placed on the smart counter) to an ending container holding the final cooked meal. This transfer path is made up of a sequence of ingredient transfer events from one container to another container. To track this path, a *weight matching* algorithm [2] from our previous work is used. That is, the weight sensors underneath the counter, cabinet, and stove can detect weight changes. By matching the equal amount of the weight decrease (e.g., a food container) and the weight increase (e.g., the food mixer pan), we can infer an ingredient transfer from the food container to the food mixer pan. Using a public nutritional database that provides nutrition values for each food ingredient type [10], our system can then calculate and display overall nutrition facts in each container.

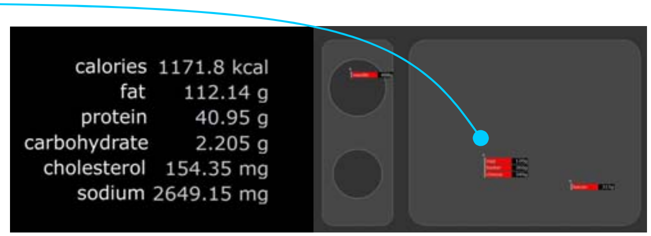

figure 5. User interface of our smart kitchen system. We display nutrition facts about latest ingredients on the left hand side, and overall ingredient information on the right hand side.

After determining nutrition facts of the food ingredients, our system provides awareness feedbacks to raise user's awareness on healthy quality of food ingredients.

User interface and providing awareness
We make use of a LCD display to show the composition of food ingredients in each container on the counter and its nutrition facts. Since users are typically busy during their cooking process, the design of this interface should be as simple and intuitive as possible without demanding high cognitive load on users. Our interface is shown in Figure 5, with nutrition facts of current container and overview of food ingredients information in the system.

Preliminary Evaluation
In our preliminary evaluation, we invited one experienced household cook to participate in our smart kitchen system to cook spaghetti for 4 main-course servings with the following recipe:

1. Slice bacon into small strips. Heat the oil in a deep skillet over medium flame. Add the bacon for about 3 minutes until it is crisp and the fat is rendered.

2. Cook spaghetti in a 6-quart pot of boiling salted water until al dente.
3. While pasta is being cooked, beat together 4 eggs, whipped crème (315ml), cheese powder (50g), bacon from step 1, and 1/4 teaspoon salt in a small bowl.
4. Drain spaghetti in a colander and then pour egg mixture into the pasta in a pot, then toss with tongs over moderate heat to combine. Serve immediately.

In our experiment, the user finished cooking without any mistakes. After the cook finished cooking, she acquired the nutrition facts of final servings so that every family member can know the detailed information (including food ingredients) about the serving in his/her dish.

The average error in tracking food ingredient to its final container is about 10-15 grams. This error is caused by two factors. The first one is that the accuracy of our weighing sensors is 5 grams. The second one is that on average, each good ingredient is transferred 2-3 times. Take bacon as example: it was first moved from the counter to stove for frying first, then moved back to the container on the counter, and finally mixed with the sauce.

We observed when the cook noticed certain ingredients containing very high calories (e.g. bacon and whipped crème) as shown by our system, she reduced to approximately 90% of her originally prepared sliced bacon and whipped crème amount. That is, after slicing bacon, she only heated about 90% of the sliced bacon. The cook mentioned that she was surprised about the high calorie of these food ingredients, so she decided to reduce their amounts.

We have reported a preliminary evaluation involving one user only in this work-in-progress paper. In our future work, we will certainly involve multiple users with different experience levels and more varieties of recipes.

Discussion

Design of user interface

The current visual feedbacks still occupy too much of the cook's attention such that it distracts her from cooking. Our user suggested that some audio feedback can be incorporated to alert her about certain unhealthy ingredients. This will free the user from continuously looking at the LCD display.

Response time

Our system's response time and robustness are important factors in providing satisfactory user experiences. Our current system has an average response time of 2 seconds for reporting nutritional information for food ingredient placed in it, which is too long for rapid paced cooking actions of an experienced cook. Our user commented that waiting for the system's response is rather annoying in cooking, because maintaining a natural pace and speed in cooking is very important. This slow system response time is due to our ADC (analog-to-Digital Converter) stability, which can be improved in our next prototype.

Limitations

Our current prototype cannot recognize concurrent or interleaving events, e.g. take two dishes from a counter at the same time and then immediately put their ingredients into the pan on the stove. In our next prototype, we will incorporate additional sensors to enable accurate detection of concurrent events.

Future Work and Conclusion

Our smart kitchen applies digital technology to enhance traditional meal preparation and cooking process by raising awareness of the nutrition facts in food ingredients that go into a meal. The goal is to promote healthy cooking. Our smart kitchen is augmented with sensors to detect activities related to cooking process and then provide digital awareness feedbacks on nutritional information. We have implemented a preliminary prototype and conducted a preliminary evaluation. In the future, we would like to invite more users to participate in the design and evaluation process, and enhance our accuracy and robustness of technology.

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