Mom's Tray: Real-time Dietary Monitoring System

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ABSTRACT

Mom's Tray is a dietary monitoring system that integrates smart tray with embedded sensors, pre-arranged and RFID-tagged food packages, and a mobile app to provide a real-time feedback on food ordering and consumption in a school cafeteria setup.

CCS CONCEPTS

• **Human-centered computing → User interface toolkits**; **Empirical studies in interaction design**;

KEYWORDS

Monitoring dietary behavior, Pervasive computing

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1 INTRODUCTION AND RELATED WORK

An increase in the adoption of mobile devices, such as smartphones, smartwatches, and embedded everyday use products such as Nike+ unavoidably turns the focus of technology on monitoring humans. This shift is amplified but a current culture that values health and physical activities as a response to an increased awareness on healthy living habits with the ability to afford them. An important part of this new culture is the focus on the diet. Whether one is concerned with organic production of food, allergies, or calorie intakes, it all points to the need for developing ways for consumer to better understanding products they consume.

This presentation discusses Mom's Tray, a dietary monitoring system that integrates smart tray with embedded sensors, pre-arranged and RFID-tagged food packages, and a mobile app that provides a real-time feedback.

There are a number of existing products and research prototypes that address similar needs. In app market, there are lots of mobile applications such as MyFitnessPal, Lose It! and Lifesum that monitor the user's dietary behavior. These applications allow users to record what they had for their meals, and show statistics based on the eating history. The users enter the list of foods intake and amount of them either manually or by searching from the database that contains nutrient information about foods. Researchers utilized various types of sensors for monitoring dietary behavior. They used piezoelectric vibration sensor to detect eating habits [Alshurafa et al. 2015], multiple sensors to detect children's eating actions and chosen food [Kadomura et al. 2013], and load cells to control the eating speed in real-time [Kim et al. 2016]. Also, they conducted image processing to recognize food on the plate [Ciocca et al. 2015] and measure its volume [Sun et al. 2014].

However, these previous works still have rooms for improvement. Users are too much involved in the process of entering food information. Since searching and inputting the data is a tedious task for every meal, people usually fail to keep recording it. Moreover, it is difficult to record exact amount of food consumed. In most cases, people do not measure the weight of what they eat, and many applications use units such as "one portion" to input the amount, which might be inaccurate in calculating nutrients consumed. Furthermore, the recording process is often done after eating, which means that there is no feedback during the moment of decision. Therefore, people may feel hard to balance among meals in a day, or they have to eat only pre-defined menu.

Mom's Tray is designed to solve these problems. The system removes the tedious task of recording nutrient information with simple technologies. The only thing the user should do is putting the dishes on the tray. Also, the mobile application provides real-time data of what is on the tray. This gives a guideline for choosing the dishes with well-balanced nutrients.

2 PRELIMINARY STUDY

2.1 Interview

There were two interviews with dietitians before we design a new smart tray. The first interview was for a dietitian in the east restaurant in KAIST campus, and the second one was for a cook in a catering service company. The second interviewee worked as a dietitian as well as a cook. We conducted an interview with the first dietitian through offline meeting and the second dietitian over the phone. There was 30 minutes interview session for each dietitian and I gave a present worth about 5,000 KRW after the interview.

During the interview, We asked four main questions (1) basic information about the dietitian, (2) how they organize menu, (3) how the customers choose their meal, and (4) opinions about the smart food tray design. For presenting the result of the interview below, we used 'D1' and 'D2' to denote the dietitians, respectively.

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From the interview, we could check how they organize every day menu in detail. Both dietitians answered that they consider carbohydrate, protein, fat, and vitamins as very basic criteria. D2 also mentioned that not only the nutrients but also color composition of the side dishes as important factors. However, D1 answered that it is difficult to reflect exact amount of daily recommendation for each nutrients. She said, "Of course we need to follow that standard, but it is much more important to consider which menu is popular or preferred among the students. Although we prepare healthy meals, it is useless if they don't like it." Similarly, D2 said that "For example, if we should let the customers have more vitamins, we provide vegetable shakes or juices to fulfill the nutrient with preferred menu."

Both dietitians chose sodium as an important factor, since the consumption of sodium is very high compared to other countries due to the soup. They check the level of sodium using salinometer and provide less salty soup than the standard. Moreover, they try to follow the trends of nutrients, such as decreasing consumption of carbohydrates or adding more meat and fish which contain proteins more.

We also checked how the customers choose what to eat in the third main question. D1 answered that there are two types of restaurants providing different forms of meal. One is "set menu" which every dishes are already set, and the other is "cafeteria" which customers can choose what to have among many side dishes with various combinations. Also, she mentioned that there are preferred and less preferred dishes so that there occurs difference in the total consumption of each dish. D2 answered that there could be imbalance in nutrients if the customers do not choose all the dishes in "cafeteria" type. Therefore, the customer's choice becomes crucial in balancing those nutrients. He also said that "In most cases, the customers do not eat some food because it has very different taste from what they expected. It is hard to control the amount of leftover when it becomes a matter of preference, even there is imbalance in nutrients." To motivate the customers to have more balanced meals, both dietitians various ways such as using posters that suggest having fruits in season, or campaign for having breakfast to avoid overeating. Nevertheless, they said it was not easy to change the customer's behavior.

2.2 Survey

We conducted a survey with students in KAIST campus. 35 students (17 females) participated in the survey, and their average age was 25.7 (sd: 3.9). The questions were composed of three main parts, (1) how the students use restaurants in the campus, (2) how the students manage their health, especially for monitoring their dietary behavior, and (3) their opinions about designing new smart tray.

80.0% of the students use restaurants in the campus more than 3 days a week. Among different types of restaurants, 45.7% of students mainly use set menu which includes pre-set side dishes. 25.7% of students use restaurant where they can choose side dishes among many options, and other 25.7% go to the restaurant where they can control amount of side dishes with fixed menu. Overall, students showed almost neutral but slightly dissatisfied with their experiences in these restaurants (mean: 2.97, sd: 0.81).

We also asked importance of four criteria (taste, amount of food, price, and balance in nutrients) for the students when they choose one of the restaurants for their meals. This question was done in 5-Likert scale, and students selected 1 for not important at all while 5 for very important. Students chose taste as the most important factor and scored 3.91 (sd: 1.05) in average. They chose price of the meal (mean: 3.83, sd: 1.03) as second factor, and the amount of food for third one (mean: 3.26, sd: 1.00). They considered balance in nutrients for their meals compared to other factors (mean: 3.09, sd: 1.16).

From this survey, we could find how students manage their health and dietary behavior. Most of students are interested in personal health care (mean: 3.74, sd: 0.77), and 27 students do exercise for their health. Among the 35 responses, 25 students had experience of controlling their dietary behavior for healthy life and 23 of them mentioned "losing weight" for the purpose of that experience. 3 students controlled their dietary behavior because of diseases, such as indigestion, constipation, or atopic dermatitis. Students who had never experienced mentioned "cannot find needs for doing it," "not interested," and "lack of information" as reasons for their answers.

More than half of the students (57.1%) had experience of recording what they ate. Most students took picture of the food, and they used smartphone application that manages health care to input the list of food. Sometimes, they write down or type the menu manually. During doing this, students found some inconvenience. The main issue was that it is very difficult to check exact amount of food or detailed nutrients information. Sometimes, when they took a picture, they felt tedious to do it every day and organize it again. In case there is no data in the database of the application, they had to input the information manually which demotivated them to continue.

After reading short description about sketch of the smart tray, students answered that they would like to use this tray (mean: 3.83, sd: 1.00) and they thought the tray could help users in managing the dietary behavior (mean: 4.17, sd: 0.81). For additional opinions, they suggested functions such as "recommending dishes based on the menu on that day," "showing statistics for nutrients consumption weekly," and "setting individual goals and rewarding if the user achieves them."

3 SYSTEM IMPLEMENTATION

Based on the needs of dietitians and students in our preliminary study above, we designed a new smart tray system, named "Mom's Tray." Mom's Tray is not only a physical hardware, but a system consists of a tray, a server, and a mobile application. The tray is composed of several sensors and reads information about food on it. Then, the data is sent to the server in the form of PHP file. For real-time interaction with the user, Mom's Tray utilizes the user's smartphone as a contact point where he can check food information during choosing the dishes. Detailed information about each part is described in below.

3.1 Hardware Design

The proposed smart tray consists of Wemos D1 Mini NodeMcu Lua ESP8266 WiFi development board, MFRC522 RFID card reader

Figure 1: Hardware settings of Mom's Tray for both sides.

module (13.56 MHz), and FSR-406 force sensing resistor. Each dish and food container has an integrated a passive NFC tags in the position that would allow for an easy tag registration with the embedded reader module. Additionally, the smartphone was also equipped with a NSF tag to allow for the phone association with the tray–matching tray users.

RFID card reader is attached beneath the tray to read information of the NFC tags and recognize which dish is put on that position or who is using the tray. To avoid taking spaces for food, RFID reader modules were installed on the underside of the tray. The sensitivity and range of the reader modules allows for NFC tags to be placed within approximately 3 cm, which was sufficient when considering thickness of the tray and the small offset at the base of the plate. The force sensing resistor was used to measure the weight of the dish. Since it is originally designed for measuring pressure, we add code to convert the value to the corresponding weight.

ESP8266 microcontroller was connected with both RFID card reader and force sensing resistor, and was also attached beneath the tray. ESP8266 boards used native WiFi connectivity to transmit sensor data to the MySQL database. On the server side, dish IDs were matched with types of food and their nutritional information.

The smart tray used subdivisions (sectors) that are traditionally associated with various food types. However, the tray was agnostic about these locations so any combination of food could be used. For each sector, all the three hardware components described above were installed. With this design approach, it becomes possible to manage various foods at the same time by just putting the dishes on the tray. As shown in the Fig 1, the tray has three sectors for the dishes and one for the user's smartphone. Also, the schematic sketch of each set is illustrated as Fig 2. After we made connection between sensors and microcontroller, we fixed them on the tray tightly.

3.2 Mobile Application Design

A mobile application for Android was developed to provide an opportunity for real-time interactions between Mom's Tray users and hardware. The application imports sensor data from an outside database and shows it to the user in an interactive way.

The app's user interface (UI) is composed of three vignettes-tabs: personal record, statistics, and user settings. The screen for each tab is shown in Fig 3, from the left to right, respectively. The record tab shows total amount of each nutritious category that is present on the tray. Nutritious information includes energy in kilocalories, carbohydrate, protein, fat, sodium, and cholesterol. Only nutrient information are recorded in the app since they are commonly used in commercial products. The list could be expanded if users were interested in more categories.

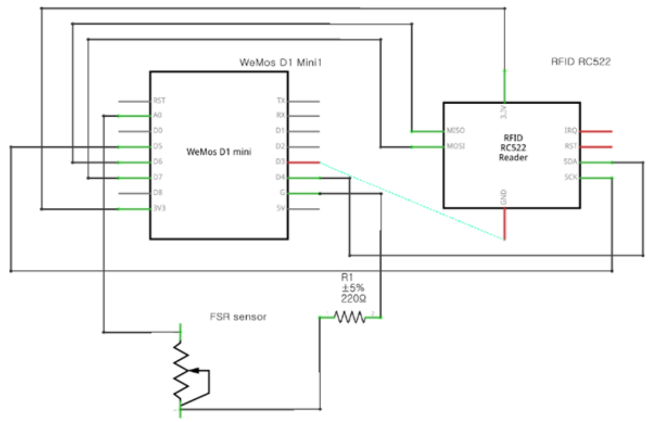

Figure 2: Schematic view of Mom's Tray.

In the graph, the total amount nutrition on the tray is represented in blue bars while recommended amount of nutrition is shown in red bars. This graph is redrawn with updated data repeatedly every 3 seconds, which makes the user to see the most recent nutrient information on the tray. The statistics tab shows user's history of consumption both as daily and weekly tallies. Users can interact with the charts to get additional information. With this graph, they can check distribution of calorie consumption during the day and remaining or excessive amount of calories based on the recommendation. They can check weekly information in a form of line chart, so that they are able to see the trend of their dietary behavior.

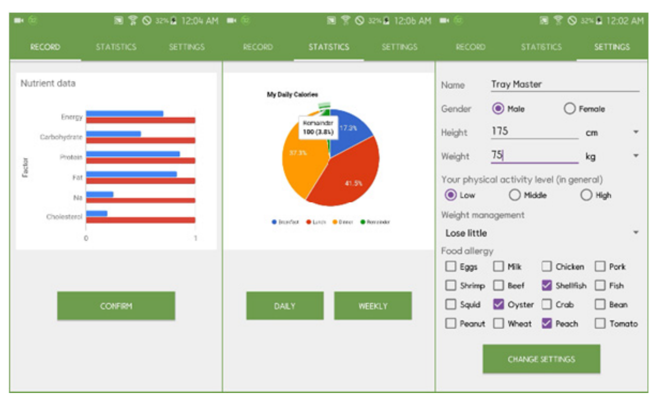

Figure 3: Screenshots from mobile application of Mom's Tray.

The app can be customized using settings tab, which allows the users to input their personal information such as their physical state (e.g., gender, height, weight, and physical activities in usual) and goal of weight management. With the values, the application calculates the recommended intake of calories and uses it in other tabs. Additionally, users can specify their food-related constraints such as the type of allergies. Based on the information, the app warns users if they choose foods that may cause allergic reactions.

4 USAGE SCENARIOS

Mom's Tray assists the user at the cafeteria in food selection and tracking the history of past dining. A user initiates the process by starting the app and placing a RFID-enabled smartphone on the tray. This registers a user with the tray and assigns every dish placed on the tray to that user. The next step for a user is to select dishes and place them on the tray. The tray automatically recognizes which dishes are there and measures their initial weights. The mobile application shows the total amount of each nutrient that is calculated in the server, and this information helps the user with nutritional balance for his meal. Since the app continuously updates information during choosing dishes, the user can have feedback in real-time and change his decision by following the guideline. When the user finishes his meal and stop recording, the amount of nutrient consumed is uploaded on the server. He can always have feedback by checking the history and make plans for what to eat more or less during the next meal.

Figure 4: Usage scenario of Mom's Tray in a cafeteria.

5 FUTURE WORKS

5.1 Update Functions and Design Components

We conducted a small exhibition session on May 19th to introduce Mom's Tray and have feedback from other students (Fig 5). During the one-day exhibition, many participants including professors and students had chance to see this prototype and gave some meaningful feedbacks for improving the work. We are considering update some functions and design components following their opinions.

For designing dishes, they mentioned that there should be different colors or signs to indicate that each dish has no same food on it. When they saw this system, dish is also an important part for providing food information at a glance. One of the participants said that "Though this system works with NFC tags, you can help the users in easier way by marking different colors to inform which food should be consumed for fulfilling a specific nutrient." Since we mainly focused on designing the tray, we could improve this system by designing the dishes and provide better user experience as well.

Moreover, one of the insightful feedbacks was tagging price on the NFC tag. When we go to cafeteria, there always occurs bottleneck right in front of the counter. In the campus cafeteria, cashiers manually check the dishes, calculate the total cost one by one, and have cash or credit card for payment. However, it is too old way even we are living in the age of Internet of Things. We could make this process simple by connecting price on the NFC tag as well as nutrient information. As people put dishes on the tray, it also calculates the cost automatically and sends that information to the counter.

Figure 5: An exhibition session to introduce the prototype.

5.2 Pilot Study

During this study, we could find out opinions from the potential users and stakeholders by conducting interview, survey, and an exhibition session. However, to prove this system works well and check practical problems, we need to conduct a pilot study in either laboratory or real-world situations.

For the pilot study, we are trying to recruit around 10 students to participate in. From the pilot study, we can check overall user experience of using Mom's tray. Also, by conducting a within subject controlled experiment, it is possible to find out different experiences the participants may feel. As shown in the survey session, students take pictures, utilize healthcare mobile application, and write down manually to record what they have eaten. After the pilot study, we can see the pros and cons of using Mom's Tray compared to their previous experiences and get more feedback to improve the prototype as well.

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