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CalNag: Effortless Multiuser Calorie Tracking

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***Abstract*—Self-tracking of food intake has been studied at length, but many challenges still remain. Current systems often require significant effort from users, and work that has tried to reduce it resulted in low accuracy or delays. Effort is a major barrier to long term use of self-tracking systems. We propose CalNag, a system that integrates a weighing scale, a barcode reader, and a cloud based service. Together, they allow users to track accurate calorie consumption when preparing food at home, requiring minimal effort for each interaction with the system. Through hand-geometry bio-identification, CalNag seamlessly works for multiple users. We have developed a working prototype and conducted a pilot user study. Our results suggest that CalNag's architecture is a promising solution to effectively promote long term self-tracking of diet.**

Keywords—Quantified self, self-tracking, self-monitoring, bio-identification.

I. Introduction

Systems to track health indicators such as weight, diet, and exercise have gained a lot of traction recently. A 2013 poll estimated that 60% of US adults keep track of one or more of these health indicators, and 49% of them report that self-tracking has had a significant positive effect on their health [1]. Today, tracking food intake is comprehensively supported by a plethora of applications and quasi-smart weight scales used for: a) monitoring calorie and nutrient consumption and setting personalized goals, and b) preventing accidental consumption of undesired or harmful food (e.g. dairy, peanuts). However, shortcomings of such systems include inaccuracies, unintuitive and wearisome workflows, and consequently low adoption and high abandonment rates [2].

We aim at creating a system for diet self-tracking by building an intelligent, unobtrusive home device that keeps track of calories consumed by members of a household. This system will require fewer steps for recording a meal, thereby reducing the burden on the user and arguably mitigating abandonment of the system. The device offers users a visualization of their data, which is known to affect the user's food consumption patterns [3], and would also alert them whenever their meal includes known allergens or ingredients that the user cannot or does not want to consume.

We propose CalNag, a cloud-connected device that incorporates a barcode reader, a weighing scale, and a camera for bio-identification. To protect users' privacy, bio-identification is done by running Gaussian Mixture Model (GMM) on hand-geometry features extracted from images of a user's palm [4]. CalNag identifies food by scanning the barcode, and determines portion size through a weighing scale. In addition to providing consumption information in-situ, CalNag sends an alert to the user via mobile app when allergic ingredients are found in the food scanned. The novelty of our system is two-fold: a) bio-identification via a privacy sensitive technique which engenders the usage of this system within a household, and b) increased accuracy and unobtrusiveness derived by using a weighing mechanism which complements the food-identification system. In order to evaluate CalNag, we have developed a working prototype and conducted a pilot study. In the following sections, we describe the system and discuss our promising preliminary results.

II. Related Work

In the past half-decade, many calorie tracking systems have been proposed. Self-journaling applications (e.g. [5][6]) often require a significant amount of effort from users. Devices that show nutritional information while cooking in the kitchen (e.g. [3][7]) are unaware of consumption patterns by users. Some systems crowdsource nutritional information [8][9][10], but this approach results in delays and inaccurate statistics. Other systems that use computer vision techniques [11][12][13] or sensors [14] to estimate the quantity of food, type of preparation, and ingredients to calculate the amount of calories are prone to inaccuracies due to technical challenges such as imprecise volume detection and variance in light conditions.

Commercially available systems for tracking food include mobile applications such as MyFitnessPal[1] and FatSecret[2]. Together, they have been downloaded over 1.3 million times on Android devices. Both allow users to scan a barcode to determine what they are having, but the task of determining the portion size is the responsibility of the user. Given that portion size is fundamental for calculating the nutritional properties of a meal, users need to either make estimates with varying accuracy or weight each item themselves. Smart scales have been created with the goal of helping users more accurately determine the nutritional information of their meal, but they also demand significant effort. The Perfect Portions Scale[3] requires entering the code of a particular food item; it is the user's responsibility to either search for the code or memorize it. Orange Chef[4] is a smart scale which is integrated with a mobile app, but users still need to navigate to the app to select a food item, a process which involves many steps. None of these scales are built to identify the user and instead rely on attributing calories to the paired user-device i.e., a phone.

[1]https://www.myfitnesspal.com/
[2]https://www.fatsecret.com/
[3]http://www.perfectportionsscale.com/
[4]http://theorangechef.com

Overall, drawbacks of current systems include required manual effort, inaccurate nutritional information by either machine or crowd workers, and challenges in determining the exact amount, type and preparation of food consumed by individuals. All of these lead to users eventually abandoning the system [2]. Effort required can be deterring enough to discourage the behavior being recorded, and psychologists have used it as an approach to help patients overcome undesired habits, such as smoking [15]. The rationale behind it is that the person will abstain from the behavior in order to avoid registering it. CalNag is intended to be placed unobtrusively in a kitchen, so that users can normally prepare their food on its surface. Only one short extra step would be added to their routine– scanning a barcode. By combining the barcode with the weight measured, the system can accurately calculate the nutritional properties of the meal. We anticipate that this workflow would be faster and require less effort from the user, while still providing accurate information. Consequently, it has the potential to prevent or delay abandonment of the system. We further describe CalNag in the following section.

III. Prototype Description

We have built a system *'CalNag'* that has four major components: a *physical device* that could be integrated into a smart kitchen environment, a *web interface* which can be presented in a kitchen *in-situ* as well as accessed via a mobile or desktop browser, a *mobile application* which allows users to monitor, analyze and add information about their food intake, and a *cloud-based server* which stores users' information and preferences. The architecture of the system is shown in Figure 1. The details of each component are as follows:

A. Physical Device (Hardware)

An Internet connected Raspberry pi is attached to three sensors: a) a barcode reader to identify the food, b) a weighing scale to measure the portion size and, c) a camera for biometric identification. Cognizant of the fact that this system is used within a household and being mindful of users' rising concern for privacy in IoT (Internet of Things) environments [16], we leverage the technique of biometric identification through hand-geometry measurements using Gaussian Mixture Model (GMM) [4], a technique known to have a 97% accuracy rate for identification. Geometric features such as ratio of palm-width to finger-width and length and width of the fingers were extracted and used for identification. Currently, non-geometric features such as skin-color were ignored, but can potentially be used in future versions. These sensors act as agents and post their information on a blackboard component, which then is pushed to our RESTful cloud service.

B. Cloud Service

The cloud service has three parts: a) a database to store user preferences and timestamped user consumption, b) a RESTful endpoint to add as well as retrieve user consumption data, and c) a real-time push system which sends time-sensitive notifications to the web-dashboard and mobile app. As the food identification is done via the barcode, we use a crowd-sourced database of open food facts[5] which maps barcodes to nutritional information.

[5]http://openfoodfacts.org/

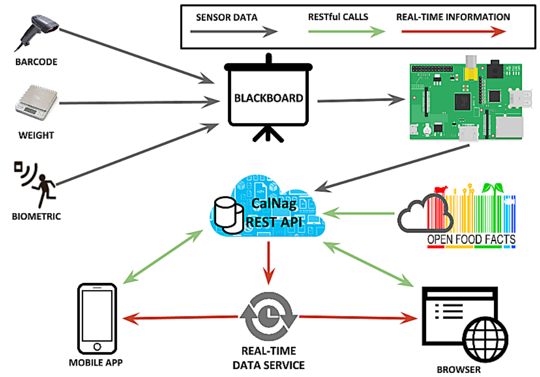

Fig. 1. Architecture for CalNag

C. Dashboard

A display connected to the hardware shows the overview of user's consumption via a web-dashboard. The web-based dashboard presents nutritional information about the meal consumed, such as the amount of energy (in Calories), carbohydrates, fats, and proteins. User's daily consumption, daily goals as well as weekly and monthly trends are also shown on the dashboard. Notifications appear when 'restricted' ingredients are detected in the food the user scans. The daily goals and restricted ingredients are set by the user via CalNag's mobile app.

Fig. 2. CalNag Dashboard (left) and Hardware Device (right)

Fig. 3. CalNag App. Configuration page (left) and home screen (right)

D. Mobile App

The mobile app (Figure 3) allows users to review their consumption, set goals and dietary restrictions, as well as receive in-time notification if allergens are detected. In addition, users can also add information about food they consumed outside the household by manually entering information like they would in a journal or scanning a barcode via the mobile app. Currently the mobile app is required only when adding user information to the system. At all other times, the user need not have a cell-phone handy while using CalNag's hardware within the household as the attached display showing the dashboard obviates this need.

IV. Use Case

Let's imagine a day in the life of a user - Bob. Bob wants to lose weight and decides to monitor his calorie consumption and reduce his daily fat intake. He also needs to avoid peanuts due to his allergies. He tries several mobile apps but eventually abandons them due to tiresome workflows, inaccuracies and the burden of permanently carrying his phone. Bob decides to install CalNag in his kitchen and downloads the complementary mobile app. The app allows Bob to add information about his weight, his daily consumption goals for various nutrients and dietary restrictions. He also uploads images of his palm via the camera on the device so that CalNag can identify Bob when he uses the kitchen-installed device next.

Bob is now ready to start using the system. He takes a pack of frozen vegetables from the refrigerator. Noting that there are multiple servings in the pack, he only takes the amount he plans to eat. He puts it into the bowl on CalNag's scale and scans the barcode. During this process, CalNag takes an image of his hand and identifies Bob. Using this information about the portion weight, the food, and the user, CalNag calculates the exact nutrient value and instantaneously updates the attached display, as well as sends a notification to Bob on his mobile app. Upon accessing the notification, Bob can see precise nutrient information about the food. The app also shows his progress towards a daily goal in the form of a progress bar. While reviewing the notification, Bob can still indicate what percentage of this food he will be consuming, in case he does not eat all of it. In addition to the vegetables, Bob decides to have some cookies. He takes the box and picks some to eat, and then follows again the above process. Bob immediately receives a notification on the attached display as well as his mobile phone alerting him about the presence of peanuts in the food. CalNag had compared Bob's dietary restrictions with the open food facts database and found a match.

At times when Bob is not at home, he can still use the mobile app to scan barcodes and '*guesstimate*' the portion size. In case of absence of a barcode, he can enter data manually or select the food from a prepopulated list derived from CalNag's crowd-sourced database. The calories logged via mobile app would be integrated with those logged via the household device to form a holistic picture of Bob's daily consumption.

Sustained use of CalNag helps Bob to keep track of his calorie and fat consumption. He has the option to get an itemized list of things he consumed on any particular day, as well as get an overview of his consumption for any period of time. He also has the opportunity to change or add goals via the mobile app.

V. Pilot Study

We have conducted a pilot usability study with our prototype in order to gauge how effective and user-friendly the system is. Given that one of the major goals of our system is to reduce the effort required to count calories in everyday meals, we aimed to find out whether potential users would find this design attractive and less burdensome than contemporary systems.

A. Participants

In order to obtain a holistic perspective, we selected participants with diverse characteristics through an eligibility survey. We invited four people, chosen according to the following criteria: two people who had previous experience in calorie tracking systems, and two who did not; two who had diet restrictions such as food allergies, and two who did not; two males and two females. All participants were undergraduate students, and each received a $5 Starbucks gift card.

B. Procedure

The pilot usability study took approximately thirty minutes for each participant. We first gave the participants a walk-through of CalNag, describing the scenarios, user interface of the mobile app and dashboard. Then, participants were told to conduct two tasks of logging calorie consumption through CalNag as well as through a standalone mobile app, FatSecret. We observed participants' actions during the experiment and inquired about their perceptions of the CalNag system, compared to the standalone app.

C. Results

Three of the four participants reported that they would choose CalNag over other options. All participants expressed their appreciation of the weight detection feature as it automatically calculates accurate portion size of a meal with little user effort. All four said that hand recognition is a good feature due to its convenience, though one would like an alternative verification method via password based log-in due to a past experiences with inaccurate biometric recognition system. Moreover, three participants felt that it was important to provide a mobile app in addition to the barcode scanner and scale, since people often eat outside. Participants also wanted social network integration via the mobile app.

VI. Discussion

The results of our pilot study indicate that CalNag has the potential to reduce the effort required to accurately track meals. A long term comparative study is needed to reinforce this finding. Table I summarizes how the features of CalNag compare with existing food tracking systems.

TABLE I. Comparative analysis of CalNag

	Mobile Apps	Smart Scales	CalNag
Barcode scanning	✓	✗	✓
Weight detection	✗	✓	✓
User detection	✓	✗	✓
Low effort	✗	✗	✓
Multiple users	✗	✓	✓

While CalNag combines positive features of both mobile apps and smart scales, its novelty is strongest in a household where multiple people frequently consume food that a) has packaging with a barcode, and b) only requires simple steps in its preparation. Both are increasingly common [17]. More intricate home-cooked meals, as well as items which do not have a barcode, would not significantly benefit from our system's novel features. For the former, additional functionality for registering the nutritional information of a recipe while it is prepared could be included - as is done by systems like calorie-counter[6]. The latter could be addressed through image recognition; only the type of item would need to be identified, as the scale can measure the portion size.

During the pilot study, we faced challenges in our prototype due to its single unidirectional barcode reader. Scanning a barcode on an already open package was sometimes awkward and resulted in accidental spillage, but this problem could easily be solved in the future by integrating two omnidirectional orthogonal readers into the device. We also anticipate additional challenges in a future implementation of CalNag. Here we discuss those and propose some potential solutions. CalNag assumes that users will prepare their own meals, but allowing a second party to register a meal could be integrated into the system. While it is possible to create a mobile version of the physical device that is part of CalNag, we believe that a better approach would be for restaurants to provide machine readable code linked to the nutritional information of the meal. Chain restaurants in the US are already required to provide nutritional information [18]. Including barcodes to their menus would allow CalNag and similar applications to easily register meals bought from such businesses. Other potential features could include scanning food items in a grocery store to detect allergens, supporting temporary food restrictions - such as those required before a medical procedure, and installing CalNag in kitchen appliances like ovens, microwaves and cook-tops.

VII. Conclusion

In this paper we have described CalNag, a multi-user calorie tracking system that can also alert users of unwanted ingredients. It includes a physical device with a barcode reader, a scale, a privacy sensitive bio-identification mechanism, as well as a cloud service, and a mobile application. CalNag offers users a less burdensome way of keeping track of their food intake, as they only need to place their meal on the device and scan a barcode. It also alerts users of any allergens or unwanted ingredients detected in the meal. The system caters to multiple users in a household seamlessly, as it is able to determine who is operating it through an image of the person's hand. Since these features greatly simplify the registration of meals compared to widely adopted systems for similar purposes, we expect a noticeable lower abandonment rate. While a longitudinal study is needed to confirm this, the results of a pilot study indicate that CalNag can indeed lower the effort required by the user and drastically simplify the process of logging calorie consumption. We envision the system to be integrated into a smart kitchen environment, where members of a household would have access to accurate information about their meals on-demand and in real-time.

[6]http://caloriecounter.com/

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