A Pervasive Dietary Data Recording System

Junqing Shang, Kishore Sundara-Rajan, Levi Lindsey, Alexander Mamishev
Department of Electrical Engineering
University of Washington
Seattle, USA
shangjq,kishore,levisl,mamishev@uw.edu

Eric Johnson, Ankur Teredesai
Institute of Technology
University of Washington Tacoma
Tacoma, USA
ankurt,edj371@uw.edu

Alan Kristal
Public Sciences Division
Cancer Division
Fred Hutchinson Cancer Research Center
Seattle, USA
akristal@fhcrc.org

***Abstract*—Electronic sensors and various digital devices have been quite successful in improving collection of physical activity data in a pervasive manner, and we believe that advances in dietary assessment can be achieved using similar strategies. Dietary assessment is a critical yet understudied component within the domain of recent advances in electronic health records management. The design of a system for real-time recording of food intake requires considerable research to optimize both system characteristics and data collection procedures, and rigorous validation to confirm its superiority compared to paper-based methods for self-report. We propose to demonstrate a functional prototype of a Dietary Data Recording System (DDRS), which consists of an electronic data collection device and the software and protocols necessary to support data capture and calculation of nutrient intake. A key innovative feature of the DDRS is the use of a video camera and a laser-generated grid of distances to food surfaces, which allows calculation of food volume. This prototype system is a first step in designing an overall framework to support a realistic and rigorous evaluation of whether real-time, electronic collection of dietary data is feasible, acceptable and valid for better health data management. Components demonstrated include a real-time data collection application based on the Google Android OS, a stream based data transfer and on the fly evaluation.**

***Keywords*-Pervasive diet data collection; health monitoring; food volume measurement**

I. Introduction

Valid measurement of the intakes of foods, nutrients and bioactive food components in free-living persons is extraordinarily challenging [1]. Currently available, standard measures of foods actually consumed (paper-based, multiple-day food diaries and interviewer-administered 24-hr dietary recalls) have significant limitations due to bias, error, participant under-reporting, and staff and participant burden and cost [2]. However, through the use of advanced technology, such as miniaturized sensors, data recorders, image processing and voice recognition, it should now be possible to collect more objective data on food consumption in real time and at moderate cost.

Presented is a functional prototype of a Dietary Data Recording System (DDRS), which consists of an electronic data collection device and the software and protocols necessary to support data capture and calculation of nutrient intake. One of the challenging problems in dietary assessment is to measure the volume of food intake. A key innovative feature of the DDRS is the use of a video camera and a laser-generated grid of distances to food surfaces, which will allow calculation of food volume. This prototype system is sufficiently sophisticated to support a realistic and rigorous evaluation of whether real-time, electronic collection of dietary data is feasible, acceptable and valid.

II. Implementation

The DDRS uses a client-server configuration. A smart phone is used as the client to collect data. The data is then sent to a server via a wireless network. The server then stores and processes the data. The stored data in DDRS will be used by clinicians for further nutrient analysis. In the following, we describe three main components in the system: the mobile application, the web service, and the volume measurement.

A. Mobile Phone

We used a smart phone with an attachment as our data collection device. The mobile application was developed by JAVA on the Android operating system. The Google Nexus One was chosen as the smart phone for development, However, other Android-based phones could be used. To generate the range image of food and estimate its volume, we use an active vision technique that involves a video camera and a laser module [3], [4], [5], [6]. The external laser device is integrated into the attachment, and controlled by our mobile application via Bluetooth.

The application was designed based on the questionnaire from Fred Hutchinson Cancer Research Center. It contains mainly two kinds of data, the survey questions and the meal data. The application first presents the user with a main menu. At the beginning and in the end of a study, the user answers a series of questions, such as eating habits. Figure 1 shows the main menu and an example survey question.

In the middle of the study, the user records the intake of meals. For each meal, the user answers questions like meal time and place, and takes video, audio, and/or pictures of the food and/or bar code, as in Figure 2. All the data collected

Figure 1. Main menu and Sample Survey Question

are stored in XML files and uploaded to the web service, where the XML is parsed and the information stored in a database for further processing.

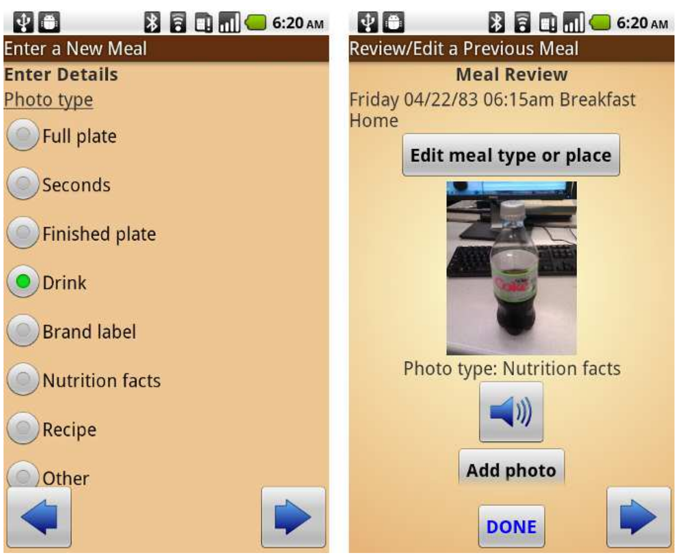

Figure 2. Sample Meal Entry Screens

B. Web Service

The web service that supports the central upload of user data is a RESTful application, supporting atomic commits or uploads of an entire study from data collection devices or from a browser. There are three main modules to the web service: the survey module, the authentication and user management module, and the meal detail and processing module.

The surveys in the study are defined using a simple DSL (Domain Specific Language). The survey module is based on the Surveyor Rails plug-in designed out of the need to deliver clinical research surveys to large populations. It supports question dependency and answer variation. Power users author new surveys or edit existing surveys in text files for publication. Three surveys are defined for the DDRS: Beginning of Study, Meal Times, and End of Study.

The authentication module is based on a RESTful authentication plug-in that supports login/logout functionality, secure password handling, account activation by validating email, account approval and disabling by an administrator. It also supports rudimentary hooks for authorization and access control based on application roles.

The meal detail and processing module is also implemented within an MVC framework. Atomic commits of data based on web service calls are made using the particular study and the users identification. The meal detail includes the time and place, the type of meal being recorded, and potentially several types of media, such as audio, bar code pictures, and video recordings with an associated batch of position, acceleration, azimuth, pitch and roll data. When the meal detail data is uploaded, it is stored and volume estimation scripts are executed. The results of the volume estimations are appended to the meal data.

C. Volume Measurement

Volume measurement of food is the most challenging component in DDRS. With the progress of research in computer vision, many vision-based systems of measuring foods have been proposed to-date. Some people developed methods to estimate the fruit volume under controlled surroundings, such as fixing the position of the camera or using a pair of cameras [7]. Others proposed methods for less controlled environments, but fiducial markers are located by the side of the foods [8], [9], [10]. We propose an approach to measure food volume from a video camera and a laser module using active vision techniques [3], [4], [5], [6]. The laser module illuminates the food and the camera collects video sequences with the laser grid projecting onto the food. Figure 3 shows the concept of our approach.

Calibration is applied between the camera and laser so that we can determine the geometric relationship. For a calibrated system, the algorithm for 3D reconstruction contains 3 main steps, which are a) depth image generation, b) registration of depth images from different directions, and c) food volume estimation. First, an optical triangulation method is used to estimate the distance from the camera to food, since the laser grid appears at different positions in the cameras field of view depending on the distance. A depth image can be generated from one video frame at a certain direction, and represents a part of the 3D shape of the food. Then, all depth images from different directions are registered together to generate the 3D model of the food. Last, the food volume

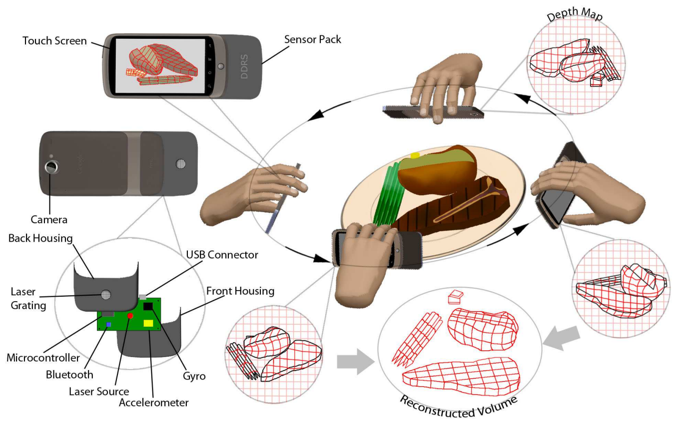

Figure 3. Concept of Volume Estimation in DDRS

is estimated from the 3D mesh of the reconstruction result. Figure 4 shows one video frame with the laser grid, and shows the 3D model of the reconstructed mango.

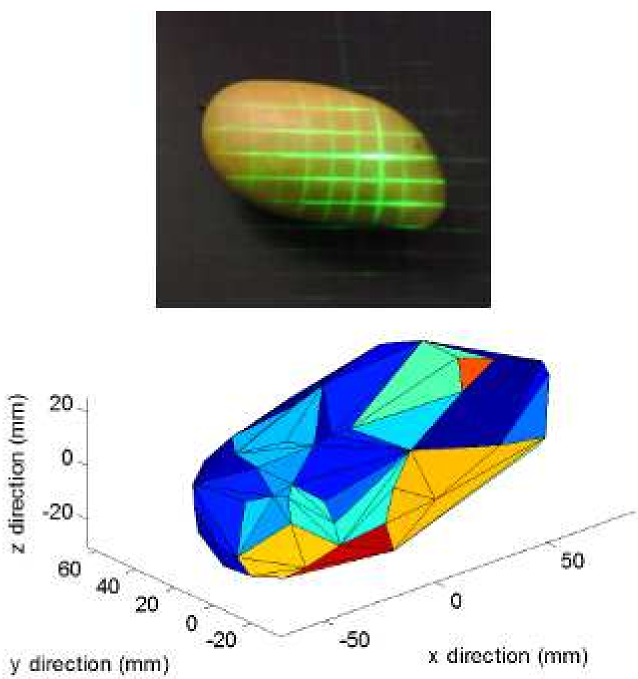

Figure 4. Video Frame with Laser Grid and 3D Reconstruction

III. Demonstration Scenario

Our demonstration is based on a simulation of an entire data collection, storing and processing scenario. There are four steps to data collection from a user's perspective. First, the user starts with answering the survey questions. Then, the user enters a new meal by recording the intake data. Here the user needs to answer the questions, turn on the laser, and collect video. The user then answers the survey question again to simulate the end of the study. Finally, the data is uploaded to a web service as XML. The web service parses the XML and stores the information in a database. An asynchronous service calls the algorithm to process the volume reconstruction and updates the database with the volume estimation.

IV. Conclusion

In this paper we demonstrate the prototype of DDRS that efficiently collects and processes nutrient data. It builds a solid foundation for possible further development. The future work includes reducing the error of volume estimation, increasing the usability of the system, and validating the system with user testing.

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