**EatAR: Mobile Augmented Reality Nutrition Assessment**

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**ABSTRACT:**

Accurate assessment of nutrition information is an important part in the prevention and treatment of a multitude of diseases, but remains a challenging task, especially for the non-expert. We present a mobile augmented reality application, which assists users in the assessment of nutritional information of their meals. The user sketches the 3D form of food and on the basis of a user-selected food type nutrition information is computed. Thus volume estimation of food is required for accurate nutrition information assessment. This work focuses on an evaluation of the length and volume measurement accuracy of the developed augmented reality application and puts the results into relation with actual food energy-densities.

1 **INTRODUCTION**

Optimized food intake is an important factor in the prevention and treatment of a multitude of diseases. The prevention of obesity is a main concern in populations worldwide, as obesity dramatically increases the risk of cardiovascular diseases and diabetes mellitus type 2. Obesity is estimated to increase the cost of medical care by 30\% on average [1]. One measure for the prevention of obesity is the education in matters of diet and nutrition. Another measure is to keep food diaries (food logging). For many other conditions the accurate assessment of nutrition values is critical, too one of the most prominent diseases being diabetes mellitus. For diabetes the accurate assessment of the intake of carbohydrates is crucial in order to determine the amount of insulin required.

Food logging in general and especially the assessment of nutritional values of served meals are complicated tasks. Conventional methods require time consuming weighing or error-prone guessing of the weight and a cumbersome search in long lists for best matching food items to determine the nutritional values. Most people have difficulties with the correct estimation of portion sizes [2].

Thus there is a need for easily applicable support systems for portion estimation. The focus of our work is on mobile interactive augmented reality support systems for portion estimation. Mobile interactive augmented reality (AR) support systems can play an important role the training and support of nutrition assessment. Mobile AR applications show the camera image of the real physical world on a mobile device screen and overlay the image of the real world with virtual computer-rendered content.

Fiducial markers (e.g. credit cards with special patterns) in the real world image and computer-vision algorithms allow an alignment of the real image and the virtual image, i.e. correctly sized 3D objects can be placed in the real world image. For the use case of nutrition and diet education, food items can be placed in the real world in the correct scale. Furthermore the user can interact in 3D with the virtual food, i.e. see the virtual food from different viewing angles (always with the correct scale). Therefore a more realistic and intuitive assessment of the portion size or 3D shape is achieved with AR as compared to 2D images of food.
In this work we propose a mobile AR application (Eat\textsubscript{AR}) that helps the users to assess the nutritional value of served meals (see Figure 1). Compared to conventional food logging approaches our proposed method assists the user in volume assessment and gives an improved intuition for food portion size. More concisely our contribution answers the following research questions:

- Can mobile AR apps be employed in the case of nutrition assessment?
- Is the accuracy of mobile AR systems sufficient for nutrition assessment?

Figure 1. Mobile Augmented Reality Nutrition Assessment

2 RELATED WORK

In previous work [3] it is concluded that mobile devices can be a valuable and useful tool for food logging. Further results on the usability of mobile applications for dietary assessment can be found in [4].

Strongly related to our work is the effort by the TADA project (technology assisted dietary assessment, www.tadaproject.com), which is funded by National Institutes of Health (NIH). The project has a similar target, namely to research and develop technology to assist users in assessing their diet. The TADA research group is working on mobile single image based dietary support systems, i.e. the user takes a single photo of the food and the application should automatically determine volume the entire nutritional information of the meal on the basis of these data. Their work focuses on North-American diet and context. We think that their image-based approach is interesting and challenging, but we believe that completely automatic nutritional information estimation on the basis of a single image is likely to work only in controlled environments. More details on their system can be found in [5]. Thus the focus of our work will be on user interaction with a mobile AR application, which we believe to lead to more robust results in real world application.

3 A MOBILE AUGMENTED REALITY APP FOR NUTRITION ASSESSMENT

A prototype of a mobile AR application (Eat\textsubscript{AR}) for assisting users in nutrition assessment was developed with the Unity3D framework\textsuperscript{1} and Qualcomm’s Vuforia platform\textsuperscript{2}.

\textsuperscript{1} http://unity3d.com/
\textsuperscript{2} http://www.qualcomm.com/solutions/augmented-reality
The EatAR application provides a simple user interface for the approximation of the 3D form of the food on the plate (see Figure 1). The user positions the smartphone such that the plate is captured by the camera. The camera image is shown on the screen and the user defines 3D forms (approximating the food on the plate) with simple touch gestures. The duration of the touch event determines the height and width of the 3D form (the longer the bigger). Thus the user is provided with an intuitive and interactive interface, that allows to "paint" the food on the plate. The food type can be selected for each 3D form (hidden menu on the left of the screen). The volume of the 3D forms is computed when the user presses the green checkmark on the right bottom of the smartphone screen (see Figure 1). The nutritional values of the meal (all the food items on the plate) are computed based on the volume and the nutritional value information for each food type per volume. The nutritional information per volume is derived from the public food database of the US department of agriculture (USDA-DB). In Figure 2 the kilocalories per volume for food from the USDA-DB are shown.

![Figure 2. The energy of foods per cm³ (results derived from USDA-DB)](image)

4 RESULTS

The accuracy of length measurement of the marker-based mobile AR application was evaluated for two state-of-the-art mobile phones, Samsung’s Galaxy SIII and the Apple’s iPhone5S. These results provide a basis for the analysis of the volume estimation accuracy of our mobile AR system. The accuracy of length measurement was assessed with a custom mobile application (see Figure 3), which overlays the camera image with virtual rulers. The virtual and the physical rulers should optimally match exactly. However, due to camera imperfections (limited resolution, camera distortion) and numerical inaccuracies the registration between virtual and physical world will not always be completely accurate. The errors (between physical truth and estimated virtual length) were collected for many different views that occur in a natural usage situation (sitting in front of a table). Figure 3 shows a frontal view of the rulers and the credit card sized fiducial marker, which is used for the registration. The difference between the real world and the virtual world has been determined at the 5 cm mark of the physical vertical ruler.

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3 http://ndb.nal.usda.gov/ndb/search/list
For the Galaxy SIII, the histogram of errors of 60 different views is shown in Figure 4. The average error for the Galaxy SIII was 0.17 cm and standard deviation was 0.24 cm.

For the IPhone5S the histogram of errors of 90 different views is shown in Figure 5. The average error with the IPhone5S was 0.24 cm and the standard deviation was 0.21 cm.

5 DISCUSSION
The energy density of different food types in the USDA-DB varies greatly, thus an accurate choice of the food type has a major impact on the accuracy of the nutrition assessment. The average errors are relatively low for both mobile phones (SIII and IPhone5S). The errors are not centered to zero, but have a slight tendency towards positive errors. Thus an improvement of
the accuracy could be achieved by subtracting the average error. The standard deviation of is below 0.24 cm for both mobile phones. Overall the results on accuracy of length assessment are promising, especially as mobile-phone specific adaptions can improve average accuracy significantly. In case of hemisphere with a radius of 5cm (e.g. a larger portion of rice) and a positive error of 0.25 cm (i.e. 0.125 cm error on the radius) the volume error is 20.13cm³ which corresponds to 7% relative error. If we assume a low energy density of 1 kcal / cm³ (see Figure 2 for examples of foods with this energy density) the resulting error in energy estimation is 20.13 kcal. For high-energy-density foods (around 8 kcal / cm³) the error goes up to 161.04 kcal, which is moderate compared to 2094 kcal of the whole serving.

Overall, results indicate that mobile AR applications can be a valuable assistance tool for nutrition assessment and that the accuracy of the length and volume measurement is sufficient to be the basis for an improved nutrition assessment.

6 CONCLUSION AND OUTLOOK
In this work we presented EatAR, a mobile AR application, which can be employed for nutrition assessment. Our results indicate that the accuracy of our mobile AR system is sufficient to assess nutritional information, especially as phone-specific optimization could significantly improve the system’s accuracy. A very important factor is the accurate choice of food type, i.e., the availability of accurate nutritional information per volume. Thus user-friendly food selection systems will also be a future research topic (current systems mainly rely on text-based search in large databases, as the USDA-DB).

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