Fruitify: Nutritionally Augmenting Fruits through Markerless-based Augmented Reality

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***Abstract*— In the past few decades, a significant decrease in fruit consumption around the world has resulted in a hiking rate of cardiovascular diseases and obesity among youngsters. In order to address this issue, healthy eating is being recommended. However, awareness on nutritional information on fruits remain an important challenge that still needs to be addressed even though various sources in the form of books, websites and mobile applications are already available. This is also potentially due to the limited interaction and engagement with such sources. One technology that has shown to improve engagement, enhance understanding and provide a unique learning experience is Augmented Reality. However, limited work has been undertaken to provide nutritional information on fruits via this technology. As such, this paper investigates the application of AR to nutritionally augment fruits through a proposed prototype called Fruitify, before discussing the usability tests performed on the application and involving end users. As key findings, a system usability scale score of 82.1% was obtained where participants expressed strong intention to utilize the tool again in the future.**

Keywords*— *Fruitify, Augmented Reality, Markerless, Nutritional Information, Awareness.

I. Introduction

During recent years, there has been an increase in obesity rates and associated health risks amongst youngsters around the world [1, 2]. In order to address this issue and to help promote a healthy lifestyle among this population, healthy eating is recommended [3, 4]. An important component of healthy diet consists of fruits, which is particularly essential due to their vitamins and minerals contents [5]. As such, in order to effectively promote a healthy lifestyle, the young population needs to know the benefits of fruit consumption and as well as their nutrients. However, previous studies highlighted that awareness remains an important challenge that still needs to be addressed [6, 7], even though exists a plethora of platforms that provide nutritional information on fruits, including books, websites and mobile application. This is potentially because people who want to improve their eating style feel less engaged when utilizing such platforms style [6, 7]. Hence, newer interaction technologies are needed that not only provide the necessary information in a more intelligent manner, but also improve interaction and experience during use. One such technology that has shown to improve interaction, enhance understanding and provide a unique learning experience is Augmented Reality (AR) [8], which could potentially help further improve awareness. This technology was found to have a huge potential contribution in the field of medicines [9] for visualization of 3D lungs, cardiovascular surgery and many other types of surgeries [10]. Similarly, AR was also regarded to have many prospects in education and training as it can make educational environments more productive, pleasurable, and interactive [11]. However, even though literature showed the prospects of AR to enhance learning, limited work has been done in relation to providing nutritional information on fruits. Taking cognizance of these gaps, this paper investigates the application of AR to nutritionally augment fruits through a proposed prototype called Fruitify, before presenting the findings following experimentation performed on the application and involving end users.

The paper is structured as follows: In the next section, related work pertaining to the use of AR to provide nutritional information on fruits is provided. Then, part III extends literature to describe Fruitify, an AR-based application that nutritionally augments fruits. Sections IV and V discuss the evaluation conducted along with an analysis of key findings. Finally, the paper is concluded in section VI.

II. Related Work

In a previously published study [12], an AR based prototype was proposed for providing nutritional information on mobile platform to also display 3D objects and visualize the information in graphical form using gauge meters. This study however only provides limited nutritional information on protein, fats and carbohydrates of a limited number of fruits and no evaluation was also performed involving end-users. Likewise, Blippar [13] is another AR-based tool which is well-known for bringing various types of objects to life through smartphones and wearables. Rather than providing customized information, it searches through the internet using keywords of the detected objects and displays all information from the internet, indifferent to the credibility of the websites the information was taken from. Additionally, MANGO [14] is a video based food recognition tool and includes assessment through a dietary questionnaire before using a food recognition option to fit the users' profile. Rather than focusing directly on fruits, the food dataset of MANGO contains only dishes to support grocery shopping. Similarly, Eat_{AR} [15] is an AR application for assisting users in nutritional assessment focusing on the volume and food portion size of served meals. Rather than providing nutritional information (e.g. vitamins and minerals), nutritional value is estimated and displayed to the user based on food portion size. As such, an accurate food choice type is necessary to avoid getting wrong nutritional information. A comparative analysis through application of the existing tools is summarized in Table 1.

Features	Mobile Application Name			
	MANGO	***Eat$_{AR}$***	***Blippar***	***Nutritional Information Visualization***
Focus on nutritional Information of Fruits	✗	✗	✗	✗
Displays nutritional information	✓	✓	✓	✓
Track nutritional intake	✗	✗	✗	✗
Provide further health details on fruits	✗	✗	✗	✗
Available in market	✗	✗	✓	✓
Membership needed	✓	✗	✓	✗

Table 1 - Related AR-based Solutions

As shown in Table 1, although all applications could provide nutritional intakes and dietary information, none of them directly focused on fruits. As such, information provided was either limited or not very relevant. Some applications including MANGO and Blippar also require membership for use and this could be a restricting factor. In addition to membership details, same applications also seek various details such as illness, weight, height, address, thus making the registration process longer and time-consuming. Additionally, existing solutions do not keep track and record of the amount of nutrients consumed during a particular timeframe (e.g. daily, weekly or monthly). This is important as it allows people to control their daily nutrition intake [16] thus helping in prevention of chronic diseases.

Furthermore, none of the studies evaluated the usability of the application. This is particularly important so as to be able to evaluate user's experience while using the application in order to obtain intuitive information on different aspects including efficiency, effectiveness and overall satisfaction of end users [17]. To address these gaps, an AR based tool called Fruitify was proposed to nutritionally augment fruits, as discussed in the next section.

III. FRUITIFY: NUTRITIONALLY AUGMENTING FRUITS

In order to achieve the purpose of this paper, an AR-based application that nutritionally augments fruits, named Fruitify was designed and implemented. Rather than using head-mounted display for AR, the camera of the mobile phone was chosen because of accessibility reasons to the target audience, that is, youngsters. Also, the number of mobile devices has already exceeded the number of people present on the planet and adoption of such devices is rapidly multiplying at a rate of five times faster than human beings [18]. Amongst mobile operating systems, Android was chosen because it is regarded as the most popular operating system being utilized around the world [19].

In terms of design decision, marker-less based AR was chosen rather that marker-based AR because such approach would be more convenient to the end-users. In other words, when using marker-less based AR, youngsters would not need any specific markers and can directly scan the fruit using their mobile phone camera. As such, for developing the marker-less based AR application, Unity3D[1] (version 5.6) and Vuforia SDK[2] (version 6.2) were chosen due to their popularity in terms of development of such tools [20]. Unity3D is a game development platform, used to develop high quality 2D and 3D games and is also widely used for augmented reality software. On the other hand, Vuforia SDK is used to build Android and iOS applications for mobile devices and digital eyewear. Additionally, Vuforia Object Scanner (APK version) was also utilized to scan 3D objects before saving same in the Vuforia database and eventually imported in Unity 3D. The architectural diagram Fruitify is given in Fig. I. Also, some energy saving design techniques were considered so as to diminish energy consumption of the application in order to reduce the impacts of the system on the natural eco-system [26].

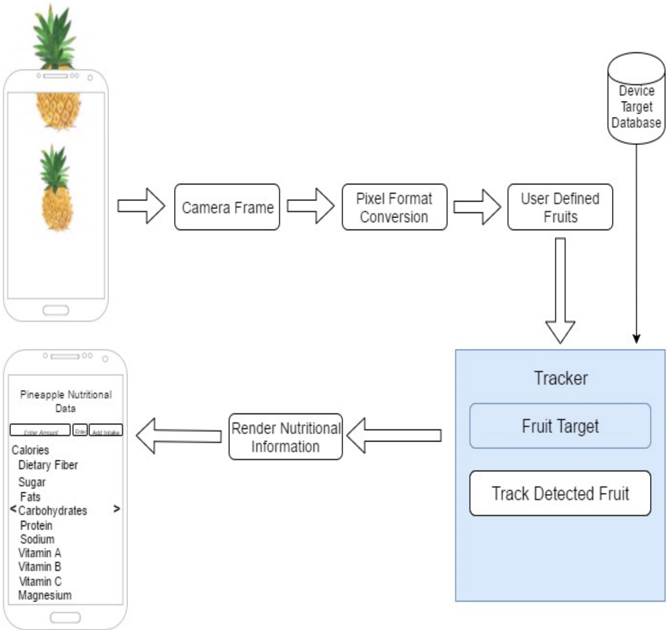


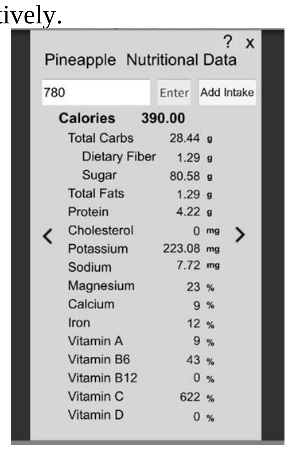
Fig. I - Architectural Diagram of Fruitify

As key features of Fruitify, it is able to detect and recognize different fruits through mobile phone camera, following which, it displays nutritional information (e.g. maximum daily intake value, protein information, vitamins percentages, carbohydrates) related to the identified target, after the user enters the desired amount of the fruit in grams. Additionally, the user is also able to view background information and facts about the identified fruit both in online and offline modes. Furthermore, the end user can also keep track of nutritional information from the fruits consumed where daily, weekly and periodic statics and reports could be generated and exported. Screenshots of the implemented prototype are given in Fig. II where Fig. IIa shows the object scanner function scanning a

[1] Unity 3D, available at: https://unity3d.com/
[2] Vuforia SDK, available at: https://www.vuforia.com/

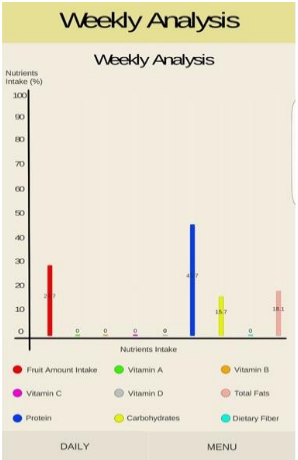
pineapple and once the target is detected, relevant nutritional information about the fruit is given in Fig. IIb. The daily and periodic (weekly or monthly) nutritional statistics are also shown in Fig. IIc Fig. IId respectively.

(a) Object scanner



(b) Nutritional information

(c) Daily Breakdown



(d) Weekly Statistics

Fig. II - Fruitify screenshots

IV. EVALUATION

As discussed earlier, it is important to evaluate the usability of Fruitify in order to obtain intuitive information pertaining to user experience. For this, the cognitive walk-through and the system usability scale (SUS) were utilized. The choice of these approaches was principally due to their various benefits as highlighted in a previous study including successful revelation of larger amount of usability problems [21]. Also, SUS was chosen over Heuristic evaluation because Heuristic evaluation requires experts' reviews in the AR field which was challenging due to a lack of AR experts. For determining the SUS score, 10 usability related criteria were formulated (as in Table II) where participants have to answer based on a Likert-5 scale. In terms of recruitment of participants, as the cognitive walkthrough is more of a quantitative approach which requires tasks to be performed, 20 participants were randomly selected in order to obtain reliable data [21]. This also meets the recruitment requirements for such quantitative study as recommended by Nielsen [21].

The evaluation was carried out at Middlesex University (Mauritius Branch Campus) and the target participants were principally youngsters studying undergraduate courses and aged between 18 and 25. As recruitment method, Hallway or Guerrilla Testing method which involves asking anyone or passers-by to participate was chosen because of its simplicity. Also, this method increases the chances of having an unbiased evaluation, since the users are not existing users [22]. As recruitment criterion, only participants owning an Android based phone were selected due to compatibility reasons with the application being evaluated.

In terms of procedures, once the research consent form was filled-in by the participant, brief training was given on the purpose of Fruitify and the research. Then the participant had to install the application and was given 3 days to practically utilize the tool in order to perform key tasks including scanning particular fruits and recording their nutritional values, recording and tracking their daily and weekly nutrient intakes. After these 3 days, each participant was called for a debriefing session during which data on the usability of the application was collected through a questionnaire (also containing the 10 SUS related criteria). During this session, the recordings made by the participants were also cross-checked in order to ensure that the tasks were well completed. Finally, the collected data was statistically analyzed.

V. RESULTS AND DISCUSSIONS

In terms of demographic details of the participants, 75% were males and 25% were female. Also, 55% of participants were aged between 22 and 25 years and the rest aged 18-21 years. Furthermore, all participants were studying undergraduate courses including law, international business, psychology and information technology related courses. During the debriefing session, it was also revealed that none of the participants previously utilized augmented reality to obtain nutritional information on fruits, before their experience with Fruitify. As for task completion rate, all participants could complete all the planned tasks successfully besides viewing the weekly nutritional information (as in Fig. IId), which only 80% of participants could complete. This was because the remaining participants thought the statistics were only for the whole week and have been using the application for only 3 days. The compiled SUS results following the experiment are given in Table II with the different criterion represented over a Likert-5 scale where 1 represents highly disagree and 5 representing highly agree.

Usability Criterion	Avg. Score (over 5)
Intention to use the application frequently	**4.8**
Application is complex to use.	**1.5**
Application is intuitive to use	**4.1**
Comfortable to use application	**3.3**
Application gives sufficient information on fruits	**4.2**
Recommend the application to other people	**4.0**
Application is awkward to use	**1.0**

Functions of the application were well integrated	**4.5**
Application interface is well designed	**4.0**
Application meets its requirements	**4.7**

Table II - SUS Score

As compiled in Table II, the highest score was obtained for intention to utilize the application frequently. This was principally because the participants really enjoyed the practical experience with augmented reality to obtain meaningful health-related information on fruits. This result also highlights the prospects of AR for providing health related information. On the other hand, the lowest score was obtained for comfortability to use the application. The highlighted reason was principally because some fruits took time to detect, especially those having smooth surfaces (e.g. apple and grapes). Furthermore, other minor contributors consisted of inflexible buttons, or delay in display of information. Overall, the score 82.1%, was also obtained on the SUS marker sheet with scores ranging between the range 51.7% to 82.1% meaning that the application meets its usability requirements. However, the experimentation also revealed different limitations of using AR for augmenting nutritional information on fruits, discussed as follows:

- Smooth v/s rough surfaces

It was highlighted by end users that during scanning, fruits with rough surfaces (e.g. pineapple, kiwi and dragon fruit) were being instantly recognized as compared those having smooth surfaces (e.g. apple, orange and grape). Some users mentioned that different attempts had to be made in order to detect and recognize fruits with smooth surfaces thus consuming further time. This has also been a reported issue with Vuforia SDK and the Vuforia Object Scanner [23].

- Lighting conditions

End users also faced challenges during object detection with varying lighting conditions. It was highlighted that fruits placed in better lighting areas, that is, light which better exposes or are directly exposed to the fruits deliver better results.

- Resource intensive

Many participants also highlighted that utilizing the application was resource intensive such that it causes the mobile phone to heat up. This is principally due to the use of the camera which analyses images to identify the pre-defined targets (fruits) in real-time mode.

- Estimation of fruit weight in grams

One of the key limitations of the application was that the user needs to enter the fruit weight in grams so as to obtain the correct nutritional information. In this process, most users only estimated the weight and this in turn affected the accuracy of the end results produced. As such, a better weight estimation technique is could be added in the application based on the size of the fruit.

VI. CONCLUDING REMARKS

Even though there are various sources that already provide nutritional information on fruits, there has been an increase in obesity rates and associated health risks amongst youngsters around the world. As such, newer ways to provide nutritional information on fruits or newer interaction technologies are needed. This paper investigated the application of augmented reality to nutritionally augment fruits through a proposed prototype called Fruitify which was developed using Vuforia and Unity 3D. Fruitify utilizes marker-less based AR technology to detect fruits through the camera of mobile phones and provide nutritional information including vitamins, minerals and calories, among others. Using the same tool, end users can also track their nutritional intakes and obtain periodic statics (e.g. daily, weekly, monthly) which could be further analyzed before appropriate actions taken.

To evaluate the usability of the proposed tool and to obtain insightful information on user's experience, an experiment involving 20 participants was conducted using cognitive walk-through and the system usability scale. During the experiment, all users were able to complete most of the tasks and the highest score obtained was for intention to use the application frequently. This also highlights the prospects of augmented reality as a means for providing nutritional information on fruits in practice. Overall, a SUS score of 82.1% was obtained thus also confirming that the application meets its usability requirements.

As future work, further effort is needed to estimate the weight of fruits so as to automate and provide accurate nutritional information. Furthermore, further solutions need to be investigated on how to better address issues pertaining to smooth surfaces, lighting conditions and to better optimize resources utilized by the application. Moreover, the co-relation between Fruitify and decrease in obesity rate could be further investigated, before extending the solution to other platforms including iOS.

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