Food Recognition for Dietary Monitoring during Smoke Quitting

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Abstract: This paper presents the current state of an ongoing project which aims to study, develop and evaluate an automatic framework able to track and monitor the dietary habits of people involved in a smoke quitting protocol. The system will periodically acquire images of the food consumed by the users, which will be analysed by modern food recognition algorithms able to extract and infer semantic information from food images. The extracted information, together with other contextual data, will be exploited to perform advanced inferences and to make correlations between eating habits and smoke quitting process steps, providing specific information to the clinicians about the response to the quitting protocol that are directly related to observable changes in eating habits.

1 INTRODUCTION

Food recognition from digital images for the analysis of dietary habits has become an important aspect in health monitoring application in different domains. On the other hand, food monitoring is a crucial part of human life since the health is strictly affected by diet (Nishida et al., 2004). The impact of food in people life led research efforts to develop new methods for automatic food intake monitoring and food logging (Kitamura et al., 2010). This paper presents the current state of the FoodRec project, which objective is the study, development and evaluation of state of the art digital technologies to define a framework able to track the dietary habits of an observed person, and make correlations with the smoking cessation process that the subject is performing. The system will periodically acquire images of the food eaten by the patient over time, that will then be processed by food recognition algorithms able to detect and extract semantic information from the images containing food. The extracted data will be exploited to infer the dietary habits, the kind and amount of taken food, how much time the user spends eating during the day, how many and what times the user has a meal, etc. Inferences performed on different days can be compared and further processed to perform analysis on user's habits changes and other inferences related to user's behaviour, such as increase of junk food intake and mood changes over time. The recording and semantic organization of daily habits can help a doctor to have a better opinion with respect to the patient's behaviour, quitting treatment response and hence his health needs. So far, many efforts have been spent in the application of technology on smoke monitoring (Ortis et al., 2020a) and food recognition (Allegra et al., 2020), this project represents the first attempt of the application of Artificial Intelligence (AI) and multidisciplinary competences for the definition of a framework able to drive and support people who are trying to stop smoking, by acting on multiple aspects simultaneously. The Food Recognition project (FoodRec) is granted by the Foundation for a Smoke-Free World (FSFW) [1]. The reminder of the paper is organized as follows. Section 2 describes the project pipeline, which is organized into six main phases (see Figure 1). Section 3 presents the expected outcomes of the project's outputs with respect to the smoking quitting support given by the developed system for

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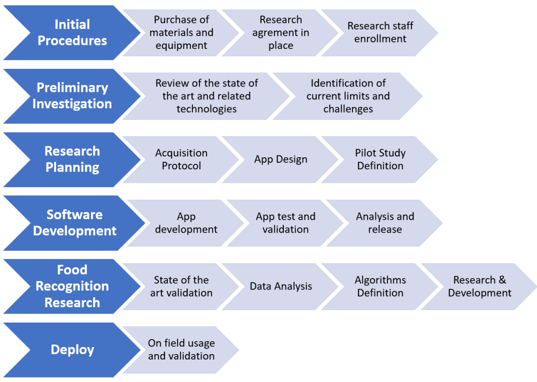


Figure 1: FoodREC project's phases.

dietary monitoring. Section 4 concludes the paper by describing the current state of the project and proposing future directions.

2 FoodRec: RESEARCH PLAN

The project involves several phases, which are sketched by the chart shown in Figure 1. The diagram shows five main phases, the first ones are related to preliminary studies and research, whereas the last ones regard the development of algorithms and software, toward the final deploy of the obtained solutions. With respect to the diagram in Figure 1, we can group the project's phases into two main macro-tasks, which are detailed in the following paragraphs.

2.1 State of the Art Evaluation

After initial procedures (see Figure 1) have been completed, the research staff focused on the preliminary investigation of the tasks and research problems related to the project purposes. This included the study of the state of the art related to food recognition and dietary monitoring technologies. As a result, a report concerning the existing products and approaches in terms of algorithms and smartphone apps has been produced and published in (Allegra et al., 2020), detailing the features and performances of each evaluated solution. The results of the study in (Allegra et al., 2020), revealed that modern food recognition techniques can support the traditional self-reporting approaches for eating diary, however, more efforts should be devoted to the definition of large scale labelled image datasets. The new dataset design should focus on the quality of annotations related to the type of food, areas, quantities and calories of each food item depicted in an image. So far, state-of-the-art focused on specific tasks performed in controlled conditions. The extreme variability of food appearance makes this task challenging. Especially for ingredients inference and, hence, for nutritional values estimation. The study concludes that food recognition for dietary monitoring is still an in-progress technology, and more efforts are needed to reach standards for reliable medical protocols, such as smoke quitting programmes.

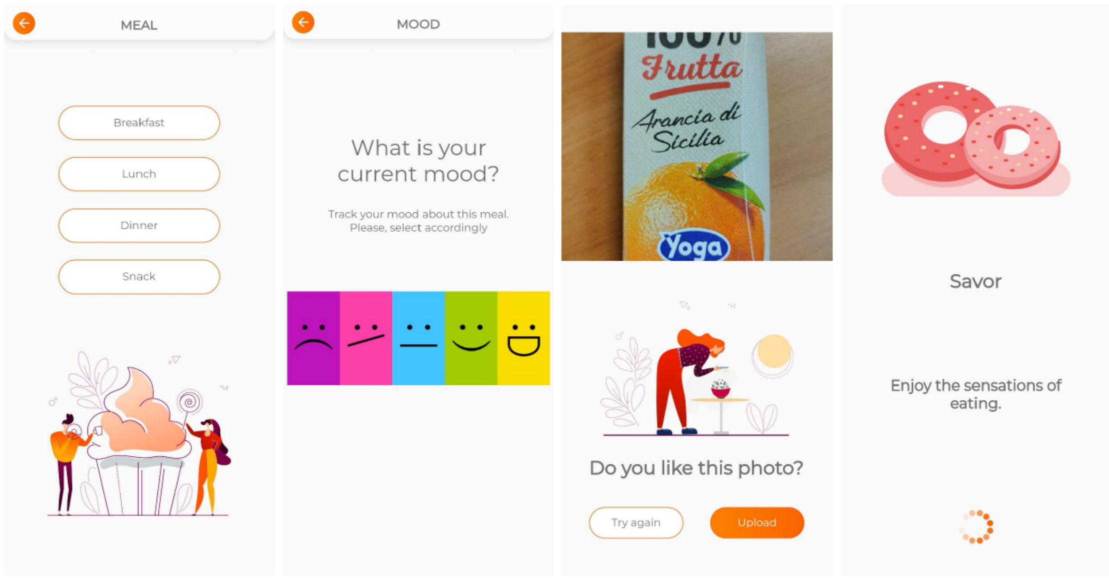
2.2 Applied Research and Development

After the study of the state of the art, and consequent analysis and definition of current limits and challenges, the research moved to the applied research and development phase. This phase has a dual objective. One is related to the development of the technological aspects of the framework, the other one is related to the development of analysis algorithms.

The iOS/Android FoodRec smartphone app for image acquisition and analysis, and dietary monitoring has been released, and is currently under testing by selected users. The mobile app FoodRec has been designed with the objective of providing a smart and accessible system for the daily eating habits monitoring of the users, with the definition of a dietary diary. The innovation that characterize the FoodRec app is the automatisms related to the food analysis and associated inferences. Indeed, the user just uploads a picture on the system, then all inferences are performed automatically, by means of Computer Vision and Artificial Intelligence technologies.

Figure 2 shows the main interface screens of the FoodRec app. First, a meal over four possibilities is chosen (a), then the app requires to state the mood associated to the meal (b), then the picture is taken (c) and uploaded (d). The app automatically learns the daytimes associated to food intake, and sends a notification to the user if the meal has not been inserted yet at the expected time. After the image is uploaded to the server, the recognition algorithms are applied, and the resulting inferences are shown in the app interface, as in the example shown in Figure 2. At this step, the user can edit the results (if needed) and confirm the new record for the eating diary. The information about user corrections are exploited for the further improvements of the algorithms, as well as their specialization with respect to the specific user habits.

FoodRec developed features also include water intake and weight tracker. Moreover, the user can inspect the statistics related to his/her eating habits, including the dominant food categories, ingredients, as well as temporal visualizations of specific parameters (see Figure 3).



(a) (b) (c) (d)

Figure 2: FoodRec example screens. Meal selection (a), mood associated to the meal (b), picture upload, motivational sentence (d).

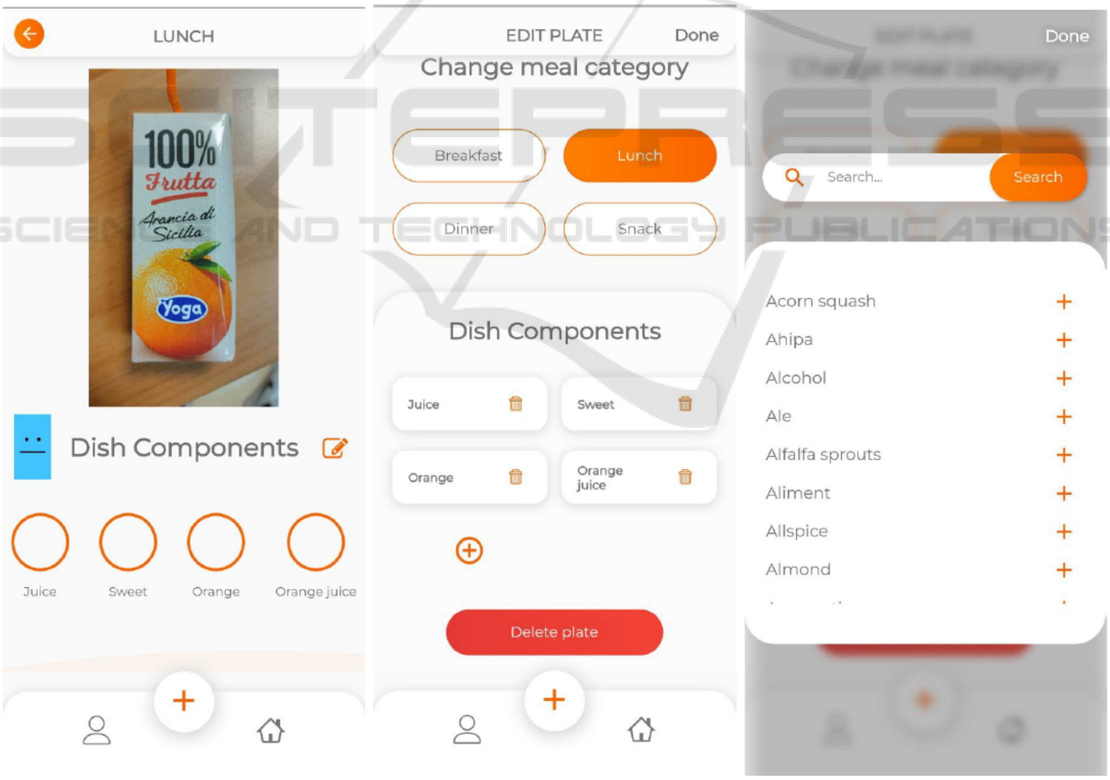
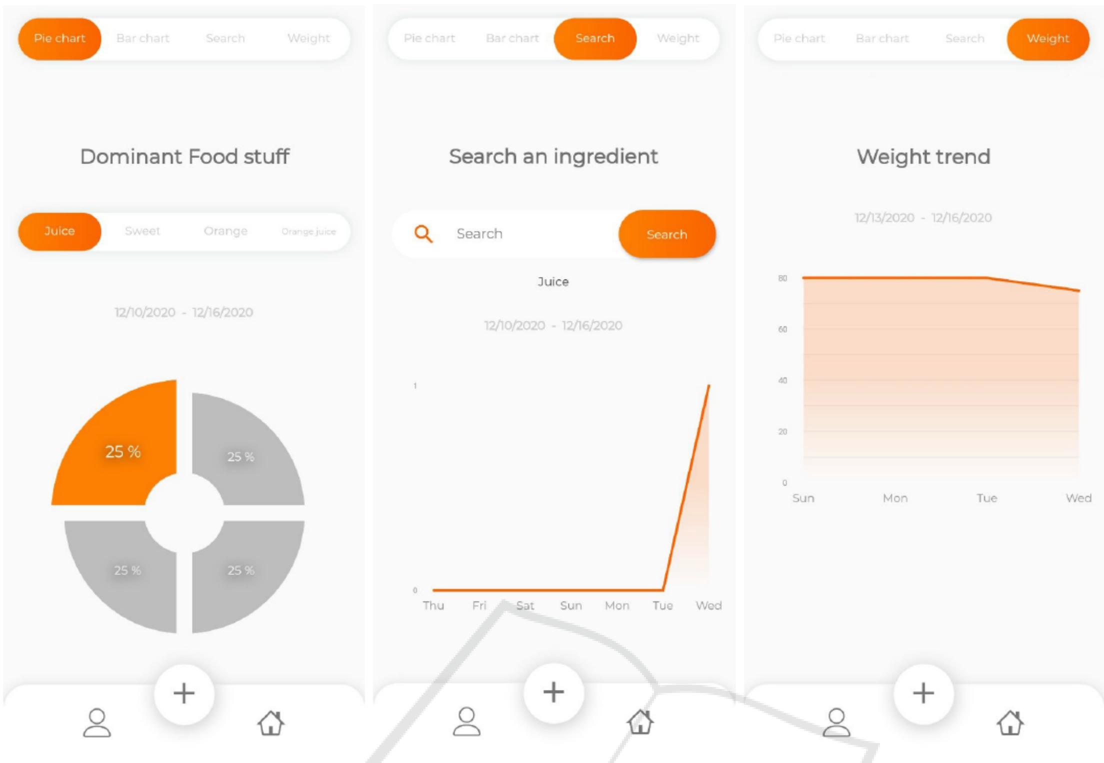


Figure 3: FoodRec interface showing the results of the food recognition system.

The analysis algorithms will comprise several steps, including image normalization, registration, feature extraction, food detection and classification. The research team is currently evaluating new methods and techniques for the improve of the performances of the food recognition algorithms exploited by the system. In particular, the efforts are devoted to three main tasks:



(a) (b) (c)

Figure 4: FoodRec in-app statistics.

- Food Segmentation: the aim of this task is the segmentation of the multiple food items that are depicted in a meal picture. This will output the areas of the pixels associated to each food item.
- Food Classification: this classic task combined with the food segmentation output will provide a semantic segmentation of the input image, which details at pixel level the parts of the image related to specific food categories.
- Volume Estimation: this task represents one of the most difficult aimed achievements. Indeed, the objective of this task is to estimate the volume of each food item. This task results very challenging because it involves the estimation of 3D information from monocular vision, at very small scale detail.

At this current stage, research methods related to the above mentioned tasks have been applied only on images available from state of the art in food recognition and image segmentation (Badrinarayanan et al., 2017) (Long et al., 2015) (Chen et al., 2014) (Noh et al., 2015) (Ronneberger et al., 2015). However, we plan to specialize such algorithms on the data coming from the FoodRec app, which is specific with respect to our purposes. The proposed system aims to recognize food items of specific users and monitor their habits. This task significantly differs from the recognition of any food instance depicted by a picture, such as happens in the development of general purposes food recognition systems. Figure 5 shows the proposed architecture. In particular, a common multi-label food classifier is composed by a Convolutional Neural Network which defines a meaningful feature representation for the input images, based on the training task. Then, the representation is fed to multiple logistic units (i.e., blue circles in the Figure) which are activated if the associated food item is present in the picture. The proposed architecture will take into account the specific user that uploaded the picture. Indeed, since the proposed system is aimed to systematically analyse and infer user habits, our objective is to add to the food classification pipeline a bias related to the user. As consequence, the individual logistic activations will be fed with a feature that is obtained by concatenating the image and user feature. The latter one, is represented by the weight matrix W in Figure 5, which will be learned from the users' habits during the training stage.

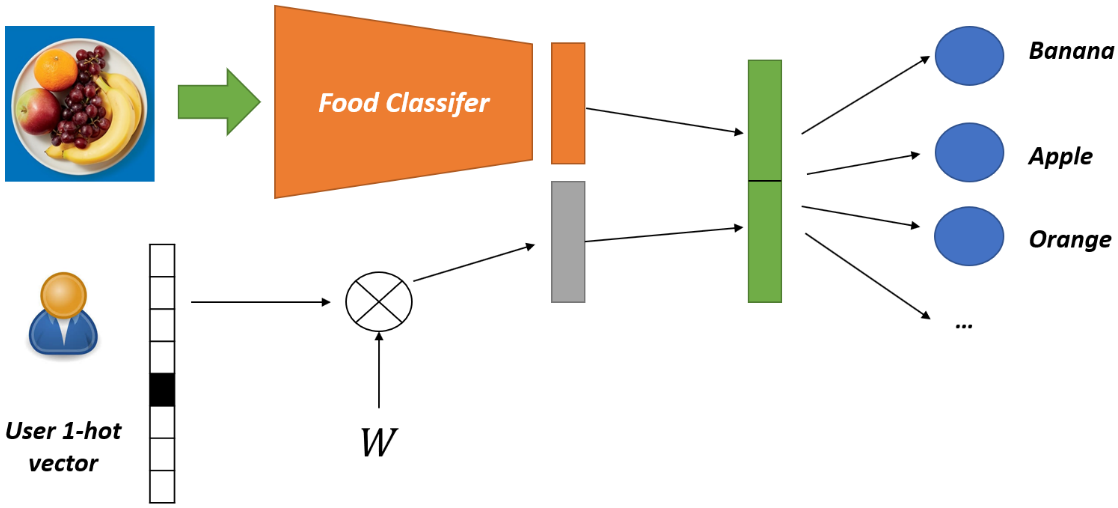


Figure 5: Food recognition proposed architecture. Blue circles depict independent logistic activations for specific classes, which are activated by the presence of the food item in the visual content taking into account the bias given by the user.

3 EXPECTED OUTCOMES

Abstinence from smoking is associated with several negative effects, including irritability, gain of weight and eating disorders, especially in the first period of abstinence. All these effects are connected one each others. The output of the food recognition system will provide indications about the user dietary habits and anomalies, at different times during the smoke quitting progress. The evaluation strategy will leverage well-known statistical methodologies for assessing correlations between the observed data and known information about the smoking quitting treatment.

4 STATE OF THE PROJECT AND FUTURE DIRECTIONS

At this stage, the initial procedures, preliminary investigation and research planing phases of the project (see Figure 1) have been completed. The other phases, except the final deploy, are currently being carried out. Furthermore, the FoodRec app has been tested and evaluated with a small controlled group of test users. The tests were carried out for a period of about four months that began on 12 August 2020 and ended on 02 December 2020, with the participation of 149 people aged between 19 and 60. The Table 1 summarizes the mainly statistics and activities performed by the users in the aforementioned tests. In particular, the Table 1a shows the number of interactions there were among the users and the main features of FoodRec (i.e., the upload of a meal's photo or the update of the drunk water), instead the Table 1b reports the distribution of the uploaded photos among the following categories: breakfast, lunch, snack and dinner. Once the tests have been ended, the users participated to a survey panel, reporting the feedback with respect to the app usage, which will be exploited to further improve the app features. The next step will be the evaluation on a larger audience of users in real-case scenarios (i.e., not controlled users). Such "on the wild" evaluation will produce a large set of real-case images from real users of the system, which will be exploited to develop novel algorithms and inference methods for the specific purposes of the project.

The developed dietary monitoring system could be extended to work with videos recorded by a fixed camera system, considering a set of cameras recording the scene from different fixed points of view. The collected data about the mood associated to food images (see Figure 2-b) can be combined with approaches related to sentiment analysis based on images (Ortis et al., 2020b). Such approaches can be investigated in order to automatically infer the mood of the user (e.g., depression, happiness, etc.) based on the dietary monitoring, avoiding to ask the user about his/her mood.

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Table 1: FoodRec - Usage statistics.

Usage Statistics	*Counts*
Participants	149
Meals upload	1657
Drinks update	721

(a) Usage frequencies.

Meal Type	*Counts*
Breakfast	396
Lunch	553
Snack	305
Dinner	403

(b) Meals type frequencies.

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