Segmentation, Recognition and 3D Reconstruction of Meal Images towards Carbohydrate Estimation for Diabetic Patients*

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Abstract— This paper presents a computer vision based system towards the automatic carbohydrate (CHO) intake monitoring on mobile devices for diabetic patients. The promising results of the proposed system justify the choice of the architecture, considering the numerous challenges of the problem.

I. INTRODUCTION

The amount of prandial insulin bolus needed by the insulin dependent diabetic patients is closely related to their carbohydrate (CHO) intake. However, diabetic patients often face difficulties in counting CHO accurately. Recently, automatic food intake monitoring systems were developed for mobile devices, based on computer vision techniques.

II. SYSTEM DESCRIPTION

In this paper a novel, computer vision based system is proposed aiming at counting meal’s CHO for diabetic patients. The proposed system (Fig. 1) takes as an input two images of served foods on a plate, from slightly different viewpoints.

First, image segmentation is carried out to separate the different food items. The input image is smoothed by a bilateral filter while colour quantization reduces the image colours to 11. A connected component analysis follows producing the initial segmentation. Segments with an area below a certain threshold are merged with the most similar adjacent segment in terms of colour. The resulting segments that touch the image borders are considered as background.

The image segments produced by the previous stage are described by colour and texture features and classified into one of the six pre-defined food classes: meat, breaded food, rice, pasta, potatoes and vegetables. The histogram values of a pre-clustered colour space are used as colour features. The hierarchical k-means algorithm is applied to cluster the colour space of the used image set, so the 512 most dominant food colours are determined. In addition, the Local Binary Pattern (LBP) operator is used, producing a 256-bin histogram that describes the local intensity texture. Thus, a vector of 768 features is created and fed to a SVM with a Radial Basis Function (RBF) kernel.

Two-view geometry is used to estimate the 3D shape of food items containing CHOs. Key-points are extracted from both images by the Scale-Invariant Feature Transform (SIFT) and Speeded Up Robust Features (SURF) detectors, while point matching is performed by a kD-Tree. The fundamental matrix is computed by a random sample consensus (RANSAC) scheme. Two 3D reconstruction approaches were implemented: i) sparse, which uses only the original point matches to create a 3D model and ii) dense, in which every pixel is considered as a potential point match. Dense reconstruction proved more precise; however it is used only when sparse 3D fails due to its high computational cost. An easily recognisable object is placed in the field of view in advance to provide a scale reference so the actual volume and CHO content can be estimated.

III. EXPERIMENTAL RESULTS

For testing the segmentation algorithm 50 multiple-food images were taken and manually annotated. The evaluation metric was based on the comparison of the result with the ground truth, producing an error estimate in the range of [0, 1]. The resulted error, 0.6, was satisfactory considering the difficulty of the problem and the strictness of the used metric. For testing the food recognition, 13,442 image patches were cropped from more than 5000 food images which gathered from the web. The resulted classification accuracy was in the order of 88% proving the effectiveness of the proposed method. The accuracy of the food volume estimation using multi view 3D reconstruction was evaluated using food models with predefined volume and CHO content. The pictures were obtained in real life conditions by smart phone camera. The mean relative error for the CHO computation was 14%.

*Research has received funding from the European Union Seventh Framework Programme (FP7-PEOPLE-2011-IAPP) under grant agreement n° 286408 [www.gocarb.eu].

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