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FOREWORD

The 21st edition of the Portuguese Conference on Pattern Recognition, RECPAD 2015, is held at the Universidade of the Algarve (UAlg), Faro, Portugal on the 30th of October, 2015. It is a great honour for UAlg and for the members of the Organizing Committee to have this opportunity to put together this conference.

From the 32 received submissions, 30 papers were accepted. All submissions were double blind and were send to be reviewed by three members of the Technical Committee. All papers had at least one review feedback, most of them 2 or 3 reviews. The conference closing session will include the Best Paper Award and also the ceremony of the APRP Master Thesis Award.

An invited lecture by Prof. Norbert Krüger, Maersk Mc-Kinney Moller Institute for Production Technology, University of Southern Denmark, will present a talk on Deep Hierarchies in Human and Computer Vision.

We are very happy to have the support of the following sponsors: Eva Hotel which helped us in the hotel and dinner conference logistics, and SPIC – Creative Solution for all the layouts and graphics.

On behalf of the organising committee, thank you to all the people involved to this event, namely, the members of the Technical Committee, the Portuguese Association for Pattern Recognition, APRP, specially its president, Prof. Jaime S. Cardoso and to the University of the Algarve – Instituto Superior de Engenharia, with a special thanks to Prof. Ilídio Mestre, director of the institute which will held the conference. Finally, we would like to thanks the CINTAL – *Centro de Investigação Tecnológica do Algarve*, and the precious help from Dr[a]. Gisela Oliveira, with all the work related to the registrations and invoices.

We hope you enjoy this year's edition of RECPAD.

Beef Quality Evaluation System

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Abstract

Applying computer vision in meat quality evaluation has been an active area of research in recent years. Accurate segmentation of beef-marbling images plays an important role in making the correct decision on beef-marbling score in an automatic beef quality grading system. The purpose of this study is to develop a new segmentation method to correctly separate the fat flecks from the muscle in the rib-eye region in a beef image. This paper presents an automatic system for beef marbling measuring which is composed of discriminant threshold selection method and run length processing. From the experimental results, it has been confirmed that the proposed system enables high quality grading of beef marbling, and robust region segmentation of the actual beef rib-eye image into lean and fat regions.

1 Introduction

The existing methods for meat quality classification rely heavily on visual evaluation of certain characteristics of the carcasses which according to the United States Department of Agriculture beef quality grading system, are the abundance of marbling, the colour of muscle and the skeletal maturity [7]. The features of *longissimus dorsi* (LD) colour, marbling and surface texture can be used to generate predictive models of eating quality parameters using classical statistical methods [3].

Marbling in beef is an important factor that influences taste, juiciness, tenderness and flavour [4] and it is often considered by consumers as the primary factor when buying meat in view of its contribution to sensory characteristics of meat [2]. Beef marbling is evaluated in terms of the content of fat and the distribution of fat particles. For current standards of grading beef quality, the beef marbling score is assigned from visual appraisal of the LD muscle. Generally a grader determines the grade of the marbling by visual inspection, which involves the collation of the actual carcass cross-section with published standard photographs illustrating marbling abundance of each grade. Although graders are professionally trained, subjective evaluation often lead to inconsistencies and variations.

The beef-marbling pattern is irregular, complex and varied. There is not clear bound between the lean region and the fat one. In spite of many researches accurate segmentation of beef marbling remains a challenging problem in automatically grading beef marbling by machine vision and image processing [1, 3, 6]. These evaluation methods do not replace the sensory evaluation, but allow a standardized methodology [2].

Chen and Qin [1] described a method for identifying the inter-muscular fat streaks by thresholding based on a between-class variance method. It performs well both in relatively light and also in relatively dark images, and this has shown to be more robust than eight standard algorithms, including region growing, the Otsu method and maximum entropy thresholding.

Jackman et al. [3] used Fuzzy C-means to split colour image into background, lean and fat. Then, they manually chose the threshold level to remove marbling pixels and eliminate any background pixels. All holes in LD image with 3 pixels or larger are considered as marbling.

Relatively good segmentation results have been obtained by the clustering method, which can provide the segmentation of fat flecks from lean muscle regardless the image histogram as proposed by Subbiah et al. in [6]. The original image was segmented into red lean muscle, white marbling and blue background. A number of images contained partially buried marbling flecks, which led to an overestimate of the LD muscle as the pink pixels were not classed as marbling. A thresholding operation was performed to remove those pixels from the LD image. The reflection of any connective tissue surrounding the LD of the muscle folds inwards were removed manually.

However, clustering analysis is an iteration process that has the disadvantages of being time-consuming and of low efficiency compared to the method based on thresholding. In order to reduce computation time, some efforts have been made to reduce the dimensionality of the original image. For instance, Subbiah et al. [6] reduced the image size by down sampling and Pang et al. [5] reduced the dimensionality of the original image by resampling.

In this paper we propose a computer vision framework that can be used in beef quality evaluation. The key idea is to measure the percentage of marbling in the muscle to obtain a beef quality evaluation system.

The paper is organized as follows: In “Materials and Methods,” the proposed computer vision framework and the experiments are explained. In “Results and Discussion,” the results obtained in several experiments are shown. Finally in “Conclusions” some concluding remarks are given.

2 Materials and Methods

The proposed framework used to design automatically a computer vision system for beef quality evaluation consists of five steps:

1. Image acquisition: A digital image of the beef under test is taken.
2. Pre-processing: The digital image is improved in order to enhance the details.
3. Segmentation: The region of interest (LD muscle) is found and isolated from the background of the scene.
4. Feature extraction/selection: Significant features of the beef are extracted in order to isolate the muscle and the marbling.
5. Classification: The extracted features are measured automatically in order to evaluate its quality.

2.1 Data Acquisition

Samples were obtained from carcasses in *Terra Fria Carnes* slaughterhouse. The materials included 83 cross sections in the standard location for measuring marbling.

All sample images were captured under the slaughter house artificial illumination. A removable pan with a white surface was used to position the steak in the camera field-of-view. The flash unit in the digital camera was not used because the light reflectance on meat surface lead to brightness errors.

2.2 Proposed Method

The process for checking beef marbling by image analysis can be largely divided into two sub-processes, based on the process of visual inspection performed by the graders. The initial process is to segment a cross-sectional image of beef carcass rib-eye into lean and fat regions. The second is to quantify features of beef marbling which are then used to estimate the beef quality.

The image pre-processing refers to the operation separating the rib-eye from the background. This is a necessary procedure for the segmentation of marbling, which is composed of several operations such as thresholding and morphological operation. As the images have a very complex background, it was decided to make a cut on the original images in order to reduce most objects of the background obtaining simpler and easier images to segment.

Since there are different light conditions among image acquisition tasks, we used the Lab colour space to calibrate the brightness of the images. In order to segment the LD muscle and extract the background we use an optimal linear combination of the RGB colour components with a threshold technique $(R > 80, G < 60, B < 120)$. Then, we applied morphological operations to correct the marbling regions as presented in Figure 1. We began with a close operation with a disk of 10 followed by a hole filling operation obtaining the region of interest.

After the segmentation of the region of interest area, the next step was to achieve the segmentation of the beef, in order to separate the

muscle without marbling from the total fat existing on the piece of meat. This operation was carried out applying morphological operations to segment the muscle from the intermuscular fat as shown in Figure 2.

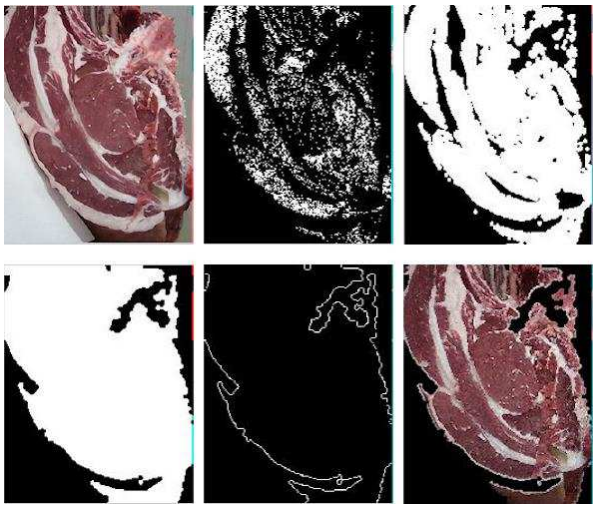

Figure 1: Extraction of the region of interest from the background.

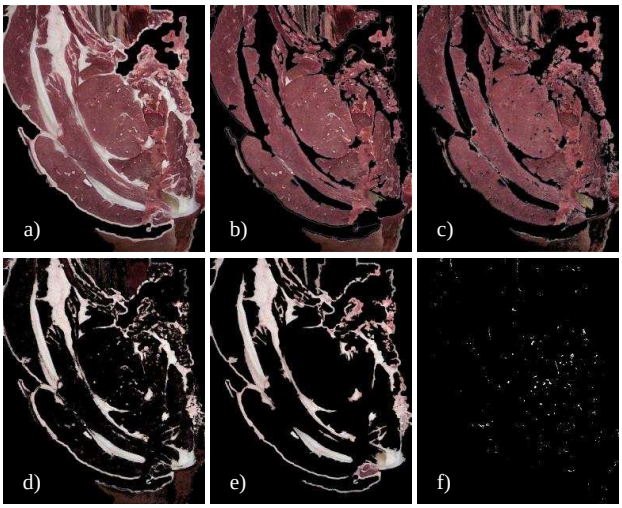

Figure 2: Extracted features: a) piece of beef; b) the muscle with marbling; c) the muscle without marbling; d) the total fat in a piece of beef; e) the intermuscular fat; f) intramuscular fat (marbling).

We obtained the total fat in the beef through a threshold technique based on the green component of RGB image (Figure 2.d). We removed marbling using morphological operations (Figure 2.e). In order to obtain the marbling Figure 2.f), we subtracted the image presented in Figure 2.e) from the beef image.

3 Results and Discussion

Figure 3 shows an example of the segmentation between the largest LD muscle area and its marbling.

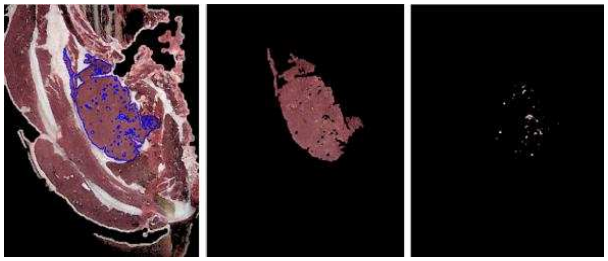

Figure 3: Left: original muscle image; middle: LD muscle image; right: marbling fat image.

To obtain the percentage of marbling we compared the marbling in each muscle with the total area of the muscle, as presented in Table 1.

Table 1: Percentage of marbling in the muscle of Figure 3.

Muscle LD	Muscle	Marbling
100%	98.12%	1.88%

We conducted our experiments using the proposed segmentation algorithm on the 83 sample images. Although the algorithm produce good results in most of the images in some of them it gives higher marbling percentage than it really exists in the beef. A reasonable explanation is that the moisture on the surface of beef rib-eye will cause reflection of light under a good lighting condition affecting to a degree the image processing which will be considered as marbling.

4 Conclusions

Image processing methods such as grey-scale transformation, contrast enlargement, morphological operations and binary segmentation, were used to process the image to effectively extract the rib-eye area of the cattle.

From the experimental results it has been confirmed that the proposed system enables high quality grading of beef marbling and robust region segmentation of the actual beef rib-eye image into lean and fat regions.

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