Beef Grading Using Computer Vision and Python / Matlab

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Abstract : This work determines the quality grade of the beef from the beef image given to the algorithm for the grading.

Methods : We have designed and developed a Computer Vision algorithm using Python / Matlab which grades the quality of the beef from the five different categories based on the different parameters for each grade quality of the beef by which each one differ from each other as defined by the USDA (United States Department of Agriculture).

Results : As defined by USDA (United Stated Department of Agriculture) beef is mainly categorized in five categories with each differentiating from each other on the basis of the intramuscular fat percentage present in it. The algorithm designed performs the similar task of determining the quality grade of beef easily and efficiently from the five different grades which are : Utility Grade (2.2 % and lower) ; Select Grade (3.9 % - 2.3 %) ; Choice Grade (9.8 % - 4.0 %) ; Prime Grade (9.9 % to 12.2 %) ; and Wagyu (12.3% and higher). The algorithm calculates the intramuscular fat percentage and then predicts the grade of the beef.

Conclusion : Promising results are obtained for the unknown grade of the beef type by the use of the algorithm designed.

Significance : Automated grading algorithm is a promising alternate to manual prediction for the beef grade; especially in areas lacking experienced graders.

Keywords : Beef Grading, Computer Vision, Image Processing, Marbling, Maturity.

Introduction

The USDA grade shields are highly regarded as symbols of safe, high-quality beef. Quality grades are widely used as a **"language"** within the beef industry, making business transactions easier and providing a vital link to support to the rural people. Consumers, as well as those involved in the marketing of agricultural products, benefit from the greater efficiency permitted by the availability and application of grade standards.

Beef is evaluated by high -skilled USDA meat graders using a subjective characteristic assessment process and electronic instruments to measure meat characteristics. There characteristics follow the official grade standards developed, maintained and interpreted by USDA's Agricultural Marketing Service.

By the use of **Computer Vision** and **Image Processing** the process of grading becomes easy as by the development of an algorithm with a set of instructions written in both **Python** and **Matlab** the process of grading becomes easy and fast, as by talking a high quality image of the

beef and passing it through the algorithm, the algorithm on calculating the percentage of then intramuscular fat and the percentage of meat in the beef predicts the grade of the beef from the five main grades of the beef and also shows the percentage of then intramuscular fat and then meat in the particular beef image.

Methodology

A. Computer Vision

[4] Computer Vision, often abbreviated as CV, is defined as a field of study that seeks to develop techniques to help computer **"see"** and understand the content of digital images such as photographs and videos.

Computer Vision tasks include methods for acquiring, processing, analyzing and understanding digital images, and extraction of high-dimensional data from the real world in order to produce numerical or symbolic information.

The Scientific discipline of Computer Vision is concerned with the theory behind artificial systems that extract information from the images. The image data can take many forms, such as video sequences, views from multiple cameras, or multi-dimensional data from a medical scanner. The technological discipline of Computer Vision seeks to apply its theories and models to the construction of Computer Vision systems.

B. Image Processing

[5] Digital Image Processing consists of the manipulation of images using digital computers. Digital image processing is to process images by computer. Digital image processing can be defined as subjecting a numerical representation of an object to a series of operations in order to obtain a desired result.

Digital image processing consist of the conversion of a physical image into a corresponding digital image and the extraction of significant information from the digital image by applying various algorithms.

Digital image processing mainly include image collection, image processing, and image analysis. At its most basic level, a digital image processing system is comprised of three components, i.e., a computer system on which to process images, an image digitizer, and an image display device.

C. Types of Images

1. **Binary Image -** The binary image as its name suggests, contain only two pixel elements i.e., 0 and 1, where 0 refers to black and 1 refers to white. The image is also known as Monochrome.
2. **Black and White Image -** The image which consist of only black and white color is called black and white image.
3. **8 bit Color Format –** It is the most famous image format. It has 256 different shades of colors in it and is commonly known as Greyscale Image. In this format, 0 stands for Black, and 255 stands for White, and 127 stands for Gray.
4. **16 bit Color Format –** It is a color image format. It has 65,536 different colors in it. It is also known as High Color Format. In this format the distribution of color is not same as Grayscale Image.

Beef Grades

[1] The USDA quality grades for steer and heifer carcasses are determined by balancing maturity and degree of marbling.

Maturity refers to the physiological age of the live animal. Physiological maturity is determined by the ossification (cartilage turning to bone) pattern of the backbone, lean color, and rib bone shape and color. The most important factor is the ossification pattern of the dorsal tip (button) of the thoracic vertebrae. The thoracic vertebrae is the section of the backbone that has the ribs attached. In **A** maturity cattle, the buttons will have no to very little ossification, the ribs are red and round, the lean color is light red and the lean texture is fine. A cattle mature, the buttons contain greater ossification, the ribs become whiter and flatter, the lean color becomes darker and the meat texture becomes more coarse(grainy).

Marbling is defined as the flecks of flat within the muscle (i.e., intramuscular fat) and is associated with the flavor and juiciness of meat. Greater marbling levels tend to improve eating satisfaction.

Marbling is evaluated in the ribeye muscle between the 12^{th} and 13^{th} ribs. The greater the amount of marbling, the higher the quality grade.

A. Different Grades of Beef

[1] Based on the USDA (United States Department of Agriculture) the beef is mainly divided into five major grades based on the different percentage of intramuscular fat present in it which are as follows :

1. **Utility Grade** – The beef which does not have much of intramuscular fat and has a very pretty color it.

   It is little bit darker red then the other kinds of steak but has a very less fat and is a little bit more chewy.

   This steak mainly comes from something over 30 months of age which possess one or more risk which is BSE.

2. **Select Grade** – It is very uniform in quality and normally leaner than the higher grades. It is fairly tender, but, because it has less marbling, it may lack some of the juiciness and flavor of the higher grades.

   It has 40% more intramuscular fat than Utility grade. This steak comes from something within 30 months of age or less.

3. **Choice Grade** – It is high quality, but has less marbling than prime. Choice roasts and steaks from the lion and rib will be very tender, juicy, and flavorful and are suited for dry-heat cooking.

   It comes from Black Angus animals. This steak comes mainly from something of 30 to 42 months of maturity.

4. **Prime Grade** – The first grading is prime grade beef. This is the highest quality grade when it comes to tenderness, flavor, and juiciness. It comes from young cattle's.

   This steak comes mainly from something of 9 to 30 months of maturity.

5. **Wagyu** – It is also known as Japanese Beef Kobe. It has 40 to 50% more intramuscular fat than the prime grade beef.

Following below is the table showing the percentage of intramuscular fat percentage in the different grades of beef –

Beef Grade	Percentage of Intramuscular fat
Utility Grade	2.2% and lower
Select Grade	2.3% - 3.9%
Choice Grade	4.0% - 9.8%
Prime Grade	9.9% - 12.2%
Wagyu	12.3% and higher

Figure 1

Dataset

A dataset is a collection of data. Data can be any unprocessed fact, value, text, sound or picture that is not being interpreted and analyzed.

The dataset available to us at time consisted of 37 different image samples of beef of different grades which are not graded.

Each sample image of the beef image contain different percentage of intramuscular fat, marbling , maturity, etc.

Below is an example of beef image available in the dataset:

Figure 2

Algorithm Designing

An algorithm is a sequence of steps to solve a problem. Design and Analysis of algorithm is very important for designing algorithm to solve different types of problems.

Algorithm design refers to a method or a mathematical process for problem-solving and engineering algorithms.

Below shown is the flow chart showing the steps taken in the designing and implementation of the algorithm :

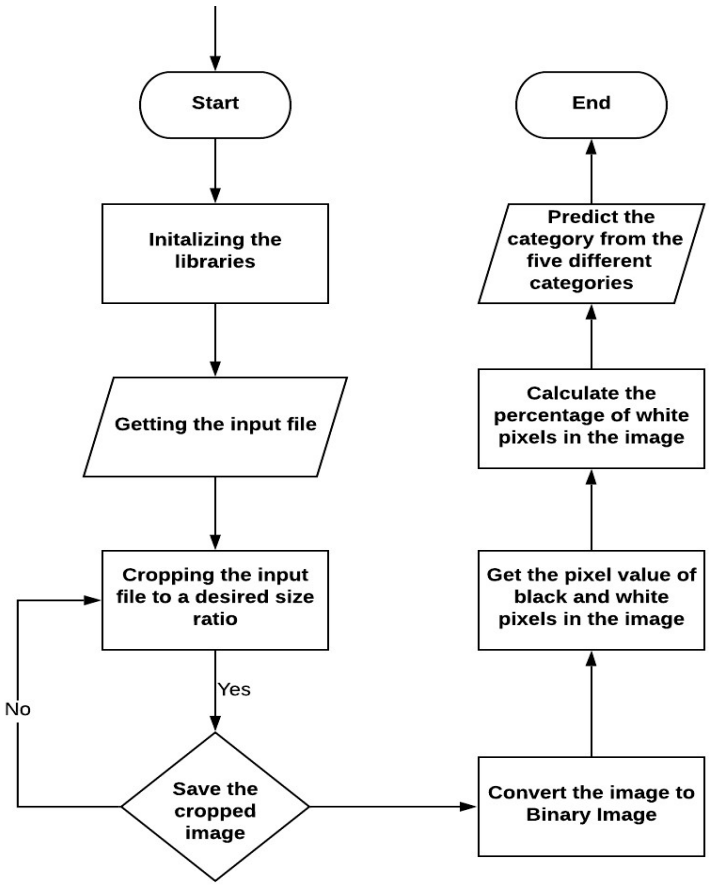

Figure 3

A. Cropping of the Image

Cropping is the removal of unwanted outer areas from a photographic or illustrated image. The process usually consists of the removal of some of the peripheral areas of an image to remove extraneous trash from the picture, to improve its framing, to change the aspect ratio, or to accentuate or isolate the subject matter from its background.

In Matlab,

imcrop (I, rect) crops the image **I** according to the position and dimension specified in the crop rectangle rect or an **images.spatialref. Rectangle object**. The crop rectangle, **rect**, is a vector of the **form [x, y, width, height]** that specifies the size and position of the cropped image in spatial coordinates.

In Python,

PIL is the library which provides the python interpreter with image editing capabilities.

PIL.Image.crop() method is used to crop a rectangular portion of any image.

Below mentioned is the cropped image sample using both Python and Matlab –

Figure 4

B. Converting the Image

A binary image is the type of image where each pixel is black or white. Here 0 represent black and 1 represent white pixel.

In Matlab,

im2bw (I, level) converts the grayscale image **I** to binary image **BW**, by replacing all pixels In the input image with luminance greater than level with the value 1 (white) and replacing all the other pixels with the value 0 (black).

This range is relative to the signal levels possible for the image's class. Therefore, a level value of 0.5 corresponds to an intensity value halfway between the maximum and minimum value of the class.

In Python,

Thresholding is a technique in OpenCV, which is the assignment of pixels values in relation to the threshold value provided. In thresholding, each pixel value is compared with the threshold value. If the pixel value is smaller than the threshold, it is set to 0, otherwise, it is set to a maximum value(generally 255).

cv2.Color(original_Image, cv2.COLOR_BGR2GRAY)

converts the image to grayscale image and after adding the threshold value it differentiates between the maximum and minimum value and sets the value 1 for white and 0 for black. Below is the code for adding the threshold values to the image.

cv2.threshold(img, 127, 255, cv2.THRESH_BINARY)

Below mentioned is an example of the image sample converted to binary image –

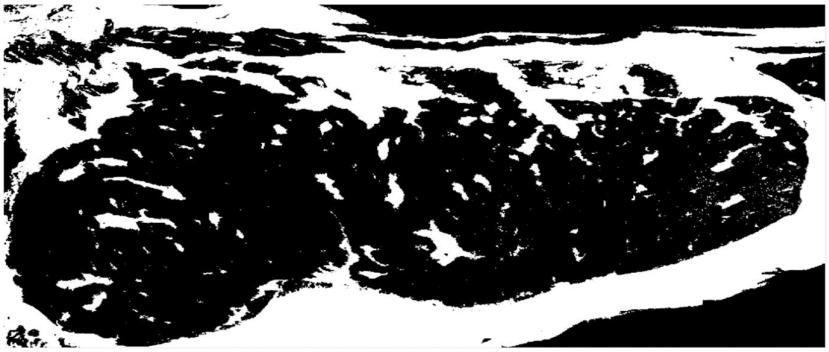

Figure 5

C. Calculating the white and black pixels percentage

The number of pixels in an image can be calculated by multiplying pixel columns by pixel rows. The resolution of the image is described with the se of two positive integer numbers, where the first number is the number of pixel column (width) and the second is the number of pixel rows (height).

In Matlab,

```
pix = size ( newmap );
no_of_pix  =  pix ( 1 ) * pix ( 2 );
no_of_white_pix  = sum ( sum ( newmap == 1 ) );
percent_of_white_pix = ( ( no_of_white_pix * 100 / no_of_pix ) + 2 );
```

this code works to calculate the percentage of white pixels i.e., the intramuscular fat percentage of fat in the beef and then, by subtracting the percentage of intramuscular fat from total of 100 we get the percentage of the black pixels i.e., the meat portion of the beef.

In Python,

```
m, n = img.shape
print ( " { } white pixels, out of { } pixels in total.".format ( img.sum ( ), m * n ) )
percentage = ( ( img.sum ( ) ) / ( m * n ) * 100 )
```

this code calculates the total pixels in the image and then calculates the amount of white pixels in the image i.e., intermuscular fat of the beef and then by dividing the amount of amount of white pixels by total pixels in the image we get the percentage of intermuscular fat present in the beef and by subtracting the percentage of intermuscular fat from 100 we get the percentage of meat in the beef.

D. Predictions

Prediction refers to the output of an algorithm after it has been applied on the test data.

After the beef image from the start has been cropped and has been converted to binary image and the percentage of white and black pixels has been noted, by the use of the **if else condition** all the various categories of the beef can be defined with the differentiation criteria between each category by the percentage of intramuscular fat present in the beef as defined by the **USDA** and then the category of the beef image to be determined can be easily determined.

Summary

[7] The USDA meat grading system sets standards of quality and cutability (yield of edible meat) used in buying and selling of meat. As a voluntary program administered by the United States Department of Agriculture (USDA), the cost of the quality and yield grading program is borne by meat packers. Grading provides consumers an assurance that the product purchased conforms to an expected standard of palatability.

By the use of the algorithm designed it makes determining of the grade of the beef easy, and helps to grade large amount of beef belonging to unknown categories quick and easy.

Our future work is to improve the performance of the algorithm designed and also improve the runtime efficiency of the algorithm.

Conclusion

In this paper, we designed and implemented a Computer Vision algorithm to grade the quality of beef using the beef images. Our processing pipeline consisted of various steps each inter-related with each other : the steps included the cropping of the beef image in order to focus at the centre of the beef from where the quality grade is determined, it involved converting the image to black and white image so that, the percentage of the intramuscular fat can be calculated easily and then on the basis of the USDA standards the beef can be graded in to then category it belongs to easily.

References

[1] USDA Beef Quality and Yield Grades – Dan S. Hale, Kyla Goodson, and Jerry W. Savell

https://meat.tamu.edu/beefgrading/

[2] Understanding Yield Grades and Quality Grades for Value – Added Beef Producers and Marketers – Rob Holland, Dwight Loveday

https://extension.tennessee.edu/publications/Documents/SP755.pdf

[3] How the USDA Grades American Beef

https://www.bestonlinesteaks.com/How-the-USDA-Grades-American-Beef

[4] Computer Vision : Algorithms and Applications by Richard Szeliski

https://szeliski.org/Book/drafts/SzeliskiBook 20100903 draft.pdf

[5] Digital Image Processing by Rafael C. Gonzalez, Richard E. Woods

http://www.imageprocessingplace.com/downloads_V3/dip4e_downloads/dip4e_sample_book_material/dip4e_detailed_TOC.pdf

[6] Fundamentals of Digital Image Processing – A Practical Approach with Examples in Matlab by Chris Solomon, Toby Breckon.

[7] USDA Grading Module and Simulation

https://www.beefresearch.org/usdagradingmodulesimulation.aspx

[8] The Relationship Between Marbling and Intramuscular Fat

https://www.sites.ext.vt.edu/newsletter-archive/livestock/aps-02_12/aps-171.html

[9] Intramuscular Fat

https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/intramuscular-fat