A Review of Linear Algebra Applications in Image Processing and Food Quality Evaluations

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Abstract

The following paper discusses how to apply linear algebra methods to increase effectiveness and efficiency of evaluations on food. As such, the paper gives a brief background of Linear Algebra, its applications in imaging, and how to form a basis for food quality evaluation. With this in mind, the paper aims to meet this by discussing different algorithms and methods such as Compression Algorithms, Change Detection, Object Based Image Analysis, and its applications for food processing. As such, this paper's ultimate objective is to form a basis for food quality evaluation while applying the previously mentioned methods to create effective, clean, and consistent ways to properly evaluate food.

1 Introduction

Linear algebra is a useful tool in image processing. The use of matrices within code allows for simpler programming, and thus improved run time. Linear algebra mappings are also useful in solving issues within image capturing by allowing for the manipulation of input and output images through pixel mapping. In image processing, the pixels of computers, televisions, and phones use RGB scaling. These RGB values store as a single integer of Mod 65536, 256, 1 to r, g, and b respectively. On the contrary, a black and white image stores as an array of 0's and 1's. With this much complexity, big images can create costly run times. As such, there are algorithms that exist to reduce such run times, using many different linear algebra to compress and simplify the process. Two very useful methods are Block processing which takes images and processes them in sections and Singular Value Decomposition which factorizes a matrix in a generalized matrix $M = UDV^T$. Using these methods as a basis, we can apply further image compression algorithms, reduce runtime of such algorithms, and better classify items in images to create a faster and more productive environment which we can use to specify on food analysis.

2 Image Compression Algorithms and Applications to Food Evaluation

There are many different methods and algorithms to compress and reduce the size and quality of imaging. In the context of food quality evaluation, we can use image compression to simplify complex food images into simpler details and sections to analyze. One such image compression algorithm involves Singular Value Decomposition, or an SVD. Singular Value Decomposition allow us to break up an image into an orthogonal matrix and use a rank parameter to return an image of relatable quality. To turn an image into an SVD, we must convert the image matrix into the three matrix equation as follows: $Rank(A) = k : A_k = S_1U_1V_1^T + ... + S_kU_kV_k^T$. Out of the three matrices, U is the most important as it contains the eigenvalues of the original image. Applying this to examination of food quality, we can use SVDs to find an optimal rank of k eigenvalues of the image A to both find a more decompressed image and to generalize complex details into identifiable traits of given food items. In addition to SVDs, we can use another algorithm called Block Truncation Coding (BTC) to increase the efficiency of our image processing. What Block Truncation Coding does is break apart a larger image into groups of smaller sub-images and determines whether each pixel is greater than or less than the mean of the pixels in the sub-block. The values are then stored in a bit plane where "a is the number of pixel values greater than or equal to [the mean] and b is the number of pixels whose values are less than the mean $a, b = \bar{x} - \sigma\sqrt{n^+/n^-}$"[3]. In food quality evaluation, we can use a BTC approach to focus on specific areas of one or multiple food objects at the same time to examine either individual food items in a group and regions of food that are more susceptible to quality deterioration. Combining the two algorithms, we can use SVDs to simplify food object images and BTC to generalize regions on food objects, allowing quicker and more efficient food quality evaluations.

3 Change Detection For Food Processing

In addition to altering food images, knowing how to identify changes and anomalies in food items is critical for proper quality evaluation. Change detection, a constantly running algorithm, allows for real-time checks on changes in imagery. In real-world examples, applications of change detection allow for sudden changes to be seen or detected quickly such as the detection of intruders, the superposition of objects in new environments, and the compression of images through selective processing. To use change detection for food quality evaluation, a change detection algorithm can be implemented using a standard basis of perfect quality and comparing the food object in question. With the algorithm analyzing several different angles of a food object to its sample, it can give the food object in question a quality grading based on the similarity to the perfect basis in question. Many different subforms of change detection methods exist for different applications in the real world. For food quality evaluation, the simplest form of change detection, a Statistical Change Detection (SCD) model, will be of best use. A standard SCD model directly compares the initial hypothesis of an image H_0 to a different altered image of different hypothesis H_1. The model takes the difference between the altered image and the initial image and outputs a binary matrix of the pixels changed by at least a given threshold. In food quality evaluation, an SCD model can be used to find regions of a food item that may be rotten or misformed. Unfortunately, change detection can only help with imagery of the food on the outside or any exposed surfaces of the food object in question. As such, for foods that do not change much in appearance when spoiled, only using a change detection comparison is not sufficient for analysis.

4 Object Based Image Analysis

To further help with analysis on food quality, an object-based association algorithm can be implemented to better sort and identify food objects and their traits. In the past, pixel and subpixel analysis was used in Object Based Image Analysis (OBIA). However, focus is now on algorithms to associate pixels in an image to corresponding objects. In general, "OBIA builds on older segmentation, edge-detection, feature extraction, and classification concepts"[2]. As such, we can implement these OBIA methods to identify food items more accurately and efficiently. One such OBIA method that will be useful for food analysis is a Maximum Likelihood Classification algorithm. This algorithm allows certain identifiable traits to be associated with specific objects over many samples. For food quality evaluation, we can feed tons of sample food objects and have a likelihood classification of a food object based upon traits observed in the food object. In addition, we can combine this with another useful OBIA method for food analysis: characteristic classification. Similar to likelihood classification, characteristic classification focuses on specific features of an item rather than the item itself. As such, food objects can be evaluated more accurately by identifying characteristics in the image and correlating it to both food type and quality. To improve storage and better represent these algorithms, we can implement an Artificial Neural Network (ANN). In a food quality evaluation, an ANN can be used for improved logic and more complete decision making when thoroughly evaluating the quality of a given food item while representing the algorithms better. With these OBIA algorithms, we can represent foods as objects, implement better identification algorithms for food objects based on OBIA, and promote reinforcement learning on our algorithms to identify foods both quicker and more accurately over time.

5 Image Processing in Food Quality Evaluations

With these methods in mind, there are many applications of image processing in food quality evaluation. Recent image processing techniques have become useful in determining the properties of food. Such techniques have the abilities to characterize important properties in evaluating food quality, such as size, shape, color, and texture. These properties are useful in analyzing the health of a food and whether or not it should be consumed. It should be noted, however, that image processing in this sense is very reliant on the quality of the image. Image quality can be affected by the lighting in which it is taken, the amount of sound contained in the image, and also the background of the image.

The first issue that can impact image quality is light. The lighting in which a picture is taken can influence its quality, when using CCD cameras. These cameras convert light into electrical charge[4]. This creates a high quality image that can be analyzed. In food processing, the object must also be imaged at many different angles in order to evaluate its entire outer surface. Using multiple CCD cameras at different angles will achieve the desired result. Beyond that, filters can also be applied to the cameras in order to evaluate foods in changing spectral regions. This becomes a necessary application to see different tissues on a food's surface. Another reason to use filters is for the detection of possible skin issues. This can be noted in Figure 1 below, as we see fruits with varying skin diseases being analyzed. In row (A) we see the initial input image and in row (B) the output image created by the computer. As can be seen the first column looks very healthy, while the last column seems to have substantial malformations. This image processing technique is necessary to analyze the external properties of a food. The other necessity in image capture in food evaluation is internal imaging.

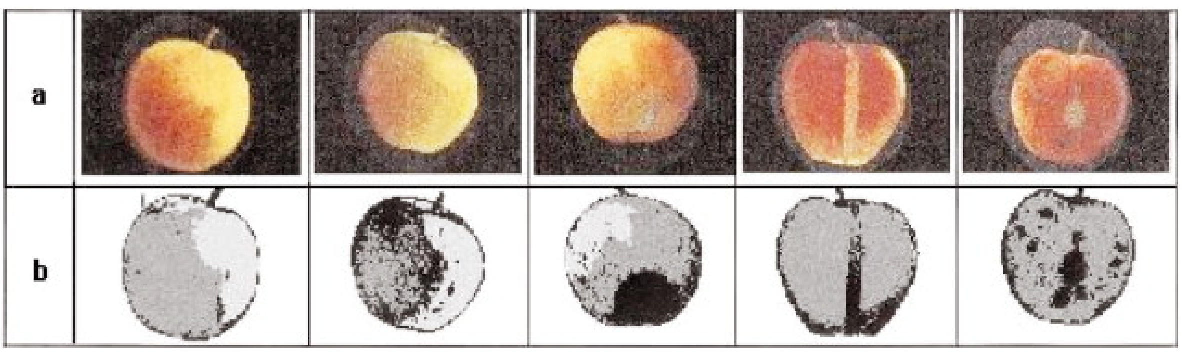

Figure 1: Figure 1: Images taken of a food, with malformations highlighted by image processing

Internal imaging in food quality evaluations is required to avoid making incisions in a food, and there are many techniques used to obtain images of internal structure. In order to analyze internal structures of a food it becomes useful to use means other than CCD cameras. Such techniques are MRIs, ultrasounds, and CT scans. Ultrasounds are a newer technology in food evaluation that help measure certain characteristics within foods. They are specifically useful for imaging tissues. In certain food industries, such as the meat industry, the analysis of tissue is very important in determining the quality of the cut or its level of safeness to eat. The quality of cuts are determined by factors such as fat thickness and yield estimates. These characteristics can all be analyzed using ultrasounds. MRI's, on the other hand, are useful image capture techniques that are used to measure moisture in foods and its internal movement. This property of the food can be analyzed to determine the effects of thawing and freezing, estimation of yield, and water loss properties. In this sense, MRI's become a useful technique that allows for the categorization of foods. They help separate foods that are safe and unsafe to freeze, as well as foods that need to maintain a certain water level in order to remain healthy. CT scans are another internal imaging technique that allows for the creation of pictures of a food's structure. This is done through a cross sectional technique that stacks images to create a broader image. CT scans are used in the fish, meat, fruit, and vegetable industries as a way to analyze the internal structure of the food and find any unhealthy properties. Although these techniques are useful, there are also many issues that arise with their use.

Image capture with the internal methods are subject to having certain amounts of sound within the image, which impacts its quality. In order to deal with such an issue there are techniques that can be applied to the image. Image pre-processing is a way around the issues caused by sound because it improves the images data and suppresses distortion. As such, there are two types of pre-processing. Pixel pre-processing is a technique that maps an input image to an output image. Under this assumption each output pixel takes a mapping to an input pixel of the same coordinate. Mapping pixels in this way improves the data of the image, thus allowing for sound suppression. The other technique is local pre-processing. This technique uses small neighborhoods of pixels in an input image and maps them to the output image, thus creating a new brightness value for the output image[4]. Such techniques are ways around sound impacting image quality, but there are more issues. Another issue of image capture involves dissecting the image in order to find what needs to be analyzed. Thus, a technique called segmentation becomes important. Segmenting images is necessary to divide an image into what needs to be analyzed versus the background of the image, which is of no importance. Segmentation takes the form of three techniques in food analysis. Threshold based imaging segments an image by dividing it into interior and exterior points, while gradient based techniques seek to detect the edge of the object in order to segment the image from the background. Lastly, classification based techniques segment images by assigning to each pixel a different object[4]. Image analysis in this sense allows for the removal of a background, so that only the food is being evaluated.

The segmentation of images is especially important in the technique of hyperspectral imaging, which itself is a non-invasive way to analyze the quality of a food's interior. Based on the movement of the camera and the spectrograph created by the food a hyperspectral image can be developed using three techniques. They are point-to-point, line-by-line, and area scanning. The most useful of these techniques in the food industry is line-by-line spectral scanning because this method can be used in conjunction with a conveyor belt, a common tool in food packing. The technique itself is also relatively simple. It uses a light, camera, spectrograph, and computer to capture the image. The computer captures the image in real time and produces a hyperspectral image of the food. The resulting image is a combination of images at discrete, continuous, spectral widths of which a reflectance spectrum can be found for any region of the image[5]. Such a procedure eliminates the need for invasive food quality analysis.

6 Discussion and Conclusion

In linear algebra, there are very useful techniques that allow for decreased code run time, and thus real time image analysis. This image analysis allows for the evaluation of food quality. In image compression the use of singular value decomposition and block truncation coding allows for the focus on specific areas of food objects to examine either individual food items in a group and regions of food that are likely to quality deterioration. With change detection a statistical change detection model can be used to help with imagery of the food on the outside or any exposed surfaces of the food object in question. This allows for the detection of spoiled or altered food. Finally, object based image analysis creates algorithms that allow certain identifiable traits to be associated with specific objects over many samples. Thus, a catalog of healthy foods can be created and used of foods and their quality. This allows for more complete decision making when thoroughly evaluating the quality of a given food item while representing the algorithms better.

Such image analysis techniques are very useful in the application of food quality evaluations. The many techniques that can be used to obtain food images all have certain issues that impact their quality. Such issues can be avoided or corrected through the use of image processing techniques. These techniques include image pre-processing, segmentation, and hyperspectral imaging. Using image capture in this application also helps to avoid invasive techniques in food quality evaluations, and identifies possible surface level issues as well. Such applications of linear algebra and image processing are necessary in food quality evaluations. Food quality is an important factor in human health, and so it is key to analyze the properties of a food before reaching distribution sites.

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