23 - Leitura - Computer Vision Applied To The Inspection And Quality Control Of Fruits And Vegetables (III)

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Computer vision is a great ally in industry with a broad range of applications. As cited by the paper:

> terrestrial and aerial mapping of
> natural resources, crop monitoring, precision agriculture,
> robotics, automatic guiding, non-destructive inspection
> of product properties, quality control and sorting in
> processing lines and the general automation of processes

This is due to its ability to produce significant amounts of information, even further from what human eyes can see. Furthermore, computers are deterministic and objective in their approach, therefore by employing them instead of humans to do certain tasks we eliminate human error and, if we have a reliable enough algorithm we can be sure to get the best possible result.

2. Theoretical support

2.1 Computer vision system

One use that has been growing is the measure of color attributes in food. The success of a monitoring system depend largely on the hardware configuration of the computer vision system, whose most important components are the lightning and a camera.

2.2 Lighting

The lighting should be carefully considered as the color of the light influences directly the appearance of the food sample. The sample must be evenly illuminated for a good and reliable result, since sharp reflections or dark shadows will interfere with the interpretation of the computer. When measuring a flat sample for example, we can usa a 45° angle light incidence since it will not create shadows and the angle will prevent reflections directly into the camera. On the other hand, when sampling a spherical object it's more convenient to use a diffuse light so it's lit more evenly despite its uneven shape.

Another tool used to prevent unwanted reflections are polarizing filters with cross-polarization techniques to eliminate most of specular reflection.

In some cases with translucent objects it is of interest to put the light behind the sample. In this case it's even more interesting to see the effect of including a broader light spectrum in the lighting system, even going into the infrared region, which reveals more information that can be useful.

Most recent lighting systems use LEDs for their price, low energy consumption and efficiency.

Care should be taken with the use of fluorescent light since certain wavelengths emitted can cause damage to organic matter. However these emissions can have their uses, for example when detecting for damage caused by frost since these wavelengths excite certain molecules that relax emitting lower radiation energy that can be detected.

2.3 Image acquisition

In computer vision we use cameras to gather the information, so it can be said to be one of the most important parts of the system.

One option is to use linear cameras, which are composed of only one line of pixels and used in applications where the sample moves in front of the camera or vice versa, thus capturing the entire picture one row at a time. Matrix cameras are more commonly used, especially nowadays where they have become cheaper to produce and with more closely packed pixels to increase resolution.

Some applications require the image acquisition to be bound to specific features in different wavelengths. Multi-spectral cameras can be used in this case to isolate the desired bands. These systems are called hyper-spectral systems.

Other developments that aid the application discussed are FSAOs, which are adjustable band pass filters, and further developments in computing power, higher resolution cameras, data transfer protocols, etc..

2.4 Image processing techniques

2.4.1 Color space transformations

The most commonly used color space is the RGB, however due to its problems the sRGB method was created. It allows for greater reproducibility among other devices.

2.4.2 Color calibration methods

Image quality in computer vision depends on reproducibility and accuracy, especially for consistent color measurements. Cameras use CCD chips with RGB filters, but outputs vary across devices and over time, requiring careful calibration to ensure reliable results, essential in quality control applications.

2.4.3 Color constancy and illumination estimation

There are three factors affecting the image recorded by a camera, which are the physical content of the scene, the illumination incident on the scene, and the characteristics of the camera. The same object can appear as a different color depending on the lighting.
Computational color constancy has the goal of finding an invariant scene description from an image taken under unknown lighting conditions. The algorithms to fulfill such task can be supervised or unsupervised machine learning algorithms.

3 Applications in the inspection and control of quality characteristics

3.1 Color

Recognized as a primary quality indicator, color assessment is critical for determining food appearance and freshness. Computer vision systems assess color using standard models like sRGB and L_a_b* to evaluate freshness and appeal, often as a substitute for sensory evaluation.

3.2 Size and Volume

Product size is tied to market pricing and consumer expectations. Computer vision allows for accurate measurement of product dimensions even for irregularly shaped items, by combining images from multiple angles and using algorithms to calculate volume.

3.3 Shape

Shape is another quality characteristic that influences consumer preference, as abnormal shapes may lower market value. Computer vision systems assess shape by analyzing contours and structures, which is especially useful in identifying defects that deviate from standard forms.

3.4 Texture

Texture analysis, often integrated with color, plays a role in identifying surface defects or maturity levels. By analyzing patterns and contrasts, computer vision helps in segmenting images and isolating areas of interest for more precise inspection.