Detection of Greening in Potatoes using Image Processing Techniques

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Abstract: Quality is one of the important factors in marketing of agricultural products. Grading machines have great importance in the quality inspection systems. Most of the current grading machines operate based on machine vision systems to detect blemishes and defects of products, where one image or more are taken for each individual object and the results of processing will decide the quality of the object. One of the major blemishes in potatoes is physiological skin greening, which has negative influence on human health. In this research, a simple machine vision algorithm has been developed in order to detect physiological skin greening of potato tubers rapidly and precisely. The experimental image acquisition setup was consisted of an image capturing box equipped with lighting system, a color CCD camera, and a capturing card. The data set consisted of 25 images of potatoes with physiological skin greening blemishes. Image pre-preprocessing has been carried out to modify the non-uniform distribution of background light intensity. Since potatoes have bright skin, the CCD was saturated in a small part of each image. These parts were eliminated from the images using a relation found between RGB and HSI spaces. The difference between red and green components of RGB space for green parts of potatoes was lower than that of other parts. Finally, the $1.02R - G$ relation was found to be suitable for detection of green parts of potato tubers. The average of error between actual green parts area and estimated green parts area for 25 images was 5.26%.
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1. Introduction

Recently, there are a lot of researches work have been carried out by depending on the computer; in order to reduce the processing time and to provide accurate results. Digital image processing, as a computer based technique, has been extremely used by scientists to solve problems in agriculture (Chen *et al*., 2002). In the case of potato product, most of the research works focused on potato inspection without singulation (Marchant *et al*., 1990; Al-Mallahi *et al*., 2010) and blemish detection (like black dot, silver surface, common scab, etc.) (Barnes *et al*., 2010).

Potatoes contain toxic compounds known as *glycoalkaloids*, of which the most prevalent are *solanine* and *chaconine*. This toxin affects the nervous system, causing weakness and confusion. Exposure to light, physical damage, and age increase *glycoalkaloid* content within the tuber. The highest concentrations occur just underneath the skin. Light exposure causes greening from chlorophyll synthesis, thus giving a visual clue as to areas of the tuber that may have become more toxic (Olsen and Brandt, 2005). Since consumption of green parts of potato is harmful to human, this is very important to develop an inspection system to reject green potatoes during sorting process. Hence, this paper aims to introduce a machine vision algorithm to estimate the potato green surface area.

2. Image Acquisition and Preprocessing

To do experiments 100 potatoes were selected in which 25 of them had the physiological skin greening defect. An image-capturing system was designed to provide an enclosed and uniform light illumination and to obtain standard images from the samples. The size of the capturing chamber was L: 40 cm, W: 40 cm, and H: 40 cm. A sample holder (25 cm × 30 cm) was placed at the bottom of the box and covered by a black fabric to eliminate the shadows. Samples were illuminated using two parallel lamps (with one fluorescent tube in each lamp, model 391 Deluxe, Natural Daylight, 10W, Farhad Lighting Co., Iran) equipped with light diffuser. The two fluorescent tubes (391 mm) were placed 35 cm above and parallel to the sample holder. A color CCD camera (CNB, 560 TV line, model GA4162PF, Korea) was positioned horizontally in the center of the chamber and vertically over the sample holder at a distance of 40 cm. The angle between the camera lens (CCTV Lens, f=1.4, model LVA0660D, China)

and the lighting source axis was 90°. The video frames were sent via a TV capture device (Axtrom, XT-TV100, Korea) to a computer (IBM, 2.2 GHz CPU, 160 GB hard disc, and 1 GB RAM) provided with image acquisition and processing toolboxes of MATLAB software (Version R2009a, The MathWorks Inc., MA, USA) to visualize, acquire and process the images directly from the computer.

After image acquisition, some preprocessing operations were carried out on images to segment potatoes from the background. The summarized description of these operations is as following:

1. Obtaining grey images from the RGB space channels.
2. Obtaining binary image of samples using defined threshold values for R and B channels (20<R<40 and 5<B<30).
3. Removing the noise (small external materials with an area under 20 pixels) using erosion operation.
4. Filling the holes in the segmented binary image to obtain an actual binary image using dilation operation.
5. Multiplying the obtained binary images in R, G, and B channels.
6. Obtaining RGB images by combination of grey images obtained from the previous step.

Figure 1 shows the results of above operations.

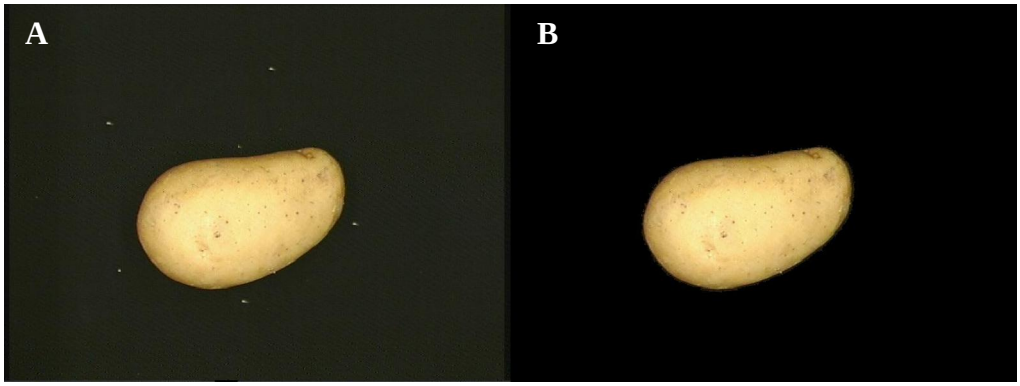

Figure 1. A. Original acquired image and B. Image after preprocessing operations

3. Determination of Greening Degree

To determine the area of green parts, the color specifications of green and non-green parts in the RGB (Red-Green-Blue) space was extracted first (Figure 2-A and B).

According to the Figure 2-A and B, the difference between R and G components for green parts is higher than that for non-green ones. The following relation was found to extract green parts:

$$P_{green\ parts}=1.02\times R - G \quad (1)$$

Result of relation 1 is shown in Figure 3-B.

During the image analysis, it became clear some parts of potato, which were under intensive light, are extracted with green parts. The reason for this phenomenon is closeness of gray level between R and G components (Figure 2-C). To solve this problem, these parts were extracted separately using the relation found between RGB and HSI (Hue-Saturation-Intensity) spaces as following:

$$P_{saturated\ parts}=1.4\times G - S \quad (2)$$

Figure 3-C shows the result of above relation. Finally, green parts were obtained by subtraction relation 1 from 2 (Figure 3-D). The area of both whole potato and extracted green parts was computed using *reprops* function in MATLAB. The following relation was used to find the greening degree of potatoes.

$$\text{Degree of greening} = P/t \times 100 \quad (3)$$

where P and t are the area of whole potato and green parts, respectively.

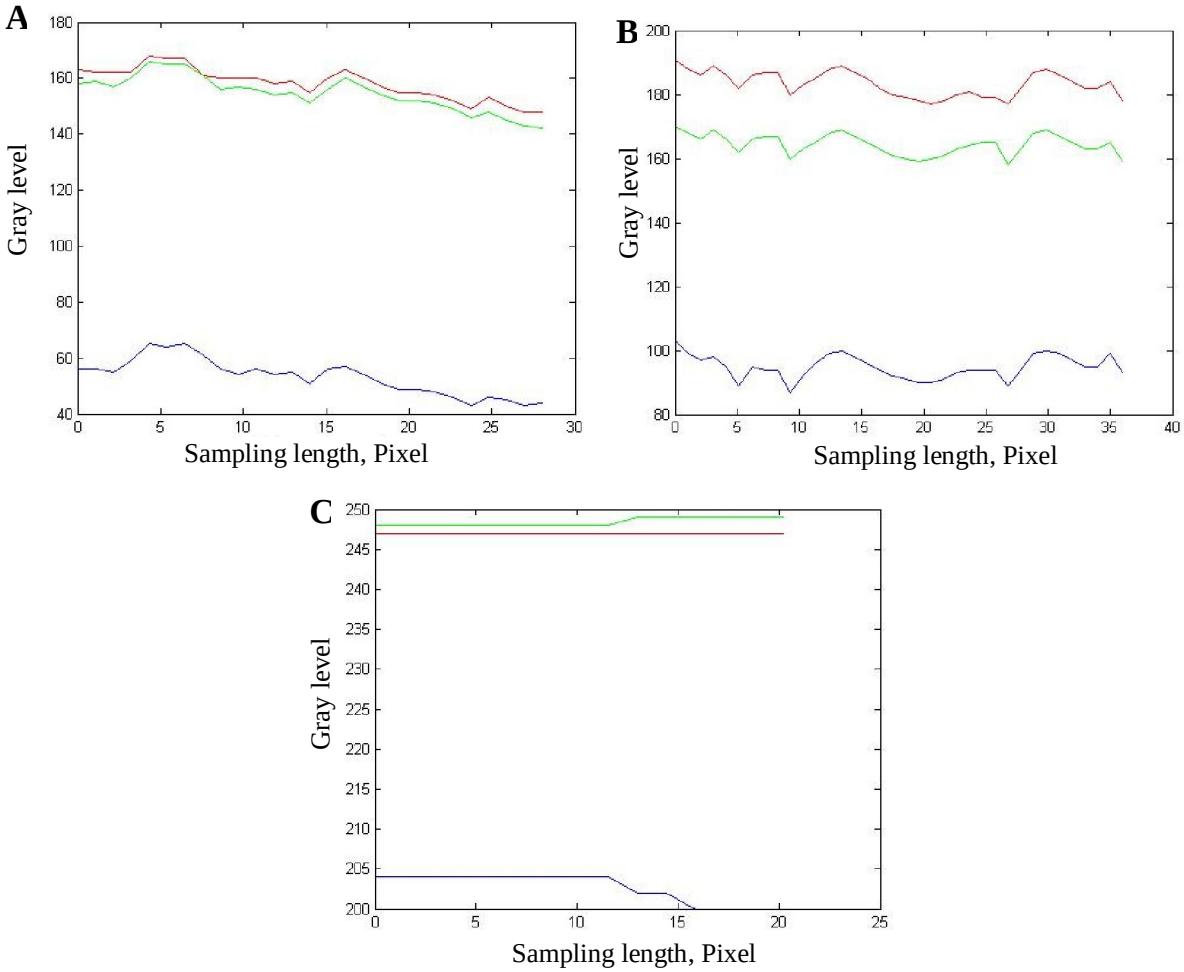

Figure 2. Potato color specification: A. Green parts, B. Non-green parts, and C. Saturated parts

4. Test of proposed algorithm

In order to evaluate the performance of the proposed algorithm, potato images were transmitted to Paint software to substitute green parts by red color (Figure 4). After that the area of red parts was computed using an own script in MATLAB. Performance of the algorithm was evaluated using the following formula:

$$\%\varepsilon = \frac{|A-T|}{T} \times 100 \quad (4)$$

where ε, A, and T are the error value, area of green parts extracted by algorithm, and area of red parts in the test image, respectively.

Figure 5 shows the result of the green parts area of 25 potatoes estimated by the algorithm compared to the actual green area. The results showed that the average error of the algorithm is 5.25%. This shows the algorithm has enough accuracy to be used in sorting systems.

5. Conclusion

Physiological skin greening is an important blemish in potato, which has harmful influence on the human body. To overcome this challenge, the use of machine vision to analyze the greening area of potatoes is suggested. A machine vision based algorithm was proposed in RGB and HIS spaces. Test of the algorithm using comparing the estimated green area by algorithm and actual area of greening showed the potential of the algorithm for its purpose.

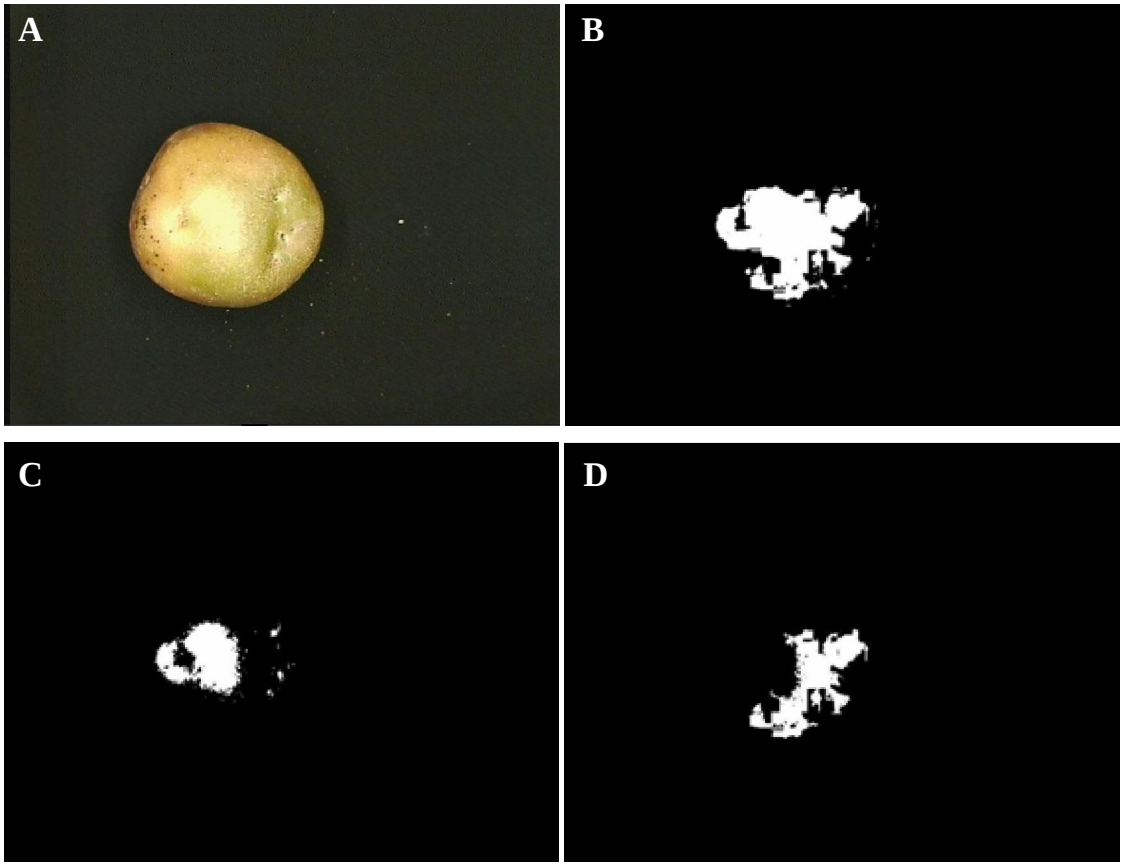

Figure 3. Determination of green parts. A. Original image, B. Extraction of green and saturated parts (result of relation 1), C. Extraction of saturated parts (result of relation 2), and D. Extraction of pure green parts

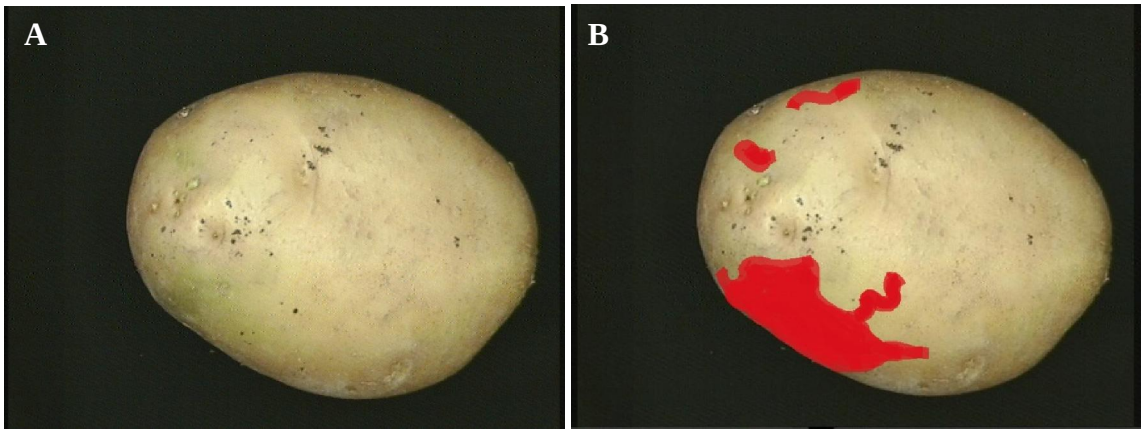

Figure 4. A. Original image of potato with green parts. B. Substitution of green parts by red color

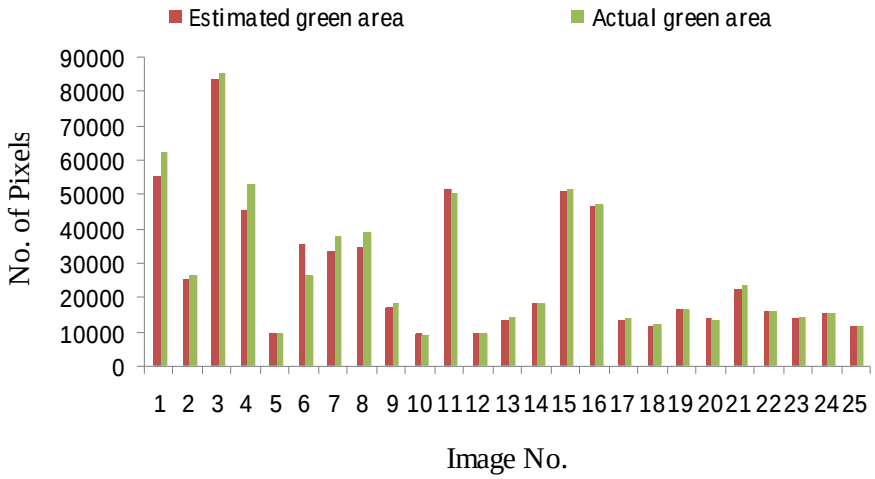

Figure 5. Comparison between estimated (by algorithm) and actual area of green parts

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