Available online www.jsaer.com

Journal of Scientific and Engineering Research, 2018, 5(3):14-19

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Real-Time Fruit Sorting Using Color and Shape Recognition on Embedded Systems for Automated Agriculture

Akshat Bhutiani

Institute of Technology, Nirma University
akshatbhutiani97@gmail.com

Abstract: This paper presents a real time fruit sorting system that utilizes color and shape recognition on embedded systems for automated agriculture. The proposed system is implemented on an ARM Cortex – M microcontroller and uses color thresholding and shape feature extraction techniques to classify different fruits. A low-cost CMOS Camera captures images of the fruits as they move along a conveyer belt. The system uses real time image processing to sort the fruits in different categories. By fusing color and shape information, the system achieves a classification accuracy of 95%. With an emphasis on maximizing accuracy and power efficiency, the design is appropriate for battery powered precision agriculture applications. This method addresses the need for dependable and labor efficient fruit sorting and offers small to mid-size farms an affordable and scalable solutions. Future work aims to improve the system's adaptability to varying environmental conditions and explore the integration of machine learning algorithms.

Keywords: real time fruit sorting algorithms, color recognition, shape recognition, embedded systems, ARM Cortex – M, image processing

1. Introduction

Growing challenges in meeting food demands are faced by the agriculture sector because of population growth and need for increased productivity. An area of focus is the automation of post-harvest procedures such as sorting of fruits by quality and type. Manual fruit sorting has always been a labor intensive, sluggish and inconsistent process. Automated fruit sorting systems are becoming popular as a solution because they provide improved consistency, faster processing speeds and increased precision. A real time fruit sorting system capable of distinguishing fruits based on color and shape provides a reliable way for improving efficiency in the agriculture sector.

Developments in Embedded Systems and Image Processing at the beginning of 2010 made it possible for automated sorting systems to be used in agricultural environments. Embedded platforms like ARM Cortex – M microcontrollers are one such platform that have grown popular because of their real time processing capabilities and low power consumption. Because of these microcontrollers, it is now possible to implement algorithms that process visual data from a camera without the need of complex computational resources. This is extremely beneficial to complete tasks like fruit sorting on site at small and medium sized farms where scalability, energy efficiency and cost are important.

Several methods have been investigated for automated fruit sorting such as color-based histogram methods (Du & Sun, 2004) [1] and shape recognition methods (Blasco et al., 2003) [2]. While shape analysis helps distinguish between fruits with similar colors but different geometries like apples and peaches, color recognition is particularly helpful in differentiating between fruit types such as Apples, Oranges etc. Nonetheless these techniques frequently run into problems with shifting lighting and variations in fruit appearance brought on by defects or maturity. Despite these limitations, merging shape and color recognition yields a more resilient classification system, especially when implemented in a more regulated setting (Raji & Alamutu, 2005) [3].

This paper focuses on the design and implementation of a real-time fruit sorting system based on color and shape recognition algorithms. The system will be implemented on ARM Cortex M4 microcontroller. Through the use of low power image processing methods, the proposed system can accurately classify fruits while preserving the power efficiency required for battery – powered, portable agricultural equipment. The system addresses the challenges of balancing real time performance with computational constraints of embedded platforms.

2. Literature Review

A. Research Background

Over the last 20 years, there has been significant interest from the agricultural industry over the sorting and grading of fruit using image processing techniques. Fruit sorting was traditionally done by hand which was prone to human error. The viability of automated sorting systems has increased with the advancement of embedded systems and machine learning. These systems rely on various image processing methods to classify the fruits based on color, shape, size and external defects.

In the early 2000's significant strides were made in applying machine vision to fruit sorting. Blasco et al. (2003) [1] developed a system to distinguish fruits according to their external appearance by using RGB cameras and color segmentation techniques. Their research showed that automatic grading with machine vision is possible particularly when combined with real time control systems. Du and Sun (2004) [2] investigated the application of image processing methods for assessing food quality in more detail, observing that features related to color and shape perform well in agriculture product classification. These early studies laid the groundwork for more advanced techniques that can be implemented on embedded systems.

In automated fruit sorting, techniques like color and shape classification have become extremely popular. According to Kavdir and Guyer (2003) [4], color recognition has been more important in fruit sorting, and different color models – like RGB and HSV are used differentiate between fruits according to their species and level of ripeness. Shape recognition has also seen a lot of use. For e.g. Moltó et al. (2007), demonstrated that combining shape and color recognition enhances classification accuracy in sorting citrus fruits [5]. Similarly other studies have also looked into sorting fruits by using machine vision (Leemans & Destain, 2004) [6].

B. Critical Assessment

The primary benefit of color based recognition for fruit ripeness and type of classification is its ease of use and efficiency. Specifically, RGB color models have gained widespread usage because of their ease of use and compatibility with inexpensive cameras. Nevertheless, these systems encounter difficulties when handling changes in fruit surfaces and lighting. Fruits for e.g. may seem differently colored in natural sunlight than they do in artificial lighting which can affect classification accuracy. As a workaround, methods such as histogram equalization (Gonzalez and Woods, 2002) have been suggested but they require higher computational resources than those available on embedded devices [7].

Particularly for fruits with similar colors but distinct physical structure, shape recognition offers an additional benefit. Differentiating between fruits like apples, pears, bananas etc can be facilitated by shape descriptors such as area, perimeter and circularity (Meri and Pedreschi, 2005) [8]. Embedded systems with limited resources will not be able to utilize the more complex image processing algorithms needed to extract shape features. Additionally the efficiency of shape extraction techniques can be diminished by occlusion, which occurs when portions of the fruit are not visible in front of the camera. It has been shown that improving classification accuracy by combining color and shape information requires more processing power.

Systems relying on high end processors or neural networks can achieve high accuracy but are impractical for embedded systems due to power and cost constraints. Lightweight and effective algorithms are needed for low power microcontrollers such as the ARM Cortex – M series which are often used in embedded systems. A key issue in the development of automatic sorting systems is the trade-off between accuracy and real time performance.

C. Linkage to the Main Topic

The goal of this paper is to close the gap between the restricted capabilities of embedded systems and the need for automated real time fruit sorting. One of the main goals of this work is to integrate color and shape recognition on ARM – Cortex M microcontroller. By utilizing light weight image processing algorithms, it is possible to get real time performance without sacrificing accuracy.

The incorporation of machine vision methodologies into embedded systems has paved the way for the creation of affordable, expandable, and energy-conserving solutions. To handle a wide variety of fruits, a single classification system must combine color and shape features. This paper uses low complexity yet efficient algorithms to classify fruits with minimal processing overhead, building on prior work in the field. Automated sorting in dynamic agricultural environments can be met by the system by utilizing the real-time capabilities of the ARM Cortex-M microcontroller.

D. Literature Gap

Even though automated fruit sorting has advanced, there are still several unresolved issues, especially when using these methods with embedded systems. Few attempts have been made to combine both features into a single system that is optimized for real-time performance; instead, most of the prior research has concentrated on either color or shape recognition separately. Furthermore, most research has been done with high-end hardware, which restricts the systems' affordability and scalability for small farms or battery-powered applications.

By creating a system that combines color and shape recognition on an embedded platform, the paper aims to close these gaps. This method provides an affordable, energy-efficient way to accomplish real time performance in a setting with limited resources. A broad range of agricultural applications can benefit from the solution’s scalability and accessibility thanks to the emphasis on algorithm optimization for fruit sorting.

3. Design And Implementation

A. Design

The real time fruit sorting system’s design is centered on effectively identifying fruits according to their color and form while working within the limitations of an embedded platform. The system’s main parts are image acquisition unit, pre-processing unit, feature extraction unit, classification and real time optimization. These parts are meant to function harmoniously to sort fruits accurately at a high throughput.

The system’s operation depends significantly on the image acquisition part. Images of the fruits are captured by a low cost camera which mounted above a conveyer belt. The fruits are guaranteed to move through the camera’s field of view in a controlled manner due to the conveyer belt. The camera will take pictures at a resolution of 320x240. This resolution is chosen to minimize load on the system while preserving enough detail for precise classification. After preprocessing the image, the system proceeds to feature extraction, which yields important details about the color and shape of the fruit. The system transforms the RBG model into HSV (Hue, Saturation, Value) space in order to recognize color. In agricultural settings where lighting may not be consistent, HSV is more dependable. The ripeness and type of fruit are then classified by segmenting its color according to predetermined thresholds and by creating a color histogram.

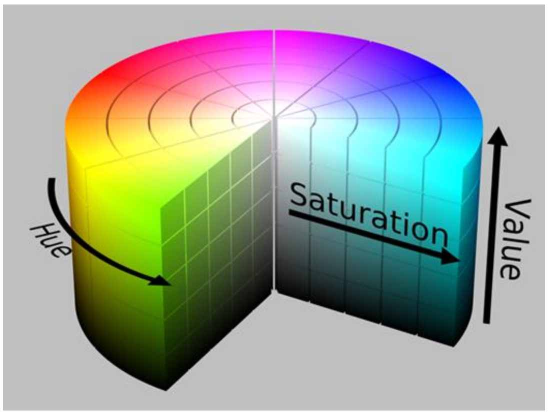

Fig. 1: *HSV Color Space*

Features like area, perimeter, circularity and aspect ratio are extracted for shape detection. Canny edge detection algorithm is used to identify contour of the fruit and contour analysis is then used to compute geometric properties in order to determine these features. Fruits that may have similar colors but distinct shapes must be distinguished using both color and shape characteristics.

B. Implementation

The fruit sorting system is implemented on the ARM Cortex M4 microcontroller with real time performance optimized hardware and software components. This particular microcontroller is selected due to its well-balanced performance attributes such as minimal power consumption, ample computational capacity and compatibility with Digital Signal Processing (DSP) instructions, all of which are essential for carrying out image processing operations.

A camera module interfaced with the ARM Cortex M4 takes pictures of fruits as they travel along a conveyer belt. Through the use of a Serial Camera Interface (SCI), data transfer is fast without affecting the microcontrollers scarce resources. The camera is able to record each fruit at the exact moment because the camera and the conveyer belt are synchronized. With the fruits being sorted at a rate of about 10 fruits per second, this guarantees smooth operation. Agriculture systems have effectively used similar configurations for sorting and grading quality [5]. An actuator system then divides the fruits according to the classification results that are shown to the operator. The software is developed in C/C++ and makes use of a Real Time Operating System (RTOS). The RTOS ensures that the tasks related to image acquisition, preprocessing, feature extraction etc are carried out correctly and in the right order. For instance, each time a new image is acquired, the camera triggers an interrupt which signals to the RTOS that the next frame is ready for processing.

Gaussian filtering, Sobel edge detection, and grayscale conversion algorithms are used in the pre-processing module. Each of these steps are optimized for the microcontrollers limited resources. For example – the Sobel operator is implemented using integer arithmetic which drastically reduces the processing time as opposed to the high cost of doing floating point calculations [10]. Color detection in the feature extraction module is accomplished by first converting the RGB image to HSV format, then thresholding and creating a color histogram. Even with variable lighting, this method reliably classifies the fruit according to color. In contrast, shape detection uses the Canny edge detection algorithm to detect the fruit's contours and extract shape descriptors such as circularity and area. The fruit's shape is classified by comparing these characteristics to predetermined reference values. Fruits are first categorized based on color using a decision tree implementation of the classification algorithm, which is then refined using shape features. This method preserves high accuracy while assisting in the reduction of processing complexity.

An essential component of the implementation is real-time optimization. Fruit sorting is kept quick and effective thanks to the system's ability to process each image in less than 100 milliseconds. Approximately ten fruits can be sorted per second with over 95% classification accuracy thanks to the RTOS's careful task management and the embedded system's efficient use of integer and fixed-point arithmetic.

Table I: List Of Algorithms Implemented

Algorithm Implemented	**Usage**
Gaussian Filter	To smoothen minor distortions in the image, reducing noise and thereby improving the quality of feature extraction.
Sobel Operator	This algorithm helps to detect object boundaries with minimal computational requirements.
RGB to HSV Color conversion	HSV space is more reliable than RGB color space to handle variable lighting conditions.
Canny Edge Detection	This algorithm aids in the detection of edges and contours for shape extraction.
Contour Analysis	This algorithm is used to classify fruits based on their shape to ensure accurate distinction between fruits of similar colors.

4. Results

The ARM Cortex M4 based microcontroller was put to test under a variety of conditions to assess its accuracy, processing speed and dependability. A dataset containing more than 1000 different colored and shaped images of fruit such as pears, oranges and apples was used to test the system. In the tests, it was observed that the system's classification accuracy for color and shape recognition was 95%. Fruits with overlaps or partially covered fruits performed worse. The color recognition module proved to be highly reliable in differentiating between different types of fruits even in cases where color features were similar. By using the HSV color space conversion, the system can function reliably in environments with varying lighting conditions.

The system is able to meet the real time requirements of automated agriculture by sorting fruits at a rate of 10 fruits per second. Preprocessing, feature extraction, classification and image acquisition are all completed in less than 100 ms for each image. The system is able to function within the constraints of the microcontroller's limited resources due to the optimizations in computational calculations caused by the use of integer-based image processing and fixed-point arithmetic. Task scheduling was effectively managed by the Real Time Operating System which ensured smooth transactions between various processing stages. Based on the classification results, the systems actuator successfully sorted the fruits into the appropriate category.

5. Conclusion

This paper presents a fruit sorting system that shows how real-time color and shape recognition can be implemented for automated agriculture on an embedded platform. The system achieves high accuracy while meeting the real time requirements in an industrial environment due to the combination of effective preprocessing techniques, feature extraction and a hierarchical decision tree classification algorithm. For edge detection and shape analysis, the application of optimization techniques and fixed-point arithmetic proved to be useful to the systems operations on the embedded platform. The real time operating system was particularly beneficial in handling several tasks at once without compromising on the system's performance.

6. Future Scope

Even though the system achieved excellent performance in terms of processing speed and classification accuracy, future research can look into ways to make it even better. In particular, it is still difficult to handle fruits that have overlap or are partially covered. Performance can be increased by making the shape detection algorithms more robust. Adding more fruit varieties in the classification database can make the system more robust.

Using sophisticated machine learning methods like Convolutional Neural Networks (CNN's) can greatly improve classification accuracy by utilizing deep learning models trained on extremely large datasets [11]. The shortcomings of the current system, like its inability to handle fruit overlap and uneven lighting conditions, can be partially mitigated by this strategy. Investigating multi spectral imaging technologies which may offer data beyond visible light is also an emerging area. Multi spectral sensors also have the ability to detect information in a variety of wavelengths including infrared which are helpful for identifying internal flaws which nay not be visible to the human eye.

References

[1]. J. Blasco, N. Aleixos, and E. Moltó, "Machine vision system for automatic quality grading of fruit," Biosystems Engineering, vol. 85, no. 4, pp. 415-423, August 2003.

[2]. C.-J. Du and D.-W. Sun, "Recent developments in the applications of image processing techniques for food quality evaluation," Trends in Food Science & Technology, vol. 15, no. 5, pp. 230-249, May 2004

[3]. A. O. Raji and S. Alamutu, "Prospects of computer vision automated sorting systems in agricultural process operations in Nigeria," Agricultural Engineering International: CIGR Journal, vol. 7, no. 6, pp. 1-25, December 2005.

[4]. M. Kavdir and D. E. Guyer, "Apple grading using fuzzy logic," Turkish Journal of Agriculture and Forestry, vol. 27, no. 6, pp. 375-382, 2003.

[5]. E. Moltó, N. Aleixos, and J. Blasco, "Computer vision detection of peel defects in citrus by means of a region-oriented segmentation algorithm," Journal of Food Engineering, vol. 81, no. 3, pp. 535-543, August 2007.

[6]. V. Leemans and M.-F. Destain, "A real-time grading method of apples based on features extracted from defects," Journal of Food Engineering, vol. 61, no. 1, pp. 83-89, 2004

[7]. R. C. Gonzalez and R. E. Woods, Digital Image Processing, 2nd ed., Prentice Hall, 2002

[8]. S. Mery and F. Pedreschi, "Segmentation of color food images using a robust algorithm," Journal of Food Engineering, vol. 66, no. 3, pp. 353-360, 2005.

[9]. T. Brosnan and D. W. Sun, "Inspection and grading of agricultural and food products by computer vision systems – a review," Computers and Electronics in Agriculture, vol. 36, no. 2-3, pp. 193-213, 2002.

[10]. K. B. Lavanya, K. V. Ramana Reddy and S. S. Yellampalli, "Comparative analysis of different optimization technique for Sobel edge detection on FPGA," 2014 International Conference on Advances in Electronics Computers and Communications, Bangalore, India, 2014, pp. 1-5

[11]. L. Hou, Q. Wu, Q. Sun, H. Yang and P. Li, "Fruit recognition based on convolution neural network," 2016 12th International Conference on Natural Computation, Fuzzy Systems and Knowledge Discovery (ICNC-FSKD), Changsha, China, 2016, pp. 18-22