

An Efficient FPGA Architecture to Automatically Detect the Condition of Orange Fruit

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ABSTRACT

Indian economy is highly dependent on agriculture and horticulture, with fruits serving as the primary source of the income. Fruit classification is a time-consuming process, and the conventional method of identifying based on naked-eye observation by experts is both time-consuming and induces eye fatigue. Images must be precise and in static environment to ensure that precision and output of the information collected are critical and viable. The work proposes automatic orange fruit classification system architecture and is being coded using VHDL language and implemented using SPARTAN 6 FPGA. To get optimized hardware architecture, the filter, feature extraction, and matching blocks are optimized in terms of hardware utilization. To retain the fruit properties at fruit extraction, Q-point numbers are noted. The results are compared and proven that the proposed architecture is efficient and is giving success rate of 88% in detecting the fruit condition effectively with fewer hardware resources.

Keywords: Background Subtraction method, Binarization, FPGA Implementation, Fruit classification, Image Processing.

1. INTRODUCTION

The agriculture is backbone of India and the nation's economy depends on it. According to some scientific estimates, the ratio of food demand to supply will be 80:30 in the coming days. As a result, it is a difficult task to stay prepared and meet potential demands; to deal with such conditions, new strategies and systems for implementation are needed. The high cost, subjectivity, tediousness, and inconsistency associated with the human sorting of fruit varieties result from manual sorting. A method for separating fruit varieties is required, and as a result, a reliable technique for discriminating varieties quickly and non-destructively is required. To understand images, a great number of real-world applications viz autonomous vehicles, apparatus recognition, face and robotics recognition depends on attempting to emulate the human brain's on the food industry, fruit and vegetables make up a substantial portion of fresh production, and their naming is object recognition. Traditionally, fruit and vegetables are visually tested. A continuous and constant aspect recognition technique is required to preserve consistency in human classification. The agriculture sector utilizes computerized classification methods and

frequently relies on software for pre- and post-harvest crop analysis [17-20].

When it pertains to the food sector, machine vision is the mathematical processing of visual data in the form of images, and it is a challenging task. As imaging techniques have advanced, the visual data of fruits and vegetables has evolved from digital to multispectral, resulting in more comprehensive computer vision, which is now being utilized as an emerging standard [21-25].

Orange fruit is used in many food processing, industries to produce products such as orange juice, orange cake, etc. Due to the market requirement, it is essential to process many fruits which requires automated classification. Generally, software-based classification techniques are used which requires more time due to the virtual environment created by the software environment requires bulky setup which is not very cost-effective. To overcome this, we have proposed architecture for ASIC level implementation, the architecture is implemented using Spartan -6 FPGA with the help of VHDL language [26-32].

1.1. Literature Survey

Nu *et al.* [1] proposed architecture and can classify fruits in real time via higher resolution visuals. The design was evaluated on a Spartan6 FPGA. The capacity planning demonstrates that more complicated modules and processing steps are done to increase performance. Jhawar *et al.* [2] carried out work on 160 orange fruits which were harvested from various geographical places in Maharashtra's Vidarbha region. Given a single-color image with a resolution of 640x480 pixels, the system would automatically identify an orange fruit from that area. With a digital camera inside a special box with intensity 430 lux inside only four characteristics are used to group oranges into four categories based on maturity level and three categories based on size. Two novel Pattern Recognition techniques were proposed in this paper: Multi-Seed Nearest Neighbour Technique and Linear Regression based technique, though the Nearest Neighbour Prototype technique is also used, the maturity of an unknown orange fruit can be specifically predicted using a regression-based methodology, allowing classification into multiple groups with desired lifespans. The success rate in the experiments was between 90% and 99%. Avalekar *et al.* [3] proposed a method where he used a neural network to describe a tomato grading system based on color models. This device is beneficial because it combines software and hardware. Hardware assembly is used to solve problems that cannot be solved by software.

Artificial lightings are used to avoid false colors from being produced by natural light or other sources of light. The parts are rendered in a tray to prevent the tomatoes from overlapping. The YCbCr color space is used to count the tomatoes, and the connectivity of components function is used. The image database, which includes various tomato categories, is manually generated. Ten of images are used to train network for each group. The neural network RGB color space is used for training. It is also done in this paper to reduce the number of features. After smoothing the picture, only the "R" and "G" color spaces are used. López-García *et al.* [4] proposes an experimental work in which about 120 orange samples and mandarins from four different cultivars such as Clemenules, Marisol, Fortune, and Valencia. Person defect detection success rate was 91.5 percent, while damaged/sound sample classification success rate was 94.2 percent. These findings indicate that the process under investigation is appropriate for the purpose of citrus inspection. These data suggest that the method under investigation is appropriate for inspecting citrus. Ahmad *et al.* [5] proposed with an accuracy rate of 86%, the color image analysis of melons was combined with random forest may be utilized to distinguish between harvesting ages of 46, 53, 60, and 67 days after planting. Then, however was unable to distinguish melons which were collected

in 60 and 67 days after planting with great accuracy since both groups of melons had reached their ripening stage. Carolina *et. al* [6] uses a camera with accurate image sensor and image processing is built in MATLAB software using image processing techniques for RGB parameters that can be used to perform characterization of orange maturity, image conditioning by pre-processing the image and applying filters to monitor shadows and lighting that could influence image analysis.

2. PROPOSED ARCHITECTURE

The proposed fruit classification architecture is shown in Figure 1 which is suitable for hardware implementation. The color components of the input fruit image are separated by Pre-processing block which is then filtered by the Filtering block. The filtered image is then used by the Region of Interest block to extract the portion of the image containing fruit pixels. The features of the fruit are extracted through Feature Extraction block and again filtered by Box Filter. These features are then used by the Comparison and Decision block to decide the condition of the fruit.

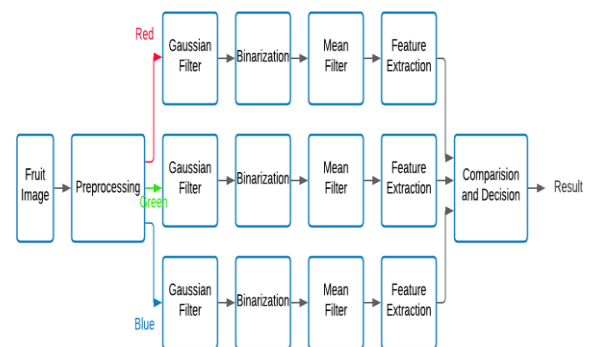


Figure 1 Proposed Fruit Classification Architecture

2.1. Data Acquisition of Fruit Image

Fruit image can be taken from a higher resolution camera so that distortion is avoided and a sample of fruit and its value will be resized into 0-255 pixels, a sample of fruit image is shown in Figure 2. Raw images are inappropriate for extracting relevant characteristics for computer vision and image processing. As a result, numerous filtering sections can be added to this part to receive the most precise information about fruits. It is done primarily to improve the data's dependability.

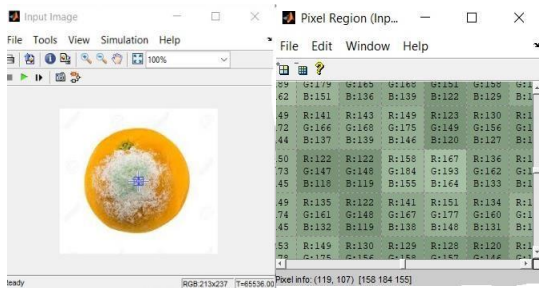


Figure 2 Fruit Image and its pixel region

2.2 Pre-processing

The color components of the input image are separated using System Generator [7] tools in Pre-processing block along with resizing operation. In most cases, it is done primarily to improve the data's dependability. Images captured with RGB sensors may have missed some information because of congestion, diffraction, distortion, and differing sensor selectivity to physical input from the surroundings. When three-dimensional entities are portrayed in two-dimensional images, geometric distortion occurs, and it is based on the camera and subject's relative positions.

2.3 Pre-processing

The Gaussian filter is used as a filtering block. The filter architecture presented by Sateesh et al. [8] is used to implement the Filtering block where the Addition and subtraction block are replaced by high-speed adder and Subtraction architecture [9].

2.4 Region of Interest

In this section, the modified background subtraction [10] techniques are used for extracting the correct region of interest defined by the fruit image. Here a perfect circle image is used as a background image for extracting the region of interest.

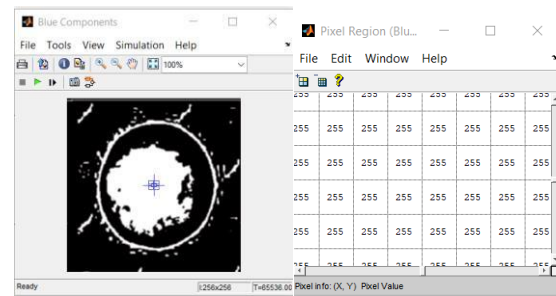
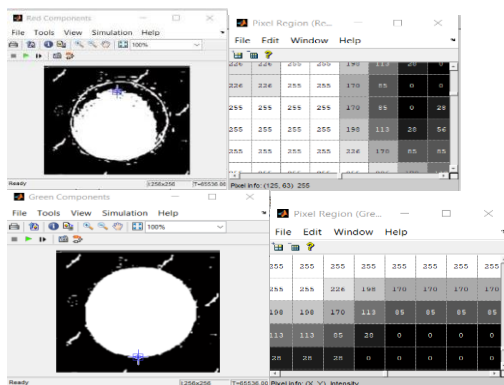


Figure 3: Red, Green, and Blue components after pre-processing of Fruit Image and its pixel region

2.5 Feature Extraction

In this scenario, the feature of the fruit is number of total pixels contained in the fruit image at each plane. General counter with enabling port [8] is used to implement this block. Feature extraction is the process of reducing a large data set to a smaller collection of data. The reduced data set obtained has all the characteristics of the original data set. Principal component analysis, deep feature synthesis, latent semantic analysis, edge detection, blob detection, and other feature extraction techniques were used. The physical properties of a thing that distinguish it from other items are known as features. Fruit and vegetables have a variety of physical qualities, such as color, texture, shape, and size, that can be used to classify them effectively. Fruit and vegetables have a wide range of similarities and differences within and between classes [33].

2.6 Box Filter, Comparison and Decision

Similar to the filtering block, the box filter [11] equation is implemented in this stage.

The features of the three-color planes are compared at this block to get the condition of the fruit. It is a counter which is used to count the red, green, and blue values, then the comparison of red and green will be done, which is maximum will be considered to compare with a blue hue. The first comparison will be treated as A and the blue hue will be treated as B, if B is greater than A then the fruit image will be Bad else fruit will be treated as Good [34-37].

3. FPGA BASED ARCHITECTURE IMPLEMENTATION

The intended architecture is implemented using the System Generator tool on a Xilinx ATLYS [12] FPGA board with Spartan-6 FPGA [7]. The architecture is written in VHDL [13] and synthesized with a System Generator utilizing the Xilinx ISE tool [14].

Table 1. Hardware Utilizations of Proposed Fruit Classification System

Parameters	Hardware Utilizations
FPGA	Spartan-6 (XC6SLX45-3CSG324)
Slice Registers	2,178
Flip Flops	1,539
Logic	2,986
Slice LUTs	3,470
Memory	440
Shift Register	440
occupied Slices	1,375
LUT-FF Pairs	4,243

Hardware components used in the proposed architecture is given in Table 1. The snapshot of the System Generator model of the proposed architecture is shown in Figure 4.[38-41]

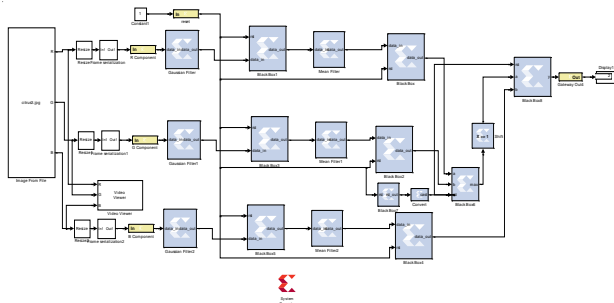


Figure 4 The Schematic of the Proposed System Generator Model

The camera and it will be converted into RGB hue, and resizing will be done by converting the image into 256X256 pixels, then frame serialization will be done by converting given matrix into transpose, the 2D image will be converted to 1D, each 1D data will be of 8bit data of particular colour. After the conversion of the given image, the Gaussian mask will be applied as it will be giving effective computational efficiency, gives higher significance to pixels near the edge, it's also effective for removing Gaussian noise. After removing the Gaussian noise, binarization will be done as it will be suitable for further image processing, one more layer of mean filter box is added to remove noises to get an accurate result of the given image, comparators are used to compare the threshold values of RGB, initially red and green colours will be compared, as red and green presence indicates the quality of good fruit, if the more blue hue is present, it will be indicating the result of bad fruit. A particular hue is counted and compared, and a decision will be taken.

4. PERFORMANCE ANALYSIS

To analyse the performance of the proposed architecture generally three mathematical equations [15] are used which are given below.

FRR (False Rejection Ratio):

$$\%FRR = \frac{\text{Number of good fruits rejected}}{\text{Total Number of fruits in database}} \times 100 = \frac{3}{50} = 6\%$$

FAR (False Acceptance Ratio):




$$\%FAR = \frac{\text{Number of bad fruits accepted}}{\text{total Number of fruits in database}} \times 100 = \frac{3}{50} = 6\%$$

TSR (Total Success Rate):

$$\%TSR = \frac{\text{Number of good or bad fruits matched correctly}}{\text{total Number of fruits in database}} \times 100 = \frac{44}{50} \times 100 = 88\%$$

From those equations, we can tabulate the performance of the system in Table 2.

Table 2. Performance analysis results

Input Images	Actual Result	Detected Result	% FRR	% FAR	% TSR
Citrus 1 	Bad	Bad	6	6	88
Citrus 2 	Good	Good			
Citrus 3 	Bad	Good			

***NOTE:** Around 50 Citrus fruits images were taken for analyzing the performance of the system, for simplicity 3 samples have been added in the table

The success rate of proposed architecture is compared with the existing techniques [16] that are greater than existing. The hardware resources of proposed architecture compare with the existing techniques which is proposed in research work [1] which is less than the existing methods. The proposed methods results are tabulated in Tables 3 and 4.

Table 3. Performance results comparison of state of art Existing Technique.

Methods	Technique	%TSR
Juan Pablo Mercol et al. [16]	J48	76.3 %
Proposed	---	88 %

Table 4. Hardware resources Comparison with Existing Technique.

Parameters	Hardware Utilizations	Hardware Utilizations
	Marco Aurelio Nuño-Maganda et al.[2016]	Proposed
FPGA	Spartan-6	Spartan-6 (XC6SLX45-3CSG324)
Slice Register	184,307	2,178
Slice LUTs	92,152	3,470
Memory	268)	440
occupied Slices	23,038	1,375

In[12]. Jyoti Jhawar Orange Sorting is done by applying Pattern Recognition on Colour Image using Nearest Neighbour Technique and Linear Regression based technique, however in[2] damaged orange fruit detection is not handled whereas in the proposed architecture damaged fruit is identified by using compact and effective architecture.[42-46]

5. CONCLUSION

Automatic orange fruit identification architecture is proposed in this paper and is being coded using VHDL language and implemented using SPARTAN 6 FPGA. to urge optimized hardware architecture, the filter, feature extraction, and matching blocks are optimized in terms of hardware utilization. To retain the fruit properties at fruit extraction, Q- point numbers are considered. The comparison results show that the proposed architecture is efficient in detecting the fruit condition effectively with the least hardware requirement and 88% efficiency Achieved using proposed architecture.

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