A color classification algorithm for vision based pallet inspection applicable in pharmaceutical industries

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ABSTRACT

Pallet inspection is one of the important applications of machine vision technology in a variety of industries. Pallet refers to the arrangement of discrete objects in a matrix form in fixed locations. Blister packs in pharmaceutical are similar arrangements which throws the same challenges. The location of the right component in the right place and absence of components in the one or more location in the pallet is important parameters to be inspected. Industries which adopt mixed production approach for manufacturing approach will have to deal with issues like mixture of more than one type of products inside a pallet. In pallet inspection color is often one of the important cue. This paper presents a color classification algorithm meant for pallet inspection in a typical application in a manufacturing industry dealing with mixed production. The pallet inspection is carried out without pose invariance. The challenges in the application are identified and described in detail. The algorithm is prepared and implemented in MATLAB platform to inspect for missing and odd parts. The novelty of the algorithm is its ability to detect the correct part in the pallet without user input based on the majority number of parts.

KEY WORDS: Pallet Inspection, Color Classification, RGB Space, Odd Components, Missing Components.

1. INTRODUCTION

Manufacturing industries often use the method of palletization approach for securing goods produced. Palletization of goods can improve cycle times, reduce time and labor costs of setup, make automated handling easy. There are pally ways of palletizing manufactured goods such as arrangement in a matrix form, stacking etc. The arrangement of goods in a pallet is subjected to defects both in case of manual and automated positioning. Defects include pallet location without components, wrong component in a pallet location and in some cases even wrong pose of parts in a particular pallet location. The correctness of a part in a pallet location is based on features such as color, texture, size, shape, labels, etc. Inspecting these defects is very important since goods once palletized they are generally meant to be dispatched to the end user. Manually inspected pallet have less accuracy due to stress involved in the task, but these types of errors are eliminated in the machine vision system. Advances in technology have resulted in better and cheaper in image analysis equipment an increasing number of machine vision system have been used for pallet inspection. Vision based Pallet inspection system have a capabilities like automatically inspect pallet for damage, missing and odd component. The pallet may be of any color and the presentation may be carried out manually or presented on a conveyor or in a stack.

Vision based pallet inspection may be either 2 dimensional /3 dimensional. The system generally has the ability to sort the incoming pallets based on the type and quality, classify them into defined grades. Various automated visual inspection method for pallet inspection is developed in the past decade. These approaches can be classified into three main categories namely reference comparison, non-reference verification and hybrid techniques. In reference comparison, pallet to be inspected is first scanned and its image is compared to that of standard pallet to identify the defect part. This method generally utilizes template matching technique. The limitation of this approach are need large reference data depending on the number of types of parts involved in the pallet and the pallet itself. In non-reference verification, the task is to check the missing and odd component present in the pallet. The method is also called design rule technique. The hybrid technique is the combination of reference and non-reference method. Though the hybrid approach has the advantages of the both techniques, generally they are too complex and may result in high computational costs. A typical machine vision system employed for color based pallet inspection generally consist of five different steps such as understanding scene constraints and selection of hardware, image acquisition, image analysis, recognition of certain features or objects within the image, displaying the color of interest in the operator display. In this paper, a color classification algorithm is presented for the purpose of pallet inspection.

2. EXPERIMENTAL

The pallet inspection task was developed with a mock-up setup consisting of metallic objects of different colors placed in a black colored pallet. The application is basically an offline task where one image of the pallet is acquired once after the components are arranged in the pallet manually. The nature of application is summarized in Table 1.

Scene Constraints: Scene constraint is the first consideration for any machine vision system. The design process which basically involves selection of the right hardware components and the algorithm is completely based the constraints posed by the application scene. The various scene constraints are listed in the Table 2.

Table.1.Nature of Application

Parameter	Specification
Size of the smallest feature to be detected	12 mm
Inspection Type	100% Inspection
Offline/Inline Inspection	Offline Inspection
Retrofit/New Design	New Design
Nature of Decision Making	Accept / Reject

Table.2. Scene Constraints

Parameter	Specification
Discrete parts/Endless material	Discrete Parts
Dimensions (min, max)	12 mm height and diameter cylindrical parts
Colour and Surface Finish	Multiple colours and moderate secularity
Changes due to handling	No
Number of part types	2
Difference of parts	Colour
Batch production	Yes
Can production change be addressed?	Yes
Indexed/Continuous/Manual Positioning	Manual
Tolerances in positioning (x, y, z translations and rotations)	Part position in pallet is fixed. Pallet location relative to camera must have a tolerance of around 1mm in *x* and *y* direction
Max. number of parts in view	30
Overlapping and touching parts	No
Environmental factors (if any)	Ambient Light

The primary scene constraint in any application is the identifying whether the scene to be imaged has discrete parts or endless material. Endless material may be images with a line scan camera. Since the current work involves discrete parts, a area scan camera is opted. The dimension of the pallet and sufficient tolerances areconsidered to choose the field of view of the camera. One of the important constraints is the specular reflection of the objects in the pallet since they are painted with glossy paint. Specular reflection introduces inhomogenity in the colours which cannot be completely avoided by illumination alone. This is taken care in the algorithm by carefully choosing the thresholds for the various colours. Details of the effect of specularity was studied. Inspite of the ceiling mounted LED illumination the system is not completely inert to ambient lighting hence sufficient provision is made to avoid the system's interaction with the ambient light.

Imaging Specifications: The various important specifications of the imaging system are listed in Table 2.

Table.3. Imaging System Specifications

Parameter		Specification
Field of View	Maximum part size	100 mm × 80 mm
	Tolerance in positioning	±1 mm
	Margin	~ 15 mm
	Adaption to the aspect ratio of the camera sensor	No
Light Source		White LED Light
Lighting Model		Partially diffused bright field incident lighting
Camera Make &Model		Logitech Webcam C920
Sensor Type		CMOS
Scan Type		Area Scan, Progressive
Interface		USB 2.0
Resolution		1200 × 1600
Operating Frame Rate		30 Frames Per Second (fps)
Mode of operation		RGB8
Trigger Type		Software trigger

Image Acquisition Time	~150ms
Processor	Intel(R) Core(TM) i5 @ 2.00GHz Quad core
Memory	4GB, 1600MHz

Fig. 1. Photograph of the Experimental Setup

Image Acquisition and Pre-Processing: The parts in the pallet and the pallet itself are manually positioned and hence the image acquisition is carried out using software triggered one frame per trigger. The camera supports YUY_1600×1200 over the win video software adaptor for image acquisition. Since the application is about color segmentation 'RGB' color space is chosen for acquisition. The camera supports an automatic focus and exposure which is required to acquire sharp and bright image. The backlight compensation is not utilized to ensure no changes in image contrast during runtime. The raw images of a sample pallets acquired from the camera are shown in Fig.2. The sample images show various kinds of defects such as missing locations and oddly placed components.

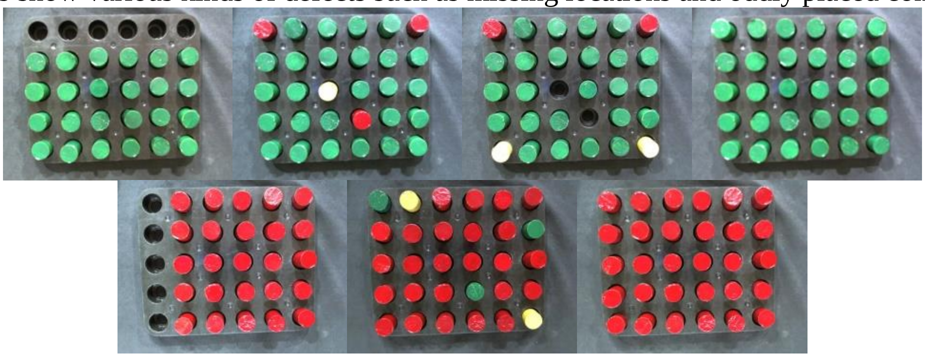
Fig.2. Sample Images of the Pallet

One of the issues with the pallet placement with reference to the camera is the pallet is slightly rotated with reference to the horizontal axis which must be compensated in image processing. Hence the raw acquired image is subjected to a rotation of 2 degrees in the negative direction with the horizontal axis of the image as the reference. Since image rotation is an image interpolation where there is a good chance for artifacts to be introduced into images, bi-cubic interpolation algorithm is utilized for the same. This ensures that original image and the rotate image are not differing much. The original image and rotated image are shown in Fig.3. It may be observed the interpolation has increased the size of the image slightly and zero padding have been along the corner of the image.

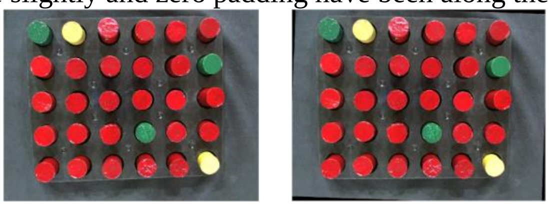
Fig.3. Sample Raw Image and Rotated Image

RGB Space: The RGB color space is based on the primary colors of light namely red, green and blue. The primary colors of light are the secondary colors of pigments. The primary colors of light are used to explain the color of light may it be the light recorded by a camera or a color emitted by a light projector. The basic idea of the RGB space is to have a linear combination of R, G and B for any given color. The RGB space is basically a Cartesian coordinate system with R, G and B along the three orthogonal axes. Fig.4 illustrates the RGB space. Generally a normalized range is used to represent the scale for the three axes. This ensures inertness to variations in the quantization levels of the camera used for a given application.

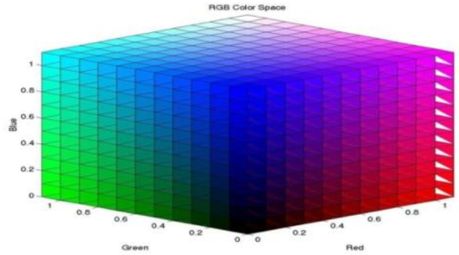

Fig.4. RGB Color Space with Normalized Values

Region of Interest: The first step in the algorithm is to extract the Regions of Interest (ROI) which is nothing but the objects in the pallet. This is possible in the current scenario since the pallet is manually is positioned and the location of the pallet with respect to the camera is constant. ROI of size 30 × 30 pixels is chosen. The ROI is selected automatically by incrementing the row and column coordinates. The increments of the row and column is chosen offline as a onetime process. Fig. 4 shows the ROI for a sample pallet shown in Fig.3. It is very clearly evident that the natural texture of the object and specular reflections due to the glossy surface has resulted in severe variations in the color of the object. The sample image shows the odd colored objects namely green and yellow in which by majority red is the right component for the pallet. The yellow colored object is intentionally bordered to ensure contrast with the background. The average values of red, green and blue in the ROI is taken for any further processing. It can be observed from the images; white is the predominant color which is same values for the R, G, B components in the image. The averaging approach is justified since, as a white color value uniformly offsets the R, G, B values and hence the originality required for color identification is preserved. In other words the biasing during the averaging process is completely based on the overall color of the object wherein the ROI is chosen.

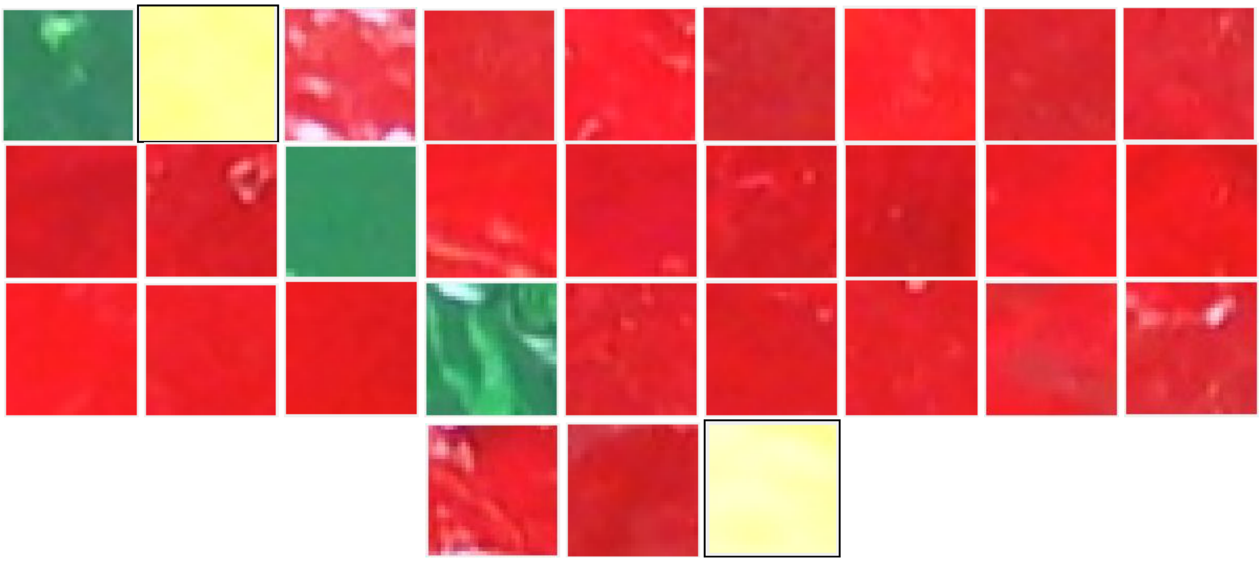

Fig.5.Sample Regions of Interest from a Single Pallet Image

Image Analysis: Image analysis refers the process of extracting of meaningful attributes from the image by subjecting the images to some mathematical operation. It is based on the extracted attributes; the decision making is generally carried out in machine vision applications. The images analysis has mainly three main roles. The first role is to identify the right color in the pallet. This is carried out by identifying the colors in all the pallet locations and the right color is chosen by the color which is present in the majority of the pallet locations. This approach works for all situations but for one special case. Since the pallet size is 30, there is a chance two different colors may be present in equal numbers. This case is often not practical since by probability the number of oddly placed components may not be generally greater than 20 percentage of the total number of components. The second role of the image analysis algorithm is to identify based on the majority estimated, whether it belongs to the class right component or odd component. The third role is to identify missing components. Since the pallet is black in color, when pallet location is not containing any component, the region would be dark in image. This is measured in the grayscale by converting the color image to grayscale image using the standard averaging approach. The following section of the paper describes the color classification algorithm in detail. Fig. 5 shows the flow chart of the complete algorithm.

Color Classification: The algorithm of the color inspection system is composed of two main steps. The first step is that RGB colors are converted into gray and average of the colors and the gray image is taken to get the intensity values. Secondly, the colors are identified separately by comparing the different pixel values of the RGB. The maximum intensity value corresponds to red, the minimum intensity value corresponds to green, the intensity value which is lesser than green gives the blue and the lowest intensity value correspond to the background. From repeated trials a threshold value of 50 for the grayscale level is found to satisfactorily identify missing components. The trials were conducted for all the locations of the pallet to ensure robustness. Then non-zeros are formed and the pixel coordinates are stored in the single array index. Once the colors are classified, image processing is performed to identify the color of interest. The size of each color is compared and the intensity value which occur maximum number of times is known as the color of interest and it is the major component that appears in the palette. The remaining colors are specified as ODD component. If it contains an empty space then it is termed as MISSING component. By this way the algorithm is made easier to compute and differentiate the three different colors.

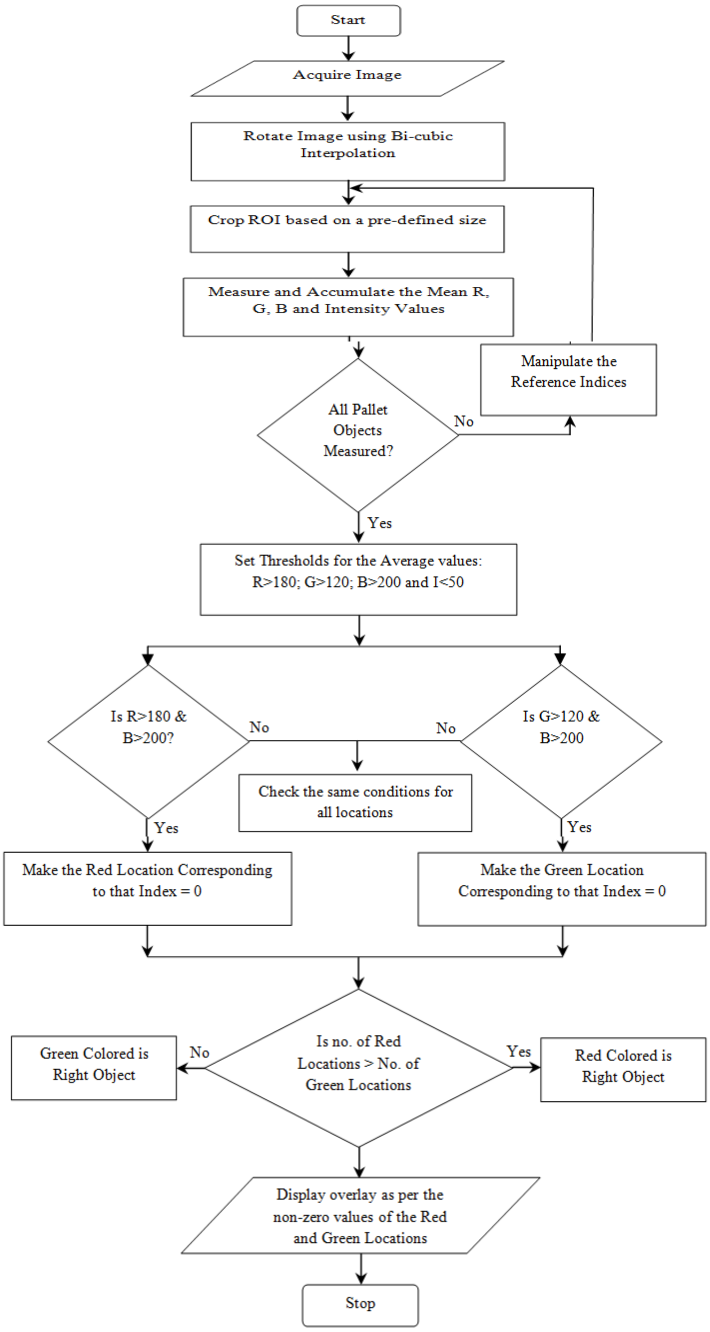

Fig.6. Flow Chart of the Algorithm

void_loc=find the pallet locations with average Intensity <50
red_loc= find the pallet locations with average Red>180
grn_loc= find the pallet locations with average Green>120
blu_loc= find the pallet locations with average Blue>200
for int1=1 to no. of elements in blu_loc

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for int2= 1 to no. of elements in red_loc
 if (red_loc(int2)==blu_loc(int1))
                red_loc(int2)=0
end
 end
 for int3=1 to no. of elements in grn_loc
        if(grn_loc(int3)==blu_loc(int1))
                grn_loc(int3)=0
        end
  end
end
Red = nonzero values in red_loc
Green = nonzero values in grn_loc
sample1 = array size of Red;
sample2 = array size of Green;
sample3 = array size of void_loc;
sample4 = array size of blu_loc;
x=1
y=1
if(sample1(1)>sample2(1))
Display → ‘Red is the image of interest’
for x=1 to sample2(1)
gg=Green(x)
Display on the image → 'ODD'
end
else
Display → ‘Green is the image of interest’
for y=1 to sample1(1)
rr=Red(y);
Display on the image → 'ODD'
end
end
if(sample3(1)==0)
Display → 'There is no missing component'
else
for i=1 to sample3(1)
nn=void_loc(i);
Display on the image → 'MISSING'
end
end
if(sample4(1)==0)
Display → 'There is no odd component'
else
for s=1 to sample4(1)
mm=blu_loc(s);
Display on the image → 'ODD'
end
end
```

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