Automated Visual Inspection of Plastic Products

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Abstract

A novel automated visual inspection system is presented in this paper. The system is to be used for detection and classification of defects encountered in production of moulded plastic products. Methods for detection and description of both shape and surface defects are described and analyzed. Experiments have shown promising results.

1 Introduction

Machine vision systems are emerging as more and more popular solutions for industrial production, either as robot vision systems or as automated inspection systems. The main task of a machine vision system is to provide computer understandable descriptions of objects from either single image or whole array of images. An automated visual inspection system must discover and classify any possible defects that can be detected using only product images and should be fairly quick and robust. These requirements are needed if automated systems are to be usable in real industrial production and to replace human inspection which has many drawbacks, mainly caused by tiredness and slowness (modern production methods usually facilitate productions speeds humans can't cope with). A survey of automated visual inspection can be found in [4].

In this paper, a proposition for a novel automated machine vision system for recognition of defects encountered in production of moulded plastic products will be presented. Unlike some other manufacturing processes [2, 3], automatization, and specifically visual inspection in plastic moulding industry is in an early stage. Various product defects can be encountered in moulded plastic products but ones that are detectable by visual inspection systems can roughly be divided into two groups: shape defects and surface defects. Some of the most common shape defects are flash and short moulding while most common surface defects are jetting incarty and welding lines [5]. For examples of shape defects see Figure 3 where short moulding is shown in the upper right image and flash is shown below and for surface defects see Figure 4 where welding lines can be seen.

The rest of this paper is organized as follows. A short overview of the proposed inspection system is discussed in Section 2 and is followed by discussion of the used methods for image analysis and defect classification which are presented in Section 3. In Section 4 results are presented. Conclusions are given in Section 5.

2 Automated visual inspection system

As mentioned in the introduction, defects encountered in production of moulded plastic products can be roughly divided into two groups. By following such division, automated visual inspection system should be structured in a way to utilize such division. The proposed system thus consists of two separate subsystems, one for shape inspection and other for surface inspection. Operation of each subsystem will now be discussed in more detail.

The aim of the shape inspection subsystem is to detect and classify possible shape defects. In Figure 1 an overview of the subsystem for shape defect detection is presented. Defect detection starts by image acquisition. The image of the product is obtained by using background illumination and that provides excellent contrast—nontransparent black object against the illuminated background. Such images are then segmented by using tresholding. All existing boundaries are traced and for each boundary the pattern vector is calculated. Finally, the pattern vectors are compared against the prototype vectors and a decision is made.

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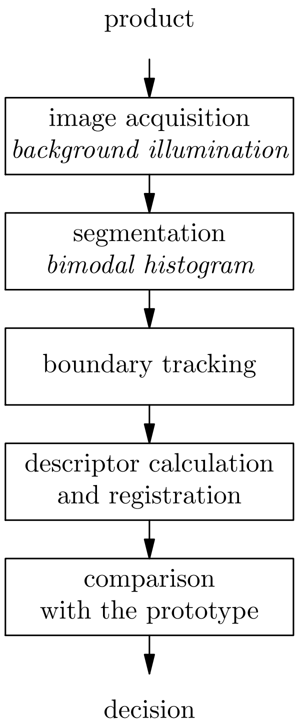

Figure 1: Shape analysis subsystem.

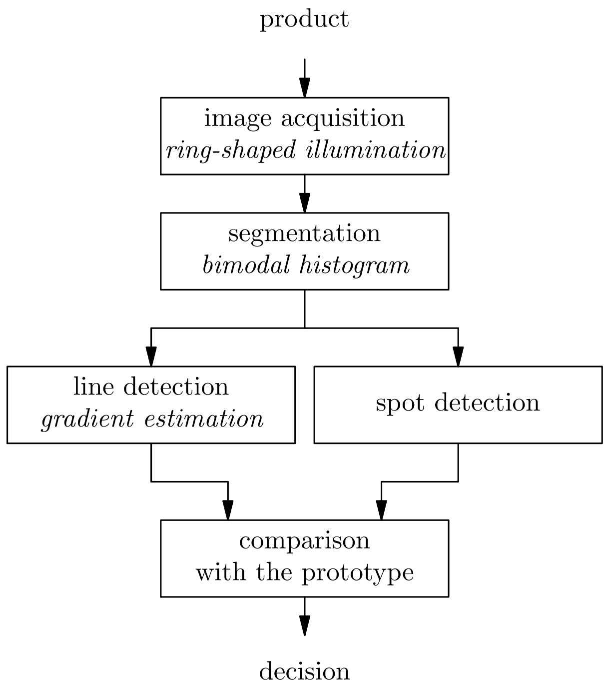

Figure 2: Surface analysis subsystem.

The surface inspection subsystem is used to detect and classify possible surface defects and its overview is shown in Figure 2. In this subsystem an image is acquired by using a diffuse ring-shaped illumination scheme. Such an illumination scheme makes surface defects as spots, lines and other surface blemishes clearly visible and, furthermore, image analysis is greatly simplified. After the image is acquired, separation of the product from the background is done. Now several algorithms are used, some of which are desinged for line detection while other are designed for spot and blemish detection. The results of the algorithms are position of the defects and some of their characteristics, and those are compared with the product prototype and decision is made.

3 Methods

As presented, the procedure for automated visual inspection consists of two separate methods, one of which is used for shape defect detection and classification, while the other is used for surface detection and classification. Both methods will be presented in the following subsections.

3.1 Shape description

As the moulded plastic products are made they are ejected to the conveyor and exact position of the object in the camera field view can not be predicted. The shape description method used should be invariant to product translation and rotation. The method described here is based on Fourier descriptors whose properties are invariance to translation, rotation and scaling.

Let the complex sequence z_0, z_1, z_2,...,z_{N-1} denote the object boundary (the boundary is obtained in the preprocessing step). The discrete Fourier transform (DFT) of this sequence is given as:

$$Z_k = \sum_{n=0}^{N-1} z_n e^{-2\pi ikn/N},\ k = 0, 1, \ldots, N-1. \quad (1)$$

Fourier descriptors are then calculated from DFT of the sequence by letting out DFT samples Z_0 and Z_1, scaling all the other elements by Z_1 and taking the absolute value of numbers obtained in such way. The Fourier descriptors are then:

$$C_{k-2} = |Z_k|/|Z_1|,\ k = 2, 3, \ldots, N-1. \quad (2)$$

The shape descriptor vector is chosen as the thirty most significant Fourier descriptors. This choice limits the usability of the method only to the borders containing more than thirty points.

The pattern vector obtained in this way must now be compared with the prototype vectors. However, before the comparison can be made, partial registration of the input image to the product prototype is necessary if we are dealing with the complex products like one shown in Figure 4. The result of image registration is the mapping of the “holes” in the product to the holes in the prototype and this enables proper comparison between pattern vectors.

3.2 Surface description

As with shape description, exact position of the object is unknown and in this case image registration is required.

The first method is the method for detecting lines and is based on the diferential gradient operator (DG). The obtained image is first convolved with two masks for x- and y-direction. This way two estimations are obtained and their combination yields final gradient magnitude and direction. Gradient map obtained in this way is then analyzed for local extrema—in such places defects exists. Analysis for local extrema is done only on previously segmented area that belongs to the product. Furthermore, local extrema must fall within certain boundaries to be declared as defects, that is, they must be greater then some predefined minimum.

The second method used for surface description is based on local gray-scale inhomogenity. Pixel gray-scale deviance from mean gray-scale value of its surroundings is calculated. We expect that in presence of an error local inhomogenity will be significant.

4 Results

We have set up an experimental image acquisition system with both background and ring-shaped illumination. That system was used for obtaining test images.

The algorithms for surface defect detection were tested with the specimens shown in Figure 3. In the left side good products are shown, and on the right side defective ones are shown. The specimens are denoted as B1 and B2 for ones on the left, L1 and L2 for ones on the right and L3 for one on the bottom. For each of these products pattern vectors are calculated. The Euclidean distances between such vectors are shown in Table 1. Data in this table indicates that distances between defective products and nondefective ones are for an order of magintude greater than distances between nondefective ones. Furthermore, distances between products with different defects are sufficient to enable the use of simple nearest neighbour classifier. At this stage of developement described algorithms were successfuly tested with the limited number of specimens and require further testing with greater number of specimens.

In Figure 4, one of the specimens with a surface defect (welding lines) is shown. Various types and sizes of DG operators were tested and lines are segemented correctly regardless of the diferential gradient operator type if the operator size is greater then some predefined size. This is required as lines that appear on the plastic products usually have blured edges that spread over larger number of pixels (for images obtained by our laboratory prototype required size of the DG operator was 5×5). Defect segmentation results are shown in the Figure 5.

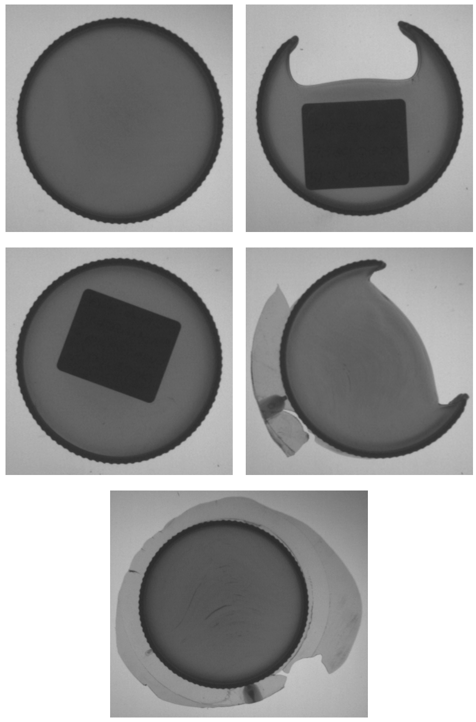

Figure 3: Product specimen.

	G1	G2	B1	B2	B3
G1	0				
G2	0.0072	0			
B1	1.0494	1.0422	0		
B2	0.8595	0.8523	0.1899	0	
B3	0.4560	0.4488	0.5934	0.4035	0

Table 1: Distances betwen product vectors.

5 Conclusion

An automated visual inspection system for defect detection and classification in production of moulded plastic products is presented in this paper. The presented methods and algorithms were successfully tested on a limited numer of specimen products and encouraging results were obtained.

The future work will be conducted on testing of

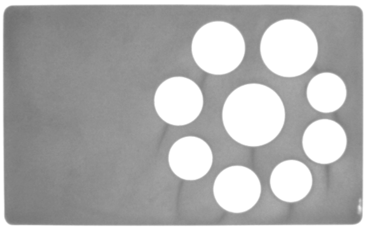

Figure 4: Product specimen.

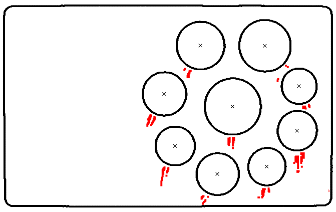

Figure 5: Segmented defects.

currently developed algorithms on a larger numer of samples and will include investigations of other methods and algorithms for defect detection and classification.

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