Automated Vision Inspection System for a Plastic Injection Mould Component

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A R T I C L E   I N F O

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A B S T R A C T

This paper presents an automated vision based defect inspection and sorting system for a plastic injection mould component called a Retractor Retaining Bush, which is an automotive safety critical component. The system identifies defects which usually occur in a plastic injection mould component. Various types of sensors and actuators were interfaced with the vision hardware and the part handling mechanism to complete the total automated vision based inspection system.

In [2], an automated visual inspection system for detection and classification of defects encountered in production of moulded plastic products was presented. Algorithms were developed for detection of shape defects like flash and short moulding and surface defects like jetting incaity and welding lines. Shape defects were identified with boundary tracking, calculation of pattern vectors followed by comparison with the prototype. Surface defects were identified with differential gradient operator and local gray-scale inhomogeneity for line detection and spot detection respectively.

The core idea of this work was to develop an automated vision based defect sorting and inspection system for a plastic injection mould component called a Retractor Retaining Bush (shown in Fig1), which is an automotive component. The retaining bush is a component with complex shape and is produced at the rate of...
2000/hr and currently the components are being inspected manually at the rate of 18000-20000 components/day necessitating the use of such an automated system. The proposed work is challenging because of the complex shape of the component and the various types of defects which the component can encounter.

The main contributions of this paper are
- Development of software for identification and sorting of defect free components. This involves a training phase for training a master component and an inspection phase to run the inspection sequence.
- Development of GUI and interfacing of sensors to complete the automated system.

A feeding system consisting of a vibratory feeder and a linear feeder was built to feed the components to the inspection station. The system built at CMTI, Bangalore is shown in Fig 2.

![Fig 1(a) and Fig 1(b)](image)

Fig 1: Top (a) and Side View (b) of the component

Fig 2: The automated retractor retaining bush sorting system at CMTI, Bangalore

### 1. Hardware Details

The inspection station consists of two cameras (AVT Pike F-032B of resolution 640 x 480), one camera viewing the component from the top, and the other camera viewing the component approximately at right angle. This type of arrangement captures majority of the defects occurring in the component. The components are dumped into the bowl of a vibratory feeder system which then orients and feeds the component in a particular orientation through the linear feeder. The arrival of the component at the station is sensed by a slot sensor, which in turn actuates a double acting cylinder to extend. This presents the component to the two cameras. The extension of the cylinder to the complete stroke is sensed by an inductive proximity sensor. After the inspection the controller signals the respective ejector to eject the component into the 'Accept' or 'Reject' bin based on the output from the vision application software. The cylinder retracts and the cycle continues.

The different types of defects commonly encountered in this component and to be inspected are:
1. Short shot which results in a partial part.
2. Component Discoloration.
3. Either of the holes in the component being filled.
4. Flash being present on the outer rim of the component.
5. Black spots on the component.
6. The part being deformed, like a bend in the lugs.

### 3. Defect Identification

Before the start of inspection, the component is trained to the system to take care of any environmental changes or lighting variations which may cause a change in the feature thresholds. The training phase stores the background images as seen by both the cameras and also extracts the thresholds of the features which define the different defect types.

During the inspection phase, the component, once it enters the inspection station is captured by both the top and the side cameras. The feature values are extracted and compared with the reference threshold values which were captured and stored during the training phase. The component is classified as defective if the feature value is out of range ($Reference\ Value \pm Tolerance\ Value$). Dimensional measurements of two critical dimensions are provided for components which are defect free.

The HALCON image processing library was used to develop the application. Simple image processing techniques are followed to identify and classify the defects. The features selected to define the different defects and the methodologies used to identify them are as described below.

The component is extracted from both images by performing subtraction of the background which was saved in the training phase. This extracts the component by eliminating the background and other external disturbances in both the top and side camera images.

Table 1 indicates the defects which are identified by the top and side cameras, the variable names given to the feature thresholds and the flag which is set for the respective defect type.

Initially, before the start of inspection, all flags are set to zero. Identification of any one of the defects will cause the component to be rejected without checking for the presence of other defects. Variables are shown in italics and underlined.
Table 1: Variable names given to the feature thresholds and the flag which is set for the respective defect type

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Camera</th>
<th>Defect Type</th>
<th>Feature Threshold variable</th>
<th>Flag which defines the defect</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Top Camera</td>
<td>Short shot (Broken Component)</td>
<td>AreaBroComp</td>
<td>BrokenComponentFlag1</td>
</tr>
<tr>
<td>2</td>
<td>Top Camera</td>
<td>Component Discoloration</td>
<td>AreaColor1</td>
<td>ColorChangeFlag1</td>
</tr>
<tr>
<td>3</td>
<td>Top Camera</td>
<td>Filled Hole</td>
<td>MinHoleArea, MaxHoleArea, Distance</td>
<td>FilledHoleFlag1</td>
</tr>
<tr>
<td>4</td>
<td>Top Camera</td>
<td>Flash</td>
<td>AreaOuter</td>
<td>FlashFlag1</td>
</tr>
<tr>
<td>5</td>
<td>Top Camera</td>
<td>Black Spots</td>
<td>SpotsThreshCAM1</td>
<td>SpotsFlag1</td>
</tr>
<tr>
<td>6</td>
<td>Side Camera</td>
<td>Component Discoloration</td>
<td>AreaColor2</td>
<td>ColorChangeFlag2</td>
</tr>
<tr>
<td>7</td>
<td>Side Camera</td>
<td>Short shot</td>
<td>Defect identified without Training</td>
<td>MissingLugFlag</td>
</tr>
<tr>
<td>8</td>
<td>Side Camera</td>
<td>Bent Lug</td>
<td>Defect identified without Training</td>
<td>BentLugFlag</td>
</tr>
<tr>
<td>9</td>
<td>Side Camera</td>
<td>Black Spots</td>
<td>SpotsThreshCAM2</td>
<td>SpotsFlag2</td>
</tr>
</tbody>
</table>

3.1 Broken Component

**Teaching:** Area of the master component (Number of pixels) is found and stored in the variable AreaBroComp.

**Inspection:** Area of the test component is found. If Area < (AreaBroComp - 2000), then the flag BrokenComponentFlag1 is enabled.

Fig 3: Broken component

3.2 Color Change

**Teaching:** Linear smoothing of the master component image is performed using a mean filter. The area of the component is found considering the gray values in the region of the mean filtered master component image and stored in the variable AreaColor1.

\[ \text{AreaColor1} = \sum_{(r,c)} g(r,c) \]

Where, g(r, c) is the gray value function in the region of the mean filtered master component image.

**Inspection:** Mean filter of the test component image is found using a mask size of 11 x 11. The area of the component is found considering the gray values in the region of the mean filtered test component image and stored in the variable AreaGray.

\[ \text{AreaGray} = \sum_{(r,c)} f(r,c) \]

Where, f(r, c) is the gray value function in the region of the mean filtered test component image.

If AreaGray < (94% of AreaColor1), then the flag ColorChangeFlag1 is enabled. The same methodology is followed for identifying color change in the side camera view.

3.3 Filled Hole

**Training:** The boundary of the master component is extracted using edge detection by 'lanser' method applied on the mean filtered image of the component. The area of this extracted boundary is computed and stored in the variable MaxArea. Further, Regions with area between \( \frac{\text{MaxArea}}{5.5} \) and \( \frac{\text{MaxArea}}{11.0} \) are selected. This selects the two holes. The areas of the two holes are found, minimum of the two is stored in MinHoleArea and Maximum of the two is stored in MaxHoleArea. Distance between the centers of the two holes is computed and stored in the variable Distance.

**Inspection:** The boundary of the test component is extracted using edge detection by 'lanser' method applied on the mean filtered image of the component. Further, regions with area between (MinHoleArea - 100) & (MaxHoleArea + 100) are selected. This selects the holes. If number of holes is less than 2 or distance between centers of the holes is less than (0.75 * Distance), then the flag FilledHoleFlag1 is enabled.

Fig 4: Component with one of the holes filled
3.4 Flash
Training: The flash normally occurs at the outer rim of the component as indicated by the rectangle in the fig.5. This outer rim of the master component is extracted using edge detection by ‘lanser’ method applied on the mean filtered image of the master component and the area of this outer rim is computed and stored in the variable $\text{AreaOuter}$.

Inspection: Three conditions are checked to find the presence of flash in the outer rim of the test component. If either of the condition is true, the presence of flash is identified and the component is rejected. Firstly, the outer rim of the component is extracted using edge detection by ‘lanser’ method applied on the mean filtered image of the test component. The area of the outer rim is computed and stored in the variable $\text{Area}$. If $\text{Area} < (\text{AreaOuter} + 75)$ or $\text{Area} < (\text{AreaOuter} - 40)$, then the flag $\text{FlashFlag1}$ is enabled. This method identifies the flash whose shape causes discontinuities or elongation of the detected edge. Secondly, an ellipse is fit to the detected edge and regions which are protruding out from the fitted ellipse and having an area above 35 pixels are selected. The threshold of 35 pixels is set to avoid false detections. If this method returns any region, then the flag $\text{FlashFlag1}$ is enabled. Thirdly, the extracted edge contour is segmented at dominant points. Dominant points are points at which there is a prominent change in direction of the contour. If the edge contour is smooth without discontinuities caused by the presence of flash, then the contour will remain un-segmented. Presence of flash causes the segmentation of the contour. If number of segments after applying segmentation is greater than one, then the flag $\text{FlashFlag1}$ is enabled.

3.5 Black Spots
Training: The Median Filter is applied on the master component image to remove noise which could be categorized wrongly as a black spot. Dark circular dots are extracted from this median filtered image by using a dot filter having a circular filter mask of size 13. Dots with area between 30 and 300 and convexity between 0.8 and 1 are selected from this dot filtered image. This step will extract multiple spots, which are nothing but lighting variations on the surface of the component. The gray value with the highest frequency of occurrence is computed in each of these dots, from their histograms. The minimum out of these gray values is stored in the variable $\text{SpotsThreshCAM1}$. This threshold will be used in the inspection phase to distinguish between spots occurring due to lighting variations and the actual black spots caused in the injection moulding process.

Inspection: The test component image is Median Filtered to remove noise. Dark circular dots are extracted from this median filtered image by using a dot filter having a circular filter mask of size 13. Dots with area between 23 and 285 and convexity between 0.6 and 0.99 are extracted. The gray value with the highest frequency of occurrence is computed in each of these dots, from their histograms. Dots which have their highest occurring gray value less than $\text{SpotsThreshCAM1}$ is categorized as black spots occurring due to injection moulding. If the number of such dots is greater than 0, then the flag $\text{SpotsFlag1}$ is enabled. The same methodology is followed for identifying black spots in the side camera view. Fig 6 shows the black spots being identified in both the views.

3.6 Missing Lug
Inspection: The lug regions in the test component image are extracted within the rectangle as shown in fig 7. Bounding box is fitted to the lugs and the leftmost positions of the bounding box are extracted to find half broken lugs. If the number of lugs is less than 2 or if the length difference between the lugs is greater than 50 pixels, then the flag $\text{MissingLugFlag}$ is enabled.

3.7 Bent Lug
Inspection: The lug regions in the test component image are extracted within the rectangle as shown in fig 8. Bounding box is fitted to the lugs and the orientation of the bounding boxes is used to extract the orientation of the lugs. If the difference in orientation between the bounding boxes of the two lugs is more than 5°, then the flag $\text{BentLugFlag}$ is enabled.
4. Automation and Graphical User Interface (GUI)

Fig 9 shows the schematic of the automated vision based inspection system.

Apart from the vision based algorithm development, interfacing of different sensors and actuators was done to complete the automation of the system. A slot sensor, an inductive proximity sensor, a solenoid valve and two relays for the two ejectors is interfaced in the application through an Advantech PCI-1761DIO card.

Fig 10 shows the GUI of the application during the training and inspection phases. GUI and interfacing is done on the Visual Studio development platform.

Table 2: Results of the Defect Identification System

<table>
<thead>
<tr>
<th></th>
<th>Classified as good components</th>
<th>Classified as defective components</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good Components</td>
<td>90%</td>
<td>10%</td>
</tr>
<tr>
<td>Defective components</td>
<td>10%</td>
<td>90%</td>
</tr>
</tbody>
</table>

5. Results and Discussion

About 250 good samples and 250 defective samples were tested to ascertain the reliability and validity of the developed algorithms to variations in the nature of defects and its effectiveness under real world scenario where there will be environmental changes which could affect the performance. The performance of the defect identification system is as indicated in table 2.

As indicated in Table2, about 10% of the total defective components were classified as good components. This false classification is mainly due to the limitation of the system in identifying the smallest defect. Keeping in mind the industry requirement, the cost factor and the low frequency of occurrence of such small defects, the system had to be designed with a minimum tradeoff on the accuracy of the defect identification system. Using cameras with higher resolutions to cater to defects of smaller sizes is expected to improve the accuracy of the defect identification system. The inspection rate of the vision system is 2 components/sec.

Conclusion

The project was to develop an automated vision based defect inspection and sorting system for the retaining bush. The retaining bush is a plastic injection mould component which develops various types of defects during its production. This system is able to capture defects like partial part, component discoloration, burn marks, flash etc, which generally occur in an injection mould component. Algorithms for detection and sorting of defective components and measurement of the critical dimensions were developed. A vibratory feeder and linear feeder were integrated with the vision system for part presentation. A Graphical User Interface was developed for operating the system. Various types of sensors and actuators were interfaced with the
vision hardware and the part handling mechanism to complete the total automated vision based inspection system for defect inspection and sorting of the retaining bush.

References


