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Automated detection of Surface defects using Salient Region detection

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Abstract: Quality control is important in the industry and its value is increasing with each passing year. In today's industry, defects in the products produced can create very important issues regarding customer and subsequent procedures for production. Surface defect detection is an important component of industry quality control. Fine defects appearing on a low-contrast surface cannot be visibly defined even by a well-trained examiner. Therefore, the development of automation systems in industries is very essential. Automated control systems that use image processing can overcome most of the disadvantages of manual control and offer manufacturers the opportunity to significantly improve quality and reduce costs. The proposed system identifies the important regions in an image and finds the various defects such as cracks on the metal surfaces. The objective is to implement the process of automation in an industry by real-time capturing of images by interfacing camera and inductive proximity sensor for finding the defects in it. Here, our proposed method helps us to acquire the knowledge about the defect in a short period of time and helps to produce defect less products consistently.

Keywords: Automation, Salient region detection, Simple Linear Iterative Clustering, Surface defects

1. Introduction

In industries, many defects occur during the manufacturing process. These defects are very fine and invisible to human eyes and will further influence the manufacturing process leading to a major loss in terms of time and money. Surface defects are loosely classified into two categories, the global variation where the complete color or texture will be varied and the second is local variation a specific point or region will be changed in their texture or color. Earlier the surface defect detection was carried using human vision however the subjectivity and speed of human eyes does not synchronize with industry needs. Advancement in sensing technology and development in image processing algorithms leads to automation process. Automated detection is an effective and efficient system to produce good quality products. Surface defect is difference in the pixel characteristics of the image. Image processing is a evolving science popularly used in various applications by industry and researchers. Earlier, Ncut[4] is employed for separating salient image contents. It captures the intrinsic color and edge information in an image. The drawback is that Ncut is less accurate than SLIC segmentation. Later various kinds of detection methods were proposed. These include Context-aware Saliency detection [5] in which the factors such as contrast and color are considered for marking salient regions, attention and boundary guided salient region detection[6] which is an automatic image processing system with high accuracy and time efficient approaches is presented for detection and classification of ceramic tile surface defects, Visual saliency technique[7] which provides an efficient way to select important information for biological and artificial vision systems, new salient region detection[9] based on statistics results for reducing the mean absolute error, a novel approach for salient region detection[11] based on segmentation and brightness of image for salient region. frequency-spatial domain model [13] which gives an in-depth analysis of detecting salient gradients belonging to important regions in the frequency domain, attention and boundary guided salient object detection [15] where background and boundary connectivity are used as features for learning-based algorithms to improve the accuracy. When the defect regions have simpler structure and texture information than the background, this approach may wrongly identify the non-salient objects. Infrared thermography is used as an imaging technology in which the thermal images of the defect and sound region varied much with recorded time. Superpixel based surface defect detection algorithm [16] was proposed and the effect of tiny noises near the defect region reduced the detection accuracy. Defect detection in steel based on entropy segmentation [17] was proposed by separating the whole information into two classes by using a threshold value. Saliency detection for strip steel surface defects [18] was proposed by using multiple constraints where only texture features were considered for classification. Later, Saliency detection was proposed in many defect detection areas such as Strip steel defect detection using Gaussian pyramid decomposition [19] , Fabric defect detection based on histogram features [20] and Surface defect saliency of magnetic tile [21]. All these models have certain drawbacks where the defect cannot be detected accurately. The proposed system provides accurate and efficient results for finding the defects which improves the quality control and reduces the need of manual inspection in industries. Here, it is carried out by capturing real-time images from the industry for finding the defects by implementing the process of automation using salient detection algorithm.

2. Proposed System

The proposed method can detect various defects in the surface of metal in industries. Since we have automated the process of defect detection using multi-scale saliency detection, it is very easy to locate the defective region in the surface of metals in industries without the need of manual inspection. Defects can be analysed on various surfaces like metals, concrete, tiles, fabrics etc. Advancement in computer vision technology and machine learning techniques has resulted in various complex algorithms. [20,21,22]The proposed method can obtain exact boundaries of the defective regions, of a metal surface which is a product from an industry, the detection method works for regions with uneven illumination and also with low contrast. In the proposed project, the process of defect detection is automated by making use of ATMEGA 2560 and inductive proximity sensor for detecting the metal moving in a conveyor. The further processing of defect detection is done using Salient region detection algorithm using MATLAB. The process of automation is done with the help of an algorithm called Salient region detection. The image is first pre-processed, and segmentation is carried out with the help of Simple Linear Iterative Clustering algorithm. SLIC [1,8] is done by combining pixels based on their color matching and proximity to the image plane. Superpixels approaches make possible batching pixels creating a perceptually meaningful region, thus, these regions carry more information than pixels by, representing relevant pixel groups [10]. These superpixels uses the over-segmentation technology [14] to divide an image into nearly uniform image blocks, which provides a more natural and logical representation of images than pixels on a regular grid. Various nearby regions contribute to boundaries [2]. Therefore, texture features are required to detect image parameters. The image texture response is obtained by combining multiple kernels for superpixel formation. For dividing the image into perceptually uniform regions [3], the approach of SLIC is used to segment an image and keep them local, compact and edge aware. The proposed system discusses about the automatic detection of metallic defects in the image captured in the real industrial environment. The results show that our method obtains excellent performances in both qualitative assessments and quantitative estimates compared to other state-of-the-art methods and satisfy the real-time requirements of actual inspection in the quality control procedure of the industries.

2.1 Image based Detection System

The proposed method in Fig.1 consists of two subsystems namely i) Image acquisition subsystem and ii) Image processing subsystem i.e., hardware and software modules. The hardware module consists of ATMEGA 2560 controller, Wireless camera, Inductive proximity sensor and DC motors.

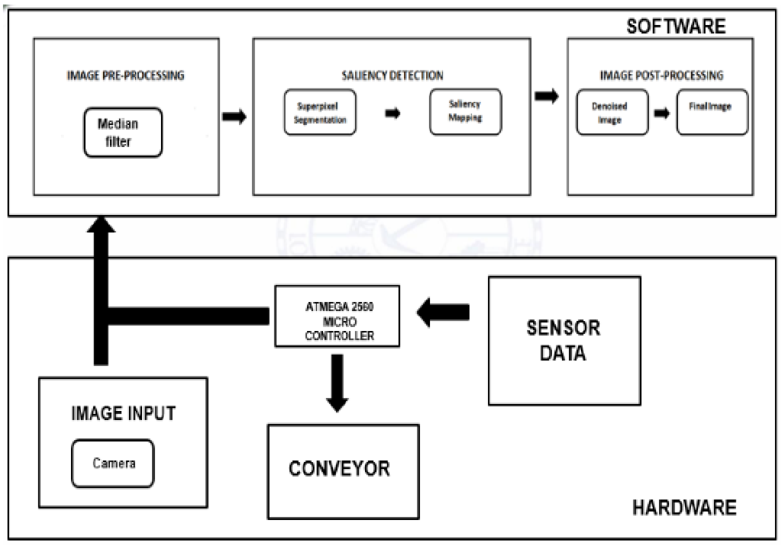

Fig.1. Block Diagram of Proposed System

2.2 Image Acquisition Subsystem

Image acquisition consists of a sensor and light illumination system to capture the image of the object, placed above the conveyor with a distance of focus of the camera. The conveyor is at the output stage of the production process of the object passing through it to quality control department. Image acquisition system consists of two processes, lighting to have uniform intensity and camera to capture the image. consists of a proximity sensor to detect the arrival of the metal product as shown in Fig.2.

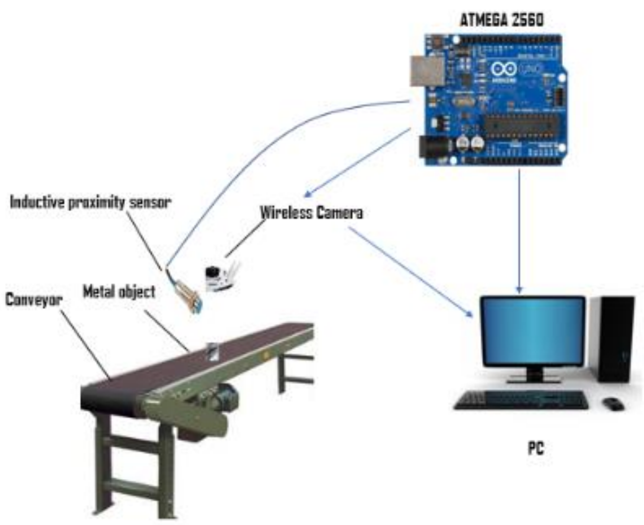

Fig.2 Experimental Setup

Electromagnetic induction is a basic concept in which when a current flow through a inductor a magnetic field will be created around it or alternatively current will flow through a current having an inductor when the magnetic field changes. A proximity sensor works in this principle and whenever an object comes near to it the magnetic field changes and results in the change in output current. This effect can be used to detect metallic objects that interact with a magnetic field. The movement of the conveyor is controlled by the DC motor in the proposed system [23, 24]. DC motor can be used in various application where continuous movement is required as in conveyors, turntables with low torque and constant low speed. As soon as the metal detected by the sensor, the conveyor will be stopped. The image will be captured by the camera and sent for further processing in the software the proposed algorithm processes the captured image for defect detection and online quality report is generated. The DC motor will start again after capturing of the image.

2.3 Image Processing Subsystem

The various steps involved in proposed automation process are given as a flowchart in Fig.3 and explained

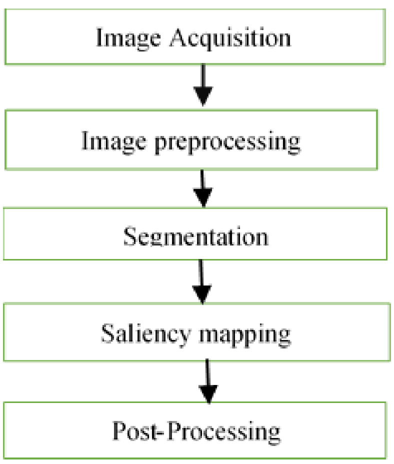

Fig.3 Flow Chart of the proposed System

Pre-processing is a method to remove unwanted noises in the background. Here, median filter is used for the removal of noises in the acquired image. Segmentation is used to divide the image into clusters with similar characteristics. SLIC Superpixel segmentation is carried out to divide the pixels into sub and superpixels. Saliency mapping is done by extracting colour features and HOG features for marking the salient regions in the image. This is known as Salient region detection algorithm which is used for marking the defective regions on the surface. Thresholding is a process in image processing method that creates a binary image based on setting a threshold value on the pixel intensity of the original image. This method of postprocessing is used for the removal of background noises.

3. Result discussions

To evaluate the accuracy of the proposed system images of two different product are captured and processed. One image is a plain metal surface and the other is a metal surface of cylindrical shape. Fig.4 gives the results after each step of our proposed system. The raw image is a plain metal surface captured through image acquisition system.

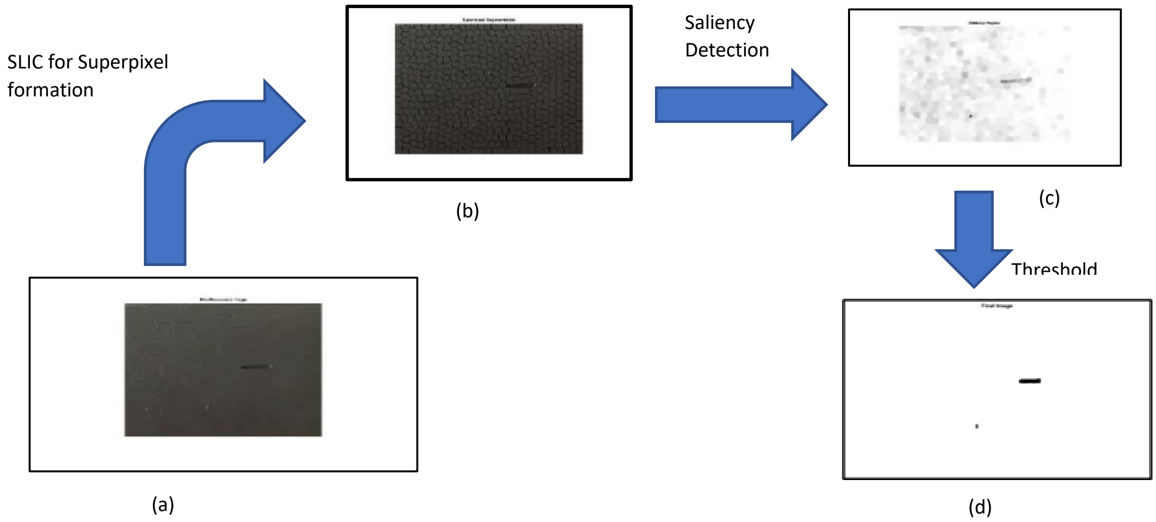

Fig.4 (a) the pre-processed image (b) Segmented using SLIC (c) After Saliency detection (d) Final image

In this module, the defective metal image is given as input to find the defective regions in the metal. Cracks in the images will result in change in the intensity and texture at the point. Fine defects appearing on a low-contrast surface cannot be visibly defined can be identified from this method.

A. Pre-processed image

Pre-processing is the method of smoothing, sampling and filtering of an image. The aim of pre-processing is to improve the image data by suppressing unwanted distortions and enhancing some features important for further processing. In this module, median filter is used to reduce the noises present in the image. The median filter is a nonlinear digital filtering technique, in which each pixel is replaced with the average value of the neighbouring pixel. According to this the non-defect pixel with high or very intensity will be average based on neighbour pixels and defect regions remains unchanged

.Such noise reduction is a common pre-processing step to enhance the outcomes of later processing. The principal concept of the median filter is to run through the signal entry, changing every entry with the median of neighbouring entries. The RGB image obtained from the camera is converted to La*B* format, L gives the intensity at each pixel, a and b represents the color components.

B. Superpixel segmentation

Segmentation is a process of dividing an image into clusters with similar characteristics. Superpixel is a primitive simple technique in the computer vision to produce semantically meaningful representation of the image. Normally an imaged consists of many pixels. Superpixel is the set of pixels which has same characteristics. It is advantageous compared to pixels because it is a compact representation, gives more information of the context and useful for image processing techniques that are computationally complex. SLIC has become a common algorithm for the superpixel formation in natural images, medical image, remote sensing images and uses k-means clustering algorithm for the grouping of pixel. The pixels are clustered based on the colour and texture using SLIC algorithm. SLIC is widely used technique and segmentation is done based on 5D [labxy] space. The distance metrics is given by

$$S = \sqrt{N/K}$$

where N is the total number of pixels in the image, K is the total number of superpixels used to segment the input image. Here we carry out subpixel and superpixel segmentation for separating defective and non-defective regions. The SLIC algorithm separates the image into subpixel and superpixels based on their texture. Based on the difference between superpixel and neighbouring pixel properties the boundaries of the grouping are iteratively restructured until all the neighbouring pixels with similar characteristic are grouped together. SLIC segmentation is easy to implement and is an excellent segmentation in minimum time. In this module, the defected area is obtained as superpixels and non-defected area is obtained as subpixels. This process is easy to compute and detect the defected area using VL_SLIC function in MATLAB .

C. Saliency region detection

Salient regions are the region of interest which requires more attention in an image. The defects in the crack region will be the saliency region. Detection of salient image regions is useful for applications like image segmentation, adaptive compression, and region- based image retrieval. We have extracted colour features and HOG features for marking the salient regions in the image. HOG is the best method for object detection. The method is fast, easy to implement and generate high quality saliency maps of the same size and resolution as the input image. In MATLAB color features are detected using pdist2 which is a pairwise distance between two sets of observation.

D. Image postprocessing

The pixels of the image obtained in salient region detection are compared with the threshold value and marked either as black or white. Thresholding is a process in image processing method that creates a binary image based on setting a threshold value on the pixel intensity of the original image. The pixels obtained in the saliency region which are lesser than the threshold value are marked black and the pixels obtained in the saliency region which are greater than the threshold value are marked white. The black part of the image represents the defective area while the white part is the non-defective part of the metal.

4. Conclusion

Thus, we have automated the process of defect detection in an industry for finding the defects in the surface. The real-time defect detection is done using saliency region detection algorithm. This is based on an observation that salient regions often have distinctive colours compared with backgrounds in human perception. However, human perception is complicated and highly nonlinear. While many such models exist, saliency detection has gained a lot of interest in image processing due to time efficient and simple algorithm. The process of automation makes it more application oriented and useful in real-time scenarios. This method can be widely used in industries for detecting defects. In this proposed system, we have considered plain surface of metals for defect detection. In future, the detection of surface defects can be expanded to detect flaws and defects in any pattern of surface.

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