Techniques for Detection of Rusting of Metals using Image Processing: A Survey

Vandana Sharma, Tejinder Thind

Abstract— Most of industries around us make use of iron machines & tools for manufacturing their products. On the other hand corrosion is a natural process that deteriorates the integrity of iron surface. Therefore, rusting of iron takes place. To avoid unwanted accidents in industries, it is necessary to detect rusting in earlier stage, so that it can be prevented. Digital Image Processing for the detection of the rusting provides fast, accurate and objectives results. There have been many techniques for detection of rust. In this paper we are describing some existing techniques for detection of rusting. We have analyzed these techniques and made comparison based o their approaches, strengths and limitations.

Keywords- Detection of Rusting, Digital Image Processing, Rust Detection Technique

I. INTRODUCTION

Iron machines and materials are used in most of industries for manufacturing products. In industries these iron materials come in contact with humidity and pollution, therefore increases the rusting of iron. Corrosion takes place when the mechanical materials come in contact with humidity and pollution in industries. Due to the attack of the corrosion, these mechanical materials undergo the fatigue that affects the integrity of the metallic surfaces. This rusting caused by corrosion causes wastage of iron materials, reduction in efficiency and costly maintenance [4]. Different departments make use of materials that are made up of iron. In Civil department, for maintaining the good quality of steel bridges, it is important to detect rust defects in advance. By detecting rust defects in advance, bridge managers can make important decisions whether to paint bridges immediately or later [2].

Electricity department makes use of crossarms that are made up of iron. These crossarms undergo the process of rusting. Depending on the rust present on these crossarms, the decisions are made by electricity department whether to reuse these crossarms or not [3]. For making such kind of decisions of classification Support Vector Machine plays an important role [1] [7]. To detect the rusting on the metal surfaces of aircrafts, texture analysis using image processing is done [5]. To use digital image processing for the detection of rusting of metals is fast, convenient, accurate and very much objective [6]. Therefore, Digital Image Processing is preferred for detection of rusting of metals.

II. COMMON STEPS FOR THE DETECTION OF RUSTING

Techniques for the detection of rusting of metals typically follow a series of certain common steps:

A. Automatic capturing of images of materials using digital camera

A Digital Camera is used for automatically taking the images of the iron made materials such as steel bridges, electrical crossarms poles, aircrafts bodies etc [2][3][5]. These captured images are then processed for the detection of the rust. It is to be ensured in these images whether there is presence of rust or not. These images are captured automatically that requires little manpower. This automatic task saves a lot of time and manpower for performing this job.

B. Apply rust detection technique to ensure presence of rust

In this step the captured images are processed to ensure whether they contain rust or not. This is the most important step for the detection of the rust. In this step the rust detection technique is applied to ensure the presence of rust [2][3][4][5]. There are different types of rust detection techniques. Each rust detection technique has its own series of steps for ensuring the presence of rust. When rust detection technique is applied on the captured images then it is ensured whether these images contain rust or not.

C. If image is rusted then calculating total rusted area

In this step of detecting rust in images, when images are found rusted then the total area that is found rusted is calculated [2]. This step is generally performed to make sure that the images is partially rusted or totally rusted. Depending on the area found rusted important decisions are to be made. Therefore, calculation of total rusted area is done.

D. To make decision on the basis of total rusted area

In this step decision is made depending on the area that is found rusted in the previous step. The decision may be like whether to paint the rusted area immediately or later [2] [5], to reuse the electrical crossarms or not [3].

Following diagram shows above four general steps for the detection of rusting diagrammatically:

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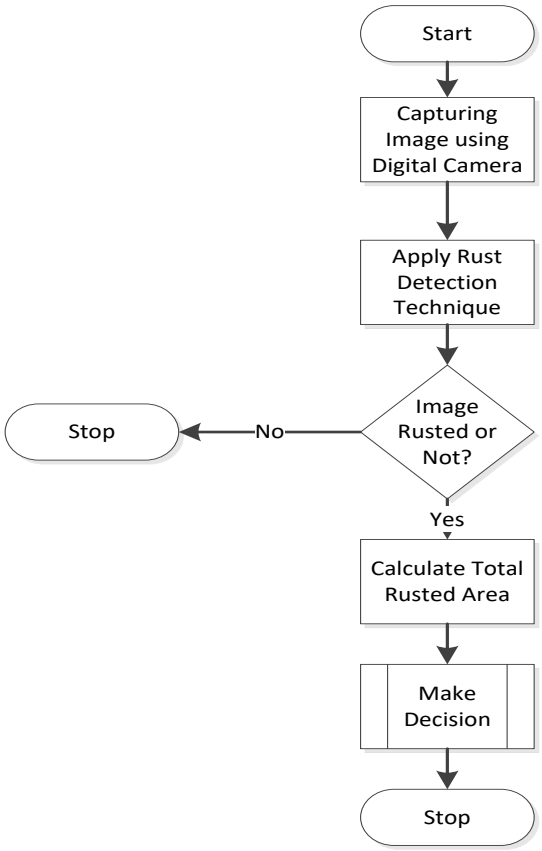

Figure1. General Steps for Detection of Rusting

III. EXISTING TECHNIQUES FOR DETECTION OF RUSTING

A. Wavelet Domain Detection of Rust

This technique is based on the concept of wavelet transforms. This is based on the non-iterative approach for the calculation of the rust percentage in the image. This method also follows the concepts of principal component analysis and classification. This technique provides entropy minimization for illumination correction in the images. This is done as a preprocessing step for completely eliminating shading effects. In this technique directly colored images are processed, therefore, there is no loss of information [2].

Algorithm for Rust Detection

This algorithm for detecting the rust defects has three steps that are Feature Vectors Extraction, Training and Detection.

Extraction of Feature Vectors, Training and Detection

In this technique two feature vectors are used for classification: entropy and energy. After applying one level of wavelet transform to all the three color planes (RGB) of the image, the entropy and energy values are calculated in each sub band B (11, 01, 10,00) [2].

The value of entropy is calculated as:

$$H(N(x,y)) = - \sum_{n=1 \text{ to } G} p(n) \log 2\ p(n)$$

where p(n) → probability that a pixel in image N(x.y) has value n and

G → no. of gray levels

The value of energy is calculated as:

$$E_B^{Ym} = 1/N^2 \sum_{i=0 \text{ to } N} \sum_{j=0 \text{ to } N} (W^{Xm}_{B,\ i,\ j})^2$$

where $W^{Xm}_{B,\ i,\ j}$ → wavelet coefficient at the (i, j) location in the subband B and

X_m → color plane (m= 1, 2, 3).

By using the feature vectors extracted in this way it is ensured whether the image is rusted or not. After that by using Principal Component Analysis (PCA), the dimensionality of the feature vector is reduced and a Transformation matrix is obtained that is further used for calculating the rusted area in the image. A classifier is also designed to classify images as rust or non-rust by using Least Mean Square Method and its value id also stored in memory and total area rusted is calculated [2].

B. Classification of the Rust Images using Support Vector Machine (SVM)

MichikoYamana and Tohru Ohashi [3] have proposed idea about classification of rusted images with the help of Support Vector Machine. In this technique, the images that are taken by a digital camera are classified in the basis of the color of the rust. The correlation between the degree of the corrosion and the color of the rust is already discovered. On the basis of this correlation, the images are classified into "Reuse" or "Retire" class by observing the color of the rust in images. Reuse class means that the equipments that fall under this class can be reused again after painting or plating and the Retire class means that the equipments that fall under this class cannot be used anymore in future due to rusting. The system based on this technique consists of a digital camera that can take good quality images. To classify the images into "Reuse" or "Retire" class there are present a no. of classification methods. But for obtaining higher accuracy, SVM is used for classification, because it provides higher accuracy among all available methods. Without extracting the features, in this technique, high degree of accuracy is obtained by compressing the image data so as to reduce the no. of features.

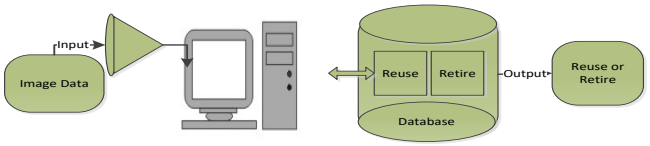

Figure2. Classification as Reuse or Retire

This system consists of a Digital camera that is attached to a computer. Image is taken by the digital camera. Then this image data is compressed by changing the size of image from 640x480 to size 4x3 for obtaining accuracy. After that this compressed image data is compared with database images and the classifier function classifies the image as "Reuse" or "Retire" [3].

C. NDE and SOM based technique for Corrosion Damage Analysis

Mariana P. Bento and Geraldo L. B. Ramalho [4] proposed an approach to detect corrosion of metals that uses Nondestructive Evaluation (NDE) and Self Organizing Mapping (SOM). In this technique, Nondestructive Evaluation (NDE) method uses Gray Level Co-occurrence Matrix (GLCM) for the detection of the change in texture of metal surfaces. Further, Self Organizing Mapping (SOM) is used for the classification of the images as rusted or non-rusted. This technique takes the digital images for detecting the corrosion, and then GLCM is applied on images for texture feature extraction.

Feature Extraction using GLCM

GLCM is used to extract following feature for rust detection:

(i) Contrast = $_k\sum k^2 \, _i\sum \, _j\sum S(i,j)$

Where S→ Gray Level Co-occurrence Matrix (GLCM) and k→ GLCM size less than one

Contrast is used to measure the dissimilarity between two pixels in the image.

(ii) Correlation = $_{ij}\sum (i*j \, S(i,j) - \mu_i \, \mu_{j)} / \sigma_i \, \sigma_j$

Where μ_i , μ_j , σ_i ,σ_j → mean value and standard deviation of line i and column j from GLCM.

Correlation represents how two pixels in image are correlated.

(iii) Energy = $_{ij}\sum S^2(i,j)$

Energy represents the sum of squared elements in GLCM.

(iv) Homogeneity = $_{ij}\sum S(i,j) / 1+(i-j)^2$

Homogeneity represents the similarity between gray values of pixels in image.

After extracting all these features the SOM is applied for clustering the images as rusted or non-rusted. Therefore the classification of images is done using SOM [4].

D. Texture Analysis Based Technique for Corrosion Detection

B.B.Zaidan and A.A.Zaidan [5] proposed a corrosion detection method that is based on texture analysis. This technique uses texture analysis method for detecting the rusted part of the image alongwith the functions Edge detection , image dilation and structure element. This technique works on the principle that roughness of the surface increases when corrosion inceases. Classification of rusted and non-rusted images is done on the basis of non-parametric classifier which is a learning algorithm. By using edge detection, segmentation if done to find out the area of interest that means to find out the rusted area. The pixels which lie on the edge or boundary have different gray value as compared to the pixels that lie outside the boundary. On the basis of this difference, segmentation of the area of interest is done.

The statistical characteristics of the image in texture analysis are helpful to determine the rusted area. For example, the range of values in rough surface will be high as compared to the range of values in smooth area [5].

Two functions used in this technique are stdfilt and entropyfilt. The stdfilt function is used to calculate the standard deviation of all the values in neighborhood pixels. The entropyfilt function is used to calculate the entropy of the neighborhood pixel values. At the end when these values are calculated the classification is done by using the non parametric classifier that classifies the image as rusted or non-rusted.

IV. COMPARISON OF EXISTING SOLUTIONS

From above description of each of the techniques presented in Section III, we can notice that each solution and techniques have its strengths and limitations. We have compared the features for different existing techniques, accuracy achieved and used methods for each existing solutions as shown in table I.

Table I: Comparison Table

SOLUTION / PARAMETERS	Sindhu Ghanta, Tanja Karp, Sangwook Lee [2]	Michiko Yamana, Hiroshi Murata, Takashi Onada, Tohru Ohashi Seiji Kato [3]	Mariana P. Bento, Fatima N. S. De Medeiros, Ialis C. De Paula Jr. Geraldo L.B. Ramalho [4]	B.B. Zaidan, A.A. Zaidan, Hamdan.O.Alanazi, Rami Alnaqueib [5]
Detection Method	Wavelet Transformation Based	Correlation Based	GLCM Based	Segmentation Based
Classification Method	Least Mean Square (LMS)	Support Vector Machine (SVM)	Self Organizing Mapping (SOM)	Non-Parametric Classifier
Methodology	Feature Extraction Based	Image Data Compression Based	Feature Extraction Based	Texture Analysis Based
Application	Highway Steel bridges	Electrical Crossarms	Oil and Gas Tanks	Aluminum Aircrafts
Accuracy	< 99%	99%	< 99%	< 99 %

V. CONCLUSION

This paper described about rust detection techniques to classify rusted and non rusted images. In this paper we made a comparison analysis on different existing rust detection techniques and methods for classification of rusted and non-rusted images. So we can say that this paper can help those researchers who are planning to research in this field, this paper will provide a helpful glimpse of existing solution for classification with their strength and limitations.

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