Investigation of Different Algorithms for Surface Defects of Steel Sheet for Quality

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ABSTRACT
In the process of inspection and quality control of steel sheets which is considered as an important issue in the metal industry surface defects of metals is one of the reasons that reduces the quality of products, also the detection of different defects in raw metals with the naked eye is very difficult and given that in recent years, automatic surface inspection system has made remarkable progress and is deemed as the research's mainstream and while the accuracy of visual inspection of people is different there is a need to a rapid, accurate, and non-destructive way to identify and classify surface defects based on the texture and form of this product and guarantee metal quality in the production process ; also, increase the production rate and helps separating defective metal from normal metal in a very short period of time. The main purpose of examining surface automatically is to investigate defective parts by comparing the user requirements and the generated images to minimize the wastes led to the product rejection to be delivered steel with better quality to the customer. Accordingly, the expression of different methods and examine them.

Keywords
Automatic surface inspection, Defects classification, Support vector machines, Gabor filter.

1. INTRODUCTION
Steel is one of the most widely- used industrial metals and of metals which has helped very much in the development of industrial society and also is considered as an important and basic industry worldwide as far as per capita steel consumption in the countries is utilized as a criterion for the development of the country. Therefore, product quality assurance is considered as the most significant industrial centers [6]. In recent decades, increased demand for higher quality product has caused to provide an optimal and efficient method for metal products which is one of the most important issues in international communities, and by early detection and accurate identification defects of steel sheets which is an important step in quality control produce higher quality products in a shorter time [1,2]. And in terms of steel industry to be able to compete with its competitors in the global markets given the recent developments, efficiency in the production of crude steel must be increased and given that visual inspection is time-consuming and does not have enough accuracy, it has led to apply automatic detection and classification method to minimize returned wastes caused by defects in products [3,4]. One of the important indicators in investigating of surface of steel is to minimize wastes and also reduce error resulting from visual which is necessary to be examined in the early stages of production, and is of very high importance has several reasons generated sometimes randomly or as a result of the surface destruction and generally these defects are divided into several categories as followings [2, 4, 5].

1.1 Surface defects of steel sheet
a) Surface defects

b) Textural defects

c) Dimensional defects

Surface defects are changes generated on the surface of the sheet such as corrosion, burn, offal (entrails) - Non-metallic materials existed on the surface of the sheet-, holes, scratches, and cracks produced on the surface of the sheet. Textural defects like folding of sheet steel and dimensional defects like being convex or concave. In Figure 1, some of these defects have been shown [1]. In this paper different methods of classifying defects have been expressed.

2. EXAMINATION OF THE CONDUCTED METHODS
Today different algorithms for detecting and classifying defects of sheet metal have been made, a mechanized method for identifying defects based on defects classification for metal products using digital X-ray images. Images classification is used for visual inspection to separate disadvantages of quality products. This is performed through texture analysis using Neural Network and is increasing as a modeling tool [2, 16]. Other algorithms have been applied for this purpose such as Gabor filters [13], wavelet packet transform [14] and Shearlet conversion employed by Shunhua Liu and his colleagues for classifying surface defects of metals [1]. Given that investigating metals surface automatically is a known issue which is being investigated, but there isn't a general method to detect failures automatically [12]. Various methods for detecting and classifying surface defects of steel and other metals automatically have been presented [6, 11].

In Table 1, a list of a number of categorized methods for different types of steel surfaces with reference has been shown. Classification process begins after the division. At this step, generally, some features of desired regions are extracted whilst finding the appropriate features and classification of detected defects with a very low cost are of the main activities of the research [6].

2.1 Artificial Neural Networks
Computational systems and methods are based on machine vision and are modeled of way of biological nervous system and human brain function to process data and information. They have non-linear mathematical structure which displays the relationship between input and output of processes and

non-linear combinations and are able to categorize the inputs to get the appropriate output and also perform classification, clustering, and modeling. This classification has been applied by Paul Raj and his colleagues for defects of steel plate [7]. And generally are control systems that solve problems by using analytical methods. Human Neural Network system of millions of neurons is proportional to the location in the body that artificial nerve cells is a model which simulates biological behavior of neurons and are dynamic adaptive systems so that can adapt itself to new conditions and also are able to respond to a new situation as well as solving problems that have deficit in clear input information or having incomplete input information. Furthermore, they can continue their performance while part of the network has been destroyed. The reason for this is that neural networks distribute their information among neurons. Moreover, calculations in them are carried out in parallel and assist us to approach conducting operations in real time with minimal training. An investigation in the field of process control of food industry by artificial networks has been conducted by Estrella Funes et al [16]. Using the extracted feature vector, the output node is classified in one of two classes: defective and no without defect. The existing method is for the detection of surface and is of the most popular methods of texture analysis and is very promising in checking low resolution surface defects and non-uniform images [3].

2.2 Support Vector Machine (SVM)

Support Vector Machines (SVM) are a classification procedure under the supervision based on the statistical learning theory and are designed for both classes issues. It is also one of the linear methods and finds the best super surface which with the maximum distance separates data related to the two classes so that no data places on the border between the two super surfaces and given that defects classification is a multi-class issue some ways to generalize SVM to multi-class problems have been mentioned [8,9]. This classification is based on finding an optimal super sheet as the decision-making surface is such that maximum the border between the two classes. The greater the distance between two parallel super sheets, the less the classification error. SIFT algorithm due to the ability to describe and extract features have been also used for SVM classifier, Suvdaa et al have used SIFT method to identify defects location and using these methods have increased the number of training samples for SVM. Although they haven't obtained a good classification performance, by using the proposed conclusion strategies have risen the classification performance significantly [10].

2.3 Gabor filter

It is a segmentation algorithm and quick search of defects and also has been used for diagnosing thin cracks and corners of the sheet by minimizing costs but isn't very sensitive to fault detection [1,11].

It extracts significant histological features of image that includes both different directions and various frequencies. Chaitali Tikhe et al. using Gabor filter for diagnosing and classifying defects for increasing the quality of metal production have inspected metals surface and have increased defects detection rate by reducing the computational time. Gabor filter has been defined by harmonic functions which is a modulated function by a Gaussian distribution [11].

2.4 Classification of principal Component analysis and K-nearest neighbor(PCA, KNN)

PCA is a useful statistical technique known with other names such as Hotelling, Karhunen- loeve and Proper Orthogonal. Given that PCA relies on the input data but if enough input data can extract the best conversion and since it is a method without feature extraction, separation analysis uses an information group in relation to any template for feature extraction with high separation capability, accordingly, Aaron et al have introduced a mechanized method of identifying defects classification for metal products [2]. It has been used in detecting pattern for features extraction and reduction of data size leading to increase the algorithm speed, also less storage space is needed and can reduce the calculation process and is sensitive to the scaling main variables. In the field of biomedical research PCA has a potential ability with the aim of using analysis of principal component of PCA to identify micro-spectrum of normal cells automatically and cancer cells obtained from confocal imaging [18].

KNN is recognized as the nearest neighbor search and is a classification method based on the nearest samples in the feature space and because of high comprehensibility and lack of need to create hypotheses on data is considered a simple and widely used method. In this method, if K is chosen 1, it is the value of the closest sample to the desired target and for larger quantities of K highest value is selected between among neighbors [2]. In addition to its advantages, it has two problems: the first one is quantification of K done by the user and is defined by mathematical formulas so that there isn't need to the user, and the other one is that to assign labels, it considers all the nearest neighbors with equal importance degree and to solve this problem Keller et al. have used the fuzzy set relation which partly improves KNN technique [17].

2.5 Fuzzy Cluster Mean (FCM)

Given that segmentation is considered as one of the of the main branches of image processing science, the accuracy of image segmentation and using a clustering algorithm has an effective role in improving the system's efficiency. FCM algorithm is used to detect defects on steel sheets and after the image production this algorithm is used for final segmentation, Changhanq Xu et al have used this method for the detection of surface defects of metals. Although the results of FCM clustering is highly dependent on the centers and number of clusters; nevertheless, the obtained results are desirable [4]. Images segmentation is a fundamental issue and trouble in many applications of image. This category in recent decades has been highly examined by segmentation algorithms, FCM has also been used as a clustering method for segmentation of color of images, the processing stage is performed by this segmentation method and Initialization for center of cluster is as a default. The main purpose of this algorithm is to minimize the error function in the process of image segmentation. Although spatial information doesn't consider pixels and may have low resistance against noise and lower accuracy in segmentation, nevertheless, the obtained conclusions are promising and also morphological operations helps very much in improving segmentation of FCM [19,20].

2.6 Shearlet conversion

This conversion has been designed as a framework for the extraction of geometric features of multi-dimensional signals and has been provided based on Laplacian pyramid along with suitable cut filter, also can analyze an image with any scale in horizontal and vertical directions and is appropriate for

analyzing image tissue with a complex background [1]. And generally this conversion can be launched in various directions and different combined scales, it is extremely effective for two-dimensional functions containing distributed discontinuities and has a relatively simple mathematical structure. Its very high sensitivity in different directions and its desirable properties have led to improved image processing programs and is one of the applications for removing images noise [15].

3. COMPARISON OF METHODS OF DEFECTS CLASSIFICATION

Discussed papers are included as the examples of classification methods based on machine vision automatically. A number of studies have been published jointly by academic and research institutions. In recent years, automatic inspection system of steel surfaces has assigned to itself a significant percentage [6]. In Table 2 this comparison has been shown.

Table 1. Classification methods for different types of steel surfaces

Classification methods	Reference	Types of steel surfaces
Artificial Neural Networks	3 , 9	Hot rolling- steel sheet
SVM	8, 9, 10	Steel ingot- hot rolling and cold rolling- steel bars
Gabor filter	1, 11	Ingot- steel strips and bars
PCA	2	Hot rolling
KNN	2	Hot rolling
FCM fuzzy cluster	4	Cold steel strips
Shearlet Conversion	1	Hot rolling

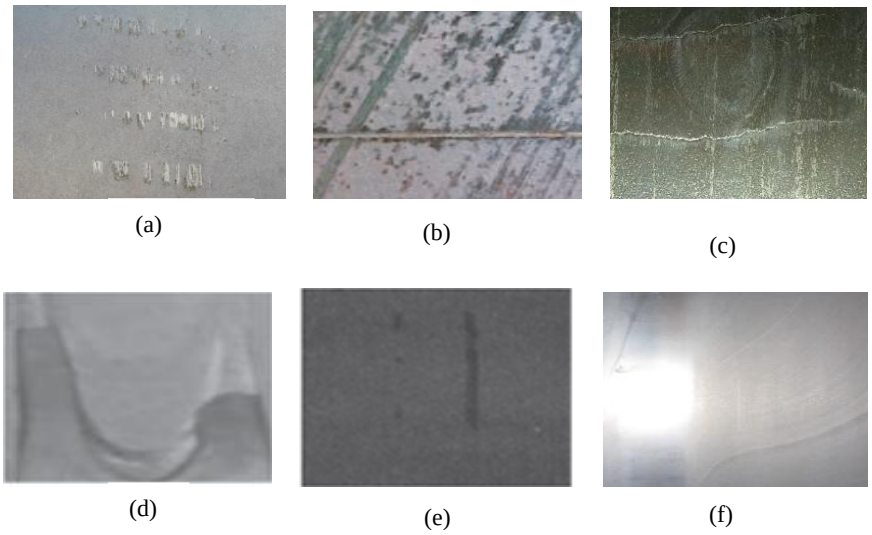

Fig 1: Sample images of hot rolled steels. Roll imprints (a), transverse scratches (b), transverse cracks (c), scar (d), oil stains (e), lighting variations (f).

Table 2. Comparison of methods of defects classification

Classification methods	Reference	Ability of recognizing fault %	Types of steel surfaces defects	Advantages	Disadvantages
Artificial Neural Networks	3 , 9	93.3%	Bubble - scratch - cracks on the side of the sheet and damages created randomly	Approaching the conducting operations in real time and checking defects with low resolution	Accuracy of results is highly dependent on the size of the training set
SVM	8, 9, 10	72- 93%	Graze - surface indentation- Scratch- Pressure line- loader bands	Obvious control and step down classification error- for data with the above dimensions, the	Performing calculations in feature space can be expensive

				respond was pretty good	
Gabor filter	1, 4	95- 98%	The fracture of sheet surface- needle holes- Stain and spot- Scratch	High speed in searching defects with the minimum cost	It doesn't have high sensitive to defects detection. And also the time needed for feature extraction is much
PCA & KNN	2	91.67%	Scratch- rippling of the sheet- Particles on the surface- Surface cracks	PCA requires little storage space. KNN has the capability of high understanding and no need to create a hypothesis.	Much calculations and weakness in distinguishing healthy and defective areas.
FCM fuzzy cluster	4	95- 98%	Surface cracks	Minimizing error function in classification	High computation time, Depending on the initial guess and Noise-sensitive
Shearlet Conversion	1	85- 89%	Scratch - water drop- Oil stains- Indentation- different brightness surface	Is very effective in eliminating images noise.	Irregular system

4. CONCLUSIONS

In this paper, the main methods of classification of sheet metal's defects including steel sheet as automatic inspection system which increases identification and classification performance significantly, has been expressed. And classification algorithms have been studied and features of a classification have been used sufficiently in detecting and classifying sheet steel's defects to enhance the quality of sheet metal which attempts to create a balance between accuracy and speed of classification. Although these methods do not solve the problem of detection and classification utterly and also a method may only be appropriate for detecting special defects. Nevertheless, the ability of these technologies especially in the field of diagnosis and classification of pattern have caused to be employed in quality control of some industries textiles, paper, and ceramics as well.

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