Application of artificial intelligence methods in nondestructive testing

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Abstract— **Non-destructive examination serves detecting material inconsistencies, assessment of material properties and measurements of object dimensions without changing their utility properties. Methods and techniques of non-destructive examination are applied in industry due to necessity of providing high quality semi-products, finished products, devices and structures. They are commonly applied to examine condition of technical devices utilised by people in order to detect defects which might lead to destruction of a structure. They are particularly significant in rocket, aviation, chemical, petrochemical, armaments, nuclear and conventional energy industries, ship building, railway industries, road, bridge and tunnel constructions as well as in other areas, and especially there, where threats to human life and environment can be found. Currently, non-destructive examinations develop in three directions: improvement of known and applied research methods, implementation of new methods and application of artificial intelligence to support a process of examination itself and assessment of quality of an examined element. The first and second direction of development shall not be discussed in detail in this study, except for a small remark.**

Keywords— nondestructive testing, artificial intelligence

I. INTRODUCTION

The main subject of this study shall be intelligent testing systems, operating on the basis of artificial intelligence algorithms. General considerations, as well as results obtained by the authors in the domain of digital radiography and electromagnetic methods shall be presented. The study shall present a scheme of information processing in human mind. Subsequently, software developed by the authors shall be described, supporting processing of radiographic photographs. Moreover, three methods of artificial intelligence shall be presented, applied for analysis of welds obtained from shipbuilding industry as well as other samples.

The present age may be referred to as age of artificial intelligence. Comprehensive works are conducted, aiming at building devices replacing a human in their intelligent actions. In order to build such a device one must first recognise the essence of human intelligence. Number of studies were written on this subject and many devices were constructed, which were supposed to replace intelligent human actions [1, 2, 4]. Alan Turing may be included in the number of pioneers of artificial intelligence research. Drawing certain synthetic conclusions from studies of psychologists, it may be stated that intelligence consists of two layers: computational and non-computational. Computational intelligence directs such processes as: making calculations, image recognition, chess playing etc. Those intelligent processes may be simulated by computer and entrust their execution with artificial intelligence systems. The other part of our intelligence cannot at present be mathematically simulated. It is responsible for such processes as awareness or feelings. Perhaps someday it will be possible to simulate it mathematically, or perhaps it shall never be possible and it shall forever remain a feature of only human mind, realised by natural brain [2, 3, 5].

Nowadays, various NDT techniques are used in industry. The most popular seems to be ultrasonic technique (over 50% of papers presented on QNDE conference), methods based on electromagnetic phenomena (over 20% of QNDE papers are related to eddy currents, MFL and others) and radiography. The artificial intelligence systems utilized in this papers are neural networks (ANN), fuzzy logic (FL) and fuzzy sets (FS). The results obtained from various non-destructive testing methods will be processed by AI methods in order to fully automatize the process of assessment of investigated sample. They are two roles that can be played by AI system during final reasoning. In the first case the system can only qualify the whole specimen as “good: or “not good” according to relevant norms and standards. In the second case the system can also provide more detailed information on defects in material e.g. by estimating their shape or classifying to specified group. At the beginning it was stated that the presented solutions only use computational intelligence of an operator. This is not 100% true, since such an element of non-computational intelligence as mood of an operator is not taken into account. However, it has impact on deterioration in recognition

II. THE SYSTEM

Developing a system for automatic specimen analysis requires building a reliable and extensive database of real images of possible defects. Possession of real images of defects is essential contexts of testing implemented algorithms for processing and radiogram analysis. In subsequent stages the

database will enable the development and adequate testing of software for automatic classification of irregularities. Model specimens were selected from a vast collection of results obtained for various NT methods. Those results were preliminarily described and classified by qualified operators. The selection was made taking into account the existence of irregularities and imperfections in the results that best characterized a particular group of irregularities. The basic operation in the classification process is recognition of the shape of every selected object with evaluation of object's features. The features describe geometrical properties of the object as well as its texture and closest surrounding.

TABLE I. LIST OF CHOSEN PARAMETERS DESCRIBING DEFECT'S SHAPE.

No.	Name
1	Area
2	Perimeter
3	Center of gravity (x)
4	Center of gravity (y)
5	Center of gravity according to brightness (x)
6	Center of gravity according to brightness (y)
7	Longer diagonal of ellipse
8	Second diagonal of ellipse
9	Perpendicular diagonal to longer diagonal
10	Angle
11	Compactness
12	Anisometry
13	Elongation
14	Lengthening index
15	Rectangularity
16	Mean Brightness
17	Max Dev of Brightness
18	L/a Ratio
19	Heywood diameter
20	Surrounding gray level
21	Surrounding mean brightness

The set of implemented features can be divided to two parts including the basis features and derivative features respectively. The derivative features are formed as nonlinear combinations of basis features. This approach extends separability of groups of defects in classification process. Table 1 shows selected basis features implemented in the system. The three first features listed in Table 1 are derived from a statistical analysis. The image of inclusion has been treated as a cloud of points in two dimensional space. Then, the PCA transform has been applied to it in order to obtain eigenvectors that characterize distribution of data in space. Then, the eigenvectors have been used as semi-axes of ellipse fitted to the object in an iterative process.

III. RESULTS FOR RADIOGRAPHY

The reasoning method based on FL allowed us to obtain 75% level of probability of crack detection, whereas probability of false alarm was 1%. Obtained POD and PFA levels rely on crack type. Results obtained by application of none of presented methods are well enough to use as sole method for weld defects detection process from digital radiograms. In POD factor comparison we can notice in accordance to long cracks, that indirect method is the best for its detection, especially based on local thresholding algorithms. Probability of small flaws detection is higher when using ANN method. Neural Network filtering gives also the best results in accordance to PFA factor. This factor is almost meaningless and lower than 0.01. The most unreliable method in comparison to ANN is a Fuzzy Logic with the PFA ten times higher. One of the most significant factors of estimation of selected methods is calculation time. It is the longest for indirect method, but it doesn't need pre-processing. The fastest method is ANN. Both ANN and Fuzzy Logic require training process for preparation. System is trained basing on the set of images containing selected flaws. According to POD and PFA factors achieved for various test images, it can be noticed, that different method gives better results for other defect types. The best solution is a fusion of all methods.

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