IOP Conf. Series: Materials Science and Engineering **327** (2018) 022040 doi:10.1088/1757-899X/327/2/022040

Neural network expert system for X-ray analysis of welded joints

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Abstract. The use of intelligent technologies for the automated analysis of product quality is one of the main trends in modern machine building. At the same time, rapid development in various spheres of human activity is experienced by methods associated with the use of artificial neural networks, as the basis for building automated intelligent diagnostic systems. Technologies of machine vision allow one to effectively detect the presence of certain regularities in the analyzed designation, including defects of welded joints according to radiography data.

1. Introduction

New technologies penetrate all spheres of human life and become more accessible, including when solving production problems. Together with the capabilities of computer technology, algorithms, data structures, information processing methods and the architecture of technical facilities are also being improved [1-2].

The increase in the amount of data processed also affects the architecture of applications and encourages developers to improve and optimize it. A separate direction of development is the use of Web-applications, which in recent years have significantly increased their capabilities. This is also relevant in the framework of ERP II strategy, which involves intensive network interaction within the enterprise management process [3].

The largest Russian manufacturers of oil and gas equipment in the block-modular design pay considerable attention to the quality of their products and the satisfaction of customers' requirements. To do this, certified quality management systems are used that meet the requirements of international standards ISO 9001-2008, ISO 14001 and OHSAS 18001, as well as the requirements of regulatory acts of oil and gas companies.

It is known that the oil and gas industry has high requirements for the quality of manufacturing technological devices. However, at the moment the examination of products is done manually, which has such drawbacks as low productivity and the essential role of the human factor.

At the same time, the quality of welded seams is of great importance, since they are the most vulnerable element of the design and one of the main methods of their joining.

For the control of welded joints, a film radiographic monitoring system is used in which the weld is surveyed and an X-ray image is generated for later analysis [4-6].

In order to increase the speed of processing of X-ray data, it is proposed to develop an intelligent diagnostic information system using artificial neural networks. After training, such system will be able to analyze images in an automated mode with minimal human participation [7-10]. In addition, the use

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of Web technologies will allow one to integrate the system into the information environment of the enterprise [3].

2. System operation algorithms

The algorithm of the information intellectual system for quality control of welded seams can be divided into two separate algorithms:

- the general algorithm of the system operation;
- algorithm of the program part of the system.

The general algorithm of the information intellectual system in the form of a block diagram is shown in figure 1a.

As can be seen from the block diagram, the operation of the information system is a cycle of actions that are produced one by one.

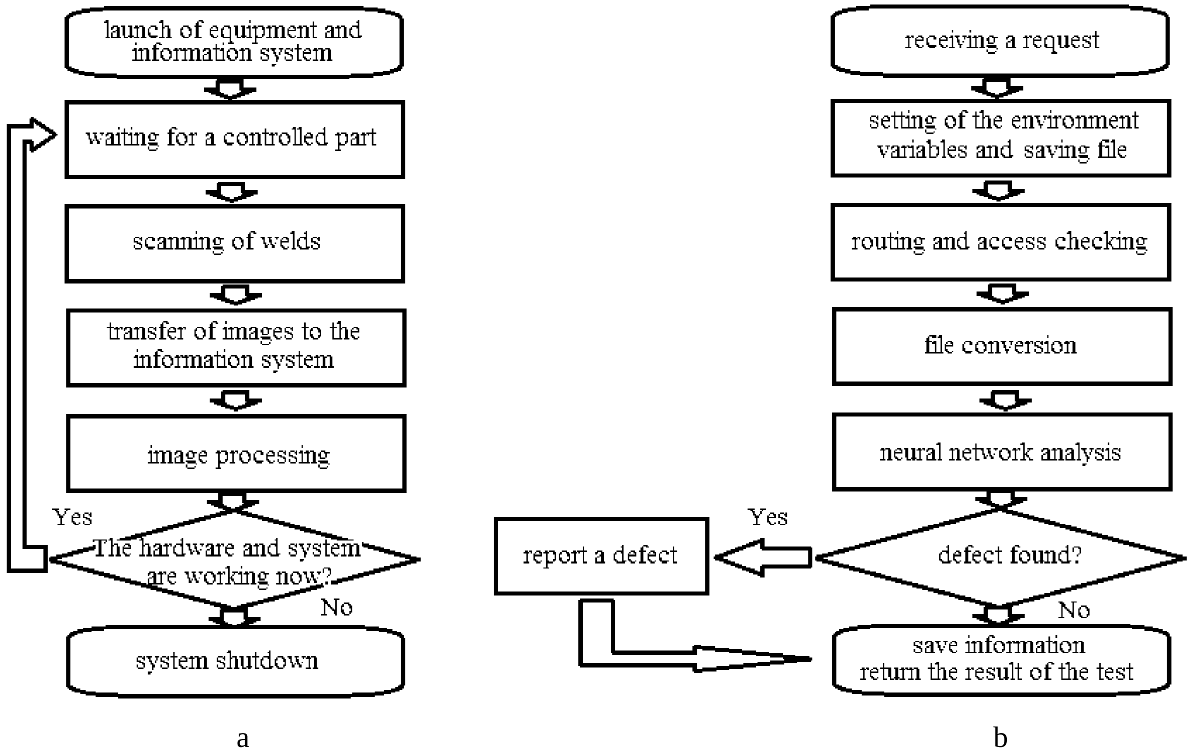

Figure 1. System operation algorithms

The radiographic scanner is waiting for the controlled part to appear in the scope, or it is waiting for the command to scan from the operator. After its appearance, the scanner scans the seams and transfers the results of scanning to a personal computer. An application that sends the scan result to the information system using the network is called up.

The algorithm of the program part of the intelligent system is shown in figure 1b.

Since the software part of an intelligent information system is essentially a Web application, the algorithm flowchart shows the sequence of application actions within a single HTTP request.

Step 1: The Web server receives the request and launches the Web application to process it.

Step 2. The programming language interpreter sets the environment variables, writes the interpreter configuration data there, information about the request and saves the transferred file to a temporary directory.

Step 3. The application, using the configuration file of the Web server, transfers control to the script, depending on the address of the transmitted request. After this, the application that makes the request has access to the Web application.

Step 4. The image is converted to the format most convenient for processing using a neural network. The need for a conversion is due to the fact that the image is transmitted in JPEG or PNG format and the RGB color model. If one analyzes the color gamut of images obtained with a radiographic scanner, one can see that all images there are in gray color, where there are black and white colors, and various shades of gray. To simplify color processing, the RGB model will be converted to the HSL model, with which black, white, and grayscale can be expressed with a single number from 0 to 255.

Step 5. At this step, the image model is analyzed after the transformation with the help of the neural network.

Step 6. The results of analysis of the image model for the detected defects are checked. If defects are found, steps 7 and 8 are performed, otherwise the transition to step 9 is performed.

Step 7. At this step, one receives the possible notification methods that are stored in the Web application database based on the type of defect.

Step 8. Alert is performed using the selected method (Email, SMS, and so on).

Step 9. At this step, the information about the request is saved so that the administrator or some other employee who has access to the application control panel can analyze the results of the application.

Step 10. The web application returns the results of its work to the application that caused it.

3. Realization of the proposed intellectual system

To develop the Web application, the programming language PHP was chosen using the Yii2 software platform. To implement the intelligent system software, UML diagrams were used.

MySQL was used as a database management system. To support the development of databases, a data model was constructed in the form of an ER-diagram.

Data exchange between the radiographic control equipment and the Web application is performed in the JSON format. The choice of this format of data exchange is due to the fact that it has an optimal ratio of the volume of transmitted data, human-friendly syntax and software support on various hardware and software platforms.

When one starts the application, it checks to see if there is an Internet connection, since the connection is necessary for the application to continue working. If there is no Internet connection, the user is given a corresponding message. If there is a connection, an HTTP GET request is made to get a list of devices. The Web application returns a list of devices in JSON format.

When one clicks on the file selection button, an OpenDialog class object is created, which implements all the functions necessary to work with the file selection dialog box. After the dialog box is closed, if the file has been selected, its content is read using the Stream class and converted to the Base64 format. The image is displayed in the application window. If an error occurs at any of the stages, the user is given a corresponding message about this.

The next step in the application is sending data to the server for verification. Before this, the following checks are made:

- whether the device is selected;
- whether the file with the image is loaded.

If at least one of the checks is not passed, the user is given an error message and the further operation of the procedure is terminated. If all the checks are successful, the following actions are performed (listed in the order they are taken):

- the request URL is generated;
- an object of class WebRequest is created;
- the request parameters (the method, the length of the request and the type of data transferred in the query) are specified;
- the body of the POST request is formed based on the selected file for verification;
- based on the response of the Web application, a WebResponse object is created;

- using the Newtonsoft library, a JSON object is created from the Web application response body;
- the content of the object is interpreted in JSON format and results are output to the form (in addition, depending on the results of the interpretation of the object, the color of the output is also changed).

In addition to the analysis of the transmitted image, the Web application also performs auxiliary actions before it, namely:

- checking the information about the device that transmitted the images (checking the presence of the device and the fact that it is currently on);
- recording of the transmitted image in Base64 format to a file on the disk;
- conversion of the transferred file from the RGB color model to the HSL color model.

The neural network is trained through the administrative panel of the system. The system administrator loads an example of the result of the radiographic scanner operation and indicates whether there is a defect on this image and if so, which one. Training can be done only for the neural network that is currently used as a neural network by default. One can change the default neural network on the Edit System Settings page. For the training of neural networks, a sample of typical images of various defects is used (figure 3), accompanied by the results of manual radiographic inspection.

In the system it is possible to create several neural networks, train them in parallel and in different algorithms and, as already mentioned above, modify the neural network used by default for image analysis. Such opportunity was introduced in order to be able to choose the most efficient one from several neural networks, or, to specify one of the neural networks to detect any one type of error, if such a necessity arises.

As a result of the work of a neural network, one of two possible outcomes is formed:

- a defect on the results of the radiographic scanner was not found;
- a defect on the results of the radiographic scanner is found.

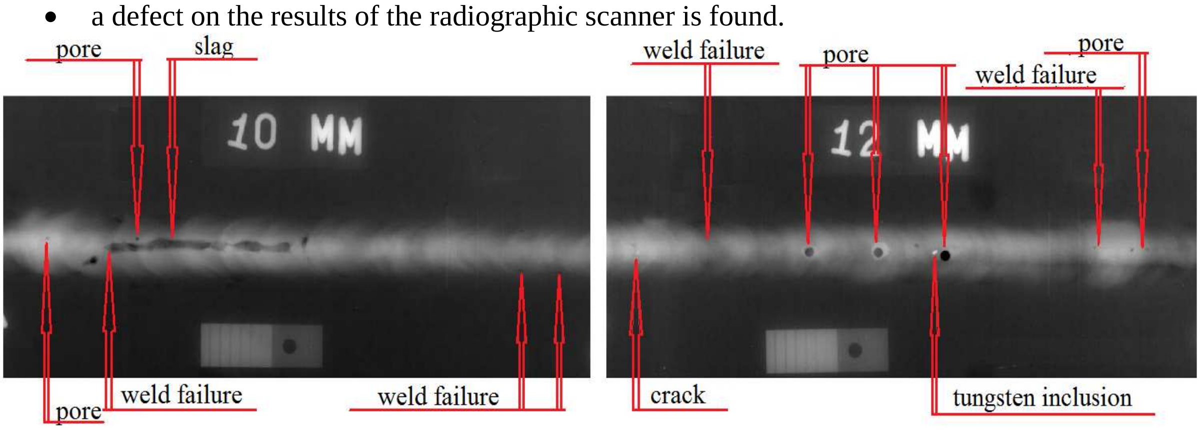

Figure 2. Examples of X-ray data, constituting the training samples

In the first variant, the system creates entries in the HistoryLogs and Requests tables and returns information to the calling application that no defects have been found.

In the second variant, the system, in addition to the actions described in the first variant, also performs notifications according to the settings specified on the corresponding page.

4. The results of the information system

The results of the information intellectual system (in emulation mode) are shown in figure 3. Verification of the correct operation of the system was carried out on a test sample of X-ray images. At the same time, the neural network was trained to recognize the failure of the weld seam and slag inclusions. According to the test results, the system provided 100% coincidence with the expert.

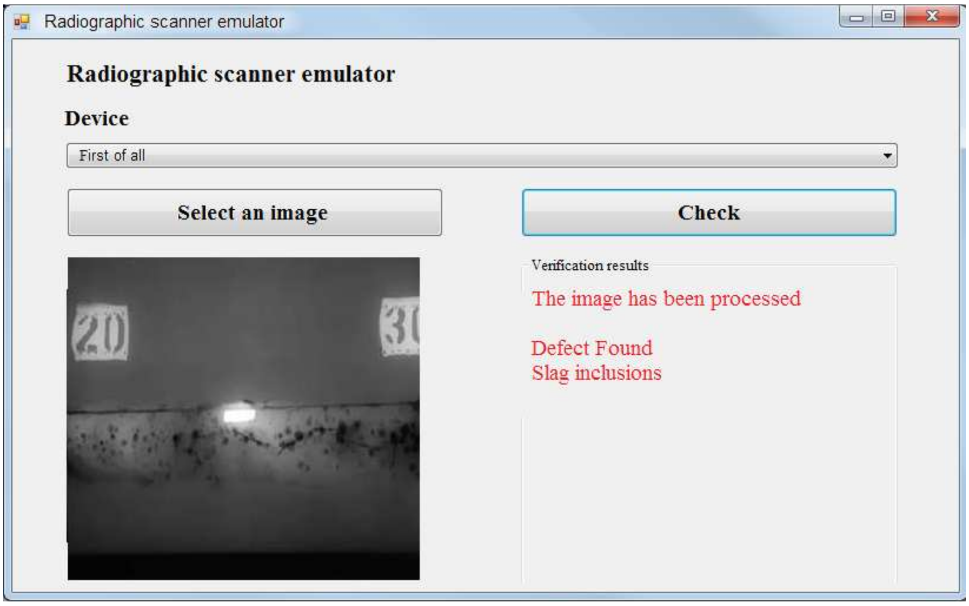

Figure 3. Weld analysis results

As a direction for the further development of research, it is planned to expand the list of detected defects, by training networks on new data sets, as well as work to identify the most effective neural network architectures and methods of their learning by comparing the various options. The problem of differentiating defects and creating a single expert system on the basis of a set of expert neural network structures also requires special attention.

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