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STUDY OF PRODUCTION ERRORS FOR VALVES USING A HAMMING NETWORK

BADANIE BŁĘDÓW PRODUKCYJNYCH ZAWORÓW Z UŻYCIEM SIECI HAMMINGA

A b s t r a c t

This paper focuses on the research carried out in the Institute of Applied Informatics of the Cracow University of Technology, targeting the full detecting damage in valve. In the paper one can find a description of own application created to verify the valve. Virtual test stand has been created using the possibilities given by present engineering software, such as designing, testing, checking for elements collisions and presenting the device.

Keywords: valve, edge detection, neural network, image analysis

S t r e s z c z e n i e

W artykule zaprezentowano badania prowadzone w Instytucie Informatyki Stosowanej Politechniki Krakowskiej, nad wykrywaniem uszkodzeń produkcyjnych zaworów. Zawarto opis stworzonego oprogramowania służącego do sprawdzania obecności oraz poprawności zamontowania elementów zaworów. Wirtualne stanowisko do badań zostało stworzone dzięki możliwościom jakie daje współczesne oprogramowanie inżynierskie, umożliwiające nie tylko projektowanie, sprawdzanie działania i ewentualnych kolizji elementów, ale także zaprezentowanie tworzonego urządzenia w formie prezentacji multimedialnej.

Słowa kluczowe: zawory, wykrywanie krawędzi, sieci neuronowe, analiza obrazu

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1. Introduction

In the contemporary world, automation, globalization and unification of standards affected each and every single branch of science and economy. This is possible due to transformation of the world around us towards the information society. Growing drive towards information technologies around the world, which becomes a global village, means that unification of standards is needed, if not necessary. IT systems become increasingly simple in terms of operation, have a large number of modules, which allow any user to work with them.

In contemporary factories, people are replaced more and more frequently by automated work stations, which are able to operate cheaper, often more precisely and commonly under conditions unfavourable to human beings. They can be also controlled remotely. Through the introduction of the computer-aided image analysis to routine and scientific analysis in quality control, it is possible to achieve improvement in the results by increasing the measurement precision or calculating additional parameters based on the image, which cannot be determined by hand, what in turns guarantees better forecast accuracy.

The tasks realized by computer image analysis systems are complex and difficult. Image analysis and content recognition is used most frequently in the computer systems referred to as **OMR** (Optical Mark Recognition). One particular and most interesting directions for image recognition software is character recognition i.e. the so-called OCR (Optical Character Recognition).

The first development steps in this area reach back the 60ties of the XXth century. They are related directly with the evolution of research on artificial neural networks and extension of computer systems and their graphical interfaces. Increase in the processing power of the contemporary computers has had and still has a substantial impact on the evolution of computer image recognition systems.

This paper examines a specific case of image analysis and content recognition, detection of production defects of an electrically driven control valve type WE 6.

2. Image analysis

Through the introduction of the computer-aided image analysis to routine and scientific analysis in diagnostics, it is possible to achieve improvement in the result quality (increasing the measurement precision or calculating additional parameters based on the image, which cannot be determined by hand), what in turns guarantees better quality of the provided diagnosis. The algorithms of quantitative image analysis exclude any mistakes, which can be committed by human beings due to lack of concentration, tiredness or optical illusions.

A typical machine vision system for quantitative image analysis fulfils the following operations:

– Image acquisition and archiving, i.e. capturing the source image from an analogue or a digital device (a photo camera, a video camera) and introducing it to the target computer.

– Initial image processing. This particular stage features isolation of the target area of interest and filtering image contents to eliminate any interference which may influence the further image processing stages.
– Image segmentation, i.e. separation of all its points into disjoint, coherent components characterized by uniformity, representing real objects depicted in the image.
– Object identification – among the segmented objects, it is necessary to identify the ones, which are to be subject to further analysis and then divide them into appropriate classes.

Object analysis – features a series of measurements describing object morphology i.e. colour, shape, size etc. Analysis and classification stages can be executed in common, by a single algorithm.

3. Edge detection

Algorithms of edge detection are subjected to continuous research carried out by many scientists, thus their number is rather large. However, the best results are provided by algorithms based on fuzzy sets, even though they need much higher number of computation operations and a single data set in the examined image may need to be processed several times. In this study, we took advantage of a fuzzy logic classifier function presented in the work entitled „Image edge detection using Fuzzy Classifier”. This particular algorithm comprises 4 basic steps:

Step 1: define the values for three parameters provided by the user i.e. low, high and? (omega, on the figure, it is represented with the symbol)

Step 2: for each pixel, calculate the difference between all 8 surrounding pixels and store them in a vector.

Step 3: For each vector, calculate the value of association function, defining the class the given pixel belongs to.

Step 4: Based on the principles of fuzzy logic, determine whether the given pixel belongs to the background or an edge.

In order to handle implementation of algorithms used to detect edges, first it is necessary to define several concepts.

Pixel neighbourhood

In the theory of cell automatons, the term “Moore's neighbourhood” or “Moore's surrounding” defines the set of eight cells, which surround the central cell i.e. the set of neighbours comprises all cells which border with the given edge or vertex. The central cell does not make part of its own surrounding. Such a surrounding comprises all neighbouring cells, bordering with edges or vertices.

The first step of this algorithm features calculation of a vector for each pixel in the image (see pixel P5 in the figure):

$$X = [X1, X2, X3, X4, X5, X6, X7, X8]$$

where:

$X1 = P1 - P5$; $X2 = P2 - P5$; $X3 = P3 - P5$; $X4 = P4 - P5$; $X5 = P6 - P5$; $X6 = P7 - P5$; $X7 = P8 - P5$; $X8 = P9 - P5$

p1	p2	p3
p4	p5	p6
p7	p8	p9

x1	x2	x3
x4	0	x5
x6	x7	x8

Fig 1. Pixel neighbourhood

Rys. 1. Piksele sąsiedztwa

Background and edge class

When vector X for the given examined pixel is already created, next it is necessary to calculate the value of two affiliation functions, describing affiliation to the class of background or the class of edge. Based on the obtained results, it is possible to determine whether the given pixel belongs to an edge or the background. An edge is relatively simple to detect when there are very large differences between the examined pixel and its surrounding. Sometimes, noise can be misinterpreted. Therefore, prior to edge detection, images are filtered to eliminate noise, though there are also algorithms based on fuzzy sets used for noise elimination. e.g. Competitive Fuzzy Edge Detection). The value of affiliation functions for the background and edge classes are calculated as follows:

Background clas

$$\begin{cases} 1 \quad \text{for} \quad X1 \le L, X2 \le L, ..., X8 \le L \\ \text{Max}\{0, 1 - \| X - \mu 1 \| 2 / \beta \quad \text{for} \quad wpp \end{cases} \tag{1}$$

Edge class

$$\begin{cases} 1 \quad \text{for} \quad X1 \ge H, X2 \ge H, ..., X8 \ge H \\ \text{Max}\{0, 1 - \| X - \mu 2 \| 2 / \beta \quad \text{for} \quad wpp \end{cases} \tag{2}$$

It is simple to notice that these functions return a value in the range [0; 1].

Classification to the given class is represented in the given figure:

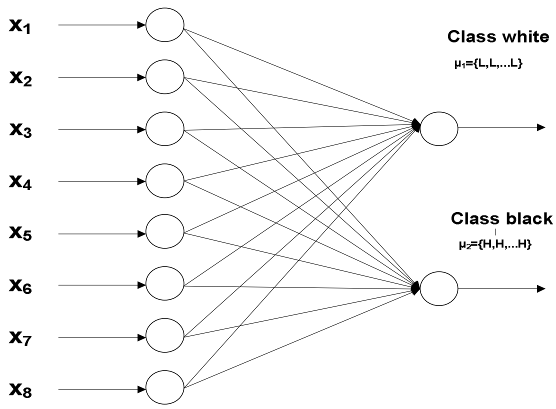

Fig. 2. Edge classification

Rys. 2. Klasyfikacja krawędzi

Calculating the value of a new pixel

When we already have the value of affiliation functions for the aforementioned classes, it is time to take decision whether the given pixel is part of an edge or the background. For that purpose, we use a set of "if ... then" rules, defined as follows:

IF the background affiliation function has a larger value **THEN** change the pixel colour to white

IF the edge affiliation function has a larger value **THEN** change the pixel colour to black

IF both affiliation functions have the same value **THEN** change the pixel colour to white

4. Discrete Fourier Transform

Discrete Fourier Transform (DFT) was used to localize and classify objects in images. DFT determines the spectral density of the examined image and provides precise information about the density distribution. The two-dimensional (2D) DFT, both simple and complex, is defined with the following formulas

$$F(u,v) = \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} f(x,y) e^{-2\pi i (\frac{xu}{M} + \frac{yv}{N})} \tag{3}$$

$$f(x,y) = \frac{1}{MN} \sum_{u=0}^{M-1} \sum_{v=0}^{N-1} F(u,v) e^{-2\pi i (\frac{xu}{M} + \frac{yv}{N})} \tag{4}$$

where:

$f(x,y)$ – image element located at (x, y),
$F(x,y)$ – Fourier transform for this point,
M, N – image dimensions.

In practical applications, Fast Fourier Transform (FFT), which was described in 1965 by two American mathematicians – J.W. Cooley and J.W. Tukey, is used for calculating Fourier transform for the examined image. This algorithm comprises decomposition of n points into a total of even and odd terms. Next, the transform is executed for each group of terms and the obtained results are summed.

This algorithm utilizes the "divide-and-conquer" method and a special form of the transformation matrix, with elements in the form of roots of one, which allows for substantial limitation of the number of executed operations, which in return shortens the time needed for calculations.

Due to Fourier transformation, the image is transformed into the frequency domain, representing the contrasts included in the examined image. Since the examined image has a binary format, all types of edges are located in the area of high frequency. An image obtained as the result of the Fourier transformation is referred to F-image. Pixels in the F-image are referred to F-pixels. The 2D Fourier transformation may be applied as a single dimension transformation, first to rows and then columns or vice versa. In both cases, the obtained result will be identical.

Pattern searching algorithm
For A – processed image
B – image with a master object
What we are looking for is:
C – image with the identified location where image B (master) is located.

$$C = \mathrm{IFFT2}(\mathrm{FFT2}(A) * \mathrm{FFT2}(\mathrm{ROT180}(B))) \geq \alpha_{SN} \quad (5)$$

where:

α_{SN}	–	coefficient learned by the neural network, informing on the location of the master
IFFT2	–	Inverse, 2D Fourier transform,
FFT2	–	2D Fourier transform,
ROT180	–	matrix (image) rotation by 180 degrees was defined as follows:

For a matrix

$$\mathrm{D} = \begin{bmatrix} d11 & d12 & d13 \\ d21 & d22 & d23 \\ d31 & d32 & d33 \end{bmatrix} \quad (6)$$

$$\mathrm{ROT180(D)} = \begin{bmatrix} d33 & d32 & d31 \\ d23 & d22 & d21 \\ d13 & d12 & d11 \end{bmatrix} \quad (7)$$

5. Hamming Network

A Hamming Network is a two-layer classifier with a flow chart presented in Fig. 4. The main goal of this network, just like in the case of a Hopfield network, is to find a pattern in the set of input patterns which resembles most the input signal. In this case, the Hamming distance is taken as a measure of similarity – it is defined as the number of bits which are different in the compared objects. This particular selection process is carried out by the first

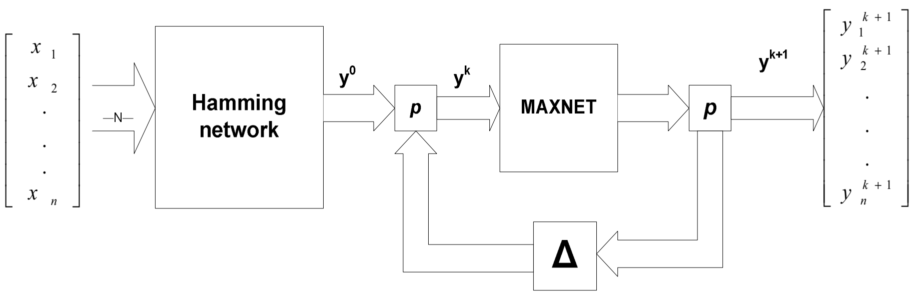

Fig. 3. A flow chart of a Hamming classifier

Rys. 3. Schemat blokowy klasyfikatora Hamminga classifier layer. The strongest output signal of a neuron is the indicator of the smallest Hamming distance between the input signal and the class pattern, which is represented by this particular neuron. The second layer, referred to as MAXNET, plays an auxiliary role. It is a recurrent network, aiming to attenuate output signals of all neurons of this layer apart from the one, which received the strongest input signal at the input.

The weights in the first layer are defined in a similar manner to the Hopfield model using a single record method, since in practice they are equal to appropriate components of the patterns saved in the network.

Since the Hamming distance between the input vector x and the stored pattern signal $s^{(m)}$ is equal to

$$\mathrm{HD}(x, s^{(m)}) = \frac{1}{2}n - \frac{1}{2}xs^{(m)} \tag{8}$$

where: n is the number of bits in the examined vectors, so by adding at the input of each element a constant input signal n/2, we obtain the total element excitation

$$\mathrm{net} = \begin{bmatrix} n - \mathrm{HD}(x,s)^{(1)} \\ .... \\ n - \mathrm{HD}(x,s)^{(p)} \end{bmatrix} \tag{9}$$

In the MAXNET network there are activating (feedback coupled with the weight of 1) and braking excitation signals, where a side breaking model is used with the weight – ε, where: $0 < \varepsilon < 1/p$ (p – is the number of elements in each network layer).

6. Examination and result analysis

The survey test station, designated for analysis of an electrically driven slide valve for presence of all elements as well as correctness of their assembly, assumes that the fully automated device comprises two modules:

- manipulation module,
- surveying module, which comprises a set of two cameras feeding the images to the application.

The task played by the manipulation module is mainly related to the transport of the examined valve unit to the test station, together with the transport of this unit from the mentioned station. This element comprises a manipulator, representing the main element of this module, together with a gripping device, designated for gripping the external, valve surfaces. The manipulator performs a closed set of repeated motions and is equipped with a fixed software, due to which it reacts without any problems to control signals provided by the surveying module.

Figure 4 presents the software description. The developed program, read the data and then processing it in the subsequent blocks, confirms proper operation.

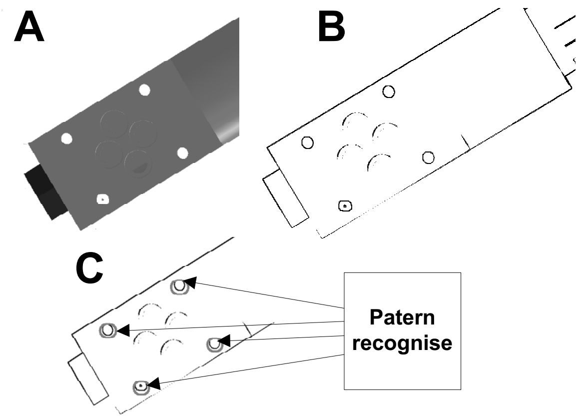

Fig. 4. A – reading in image data, B – edge detection, C – pattern recognition, D – decision

Rys. 4. A – wczytanie obrazu, B – wykrycie krawędzi, C – rozpoznanie wzorców, D – decyzja

7. Conclusions

The program together with the investigation equipment, is part of an innovative system of production analysis of an electrically driven control valve. The system is effective, fast and complex, taking advantage of the latest IT technologies and at the same time very functional. The utilization of this application allows for excluding human being from this production process.

The system can be also further extended and utilized in other branches of industry.

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