Optical Method For Monitoring Tool Control For Green Burnishing With Using Of Algorithms With Adaptive Settings

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Abstract. With regard to the complexity of the new technology and increase its reliability requirements laboriousness of control operations in industrial quality control systems increases significantly. The importance of quality management control due to the fact that its promotes the correct use of production conditions, the relevant requirements are required. Digital image processing allows to reach a new technological level of production (new technological way). The most complicated automated interpretation of information is the basis for decision-making in the management of production processes. In the case of surface analysis of tools used for processing with the using of metalworking fluids (MWF) it is more complicated. The authors suggest new algorithm for optical inspection of the wear of the cylinder tool for burnishing, which used in surface plastic deformation without using of MWF. The main advantage of proposed algorithm is the possibility of automatic recognition of images of burnisher tool with the subsequent allocation of its boundaries, finding a working surface and automatically allocating the defects and wear area. Software that implements the algorithm was developed by the authors in Matlab programming environment, but can be implemented using other programming languages.

1. Optical method of control as part of green techs

The Human Development Index (HDI) is a summary measure of average achievement in key dimensions of human development: a long and healthy life, being knowledgeable and have a decent standard of living [1]. One of the highest HDI is in United States, Russian Federation is on 50 place. The advantage of the HDI leader's is achieved by concentrating resources in the areas with the highest added value: research, development and design. Production (material stage) has the lowest added value and does not improve

HDI (for example, the people's Republic of China – 90 place). Thus, improving the wealth of citizens is impossible without the development of the country's science complex.

Creating advanced manufacturing technologies (AMT) is the main directions of research and development in postindustrial countries. AMT represents complex design and manufacturing processes in the modern technological level of individualized material objects (goods) of varying complexity, the cost of which is comparable with the value of the goods of mass production, including in countries with cheap labour [2]. AMT allows to achieve an advantage over countries with cheap labour that is needed to create not only advantageous external conditions to attract investment, but also the competitiveness of technologies in global markets.

In public the analytical report on the development of new production technologies, presented in October 2014 by Skoltech there are four areas that form the shape of a promising production in the world [3]:

1) computer technologies for modeling and production;
2) industrial and service robotics;
3) additive manufacturing;
4) new materials.

One of the main mechanism for increasing of HDI is by creating AMT related to computer technologies for modeling and production. The way for achieving new technologies now realized with National Technology Initiative (NTI) [4]. Roadmap of NTI contains new markets which will use AMT, one of them is TechNet [5]. Platforms for the implementation of new technologies will be created on large industrial enterprises so called "Factories of the future".

The authors have developed two technologies of surface plastic deformation (SPD). One of them is wide burnishing (WB), the main advantage: hypercapability (processing is carried out for several revolutions of workpiece). Other technology associated with the implementation of modern technologies in the sphere of industrial vector – «Green» technologies: burnishing (or dry burnishing) without using of metalworking fluids (MWF) [6]. This technology aims to eliminate negative effects on environment and health of workers, which many oils based on MWF in Russia Federation (based on results of ecological and toxicological characteristics). All parts of new techs must meet the requirements of AMT, including operation of tools control. The mechanical assembly productions applies organoleptic method ("by-sight”) condition monitoring of working surface of machining tool that have low confidence. The result completely depends on the qualifications of inspector - a "human factor". The constant routine work degrades the human sensory organs work, contributing to increased measurement accuracy and increasing the probability of defect products. The purpose of the authors was to improve old [7] semiautomatic algorithm. The lack of a formalized description of the key factors contributes to the uncertainty in the process and does not allows to create a universal algorithm for detecting objects on the image. Only for graphics and text segmentation tasks on digital images of documents invented hundreds of fundamentally different algorithms.

2. The concept of the algorithm

The reason for the difficulty of establishing methods and algorithms of image recognition is the lack of information that have semantic content images causal or dynamic model formation, the content of the image is not created under the influence of physically laws, which can be described in a mathematical equation, a manifests itself in the form of endless brightness-geometric structures diversity, spawn model of which are missing [8]. In the coming decades occurrence of system “understanding” any visible scene is not expected. Different groups of images of model objects are separate areas of research, such as analysis of objects on aerial photographs [9]. Currently, the field of study is not formed and includes a number of outstanding theoretical tasks and a large number of ideas and approaches.

However, the important task of machine vision can be reduced to a simple issue of detection and recognition or measurement across multiple image objects that match the model description [10]. There are different types of models from simple indicative descriptions to highly specialized and sophisticated structural models, however, there is no general principle of such functioning models in each case, therefore, it is necessary to carry out research. The development and use of models, suitable for effectively addressing the challenges of detecting relevant objects remains on the verge of science and art and represents a «know-how», or knowledge of the subject area, reflecting years of research experience on solving particular tasks.

The algorithm is applied to the field of machine vision – range of engineering technologies, methods and algorithms associated with the task of interpreting the scenes observations on its two-dimensional projections, as well as the practical application of the results of interpretation.

Algorithm aim is to «understand» images of a specific subject area – burnishing tool.

In accordance with the adopted modular D. Marr paradigm [11] image processing is performed on several consecutive levels, from the iconic representation of the object (bitmap, not structured) to a symbolic representation (vector and attributive data, relational structure) and includes the following steps (which can be divided into the processing of lower, middle and high level):

- Image preprocessing;
- Segmentation;
- Selection of geometric structures;
- Determination of the relative structure and semantics.

The algorithm is not related to computer vision systems (discipline, studying theory and basic algorithms to analyze images and scenes), but to computer vision (covers the technological scope of systems development issues: choice of lighting scenes, investigated choice characteristics of sensors, their quantity and geometry of the image sizing issues and orientation, selecting hardware for digitizing and processing, development of algorithms and their implementation) and includes the top-level algorithms (for "understanding" images) using existing low-level algorithms (for "image processing"). The algorithm can also be attributed to the more narrow field of "robots vision" on the required characteristics of the system: the need to build backward linkages by results of understanding images taking into account requirements in time (in the specific case - production time or cycle time).

Factors influencing the understanding of images cannot be formalized due to: interference and noise, occlusion effect, distorting the optical effects, abrupt change of lighting variability in objects, effects of surroundings changes between sensors and objects etc [12]. In this regard, to address similar challenges at the present time there are dozens of algorithms, each of which checks on samples of actual data covering all the negative effects. In the future it is planned to ensure sustainability of the algorithm i.e. robust which is necessary for its commercialization.

Despite the development of computer technology and the creation of specialized processing base for image simple processing, basic computation-intensive algorithms occupying seconds of computer time, that is unsuitable for mass production (important for WB). The practical tasks of image processing, as set forth in this work include many additional degrees of freedom, such as the search bright-geometric structure in the image that can be not only have an arbitrary location, orientation, and scale, but is subject to change, not only is affine or projective, but warping.

The algorithm is a development of previously application software for estimation of wear of the working part of the tool, that algorithm is presented in [7]. It allows to calculate the area of the worn working parts of any instrument by applying two primitives: rectangular and ellipse. The main disadvantage of this algorithm is that the recognition and selection of tools wear is impossible in automatic mode without operator intervention.

The presented algorithm in this paper implements automatic mode to define the boundaries of the tool and its working surface. Calculation of fields wear is made using the methods of the bounds selection on image, such as operators of Prewitt, Canny, Sobel, etc. [13, 14].

At the initial stage of analysis for performance of image processing is a gray gradation - color mode in which images are displayed in shades of gray. Grayscale mode is used to determine the brightness of each pixels color of image on the intensity of the color components in the formula (1) [11]:

$$\mathrm{Lum} = \mathrm{Red} * 0.299 + \mathrm{Green} * 0.587 + \mathrm{Blue} * 0.114, \quad (1)$$

where *Lum* – light intensity operator; Red, Green, Blue – components of red, green, and blue, respectively; 0.299, 0.587, 0.114 - the coefficients used for converting colors.

Formula (1) can be represented as integer (2):

$$\mathrm{Lum} = \frac{\mathrm{Red} * 77 + \mathrm{Green} * 150 + \mathrm{Blue} * 29}{256}. \quad (2)$$

Next, the resulting brightness value Lum is assumed for all color components by the formula (3):

$$\mathrm{Red} = \mathrm{Green} = \mathrm{Blue} = \mathrm{Lum} \quad (3)$$

The basement of the mathematical model for determining the area of tool wear is Prewitt operator [13].

Prewitt operator – the method of boundaries selection in image processing which calculates the maximum response on multiple kernels convolutions to find local targeting boundary at each pixel.

The operator uses two cores 3×3, compressing the original image to calculate approximate values of derivatives: one horizontal and one vertical.

Set: A - original image, and G_X, G_Y - two images, where each pixel contains horizontal and vertical derivative approximation which is calculated as follows:

$$G_X = \begin{bmatrix} -1 & 0 & +1 \\ -1 & 0 & +1 \\ -1 & 0 & +1 \end{bmatrix} * A \quad u \quad G_Y = \begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ +1 & +1 & +1 \end{bmatrix} * A \quad (4)$$

Each point of the image is an approximate value of magnitude of the gradient. It can be calculated, using the approximation derived:

$$G = \sqrt{G_X^2 + G_Y^2}. \quad (5)$$

Gradient direction:

$$Q = arctg\left(\frac{G_Y}{G_X}\right). \quad (6)$$

Under converting a vector graphic to a bitmap occurs error associated with an approximation of smooth borders area, complained of a particular function, discrete boundaries of the bitmap. The transition from a vector graphic to a bitmap is carried out according to the Bresenham's line algorithm [15].

General algorithm of the program is presented in the following block schematic diagram (Fig. 1).

This algorithm can be functionally divided into 2 blocks: 1) determination of the boundaries of the tool and its working surface; 2) analysis of the working surface, determination of defects and wear. Taking into account that on the analyzed instrument image there are 2 circles (the tool's border and the boundary of the working surface), the search for the circles is performed using the Hough transform for circles searching. Considering the uneven lighting and the universality of the algorithm, cyclic search of circles is performed with automatic change of sensitivity settings of Hough transform function.

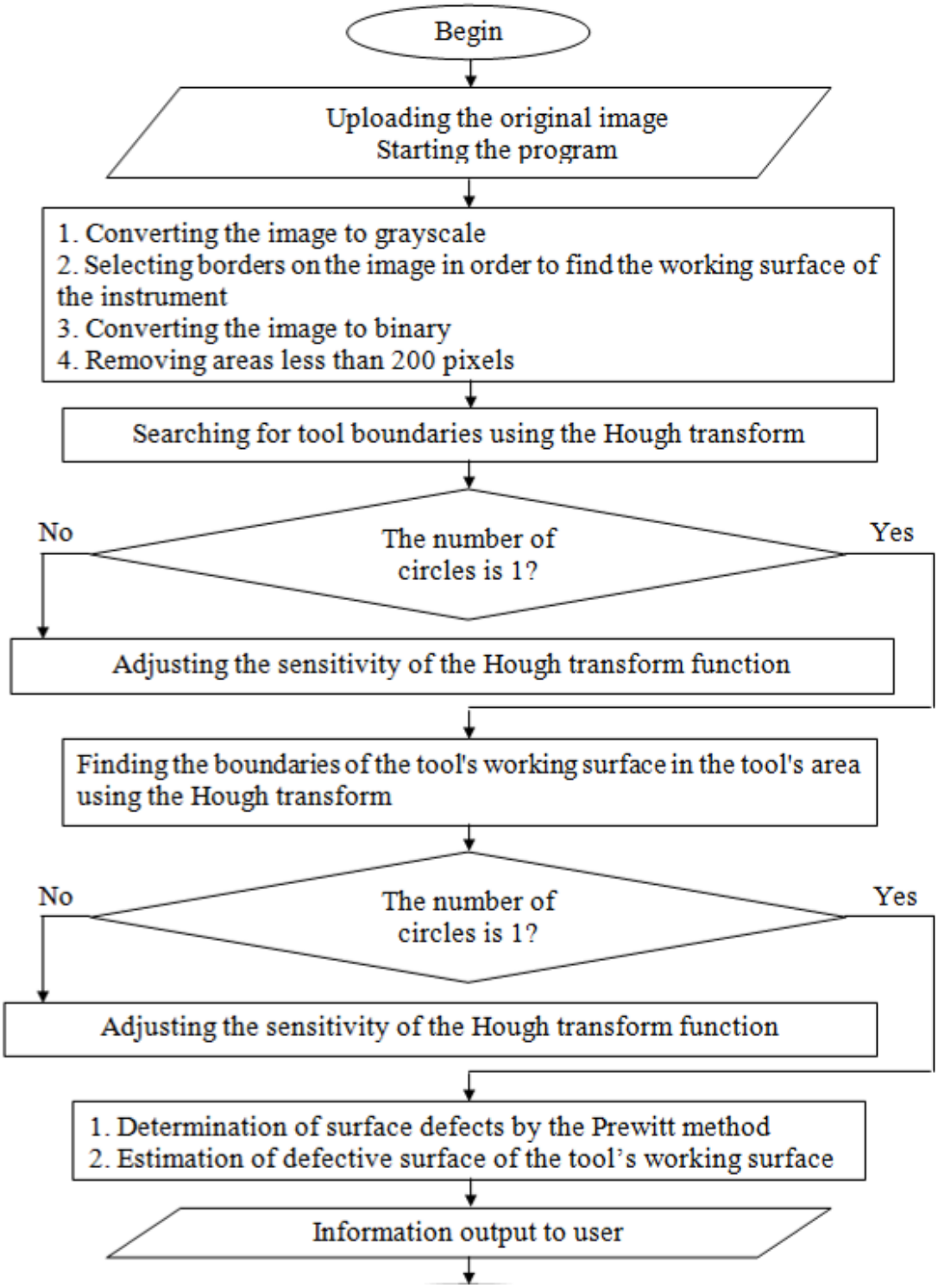

Figure 1 – The algorithm block schematic diagram

To visualize the work of algorithm the basic steps presented in the following figures.

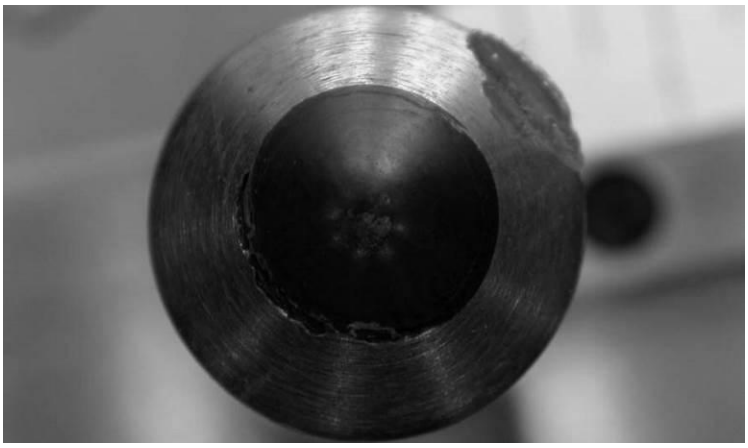

Figure 2 – The original image of burnisher

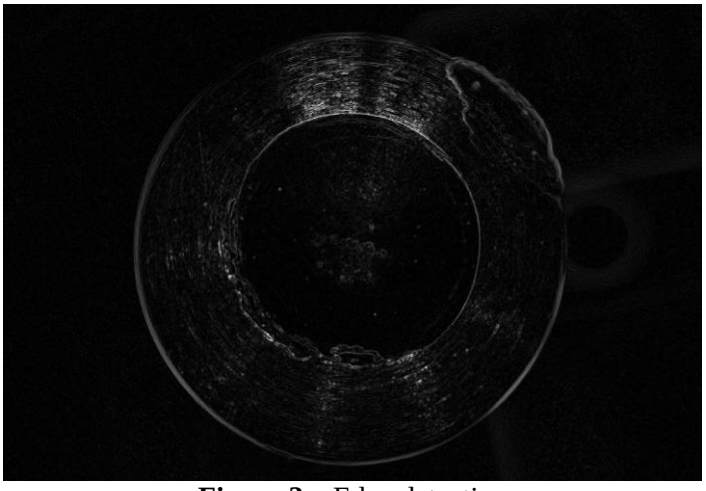

Figure 3 – Edge detection

The definition of the boundaries of the tool and its working surface is carried out using the Hough Transform (Fig. 4). Method is used to retrieve items from the image. It is designed to search for objects belonging to a certain class of shapes, using the voting procedure. The voting procedure is applied to the parameters from which objects obtain a certain class of shapes on a local maximum in the so-called accumulator space, built during calculating the Hough transformation [16].

The simplest case of Hough transform is detecting straight lines. In general, the straight line y = mx + b can be represented as a point (b, m) in the parameter space. However, vertical lines pose a problem. They would give rise to unbounded values of the slope parameter m. Thus, for computational reasons, Duda and Hart proposed the use of the Hesse normal form:

$$r = x\cos\Theta + y\sin\Theta \tag{7}$$

where r is the distance from the origin to the closest point on the straight line, and θ is the angle between the x axis and the line connecting the origin with that closest point.

It is therefore possible to associate with each line of the image a pair (r, θ). The plane (r, θ) is sometimes referred to as Hough space for the set of straight lines in two dimensions. This representation makes the Hough transform conceptually very close to the two-dimensional Radon transform [16].

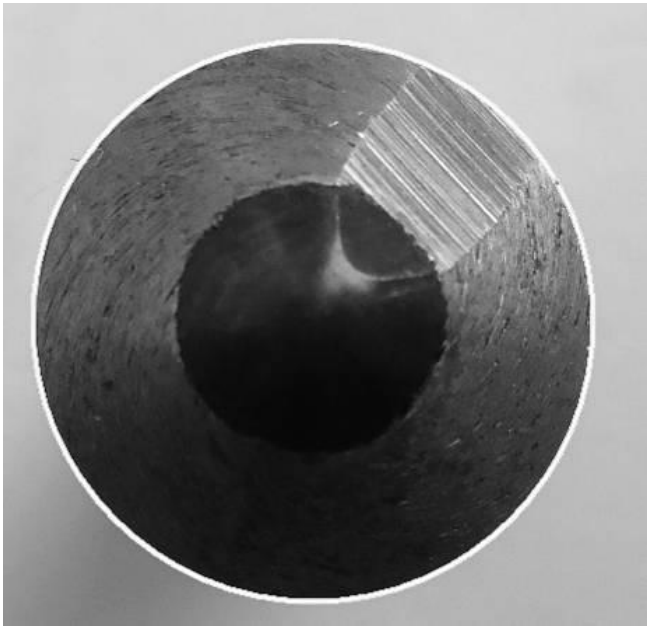

Figure 4 – Tool’s border detection using the Hough Transform

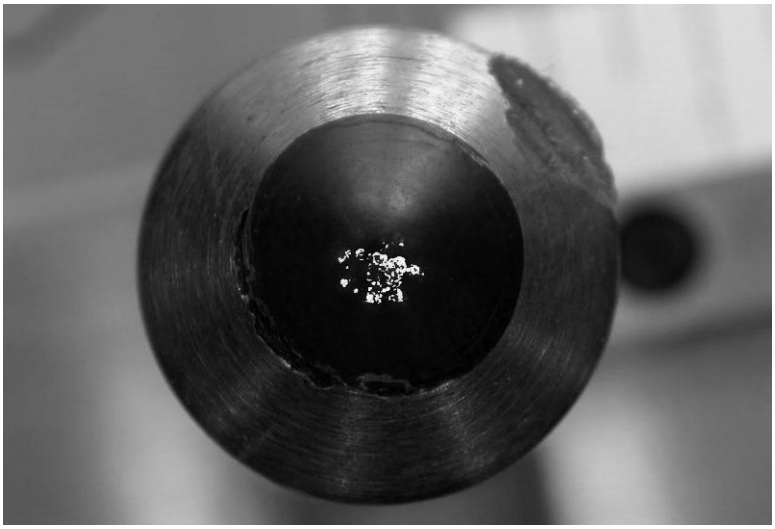

Figure 5 – Working surface area of wear defined automatically

The above steps are hidden from the user, the program displays only the end result image analysis (Fig. 5). The program window displays information about the percentage of the wear area to the entire working surface of the tool, the program adopted a decision on the possibility of further operation of the instrument based on the previously conducted life tests of different types of a burnishing tool [17].

3. Results and Discussion

Software has a high precision on the burnishers cylindrical surface defects. It is excludes influence of human factor on making decision of tool’s further exploitation. Adjustable threshold in finding the field of wear allows to optimize the cost of processing a square surface area details depending on customer requirements. Hardware requirements are not high (was used: processor Intel Core i7-2630QM CPU 2.00 GHz, RAM 4.00 Gb), However, the performance of the hardware determines the program execution speed (performance comparison was not conducted due to the variety of configurations), and depends on the customer's needs (based on output).

4. Conclusions

A range of methods of surface analysis is appeared due to the increasing growth of computing power, the average level of which is constantly growing. Currently represented algorithm is at the stage of registration of property rights, in consequence this article just the basic components of algorithm are presented in the form of flowcharts. It can be argued, that at the current stage the algorithm is “equipment reliable” if there is no negative factors polluting the surface of instrument or environment (MWF couples), that meets the conditions of work within the green technologies, and can be applied in green burnishing technology processing.

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