The Development of an Application for Microparticle Counting Using a Neural Network

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Abstract. Program application for the automatic intelligent registration of a microparticle moving is an important task for solving the problem of machine vision system development. The video file with particle movement is cut on frames. Every frame is passed to the preliminary analysis based on its noise to signal value, contrast measuring and statistical analysis. This technique allows us to accept the frame as valid and go to the microparticle counting process. It is developed the program product, which provides the selecting of the area with particles, modelling the background and count particles in the field. Three processes are occurred with particles in the experiment: guiding, fixing and flicking. The problem of the process type recognizing in which the microparticle is observed effects on the accuracy of their counting**.** The problem is suggested to solve based on neural network.

Keywords. Program Application, Machine Vision System, Microparticle Counting, Neural Network.

1 Introduction

The great scope of problems devoted to the image registration can be described by the help of automated measuring information optical system or the Machine Vision System (MVS) [1]. In our consideration MVS contains the optical source which is a laser or incoherent light or a combination of several sources; optical elements are lenses, filters and other devices for phase, amplitude and polarization modulation; a CCD or CMOS camera is received and converted optical radiation into electrical signals; the computer is for the data visualization; a software for data processing and analyzing; a protocol suite with algorithms what to do for software and hardware with a final decision of the system's working ability (Figure 1). The system can be called as an adaptive system with feedback due to which the improvement of the system by iteration method can be realized. The quality of the image is under influence of fluctuations, instabilities and aberrations of the system which total by the standard should not be higher than 10 %.

There are many practical tasks [2-6], varying from control automation of production to the construction of robotic cars, that are directly related to the task of registration of the object movement in the video file. Different strategies for frames of the video can be used to solve it. The software RADiCAL [7] provides 3D-modelling of the human movement by processing the video with the help of artificial intelligence and motion science.

Let's consider the registration of the movement objects in the micro world. Some distributions of light allow to control each atom individually or a group of atoms. Developing of data object design of the intensity pattern for controlling micro- and nanoparticles was the aim of some previous research [8,9]. Model of service providing on the use of optical laboratory in conditions of individual customer needs is represented in [10].

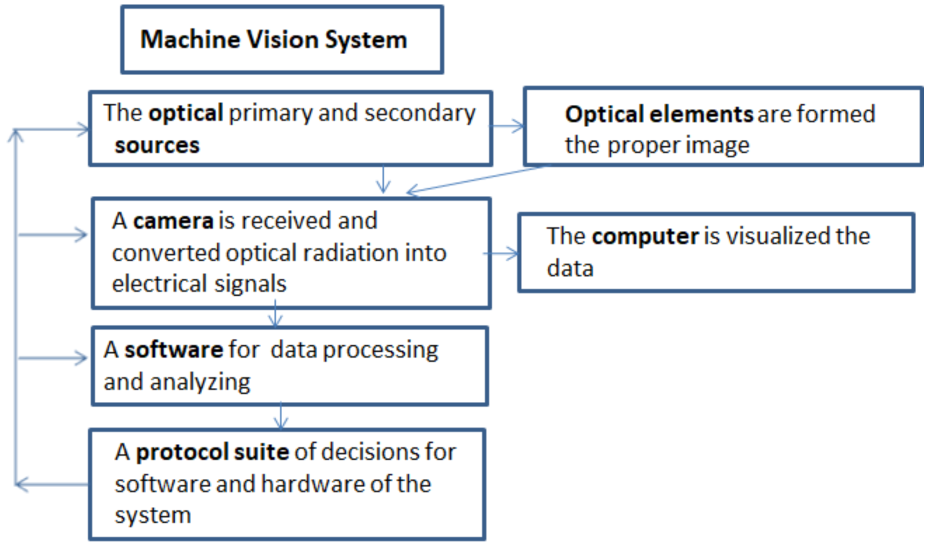
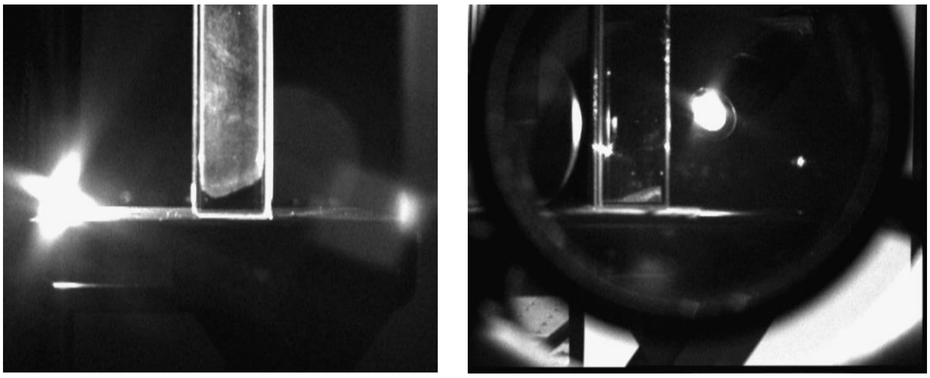


Fig. 1. Common view of the machine vision system for optical research realization

Here, we want to focus on the processing of the video file with the goal to count the number of moving micro objects. Several important stages are needed including statistical analysis of one frame, choosing the criteria of the optical image quality and making decision about finalizing step. The simple final decision is stop the record if the image does not satisfies to criteria. Another important problem is to provide high accuracy of the micro particle counting. Three processes are occurred with particles in the experiment: guiding, fixing and flicking. Incorrect recognition of the process leads to an incorrect counting of the number of particles. So, the task should be solved by the more efficient way in the process recognition that is intelligent systems are known.

2 The Image Quality and Processing.

The video file of the microparticle guiding is recorded by the camera. The one shot (Fig. 1) is required some image processing, which is shown in the information model with two parts. First one (Fig. 2a) contains preliminary and statistical analyses with the task to make conclusion about image quality and decision for using this one or taking another snapshot. Cutting of the image on Fig. 2b is realized with some requirements, which will be discussed later. Next step (Fig. 2b) for the image of particle guiding processing is segmentation of the picture and observation of the particles movement in 2D space.



a b

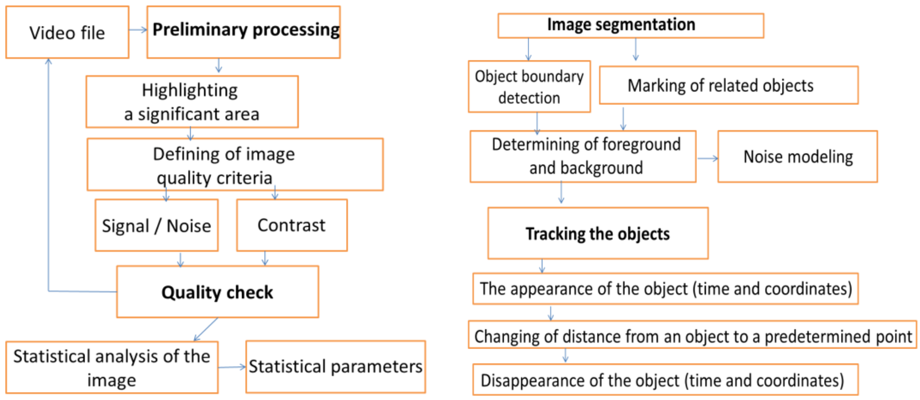
Fig. 2. a,b. One frame from the video file demonstrated a part from laser setup with chamber at different initial conditions ready for microparticles guiding recorded by CCD-camera

Let us consider the components of preliminary analysis parameters. The quality of the typical image as on Fig 2 a,b can be described by two the most common parameters: signal-to-noise ratio (SNR) and contrast ratio (CR). SNR is measured ratio of the level of a real signal to the level of background noise. For estimation of the image quality there are used Rose criterion [11] for SNR and Rayleigh rule [12] for resolution of two points by CR.

These criteria are suitable and available for our physical task and their attributes possess the features of relevance, objectivity, measurability and completeness according to the standards [13].

The first step of an optical image processing is obtaining of statistical parameters for experimental and theoretical data: the arithmetic mean $\bar{I}$, the mode I_M and the standard deviation σ. In our previous paper [13] we have shown detailed statistical analysis of the optical image.

The main stage includes segmentation of the picture and observation of the particles movement. The questions of noise modelling and background deviation are paid attention. Background modeling [14] is often used in various systems to model backgrounds and further detects moving objects in a scene, such as video surveillance, optical motion capture, and multimedia.



a b

Fig. 3. The information model of the image processing. First part (a) is devoted to the preliminary analysis. Second part (b) describes the analysis of the background deviation and revealing of the moving micro particles.

We have used the approach of background modeling for the case if the camera is stationary, that is, we have a background that changes little, and so we can build its model. We consider all points of the image that deviate significantly from the background model to be foreground objects. Thus, we can solve the problem of detection and maintenance of the object.

3 Image Analysis

We quantized the received data for intensity into the range from 0 to 255 with the step 1, which corresponds to the features of the CCD camera. More details about providing this operation for the optical image in [13]. It is worth mentioning, that due to quantization obtained results have an error of ± 0.5.

IT is considered the situation with two different initial conditions for recording the microparticle movement that are shown on figures 2a and 2b correspondingly. Preliminary stage of the image processing reveals next important information: SNR are equal to 35,79 and 14,64, which means good quality according to the Rose criterion. The contrast is defined as the ratio of the brightest color to that of the darkest color. The contrast value for both experimental optical images is about 0,937, which means high enough quality of the images.

The initial conditions for recording of the microparticles movement can be studied by statistical analysis. The picture on the Fig. 2a in comparison with the Fig. 2b is more lightning in the cell and has more pixels with high intensity. So, the value of median is much bigger for the more lighted case that can be seen clearly from the data on the Table 1. The variation curves for images on Fig. 2a and Fig. 2b are essentially different from each other (Fig. 4). They allow us easily recognize the case of recording video due to curves location in different parts of the graph. So, we can provide the statistical analysis of both cases simultaneously.

Table 1. Statistical parameters for experimental images represented in Fig. 2a and Fig. 2b.

Statistical Parameters	**Initial frame on Fig. 2a**	**Initial frame on Fig. 2b**
Mean	121,38	36,14
Standard Deviation	17,81	12,00
Median	118	34

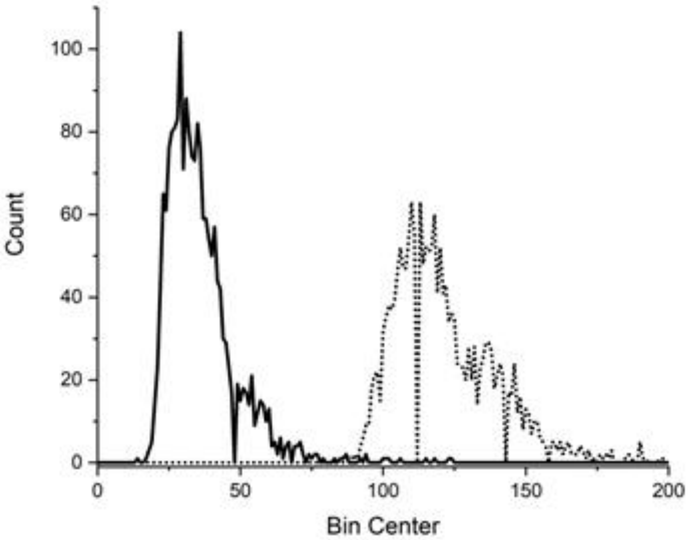


Fig. 4. Variation curves of the experimental images to Fig. 2a and Fig. 2b are marked by dotted and solid black curves correspondingly

4 Program Application for Registration of a Particle Movement

Video is a sequence of frames; each of them is displayed at a high enough frequency for the human eye to see this sequence continuously. Thus, the contents of the sequentially two frames are closely related. In this case, adjacent frames can be used to track the position and condition of an object. In addition, it is obvious that all image processing methods can be applied to individual frames. There are three basic steps to video analytics:

1. identifying of the required objects;
2. tracking the change in position and status of these objects between frames;
3. object behavior analysis.

It should be noted that object detection and tracking are two very closely related processes, as tracking often begins with the detection of the required objects, and the detection of the object again in the next sequence of frames is necessary to verify the accuracy of tracking .

Under the information process we consider the processes of obtaining, storing, transforming, presenting and transmitting information on the registration of a number of particles of a certain size. The registration of particles occurs in three ways: particle flicking when it falls down and illuminated by laser radiation, guiding the particles along the laser beam and fixing the particles on the walls of the cell. A light pulse is detected by a photodetector in our case - a camera that records the passage of a sample through a beam. Therefore, there is a need to create a software for processing the data obtained from the photodetector. So, the aim of the paper is to develop program application for the automatic registration of a microparticle moving under the influence of laser radiation.

The developed program application is represented main stage of the frame processing and counting of the moving microparticles. The AForge.NET library was selected for the representation of the task, which has ready-made implementations of motion detection algorithms. The convenient interface was developed for particle movement registration (fig. 5). It includes such icons, as

File list

Download file

Particle size

Algorithm

- Comparison with the previous frame
- Background modeling
- Comparison with the first frame

Noise reduction

Clear capture area

The total number of particles

5 Program Operation

To get started, we need to select the desired video file using the "Download File" button. After selecting the video file, the first video frame will be displayed in the interface of the program (Fig. 5). Than we have selected the areas of the interest by rectangles. It is the option to choose the particle size in the range of 1-10 pixels. In our research we have chosen 2-3 pixels.

In order to filter out unnecessary sections of the frame, we can select separate areas of motion search with the mouse; they will be displayed in the frame only when the video processing process does not work. So we can clear the selection list and set new ones.

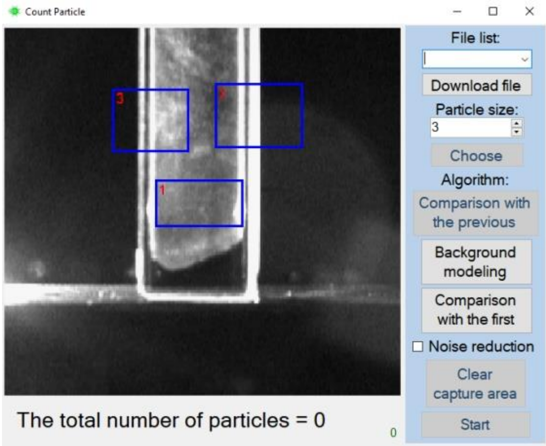


Fig. 5. – Interface view of the developed application program after uploading the video file.

There are three search algorithms, which can be chosen for video processing:

1. Comparison with the previous one.
2. Background modeling.
3. Comparison with the first frame.

The algorithm for comparison with the previous frame is selected by default. To start motion registration and particle counting, it is needed to press "Start". Also the program provides for choosing ability to reduce the noise in video.

The area where the movement was observed is highlighted by red rectangles as shown on Figure 6. The program calculates the number of particles, which is equal to 30 for considered case.

After finishing the video processing or pressing the "Stop" button, we can resume searching or download another video. The particle counter then will be reset.

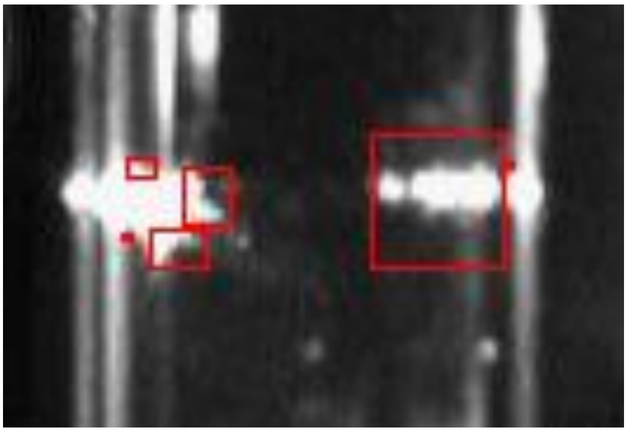


Fig. 6. Video frame with areas where the microparticles moving is registered.

Let's consider the situation, which can be observed for the case if the quality of the image is low and criteria are not satisfied. According to our choice there are two characteristics are defined for every image. In the case of signal-to-noise ratio or contrast ratio has a value out of criterion level for satisfier image quality the program is stopped the recording of the video file and visualize the proper text on the computer screen. The standard if-then construction provides this result. The question is the loosed data important for the research. The development of the alternative decision of the system can be realized by employment of the intelligent systems. The structure of an intelligent system includes a knowledge base, which can be renewed online reflects preferences for a decision making about continue or stop video record at the moment.

Very important problem in microparticles counting is right counting of the objects. Three processes are occurred with particles in the experiment: guiding, fixing and flicking. The particle is guided by laser light is change the position in the horizontal direction, as shown in Figure 7a. The object can be fixed to cell’s wall (Figure 7b) and be visible for long time of registration. And the last variant of the microparticle behavior to reveal itself at the moment of crossing laser beam that can be observed just in one frame (Figure 7c). The guided particle can be counted twice as it was two particles of flicking process. The fixed particle can be counted several times if the illumination from laser light is interrupted. Due to that the accuracy of the objects counting are become smaller. So, we have a problem of automatically recognition of the process in what particle is participated.

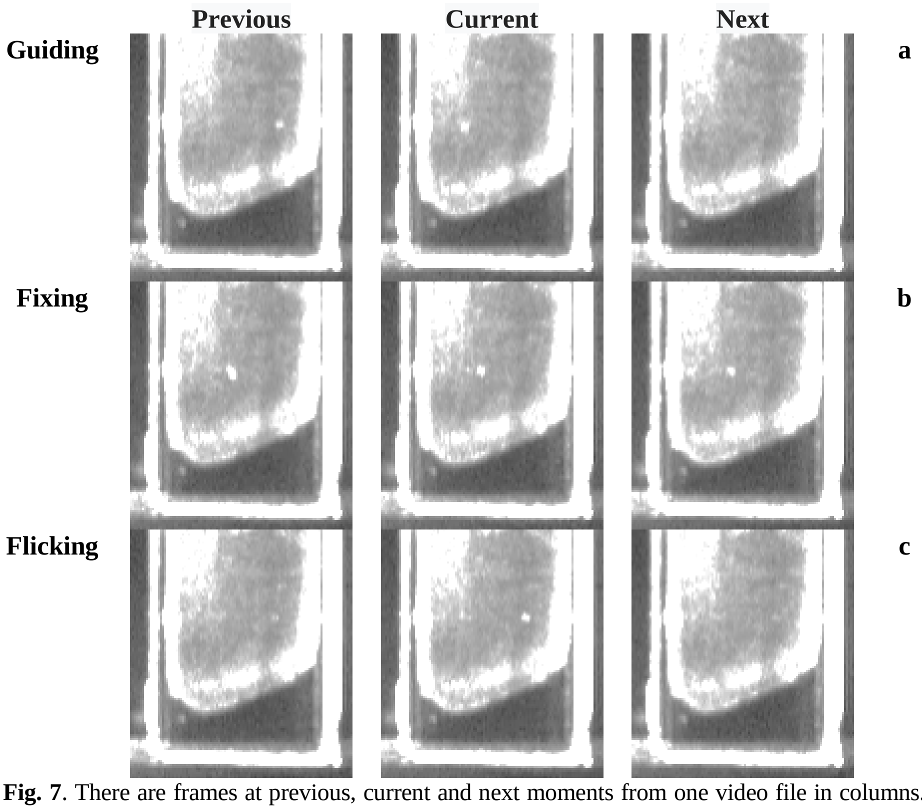


Fig. 7. There are frames at previous, current and next moments from one video file in columns. Three processes with particles in the experiment are guiding (a), fixing (b) and flicking (c) that is shown in rows.

The task is close to the problem of automated human behavior recognition system, which was resolved by the method of convolutional neural network [15]. The logistic regression of the process can be described by the vectors X and Y. The video is divided into frames with number A. Every frame consists from N=n×n pixels. We stack in matrix is called previous N·(A-2) pixels from the first frame till (A-2) frame. The matrix's called current is made from the stack of N·(A-2) pixels from the second frame till (A-1) frames and the matrix possess data about the next frame stack of N·(A-2) pixels from the third frame till A frames. So, an input feature vector X has a length is 3N (A-2) pixels. For the binary classification the value of vector Y is 1 or 0 is searched separately for the every microparticle process guiding, fixing and flicking. For the case we have m training examples with the matrices shapes X·shape = (3N (A-2), m) and Y·shape = (1, m) are represented for every process. Input $x^{(i)}$ is the value of i-th set of three images, $y^{(i)}$ is the output function, the $\hat{y}^{(i)}$ is the estimation of $y^{(i)}$ value. The function $\hat{y}^{(i)}$ of the logistic regression model measures how well the result on the entire training set with parameters *w* and *b* can be written in the view

$$\hat{y}^{(i)} = f\left(\sum_i w^T x^{(i)} + b\right).$$

6 Conclusions

In this paper the work of the Machine Vision System is presented. We focus on the developing program application for the automatic registration of a microparticle moving. For convenience, image processing is based on the information model, which consists of two stages. The preliminary one is used for the basic image characteristics as signal-to-noise ratio, contrast ratio, resolution of the system and statistical analysis for making a decision is the image enough good for next consideration. The main stage includes the segmentation of the picture, background modelling, nose reduction and observation of the particles movement.

Very important problem in microparticles counting is right counting of the objects. Three processes are occurred with particles in the experiment: guiding, fixing and flicking. Incorrect recognition of the process leads to an incorrect counting of the number of particles - they can be skipped or counted twice. So, we stated the problem of automatically recognition of the process in which micro particle is involved by the methods of artificial intelligence. The task of the process recognition is formalized and the method of deep learning system is discussed.

In the future, it is planned to continue the developing of neural network for making decision provides recognition of the process and right counting of the micro particles in the machine vision system.

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