CONTROL OF LABORATORY PROCESSES USING MODERN METHODS OF IMAGE PROCESSING

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Abstract: The thesis deals with the image processing and detection of specific objects in the image. The main objective of this work is to implement a algoritm for the control of pipetting processes based on images from the camera. In this thesis is used for image processing an open source computer vision library OpenCV and for pipette detection is used convolutional neural network. The proposed solution is still in development process. The following article describes the issue and the results of the thesis solution.

Keywords: image processing, OpenCV, cnn, dnn, convolutional neural network, application, object detection, pipette, microplate, wells, laboratory processes

1 INTRODUCTION

The *human visual system* is one of the most important sense organs through which one can perceive, explore and respond to their surroundings. Therefore, there is still an increasing effort to implement this ability also in the field of computer technology. Ability to perceive and subsequently interact with the surroundings is a very important in computer technology.

With the development of modern technology, computer vision is becoming increasingly available in areas everyday life. This is where computer vision widely used in a variety of smart devices such as phones, cameras, intelligent vehicles and various other devices [4].

2 IMAGE PROCESSING AND OBJECT DETECTION

At present, the field of image signal processing is one of the most important fields in science and technology. Image information is one of the basic communication and information channels. In general, the entire image processing process can be divided into several basic parts:

- capture and image digitization
- image preprocessing,
- image segmentation,
- description of objects,
- classification.

2.1 IMAGE PREPROCESSING

An important part of image processing is image preprocessing. It is important to prepare the captured image in an appropriate way before it will be analyzed. Specific methods and procedures are used for image preprocessing, which may include for example transformations or various image filters. The most commonly used methods for image preprocessing are:

- color transformation,
- brightness transformation,
- geometric transformation,
- noise filtering and image errors [3].

Another important part of image processing is image segmentation. The preprocessed image can be further segmented based on the parameters. The most commonly used methods for image segmentation are:

- thresholding,
- edge detection,
- background subtraction [6].

The background image subtraction method is one of the most commonly used methods where is need to segment the objects from the background of image. The principle of this image segmentation technique is to analyze each pixel in the image and evaluate its belonging to the object of interest or background in the image. The background subtraction process runs between frames. In this thesis, for background subtraction is used the *Mixture of Gaussians* algorithm called MOG.

2.2 Object detection

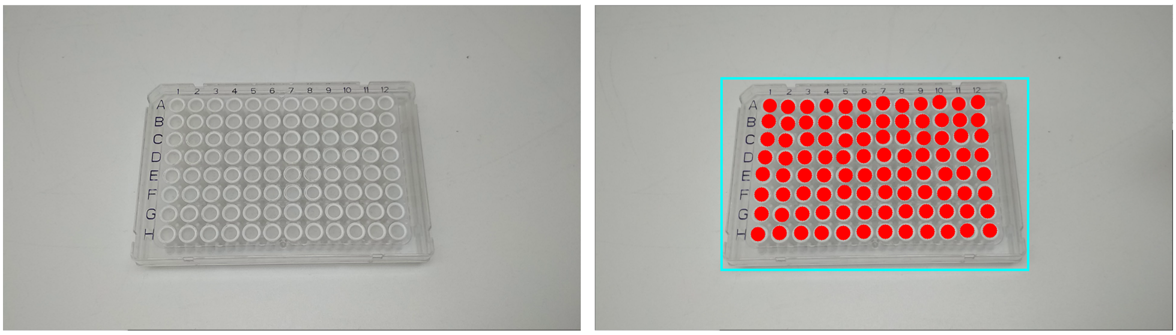
The main and important part of this work are methods for analysis of prepared processed image. This processed image is then gradually analyzed appropriately using various techniques. In this thesis, the main part of image analysis are methods for microplate detection, detection of wells in this microplate, detection of moving pipette in the image and subsequently peak of this pipette.

2.2.1 Microplate detection in the image

The detection of the microplate in the image is very important. By obtaining the position of the microplate in the image, it is possible to define a region of interest. This has the advantage that subsequent image analysis can only runs in this area of interest, resulting in savings in computing power. The position of the microplate in the image is obtained using an algorithm which analyzes the contours of objects in the image.

2.2.2 Wells detection in the microplate

By obtaining the position of the microplate in the image, it is possible for subsequent detection of the wells to runs only in this region. By defining an area of interest in the case of wells detection, it has the additional advantage that the possibility of erroneous detection of the well outside the microplate is automatically minimized. The algorithm uses the *Hough transform* to detect wells in the microplate. The following figures 1 shows the microplate detection process and the subsequent detection of the wells in the microplate.



(a) Image from camera

(b) Wells detection in a microplate

Figure 1: Illustration of microplates and wells in the image

2.2.3 Pipette detection in the image

Pipette detection in the image is one of the most robust algorithms used in this work. There are two different implementations that are already very different. The first method is a classical sagmentation method, where the pipette segmentation algorithm is based on background subtraction and subsequent analysis of contours in the image. The algorithm itself consists of several smaller parts that are logically connected to each other. Firstly, the image is sub-sampled, because of the lower computational complexity, but maintaining the accuracy of the resulting algorithm. Then the histogram equalization method is applied to this image for improve the resulting contrast. At this point, image is converted to gray scale and then is applied to the image the background subtraction method. Subsequently, various methods such as thresholding are applied to finely remove shadow in scene of the image, morphological operations and a few basics image filters. Finally, the contours in the image are analyzed to determine the shape of the pipette and the pipette peak.

The second detection method uses CNN *convolutional neural networks* to detect the pipette in the image. Specifically, it is a YOLO[1] convolutional neural network that is implemented using the Darknet[2] open source framework. YOLO (You Only Look Once) is real-time object detection system, which is accurate and at the same time one of the fastest real-time systems. This type of network consists of several smaller parts which are gradually connected. The following figure 2 shows the internal structure of the convolutional neural network. The input image is attached to the input of convolution layers system, which is first important part of this neural network. The convolution lay-

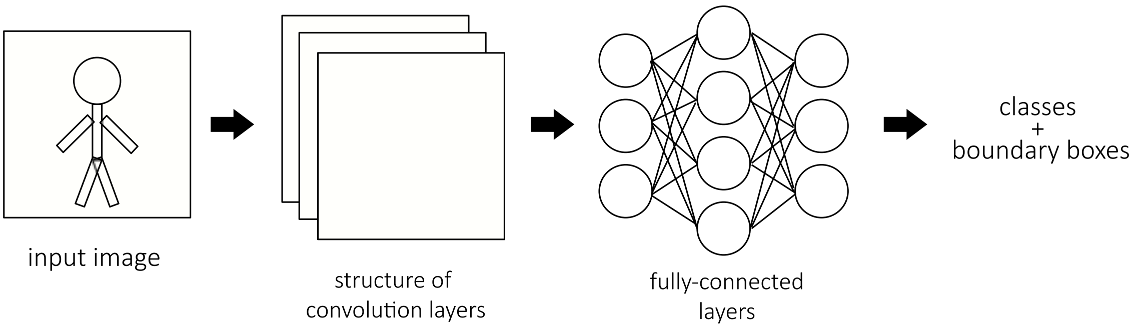


Figure 2: Illustration of convolutional neural network topology

[1]https://pjreddie.com/darknet/yolo/
[2]https://pjreddie.com/darknet/

ers consist of several tens of layers, which have different sizes. On every convolutional layer there is a operation called *convolution*. Convolution is mathematical operation, which puts the image and the convolution core into relation. The result of this operation could be, for example an subsampled image. Convolution operation can be defined as following formula

$$y[m,n] = x[m,n] * h[m,n], \tag{1}$$

where y is output image, x is input image and h convolution core [6]. Next very important part of this neural network is fully-connected layers. The result of convolutional layers process feeds into a fully-connected neural network structure, that drives the final classification decision [2]. In the case of pipette detection using neural networks is a very important part, which is learning of neural network. The result of neural network classification depends very on the quality learning of the network. There are many factors that affect the resulting network model like quality of dataset, number of learning iterations or time to stop learning [1]. The following graph 3 shows the process of neural network learning. The red curve is a relation between *mAP* (mean Average Precision) and *max batches* which means number of iteration in learning process. The blue curve indicates errors which means accuracy of the learned model. As can be seen in the graph, learning process achieved good results already at 1000 iterations [5].

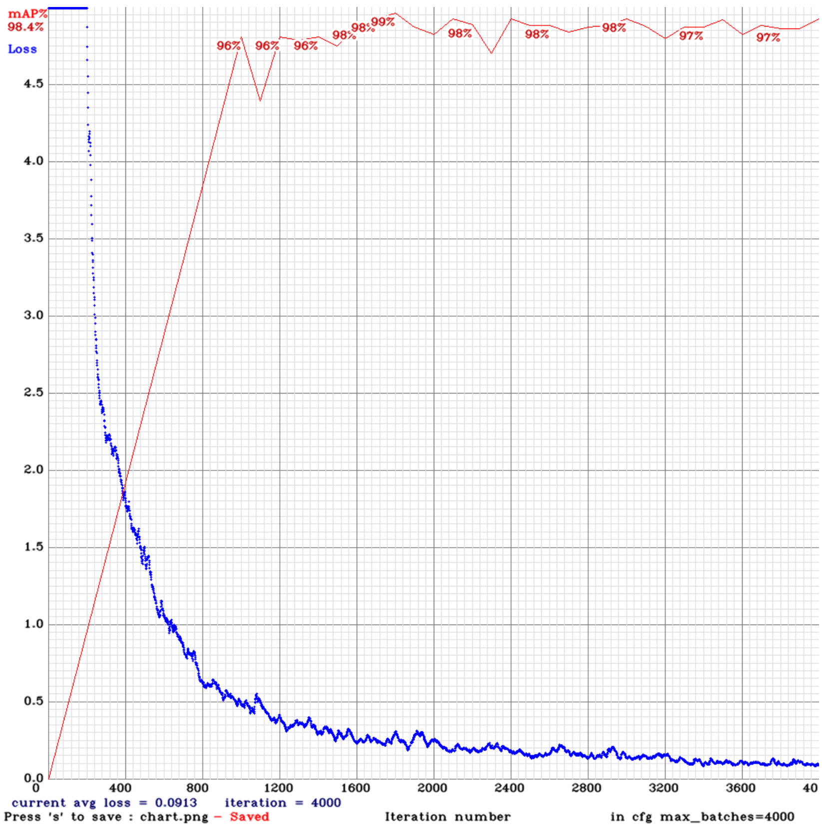
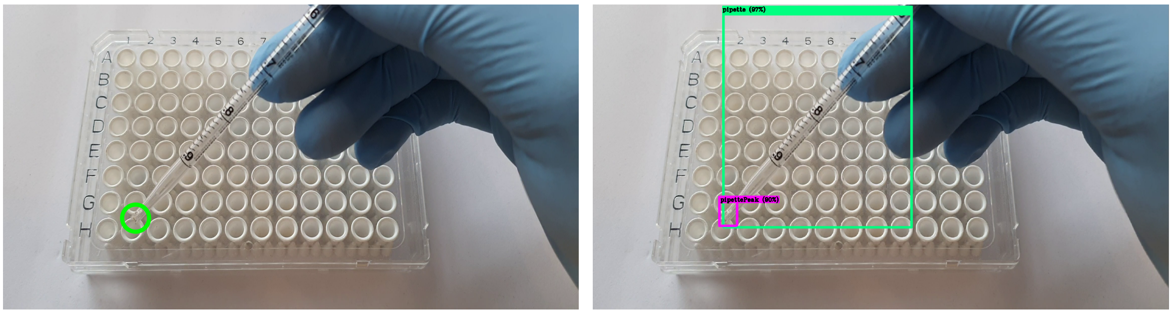


Figure 3: Process of neural network learning

3 CONCLUSION

This paper deals with image processing and object detection applied to control of laboratory process. It describes image processing and the most important part of all resulting process for pipette detection - classic segmentation method and detection method which uses convolutional neural network. The paper is focused on the implementation of the proposed system mainly description of pipette detection in image. The result of this thesis is the uses and subsequent comparison of two methods of pipette detection in the image. The following figures 4 shows the pipette detection process. Left figure



(a) Classic method of pipette detection

(b) Method of pipette detection using neural network

Figure 4: Comparison of pipette detection methods in the image

(a) shows classic method of pipette detection where is correctly marked pipette peak. Right figure (b) shows method of pipette detection using convolutional neural network. In this illustration there are correctly marked pipette peak and whole pippete. Classic method for detection is fast but not quite accurate. There are many factors which affect for resulting detection like shadows or other interference in image. Detection which uses convolutional neural network is slower but very accurate. A comparisons of CPU (Intel i7-8550U) and GPU (GTX 1080 Ti) for computational complexity of both detection algorithms is very different. Classic segmentation method with CPU has average 16 fps and with GPU acceleration has average 50 fps. Detection method uses convolutional neural network has with CPU average 0.6 and with GPU acceleration has average 38 fps. The future goal is implement detection method uses convolutional neural network on android platform and control laboratory process with this very accurate detector.

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