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The use of computer vision for automated control of gypsum feed and conveyor belt movement in the production of a gypsum plasterboard

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Abstract. The paper presents a description of the gypsum dough spill analysis method on the basis of computer vision for automated control of gypsum feed and conveyor belt speed. The task of computer vision is to control the form of gypsum dough spill on the basis of optical analysis of video data in real time.

1. Introduction

Automation of production is expedient in the part of routine operations execution, dangerous actions. One of the prospecting directions is the use of the computer vision, which allows to improve the productivity and reliability of the technological process.

Examples of the computer vision use for production processes automation are usually belong to individual objects. The detection of objects in space, their classification, determination of their position and orientation, search and analysis of details defects [1], determination of their conformity to the production parameters [2], less – working with liquid substances are considered.

This paper presents the automation method concerning one of the gypsum plasterboard production stages – automated control of gypsum feed and conveyor belt speed on the basis of optical analysis of the gypsum liquid spill form on a cardboard sheet. The effect is carried out by the analog signal to the hardware controller of the conveyor belt movement.

In Fig. 1 we can see an example of a conveyor belt for a small production with an illustration of supernumerary cases requiring operator intervention (a-d) and standard operating mode (e).

The proposed solution allows to reduce the number of spoilage received at the enterprise, practically without using manual control.
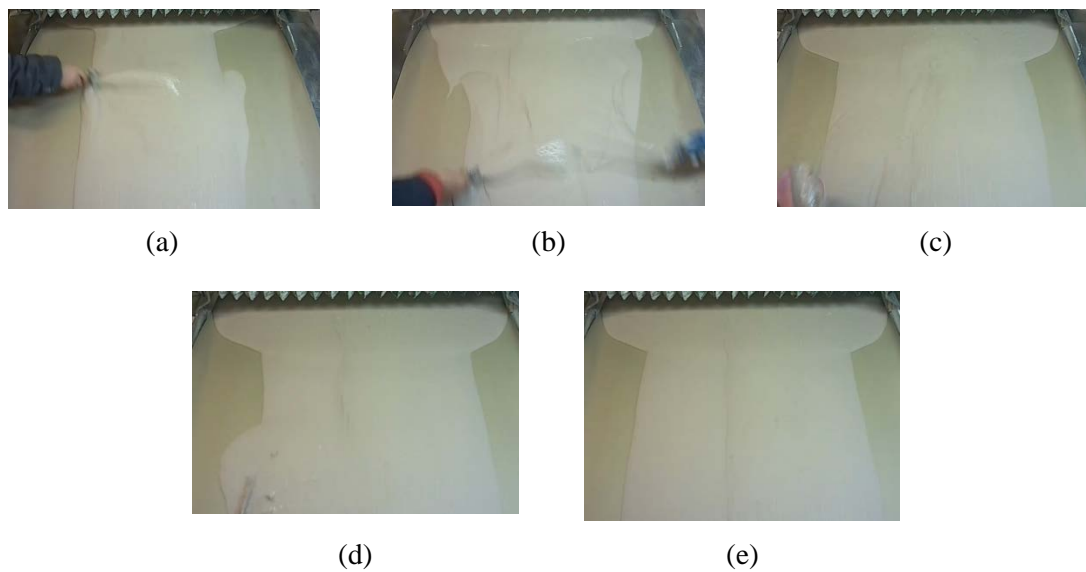
<center>(a)   (b)   (c)</center>

<center>(d)   (e)</center>

Figure 1. (a) – (d) Supernumerary cases of the form of spilled liquid, (e) Standard situation.

2. Purposes and goals of the work

The main purpose of this system is the intelligent processing of continuously incoming flow of gypsum dough to the conveyor belt, determination of its quantity, area and spill form by analyzing the RGB-video stream using classical methods of computer vision. The final output of the system work should be the analog signal pair formation in the voltage range $[-10, 10]$ Volts based on the visual estimate of the quantity of gypsum dough on the conveyor belt at time t.

Specificity of production equipment determines the need to use two output signals, describing the amount of gypsum dough on the left and right side of the visible image by the number of nozzles that serve plaster dough. These signals can be interpreted as control signals according to the specifications of the company's equipment. Thus, the increase in voltage is a signal of a dough excess and it can be classified as an order to reduce its incoming through the appropriate nozzle or increase the speed of the conveyor belt.

3. Speed control method of conveyor belt on the basis of optical analysis

The general system operation scheme (Fig. 2) includes the following stages.

1)   Arbitrary resolution camera frame is inputted. A special mask is loaded to define the contour image correctly. The area of interest is highlighted – the subRoiA rectangle with 4 specified points, which covers the visible gypsum spill area at the place of its spreading.

1.2)   The frame is trimmed to the selected rectangle.

1.3)   The image is blurred to suppress noise.

2)   Image contours are searched, the contour gradient representation of the subRoiA area is formed. The specificity of the input data is such that the color of gypsum almost completely coincides with the color of the cardboard. At certain illumination it can lead to extremely low contrast of borders, at the same time the gypsym dough itself is heterogeneous and often contains the expressed texture. Because of these peculiarities the algorithm of calculating the contour image for the color image is developed, which works effectively for the low-contrast images.

Let I – the input 2D image of dimension $w \times h$, $p_{x,y} \in I$ – three component pixel of RGB-image I with coordinates x, y; $2\,r$ – the side of the square sliding window $W_{2r \times 2r} = (w_{i,j})$, $W \subset I$, $w_{i,j}$ – the pixel of the sliding window. The calculation result is the output array of the gradient values $G = (l_{x,y})$, $l_{x,y}$ – the gradient value at the point $p_{x,y}$.

The value $l_{x,y}$ is calculated based on $w_{i,j}, x - r \leq i < x + r, y - r \leq j < y + r$ by Eq. 1:

$$l_{x,y} = \max\left(\left|p_{x,y}(r) - w_{i,j}(r)\right|, \left|p_{x,y}(g) - w_{i,j}(g)\right|, \left|p_{x,y}(b) - w_{i,j}(b)\right|\right). \tag{1}$$

The pixel intensity of the output image equals the maximum deviation found in the W area of all 3 color channels.

3)   The resulting contour image is copied with masking to eliminate unnecessary objects.

4)   The image is searched for contrasting contours using the developed version of adaptive (integral) binarization.

Let I – the input gradient single-channel image of dimension $w \times h$, B – the output binary image of dimension $w \times h$.

The image is divided into segments, using the lattice by dimension $cols/rows$, thus a lot of S segments s are got. Each segment s of the lattice consists of pixels $p_{i,j}^s$, which number is $\frac{w}{cols} \cdot \frac{h}{rows}$. The segment has 2 parameters – $\min V$ and $\max V$, corresponding to the minimum and maximum pixel intensity values calculated by the Eq.2:

$$min V_s = min\left(p_{i,j}^s\right), \, max V_s = max\left(p_{i,j}^s\right), p_{i,j}^s \in s. \tag{2}$$

Let's enter the parameters $\min Diff$ – minimally allowable scatter between the intensity of pixels in the segment s, $wThreshold$ – is a coefficient of binarization threshold. Then $\forall s \in S, \forall p_{i,j}^s \in s$ output binary pixel $b_{i,j}^s$ in segment s is calculated by Eq. 3:

$$b_{i,j}^s = \begin{cases} 1, if \ |\max V - \min V| > \min Diff \ \text{and} \ p_{i,j}^s > \max V \cdot wThreshold, \\ 0, \text{otherwise}. \end{cases} \tag{3}$$

5)   The resulting image is dilitizated to fill possible contour breaks. As a result, the image contour is formed.

6)   Free space areas are searched and marked, binary card reception of plaster test pouring is carried out.

6.1)   Two extreme areas that are not part of a gypsum dough are filled by the floodFill function of OpenCV.

6.2)   Filled pixels are chosen.

6.3)   Inversion, flooded stream of gypsum is got.

6.4)   Post-processing phase – pixel erosion, blurring, normal binarization. As a result, we get more accurate representation of the gypsum dough flow. The result is saved.

6.5)   Concerning the area of the liquid, change tracking of the amount of gypsum pixels towards total pixels number in the subRoiA area is continuing.

7)   Gypsum dough filling areas calculation is made. They break the area of interest to the lattice of rectangular areas. In this task there are 2 sets of investigated zones – the areas on the left and the areas on the right, according to the number of nozzles bringing gypsum to the belt. Each rectangular area is checked for the level of "occupancy" by the gypsum. In fact, it is the pixel number of a binary gypsum map inside a rectangular area. If the given constant is exceeded, we reckon that the zone is filled.

8)   Calculation of $outSignalLeft$ and $outSignalRight$ output signals is made.

Let $numZones$ – the number of areas for the left and right of the image, $nLFilledZones$ – the number of filled areas on the left, $nRFilledZones$ – the number of filled areas on the right.

Then the output signals are calculated by Eq. 4:

$$outSignalLeft = \frac{20 \cdot nLFilledZones}{numZones} - 10, \, outSignalRight = \frac{20 \cdot nRFilledZones}{numZones} - 10. \tag{4}$$

The error signal is formed based on an assessment by Eq. 5:

$$|outSignalLeft - outSignalRight| > errorThreshold. \tag{5}$$

If there is a significant discrepancy between the amount of gypsum on the left and on the right, nozzles do not work coherently.

The received values through a specialized driver are transferred to the DAC board, installed in the motherboard of the computer. The signal is then sent as analog to the specialized production equipment controllers.

If the speed of the belt is controlled, two signals are converted inside the controller into 1 belt speed controlling signal.
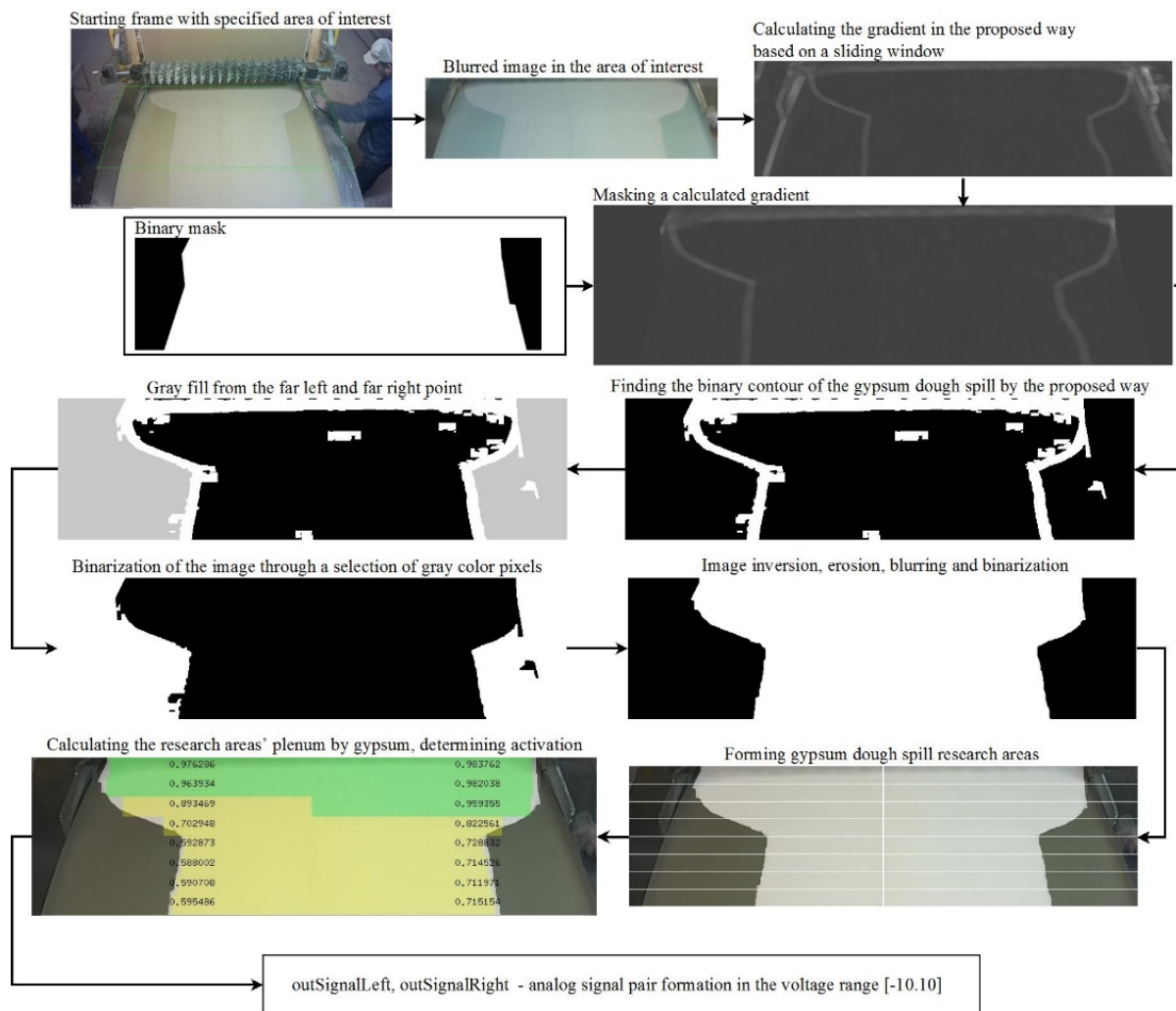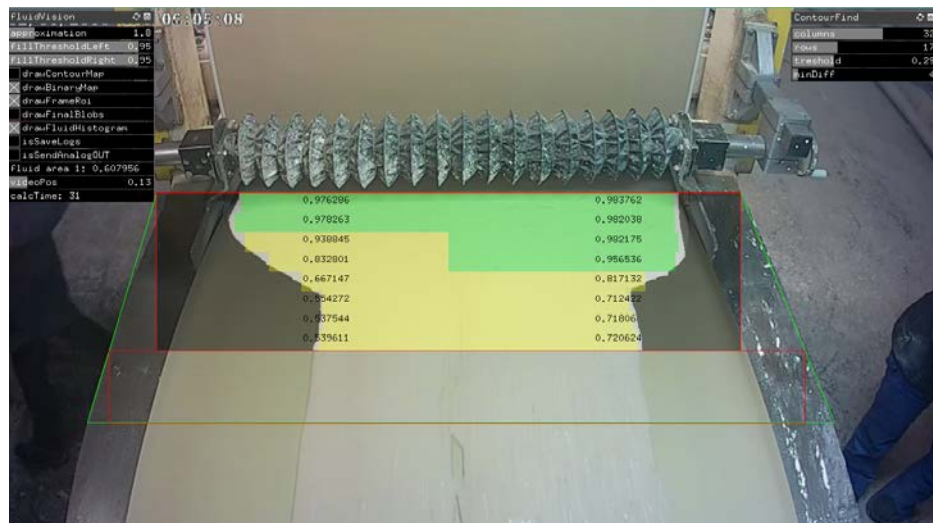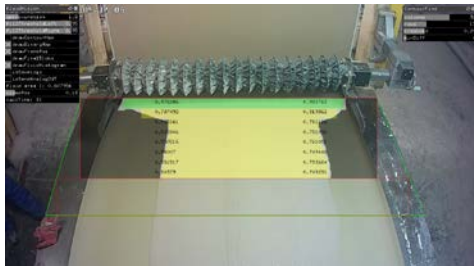
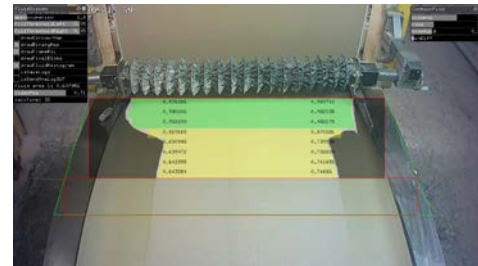

Figure 2. System operation scheme.

Fig. 3 shows the work of the proposed system, analyzing the gypsum dough flow changing of the in real time at the gypsum plasterboard production.

(a)

(b)   (c)

Figure 3. Control system operation of conveyor belt movement
(a) Imbalance of the left and the right parts, (b) Lack of gypsum (c) Optimal quantity of gypsum.

Approbation of the system was carried out using the equipment allowing to control the belt speed. The video demonstration of the system in test mode is presented in [3]. However, it is more effective to control the production of two nozzles that implements the gypsum supply. Due to the hardware limitations of the production equipment, this method of impact could not be verified.

4. Conclusions on the study and prospects for further development

Presented method allows to determine the form of plaster test surely. The peculiarity of the considered production is a light cardboard background on the conveyor belt and a bit different color of the poured plaster liquid. The fall of sunlight on gypsum and cardboard can lead to the complete disappearance of the visual boundary between the gypsum and the cardboard. Therefore, it is important to adjust properly the lighting to produce a more contrasting image. For this purpose it is necessary to create a zone with artificial illumination and to limit penetration of natural external light - the simplest way is to establish the closed box above a camera with illumination. Another solution to this problem is to use rangefinder sensors, a laser scanner that allows to obtain the actual geometry of the plaster test. This solves the problem of lighting, but increases the cost of the entire solution, the complexity of implementation and computing algorithm loading. Therefore, the most balanced option is the proposed system with a conventional camera, covered with an external box from the effect of natural light.

This automation system is inexpensive and suitable even for small businesses. For the hardware implementation any modern PC with a processor level core i3 is acceptable, ordinary Web camera can be used a s a sensor.

In our opinion, the proposed solution is quite multi-purpose and can be applied to a wide range of tasks, where the form analysis of liquid spill on the plane is required. If a video stream with a high frame rate processing in needed, the proposed solution is easily parallelized on the GPU/FPGA [4].

To increase the efficacy of automation, the proposed method can be combined with neural networks type LSTM or HTM [5, 6] in order to predict a few steps forward how the liquid spill form and/or its defined zone changes. If we talk more specifically about the network HTM, it is enough to encode the degree of filling of investigated zones in the form of sparse binary vector for this purpose as input data.

References
[1]   Popko E A, Vorob'ev A P and Vainshtein I A 2015 Experience of machine vision application in optical NDT systems *Welding and diagnostics: collected reports of the international forum* (Ekaterinburg: UrFU) pp 401-406
[2]   Steward B L, Tian L F and Tang L 2002 Distance-based control system for machine vision-based selective spraying *Transactions of the ASAE* vol. 45(5) pp 1255–1262
[3]   Video footage of the conveyor belt speed control system work in gypsum cardboard production. URL: https://www.youtube.com/watch?v=Xf1E6fV9Lzs
[4]   Treece B 2017 Embedded machine vision systems can give more, than simple visualization, *Control Engineering* 3 (69)
[5]   Hawkins J and Ahmad S 2016 Why neurons have thousands of synapses, a theory of sequence memory in neocortex *Frontiers in Neural Circuits* № 10
[6]   Jeff H, Subutai A and Yuwei C 2017 A theory of how columns in the neocortex enable learning the structure of the world *Frontiers in Neural Circuits* № 11