

**AUTOMATION AND COMPUTER-INTEGRATED TECHNOLOGIES**

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BASED ON MIRAE MX-200**<sup>1,2</sup>Aviation Computer-Integrated Complexes Department, Faculty of Air Navigation Electronics and Telecommunications, National Aviation University, Kyiv, UkraineE-mails: <sup>1</sup>svm@nau.edu.ua ORCID 0000-0002-3297-9060, <sup>2</sup>bogdanplodisty@gmail.com

**Abstract**—It is considered the main disadvantages of printed circuit boards manufacture based on the Mirae Mx-200 system. In order to reduce the level of manufacturing defects and increase productivity, it is proposed to include an intelligent unit based on the YOLO neural network in the system, which is implemented by an additional Raspberry controller included in the system. The YOLO neural network is used to process images obtained from an additionally installed video camera, which monitors the production process. In this work, based on the use of the solution to the classification problem, the problem of decision support is formulated and solved. As a result, the operations (actions) that need to be taken are determined: automatic centering, reset, cancel, etc. Using emulation with additional microcontroller connections, the problem of limited installer resources and the implementation of more complex algorithms in the installer's work is solved.

**Index Terms**—Manufacture of printed circuit boards; Mirae Mx-200 system; neural network YOLO; machine learning; artificial intelligence; emulation.

**I. INTRODUCTION**

The functions of the machine for the installation of radioelements, which is also called installation or assembly machine, can be described, as follows: the selection of the desired component, its correct orientation – centering, and then installation on the printed circuit board. All these steps for the automatic installation of surface-mounted products (SMP) must be implemented with a high degree of accuracy in order to minimize the rejection of the finished product. In addition, the element must be placed on a point of solder paste, glue, or a combination of the two, and a predetermined pressure must be applied that will not cause material to flow or damage the component body. In addition, an automatic radio installer must complete these tasks in the shortest possible time to maximize production. Finally, the equipment for automatic cell placement must be versatile enough to accommodate circuit elements in different enclosures with different pin configurations. The move to lead-free technology has had little impact on the design and function of automatic assembly machines. Indirectly, however, the need for different finishes for elements, as well as printed circuit board fiducial marks that have different reflective properties, can affect the function of machine vision systems used to accurately position both the PCB itself and the tools that are installed on it radio components.

**II. MIRAE-MX200 SYSTEM**

Mirae is one of the world's leading high-tech companies in the field of mechatronics and robotics. Mirae pioneered linear drive technology in its products and was the first to develop automatic conveyor width changing machines.

Surface mount technology used in the case of taking the element from the feeder belt by a special head under the action of pressure and machine drives, pointing the element at the chamber, screening it, selecting it and placing it correctly over the board on a unique contact track for the size and volume of the element. The assembly itself involves a number of engineering solutions, a conveyerized mounter line, worker-engineers and a host of manufacturing processes to improve production, increase efficiency levels and reduce scrap[8].

There are three types of mass installation: for small, medium and large production. This indicates the volume, number of lines, simplicity and quality of the machines. Different versions of installers and lines designed for a certain type and production speed. This paper was written with medium volume production in mind. For surface mount assembly the board layout created with an unconventional design of printed circuit boards. Unlike the name of the method, the circuit base is called SMT. The technology itself simplifies assembly and increases,

simplifying the speed of assembly as opposed to through-hole.

Mid-level SMT Pick and Place system designed for customers who have a wide part mix with medium to higher production volumes.

The Mx200 series of pick and place machines utilize next generation linear motor technology providing speed and placement accuracy of  $25\mu$  ( $3\sigma$ ) these flexible SMT assemblers are capable of placing 01005's (0402 metric) through 3.5" X 1.18" (90mm X 30mm) large SMT devices using advanced optics and inspection systems.

The Mx200 Placement Systems are available in four basic SMT assembly configurations offering large-board capability, increased feeder capacity and two different pick/place head configurations for optimal part placement flexibility. The Mx200P is the fifth machine in the 200 series and designed for the unique challenges faced when processing large substrates used in the LED lighting industry, the Mx200P can process panels up to 1200mm in length. All versions of the Mx200 series machines are built on a solid robust frame, employ one precision controlled overhead gantry, intuitive software, and offer placement rates from 15,000 through 21,000 chips per hour (IC9850).

The Mirae system has its own function block with actuators and logic, which is interfaced with the console when the installer is started. With the black and red levers, within five minutes the installer is completely suitable for starting or tweaking work program. In case of an emergency stop, it is restarted with one instruction each time. First the main unit switch is switched, later the system unit with the operating system is switched.

### III. TROUBLE AND SYSTEM ADVANTAGES MIRAE MX-200

Advantages include: no drilling process for component pins, double-sided printing of the board (usually labelled "TOP" and "BOT" sides), significant board and component reduction during application, fairly high mounting density, better improvement compared to previous soldering processes. In addition, SMD elements cost considerably less and are easier to handle in terms of size and weight. For series, large-scale production, this has enormous advantages [17].

In this work, a mass of components soldered, starting with resistors, capacitors, through to electrolytes, optocouplers, diode bridges, conventional pushbuttons, tampers, voltage converters, switches and eventually microprocessors, SIM modules and link-modules. As a result, all elements on the sensor, including liquid hybrid boards and sensors.

Each element has its own type of enclosure, unique rating, percentage of action, voltages, application and action. The most important thing in SMT is to select, select, place, adjust the take-up, draw and adjust the element as compared to the electronic circuit base. On the reel – the bobbin on which the element strip is wound – you can see the manufacturer's sticker, with special barcodes, delivery and manufacturing date, the color of the element (e.g., a LED), its serial number, properties, ratings and most importantly the main production code from the circuit base. All data is verified and supplied to the same technological standard with quality control, which has been described in the special technical document [11].

When looking at the rating, we have the unit and degree of a particular element, e.g., 10 khom, 15 pf, 1500 hf, 2.7 Nh. The degree is defined by a table: pica, nano, mile (micro), kilo, mega or the normal rating without degree. The rating itself often consists of ohms, farads, genre, volts and percent tolerance ranges.

In the circuit electronic base of the Mirae editor software, we can set the required parameters or correct them. This applies to both the feet and the enclosure. Width, length, thickness, measurement of certain areas, and a glow-in-the-machine fixation. You need to set the RGB level correctly with the highest contrast, it is important to understand what the element is made from, how it shines out, if the head of the machine is undamaged, and if there are any noticeable scuffs on it. The installer does most of the work, apart from sealing the components in the furnace, simply by checking himself with the coordinates, and then aiming at the fiducials - reference points on the board, often located on two different sides of the board diagonally. One of them has a coordinate with the start position  $T(0;0)$  and coordinates with the end position  $T1(129.831; -83.111)$ .

In addition to the main fiducials, there are fiducials for each block of multiplication boards, to edit the individual part of the boards, to correct place the elements, to disable a particular block of boards in case of a defect of several parts if production needs to finish the required number of boards, but not enough multiplication boards.

The disadvantages of the old process are the poor accuracy of the installer, the component base, the manual mode of operation and all the basic settings. The phenomenon of poor paste application greatly affects the results of the project. Therefore, it is better to use new generation automatic printers with 3D inspection and 2D editing of the stencil plane with apertures and board surface with and without paste. A basic systematic rule of thumb is a 20% offset over the

paste as tolerance for product pass-through. The old algorithms did not need additional power and new controllers.

For today production, process of PCB has some disadvantages. There are the next types of faults in production:

- not a soldered pad;
- lack of an element;
- critical link displacement;
- too much paste on the contact pad;
- a delaminated or faulty board, a deformed board;
- rotation of the circuit element;
- deformation of contact legs or housings, individual surfaces on the SMD;
- the element fits over the sealed paste;
- short circuit;
- raising the section by one contact foot.

#### IV. PROBLEM STATEMENT

*General problem statement of pattern recognition for the detection of non-formalized elements.* Problem statement of classification problem. Let  $X$  be the set of objects descriptions, and  $Y$  be the set of classes' numbers (or names). There is an unknown objective dependency – displaying  $y^*$ :  $X \rightarrow Y$ , the values of which known only on objects of the finite training sample [15]:

$$X^m = \{(x_1, y_1), \dots, (x_m, y_m)\}, \quad (1)$$

where  $X^m$  is, the training sample elements set with dimension  $m$ .

It is necessary to build an algorithm that can determine the membership arbitrary object  $x \in X$  to the class  $y \in Y$ .

#### V. PROBLEM SOLUTION

*Software tools used for printed circuit board production.* With the physical examination of the Mirae system, the basics on the SMD department, the SMD line, workflow, workforce enumeration and responsibilities, we can move on to look at the program and configuration with add-ons in the Mx-200p version.

After a successful download, the operator logs in to a number of programs required for operation. The machine creates a special IP address for itself, which it uses to download itself and link the workflow of most installations.

The first program is the "Mirae Link" garter, after which the "Mirae Vision" camera is immediately switched on, you must select your installer, the Mx-200, from the drop-down list. The camera's graphic interface with a coordinate axis and special

divisions is activated, the whole process is visible on the monitor and the image is given to the operator in black and white. After starting the camera, "Feeder information" is started, this is a prerequisite for viewing the status of connected feeders and indicating problems [10].

Remarkably, the main machine console is switched on all the time in a separate dialogue window, which shows all passages, software add-ons, functions and commands, and it is through this dialogue window that almost all settings and reprogramming of the installer can be changed.

When the camera and feeder status indicator is switched on, the machine begins to self-center, self-position and initial physical set-up with the console, all described in the console. For better understanding, it finds all the actuators, axes, rotates and moves all possible parts, turns the sensors on and off, the same happens with the camera and feeders. At the start of the process, a dialog box pops up with the date of the latest firmware, the desired server address, possible recent problems and general company and machine version information.

When the machine's tower and crane have travelled from zero to any possible point on the machine's internal coordinate axis and the machine's table travel and clamping, conveyor movement, camera inspection and stopper operation have been checked, the operator can be confident that the machine can be started in an automated process or projects can be set up [12].

For basic setup, the "Program Editor" software is used to set up any workspace prior to automatic operation, specify all functions and required parameters, use the joystick to find tape centers and create or optimize new projects together with the elimination of faults and problems in the work programs.

Also, for a complete job it is necessary to count the cycles, program steps, each iteration and the total number of blocks and multiplies on the board, for this purpose the "Program Manager" software was created. This utility allows you to playback several actions in real time and see the statistics and the amount of work done, as well as how much time is left until the end of the project.

The most important advantage is the linking of the "Program Editor" and "Program Manager". The programs are linked to each other and take data and add-ons and with each new iteration they understand via the backend server which action to take [16].

One iteration is when the board appears on the main sensor, at the point where the elements are stuffed, the operation time, the steps start counting down from the first movement of the tower with the

installer crane. The end of iteration ends when the board leaves the installer and the sensor does not notice the board.

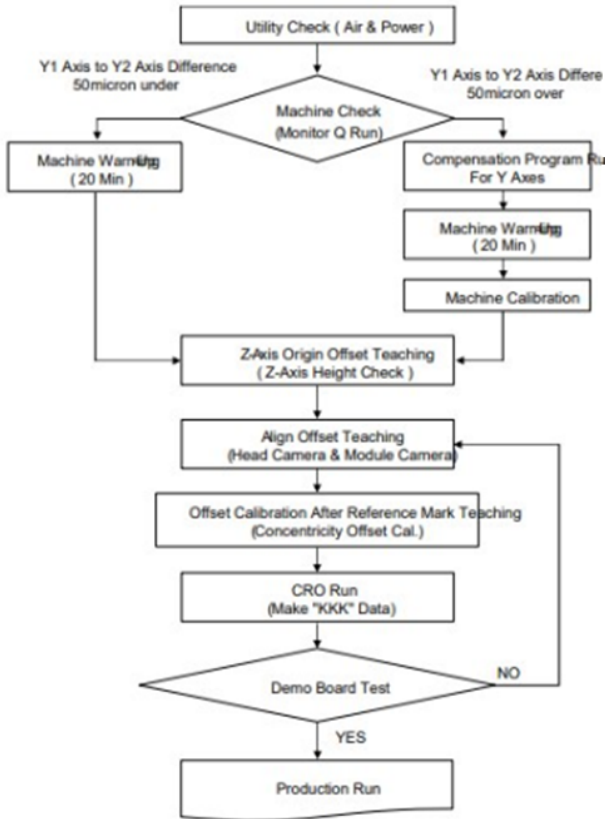


Fig. 1. Is a complete iteration of the installer's start-up by action

You can start, stop, resume the process or run a single cycle (a couple of prescribed steps) via the manager, the "Run" function. The current number of multiples is also entered when starting and tying up the project. The worker takes the project information from the display on the mounter, runs the worker's sub loaded file in a specific directory. He then divides the plan and puts the current number. The optimization in work, mass projects disabled because the program has already been created and this takes up extra time [7].

The main startup settings have a produced quantity in addition to the planned quantity, if the process started from a certain point or after any correction. In the advanced settings you can specify the direction of movement or the modes of movement of the plate, normally the conveyor mode is used, the center stop or return-to-input positions are not selectable.

The choice of starting point is usually made by the machine itself and automatically finds the circuit board, but there is the possibility of selecting a location with detection by the operator, this is done in case of a defective batch of chips or complex design of the plate, non-standard shape.

The advanced settings usually specify the time before starting in certain logical actions, movements of machine parts, decision making, usually a number constant 65308, here it is the manufacturer's choice.

In the file line it is possible to select the board passage modes, in normal run everything goes as standard, in idle the board just passes through without enrolling in the base, the conveyor only monitors the movement by sensors and pass ability. In pass-through mode, the board becomes in the conveyor and is counted, enlightened, but with limited capability without staging elements, it simply passes on.

In addition, in the PCB loading and unloading tab, a zero, clean board can be manually inserted into the conveyor and back to check the conveyor run and table clamping, pointing of reference points and viewing of contact pads with other elements on the board. The main sensors show three states of the board, on the workpiece before padding, during padding with a percentage fill slider and during exit from the installer. This is all displayed on a special area with a graphical interface [18].

There are three types of statistics with corresponding sections: component, nozzle and overall machine performance. A detailed analysis of this operation will be describe from the data taken from these sections.

*Emulation of the Mirae production system.* This project based on the emulation of the Mirae system with a Raspberry Pi 4 computer and an Arduino Uno R3 controller. For the software part, a standard set of utilities from the Mirae installer is used, which in turn is loaded into the Raspberry Pi with the Raspbian system [9].

On Figure 2 represented a Raspberry Pi 4 connection module.

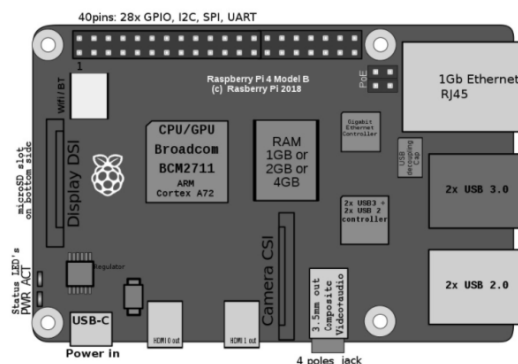


Fig. 2. Shows the Raspberry Pi with its enclosure

A future project file is created or loaded into the system, which will later have the effect of automatically centering using a program written for Arduino with emulation of a mechanical joystick and camera type OV7670.

Detailed specifications of the Raspberry Pi:

- raspberry Pi standard 40-pin GPIO socket (fully backwards compatible with previous boards);
- micro-HDMI ports (supports up to 4kp60);
- 2-way MIPI DSI display port;
- 2-way MIPI CSI camera port;
- 4-pole stereo audio and composite video port;
- H.265 (4kp60 decoding), H264 (1080p60 decoding, 1080p30 encoding);
- OpenGL ES 3.0 graphics;
- Micro-SD card slot for operating system boot and data storage;
- 5 volts DC via USB-C connector (min 3A\*);
- 5 volts DC via GPIO connector (min 3A\*);
- power over Ethernet (PoE) enabled (separate PoE hat required);
- operating temperature: 0–50 degrees C ambient temperature.

The Arduino wiring diagram is shown in Fig. 3.

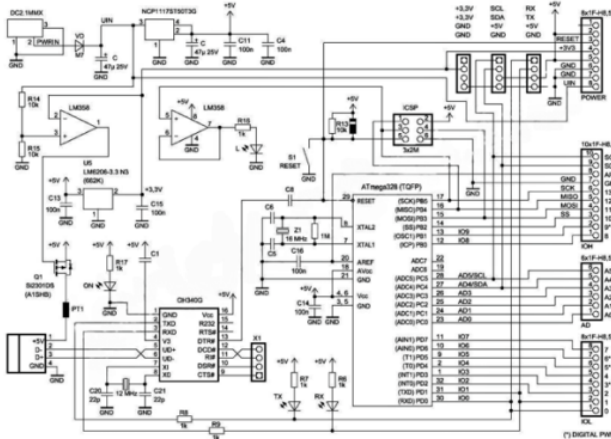


Fig. 3. Arduino scheme for connection

## VI. STRUCTURE OF A NEW TECHNOLOGICAL PROCESS

The new process system includes a number of software utilities and a set of special devices to accurately emulate the production machine and use alignment algorithms and vector triangles for the installer.

The operation of all devices includes the impact on efficiency and defects in smart sensor production, as well as on the entire department. From the moment the board enters the installer to the end of the PCB soldering in the furnace. By improving older algorithms, the engineer gets a better product and more marketable components. For new software, the specialist needs to select more powerful systems with the optimum amount of computing resources. The processing of the automatic process involves better complex solutions, which was spelled out in the code of a particular iteration. This given in the following figure: the left part takes into account the technical

means of the project, and the right part the algorithms and programs used.

For automatic alignment, a Raspberry Pi 4 handheld computer must be connected. The emulation system is operated in a step-by-step manner, starting with connecting the device to the camera module and accessing the desired program (Fig. 4).

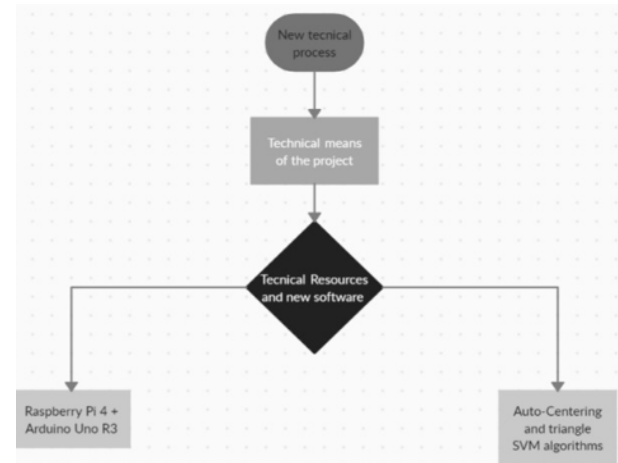


Fig. 4. The view of the system is described by the following graph

Exposure generation in the installer is implemented by dividing the frame into some number of blocks and calculating brightness (BV) in each of them. It is proposed to find maximum (BV<sub>max</sub>) and minimum (BV<sub>min</sub>) brightness in each block and calculate average brightness in lower (BV<sub>lower</sub>), upper (BV<sub>upper</sub>) and all blocks (BV<sub>mean</sub>). The scene can then be described by the following equation:

$$BV = a \cdot BV_{\text{max}} + b \cdot BV_{\text{min}} + c \cdot BV_{\text{mean}} + d \cdot BV_{\text{upper}} + e \cdot BV_{\text{lower}}.$$

After setting the  $a$ ,  $b$ ,  $c$ ,  $d$ ,  $e$  ratios, the shutter speed and aperture can be determined. The  $a$ ,  $b$ ,  $c$ ,  $d$ ,  $e$  factors must be set by the camera firmware [6].

An auto-exposure algorithm using the false position method is proposed and implemented. The algorithm is intended for industry. The main purpose is to correctly expose skin samples to identify their defects. The shutter speed is taken into account. The proposed algorithm captures skin samples with correct exposure according to lighting conditions.

In this paper, an automatic exposure algorithm with detection of illumination conditions is presented. The proposed approach detects high-contrast lighting conditions and improves the dynamic range of images. The algorithm calculates the difference between the mean value and the median value of the luminance level of the captured images and evaluates the lighting conditions.

Illumination contrast is defined as the difference between the average brightness level of the whole image and the median brightness level of all pixels in the image. If the difference between the average and median is insignificant, lighting conditions are considered normal. But if this difference exceeds some expected threshold, the lighting conditions are considered to be contrasting.

A similar approach that uses the difference between lighting conditions to detect high contrast. It is proposed to divide the frame (called the main subject area) into small areas. It is then proposed to calculate the luminance level as a combination of the average luminance of the area with the surrounding area and the corresponding weight. The authors have conducted experiments that show that the method successfully detects high-contrast scenes with a small level of exposure error [1].

Resolution is the level of detail in a digital image, measured in number of pixels (e.g., 1280×800) or dots per inch (e.g., 300 dpi). Aperture  $f$  is the unit that determines the diameter of the 'hole' in the lens. The smaller the  $f$ -value, the larger the diameter, and also the more light that reaches the camera's sensor. The "distance" between adjacent  $f$  values (e.g., 4 and 5.6) is called the  $f$ -stop, and is equivalent to the exposure value (EV). In the literature, the exposure value is also often referred to as the luminance level [3].

*Exposition.* Is the amount of light incident on the light-sensitive material that is required for a correct exposure.

The exposure equation is defined as:

$$N^2t = L \cdot S \cdot K,$$

where  $N$  is the aperture value ( $f$ -number);  $t$  is the shutter speed (or exposure time);  $S$  stands for ISO;  $K$  is the calibration constant of the light meter, according to,  $K = 12.5$ ;  $L$  is the luminance given in [kd per m in square].

*Coding a OpenCV structure.* In developing the program code, it is sufficient to leave the internal Mirae machine code and plug in one of the Python libraries, the most popular being OpenCV. It contains up to 2500 different algorithms for finding an object through an image. In addition, Deep Learning, with a neural network, is used for error detection [2].

Connecting the library applies a number of functions to find the outline of the object, the first task is to connect the image import, which is described in the section above. The next step is to recognize the machine element for each frame [4].

The initial connection is made by creating a new file, mirayobject.py via imutils and OpenCV. In addition, a number of required libraries are loaded:

“From imutils. video import VideoStream:

```
from imutils.video import FPS
import numpy as np, cv2, argparse, imutils, time”
Based on this, further arguments need to be introduced and analyses for the teams:
```

```
ap = argparse.ArgumentParser ()
The file path is set to "-prototxt": points Mirae to the file.
```

```
ap.add_argument ("-p", "--prototxt",
required=True,
help="path to Mirae 'deploy' prototxt file")
```

```
Working with a pre-prepared model, prescribe "-model"
```

```
ap.add_argument ("-m", "--model",
required=True,
help="path to Mirae pre-trained model")
```

```
ap.add_argument ("-c", "--confidence",
type=float, default=0.2,
help="minimum probability to filter weak detections")
```

```
args = vars(ap.parse_args())
```

By setting a minimum validity threshold in one of the lines, the machine will sort out rejected items depending on the project, the operator will have to select this threshold in the future for correct installation [13].

Add items to be detected by adding a tag in CLASSES:

```
CLASSES= ["Gerkon", "Resistor04_02",
"Condensator04_02", "LED06_03",
"Condensator06_03"]
```

Then random color recognition with a defined range and set is introduced:

```
COLORS = np.random.uniform(0, 255,
size=(len(CLASSES), 3))
```

The number of frames can be reduced or controlled at a certain level to optimize the project in terms of time:

```
while True:
frame = vs.read()
frame = imutils.resize(frame, width=400)
```

These commands select a single frame and set a new size.

The blob command is used to stream data into the neural network structure for element detection. In addition, you can also use it to find the altitudes and latitudes of the elements.

```
(h, w) = frame.shape[:2]
blob = cv2.dnn.blobFromImage(cv2.resize(frame,
(300, 300)),
0.007843, (300, 300), 127.5)
net.setInput(blob)
detections = net.forward ()
```

The main mark of the algorithmizing of this work is the liquidity and error in finding the circuit

elements and their further parsing, pointing by the Mirae program. The neural network needs to decide whether to circle the element and pass it on to the automatic alignment [14].

This results in elements that are in the skip area up to a certain percentage and unliquidated results for further axis alignment.

```
for i in np.arange(0, detections.shape):
    confidence = detections [0, 0, i, 2]
    if confidence > args["confidence"]:
        idx = int (detections [0, 0, i, 1])
        box = detections [0, 0, i, 3:7] * np.array([w, h, w,
h])
        (startX, startY, endX, endY) = box.astype("int")
        label = "{}: {:.2f} %".format (CLASSES [idx],
(confidence * 100))
        cv2.rectangle(frame, (startX, startY), (endX,
endY),
COLORS [idx], 2)
        y = startY - 15 if startY - 15 > 15 else startY + 15
        cv2.putText(frame, label, (startX, y),
cv2.FONT_HERSHEY_SIMPLEX, 0.5,
COLORS [idx], 2)
```

This part of the code is explained in detail below:

After pointing, the liquid components will be displayed in a frame, the illiquid ones will find the center points on their own.

The definition of liquidity is output by the detections command.

By removing the special index label, it is possible to calculate the position of the frame along the object at the liquidity threshold above [5].

The corresponding x and y coordinates, in the code, are used to display text and a rectangle.

Creating a label with a name in CLASS and a defined validity with a mediating rectangle drawing along the element, using the previously prescribed tools with colors and coordinates.

The output of each name must be within a screen with a frame, in the case of an error it will be highlighted at the bottom of the top line of the frame, and the definition can be indicated by colored text.

The Mirae installer can now take the element view after this algorithm and not use the manual joystick mode.

## VII. CONCLUSIONS

In this work with application of modern technical approaches to data processing the GPU-basic method of functioning of a neural network was chosen. To compare the methods of image recognition, a graphically based method of calculation and verification of the original data of the convolutional neural network was chosen. Compared with the results in this work, an analysis of modern literature

and scientific papers on image recognition was performed and the basic structure of the neural network was obtained.

Depending on the results of the research, it follows that reducing the core filters will reduce the processing power, as well as increase the number of processed frames per second. Research has revealed that all relevant programming libraries for the formation of a neural network cannot allow it to be easily used in more complex systems, where the neural network is generally just a structural part.

A new complex deep structural neural image identification network is proposed and formed using the recently proposed structure of a convolutional neural network together with the use of residual blocks and a pyramidal architecture. As a result, compared to the tests, we get a more accurate image recognition system.

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### **В. М. Синєглазов. Б. О. Плодистий. Інтелектуальна система виробництва друкованих плат на базі Mirae Mx-200**

У роботі розглянуто основні недоліки виробництва друкованих плат на базі системи Mirae Mx-200. З метою зниження рівня виробничого браку і підвищення продуктивності запропоновано включення в систему інтелектуального блоку на базі нейронної мережі YOLO, яка реалізується додатково включеним в систему контролером Raspberry. Нейронна мережа YOLO використовується для обробки зображень, одержуваних з додатково встановленої відеокамери, яка здійснює спостереження за процесом виробництва. У роботі на підставі використання розв'язку задачі класифікації поставлено і розв'язано задачу підтримки прийняття рішень. У результаті визначається вигляд операції (дії), яку необхідно в даний момент реалізувати: автоматичне центрування, скидання, скасування, тощо. За допомогою емуляції з додатковими підключеннями мікроконтролера вирішено проблему обмежених ресурсів пристосування для установки компонентів друкованої плати і реалізації більш складних алгоритмів в роботі такого пристосування.

**Ключові слова:** виробництво друкованих плат; система Mirae Mx-200; нейронна мережа YOLO; машинне навчання; штучний інтелект; емуляція.

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**В. М. Синеглазов, Б. А. Плодистый. Интеллектуальная система производства печатных плат на базе Mirae Mx-200**

В работе рассмотрены основные недостатки производства печатных плат на основе системы Mirae Mx-200. С целью снижения уровня производственного брака и повышения производительности предложено включение в систему интеллектуального блока на базе нейронной сети YOLO, которая реализуется дополнительно включенным в систему контроллером Raspberry. Нейронная сеть YOLO используется для обработки изображений, получаемых с дополнительно установленной видеокамеры, которая осуществляет наблюдение за процессом производства. В работе на основании использования решения задачи классификации поставлена и решена задача поддержки принятия решений. В результате определяется вид операции (действия), которую необходимо в данный момент реализовать: автоматическое центрирование, сброс, отмена и т. д. С помощью эмуляции с дополнительными подключениями микроконтроллера решена проблема ограниченных ресурсов приспособления для установки компонентов печатной платы и реализации более сложных алгоритмов в работе такого приспособления.

**Ключевые слова:** производство печатных плат; система Mirae Mx-200; нейронная сеть YOLO; машинное обучение; искусственный интеллект; эмуляция.

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