МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

Кафедра авіаційних комп’ютерно-інтегрованих комплексів

ДОПУСТИТИ ДО ЗАХИСТУ

Завідувач кафедри

Синєглазов В.М.

“ ____ ” __________2021.

ДИПЛОМНА РОБОТА

(ПОЯСНЮВАЛЬНА ЗАПИСКА)

ВИПУСНИКА ОСВІТНЬО-КВАЛІФІКАЦІЙНОГО РІВНЯ

“БАКАЛАВР”

Тема: Інтелектуальна система виробництва друкованих плат

Виконав: **Плодистий Б.О.**

Керівник:**к.т.н.** **Синєглазов В. М.**

Нормоконтролер:к.т.н. **Тупіцин М. Ф.**

Київ – 2021

EDUCATION AND SCIENCE MINISTRY OF UKRAINE

NATIONAL AVIATION UNIVERSITY

COMPUTER-INTEGRATED COMPLEXES DEPARTMENT

ADMIT TO DEFENSE
Head of department
V. M. Sineglazov

"____" ______________ 2021.

BACHELOR WORK

(EXPLANATORY NOTES)

Topic: Intellectual System for printed circuit board production

Done by:	**Plodistiy B. O.**
Supervised by:	**Sineglasov V. M.**
Normcontrolled by:	**Tupitsyn M. F.**

Kyiv 2021

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

Факультет аеронавігації, електроніки та телекомунікацій

Кафедра авіаційних комп'ютерно-інтегрованих комплексів

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ЗАТВЕРДЖУЮ

Завідувач кафедри

Синєглазов В.М.

“ ____ ” __________2021 р.

ЗАВДАННЯ

на виконання дипломної роботи студента

Плодистого Богдана Олександровича

1. **Тема проекту (роботи):** “Інтелектуальна система виробництва друкованих плат”
2. **Термін виконання проекту (роботи):** з 10.05.2021 р. до 11.06.2021 р.
3. **Вихідні данні до проекту (роботи):** метод виділення контуру цілі на відео, метод розпізнавання розмірів, номіналів, метод алгоритмізації нейронної структури процесу, введення контролерів для додаткової потужності та емуляції програмних ресурсів з додаванням автоматичного прийняття рішень.
4. **Зміст пояснювальної записки (перелік питань, що підлягають розробці):** 1. Актуальність системи відеоспостереження за контуром цілі; 2. Аналіз існуючих підходів для прикладної автоматизації виробництва; 3. Теоретичні основи системи алгоритмізації нейронних мереж; 4. Вирішення задачі виявлення елементу, контактних зон друкованої плати. 5. Покращення швидкості та зменшення умов браку згідно нових алгоритмів.
5. **Перелік обов'язкового графічного матеріалу:** 1. Структурна схема експериментальної установки; 2. Блок-схема алгоритму роботи програми; 3. Графічне зображення знайдених характерних точок; 4. Графічне зображення результатів роботи алгоритму ; 5. Папка із зображеннями

прийняття рішень. 6. Початкове зображення із виділеною рамкою та символами.

6. **Календарний план-графік**

№ пор.	Завдання	Термін виконання	Відмітка про виконання
1.	Отримання завдання	10.05.2021 – 11.05.2021	
2.	Формування мети та основних завдань дослідження	12.05.2021 – 13.05.2021	
3.	Аналіз існуючих методів	14.05.2021 – 19.05.2021	
4.	Теоретичний розгляд рішення задачі	20.05.2021 – 25.05.2021	
5.	Розробка структури системи відеоспостереження за контуром цілі	25.05.2021 – 30.05.2021	
6.	Розробка програмного та апаратного забезпечення системи відеоспостереження за контуром цілі	30.05.2021 – 05.06.2021	
7.	Оформлення пояснювальної записки	05.06.2021 – 07.06.2021	
8.	Підготовка презентації та роздаткового матеріалу	08.06.2021 – 11.06.2021	

7. **Дата видачі завдання:** “10” травня 2021 р.

Керівник дипломної роботи ____________________ В. М. Синєглазов

(підпис керівника) (П.І.Б.)

Завдання прийняв до виконання ____________________ Плодистий Б. О.

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NATIONAL AVIATION UNIVERSITY

Faculty of aeronavigation, electronics and telecommunications

Department of Aviation Computer Integrated Complexes

Educational level bachelor

Specialty: 151 "Automation and computer-integrated technologies"

APPROVED

Head of Department

Sineglazov V. M.

"____" __________2021

TASK

For the student's thesis

Plodistyi Bogdan Oleksandrovych

1. **Theme of the project:** "Intelligence system for PCB production"
2. **The term of the project (work):** from May 10, 2021 until June 11, 2021
3. **Output data to the project (work):** the method of selecting the target contour on video, the method of recognizing sizes, denominations, the method of algorithmization of the neural structure of the process, the introduction of controllers for additional power and emulation of software resources with the addition of automatic decision making.
4. **Contents of the explanatory note (list of questions to be developed):** 1. The relevance of the video surveillance system along the contour of the target. 2. Analysis of existing approaches for applied automation of production; 3. Theoretical foundations of neural network algorithmization system; 4. Solving the problem of detecting the element, the contact areas of the printed circuit board. 5. Improving the speed and reducing the conditions of marriage according to new algorithms.
5. List of compulsory graphic material: 1. Block diagram of the experimental installation; 2. Block diagram of the algorithm of the program; 3. Graphic representation of the found characteristic points; 4. Graphic representation of the results of the algorithm; 5. Folder with images of decision making. 6. Initial image with a selected frame and symbols.

6. Planned schedule:

№	**Task**	**Execution term**	**Execution mark**
1.	Task	10.05.2021 – 11.05.2021	
2.	Purpose formation and describing the main research tasks	12.05.2021 – 13.05.2021	
3.	Analysis of existing methods	14.05.2021 – 19.05.2021	
4.	Analysis of existing systems	20.05.2021 – 25.05.2021	
5.	Theoretical consideration of the problem solution	25.05.2021 – 30.05.2021	
6.	Development of software and hardware for video surveillance system of target contour	30.05.2021 – 05.06.2021	
7.	Making an explanatory note	05.06.2021 – 07.06.2021	
8.	Preparation of presentation and handouts	08.06.2021 – 11.06.2021	

7. Date of task receiving: “10” May 2021

Diploma thesis supervisor Victor M. Sineglasov

(signature)

Issued task accepted Bogdan O. Plodistyi

(signature)

АНОТАЦІЯ

Головною розробкою проекту є створення оригінальної, комбінованої, автоматизованої системи для виробництва друкованих плат з метою ліквідації браку та збільшення ефективності в часі.

Розробка програмного забезпечення включає в себе роботу нейронної мережі YOLO для поліпшення задачі ідентифікування та знаходження ліквідних і неліквідних зон з компонентного просвічування на модулі камери під управлінням контролера расбері. Прийняття рішень після чого машина розуміє яку дію варто зробити, авто центрування, скидання, скасування і т.д.

Практичним значенням роботи є комбінація декількох мікроконтролерів з установником в цеху та їх удосконалення шляхом нових алгоритмів. Основні дослідження показали як перехід з ручної роботи на автоматичну за допомогою віддаленого зв’язку можуть значно зменшити часові витрати на основні процеси департаменту.

Використовуючи емуляцію з додатковим підключенням мікроконтролерів було вирішено проблему обмеженості ресурсів установника та впровадження більш складніших алгоритмів в його дію.

Для більшої точності проекту, було розглянуто установник Mirae Mx-200, з відображенням статистики реальних проектів. Фізичне та програмне підключення дає змогу керувати машиною дистанційно.

ABSTRACT

The main development of the project is the creation of an original, combined, automated system for the production of printed circuit boards in order to eliminate rejects and increase efficiency in time.

Software development includes the operation of the YOLO neural network for improved detection and finding liquid and non-liquid areas with component clearance on the camera module under the control of the raspberry controller.

Decision making takes place in a couple of steps, after which the machine understands what action should be taken, auto centering, reset, undo, etc.

The practical significance of the work is the combination of several microcontrollers with the founder in the shop and improvement by means of new algorithms. Basic research has shown how switching from manual to automatic operation using remote communication can significantly reduce the time spent on core department processes.

Using emulation with optional microcontroller connections, the problem of limited installer resources and the implementation of more complex algorithms in the installer's operation was solved.

For greater project accuracy, the Mirae Mx-200 installer was considered, with statistics displayed for real projects. The physical and software connections allow the machine to be controlled remotely.

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GLOSSARY

YOLO – You Look Only Once

CNN – Convolutional neural network

RPI – Raspberry Pi

SMT – Surface mount technology

SMD – Surface mount device

KS – classification

MB – mother board

OB – operational block

PM – program manager

PE – program editor

EV – exposition value

OV, OM – optical module, optical vision

PCB, PWB – printed circuit board, power block

AI – artificial intelligence

RGB – red-green-blue

SVM – single vector machines

INTRODUCTION

Intelligence systems are used everywhere, even in mounting devices. Medium or mass production often uses SMD lines for soldering large batches of boards. In turn, lines are divided into semi-automatic, automatic and manual. The essence and structure of the department involves the relationship of engineers, operators, stockists and technologists to create a perfect and fast quality project.

For this development, correct norms, KPSC documents and machine performance results are introduced to verify the result of correct soldering. One of the tasks was to convert from manual to automatic correction mode, introduce remote control, successfully emulate additional devices and code them.

Prepared boards are fixed in the shop, subjected to stenciling, verification control, quick assembly of circuit elements and passing with correct soldering in the furnace with final verification of the board status.

The backbone and heart of the SMD is the installers, they install certain enclosures onto the finished textolite base with paste. The process runs from the appearance of the zero device on the gauge, the correct pass through the conveyor table, the clamping of the sides, the correct positioning of the nozzles and the air filters with the feeder panel. The machine needs a certain level of total circuit pressure and for the nozzles to work correctly. In addition, there is a 380v power cable connection.

The older models of the machines have insufficient capacity and algorithms; by strengthening their structure and software approaches, the production profits without replacing the operating principles and new machines with further reconfigurations. Two microcontrollers like the Arduino Uno R3 and the Raspberry Pi4 had to be introduced to solve this problem. They display the image perfectly and send a direct video stream to a separate screen or device. Securing the new technology, we also add a software python structure, which in turn defines elements, loads logic and machine bases faster.

The main advantage of the work is a reduction in scrap, faster lines, increased accuracy, better placement of elements on contact roads, and a couple of hours faster workflow. On the working side, the operator does not have to use the joystick every time to correct the 2D inspection on the installer's axes. Reinforcing the machine provides a further key to new algorithms, to reinforce operating units, actuators, sensors, optical cameras and all internal SMD technology.

An initial process emulation is carried out on the first unit to sort out the process and any possible future malfunctions of the host machine. When developing the process, the scale and errors must be taken into account, moving to control and amplification with the new controller can result in an accurate and stable process, depending only on further algorithmisation.

Python's core libraries are taken for clarity of detection and auto-correction of element positions, this also allows for quick remote control and connection to a local machine port with constant video streaming with decision-making.

CHAPTER 1. TECHNOLOGICAL PROCESS PRINTED CIRCUIT BOARD PRODUCTION

1.1 Technical support of PCB production

The PCB manufacturing process has been created in different ways with special machines, regulations, special documents, production types and other factors. Regulatory documents control the relationship between work systems, personnel, component suppliers and technologists. In this way, everyone has their own task in production. According to the schedule, operators take on special projects with complete kitting, specification, classification base and program for the production project. The schedule includes the number of printed in blocks (blocks from multiples), the board side and the number of classifications.

Multiples - a collection of blocks of boards, one block counts as one board, the following sections will detail the types of PCBs and multiples.

Classification - a special code, which usually has four numbers, is the main technical document in SMT, includes the required circuit base, board version and additional components. From the numerical code it is possible to quickly identify all the required data and project similarities.

Bundle - A document that describes the set of components with serial ratings, code, percentage, enclosure and the current version of the PCB. Issued for each project, with reference to the date, number of items in stock in production and the ratio of items already in work on machines or in stock.

ACIC DEPARTMENT				NAU 21 0927 000 EN			
Performed	Plodistyi B.O.			Intelligence system for printed circuit board production	N	Page	Pages all
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Consultant					431 151		
Normcontrol	Tupitsyn M. F.						
Accepted	Sineglazov V. M.						

Specification - a document describing the comparison between the program base of components and their availability in the kit, in the case of the program there is a priority of charging, enclosure and sequence numbers attached to each feeder.

The overall behaviors and relationships of the workforce in production is described by the CPSK, a document for process quality control within production, which includes diagrams and diagrams with links between operators, warehouse and technologists. It describes the correct write-off of all materials in production, recycling and reuse of materials to create a finished product.

This paper will describe the CPSK for the software base with reclamation or recycling to compare with new and old technology in production, which in turn affects the percentage of output, efficiency and waste in production. In addition, current manuals are available for all machines in production to help solve difficult or critical production stoppages in any stage of operation. These manuals show the principles of operation, internal circuitry, pistons, vacuums, drives and another robotics.

The theoretical part presents the types of breakdowns and their actual solutions with reference to engineers in rare cases, internal repairs are performed by junior and senior engineers for specific equipment. Basic design, types of software, interfaces and component parts can all be obtained, known, ordered strictly by manuals, as other instructions or things can greatly increase the number of illiquid boards in production, in the worst case causing critical breakdowns in machinery.

Technologists monitor all points of production directly in each department. Every irregularity is strictly recorded, be it an ungrounded employee or improper storage of components. The technologists' department issues all the necessary health and safety documents, certifies products at quality control, and correctly certifies working hours, breaks and quantity standards.

In their turn operators are divided into junior operators and basic operators with certain set of skills. The common goal is to automate PCB technology and surface mount technology. Each operator has rights and duties specified in service documents, e.g., knowledge of circuitry and robotics at an intermediate level and the ability to adjust and optimize programs.

Various methods are used in the production of printed circuit boards to protect workers, as prescribed in the health and safety document. These are primarily protection against static electricity for vulnerable elements in the circuitry and protection against the ingress of dirt, unnecessary actions by workers. In addition, all the protection equipment used is also useful for line operators. An anti-static wrist strap and anti-static boots enable the operator to confidently handle the PCB surface at all stages of assembly along the line. A special production coat helps to protect against unnecessary dirt, and in the event of an electrocution you can gently push the operator away or pick it up as the coat is long enough and does not conduct electricity. Also, in the event of a power outage, you don't have to worry about your health while wearing the protection. The last type of protection is the rubberized, thin gloves, which are periodically changed at almost all sites. They help to remove unnecessary dirt, displacement of paste in the case of hand laying the element and remove grease that forms on the bundles and on the inside of the palm.

The first thing to check is the condition of the compressor, which supplies compressed air through a pressurized circuit for machines with pneumatic and electric drives, in this case this is used for installers, unloaders, board loaders and automatic and manual printers.

In order to maintain the automatic operation of the machines, a proper and constant operation of the compressor and electricity supply is required. The compressor is made up of special areas such as the cooler, the drainage area, the sensor display, special filters (carbon, liquid, etc.), which need to be replaced in time to remove residual water, oil and contaminants from the circuit. This greatly affects the correct and stable pressure supply to the machines.

In order to prevent installers from burning out, the protection of production UPSs and voltage regulators is used, which display the current voltage, voltage and delta difference in the event of failures. In addition, all of this keeps the machines running, to keep the work flowing, eliminate software failures and malfunctions in the plan, physical problems, running through the last boards in the furnace. For example, a bump in the installer tower at the last pressurization, an incorrectly clamped board by the installer conveyor table.

The workshop area is fenced off with special yellow lines, a distance of one meter from machines or hazardous areas, the warehouse, special department, feeder area, repair area, electric panel room are not allowed to be crossed by personnel from other departments. Also, in case of a tour through the workshop it is possible to keep the operators safe, not to stop the work process and to see everything live without any harm to their health. Zones are set up with layouts including medicine cabinets, fire extinguishers and fire cabinets. Special routes have been created for evacuating workers, which are shown on special route maps and are specified and communicated to all personnel for a period of time after work has started.

According to process regulations, the temperature in the workshop should not exceed 18-20 degrees Celsius, as this is dangerous for the storage of paste before work, application, temporary storage of future sensors. It also affects the operation of the production oven, the humidity in the air and the activity of the workers. To keep the temperature normal, a couple of powerful production-type air conditioners with efficient operation are installed.

To eliminate excessive vapor from the beginning, end and middle of the furnace, large exhaust hoods with a strong draft are installed to eliminate the initial vapor when soldering printed circuit boards, as this has a significant impact on the operator's health when staying in the shop for long periods and loading large batches. The vapors then pass-through hoods, collecting the remaining vapors, passing them through a special filter and releasing them back outdoors. In the final stage they have a much lower degree of environmental contamination.

It is mandatory that for every point from taking the board, blotting it in the printer, running it through the installer, reviewing it on the inspection table, putting it in or running it through the furnace and final inspection, there is a special procedure - quality control - established by the technology department. This allows all processes to be controlled, eliminating unnecessary rejects and putting the entire department to work correctly. While working with a full workforce, at least an assistant or main operating engineer must be present at each point to monitor all processes.

The following will describe the basic, technologically correct workflow from start to finish of printed circuit board production in some detail:

At the starting point of quality control is a set that has been pre-checked by the warehouse and delivered in the exact and verified quantity according to the production plan. Looking at the electronic classification or the table on the monitor, the operator understands from the project code which boards, multipliers he should take to work and pre-check. Approaching a separate area with boxes, containers picking up a project it is necessary to check the condition of the box for damage, whether it is properly sealed, whether there is special foam inside.

The operator must print out the contents correctly and neatly with air bubble wrap. Check the code, quantity, version and board name according to the design. Carefully remove the moisture indicator, which changes color if the boards are stored improperly or are exposed to condensation in the packages underneath, wearing protective gloves. If the color does not change from crimson to orange or from turquoise to red (as there are two types of indicators on cardboard base), the boards are in good condition and you can proceed to the main inspection. Also, the indicators are shown in special zones with percentages ranging from 10 to 80 per cent.

The visual inspection should take into account the condition of the test points, the printed tracks, the general condition of the textolite surface, the correct paint application and the level of contamination of the board by the supplier. It is worth noting that all deliveries are partly inspected by the quality control department before being checked by the operator. If the board fails the visual inspection, it is sent to defective or illiquid boards in case all zones are interrupted or have unacceptable offsets.

The base of the circuit board consists of textolite, glass wool, plastic and carbon fibral. You must be extremely careful not to damage the surface, as you could damage yourself or the hardware. In manufacturing the boards are usually bought in bulk from Chinese or Korean mass producers, the full compositions, damage and proper handling are written in specially translated English manuals with the kit. First the design engineering department does the basic layout with the wiring, saves the design and sends the files to the company email to the manufacturer. Also, in one of the kits you can see the test board, with all the tests, poured in special liquid, cut board, delivery documents and the liquidity level of the printed circuit boards.

Once the inspection is complete, the operator selects the required number of null sensors without any sealed sides; if the first side is sealed, quality control is carried out differently. According to the design, puts the board in the magazine on the forklift, it passes on the conveyor into the automatic printer, or the operator pins (inserts under the board holes) into the manual printer and pastes each one manually or semi-automatically, then puts the boards in the magazine, exposing it later on the board loader. The condition of paste on stencil frames should be checked at the printer's point, i.e., correct positioning, quantity, level of paste application, pressure of the padders on the paste, no dried lumps, no loose apertures during pasting. If everything is correct, the paste is applied correctly, without any shortages, displacements, level and quantity, the operator takes such a board to the shop for further use, or it drives on the conveyor and the verification table can check all the imperfections and correctness of application.

During normal operation of the loader, the boards pass through a number of sensors into the setter's bifurcated conveyor belt. Further visual checks are only carried out by the operating engineers, as the heart of the automated line is the installer and many processes need to be edited and monitored in good time. Briefly describing the process, the board is driven through a pair of sensors, the worker looks at the correct positioning of the board in the conveyor and the correct clamping of the board to the table inside the installer, as well as the correct operation of the board stopper to clearly position the board for determination by the coordinate axes through the pointing camera of the machine, next figure 1.1 give you an imagination how board looks like:

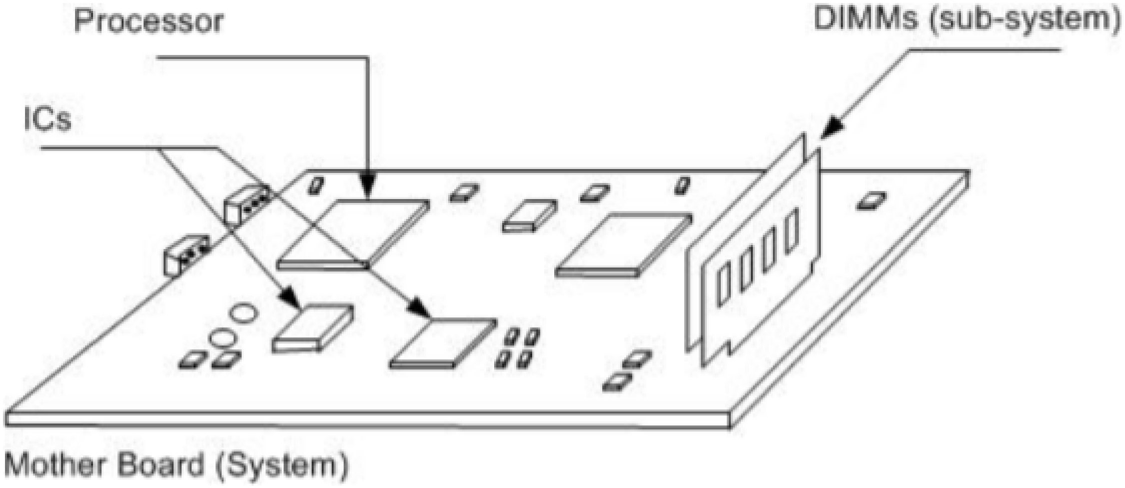


Fig. 1.1 is an example of a printed circuit board

In addition, the technician must check the entire working area, the drives, the walking head, the crane, the condition of the feeders, the pressure levels, the correct behavior of the sensors, the take-up of elements correct coordination and the automatic behavior of the machine at physical and electronic level with the linkage of the programs. Through the glass you can see the installer's quick processes, the complete iteration, the passage of the board onto the conveyor table and the verification of the number of boards in the monitor, on figure 1.2 you can see the installer crane with x-axis, y-axis:

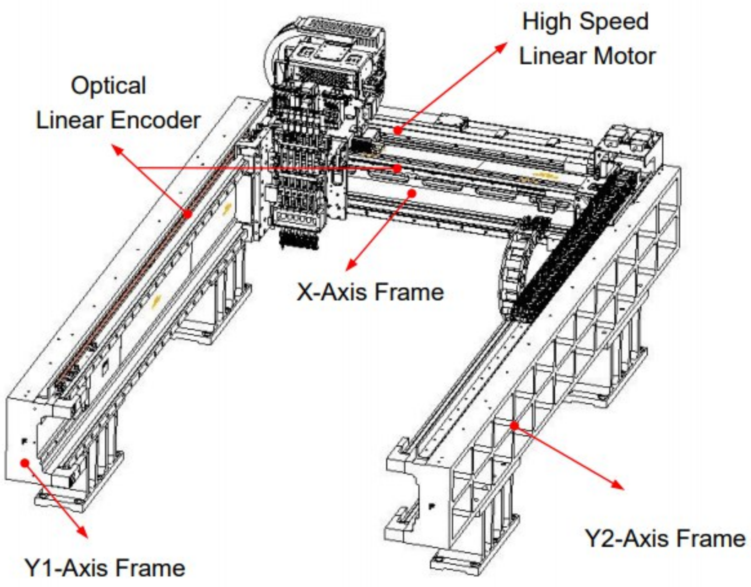


Fig. 1.2 shows the installer crane with x-axis, y-axis

A further inspection on the inspection bench consists of checking the correct positioning of the circuit elements, the likelihood of misalignment, checking the absence and possible defects of the feet, the cell body. It also checks the keys, correct polarity, in rare cases the rating. If a part is missing, it is changed by taking the correct rating from the strip and setting it carefully by hand, if operators make a mistake, any offset parts are also manually edited. The finished, tested board is sent to the furnace for proper sealing and to produce a semi-finished product - an unfinished product that can be further processed or be part of the finished product.

Among the SMD department, semi-finished parts are considered printed circuit boards and printed circuit assemblies.

A printed circuit board is a plate derived from dielectric material, with at least one ball of conductive tracks formed in its thickness or on its surface.

A printed circuit board is a printed circuit board with mechanically and electrically interconnected electronic components, and soldered.

In the melting furnace, the board passes through a couple of zones with different temperature settings, the operator in this case ensures that the correct thermal profile is shown on the display and that the boards pass neatly from the beginning to the end of the conveyor or belt of the furnace. It is important to understand that the boards must lie down correctly, the elements must not shift or fall off when seated. The sensor is often positioned in the middle, or right and left of center if the multiplier covers a small area. The board must not catch or fall out when passing, the materials from the furnace also do not fall on it, the output is a finished semi-finished product.

Using special gloves, the operator picks up a batch of PCBs and inspects them for improper SMD soldering: unsoldered components, misalignment on the board cavity, missing or excessive paste, dirty boards, unliquidated components, damage and rotated or flipped components on the sides or vice versa.

The visual check at the last point must be completed by verification of the boards and placing them on the other side for soldering or final handing over to the "AOI" system, automatic, optical and spot lighting with a wide range of methods. For proper demounting the boards must be set on a pallet, which can hold from 25 to 50 boards, depending on the size of the board. Also attached to the pallet is a special identifier, for identifying the workers, the date of soldering and the line the project was run on. After all the processes described above, the quality control operator scans the boards, puts their ID and sends them to the next departments with piercing, testing, kitting, assembly, lacquering and dip-assembly.

1.2 Surface mounting technology in production

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

Surface mount technology is 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 conveyorized SMD line, worker-engineers and a host of manufacturing processes to improve production, increase efficiency levels and reduce scrap.

There are a total of 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 are designed for a certain type and production speed. This paper is written with medium volume production in mind. For SMT assembly the board layout is created with a seemingly 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.

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.

In this work a mass of components is 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. In short, 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 section above.

When looking at the rating, we have the unit and degree of a particular element, e.g., 10 khoum, 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 correctly 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 liquid multiplication boards.

1.3 PCB production technology

In today's Printed Circuit Board technologies, you will notice a great abundance of machines, each with its own unique connection, application and name, this paper will describe the following machines:

- Loader: CL-3;
- Unloader: UL-3;
- Installers: Mx-200, Mx-200p;
- Stove: Tolo CL-3;
- Automatic and manual printer: HP-520S, YS-350.
- Solder paste balancer.
- Conveyor tables for verification and correct board passage.
- Tools for work in the CMT department.

The beginning of the SMD line is located strictly on one side of the workshop and must start from the picking area and the PCB unpacking table, near which there is a loader, in this case the Mirae CL-3. The loader is designed to feed the boards into the furnace conveyor in a timely and accurate manner.

Before describing the functionality, it is necessary to describe the operation of the SMT board magazine. A total of 2 types of magazines and pallets can be found in production, all of which are designed to carry printed circuit boards neatly through production. A big or quality control shop has up to 5 walls, 3 of which are movable, with boards of different widths and types fixed in one position. In this case 1,000 to 2,500 boards can be placed at a time.

The medium magazines are used for CMD lines directly, have 50 cells and are used when stacking in multiple rows. Before using it, it must be carefully adjusted by opening the two lower and upper retainers. Fix one movable wall strictly to the size of the board, check its oscillation inside and that it does not fall out at the end or the other side of the magazine. If you skip this point, you could lose a lot of production due to incorrectly timed set-up, this part is usually handled by trainees.

The board is inserted into the magazine with the "BOT" or "TOP" side, depending on the task from the production. The operator knows in advance where to find the park map and other documents with sides of the same project, having checked the side the operator lays the boards with the correct side, angle, tension, looking at the contact pads.

The workshop selects a separate zone on each sensor, often a soldering zone for one large defined element with a specific type of action. For example, the board will be located on the "TOP" side of the frequency transceiver. Once the operator has laid down 50 positions, he checks each one and knows in advance that this is the side from which the board is correctly driven into the automatic printer or fixed in the manual printer.

This loader model is not particularly different from the unloader, the main difference being loading the magazine from the bottom side, passing it through 50 cells and returning it from the top floor, to further load new batches of printed circuit boards.

Moving on to functionality, among the physical settings are a magazine clip, a pair of sensors for stand-alone operation, a pusher - an iron tip for pushing boards through and a conveyor-type wrench for scrolling with a board lock between the loader and the printer line with an audible traffic light.

The retainer clips are designed to hold the super-precise magazine position when the positions are rotated, if not properly clamped and retained often the pressure PCBs will break and become fully or partially unliquidated. The clamps also hold the magazine in place at the point of entry and exit. The board retainer between machines allows a safe passage of the PCB to the printer without falls, clips in the belt and conveyor breaks.

The pusher can be fixed with a crescent wrench and must be edited at the start of each project depending on where the center of the board is located for smooth pushing from the magazine. The audible traffic light always emits a strong signal so that the operator can run up and rectify the problem in good time.

Unloader sensors are usually of the same type and hit the laser at a point noticing and triggering when a target appears close by. In working mode, you can see a red beam before it appears, after approach the beam is removed and a specific actuator is triggered with a function, e.g., when the initial sensor stops lighting up, the line starts to advance and the magazine moves in and locks under the second sensor. In the event of an incorrect actuation, the equipment breaks down. Trainees receive full training even for these 'primitive' machines with narrow tasks, because they too have pneumatic and electric drives.

This machine has a connection up to 220 V, as well as its own barometer and a system with pressure loop that goes up to all circuits via special beams. Although simple in design, it has its own touch screen display with settings and internal automation. The main menu has a start and end button for automatic operation. The number of boards travelled, the machine's operating time, and the switch to other settings. In the special settings it is possible to specify a traffic light signal time before all actions and after passing the board, this is created so that after a delay the operator receives a signal that the loader is not working correctly.

Also, it is possible to change the level of magazine raising in one, two or three cells, this is done in projects with large elements like large electrolytes or

PLC devices. A prime example, a large capacitor or choke rated at 330 micro generic shaves off when another board enters the magazine, this is the problem of saving two-way projects or loading and saving one-way large PWB type chargers.

Special cells show the correct operation of the actuators and sensors, which light up when tripped, so you can understand which contact compartment has failed. It is worth noting that internal repairs and optimizations within the machines are carried out by senior foremen and senior engineers. The clamps can be monitored by means of a special button, and it is no problem to internally withdraw and insert the magazine, end at a certain position and carry out the usual activities.

The same display can be seen on the main panel of the loader, the emergency stop button, for injury or complete malfunction, sudden power outage of the room. In addition, the machine is switched on via a special on/off switch marked "on/off". This prevents the machine being switched off or on accidentally.

Both at the beginning and the end of the line by the same functionality is the UL-3 board unloader, to which the boards come via the furnace conveyor or the other side can be manually fished through the grid for one-sided projects. The magazine enters the unloader from the top side, while the reverse side exits. The quality control operator then scans the boards and issues an empty magazine.

The main setting of the unloader is made with an external pusher on the conveyor, which pushes the boards in a timely, correct way. The main sensor is set up for it, which sees the board passing through and before the shop starts, once the sensor is triggered, the pusher begins to lock the board into the shop all the way in.

Experienced operators know the importance of conventional and proofing type conveyor tables. Conventional tables are placed before and after the automatic printers, to improve the flow of the line belt, the slightest displacement can cause the board to fall or get stuck in the table, requiring instant action by the operator. In addition, they are placed after the unloader and before the loader, usually built into these types of machines.

Ribbons on the line come in narrow and flat, usually in green, the former kind being rounded and aligned strictly in the middle. The flat ones can catch a small gap and are newer and more reliable, the board can safely pass, get away from obstacles and turn slightly out of alignment without creating a critical situation. When tearing a tape, the operator should request a new one from the engineer, having first examined the mountings, the shafts, and having de-energized the machine correctly and in good time, replace the tape.

The inspection table is designed for possible long-term board testing, with a sliding, lockable conveyor. It is powered from 220V. In contrast to the loaders, it does not have a connected pressure circuit. The operator carefully double-checks the board after the installer using special criteria and a solder card opposite, on a monitor with a raspberry pi, any information can be opened quickly and conveniently to see the key or the same polarity of a component. Usually, work is done with slightly magnetized tweezers, for easy lifting of case type elements 0.2-0.4, 0.3-0.6, 0.5-0.8.

The operator can edit the length of the conveyor with a wrench in relation to the data of the board and the exact length between the rest of the line. Among the main functions are a switch to turn the table on and off, a line speed controller (usually standing at maximum speed) and a button or foot pedal for skipping liquid boards.

Before looking at the printer's functionality, it is worth noting the paste as well as, other liquids in production. These are divided into oils, pastes and alcohols in total.

Isopropyl alcohol is one of the staples on the SMD line as it has an alcohol capacity of over 98% and evaporates quickly. It is intended for wiping, cleaning stencils of dirt, rinsing and blowing off boards strictly according to the instructions. It is also used to remove dirt, textolite is afraid of water and isopropyl vaporizes completely after 5-8 seconds, leaving all dirt or residues on the special paper, which speeds up the reuse of products and the correct processing of components. Care should be taken as contact with this liquid can cause severe itching or damage to mucous membranes, use with gloves and a face mask, do not bring close to eyes. It dries hands quickly, so it is strictly prohibited to wash wounds or use as water.

Oils are used very often for SMDs, the composition and function can vary. For the furnace use a long resistant, refractory machine subspecies, to lubricate the levers and iron conveyor, which constantly dries out and wedges when moving, if the oil is automatic through the circuit system does not come, you need to monitor the level in the glass flasks and periodically without overflowing leave 60-70% oil, changed every 3-4 weeks, less dangerous for humans, the fumes do not cause harm. Strongly contaminates dressing gowns and clothes, cannot be washed out without powerful preparations.

If necessary, all moving parts, the installer turret, crane, small gears and mechanisms with automatic flashers inside the printer are coated with viscous green oil, this type is designed for constant and continuous operation of the moving parts.

The last type of liquid, solder paste, has a lot of information about it. Let's start with the correct preparation before application. The general temperature regime is related to a number of circumstances. In the first situation, the paste is kept permanently in the refrigerator with a special thermometer, which should be between 0 and 12 degrees Celsius, kept for 12 months. When taking out the paste, you need to look at the rating in this situation using lead-free paste sac305 m8, the fumes of which are less hazardous to personnel. Still should not bring it close to eyes, nose. It will stain your clothes badly.

Next the process is to put the paste to stand at room temperature for 3-4 hours, the shelf life will drop from three months in the fridge to a month in the shop at room temperature of 13 to 22 degrees Celsius to 3 months. This is quite normal. You can see some flux of about 3-3.5% per jar of paste before using the lid. If you do not mix or overheat the paste in the balancer, you can get wrong consistency and more liquid paste, when you mix cold paste from the fridge, the paste becomes non-liquid and you get "cold soldering" or "tombstone" effect. These faults will be described in a later section on faults and discrepancies.

The process of checking and finding the board itself is described in a couple of steps, from passing the board through the printer conveyor, to finding the coordinate reference points. The board is placed under a special stopper, the table is clamped, the printer camera is brought to two reference points which are preset in the software and with a special algorithm with a permissible search area it finds within a radius of 1 mm the right position of the beginning and the end of the textolite, the example of main module cameras will reproduce on figure 1.3:

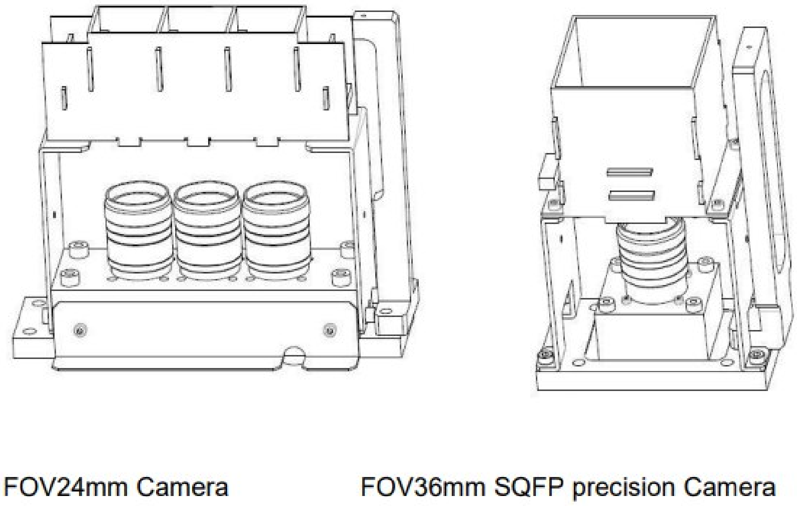


Fig. 1.3 shows the element cameras

This process uses the movement of the crane and printer head together with the camera on the front, far and home points, with exactly the same deflection of the doctoring and paper compartment. On this machine the doctor blades stand in the lower cavity, secured by special large and small locking tabs. All actions are laid down in the "test" tab.

Once the board plane has been successfully found, solder paste can be applied to the visible line on the stencil, the first blotting takes place at the operator's end. After the first blotting, the operator picks up the first board passing from the printer's exit to the inspection table for the applied paste. After performing a technical analysis with acceptable paste offsets, the worker turns on the auto-pass through the table or performs an axis correction of the design in the printer. Through the graphical interface the shift can be made down, up, right, left and along the 4 diagonal guideways by example.

When taking the paste, the operator must check the date of manufacture of the paste; if the expiry date has passed, the container must be discarded immediately. The temperature in the printer's working area must be between +18 and +25 degrees Celsius.

In total, up to 12-15 sensors can be seen on the printer, affecting the action of the drives and moving parts. The operator is aware of up to 6, input, output, near the paper outline, near the prepared board location, camera sensor and conveyor checks after the boards have been successfully blotted.

The printer can be operated with operating system support, manuals and instructions. There are many errors on the operating system, which can be eliminated with the help of the graphic interface and the correct operation of the sensors. In addition to the operating unit and piston motor, a handheld computer is mounted on the rear, a system with pressure and power supply over 220V is connected.

1.4 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.

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.

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.

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.

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.

Next figure 1.7 will show you a one iteration start production process:

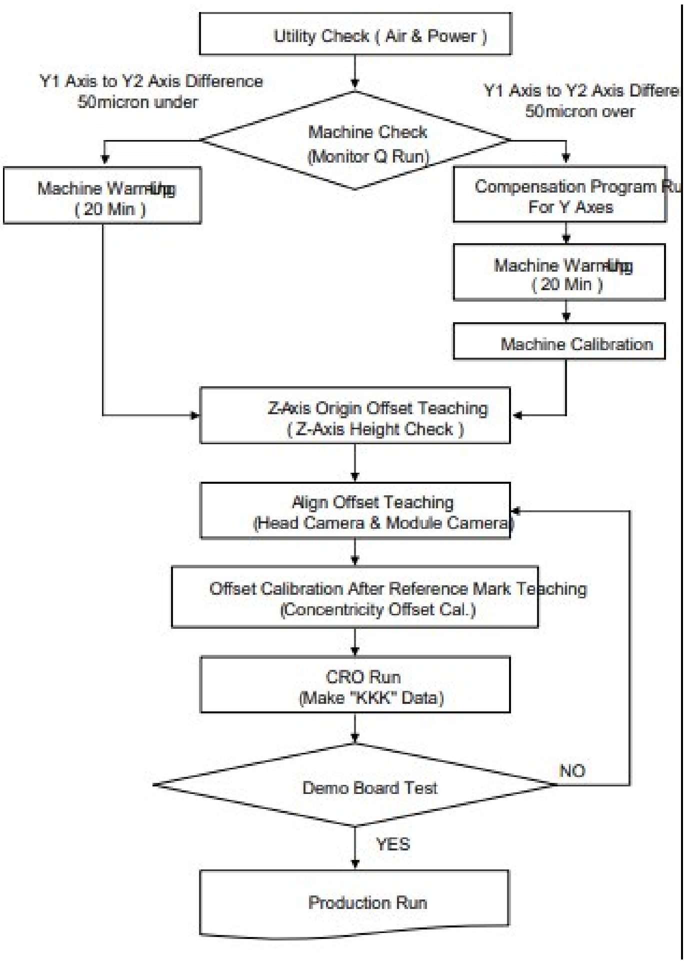

Utility Check (Air & Power)
Y1 Axis to Y2 Axis Difference 50micron under
Y1 Axis to Y2 Axis Differe 50micron over
Machine Check (Monitor Q Run)
Machine Warming Up (20 Min)
Compensation Program Ru For Y Axes
Machine Warming Up (20 Min)
Machine Calibration
Z-Axis Origin Offset Teaching (Z-Axis Height Check)
Align Offset Teaching (Head Camera & Module Camera)
Offset Calibration After Reference Mark Teaching (Concentricity Offset Cal.)
CRO Run (Make "KKK" Data)
Demo Board Test
NO
YES
Production Run

Fig. 1.7 is a complete iteration of the installer's start-up by action

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.

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.

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 CMD, 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 is disabled because the program has already been created and this takes up extra time.

The main startup settings have a produced quantity in addition to the planned quantity, if the process is 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 PCB, 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 PCB, 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 PCB, 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.

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

1.5 Emulation of the Mirae production system

This project is 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.

On figure 1.8 is represented a Raspberry Pi 4 connection module:

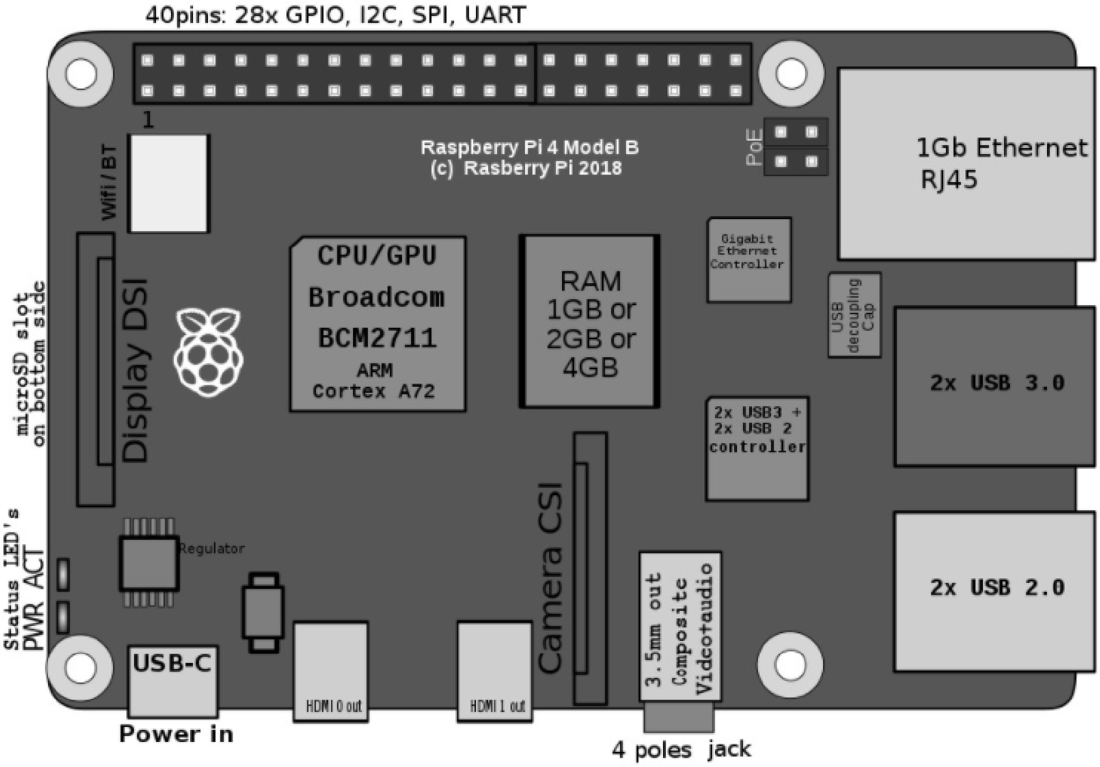


Fig. 1.8 shows the Raspberry Pi with its enclosure

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:

1. Raspberry Pi standard 40-pin GPIO socket (fully backwards compatible with previous boards)

2. micro-HDMI ports (supports up to 4kp60)

3. 2-way MIPI DSI display port
4. 2-way MIPI CSI camera port
5. 4-pole stereo audio and composite video port
6. H.265 (4kp60 decoding), H264 (1080p60 decoding, 1080p30 encoding)
7. OpenGL ES 3.0 graphics
8. Micro-SD card slot for operating system boot and data storage
9. 5 volts DC via USB-C connector (minimum 3 A *)
10. 5 volts DC via GPIO connector (minimum 3 A *)
11. Power over Ethernet (PoE) enabled (separate PoE hat required)
12. Operating temperature: 0-50 degrees C ambient temperature.

On figure 1.9 we can see a Arduino scheme for connection:

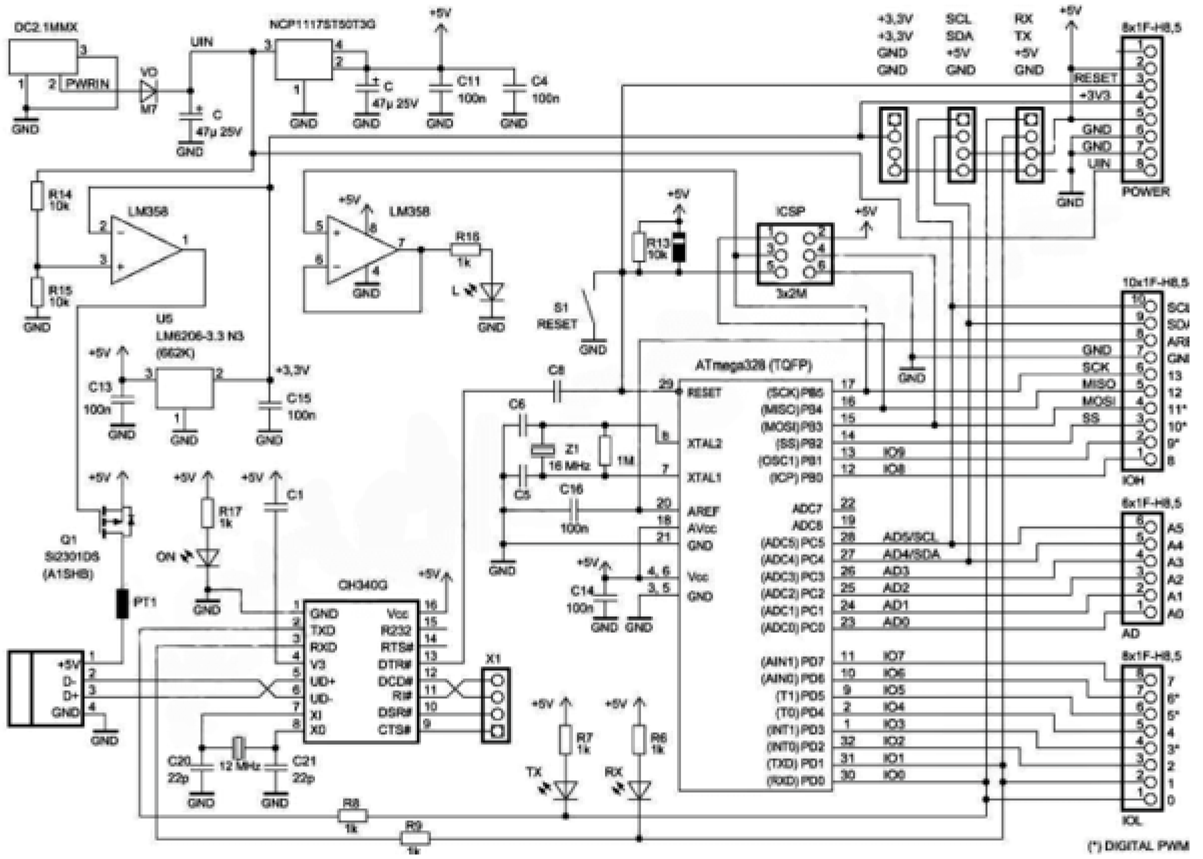


Fig. 1.9 Arduino scheme for connection

On the next chapter we obtain an new connection modules to improve software in chapter 3 and 4.

CHAPTER 2. DEVELOPMENT OF A NEW TECHNOLOGICAL PROCESS

2.1 Shortcomings of the old manufacturing process

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.

Protect the SMD operator and component base: anti-static shoes and gloves, production coat, wrist strap, earthing of all electrical machines, list of machine protection you can see on figure 2.2

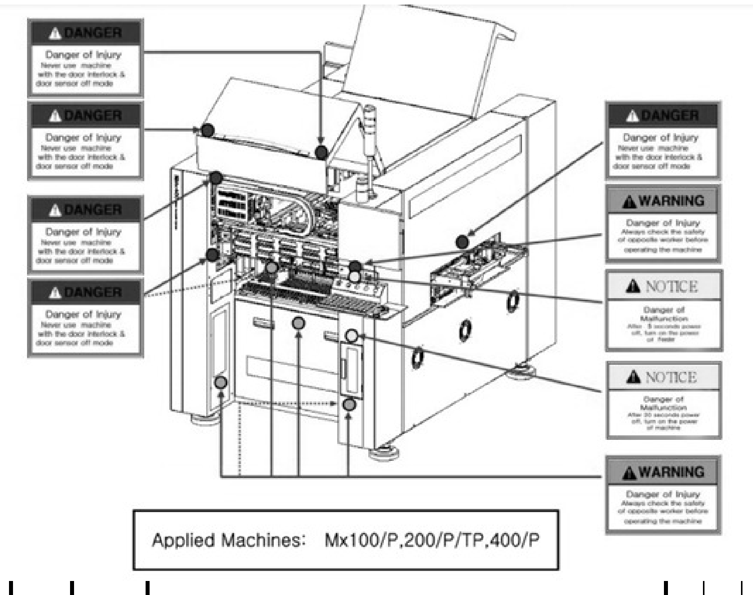

DANGER
Danger of Injury
Never use machine with the door interlock & door sensor off mode
DANGER
Danger of Injury
Never use machine with the door interlock & door sensor off mode
DANGER
Danger of Injury
Never use machine with the door interlock & door sensor off mode
DANGER
Danger of Injury
Never use machine with the door interlock & door sensor off mode
DANGER
Danger of Injury
Never use machine with the door interlock & door sensor off mode
WARNING
Danger of Injury
Always check the safety of opposite worker before operating the machine
NOTICE
Danger of Malfunction
After 5 seconds power off, turn on the power of feeder
NOTICE
Danger of Malfunction
After 20 seconds power off, turn on the power of machine
WARNING
Danger of Injury
Always check the safety of opposite worker before operating the machine
Applied Machines: Mx100/P,200/P/TP,400/P

Fig. 2.2 shows all the danger zones of Mirae type installers

Types of product shortages are divided and numbered one by one by the quality control department. A detailed scrap analysis gives a chance to a qualified engineer on the line to remove the non-liquidity.

2.2 Types of marriage

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

1. Not a soldered pad.
2. Lack of an element.
3. Critical link displacement.
4. Too much paste on the contact pad.
5. A delaminated or faulty board, a deformed board.
6. Rotation of the circuit element.
7. Deformation of contact legs or housings, individual surfaces on the SMD.
8. The element fits over the sealed paste.
9. Short circuit.
10. Raising the section by one contact foot.

On figure 2.3 it is presented correct sealing of SMD elements

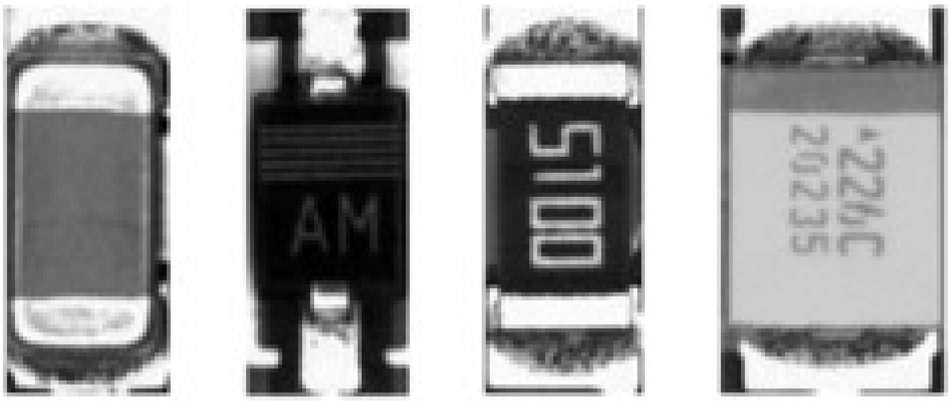


Fig. 2.3 is an example of the optimum arrangement of the components on the paste

On figure 2.4 it is presented uncorrected sealing and displacement of SMD elements

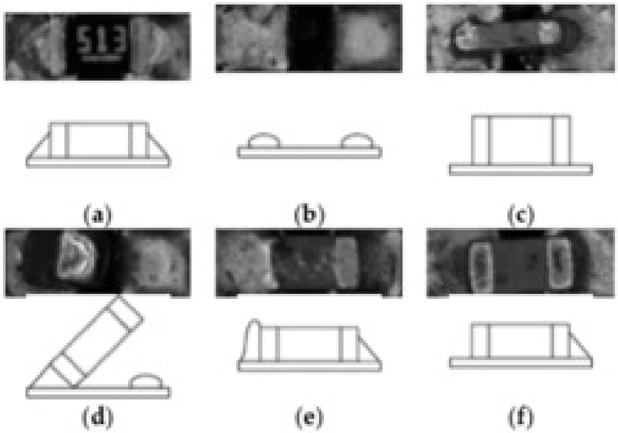


Fig. 2.4 defects after the components have been mounted on the contact pads with paste

2.3 Overview of new technological and software approaches

New technological and software approaches in this development include the creation of two algorithms, the first is the automatic alignment of the element on the circuit board. According to the theoretical process, the element is taken with a specific nozzle and recognized on one of the front cameras, all the required contours with the housing and its shape are outlined.

The software approach of the Mirae Vision system includes recognition up to a point with auto-alignment, thus requiring only manual editing via a special wired joystick for the installer. In order to create a new method, it is necessary to connect a separate module with a camera and to modulate the process on the new device, the most important thing is to confirm the correct process. The "Grape Tec" uses an "Arduino Uno R3" controller for this, which is subsequently connected to a smaller camera than in the original machine, using an algorithm to a similar optical guidance.

Having formed the basic outline of the project, it is clear that for the most part square and oval-shaped elements will need to be centered in some cases, the camera needs to point at elements whose area is much larger than the camera's field of view.

One of the best-known methods is vector visualization. The system allocates computational data to determining the outline of components by a boundary from comparable groups of vectors. This is successful because of the formation of mathematical interpolation and sub-pixel resolution, meaning that the vectors more closely match the exact shape of the component than the pixel grid, next figure 2.5 will give you an image of camera module with axis:

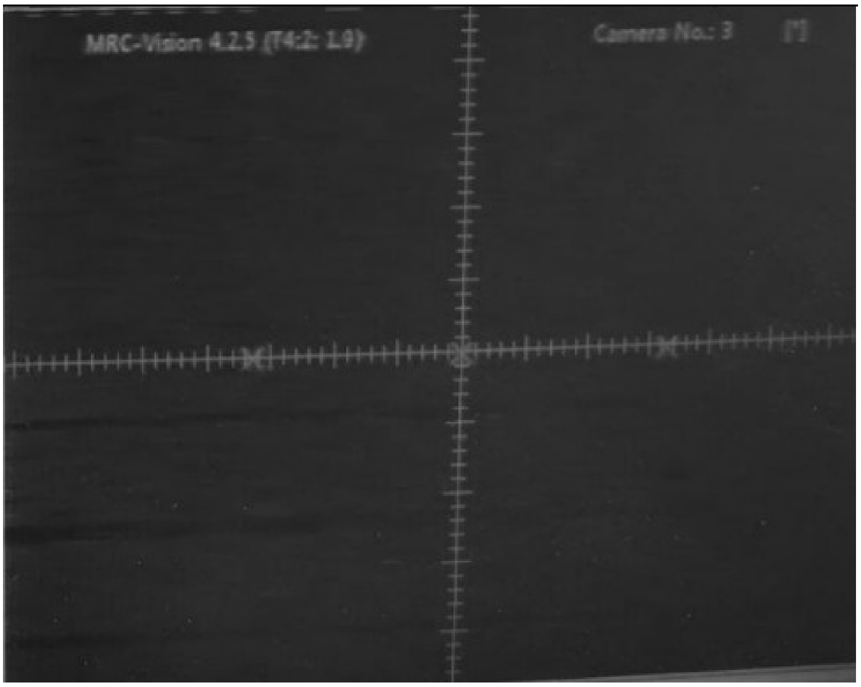


Fig. 2.5 shows the X, Y axes of the camera window without the element

On figure 2.6 you can see new configuration start:

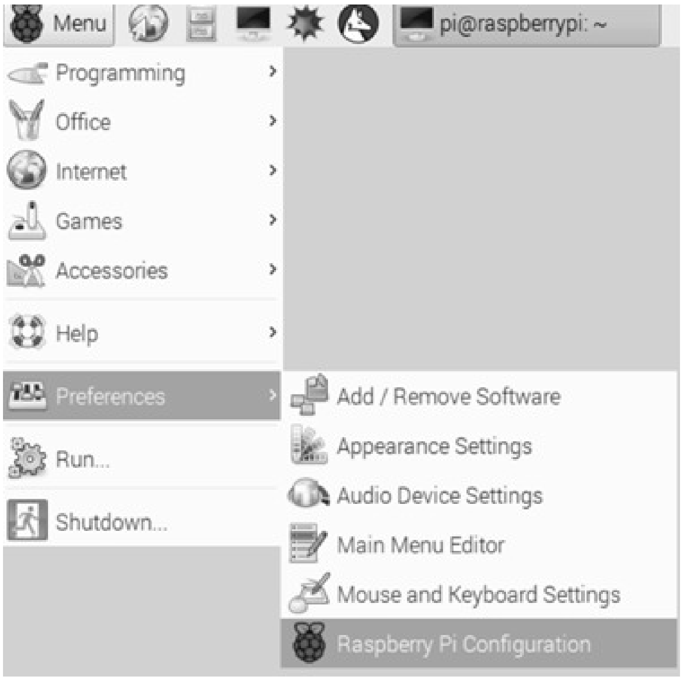
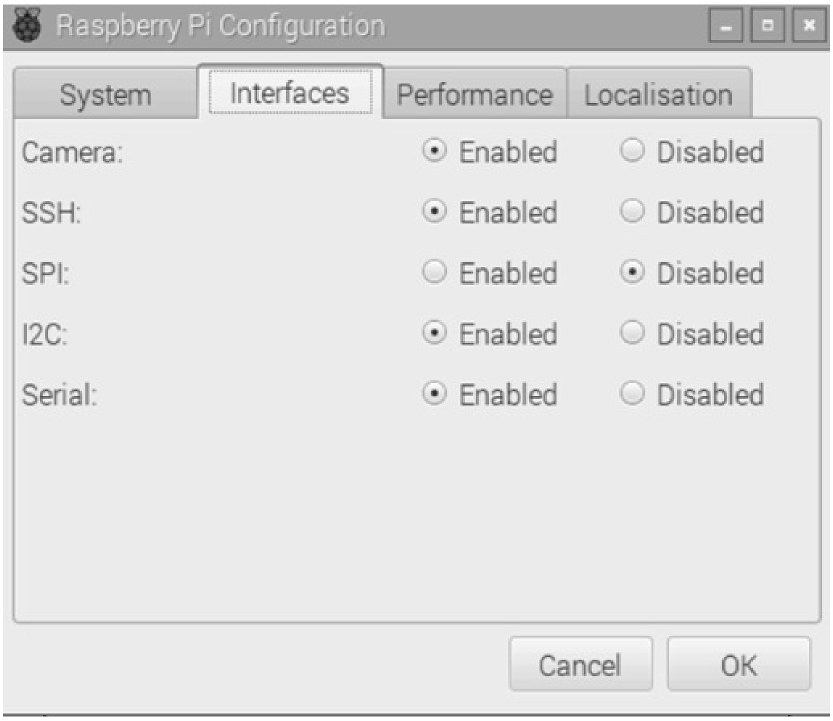


Fig. 2.6 starting the raspberry configuration

On figure 2.8 you can see camera connection interface:


Raspberry Pi Configuration

System | Interfaces | Performance | Localisation

Camera: ● Enabled ○ Disabled

SSH: ● Enabled ○ Disabled

SPI: ○ Enabled ● Disabled

I2C: ● Enabled ○ Disabled

Serial: ● Enabled ○ Disabled

Cancel OK

Fig. 2.8 It is imperative that the engineer connect the camera software as shown

If the function is not used, you need to enable it and restart the unit. After checking the installer camera module, the operator uses the camera preview, like on figure 2.9:

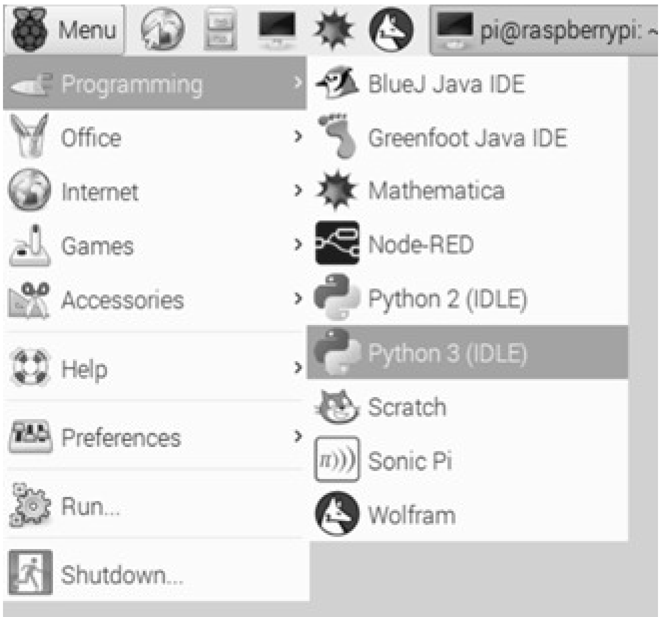


Fig. 2.9 Opening a Python program

Use apt to install the python-picamera library through the raspbian archives:

```
"sudo apt-get install python3-picamera"
```

The camera connection is available via the following code:

```
"Import picamera
From picamera import PiCamera
From time import sleep
Camera = PiCamera ()
Camera.start_preview()
sleep(20)
camera.stop_preview()"
```

After checking if the image is rotated for 20 seconds, if the image is deformed, use the "camera. rotation", in the case of the old Mirae system, the image must be rotated by 90 degrees:

```
"camera rotation=90
camera.start_preview()
sleep(20)
camera. stop_preview()"
```

As a result, check the transparency of the camera module with alpha (0;255):

```
"from picamera import PiCamera
from time import sleep
camera = PiCamera()
```

```
camera.start_preview(alpha=180)

sleep(20)

camera. stop_preview()"

" camera.start_preview()

sleep(15)

camera.capture('/home/pi/Desktop/image.jpg')

camera.stop_preview()"
```

On figure 2.10 you can see a new snapshot:

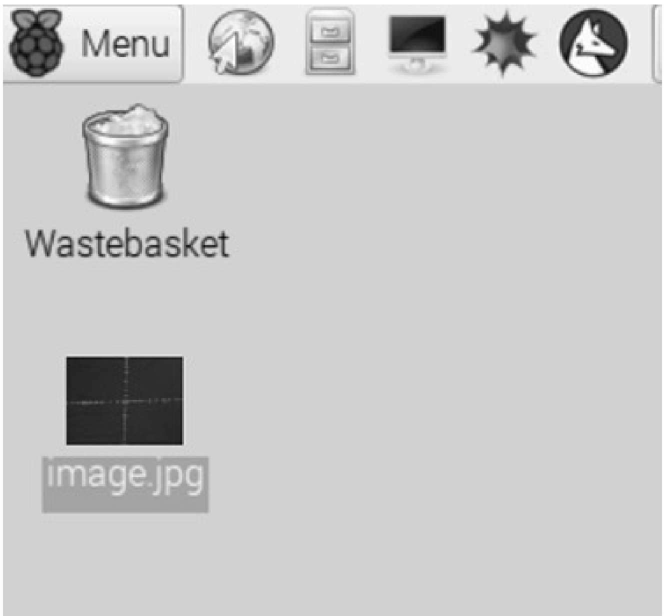


Fig. 2.10 As a result, we check the snapshot with camera. capture ()

Adding a loop and taking a couple of pictures, continue checking:

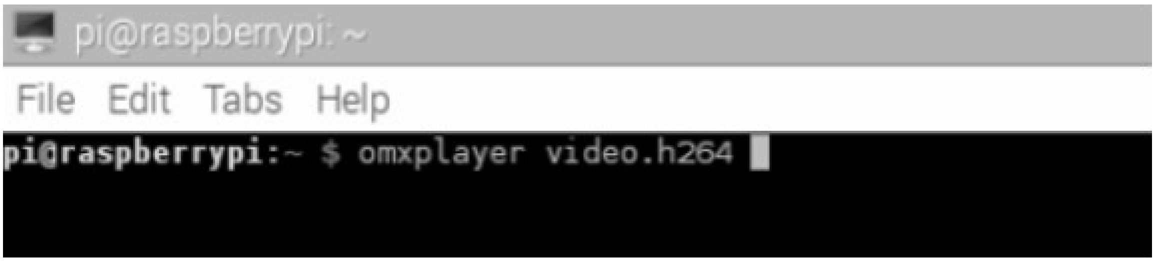
```
" camera.start_preview()

for i in range (15):

sleep (15)
```

```
camera.capture('/home/pi/Desktop/image%s.jpg' % i)

camera. stop_preview()"
```

You need to plug in a video transmission, e.g., for a minute, to centre it:

```
"stop_recording():

camera.start_preview()

camera.start_recording('/home/pi/video.h264')

sleep (60)

camera.stop_recording()

camera.stop_preview()"
```

In order to display the video, a specific codec must be entered in this work, this is "h.264", like on fig. 2.11:



```
pi@raspberrypi:~ $ omxplayer video.h264
```

Fig. 2.11 Appearance is described with the command "omxplayer video.264"

Also, the parameters related to the display of SMD components, such as brightness, contrast, rotation, stabilization, display modes selection of single-frame images and color effects should be changed.

The maximum resolution in video mode is 1920x1080, with a minimum frame rate of at least 15 frames per second:

```
camera.resolution = (2592, 1944)

camera.framerate = 15

camera.start_preview()

sleep(60)

camera.capture('/home/pi/Desktop/Mirae.jpg')

camera.

stop_preview()                                                    "
```

Effectiveness also depends on the balance of contrast and black and white images which used by the Mirae Mx-200p machine special camera, for which the operator uses the commands: fluorescent, auto, sunlight, flash.

In order to execute the code correctly after enabling the software on the raspberry pi, a video streaming task with the flask function must be generated. This is created to build the live video streaming. We need to return the live image from the camera to the monitor using a loopback device. You need to open a special function for streaming information from the generator. This utility is used in 3 tasks:

```
"z = gen ()
>>> z
<generator object gen at 0x7f06f3059c30
>>> z.next()
1
>>> z.next()
2
>>> z.next()
3
>>> z.next()”
```

```
Traceback (most recent call last):
“File "< miray>", line 1, in <module>
StopIteration"”
```

During this method, it is worth streaming together a large table of data without sorting and saving this data:

```
"from flask import Response, render_template

from app.models import Stock

def generate_stock_table():

field render_template('stock_header.html')

for stock in Stock.query.all():

field render_template('stock_row.html', stock=stock)

field render_template('stock_footer.html')

@app.route('/stock-table')

def stock_table():

return Response(generate_stock_table())"
```

The last step is for the operator to create a video stream from the installer to a conditional web page in the raspberry browser in real time. Mirae uploads itself over the local network with a specific port, the only thing you need to find out in the machine is the port address. A detailed description of the code is given below:

```
"#!/usr/bin/env python

from flask import Flask, render_template, Response

from camera import Camera

app = Flask(__mirae__)
```

```
@app.route('/')

def index():

return render_template('index.html')

def gen(camera):

while True:

frame = camera.get_frame ()

field (b'--frame\r\n')

b'Content-Type: image/jpeg\r\n\r\n' + frame + b'\r\n')

@app. route('/video_feed')

def video_feed ():

return Response (gen (Camera (),

mime type='multipart/x-mixed-replace; boundary=frame')

if __mirae__ == '__main__':

app.run (host='192.105.125.20', debug=True) "
```

Based on the past code, it is possible to build a dual route where the html page will be set with the video feed route thread, which in turn will return streaming responses to the raspberry.

All that is left to do is to implement the Camera class, which will have to connect to the camera hardware and load live video frames from it. The main thing about encapsulating the hardware dependent part of this application in a class is that this class can have different implementations for different people, while keeping the other part of the program the same. The operator thinks of this class as a device driver, provides a uniform implementation, regardless of the actual hardware used.

Another advantage of the camera class being separated from the rest of the program is that the application can easily be tricked into thinking there is a camera when in reality there is none, so the camera class can be implemented to do camera emulation without real hardware.

This will be the most efficient way to test streaming and not have to worry about the hardware until everything else is working. A simple emulation of the camera implementation can be seen below:

```
From time import time:

class Camera(object):

def __init__(self):

self.frames = [open(f + '.jpg', 'rb').read() for f in ['1', '2', '3']]

def get_frame(self):

return self.frames[int(time() % 3]"
```

This implementation reads three images from disk named 1.jpg, 2.jpg and 3.jpg and then returns them one after another several times at a rate of one frame per second. The get frame method uses the present time in seconds to determine which of the three frames is returned at any given moment.

This method for setting up video streaming on your Raspberry Pi is the most spectacular. to access live video from any automated machine, in our case the Mirae Mx-200p. The project turns your RPi's camera into a real-time webcam. It takes 7-10 minutes to set up the project with the source code.

2.4 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 an automatic process involves a more complex process prescribed in the code of a particular iteration. This you can see on fig. 2.12, part left include yes opinion, part right include right opinion.

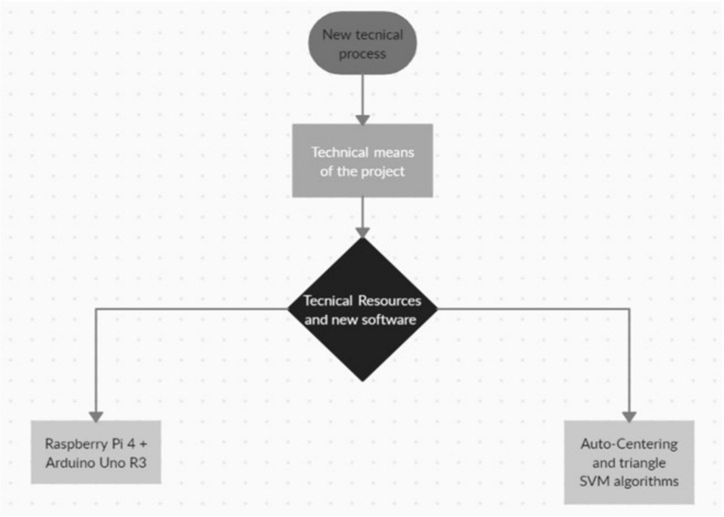

New tecnical process
Technical means of the project
Tecnical Resources and new software
Raspberry Pi 4 + Arduino Uno R3
Auto-Centering and triangle SVM algorithms

Fig. 2.12 The view of the system is described by the following graph

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.

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 max) and minimum (BV min) brightness in each block and calculate average brightness in lower (BV lower), upper (BV upper) and all blocks (BV mean). The scene can then be described by the following equation:

$$BV= a*BV*max+ b*BV*min+ c*BV*mean+ d*BV*upper+ e*BV*lower$$

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.

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.

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., 300dpi). 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.

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:

N2t=L·SK

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 [kdm2].

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.

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.

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.

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.

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[2]):
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.

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.

2.5 Types of technical toolkit for new development

In the optional connection set, the physical replacement of the "Raspberry Pi 4" with an "Arduino Uno R3" is considered to emulate this process out of production and to eliminate critical situations when the RPi first starts up. It is quite possible that the fact of breaking or stopping a program or sub-loading and creating a program inside the "Mirae Mx-200p" installer.

Reproducing this swap, the Arduino is connected to a separate camera module like "OV2732 sensor Optic Lens M12 King opt" on figure 2.13:

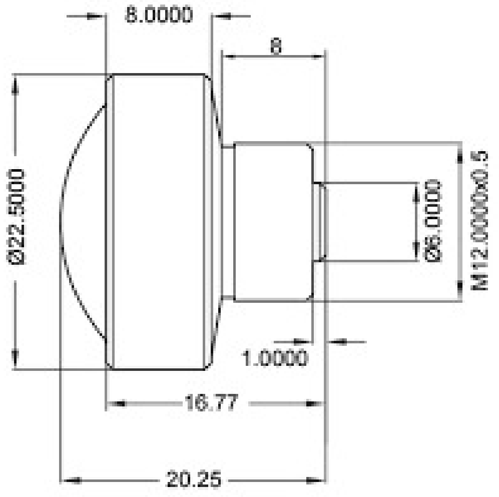


Fig. 2.13 OV2732 scheme

On fig 2.14 you can see TWX5-21 IR-Cut:

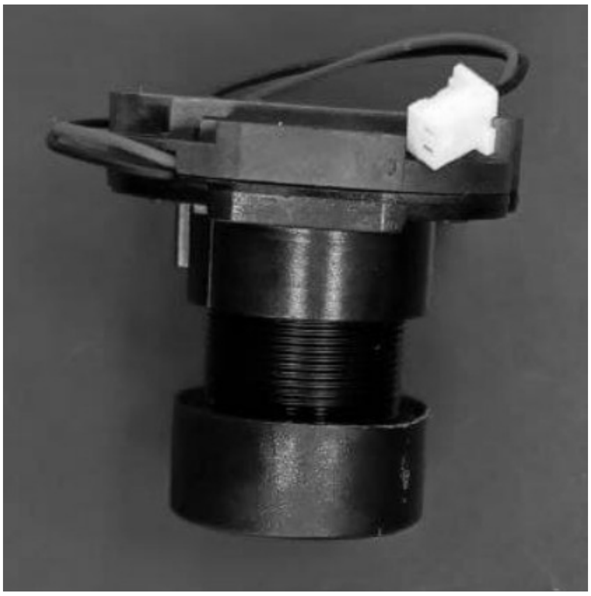


Fig. 2.14 Turn screws into the "TWX5-21-21-41(2024P) M12xP0.5 IR-Cut"

In this form, the lens camera module has 30 frames per second with a resolution of "640x480", with connection on fig. 2.15:

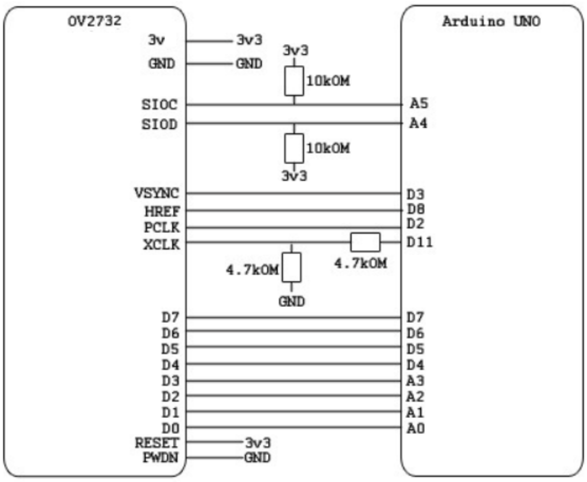


Fig 2.15 connection of the camera module to Arduino Uno R3

You need 2 4.7 and 10kOhm resistors with the I2C connections loaded, and two 4.7kohm resistors with voltage division on the clock signal.

The connection structure of the new algorithmic supply system via raspberry pi can be laid out one by one:

1. arranging the operation of the RPi camera, in the event of it being switched off:

"sudo raspi-config"

2. Install pip on the production RPi, using the function to set it:

"sudo apt-get install python-pip"

3. Loading the picamera library by loading the command:

"pip install picamera"

4. Installing the flask Python library, using the command:

"sudo pip install flask"

5. Upload a project with video streaming to the Flask domain, using the command with the edited app.py file:

```
"#!/usr/bin/env python

from flask import Flask, render_template, Response
```

The following is a discussion of camera emulation:

```
from camera import Camera
```

The camera module is selected and its further import is carried out:

Raspberry Pi camera module (requires picamera package)

```
from camera_pi import Camera
```

The desired streaming image transmission is attributed:

```
app = Flask(__mirae__)

@app. route ('/')

def index ():
```

Video streaming home page.

```
return render_template('index.html')

def gen(camera):
```

Video streaming generator function:

Display the main camera frame on the screen and adjust it further:

```
while True:

frame = camera.get_frame()

field (b'--frame\r\n')

b'Content-Type: image/jpeg\r\n\r\n' + frame + b'\r\n')

@app. route('/video_feed')

def video_feed():
```

```
return Response (gen (Camera ()),
mimetype='multipart/x-mixed-replace; boundary=frame')
if __name__ == '__main__':
app.run (host='0.0.0.0', debug=True, threaded=True)"
```

6. Change at the beginning of the line "#":

"#from camera import Camera"

Removing a comment in a line:

"From camera_pi import Camera"

7. Saving a file.

8. Using the IPconfig command to find the local IP address of Mirae RPi.

"inet addr: "mirae port" Bcast:192.168.0.255 Mask:255.255.255.0"

9. The flask server is initialized, using the python app.py.

10. In the stream the operator can see the port on which the server has been started and conducts the work, using a browser on any device it is now possible to monitor the installer remotely, the main thing is that the raspberry pi is connected to the wi-fi network. To see this, you need to enter the correct port address from http to its RPi.

11. In live video stream mode, the engineer sees the transmission being captured by the RPi.

You send live video streams to other devices using Motion JPEG, which only sends JPEG frames sequentially.

Modification of a code example to enable streaming video from a webcam using OpenCV. OpenCV uses Video Capture to return raw image bytes which are not JPEG, so the engineer needs to do an extra step of encoding the image bytes to JPEG and everything will work.

CHAPTER 3. YOLO NEURAL NETWORK ARCHITECTURE

3.1 Problem statement

The aim of this thesis is to evaluate the classification performance of the suitable deep learning models for real-time object recognition and tracking of construction vehicles.

The following objectives have been identified to fulfil the aim of this thesis work:

- To identify suitable and highly efficient deep learning models for real-time object recognition and tracking of construction vehicles.
- Evaluate the classification performance of the selected deep learning models.
- Compare the classification performance of the selected models among each other and present the results

Though the learning approach for construction vehicles is the same as for traditional transportation vehicles such as cars, when it comes to autonomous driving, there exist unique challenges for the construction vehicles as their surroundings (construction and excavation sites) and driving conditions are different compared to cars or other transportation vehicles. Additionally, the

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Performed	*Plodistyi B.O..*			*Intelligent system for printed circuit board production*	*N*	*Page*	*Pages all*
Supervisor	*Sineglasov V. M.*						
Consultant					*431 151*		
Normcontrol	*Tupitsyn N. F.*						
Accepted	*Sineglazov V. M.*						

characteristics and purpose of a construction vehicle is different from traditional transportation vehicle. Therefore, there needs to be research carried-out to evaluate the existing state-of-the-art deep learning models and identify the best deep learning model for the detection and tracking of objects in the construction/excavation environments, as only little research has been carried out in this area of study, to date.

Machine learning is one of the applications of Artificial Intelligence (AI) which enables the computers to learn on their own and perform tasks without human intervention [15].

There are numerous applications of machine learning algorithms in the field of computer vision. With the help of machine learning, formulation of

some of the most complex problems have been performed easily. Various computer programs which were previously programmed by humans, sometimes by-hand, are now being programmed without any human contribution with the help of machine learning [16]. In the recent years, due to remarkable increase in the availability of humongous sources of data and feasibility of computational resources, machine learning has become predominant with wide range of applications in our daily lives.

Before the advent of specialized neural networks, the approach used to detection of objects of given classes, it was usual to use an approach whereby the image was traversed by a sliding window, and a feature map was computed for each window position, e.g., a directional gradient histogram, or a pre-trained neural network, which was which was then fed into a classifier [5]. As a classifier, for example, a classifier based on support vector machines (SVM - support vector machine) could be used [6].

Nowadays, the problem of detection and classification of objects is usually solved by means of artificial convolutional neural networks. This is due to several reasons:

- significant progress in the field of graphics processors;

- large amount of data for training;

- better results in comparison with classical approaches;

- large number of specialised software packages for data preparation, training and neural networks.

Neural network architectures for object detection and recognition can be divided into two large groups:

1. architectures that process regions in the image (R-CNN).

2. architectures that process the whole incoming image (YOLO, SSD).

3.2 Artificial neural network

Artificial neural networks are a popular type of supervised learning model. A special case of a neural network called the convolutional neural network (CNN) is the primary focus of this thesis. The name 'Artificial Neural Networks' was given to this model because they were developed to imitate the neural function of the human brain. An artificial neural network consists of a set of neurons connected to each other and are grouped into layers to replicate the neural function of our brain [19].

Similar to the neurons in a human brain, the neurons in an artificial neural network function as units of calculation (see Figure 3.1). The connections between neurons are known as 'synapses' which are nothing but weighted values [20]. Therefore, in a simple sense, when an input value is provided at a neuron (x1, x2, ..., xn), it traverses the synapse, multiplying its value with the weighted value of the synapse (w1, w2, ..., wn) as shown in the Figure 3.1. Bias 'b' is then added to the summation of these values. This will be the output of the neuron. Since a neuron does not know its boundary, a mapping mechanism is required to map the inputs to

On this figure 3.1 you can see a Synapses signals:

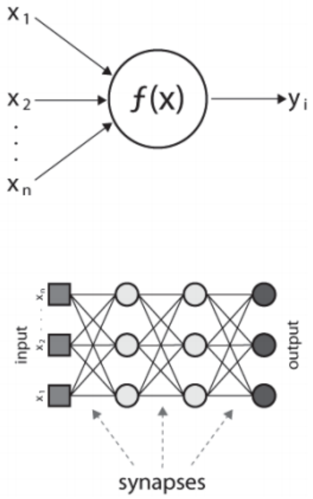


Fig. 3.1: Synapses signals

the output, known as the ‘Activation function’ [21]. In a fully connected feed-forward multi-layer network, all the outputs of a layer of neurons are fed as an input to every neuron of the next layer. As a result, some of layers get to process the original input data, while some layers get to process the data that has been obtained from neurons from the previous layer (see Figure 2.3). Therefore, the number of weights of any neuron in the network is equal to the number of neurons in the layer previous to the layer of the neuron in question [19].

$$y = \sum_{i=1}^{n} (w_n * x_n) + b \tag{2.1}$$

In the above equation, ‘x’ is the input value given at the neuron, ‘w’ is the weighted value of the synapse, ‘n’ is the number of neurons, ‘b’ is the bias and ‘y’ is the output of the network. Therefore, according to the equation (2.1), the value of output ‘y’ is equal to the summation of the product of the values of ‘x’ with their corresponding weights and bias ‘b’.

A multi-layered artificial neural network, as shown in the Figure 3.2, typically includes three types of layers: an input layer, one or more hidden layers and an output layer [19]. The input layer usually merely passes data along without modifying it. Most of the computation happens in the hidden layers. The output layer converts the hidden layer activation to an output, such as a classification. The outputs of each hidden layer serve as the inputs for the next hidden layer. The number of neurons in the output layer is equal to the number of classes trained for the neural network.

On this figure 3.2 you can see a structure of a one unit:

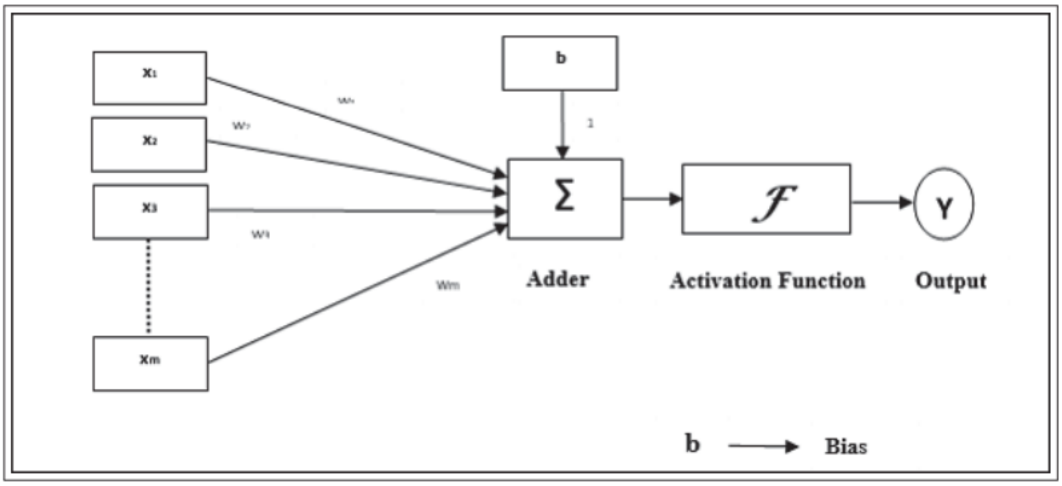


Figure 3.2: Structure of a single perceptron or neuron [4]

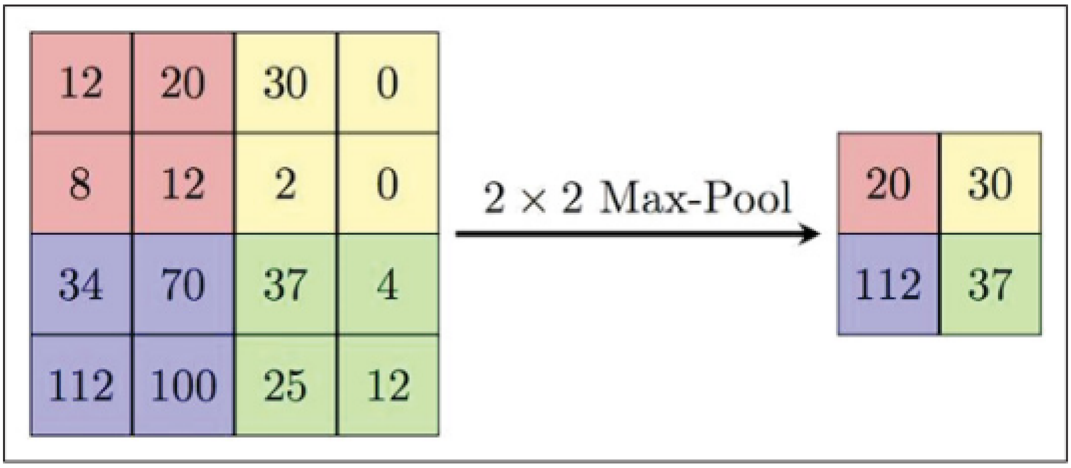
Though the artificial neural networks have shown predominant applications in various fields and aided in achieving groundbreaking innovations during recent times, the concept of neural networks is quite old. The neural networks were previously known as ‘perceptrons’ and have been in action since the 1940s [22]. They were not popular as they are now due to the fact that they were single layered and required high computational power and data which was difficult to find during that time. They have come to limelight mainly due to the inception of a technique known as ‘Backpropagation’. The technique was first put forth by Rumelhart et al. in the year 1986 [23]. Using this technique, networks can rearrange the weights of hidden layers in case the output is different from the expected output. The error is calculated and backpropagated to all the layers of the network to adjust the weights according to the requirement [22].

3.3 Convolutional and pulling layer description

A convolutional neural network consists of one or more convolutional layers. These layers can either be pooled or fully connected [35]. A convolutional layer generally executes tasks that require heavy computation. It comprises of a set of filters that have the ability to learn. Though the filters are small in size, they reach to the entire depth of the input. The dimensions of a filter are generally represented by $l * w * d$, where ‘l’ denotes the height of the length of the filter, ‘w’ denotes the width while ‘d’ denotes the depth of the feature filter which is equal to the number of color channels present.

In general, the convolution process is executed by a feature filter upon sliding on the input layer of the neural network, as a result of which a feature map is generated. The layer executing the convolution process is known as a convolutional layer. Hence, the networks that consist of convolutional layers are called as convolutional neural networks. As shown in the Figure 2.4, in the initial stages, the input layer is searched for any specific pattern by the filter. During the training of the algorithm, the filter searches for the sake of learning to recognize a pattern which eventually becomes a search to validate the existence of a specific pattern, during the testing stages. In reality, many feature filters exist, learning to recognize various patterns.

Pooling layers are also an important component of a convolutional neural network. The main function of a pooling layer is to decrease the number of parameters and computation present in the network by decreasing the spatial size gradually and continuously. This action is necessary to cut down the features that the filter has learnt and no longer requires the whereabouts of their location. There are many benefits using a pooling layer such as limiting of over-fitting, which is a state that occurs when the algorithm fits the data very closely by showing low bias and high variance. Though there are various types of pooling, max pooling is one of the most popular ones in practice. This type of pooling conveniently down-samples the layer while keeping the depth constant. Figure 3.2 shows the depiction of a pooling layer while Figure 2.6 provides an example of a 2x2 map pooling.



12	20	30	0
8	12	2	0
34	70	37	4
112	100	25	12

20	30
112	37

Fig. 3.2 Example of 2x2 Max-Pooling [7]

3.4 Architecture of YOLO neural network

In [7, 8, 9] the architecture of the neural network object detector called YOLO and its modifications are presented. The YOLO architecture was originally developed for real-time tasks. In the algorithm. YOLO algorithm divides the image into cells using a grid. For each grid cell, the probability of the presence of an object in general is estimated, then several most likely positions of the object are constructed as rectangles centered in that cell, and then for each resulting rectangle the estimation of the probabilities of presence of objects of each class under consideration in that rectangle.

In the YOLO method, the detection results are represented as a 7×7×1024 tensor. Estimating the probability of finding an object of a particular class in the current enveloping rectangle is the product of the probability estimate of an object in the cell and the probability estimate for the particular class.

In the case of YOLOv3 [9], a convolutional neural network, which consists of 53 layers, with convolutions of 3×3 and 1×1 and Residual blocks that add values from the output of the previous layer to the output of the current layer.

It is also worth noting that in YOLOv3 the detection objects is performed at three scales, which increased the quality of detection of small objects. The network scales the input image until reaches the first level of detection, at which point the filter step is equal to 32. In the subsequent convolution layers, the filter step is equal to 2. At each detection scale, the cell predicts three framing rectangles, i.e. given the scale, each cell corresponds to 9 framing rectangles.

In the next step, the rectangles are filtered by the probability of finding objects in them. Then just as in the SSD architecture, the rectangles are filtered using the algorithm for suppressing false maximums suppression algorithm.

It is known that most recognition algorithms assume that output labels are mutually exclusive. In the YOLOv1 [7] and YOLOv2 [8] apply a softmax function [10] to convert estimates into class probabilities, summing which over all classes gives one. YOLOv3 uses classification with multiple labels.

For example, the output labels can be "Pedestrian" and "Child" which are not mutually exclusive and the sum of the outputs can be greater than 1. In YOLOv3 softmax activation function is replaced by independent logistic classifiers to calculate the probability of an output belonging to a particular label.

Instead of using the root mean square error in calculating classification loss, YOLOv3 uses a binary cross-entropy loss function computed for each class. Using this technique also reduces the amount of computation required.

The state-of-the-art object detector YOLOv3 is designed to achieve high accuracy along with real-time performance. YOLOv3 is an improvement over the previous version of YOLO. It uses a single neural network, which predicts the objects position and class score in a single iteration. This is achieved by considering object detection problem as a regression problem, which in turn changes the input images to their corresponding class probabilities and positions. YOLO generates Many S x S grids from the input image and boundary boxes B are predicted, which consists of height, width, box center x and y. Each of these boxes have their own P (object probability) value and predicts the number of classes in it as C and has a conditional class probability Pclass in the S x S having an object in it. The overall prediction of the network is S x S x (Bx5 + C) in which the digit 5 represents each box coordinates as 4 and 1 as object probability. During the test, the network computes the number of classes present in each grid by using the equation (2.2). Pmin is defined at the start of the test and system detects only the objects whose Pclass > Pmin. During the post-processing stage, the duplicated detection of the same object is omitted using non-maximal suppression.

$$P(class_i) = P(class_i)|object * P(object) \qquad (2.2)$$

On this figure 3.3 we can see an image splitting and bounding prediction:

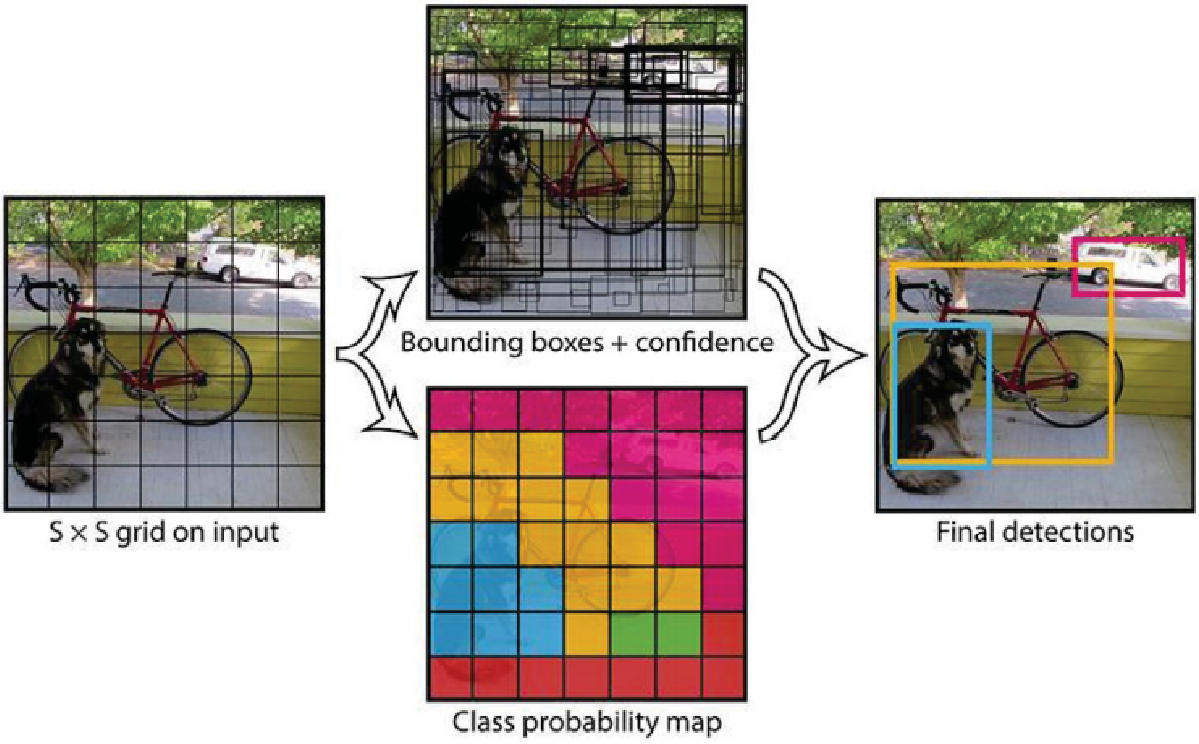


Fig. 3.3 Image Splitting and Bounding-boxes Prediction [8]

YOLOv2 used a feature extractor known as the Darknet-19, which consisted of 19 convolutional layers. The newer version of this algorithm, YOLOv3 uses a new feature extractor known as Darknet-53 which, as the name suggests, uses 53 convolutional layers while the overall algorithm consists of 75 convolutional layers and 31 other layers making it a total of 106 layers [36]. Pooling layers have been removed from the architecture and replaced by another convolutional layer with stride ‘2’, for the purpose of down-sampling. This key change has been made to prevent the loss of features during the process of pooling. Figure 2.8 which is created by ‘CyberailAB’ clearly depicts the architecture of YOLOv3 algorithm.

YOLOv3 performs detections at three different scales, as shown in the Figure 2.8. 1 x 1 detection kernels are applied on the feature maps with three unique sizes located at three unique places in the network. The shape of the detection kernel is 1x1x (B ∗ (4 + 1 + C)), where ‘B’ is the number of bounding boxes that can be predicted by a cell located on the feature map, ‘4’ represents the number of bounding box attributes, ‘1’ represents the object confidence and ‘C’ represents the number of classes. Figure 2.7 depicts the splitting of an image and bounding-box prediction in YOLOv3 and Figure 2.8 depicts the architecture of YOLOv3 algorithm trained on COCO dataset which has 80 classes and bounding boxes are considered to be 3. Therefore, the kernel size would be 1 x 1 x 255 [37]. In YOLOv3, the dimensions of the input image are down sampled by 32, 16 and 8 to make predictions at scales 3,2 and 1 respectively.

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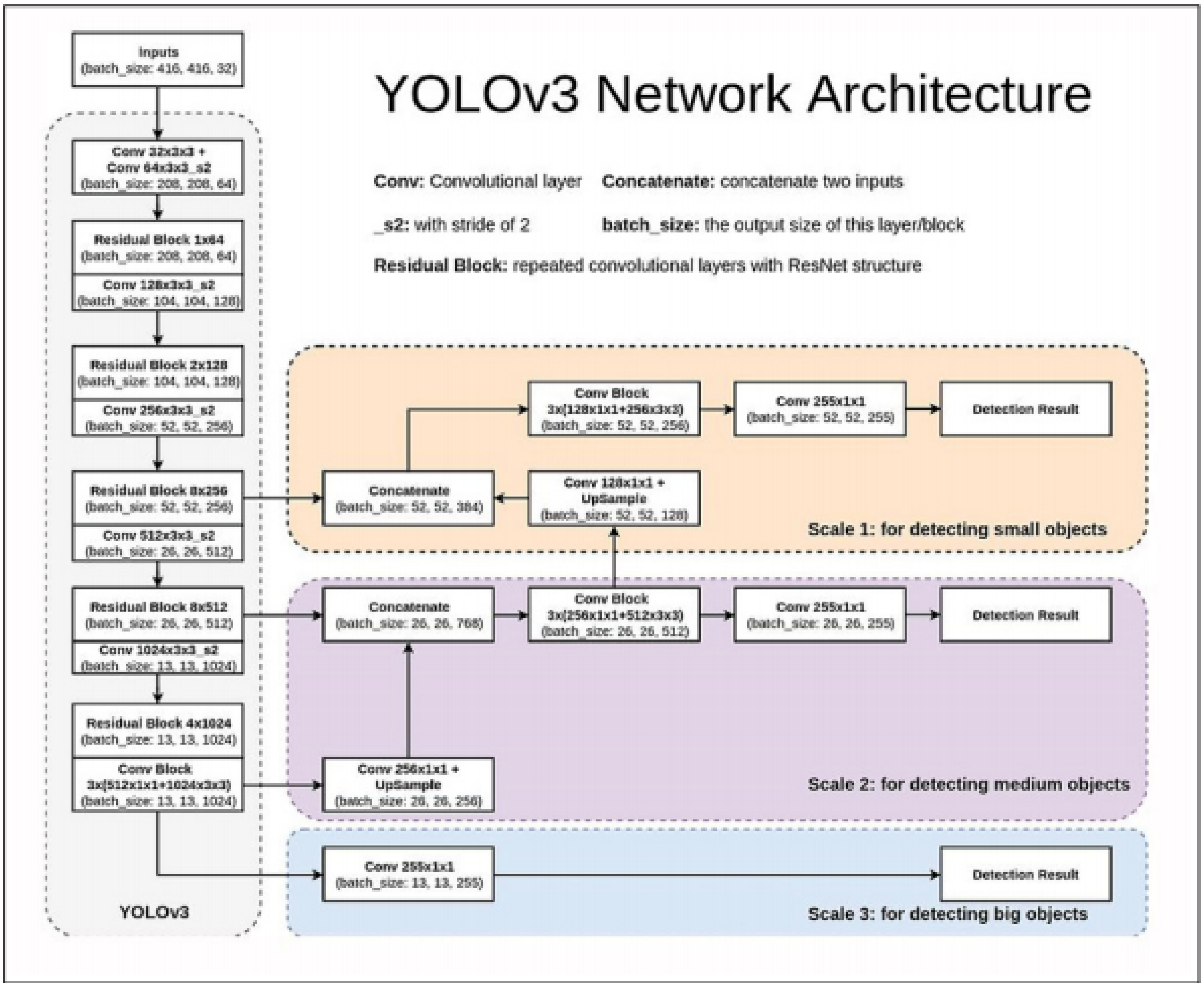

YOLOv3 Network Architecture
Conv: Convolutional layer
Concatenate: concatenate two inputs
_s2: with stride of 2
batch_size: the output size of this layer/block
Residual Block: repeated convolutional layers with ResNet structure
Inputs (batch_size: 416, 416, 32)
Conv 32x3x3 + Conv 64x3x3_s2 (batch_size: 208, 208, 64)
Residual Block 1x64 (batch_size: 208, 208, 64)
Conv 128x3x3_s2 (batch_size: 104, 104, 128)
Residual Block 2x128 (batch_size: 104, 104, 128)
Conv 256x3x3_s2 (batch_size: 52, 52, 256)
Residual Block 8x256 (batch_size: 52, 52, 256)
Conv 512x3x3_s2 (batch_size: 26, 26, 512)
Residual Block 8x512 (batch_size: 26, 26, 512)
Conv 1024x3x3_s2 (batch_size: 13, 13, 1024)
Residual Block 4x1024 (batch_size: 13, 13, 1024)
Conv Block 3x(512x1x1+1024x3x3) (batch_size: 13, 13, 1024)
YOLOv3
Conv Block 3x(128x1x1+256x3x3) (batch_size: 52, 52, 256)
Conv 255x1x1 (batch_size: 52, 52, 255)
Detection Result
Concatenate (batch_size: 52, 52, 384)
Conv 128x1x1 + UpSample (batch_size: 52, 52, 128)
Scale 1: for detecting small objects
Concatenate (batch_size: 26, 26, 768)
Conv Block 3x(256x1x1+512x3x3) (batch_size: 26, 26, 512)
Conv 255x1x1 (batch_size: 26, 26, 255)
Detection Result
Conv 256x1x1 + UpSample (batch_size: 26, 26, 256)
Scale 2: for detecting medium objects
Conv 255x1x1 (batch_size: 13, 13, 255)
Detection Result
Scale 3: for detecting big objects

Fig. 3.4: The Architecture of YOLOv3 [9]

In the Figure 2.8, the size of the input image is 416 x 416. As mentioned in the earlier section, the total number of layers in YOLOv3 is 106. As shown in the network architecture diagram Figure 2.8, the input image is down sampled by the network for the first 81 layers. Since the 81st layer has a stride of 32, the 82nd layer performs the first detection with a feature map of size 13 x 13. Since a 1 x 1 kernel is used to perform the detection, the size of the resulting detection feature map is 13 x 13 x 255 which is responsible for the detection of objects at scale 3.

Following this, the feature map from 79th layer is up sampled by 2x after subjecting it to a few convolutional layers, resulting in the dimensions 26 x 26. This is then concatenated with the feature map from 61st layer. The features are fused by subjecting the concatenated feature map to a few more 1 x 1 convolutional layers. As a result, the 94th layer performs the second detection with a feature map of 26 x 26 x 255, which is responsible for the detection of objects at scale 2.

Following the second detection, the feature map from 91st layer is up sampled by 2x after subjecting it to a few convolutional layers, resulting in the dimensions 52 x 52. This is then concatenated with the feature map from 36th layer. The features are fused by subjecting the concatenated feature map to a few more 1 x 1 convolutional layers. As a result, the 106th layer performs the third and final detection with a feature map of 52 x 52 x 255, which is responsible for the detection of objects at scale 1. As a result, YOLOv3 is better at detecting smaller objects when compared to its predecessors YOLOv2 and YOLO.

3.5 Architecture of faster R-CNN

Faster R-CNN [38] by Ren et al. is an integrated method. The main idea is to use shared convolutional layers for region proposal generation and for detection. The authors discovered that feature maps generated by object detection networks can also be used to generate the region proposals. The fully convolutional part of the Faster R-CNN network that generates the feature proposals is called a Region Proposal Network (RPN). The authors used Fast R-CNN architecture for the detection network.

A Faster R-CNN network is trained by alternating between training for Region of Interest (RoI) generation and detection. First, two separate networks are trained. Then, these networks are combined and fine-tuned. During fine-tuning, certain layers are kept fixed and certain layers are trained in turn. Figure 2.9 represents a simple depiction of the structure of Faster R-CNN model. It typically comprises of three neural networks namely a Feature Network, a Regional Proposal Network and a Detection Network [38].

The Feature Network is responsible for generating good features from the input images while maintaining the original attributes of the input image in the output, such as shape and structure. An image classification network generally takes the role as a Feature Network [39].

The Regional Proposal Network (RPN) comprises of three convolutional layers, a layer each for classification and bounding box regression while the third one is a common layer that feeds into these two layers. The Regional Proposal Layer is responsible for generating numerous bounding boxes that have a high probability of including an object. These bounding boxes are also called as Region of Interests (ROIs) [38]. A bounding box is identified using the co-ordinates of the pixels located at two diagonal corners of the box, followed by a value of 1, 0 or -1. A value of 1 indicates that there is an object present in that particular bounding box. Similarly, a value of 0 indicates that there is no object present while a value of -1 indicates that the particular bounding box can be ignored [39].

The Detection Network is responsible for generating the final class and its corresponding bounding box by taking the input from both the Feature Network and Regional Proposal Network [38]. The Detection Network generally comprises of a classification layer and a bounding box regression layer. Additionally, a pair of stacked common layers are shared among the two layers. These four layers are fully connected layers. The features are cropped as per the bounding boxes so that the network classifies only the internal part of the bounding boxes [39].

Using shared convolutional layers, region proposals are computationally almost cost free. Computing the region proposals on a CNN has the added benefit of being realizable on a GPU. Traditional RoI generation methods, such as Selective Search, are implemented using a CPU. For dealing with different shapes and sizes of the detection window, the method uses special anchor boxes instead of using a pyramid of scaled images or a pyramid of different filter sizes. The anchor boxes function as reference points to different region proposals centered on the same pixel.

In the architecture diagram of Faster R-CNN shown in Figure 2.10, the trained network receives a single image as input. In this case, the Feature Network is VGG, which is an image classification network. The shared fully convolutional layers of this network generate good feature maps from the input image while maintaining the size and structure of the original image in the output of this network.

The resulting feature maps are fed into the Regional Proposal Network (RPN). Here, a number of bounding boxes are generated by a mechanism called as anchor boxes. Anchors are nothing but the pixels present on the feature image. In general, 9 boxes of different shapes and sizes, with the anchor as their center, are generated for each anchor. This layer feeds into the classification (detection) layer and bounding box regression layer. Non-Maximum Suppression (NMS), which is an operation to reduce the number of boxes by removing the boxes that are overlapping with other boxes that have a high score based on the probability of containing an object, is applied.

These probability scores are later normalized using SoftMax function. The resulting bounding boxes (ROIs) are fed into the Detection Network along with the output of the Feature Network. Since the resulting feature maps can be of various sizes, ROI pooling layer is introduced to crop and scale the features to 14 x 14. These features are later max-pooled to 7 x 7 and fed into the Detection Network in the form of batches. The pair of stacked common fully connected layers, along with the classification layer and bounding box regression layer can be seen in the Figure 3.5. The output of this network is the generation of final class and its corresponding bounding box.

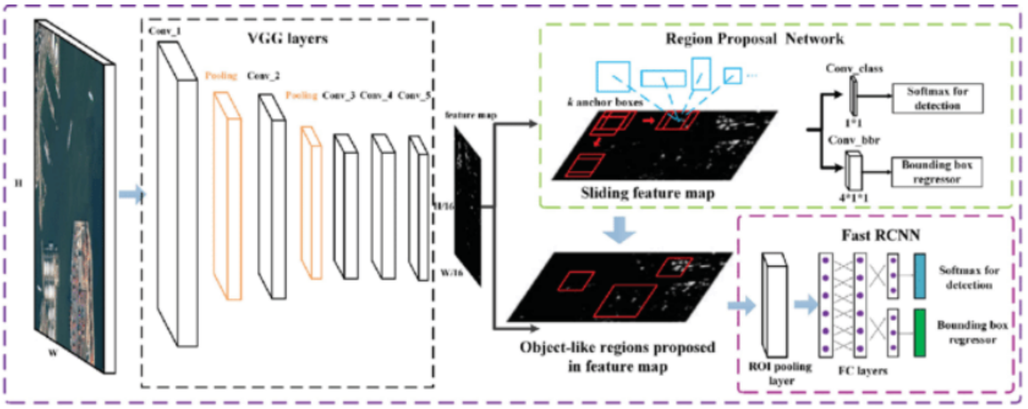


Fig. 3.5: The Architecture of Faster R-CNN [11]

CNNs are the best suited deep learning algorithm for real-time object detection and recognition. From the knowledge gathered, it is evident that most of the research and development of autonomous driving systems is being implemented on transportation vehicles such as cars while only a little research is being carried-out to evaluate the existing state-of-the-art deep learning models and identify the best deep learning model for the detection and tracking of objects in the construction/excavation environments, as only little research has been carried out in this area of study, to date Therefore, this thesis will be using CNN models to recognize small scale vehicles at real-time to evaluate the performance of these algorithms and as a step towards future innovations.

On fig. 3.6 you can see architecture of Tiny-YOLOv3:

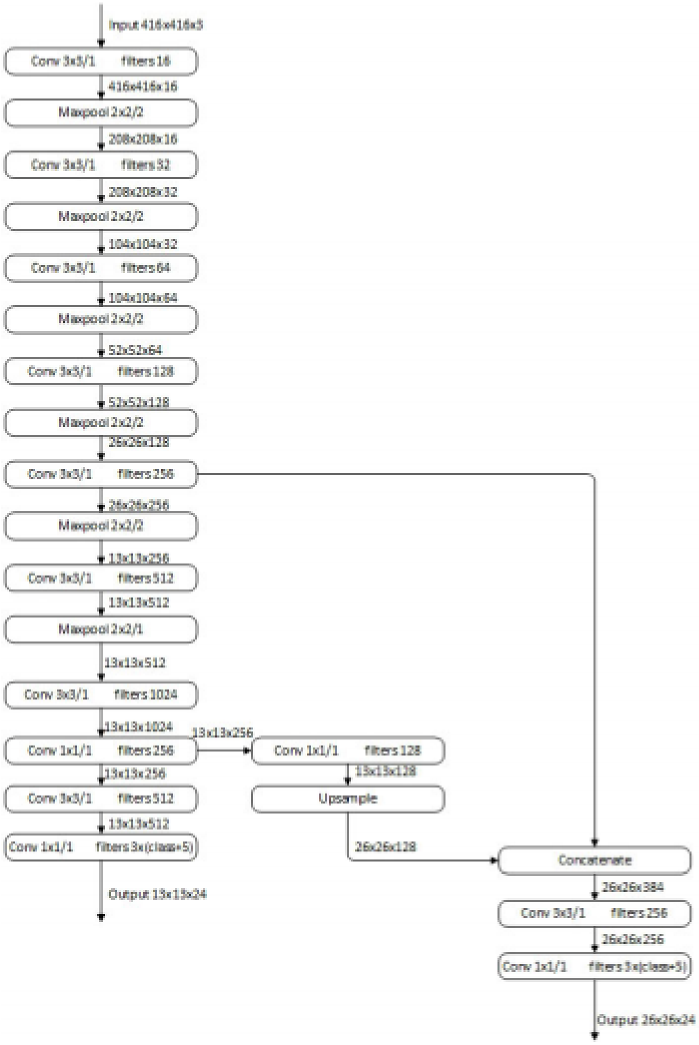
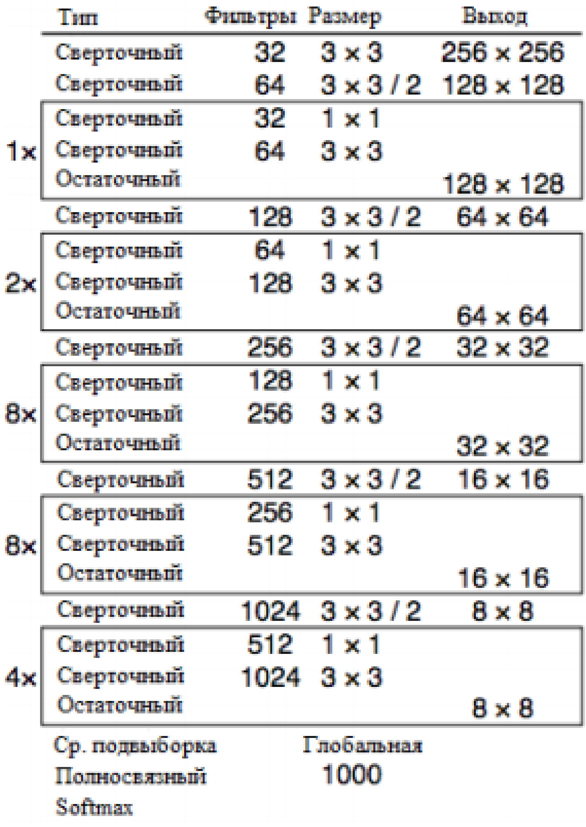


Fig. 3.6: Architecture of Tiny-YOLOv3 [12]

The structure of YOLO v.3.0 is based on the Darknet-53 model [3]. The overall layer-by-layer structure of Darknet-53 is shown in Figure 3.7.

YOLO is a convolutional neural network of composite structure. The model is based on the Darknet framework [3, 12] written in C++ programming language. It provides the entire logical structure of the computations required to run the model and train it.



	Тип	Фильтры	Размер	Выход
	Сверточный	32	3 × 3	256 × 256
	Сверточный	64	3 × 3 / 2	128 × 128
1×	Сверточный	32	1 × 1	
	Сверточный	64	3 × 3	
	Остаточный			128 × 128
	Сверточный	128	3 × 3 / 2	64 × 64
2×	Сверточный	64	1 × 1	
	Сверточный	128	3 × 3	
	Остаточный			64 × 64
	Сверточный	256	3 × 3 / 2	32 × 32
8×	Сверточный	128	1 × 1	
	Сверточный	256	3 × 3	
	Остаточный			32 × 32
	Сверточный	512	3 × 3 / 2	16 × 16
8×	Сверточный	256	1 × 1	
	Сверточный	512	3 × 3	
	Остаточный			16 × 16
	Сверточный	1024	3 × 3 / 2	8 × 8
4×	Сверточный	512	1 × 1	
	Сверточный	1024	3 × 3	
	Остаточный			8 × 8
	Ср. подвыборка		Глобальная	
	Полносвязный		1000	
	Softmax			

Fig. 3.7 Layer-by-layer structure of Darknet 53

In the next chapter considering the algorithmizing and an example of tuning the YOLO neural network. With accuracy graphs you can see changes between both neural networks.

CHAPTER 4. YOLO NETWORK ALGORITHMIZATION

4.1 Algorithmizing YOLO detection network

In the detection phase, the neural network brings the original image to a given square size and divides it into square blocks based on the hyperparameter S. Their number i is calculated as SxS. Each block at the detection stage produces a prediction about the objects whose centres are located inside the block. The prediction includes the coordinates of the centre of the object within the block and its dimensions. The number of predictions that each block produces is the hyperparameter Q.

Thus, in the process of image in-blocking we get a matrix from each block:

$$B = \begin{pmatrix} x_1 y_1 h_1 w_1 c_1 \\ \vdots \ \vdots \ \vdots \ \vdots \ \vdots \\ x_q y_q h_q w_q c_q \end{pmatrix}, \qquad (1)$$

Where $x_{i,}$ y_i – coordinates of i_n object (in pixels);

h_i, w_i - height and width of the object respectively (in pixels);

c_i - confidence indicator;

Each unit also makes a class prediction based on the features highlighted in the convolution process. Depending on the number of classes that have been initialized in the network during training, the number of output indicators will also differ. Thus, the output is a vector p per image block:

$$p=(p1,p2,...,pk) \qquad (2)$$

where, p_i – class ith probability in the unit;

k - all quality of the classes;

It is then decided whether or not there is an object inside the block. The decision is made according to the following rule:

$$(\exists i \in B) c_i > t, \tag{3}$$

Where c_i – confidence i_n indicator, t - given confidence threshold.

If there is at least one prediction whose confidence level is a given threshold t, the decision is made as to whether there is an object within the block. Its true coordinates and dimensions are defined as:

$$\begin{aligned} d_j &= d_i, & d_i &\in B_j, \\ c_i &= \max(c_k), & c_k &\in B_j, \end{aligned} \tag{4}$$

Where, $d_{j\,–}$ one of the indicator (x,y,w or h) jth object;

C_k – indicator a measure of the confidence of the kth forecast within a locale;

B_j - matrix B for a given site.

The class of this object is defined as:

$$a_j = h, \quad p_h = \max(\overrightarrow{p_j}) = \max(p_{j1}, p_{j2}, \ldots, p_{jk}), \quad h = \overline{1, k}, \tag{5}$$

Where a_j – class jth object;

P_j – vector is the probability vector of the class corresponding to jth block.

Thus each block of the image generates either one object or none. The final set of objects forms the output matrix:

$$V = \begin{pmatrix} x_1\, y_1\, h_1\, w_1\, a_1 \\ \vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots \\ x_m y_m h_m w_m a_m \end{pmatrix}, \qquad (6)$$

Where, x_i, y_i – coordinates of jth object (in pixels);

h_i, w_i – height and width of the object respectively (in pixels);

a_i – number, which corresponds to the class of this object.

When processing frame by frame, we get a constantly updated sequence of recognised objects V. Further processing of these objects to obtain the trajectories of each of the objects in this way turns into a problem of associating the objects of two consecutive frames V_i and V_{i-1} (Figure 5).

The list of objects is not constant. In the traffic detection task in question, new objects are constantly appearing on the frame and old ones are disappearing at the same rate. Moreover, neural network detection still has a certain degree of error - an object may not be recognized in one frame, but reappear in the next.

In order to ensure that the list of objects is always up-to-date, the comparison V_i - ith list of the objects - is not made with V_{i-1}, but with a constantly updated list of objects V'. Objects are only removed from V' when the number of consecutive frames in which the object is absent passes the threshold of 1.

The general detection algorithm is shown below.

1) A list of objects V_i is obtained.

2) Association between objects V_i and V'.

3) Adding new objects from V_i to V'.

4) Removal of old objects from V'.

Association between V_i and V' objects is done by using centroid analysis. For each object in V_i, the closest object in V' is found. Euclidean metric for two-dimensional space is used to estimate distances between objects:

$$dist_j = \min\left(d(v_j, v'_k)\right) = \min\{d(v_j, v'_1), d(v_j, v'_2), \dots, d(v_j, v'_m)\} =$$
$$= \min\left\{\sqrt{(x_j - x_1)^2 + (y_j - y_1)^2}, \dots, \sqrt{(x_j - x_m)^2 + (y_j - y_m)^2}\right\} \quad (7)$$

Where $dist_j$ – is the minimum distance of v_j;

V_j – jth object from V_i;

V'_k – kth object from V'.

All objects V_i are then sorted according to their respective d_j values. Each object, starting from the objects with the smallest d_j, is matched with the nearest to it object V'. The association is performed only for those objects whose shortest distance does not exceed the threshold calculated as:

$$\Delta = l \times \sqrt{w^2 + h^2}, \qquad (8)$$

Where l – frames amount, on which an object was missed;

w – fixed width of the object (in pixels);

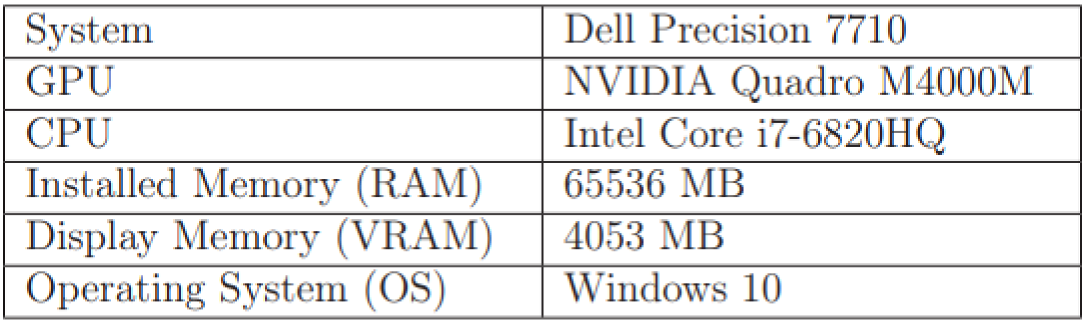
h – his high (in pixels).

Each object V' that has not been matched with an object from V_i is marked as missing from the frame. If an object is missing for 5 consecutive frames, it is declared as having left the frame and is removed from V'.

All objects from V_i for which no matching was found are added to V_i as new objects not previously fixed.

In this chapter, the main algorithms involved in the system under development have been discussed and a timeline has been given.

An experiment has been selected as the research method to answer the RQ2. An experiment has been chosen as the research method because when it comes to dealing with quantitative data, experiment is considered to be the best method. The main goal of this experiment is to evaluate the deep learning models for object recognition and tracking of construction vehicles in real-time, the deep learning models being the ones selected from the literature review.

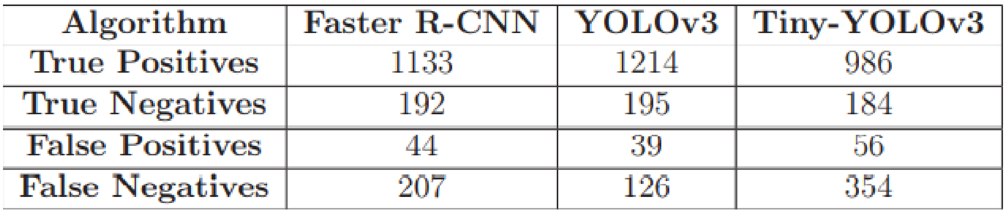


System	Dell Precision 7710
GPU	NVIDIA Quadro M4000M
CPU	Intel Core i7-6820HQ
Installed Memory (RAM)	65536 MB
Display Memory (VRAM)	4053 MB
Operating System (OS)	Windows 10

Table 4.1: Hardware Environment

4.2 Algorithm accuracy

The number of true positives, true negatives, false positives and false negatives that have been obtained by the models on the test video have been presented in the Table 4.1.



Algorithm	Faster R-CNN	YOLOv3	Tiny-YOLOv3
True Positives	1133	1214	986
True Negatives	192	195	184
False Positives	44	39	56
False Negatives	207	126	354

Table 4.2: Calculated Values of the Algorithms

From the values presented in the Table 4.1, the accuracy of the models has been calculated to be 84.07%, 89.51%, 74.05% respectively for Faster R-CNN, YOLOv3 and tiny YOLOv3 and it is visualized in Figure 4.1. The reason for the accuracy score of YOLOv3 being higher is because of its architecture where the object detections are performed at three different scales, making YOLOv3 more efficient in detecting smaller objects or detecting objects in difficult scenarios such as objects appearing partly in a certain frame. Since in certain scenarios, the objects are located on the farther side of the scaled site, they appear smaller. As a result, Faster R-CNN struggled to predict the objects with higher accuracy during these scenarios. Therefore, it can be said that the YOLOv3 model is highly accurate in the real-time detection and tracking of the construction vehicles – Hauler, Wheel Loader and Excavator at the scaled construction site environment.

Since the F1 score of a model is defined as the harmonic mean of precision and recall, it is essential that they are calculated prior to the calculation of the F1 score.

Precision:

The precision of a model is dependent on the number of true positives and number of false positives. The number of true positives and false positives have been obtained by models on the test video.

From the values presented in the Table 4.2, the precision of the models has been calculated as 0.9626, 0.9688, 0.9462 respectively for Faster R-CNN, YOLOv3 and Tiny-YOLOv3. The precision of YOLOv3 is higher that Faster R-CNN and TinyYOLOv3 is because, its predictions are very precise as it can detect at three different scales, whereas Faster R-CNN and Tiny-YOLOv3 struggled to show correct prediction where the size of the object is considerably small.

Therefore, it can be concluded that the precision of YOLOv3 in real-time detection and tracking of the construction vehicles is really good.

On fig. 4.2 you can see accuracy of different representations:

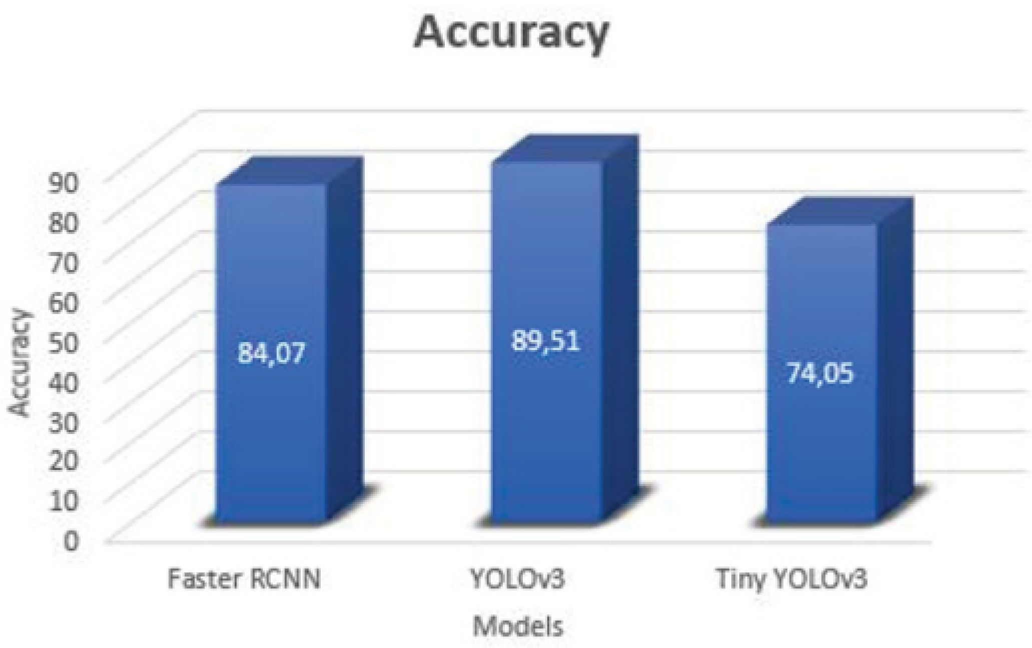
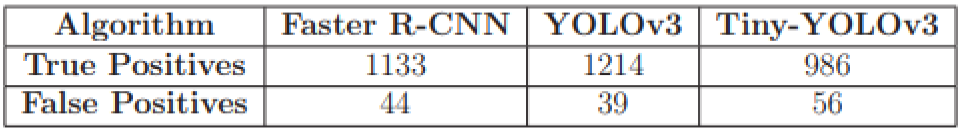


Figure 4.2: Graphical Representation of Accuracy



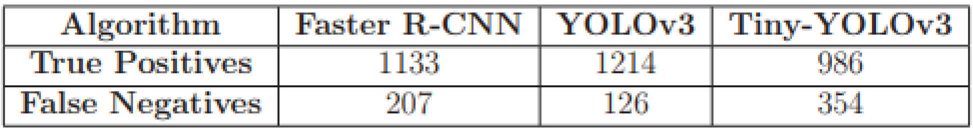
Algorithm	Faster R-CNN	YOLOv3	Tiny-YOLOv3
True Positives	1133	1214	986
False Positives	44	39	56

Table 4.3: Calculated Values of the Algorithms

scales, whereas Faster R-CNN and Tiny-YOLOv3 struggled to show correct prediction where the size of the object is considerably small. Therefore, it can be concluded that the precision of YOLOv3 in real-time detection and tracking of the construction vehicles is really good.

Recall

The recall of a model is dependent on the number of true positives and number of false negatives. The number of true positives and false negatives have been obtained by the models on the test video.



Algorithm	Faster R-CNN	YOLOv3	Tiny-YOLOv3
True Positives	1133	1214	986
False Negatives	207	126	354

Table 4.4: Calculated Values of the Algorithms

From the values presented in the Table 4.3, the recall of the models has been calculated as 0.8455, 0.9059, 0.7358 respectively for Faster R-CNN, YOLOv3 and tiny YOLOv3. The recall values for Faster R-CNN and Tiny-YOLOv3 is lower than YOLOv3 as they have shown incorrect detections in many frames where the object is farther away or the size of the object is smaller, while YOLOv3 provided better results. Therefore, it can be concluded that the recall of YOLOv3 in real-time detection and tracking of the construction vehicles is really good compared to other models selected.

On fig. 4.3 you can see a graphical representation of F1 scope:

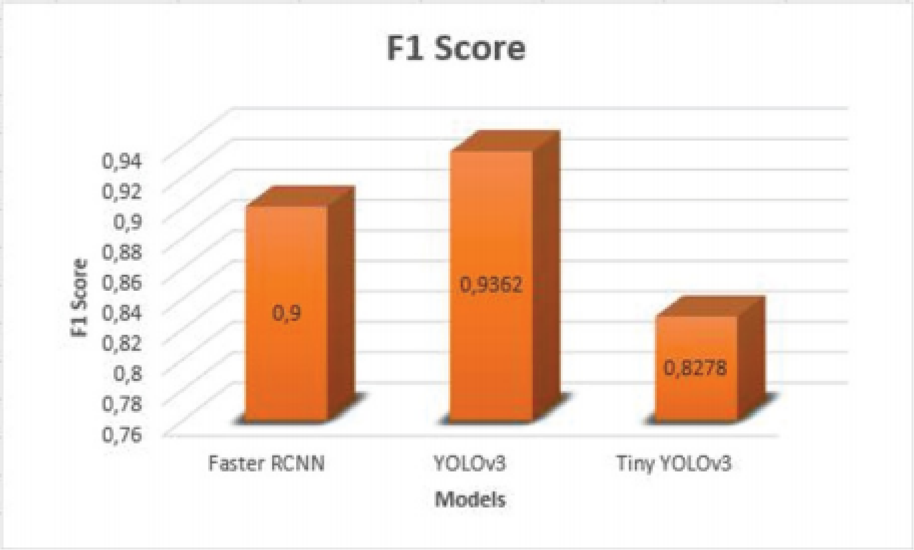


Figure 4.3: Graphical representation of F1 score

Using the Precision and Recall values obtained from the previous steps, the F1 score of the Faster R-CNN, YOLOv3 and tiny YOLOv3 models has been calculated as 0.9, 0.9362 and 0.8278 respectively and it is visualized in figure 4.2. Since the performance of the model is directly proportional to the F1 score and the upper limit of the F1 score being 1, it can be said that the performance of YOLOv3 model in real-time detection and tracking of the construction vehicles at the scaled site is higher than other models used in this experiment.

Additional code:

Software development must be created on Raspberry Pi compatible systems and Python language. The project work done depends entirely on the above technical and software methods, which are suitable for point-to-point performance improvement in the SMD department. It is not impossible to implement hybrid code or derive new systems using Java Script or C++, as the systems will have a more open structure, but will take more time to configure the algorithms and implement them in the processes of the electrical machines.

4.3 Software project additional code

Coding algorithms:

```
if len(d) > 1:
    if d[0][0] > 0.5 and ttime - d[-1][0] > 0.5:
        min_idle = min(d[0][0], ttime - d[-1][0])
    elif d[0][0] > 0.5 and ttime - d[-1][0] < 0.5:
        min_idle = d[0][0]
    elif d[0][0] < 0.5 and ttime - d[-1][0] > 0.5:
        min_idle = ttime - d[-1][0]
    else:
        min_idle = 0.5
    max_idle = max(d[0][0], ttime - d[-1][0])
    a = 0
    for j in range(len(d) - 1):
        if d[j + 1][0] - d[j][0] > 0.5:
            if a == 1:
                min_idle = min(min_idle, d[j + 1][0] - d[j][0])
else:
                min_idle = d[j + 1][0] - d[j][0]
                a += 1
        max_idle = max(max_idle, d[j + 1][0] - d[j][0])
else:
    if d[0][0] > 0.5 and ttime - d[-1][0] > 0.5:
        min_idle = min(d[0][0], ttime - d[-1][0])
    elif d[0][0] > 0.5 and ttime - d[-1][0] < 0.5:
        min_idle = d[0][0]
    elif d[0][0] < 0.5 and ttime - d[-1][0] > 0.5:
        min_idle = ttime - d[-1][0]
    else:
            min_idle = 0.5
        max_idle = max(d[0][0], ttime - d[-1][0])
    if min_idle == max_idle:
        min_idle = 0.5
    if min_idle < 0.5:
        min_idle = 0.5
    if max_idle < 0.5:
        max_idle = 0.5
    min_idle = round(min_idle * 1000000, 3)
    max_idle = round(max_idle * 1000000, 3)
    return [min_idle, max_idle]
```

Other code structure:

```
x = df.values[0]
y = df.values[1]
z = df.values[2]
xyz = np.vstack([x,y,z])
clor = [i for i in gaussian_kde(xyz)(xyz)]
clors = [i for i in gaussian_kde(xyz)(xyz)]
imax = max(clors)
for i in range(len(clors)):
    if (imax/clors[i]) > 100:
        clors[i] = clors[i] * 8
```

```
for i in range(len(x)):
    if i >= 424:
        if clor[i] > 0.3:
            clor[i] = 6
sum_all = 0.0 for i in range(21):
        sum_all += df[ko][i]**2
    l = list(map(lambda x: abs(x), df[ko].values))
    l1 = list(df[ko].values)
    l.sort(reverse=True)
    k = 1
    while (sum(map(lambda x: x**2, l[:k])) / sum_all) < 0.75:
        k += 1
    ind = []
    for i in l[:k]:
        try:
            ind.append(l1.index(i))
            try:
                ind.append(l1.index(-i))
            except:
                pass
        except:
            ind.append(l1.index(-i))
```

```
print(ko)

print(sum(map(lambda x: x**2, l[:k])) / sum_all)

print(ind)
```

CONCLUSIONS

1. In this work, an algorithm was successfully performed to connect additional devices with further emulation and direct streaming image output to the screen.

2. The manual auto correction mode was changed to automatic mode with a certain choice of actions in meaning of YOLO algorithmic work processes.

3. The project was developed based on SMD manuals, Mirae Mx-Series engineering work was taken as a basis, new algorithms and connections replaced older machine approaches.

4. Installer speed, line efficiency, element staging and scrap reduction have been increased. Stabilization and detection work both better because of a higher speed of raspberry microcontroller too.

5. Similar software framework allowed pulling the right algorithms for the microcontrollers with further customization and linking of the installer bases and programs.

6. The results of the work allowed to move old technologies to a new level without their replacement, it became possible to further develop the operating and visual blocks of the machine.

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