TECHNICAL SCHOOL CENTRE NOVA GORICA

HIGHER VOCATIONAL SCHOOL

DIPLOMA THESIS

CONTROL OF PRINTING RED DOT

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ABSTRACT

The thesis describes the theoretical and the practical basis of how vision systems and controllers function. There is a special focus on the use of machine vision. The thesis also presents the process of designing the application which controls the printing of red dots in the middle of hot plates. I have designed the above mentioned application at ETA Cerkno in the department which manufactures hot plates. The objective of the thesis is to establish quality control over the process of the printing of the red dot. With quality control functioning effectively, the problem of badly printed red dots is solved, and consequently there are fewer repairs of badly printed red dots needed. The thesis includes COGNEX In-Sight Micro vision system and Siemens S5 controller. The latter controls the functioning of the vision system and it signals any badly printed red dot. Finally, the setting up and the installation of the vision system are presented, and the program of Siemens S5 controller is described.

Keywords :

vision system, controller, machine vision, control, quality, repairing, signalling.

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1. INTRODUCTION

1.1. ETA Cerkno company

The company ETA Cerkno like member of E.G.O (Elektro Gerate, Blanc und Fischer Oberderdingen - Germany) group from 1968 produce electrical heating and regulation elements. In the field of electrical heating plates is the leading world producer and in the field of capillar thermostat leading EU producer.

Demand for the quality and acceptable price make the company realise that they should produce those products with best perspective.

At the times wheh they strougle for stabilisation, raising of income and standard they make few important decisions:

- modernisation of production process for better productivity
- direct production programe towards electrothermy and regulation
- inclusion in international market

With constant development and joint venture ETA company became leading world producer of heating plates (EGO covers 75 % of world share). That make an open road for positive economic operations and development in the future.

1.2. Production units

The production process is divided into 5 working units for better transparency of the process:

- thermo regulators
- foundry
- tools production and maintainance
- plates (where is also assembly)
- heater

We successfully produce cast iron grill plates which are one of the main heating elements in cooking technique.

The body of electric hob is made from robust cast iron with precision treatment of heat treated surface. Fast heating panels have protection against overheating.Standard models vary depending on size and connection power. Connection are made via sat screw or connector and meet the requirements of all standards and build in procedures.

ETA also produces cooking plates with a decorative enamel coating that offers outstanding resistannt surface and allow easy cleaning In the section »assembly« production is updated by robots, machine vision and almost completely automated lines for manufactoring heating plates.

Products of ETA Cerkno.

1.3. Application idea

Together with mentor in the company we decide to produce an application that will provide greater reliability of production according to defects identified in the production process.

Initially it was meant only sensor for determining the presence of red spots on the heating plates. Then we decide to install a camera for better quality control of printed red dots. The application is installed behind the machine, which prints the red dots for immediate information about any bad pixels.

I will use the SiemensS5 controller for controlling and admonition with light and sound signal to the operator of the machine for printing red dots.
The working place for packing is quite remote from the machine, which prints the red dots (about 50 plates). In case that it will be only one bad printed dot, the controller ensure that worker on the packaging notice that on the site under a light and sound signal is plate with poorly printed dot. With the application we indend to reduce the possibility that unquality product appears on the market.

Picture 2: automat for printing red dots.

Picture 3: transporter of heating plates and packaging places.

2. THEORETICAL BACKGROUND

2.1. Using machine vision

2.1.1. Efficient automation solutions

Machine vision systems with their growth in all industries and with appropriate high innovation potential are on the top of investment in companies. Machine vision is step-by-step conquering new areas. With the usefulness and without surprises machine vision systems increase productivity, reduce costs, improve product quality, provide people and enable competitiveness of production. The concept of machine vision concerns technology of artificial vision. Cameras and computers give to machines the ability to see, to identify and to make the right decision. Data that are recorded by the camera are analyzed by computer, which filters the relevant information and send the results to the control unit, which provides answers. Is the dot printed in quality? Is the staple properly installed? Are all contacts in the right place? Is the surface of the plate without blowhole casting defects? Intelligent vision system responds to all questions and more quickly with full reliability and cost effectiveness. Typical machine vision tasks include control of the surface, check assemblies, measurement techniques, identification and computer vision.

2.1.2. The quality of zero defects

Customers require seamless products from the manufacturer. Visible surface defects lead to expensive complaints, even if the product works properly. However, why is the visual final inspection in many manufacturing processes the only level that is still done manually, with great effort and often only on the basis of the control points? In most cases, the task would be much more profitable to automate by using the machine vision. The machine vision system can be 100 percent control easy to automate, even if there are large amount of material. Currently there are two basically different test methods for the automated control surface:

- detect defects on the even surface using descriptions of defects (scratches, cuts, holes, etc.)
- detect defects using the samples (including multicolour) by comparing the saved reference

Overview of continuous material ("web inspection") in general depended on the detection of the smallest defects in high speed production. Due to the progress of cameras and a large increase in capacity of computers, it is now achieving a high speed of viewing in high definition.

In recent years, colour cameras have significantly improved in terms of reliability, resolution, speed and price. Due to this, the number of solutions for colour control has increased in the field of the control surface available on the market.

2.1.3. Automatic material flow control

Automation is on the rise in all sectors of industry. The machine vision systems are often used to ensure a smooth flow of material. These systems identify the product, remember the information, which they transmit and ensure that the relevant component is delivered to the right position and that is subjected to appropriate procedural process, where there are two significantly different applications: identification of the codes and symbols, and identification of the components and positions. Identification codes and symbols register label products that contain specific information, which is decoded by the computer. There were many experiments on the methods of illumination and reading algorithms: characters, which are molded or stamped, can be read with the machine vision just as surely as code written by using the pin or inkjet/laser printer. Typical applications are the identification or verification of the bar codes, 2D codes, OCR fonts or handwriting, on components in the automotive and electronics industries, on the packaging, food and pharmaceutical products (dates of permitted use, serial numbers).

Components are identified by comparing the objects with reference models or samples (contours or other specific characters). Identifying components with the machine vision systems generally also provide information on the position of the product. Therefore, it is particularly suitable for the following applications:

- supply of parts in automatic assembly lines the delivery devices,
- sorting and packing of various types of parts and materials
- monitoring parts on automated production machinery.

Users benefit from highly reliable identification, which can be achieved in difficult conditions in production plants. Rates of reliable identification can be reproduced at dirty surfaces, poor quality characters and poorly defined contours.

2.1.4. 100% control

The use of machine vision to control the completeness is prevailing in the assembly plants. Black and white and colour camera exercise control during the process or as a final output, if the components were properly composed. Cameras also check the presence and the correct position of the various components. In some cases, surface control is also carried out simultaneously. In the electronics industry, circuit boards are controlled according to the regularity of contacts and to the complete composition of components. In the production of components, which is important for safety, machine vision enables 100 percent control of production and ensures full traceability. The total number of required examinations for a 100 percent fully control varies from the complexity of the tested materials. For this purpose, the testing system is equipped with one or more array cameras and with an adequate number of lit. If the robot positions the observed object in front of the camera, it can generate different views of capturing images. Final checks are not adequate for people, because the work is too monotonous and because the speed of production is often too fast for human testing. Thus, machine vision systems are more reliable, faster and more economical.

2.1.5. Non-contact, flexible and fast

The machine vision is mostly used in the area of quality control, which comprises the control surfaces, control of completeness and measurement technique. The size of the tested components is not important in relation to the precise measurement by using machine vision. The machine vision systems can control the dimensional accuracy of the electronic modules in micrometres or they can carry out a three-dimensional measurement. In comparison with the respective approach, several advantages are provided by the machine vision: a non-contact measurement is extremely fast and can be implemented in the production cycle. Instead of taking random samples and inserting into the measuring device, the machine vision works 'inline' and reliably measures each individual component without limiting the pace of production. Two-dimensional information (length, width, etc.) can be obtained relatively easily by using the lighting in the background, which is not always possible and it depends on the production environment. Measurements should often be carried out by using side lighting, where the effects such as a parallax error or a surface of different reflectivity are prevented with the precise methods of calibration, high-quality optics and algorithms for secure adjustment. At the top are 3D techniques such as light 'sectioning' or stereometric methods for measuring various objects. These non-contact procedures allow accurate measurement, comparable to the results of measurement systems on dot, except in cases, where the measurements with machine vision systems are considerably faster and more flexible.

2.1.6. Robot vision

As the name implies, the robot vision system is the robot's eye. Its main tasks include positioning, determining the grasping and precise positioning of each geometry. After the robot vision has identified the type of object and recognized its location, a reliable approach is guaranteed and also an important prerequisite for automated production. The centerpiece of the potential areas of application is completely automated assembly line. Robot vision systems offer a high degree of flexibility of the entire system in combination with improved positioning accuracy and quality of product. Defects in the delivery system and foreign objects are quickly recognized as well as the precise determination of position. The system stops before damage occurs. High precision mechanical and therefore expensive delivery systems may thus be called off.
One of the special features of robot vision is that the spatial coordinate system of robot and of machine vision are aligned with each other, and that the machine vision system is precisely calibrated. The communication between the two systems is standardized and simple.

Typical applications include:

- managed and optimized application assembly
- the fitting assembly
- improved quality of welding by determining the exact position during the robotic welding
- palletizing and depalletizing,
- positioning of components.

Robots that can 'see', already enable the more flexible and effective production. In the near future they will be able to participate interactively with the people and work with them hand in hand as a product assistant in a joint, distributed work area without protective fencing.

2.1.7. Machine vision in security, medicine and transport

Machine vision technology is increasingly used also outside factories, in medicine, in laboratories, on motorways, on car parks, in banks, in public places, in retail logistics. These non-productive applications represent already one-quarter of the total sales of machine vision sector, which proves that the technology behind the innovation is in fact present in every aspect of daily life.

Examples of non-production machine vision applications:

- automatic blood cell counts
- reading license plates
- biometric access control and identification of faces
- automatic recognition of suspicious activities in public places
- reading lottery tickets or money orders
- sorting of mail and logistics of packages
- machine vision system for car driver assistance
- road radars.

The benefits of machine vision are widely used also outside the industrial production, where can provide improved security and optimized processes. The potential of this technology in these areas is far from the exploited, a lot of innovation is still in development.

2.1.8. Machine vision is an investment that is economical

The machine vision technology is constantly expanding to new areas. Although the new technology options bring a positive development, the real driving force is the cost-effectiveness of machine vision systems. Lastly the investment must be profitable. Experts say that the investment in machine vision is redeemed after 6 to 18 months. After that period, the machine vision systems bring money saving every day.

The machine vision systems identify the defective components in the earliest stage of production. These components are immediately removed from the production process, which saves costs. In many cases, the removed component can be re-engaged in the production process, which saves material. Defective components never reach the next level in production and therefore do not entail any resulting costs.
The electronic eye of the machine vision is replacing the visual control of the quality of employees at many stages of the production and thereby increases the availability and the reproducibility of the process. Highly qualified personnel can be employed more productively in other areas and work more effectively for the company and with the increased motivation to perform more complicated tasks.
Due to the complexity of highly automated production lines, there is always the possibility that irregularities can suspend the entire production process. Cameras constantly monitor critical areas and reduce production downtimes. Furthermore, system identifies the re-defects that can be then systematically removed, preferably at their source. The result is in increased productivity and in the system availability.
Machine vision brings quality closer to the final aim: no errors. Higher quality yields competitive advantages, especially in areas, which are safety critical, where the leap in quality often allows companies to reach new markets. Clients are willing to pay more for better products, while the appeal does not bring only unsatisfied clients, but also additional costs. The capacity of the machine vision technology is constantly increasing. Computer hardware capacity is constantly increasing, while it is simultaneously becoming more economical. Today's machine vision technology is modular and scalable. Users can choose from standard systems, cost-effective systems for simple tasks to complex systems, which solve problems that were previously insoluble.

2.2. Description of the camera In-Sight Micro 1020

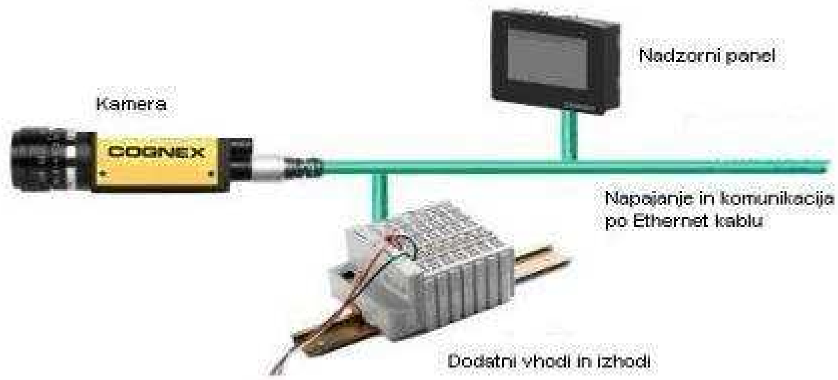
This is for now the smallest minimum vision system that offers everything needed for the construction and solution of complex applications. Cognex is one of the most advanced companies in the area of the development of machine vision systems. A special feature are the extremely compact external dimensions of the camera, with its 30 x 30 x 60 mm strongly affects the segment of "remote-head" systems. In its small housing combines both capture image processing and with the Texas Instruments processor is the fastest among the smallest. The processor is so powerful that in some algorithms surpasses models from higher price ranges.

Picture 4. Camera Cognex In-Sight Micro (source: http://www.cognex.com)

Robust steel housing with industrial connectors
PoE combines electric supply and Ethernet in one cabel
Three digital signals on camera
Picture 640x480x(VGA)
Dimension 30x30x60xmm

Table 1: characteristics of intelligent camera.

A special feature of this camera is simultaneous communication and power supply via PoE (Power Over Ethernet), which simplifies wiring and by this it enables the In-Sight Micro with power supply via conventional Ethernet communications cable. In-Sight Micro communicates externally through a simple industrial Ethernet interface, understands all the major protocols: PROFINET, Modbus TCP/IP, Ethernet/IP, which provides good connectivity. Along the industrial communication protocols, In-Sight Micro offers also connector on the housing with three digital signals. Cognex as expansion module for Micro offers WAGO Ethernet interface, capable of addressing up to 256 input/output points, in order to extend the additional digital input/output signals. In-Sight Micro is currently the smallest, most intelligent and simplest 'all-in-one' vision sensor in the world. Small in dimension, large in capacity offers a full range of Cognex verified vision tools.

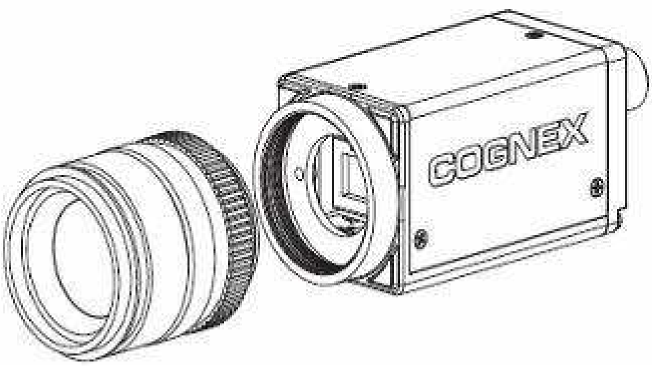


Picture 5: Example of connecting inteligent camera (source: http://www.cognex.com)

2.2.1. Characteristics of camera In-Sight Micro 1020

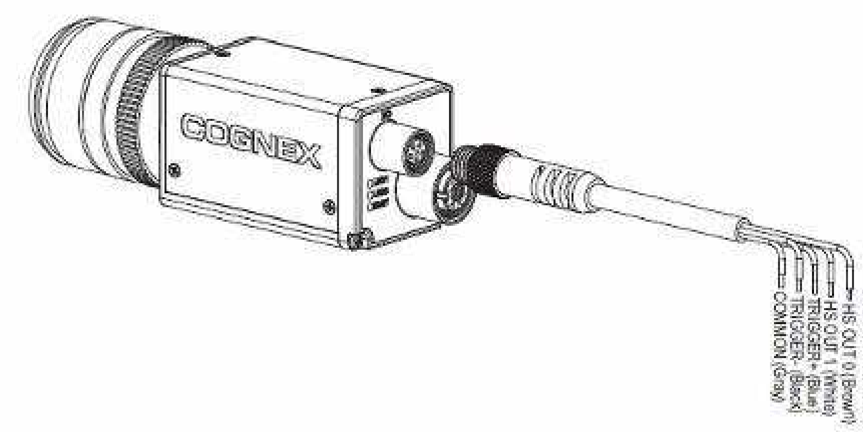
Memory of the camera	64 MB flash
Sensor	1/3 inh CCD
CCD sensor characteristics	5.92 mm diagonalno 7.4 x 7.4 µm pixla˛
Resolution	640x480
Speed of electronic sensor on the camera	16 µs do 1000 ms
Lense type	CS-mount in C-mount
Grey scale	256 sivih stopenj (8 bit/pixel)
Pictures / second	60 slik na sekundo
Temperature area for operation	0° C do 45° C
protection	IP51

Table 2 characteristics of camera

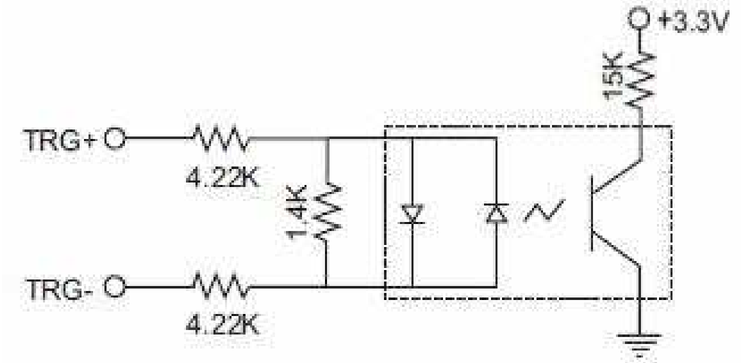


Picture 6: intelligent camera with objective.

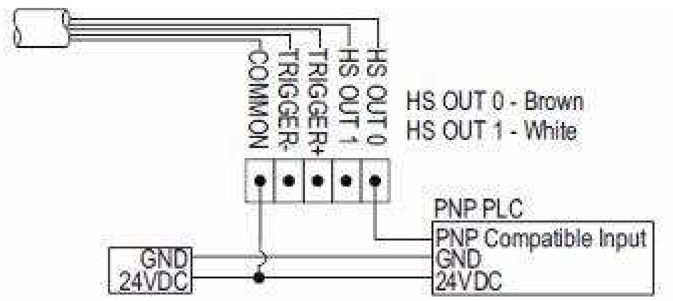
2.2.2. Inputs and outputs of camera



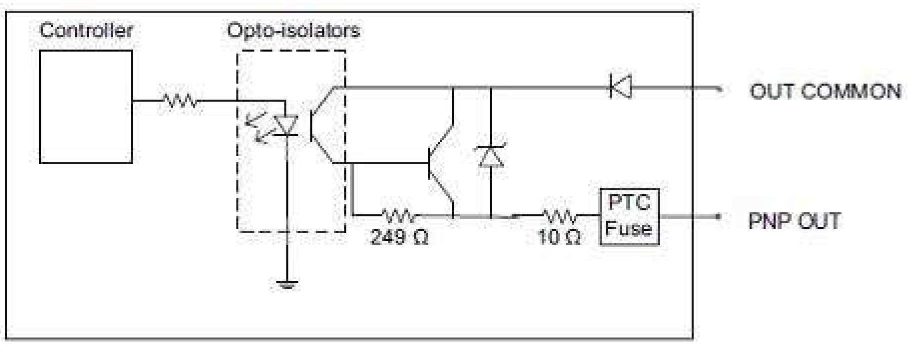
Picture 7: Connection input and output digital signals



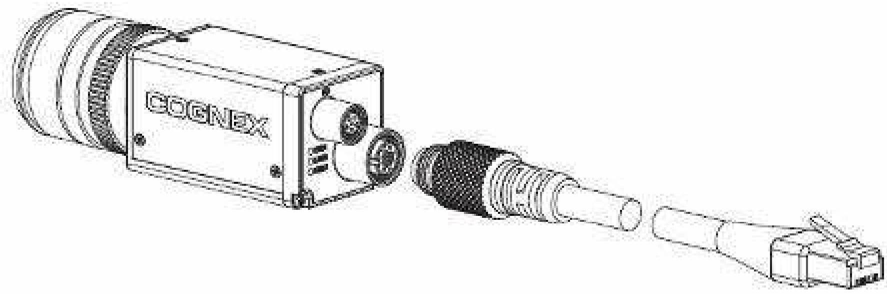
Picture 8: Scheme of connection optically separated starter of camera.



Picture 9: scheme of connection on outputs



Picture 10: scheme of optically separated outputs of camera.



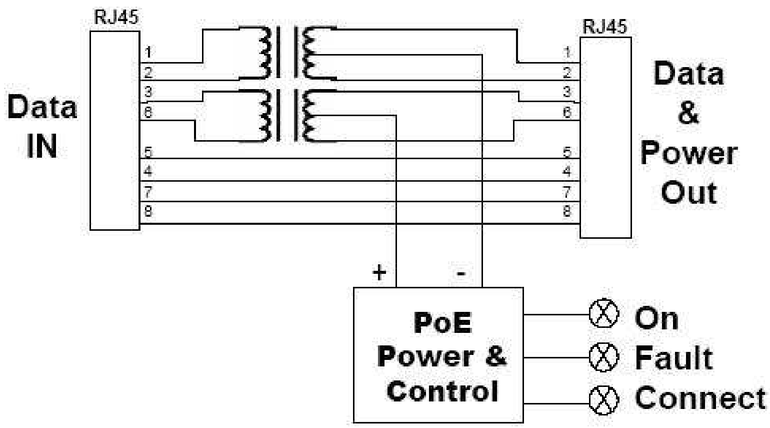
Picture 11: communication and feeder cable in one.

2.2.3. Power Supply Camera with RJ45 connector

The camera is powered via Ethernet cable (RJ45 connector), while it can also communicate with the camera for example programming. If it is connected to the additional panel, the image, seen by the camera, will be monitored live and it is also possible to change the settings.

Picture 12: power supply for camera POE30U-560.

Supplier power – 30 W, power 220 V, temperature zone 0^{o}c to 40^{o}c



Blok diagram 1: camera power supply POE30U-560

2.3. Automation Controllers

2.3.1. General

Since their inception in the early 70s, controllers have become an essential part of automation and control systems. They have developed to such an extent that they do not compete only with relay, but also with other control devices. Controllers have replaced hard wired logic, analog controller, and even mini-computers. Their capabilities are increasing so rapidly that new ideas and solutions appear monthly. Controllers were developed to quickly react to changes in the applications allowing the program to be quickly changed without the need to change the physical wiring. Automation industry has rapidly taken them up and consequently today they provide a solution to countless applications in virtually all industries. Most controllers are the core of the entire automation structures caring out a number of automation functions such as control, regulation, or data acquisition. The applicability of the controllers is mainly in tasks with the prevailing binary signals. In fact, these types of tasks led to the controllers, so they do not constitute any problems for the present controllers. Controllers have improved a lot since their inception as today they also provide functions for acquisition and process of analog signals, regulation, computation and communication. The designer is often faced with the fact that on the market there is quite a large number of producers. The main differences between controllers appear in the hardware, software, processing speed and price. This brings us to the fact that we must be quite careful when choosing a controller, especially if the process that we want to automate, already has the existing hardware and we would like to keep it. In smaller processes controllers are used independently without additional items for display. Here they are used because of its processing speed and specific set of peripherals, which may significantly increase the scope.

Nevertheless, we must pay attention to certain facts, which restrict the use of controller in the process:

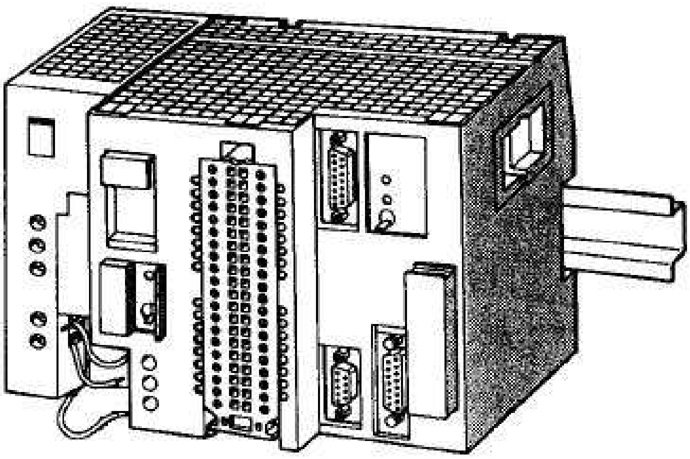
- adding peripherals can significantly increase the price of the controller which questions the cost-effectiveness of the automation that uses a controller
- the controller is basically designed to process binary signals, and we need to take into account additional often longer computation times. These times can be reduced with the use of additional peripherals, thereby is again an issue of cost-effectiveness.
- meeting the standards, especially in hardware compatibility.
- configuration, fault diagnosis and documentation are still concepts that we need to be very careful about in relation to the ability of the controller and its software.

Insufficiency in meeting these terms may in further life of the automation structure significantly increase the cost on the occurrence of errors and in finding solutions.

2.3.2. Controller Siemens S5 Operation

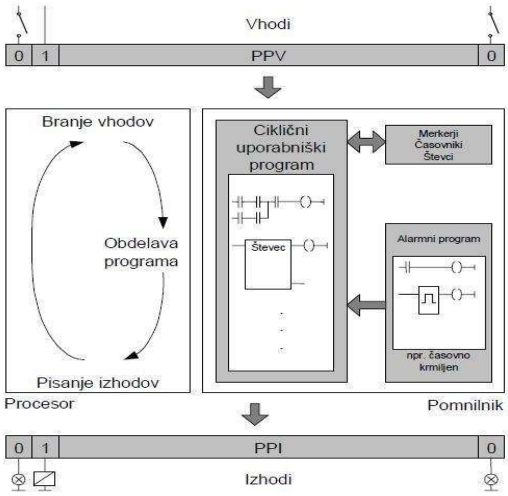
The controller is the core of an automated system that can realize different control functions. These can range from plain control all the way to regulation, measurement... Depending on the controller (or multiple connected controllers) and modules that are connected on it, a wide variety of automation structures can be made.

The controller is basically a computer without a display, keyboard and optical unit, comprising the remaining elements such as processor, memory (RAM and EPROM), input/output process interfaces and serial communication interface to connect to other computers. Input and output devices are modules through which the controller connects to the process. It is often necessary to communicate with other factors in the process, and then the very controller is added to the communication module through which you can access the network.

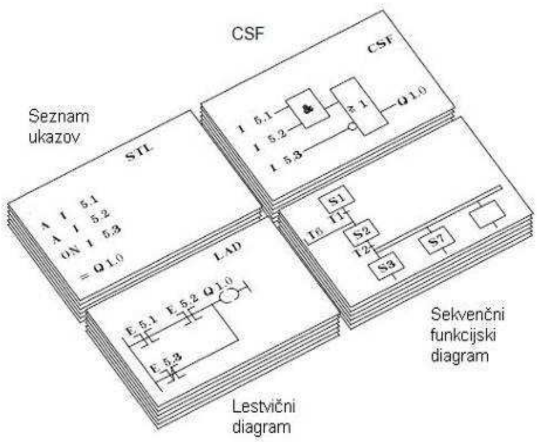


Picture 13: controller S5-95U (source: Siemens S5 manual)

The overview of the implementation of application program is on (Figure 14). At the beginning of the process the mapping of inputs is carried out and then the program processing starts. During the implementation the program can be interrupted by alarms or timers. After the end of the cycle process is carried out



Picture 14: controller activity



Picture 15: programing methods

3. RED DOT PRINTING AUTOMATISATION CONTROL

3.1. Machine for printing red dot

Picture 16: machine for printing red dot

Machine for printing red dots operates on the principle of the press printing. Those machines have clean footprint, minimal blade wear out and long life period. The machine is attached to a varnish conveyor which unable to move synchronously with conveyor. With tongs lift the plate from conveyor and level it. Then cylinders »take« the colour form tub, stamp it on the plate and lay down on conveyor.
Next operation is detaching printing machine from conveyor and return back quickly to starting position and repeat the procedure for next plate on the conveyor.

Picture 17: tampoprint for printing red dot

3.1.1. Product which will be controlled by camera

Picture 18: heating plate with red dot

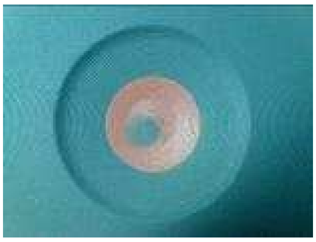
The application will control the red dot in the middle of the plate. Failures for printing red dots may occur because of different reasons:

- lack of colour in the tub
- incorrect position of the printing plates
- various foreign bodies, which appear on the surface of the plate

For optimal red dot we consider:

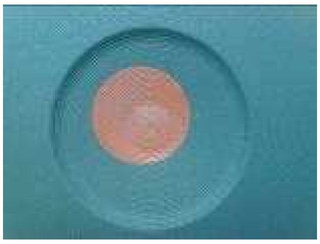
- Without black stain within the dot,
- circular,
- centrically,
- without stain outside printed dot,
- visually good looking.

Few examples of bad printed red dot's:



Picture 19: Example of black spot within red dot

Picture 20: example of bad print on the edge of red dot



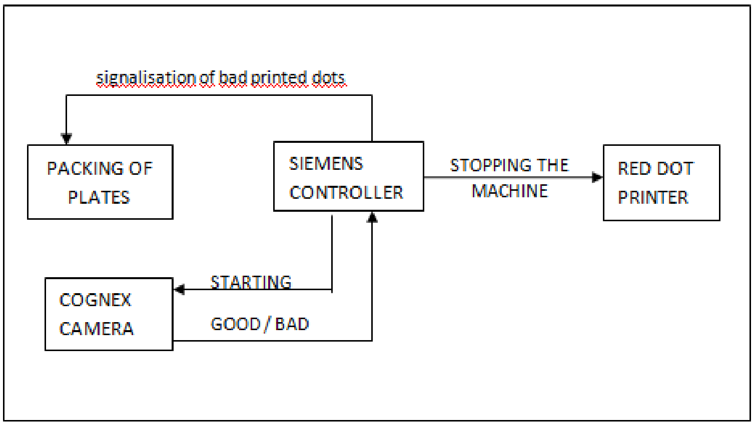
Picture 21: example-red dot is not centrical

Picture 22: example of spot outside of red dot

Considering possible faults that may appear I choose machine sight – intelligent camera for optical control of faults. With such camera is almost entirely possible to assure before mentioned criteria of quality printed red dot.

3.2. Planning the application

Most of successful companies decide to modernise machines and production process. Modernisation by itself is crucial for existence on the market and competitiveness. Quality of products have most important role in ETA company therefore I decide to make a system for controlling the quality of printing red dot. In the planning phase I had to decide which type of optical camera for machine sight to choose.
With representative of Tipteh company from Ljubljana I arrange to present their products. In their offer they have also special sensors (called checkers) operating on the principle of big number of sensors.
On the visual field of the camera for controlling inputs and outputs is possible to programme scale diagram. This type of camera don't make possible to look the centre, dots or contrast, so I decide for the camera In-Sight Micro 1020 of Cognex producer.



Block diagram 2: Working of the application

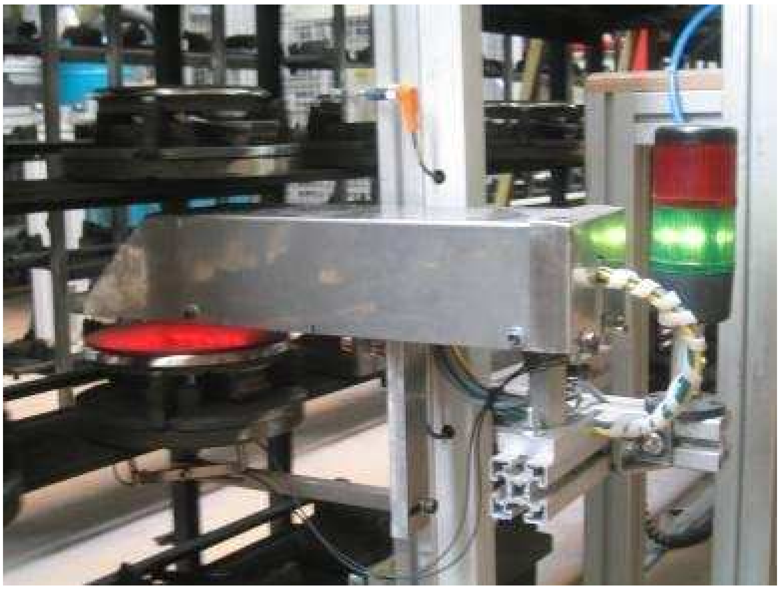
I couldn't make planned application only with camera because of too little inputs and outputs so I use also controller Siemens S5-95U available in the company (unused) and adopt it for starting camera and signalisation in case of bad printed dots.

We can see working of the application on block diagram No.2

3.3. Making the application

3.3.1. Setting up the camera

Camera produced by Cognex is extremely small which suggests already its name –Sight Micro. Before installing the camera appears a problem, how to install a camera that during the operation would not be damaged and would still operate reliably. The camera watches (measures) object which moves to the camera and actuate the precise Siemens optical sensor controller.



Picture 23: camera with protection shield

Picture 24: camera without protection shield

Considering that the camera is really very small in a given project is still too big for fitting on the place where it could work. Therefore I choose a camera with the mirror. At the beginning I was very confident that the application will work through the mirror. However, by choosing the right lighting device is effective and reliable. The camera fixed in a certain position is vulnerable to injuries, because the conveyor is constantly passing by. Since the camera is installed above the plate (Fig. 25), I decide to put the camera on rotating holder – in case of poorly fitted plate on conveyor hits the camera. Camera withdrawn from the site and thus prevent damage to camera. On rotating holder is mounted the spring which unable the camera to turn back on the right position for measuring.

3.3.2. Lighting of intelligent camera

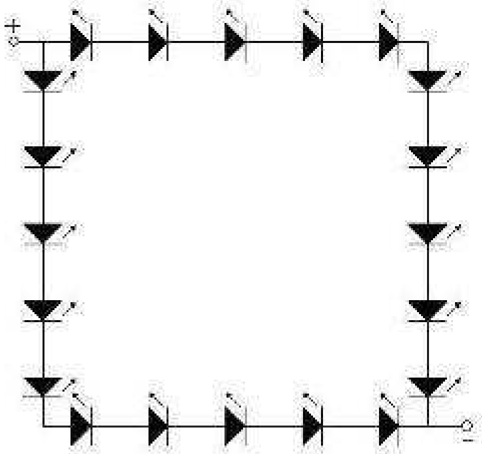
Checking the supply of lighting for machine vision cameras I have not found any suitable for my project, so I decided to produce my own system for lighting with high light-emitting LEDs.

For machine vision lighting of observed or measured product plays an important and crucial role.
In this project I had to pick a diode which has great intensity and a relatively diffused light beam. I've used 20 diodes. I connect by order 10 of them together to get 22 V. To regulate light intensity of LEDs I have used the additional potentiometer. The most evident light produced by LEDs perceived by camera is red. I also tried the white LEDs, but the dot on the screen was very weak-sighted. With red light produced by LEDs the image of dot on the screen is very well seen because the dot is also red.
For measuring centrical printing of dot it was necessary to install lighting to an angle of 45^{O} which unable to see the crossing into centre of the plate.

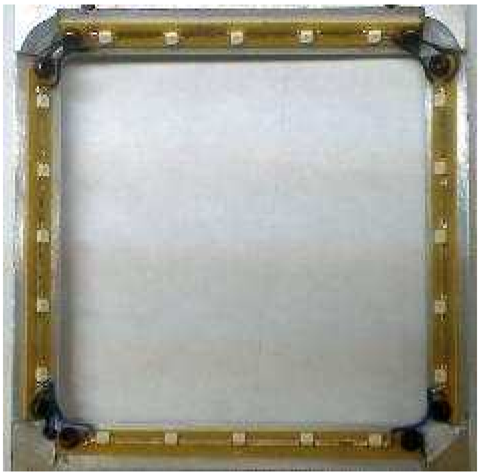
Picture 25: high lighted red LED diode

Producer	AVAGO TECHNOLOGIES
Production mark	HSMZ-A100-R00J1
type	PLCC-2
Colour	red
Angle of lighting	120°
voltage	2.2V
Temperature range	-40°C do +100°C
Max. electric current	30mA
Lens type	Normal transparent
luminosity	400mcd
Size	630nm

Table 4: technical characteristics of high lighted LED diode



Picture 26: electro scheme of high-lighted LED diodes



Picture 27: fixed red LED diodes on aluminium frame

Picture 28: functioning of lighting the camera

3.3.3. Optical sensor for starting the camera

For starting the camera I originally used ordinary capacitive sensor, but for precise triggering and capture images not worked because of inaccurate activation. Later I tried optical sensor and install it directly below the plate centre. The accuracy of the trigger is very important because image must be captured always at the precise point, otherwise measurement error can appear due to different lighting. I was thinking about using timer to delay triggering the camera, but the controller is not fast enough for precise triggering. The camera by itself has a quick entrance but we lost the benefits of it binding the camera through the controller. In our project this is not crucial and relevant.

Picture 29: optical sensor

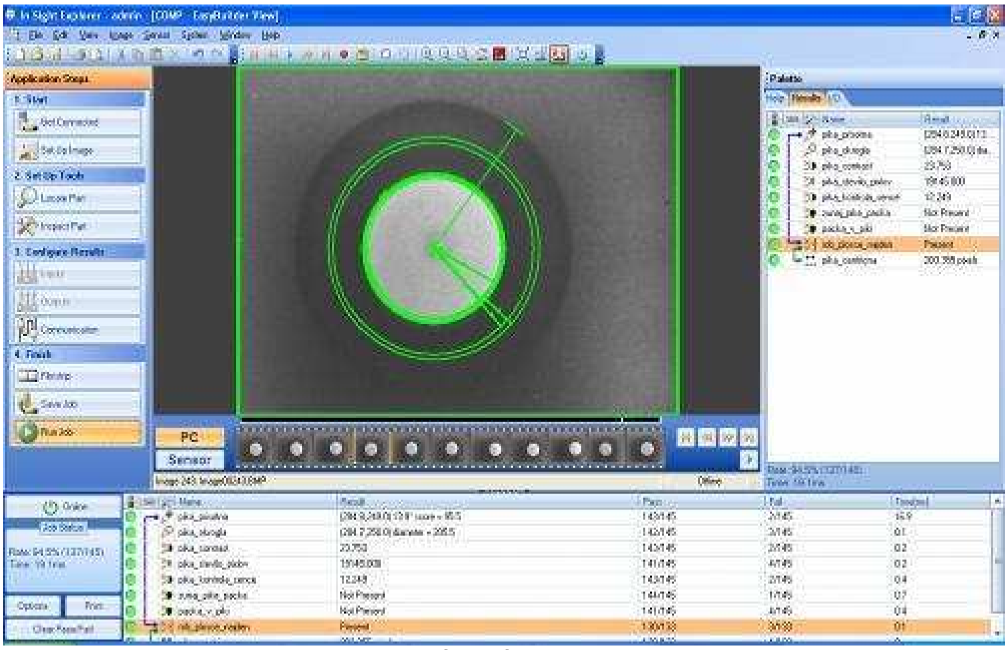
Picture 30: optical sensor set under lighting

3.3.4. Program interface In-sight Explorer

For automated operation (programming) of the camera EasyBuilder program is required. It works via Ethernet RJ45 connector, which is connected to the power supply (Figure 12). The camera itself has its own IP address and it works over TCP/IP protocol.

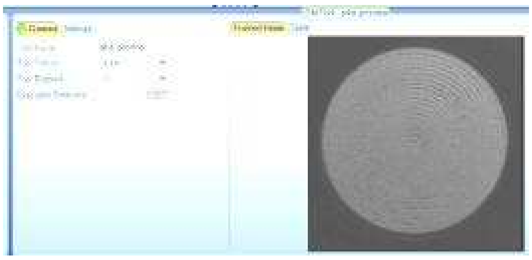
Picture 31: programe interface

3.3.5. Programme for controlling red dot printing



Picture 32: programe interface for programing the camera

The program itself has few steps to prepare the camera for automatic operation. Firstly we must set the reference image (object and structure) which will be inspected. I set it to search for printed red dots in the middle of the plate heating surface. The camera searches for presence of the reference image on the whole visual field 640 x 480 pixels.

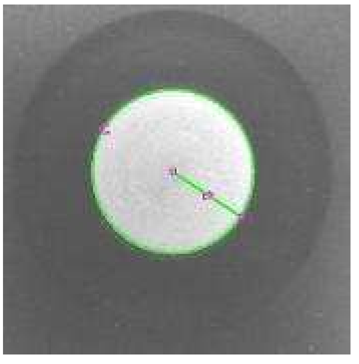


Picture 33: reference picture

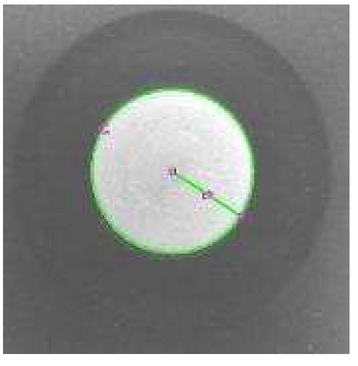
If the dot is printed on a heating plate the programme performs the following measurement: dot_circular
With this measurement check if a dot is circular.
Within bright green area on the image application checks if the observed object is circular (Fig. 34). In case that grey colour withdraw from border defined by light green circles there is an error.

Picture 34: checking the circularity of dot

Errors inside spot checks on the way to set a certain gray area, the upper and lower limits, the camera counts the number of pixels in a dot on the set value

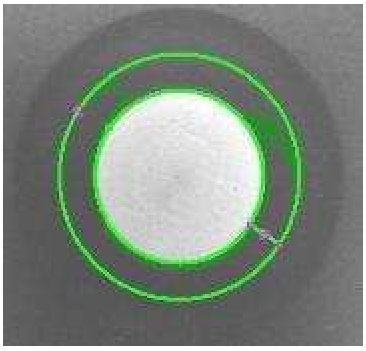


Picture 35: checking the circularity of dot



Picture 36: checking mistakes at inner circle of printed dot

Checking if some smudge spot appears outside the so called shadow area. In this area there should be no bright stains. On the figure this field is between the two light green circles.

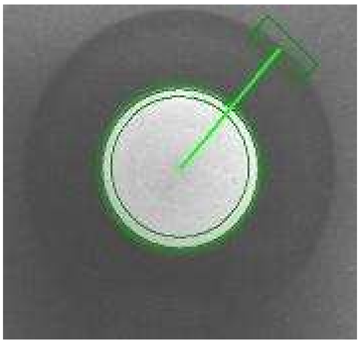


Picture 37: checking stains outside printed dot

The program:

- verifies if the dot is in the centre regarding the inner ring of heating plate
- locates the transition from bright to dark and there then set the edge of the circle.

Lighting plays a key role that application find the edge –each heating plate must be equally illuminated, otherwise it cannot find the edge.
The problem of irregular illumination can appear in the varnish conveyor. Since not everyone is exactly the same height some specified tolerances appear.
To get most precise measurements every heating plate must be at the same relative position to the camera. After the program finds the edge measurement is focused to the centre of predefined circle of dot. Correct installation of the camera inclined at an angle of 45^{O} help to find and define the edge (Fig. 29).



Picture 38: checking if printed dot is in the centre

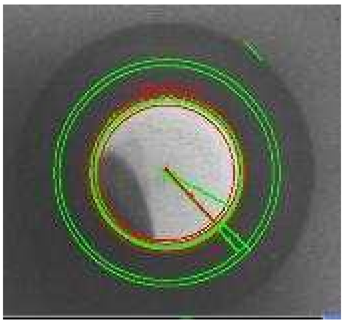
Controlled and measured values for control of printed red dot:

Name	Result
pika_prisotna	(334.2,233.0) 14.5° score = 96.5
pika_okrogla	(333.9,233.7) diameter = 202.0
pika_contrast	30.371
pika_stevilo_pixlov	17603.000
pika_kontrola_sence	14.883
zunaj_pike_packa	Not Present
temna_packa_v_piki	Not Present
rob_plosce_najden	Present
pika_centricna	204.196 pixels

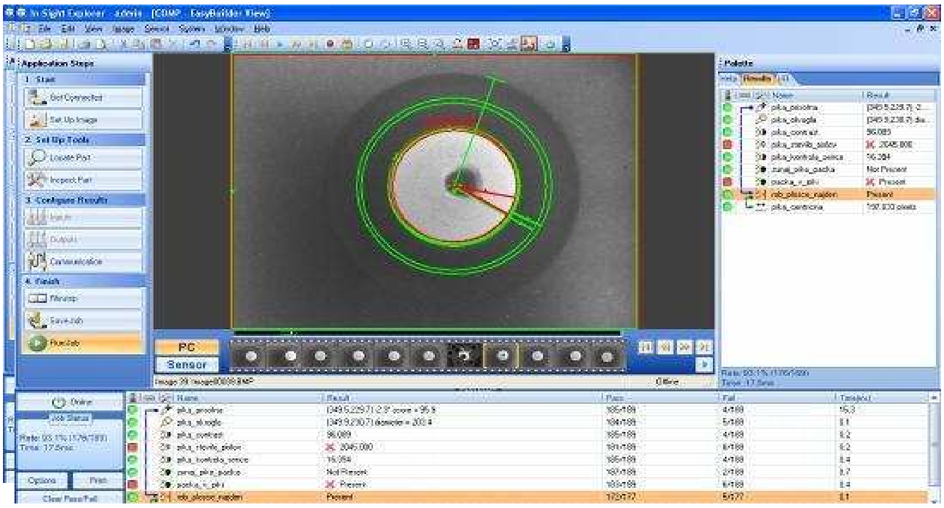
Picture 39: set up values in the programme

In the case that bad printed dot appears, the program detects an irregularity and turns on a camera output for a »bad dot«.

If we follow the camera operations via computer we get on a screen graphical review of detected and perceived irregularities. In this case (Fig. 39) camera detects irregularity in the »roundness« and errors inside the dot.



Picture 40: example of bad printed dot

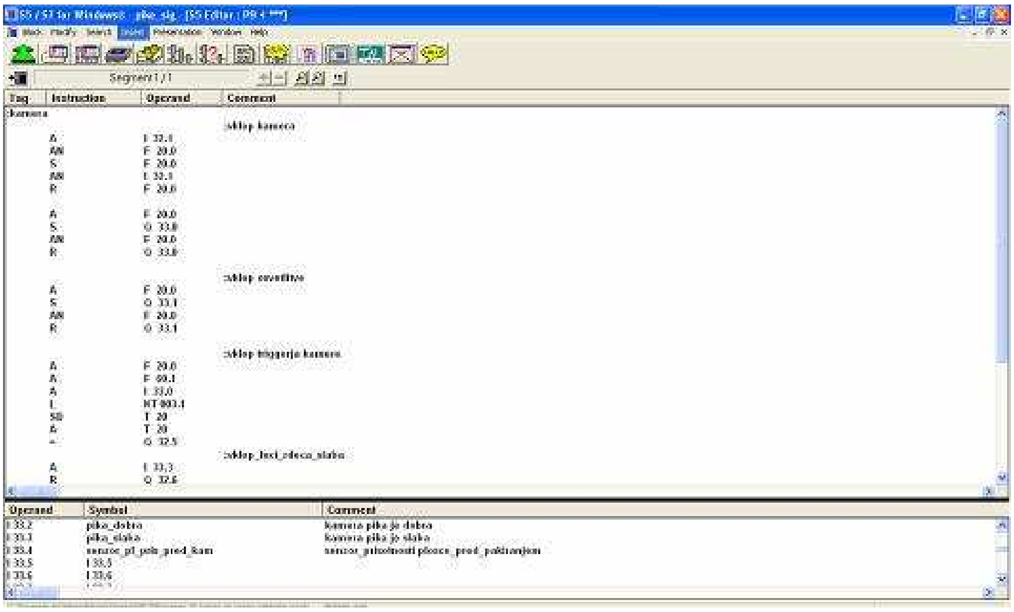


Picture 41: example of bad printed dot shown in the programme

In case of bad printed dot the programme display on the monitor (Figure 40) results and errors occurred. If any failure appears on the set parameters, the camera turns on output set for the error signal. This signal is further processed by Siemens controller – warn the worker on packaging of the product failure. When a program is tested and it works as we would like, we store it in the camera internal memory and indicate that the program starts when camera is turned on. Later we can optional add some changes in case we'd like to set different parameters.

3.3.6. Programming of Siemens S5 controller

Programme interface S5/S7 for Windows:



Picture 42: interface for programming in S5

With this program interface I write a programme for

- starting the camera and signalisation when bad printed dot appear
- eventual stop of automatic machine for printing dots (if bad printed dots will follow in a row)
- alerting on the packing place when dot is poorly printed.

I decided to use STL or text mode programming. The command is composed from operations and operands. Operand has a serial number or parameter.

Legend of operands in the programme for Siemens S5 controller:

- I – input
- Q – output
- F – marker (memory bit)
- T – timer

3.3.7. Programme in S5 controller for signalisation and control

Inputs and outputs on the controller:

outputs		inputs	
Q 32.3	Light with alarm on packing	I 32.1	key starting the camera
Q 32.4	alarm	I 32.3	key starting the alarm
Q 32.5	camera trigger	I 33.0	position sensor
Q 32.6	Green light camera	I 33.2	camera – good dot
Q 32.7	Red light camera	I 33.3	camera – bad dot
Q 33.0	Starting the camera	I 33.4	Sensor – presence of heating plate in front of the camera
Q 33.1	Starting the lighting	I 33.5	Sensor – optical camera trigger

Table 5: inputs and outputs of S5 controller

3.4. Application operating

Controller via optical sensor that is mounted under the camera holder start the camera (send the signal when to check the reference image). Sensor that verifies the presence of the heating plate is located in front of the camera. This signal can be moved with an additional sensor mounted on the top of conveyor for heating plates and determine when the conveyor is on the position (centre of heating plate).
When plate arrives into position interrupt a beam of optical sensor and send a signal to controller to check the reference image.

Camera in few milliseconds verified whether good or bad dot is printed based on a program. The controller then turns on signal light indicating if the product is good or bad. A red light indicates bad printed dot and green a good one. Heating plates are moving on varnish conveyor to workers on the packing place. In case of bad printed dot the signal moves synchronously with conveyor over the sensor at the top of the plate holder and warn the worker with light and sound signal. At packing place workers so get the information which heating plates are good and went for shipping and which have defect and are eliminate from packaging process and send them to repairmen.
Program in the controller monitors a sequence of bad printed dots.

In the event of three consecutive poorly printed dots may mean that something is wrong with the printing machine. Machine operator hearing sound alert can immediately eliminate the defect and thereby minimize the number of poorly printed dots. Before applying the application workers found defects not earlier than on a packing phase which meant more additional repair and hence additional costs.

With installing this application the number of bad printed dots decreased from 40 to 5 from the moment when the application perceive the information to the moment when the mistake is abolished.

4. CONCLUSION

Global market requires products with no errors. Only with the philosophy and strategy of zero defects in the manufacturing process may be closer to market requirements. The human factor plays a very significant role on the quality. It’s almost impossible to assure 100% control of the production. In production process is therefore necessary to ensure the system that will automatically monitor itself. That is the only way to ensure 100% quality and also facilitate the work of man.
I have successfully realized the goals I have set in the thesis. Construction and installation of camera in a fairly difficult environment in which the controlled product is constantly moving, and above it there is no room to install the cameras was a challenge. I learned a lot about machine vision and realise that lighting of observed product is crucial. Programming of machine vision by itself became much simpler thanks to software development.
I have gained experience in programming Siemens controller. I believe that in the future machine vision will play a key role in production quality control.
Upgrading of the control of printed red dots on heating plates which assure qualitative printing without mistakes could be robotic packing.

5. ACRONIMS, CONTRACTIONS

*****	Flash memory
*****	Remote head
*****	Vision system
*****	WAGO Ethernet
*****	Web inspection
CCD	Charge-coupled device
EPROM	Erasable programmable read-only memory
ModBus	Serial communications protocol
OCR	Optical character recognition
PoE	Power ower Ethernet
PROFINET	Open industrial Ethernet standard
RAM	Random-access memory
RJ-45	The 8 Position 8 Contact modular plugs
TCP/IP	Transmission control protocol/internet protocol
Pixel	The smallest discrete component of an image

6. LITERATURE

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7. RESOURCES

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I'd like to thank ETA Cerkno company which unabled me to do my diploma work offered me inteligent camera and control equipment.

8. Attachment A: ELECTRO PLAN - CONTROLER SIEMENS S5