

SAIMAA UNIVERSITY OF APPLIED SCIENCES
Technology/Lappeenranta
Degree Programme in Mechanical Engineering and Production Technology

Joni Sipponen

EMPLOYING MACHINE VISION TO A MANUFACTURING LINE

Final thesis 2010

ABSTRACT

Joni Sipponen

Employing machine vision to a manufacturing line, 49 pages, 4 appendices

Saimaa University of Applied Sciences, Lappeenranta

Technology, Mechanical Engineering and Production Technology

Automation and Information Technology

Final Thesis 2010

Instructor: Senior lecturer Timo Eloranta, Saimaa University of Applied Sciences

The purpose of this thesis was to implement a machine vision system to an assembly line to fix an incorrect placement of a part. If the part is incorrectly positioned, the robot cannot pick it up and the assembly line will come to a stop.

The machine vision is connected to a programmable logic controller and the robot. This system is configured to work seamlessly as part of the assembly line. Machine vision will detect if the part is not correctly placed and a flow of air will push the part to the correct position.

This thesis was done for the Saimaa University of Applied Sciences. Part of the thesis was to make simple instructions for students, so they are able to quickly learn how to configure the machine vision.

The thesis was structured into studying the background of the problem, presenting methods for solving the problem, selecting the method, configuring machine vision, programming the system, and creating the system for fixing the position.

Keywords: Machine vision, automation, programmable logic controller

TIIVISTELMÄ

Joni Sipponen

Konenäön käyttöönotto tuotantolinjalle, 49 sivua, 4 liitettä

Saimaan ammattikorkeakoulu, Lappeenranta

Tekniikka, Mechanical Engineering and Production Technology

Automation and Information Technology

Ohjaaja: Lehtori Timo Eloranta, Saimaan ammattikorkeakoulu

Lopputyön tavoite oli käyttää konenäköä korjaamaan kokoonpanolinjalla esiintyvä ongelma, jossa osa on väärässä asennossa. Jos osa ei ole kunnolla paikallaan, robotti ei voi nostaa sitä ja kokoonpanolinjan tuotanto pysähtyy.

Konenäkö liitettiin ohjelmoitavaan logiikkaan sekä robottiin ja järjestelmä konfiguroitiin toimimaan saumattomasti osana kokoonpanolinjaa. Konenäkö havaitsee jos osa on väärässä asennossa ja ilmasuihku työntää sen paikoilleen.

Tämä opinnäytetyö tehtiin Saimaan ammattikorkeakoululle. Osa työtä oli tehdä opiskelijoille yksinkertaiset ohjeet, joista he voivat nopeasti oppia kuinka konfiguroida tämä konenäköjärjestelmä.

Opinnäytetyö on rakenteellisesti jaoteltu seuraaviin aiheisiin: ongelman taustatutkimus, ratkaisuvaihtoehdot, vaihtoehdon valinta, konenäön konfigurointi, järjestelmän ohjelmointi ja asennonkorjausjärjestelmän luonti.

Asiasanat: Konenäkö, automaatio, ohjelmoitava logiikka

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1 INTRODUCTION

This thesis concentrates on implementing an automatic visual inspection system to a production line. Machine vision is technology which belongs to factory automation, it is a system that takes pictures and interprets them to find defects or categorize products.

Machine vision systems started to be used widely in the 1980s but the systems were expensive and required a deep knowledge in computer programming. The use of machine vision has increased and continues to increase in the industry due to development of smart cameras which do not need a computer. They possess all the necessary equipment for machine vision system. These smart cameras are small, durable and easy to configure by production engineers (Connolly 2003).

1.1 Description of the work

The purpose of this final thesis is to implement a machine vision system to a production line to fix a possible problem situation. The production line consists of Festo's educational MPS (Modular Production System) equipment which is assembling cylinders. The machine vision sensor is placed so that it will check that a part is positioned correctly (see figure 1.1 below).

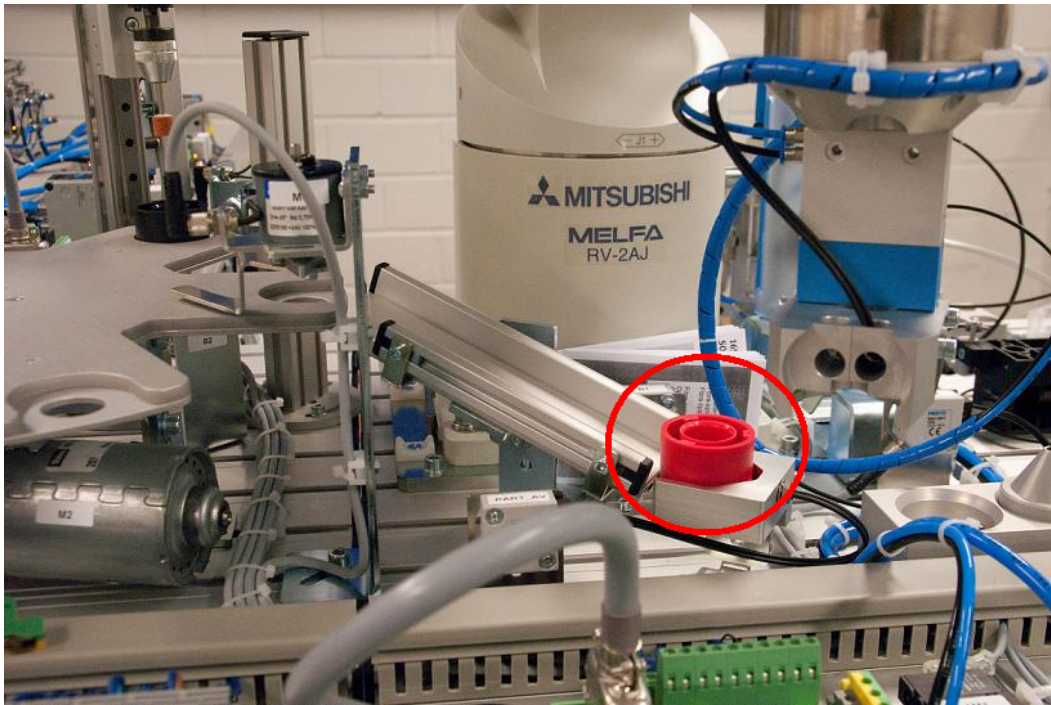


Figure 1.1 Festo MPS assembly line and a correctly positioned part

If the part is incorrectly positioned the assembly line cannot continue working and will come to a halt. Part of the thesis is to create a mechanism which fixes the incorrect position so the assembly line can continue working.

1.2 The objective

The objectives of the final thesis are to study and understand the background of the problem, find out possible solutions and implement a machine vision system to solve the problem. The most important part of the thesis is to study and implement a machine vision system, and to find a way to correct the position of the part. Implementing the machine vision consists of planning the placement of the equipment, configuring the machine vision, connecting the machine vision to work together with a programmable logic controller (PLC) and creating a system that fixes incorrect position. Also part of the thesis is to create instructions for automation students on how to configure the machine vision system.

2 MANUFACTURING LINE AND MACHINE VISION

This chapter introduces the manufacturing line equipment related to the thesis, following an explanation of the basic working principles of machine vision and description of the smart camera which is to be implemented.

2.1 Manufacturing line

For understanding the problem, it is relevant to know how the manufacturing line equipment works adjacent to the problem. The working area and equipment in the vicinity of the problem is shown below in figure 2.1.

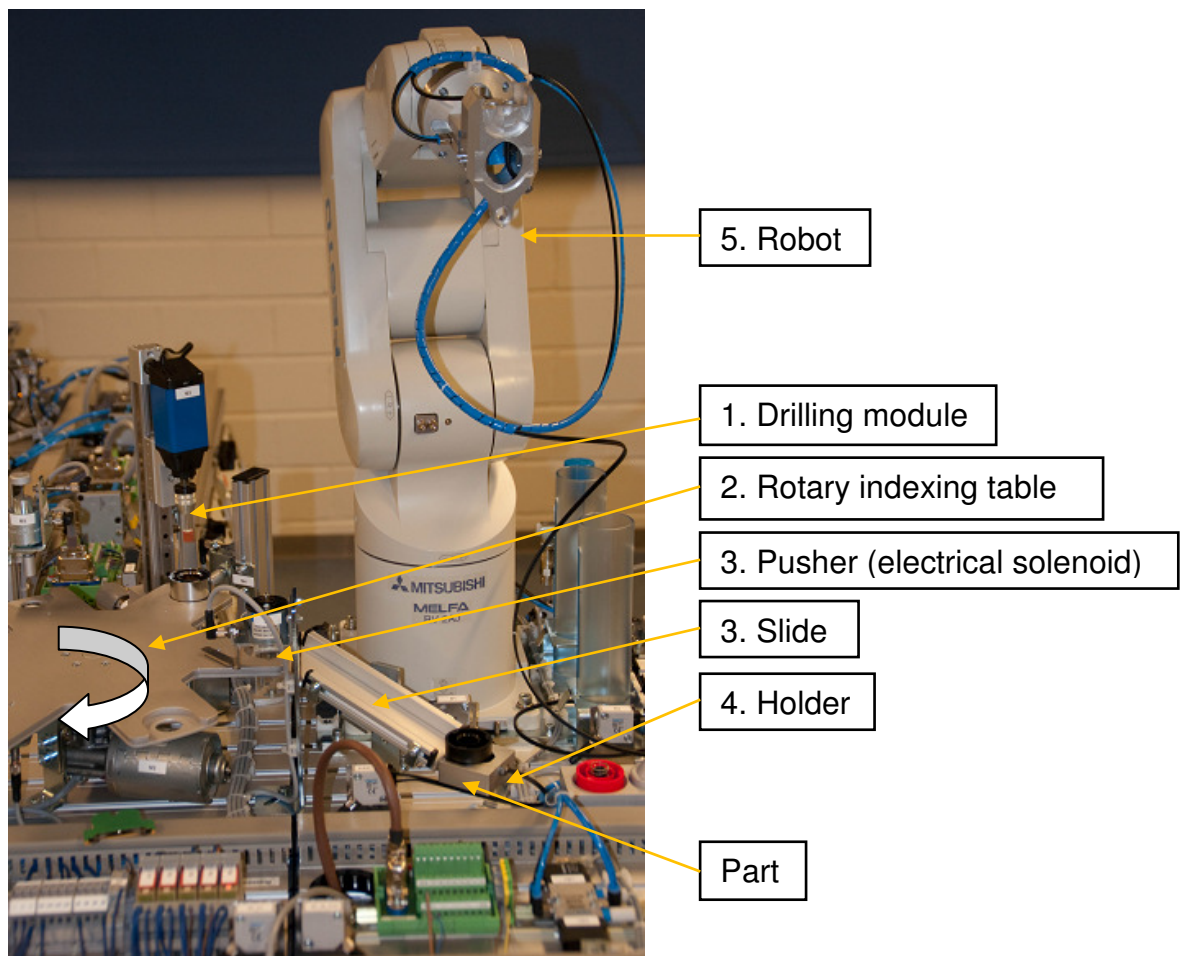


Figure 2.1 Manufacturing line and equipment

This area of the assembly line works in the following way:

1. The part is drilled in the drilling module.
2. The rotary indexing table rotates the part next to the pusher.
3. The pusher pushes the part down the slide.
4. The part reaches the holder.
5. The robot picks up the part. The cycle starts again.

Problem situation occurs when a part does not reach the holder completely but stays partly on the slider. When the part is not in correct position the robot will fail to pick up the part.

2.2 Machine vision

When talking about machine vision it means a computer vision system that is used to replace a worker by taking pictures and processing them. The basic working principle of machine vision is that a camera takes a picture, and sends it to a computer. The computer will accept or reject the status according to the rules programmed in it. That decision will be sent to another device which will then function according to that information. Smart cameras are machine vision systems that do not need an external computer but have a controller which acts as the computer.

Black and white machine vision systems have replaced humans in many areas but color machine vision has a reputation for being expensive and difficult to use. This assumption is based on experience with older systems. (Soloman, p.543.)

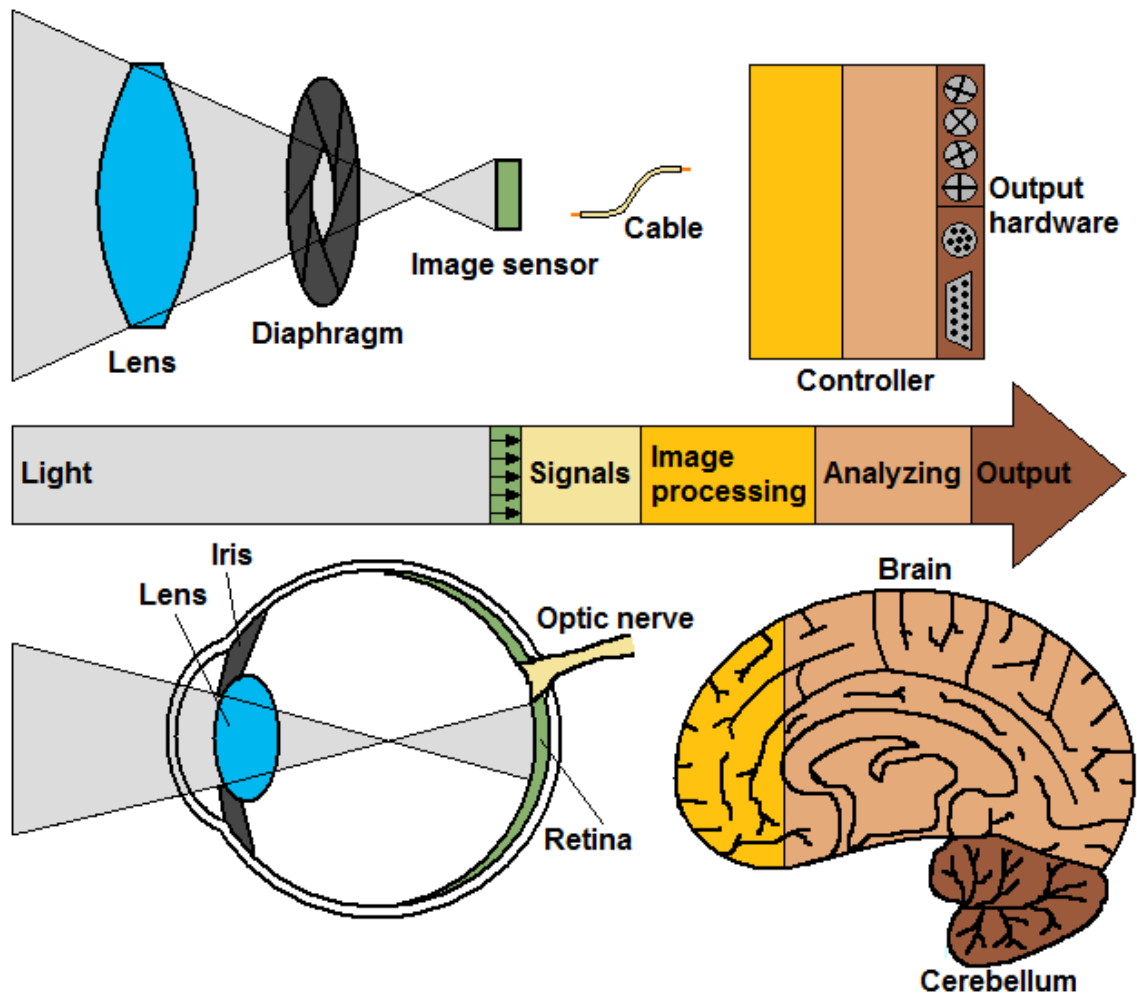
There is a wide variety of applications ranging from manufacturing line product inspection, to helping AGVs (Automated Guided Vehicles) to find their way in a warehouse (Sarviluoma 2009).

2.2.1 Comparing machine vision and human vision

In this chapter the term human vision is used to indicate human performing an inspection. It is easy to understand machine vision by comparing machine

vision system to a worker. Many parts of the machine vision system are analogous to human vision.

The functions of a worker who inspects a part can be roughly divided into observation, thinking and taking action. Observation consists of light reflected on the surface of the retina which becomes signals. The signals travel through the optic nerve into the brain which processes the information to create an image. Thinking is consisted of analyzing the information in the image and deciding if the part is acceptable and if taking action is needed. The following figure 2.2 shows the functions of the main components in human and machine vision.



Function	Machine vision	Human vision
Focuses the light to a smaller area	Lens	Lens
Regulates the amount of light	Diaphragm	Iris
Changes the light into signals	Image sensor	Retina
Transmits the signals to be processed	Cable	Optic nerve
Processed the signals to image	Controller	Brain
Analyzes the image and decides action	Controller	Brain
Sends signals to other devices	Output	Cerebellum

Figure 2.2 Function of machine and human vision

The arrow in the middle of the figure shows the flow of information which is affecting the output, based on programmed rules on the vision system. The difference in camera and human eye is that camera takes a picture, while human eye is constantly monitoring the image like a video camera.

When comparing human vision with machine vision on a “solution to a problem” basis they are very different. The image processing capabilities of the brain are greatly superior to any machine vision controller/computer software. The brain

can adjust well to under/over lighted images and constant adjusting of the image quality ensures function in changing environments. (Hornberg 2006, pp.29 - 31.)

To ensure reliable operation for machine vision, the lighting conditions must usually be highly controlled. Machine vision is better in that the camera does not get tired, distracted, bored or sick, and in a controlled environment machine vision is cheaper, less risky and more reliable. Using machine vision it is possible to calculate distances and areas, gain accurate numerical values and it enables high speed examination of defects that may be difficult for a worker to notice.

2.2.2 CCD-sensor

Machine vision system cannot function without a clear image, so it is very important to guarantee a steady environment for the camera to work. The previous chapter explained the overview of machine vision components and this chapter explains how a camera works to be able to understand issues that affect image quality. Digital cameras have an image sensor which is responsible for capturing the image, equivalent to a film on a traditional camera. The most used image sensor type in digital cameras is CCD (charge-coupled device) sensor (figure 2.3).

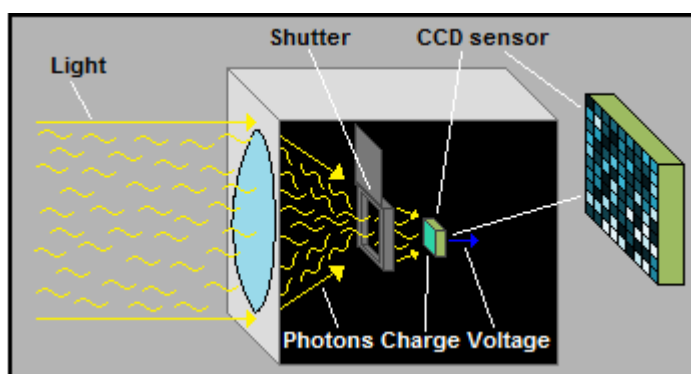


Figure 2.3 CCD sensor and shutter inside a camera

CCD sensor consists of cells and each cell obtains an electric charge proportional to the intensity of light projected on to it. The charges are converted into voltages which are used to form a black and white image. (Ochi et al. 1997.)

A shutter is a device inside the camera which opens for a period of time to let light pass into the image sensor. The time the shutter remains open, allowing more light to pass onto the sensor, is called shutter speed. In lower light conditions the shutter needs to stay open longer and if the object or the camera is moving, it can blur the image. A bigger aperture, which is adjusted by the diaphragm (see figure 2.2), allows more light to reach the sensor in shorter time but causes loss in depth of field (the area of a picture that is sharp).

2.2.3 Controlling lighting

Depending on the application the need for lighting is very different. Lighting is used to help the camera get accurate information about issues important for the examining.

When examining the shape or position of an object, often back lighting is used to highlight the edges for easy recognition (figure 2.4). Reflected lighting is used when performing surface inspections, to gain uniform light distribution on the surface of the object. (F150-3 vision sensor manual 1, 2002, pp.23-24.)

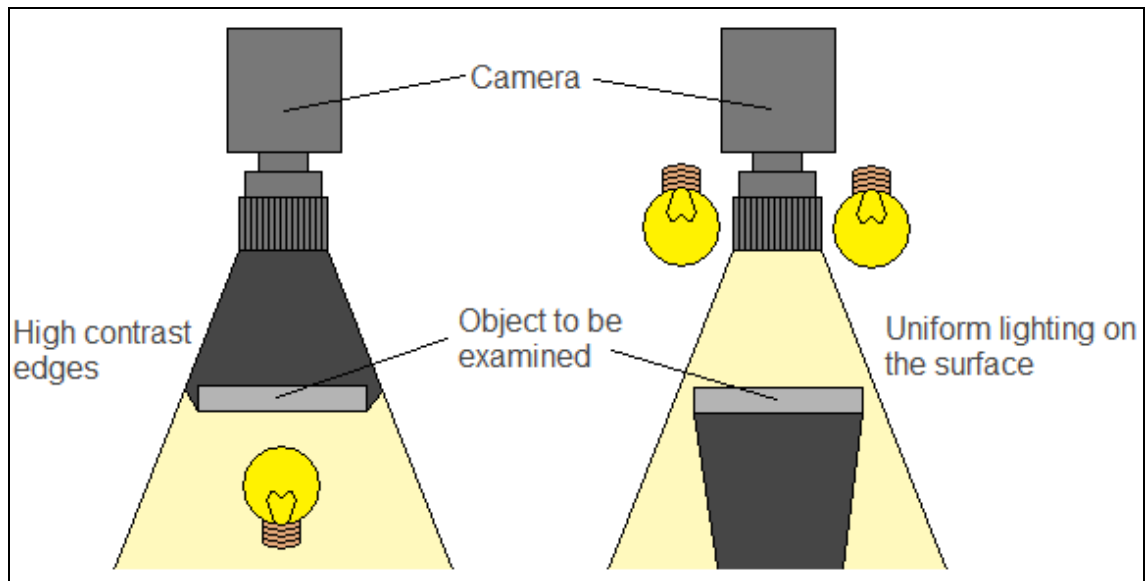


Figure 2.4 Back lighting and reflected lighting on an object

This figure shows only two basic examples of different lighting options, when applying machine vision to a specific application, it is necessary to customize the lighting according to the needs. Color of the light emitted by the light source is an important factor that can be used to highlight parts of specific color and diminish others (Hornberg 2006, pp.116 - 117).

2.3 F150 Machine vision

Machine vision used in this thesis is Omron F150-3 vision sensor. It features adjustable shutter speed, nine measurement methods, settings for 16 different measurement conditions (for different objects) and storing 23 latest measurement images to memory. The camera is black and white, and the system can be used with two cameras if needed. (F150-3 vision sensor manual 1, 2002.)

3 CAUSE OF THE PROBLEM AND HOW TO PREVENT IT

This chapter describes how the failure occurs and what mechanical reasons are behind it. It also illustrates possible methods for preventing the problem.

3.1 Analyzing the failure situation

When the pusher hits the part it is intended to give the part momentum to slide down and reach the holder, but sometimes the part hits the walls of the slider and loses its kinetic energy and will not reach the end of the holder. Figure 3.1 shows the initial impact from the pusher with a white explosion, movement of the part with red arrows and the major impact points with yellow explosions.

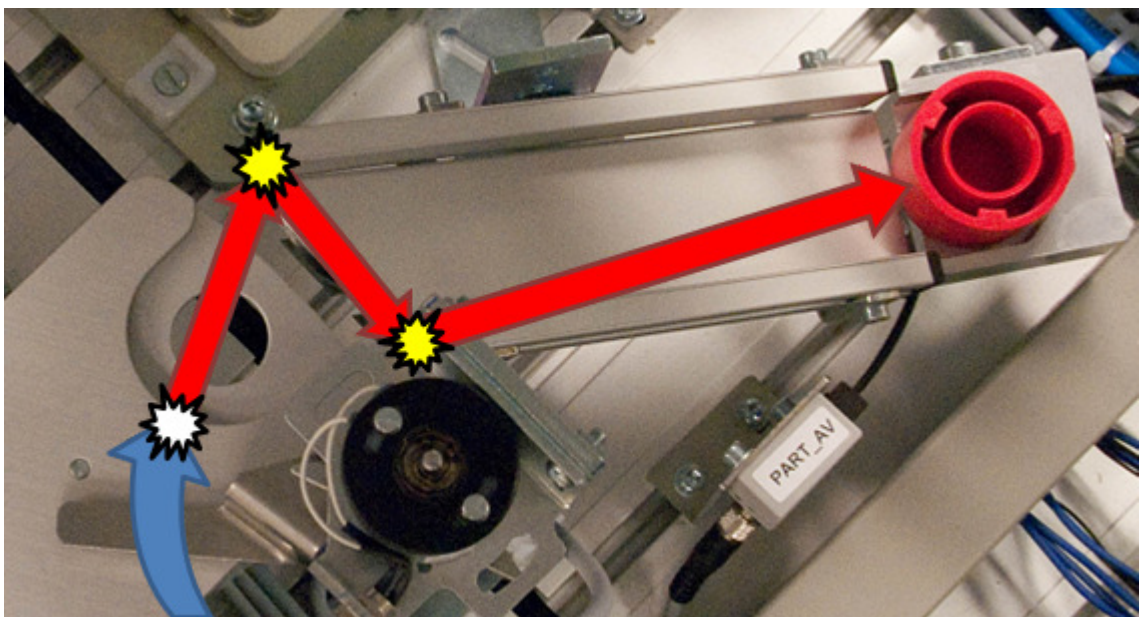


Figure 3.1 Impact points that cause the part to lose most of its momentum

The arrows in the figure show a rough estimate of the part's movement when it reaches the holder. Faulty condition occurs mostly because the position of the part is not always the same in the rotary indexing table when the pusher hits the part.

Figure 3.2 below shows approximation vectors of a typical failure situation and how the impacts to the sides of the slide cause the part to lose its movement energy.

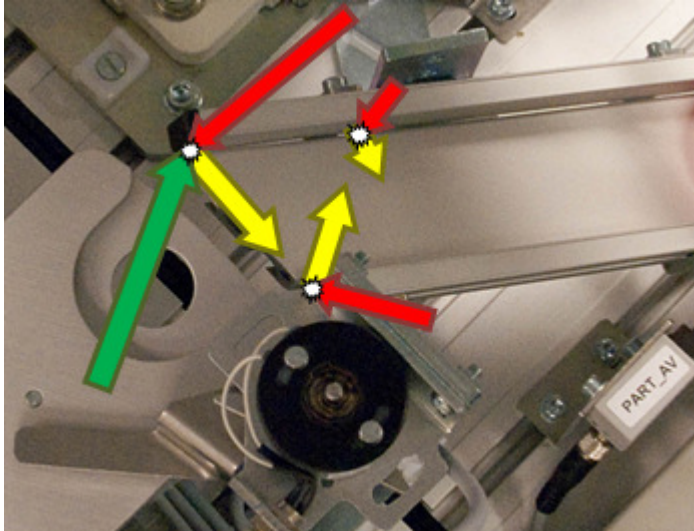


Figure 3.2 Estimation of typical resultant vectors caused by the impacts

Green arrow shows the initial movement vector, red arrows show how the impacts reduce the kinetic energy of the part and yellow arrows show the resultants after impacts. After the part has lost all or most of its kinetic energy, the friction of the aluminum slide will resist the movement of the part. Consequently, the part will not be able to gain the necessary energy to reach the end of the holder.

3.2 Reducing loss in momentum

There are multiple ways to reduce the initial impact with the slide and conserve enough momentum for the part to reach the holder. Figure 3.3 illustrates examples of different ways to change the behavior of the part.

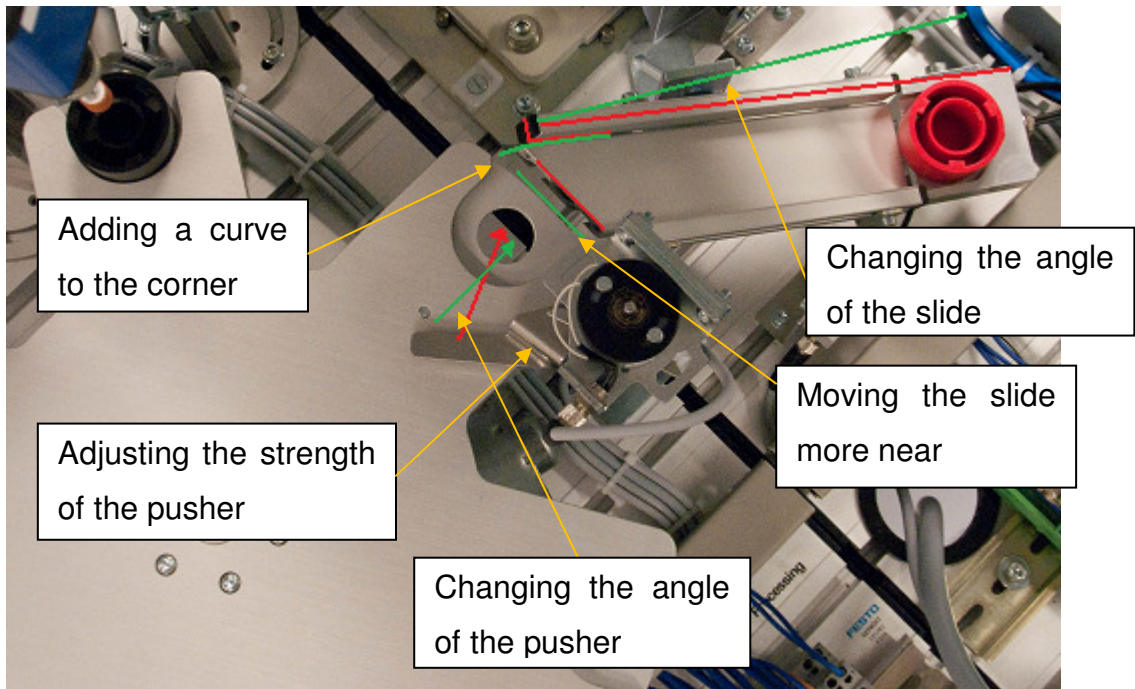


Figure 3.3 Possible solutions for reducing the impact with the corner

These solutions would probably be the most simple and efficient way to solve the problem and with little amount of empirical testing the problem could be solved.

3.3 Helping the part to reach the holder

It is possible to solve the problem by ignoring the loss of momentum and helping the part to reach the holder by increasing the energy it gains while sliding down. Figure 3.4 shows two different solutions that would help the part gain more momentum.

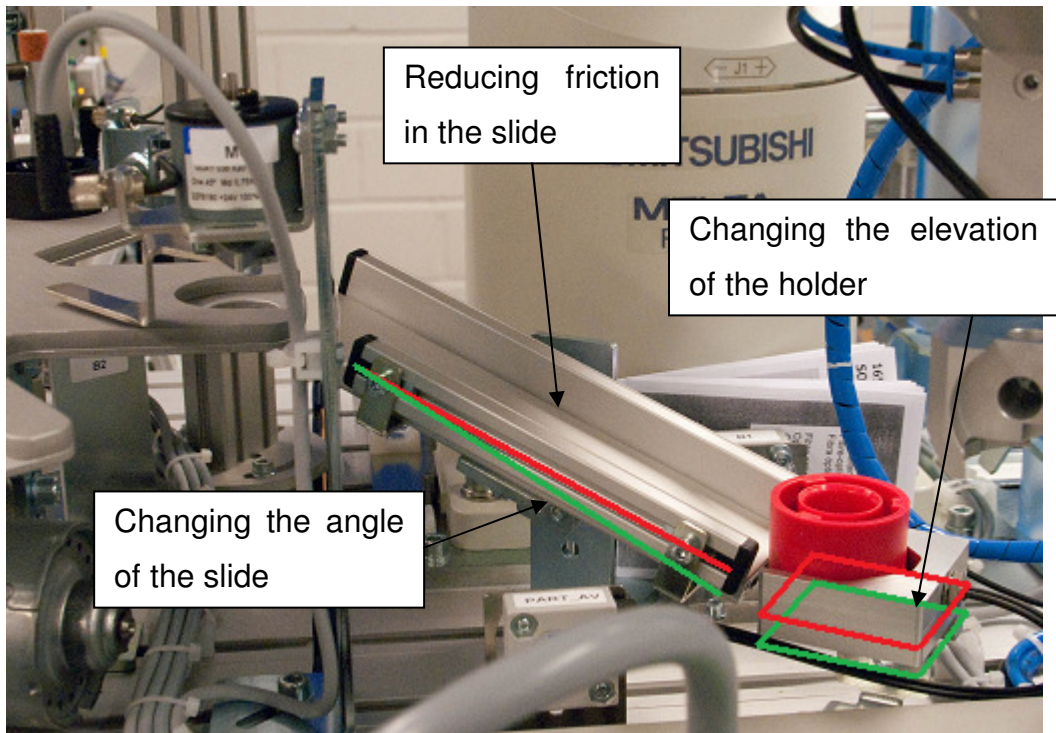


Figure 3.4 How to increase the momentum when the part is sliding down

If increasing the momentum of the part too much, the part may bounce back from the holder to the slide. Lowering the elevation of the holder could prevent the part from bouncing back as shown in the figure.

3.4 Reducing the friction

The effect of friction is significant in the failure of the part to reach the holder. A possible solution to the problem is to reduce the friction between the part and the slide to achieve necessary momentum to reach the holder completely. This approach is studied in depth in the following chapters.

3.4.1 Friction coefficients

Finding out friction coefficients is necessary in order to find out how much the friction should be reduced. It is essential to note that empirical tests showed that the static friction between the aluminum slide and plastic cylinder is not enough to stop the part in the middle of the slide. Static friction is therefore omitted from

the study. Figure 3.5 shows a free body diagram of the situation. Air resistance is not included in the free body diagram or the calculations but will be addressed later.

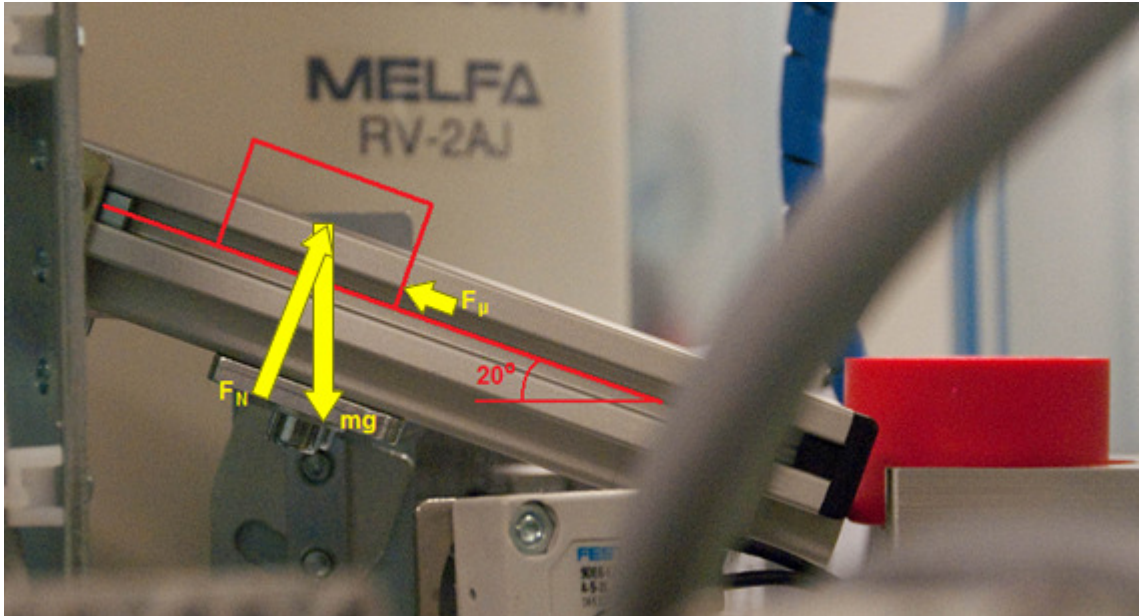


Figure 3.5 Free body diagram of the part on the slide

The following calculations were done to find out the kinetic friction coefficient between the parts and the aluminum slide. The equation 3.1 below shows the total force (sum of all forces) affecting the part:

$$F = \sin 20^\circ \times mg - u_k \times \cos 20^\circ \times mg \quad (3.1)$$

Total force is equal to pull of the gravity minus the friction force. Using the equation $F = ma$ it is possible to say that:

$$a = \frac{F}{m} = \frac{\sin 20^\circ \times \cancel{m}g - u_k \times \cos 20^\circ \times \cancel{m}g}{\cancel{m}} \quad (3.2)$$

After reducing the mass from the equation the result is:

$$a = \sin 20^\circ \times g - u_k \times \cos 20^\circ \times g \quad (3.3)$$

It is possible to add the previous equation (3.3) to the following:

$$x = x_0 + v_0 t + \frac{1}{2} a t^2 \quad (3.4)$$

As the initial position x_0 and velocity v_0 are zero the equation will be:

$$x = \frac{1}{2} (\sin 20^\circ \times g - u_k \times \cos 20^\circ \times g) t^2 \quad (3.5)$$

Solving the kinetic friction will change the equation into the following form:

$$u_k = -\frac{2\left(\frac{x}{t^2}\right) - \sin 20^\circ \times g}{\cos 20^\circ \times g} \quad (3.6)$$

It is now possible to calculate the estimated kinetic friction coefficient using this equation. To find out the time a total of 20 test slides were done for each three different plastic parts. After removing the outliers from the results (See appendix 1) the average times were calculated. When knowing the time and distance the coefficients were calculated. The resulting kinetic friction coefficients of the parts are listed in the table 3.1

Color of the part	Time taken to slide 10cm	Kinetic friction coefficient
Red	548ms	0.30
Black	649ms	0.32
Silver	304ms	0.15

Table 3.1 Kinetic friction coefficients of the parts

The paint on the red and black parts seem to have about the same kinetic friction coefficient with the aluminum slide, but the silver colored part has definitely a lower coefficient and the difference in time is significant. It must be taken into account that these are rough estimates which are heavily influenced

by unstable measuring circumstances, dropping the part by hand to the slide and measuring the time manually. The calculations also do not take into account the air resistance which may have an effect on the lightweight plastic cylinder bottom and thus affect the estimated coefficients.

3.4.2 Air resistance

The air resistance is necessary to evaluate, because of the possible effect it has on the calculation of the friction coefficient. The force of the air resistance encountered by the parts is calculated using drag equation:

$$F_d = c_w A \times \frac{1}{2} \rho v^2 \quad (3.7)$$

Figure 3.6 illustrates the behavior of the air flow on the part.



Figure 3.6 Air flow around the part when it is sliding in a 20 degree slope

This figure shows that when the part is sliding down in an angle, part of the air resisting the movement travels inside the cavities of the cylinder bottom, while other part of the air circles the cylinder smoothly. These are the reasons why drag coefficient c_w is estimated to be 0.9.

The frontal area of the red and silver parts in 20 degree slide is approximately 14 cm² and the smaller black part 13 cm². The calculated air resistance is compared to the friction and gravity force to find out the significance of air resistance (table 3.2 below).

		Red	Black	Silver
Mass of the cylinder bottom	m	14g	12g	14g
Kinetic friction coefficient	u_k	0,3	0,31	0,25
Drag coefficient	c_w	0,9	0,9	0,9
Frontal area of the cylinder bottom	A	14cm ²	13cm ²	14cm ²
Average velocity	v	0,28m/s	0,24m/s	0,51m/s
Average air resistance (drag)	F_d	0,06mN	0,04mN	0,21mN
Friction force	F_μ	38,7mN	34,3mN	32,3mN
Gravity force	F_G	47,0mN	40,3mN	47,0mN
Drag force compared to friction force		0,2%	0,1%	0,7%
Drag force compared to gravity force		0,1%	0,1%	0,5%

Table 3.2 Properties and forces affecting the parts

This table shows that the air resistance has an insignificant effect on the red and black parts (0.1-0.2%) when comparing to friction or gravity. The silver part is affected much more due to the higher velocity of the part. The estimated drag force on the silver part is still less than 1% and even when taking into account possible mistakes in evaluating the drag coefficient or other factors, air resistance can be considered negligible.

3.4.3 The force needed to reach the holder

The failure situation occurs when the part does not have enough momentum to overcome the impact force and friction force when touching the holder. It is very complicated to calculate the effect of impact and the friction which is heavily affected by surface quality. The energy needed is estimated by measuring the minimum distance from where the part reaches the holder completely. Figure 3.7 below shows the forces affecting the part when it is reaching the holder.

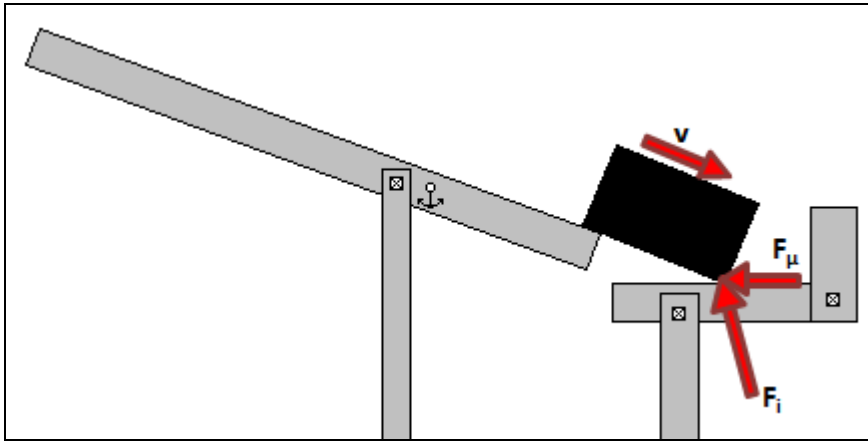


Figure 3.7 Friction and impact forces when the part reaches the holder

Calculations will be done using the black cylinder bottom since it possesses the smallest total force and is the most likely part to cause failure. The kinetic energy equation will be used to evaluate the required energy to pass the part to the holder.

$$E_k = \frac{1}{2}mv^2 \quad (3.8) \quad v^2 = v_0^2 + 2a(x - x_0) \quad (3.9)$$

When combining these two equations it is possible to say:

$$E_k = \frac{1}{2}m \times 2a \times x \quad (3.10)$$

The distance (x) from where the part achieves necessary kinetic energy to reach the holder is measured to be 12 cm. By using the formula above (3.10), the needed force to overcome the impact and friction of the holder is calculated to be 0.72mJ.

3.4.4 The required reduction of friction

The worst case is that the part loses all of its kinetic energy, stops and starts to slide down. Experiments showed that in the worst case the part has only 8 cm

distance to slide down before reaching the holder. That distance will be used to evaluate how much the friction needs to be reduced.

The same formula used to calculate the energy needed to reach the holder is altered as shown below.

$$E_k = \frac{1}{2} m \times 2a \times x = \frac{1}{2} m \times 2 \left(\frac{F}{m} \right) \times x = \frac{1}{2} m \times 2 \left(\frac{F}{m} \right) \times x \rightarrow E_k = F \times x \quad (3.11)$$

By replacing acceleration (a) with force (F) divided by mass (m), the equation can be simplified to the general formula of work.

To find out the necessary kinetic friction coefficient, the formula is altered by replacing the total force (F) with the gravity force (F_G) minus friction force (F_μ). After that the friction force is replaced with its components.

$$E_k = F \times x = (F_G - F_\mu) \times x = (F_G - u_k \times \cos 20^\circ \times mg) \times x \quad (3.12)$$

To find out the friction coefficient the formula is changed into:

$$u_k = \frac{F_G - \frac{E_k}{x}}{\cos 20^\circ \times mg} \quad (3.13)$$

The results for the maximum kinetic friction coefficients that allow the part to pass inside the holder without failure are shown in table 3.3.

Red part	0.29
Black part	0.28
Silver part	0.29

Table 3.3 Maximum kinetic friction coefficients

Note that the silver part already has a much lower kinetic friction coefficient (see table 3.1) and does not experience the problem situation. The black part has a bit lower value. This is because it has less mass and it needs more velocity to achieve the same kinetic energy as the other parts. These values represent the maximum kinetic friction coefficients that allow the part pass in to the holder reliably. They could be achieved using for example painting the surface of the slide, using another material than aluminum for the slide, sanding the surface to be smoother, etc.

4. FIXING INCORRECT POSITION

This chapter does not focus on preventing the problem but instead presents logic driven solutions for fixing the problem. The chapter presents different logic systems for fixing the incorrect position and evaluates them. The method used for mechanically fixing the position is selected later.

4.1 Dumb system

The idea of dumb system is that the logic does not know if the part is correctly placed or not. The system would try to fix the position always, forcing the part to reach the holder. The weak point of the system is that it has no way of knowing if the position was fixed correctly. This could be done using either the robot or a programmable logic controller.

4.2 Smart system

This system would know when the part is correctly placed by using a sensor. Only when there is a problem it would attempt to fix the position. After fixing the position, the system checks the position again and gives a go-signal for the robot.

Table 4.1 shows different possibilities for a smart system. Proximity sensor refers to any simple sensor (e.g. photoelectric, capacitive) detecting presence of the part.

Sensor	Logic controller	Pros	Cons
Proximity sensor	PLC	Simple	Inaccurate
Machine vision	PLC	Accurate, reliable	Complex
Proximity sensor	Robot	Simple	Inaccurate
Machine vision	Robot	Accurate, reliable	Complex

Table 4.1 Pros and cons of smart position fixing systems

Simplicity of using a proximity sensor for sensing is offset by the inaccuracy. A much more complex machine vision system is more reliable and accurate. Using the robot is perceived as equally functional system as PLC.

4.3 Comparison of methods

Comparison is done by assigning points and weights for the systems. The following table 4.2 shows the importance of different issues related to the comparison.

Issue	Importance (1-3)
Educational value	3
Versatility	2
Reliability	1

Table 4.2 Importance of different issues in position fixing systems

The importance values assigned to the table are reflected from the idea to create a system from where students can learn automation and create their own systems. Creating a relatively reliable system is of course a requirement.

Table 4.3 shows the evaluated points from 1-5, that were assigned for each method to compare them.

Controlling system	Educational value	Versatility	Reliability	Total Σ
PLC (dumb system)	1	1	1	3
Robot (dumb system)	1	1	1	3
Sensor + PLC	3	2	3	8
MV + PLC	5	5	5	15
Sensor + Robot	2	2	3	7
MV + Robot	4	5	5	14

Table 4.3 Points for position fixing systems

Dumb systems scored the minimum points and the machine vision sensed systems scored the highest. Difference of one point in the educational values of robot and PLC controlled systems is due to heavy reliance on robot programming which is not perceived to be as challenging as using the PLC. Also, using extensive amounts of robot logic would be a burden to the I/O (input/output) connections of the robot, limiting functionality, whereas the PLC has abundant I/O connections available.

Weighed points are shown below in table 4.4.

Controlling system	Educational value	Versatility	Reliability	Total Σ
PLC (dumb system)	3	2	1	6
Robot (dumb system)	3	2	1	6
Sensor + PLC	9	4	3	16
MV + PLC	15	10	5	30
Sensor + Robot	6	4	3	13
MV + Robot	12	10	5	27

Table 4.4 Weighed points for position fixing systems

Weights make the difference even more clear. Machine vision used with PLC gains the most points and is the selected method for correcting the position of the part.

5 IMPLEMENTING MACHINE VISION

The main part of this thesis is to create a functioning fault recognition/fixing system via the aid of machine vision and this chapter will describe the work done from scratch to a working system. The subchapters will be describing the following topics:

- 5.1 Equipment placement
- 5.2 Configuring the machine vision
- 5.3 Methods for position correction
- 5.4 Programming of the PLC and the robot

The chapters are not in chronological order, because in reality the work was done in many levels at the same time and it is much more feasible for the reader to understand them when presented individually.

5.1 Equipment placement

When choosing the placement for the equipment it was necessary to consider the following basic prerequisites:

- Ability of the machinery to work as expected
- Rigid attaching
- Environmental disruptions
- Obstacle free access to nearby equipment
- Safety issues for the users

The equipment was placed considering these issues.

The installation environment is very stable as it is a school automation laboratory. There are no problems arising from temperature, condensation,

humidity, dust, vibration, chemicals, gases or other possibly hazardous issues for the equipment. As the equipment is designed to be used in much worse environment (factory) the surroundings are very reliable. The only concerns the environment brings are the other equipment in close proximity, power cables and users.

5.1.1 Equipment list

The equipment used in the system are shown and numbered in figure 5.1, and the following will explain the essential characteristics and special considerations for the placement of involved machinery.

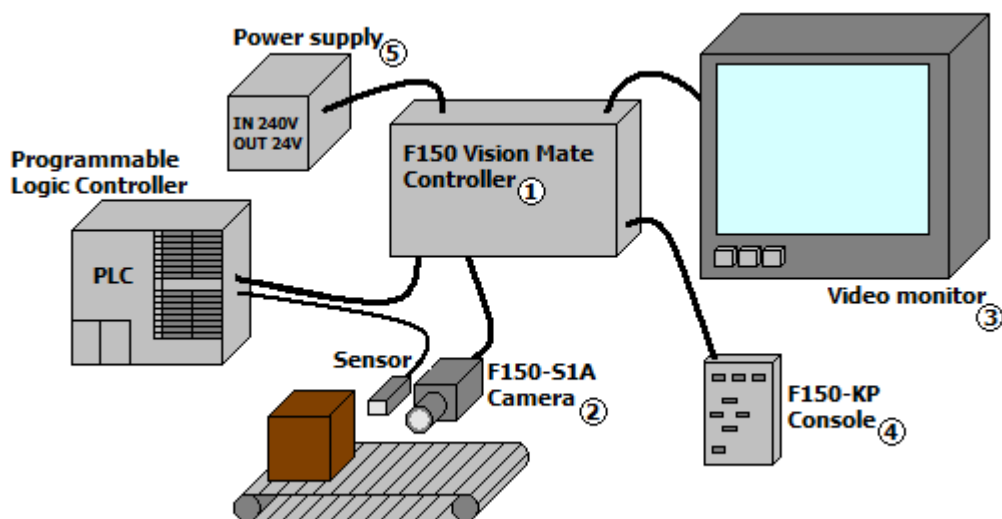


Figure 5.1 Overview of a typical F150 setup

This figure shows a usual application of a machine vision system for checking product defects on a conveyor belt.

1. F150 Vision Mate Controller

The F150 Controller is the core of the system that handles the interpretation of the picture provided by the camera and decides according to set rules if the part is accepted or not. It incorporates the inputs and outputs to sensors and logic

controllers, so it should be located in a place which allows easy connection to this equipment.

F150 must be installed in a specific orientation and needs to have a minimum clearance of 50 mm above and below to improve heat dissipation. There should be 200 mm space between the controller and power cables to avoid electrical noise. (F150-3 vision sensor manual 1, 2002, pp.2-4.)

2. F150-S1A Camera

The camera is responsible for taking the pictures and sending them to the F150 Controller. Special consideration for the placement of the camera must be done due to the importance of clear image and gaining the needed information from the picture. Due to the environment (students) accidental knocks may change the orientation of the camera. Rigid attaching is important. Camera case is connected to internal circuit 0V line and should not be grounded to avoid noise interference (F150-3 vision sensor manual 1, 2002, p.4).

3. Ikegami Video Monitor

The video monitor is to be placed in an accessible place to be able to monitor the function of the camera and to adjust the settings of the controller.

4. F150-KP Console

The console is used to configure the controller. It should be readily available for using and have a location where it can be put safely when not in use.

5. S82K-03024 Power supply

Care must be taken in the placement of the power supply as hazardous voltages are involved (230VAC).

5.1.2 Camera placement issues

Selecting the location for the camera (shown in figure 5.2) is very important to ensure reliable operation.



Figure 5.2 Omron F150-S1A camera and Pentax C2514-M 25 mm lens

There was a number of limiting factors such as:

- Obstacle free view to the part
- Minimum focusing distance
- Correct size of the image (distance of the camera from the object)

Other issues that may have had an effect were:

- Possibility of additional lighting
- Possibility of using a background

However, the main concern was that which method of measurement would be used. That is because the method of measurement affects what the camera needs to see and what not. Unnecessary information in the image could disrupt reliable operation.

So, in order to find possible locations for the camera a measurement method was selected first. There were eight possible methods of measurement which could be used to find out the placement of the part.

1. Binary center of gravity is used to find out the center of gravity of the part and its position.
2. Binary area is used to calculate the area/size of the object.
3. Binary axis angle finds out the angle of major axis of the object.
4. Gray search compares the part to an existing part in the memory and gives a correlation value and coordinates for the part.
5. Precise search is the same as gray search except it gives the location of the part in sub-pixels (more accurately).
6. Gray edge position finds out the coordinates of an edge in the part.
7. Density averaging measures the average density based on differences in the brightness.
8. Relative search measures the distance of a pre-registered feature to a reference point.

These different measurement methods were evaluated according to four important properties; importance of lighting, importance of camera view (from which angles and positions the picture should be taken), accuracy of the measurement and reliability which means the probability of error. These were evaluated with a scale of 1-3 as shown in table 5.1.

Method of measurement	Lighting	Camera view	Accuracy	Reliability	Total Σ
Binary center of gravity	2	2	2	2	8
Binary area	2	1	1	1	5
Binary axis angle	3	2	1	2	8
Gray search	2	2	2	2	8
Precise search	2	2	3	2	9
Gray edge position	3	3	2	3	11
Density averaging	1	1	1	1	4
Relative search	3	2	3	2	10

Table 5.1 Differences in measurement methods

The best suited modes without using weighed values for the properties are gray edge position, relative search and precise search.

Weighed importance of different properties were assigned and can be seen in the following table 4.2.

Issue	Importance
Lighting requirements	2
Camera view requirements	2
Accuracy	1
Reliability	3

Table 5.2 Weights of measurement method properties

Reliability was selected as the most important issue. Accuracy was weighted low as it is easy to achieve the necessary accuracy for this application.

The following table 5.3 shows the points after adding the weights of the properties.

Method of measurement	Lighting	Camera view	Accuracy	Reliability	Total Σ
Binary center of gravity	4	4	2	6	16
Binary area	4	2	1	3	10
Binary axis angle	6	4	1	6	17
Gray search	4	4	2	6	16
Precise search	4	4	3	6	17
Gray edge position	6	6	2	9	23
Density averaging	2	2	1	3	8
Relative search	6	4	3	6	19

Table 5.3 Weighed differences in measurement methods

The results are similar to table 5.1. Gray edge position is the best choice and the second is relative search. Gray edge position is superior due to its simple working method which is not so dependent on lighting to provide accurate results. The method will find an edge of the part and find out the coordinates of that edge to evaluate if the part is positioned correctly; there is no need for large area consistent lighting because only a small portion of the part is used to check the location. Relative search is also satisfactory but inferior due to more demanding camera positioning requirement.

5.1.3 Equipment locations

Positioning the camera was relatively simple as there were very few options where to place it. The figure below shows where the camera was placed.

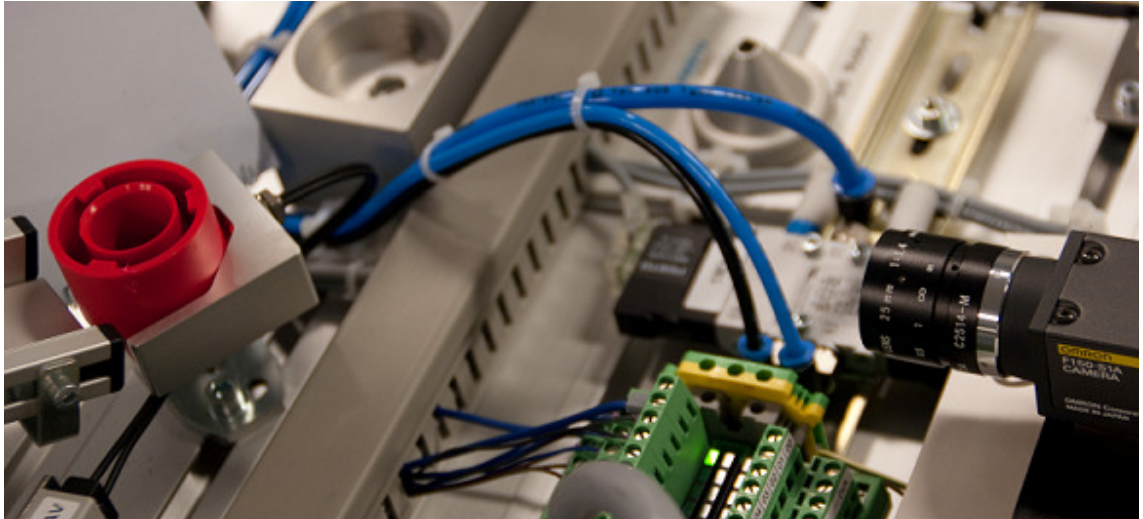


Figure 5.3 Location of the camera

This location gives a clear image of the parts edge and is not obstructing the use or maintenance of other equipment.

The image given by the camera from the selected position is shown below in figure 5.4.

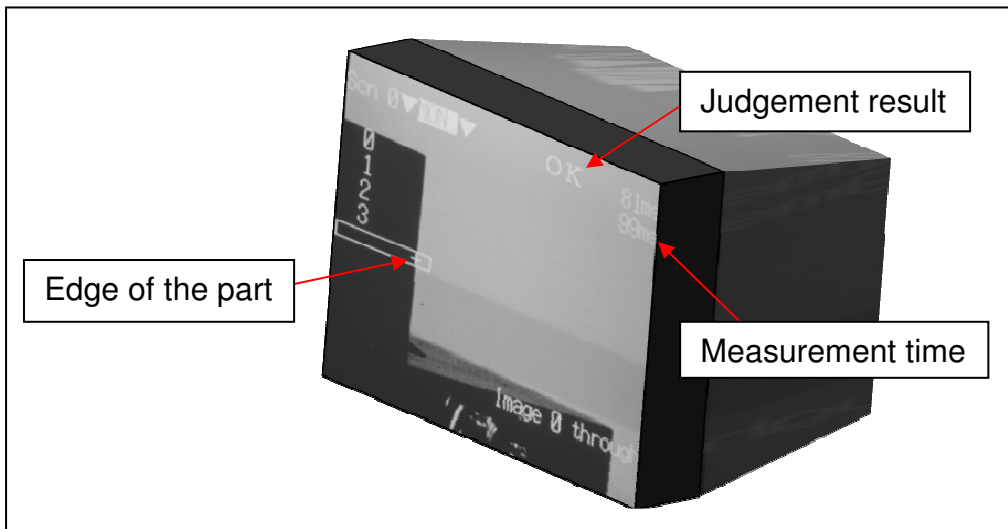


Figure 5.4 Visualization of the monitor and camera image

The figure shows the operation of gray edge position.

The controller, screen and console were placed under the table and out of the way. The power source was placed on the other side of the table near a power

plug. When in normal use, there is no need to access this equipment. However, when needed they are easily accessible.

5.2 Configuring the machine vision measurement

Configuring the camera was started by adjusting the image from the camera to be clear. Shutter speed was set to the slowest (1/100s) to make the image bright enough and the image was filtered to make the contrast between the part and background high. Lighting was not added but only an A4 sheet of paper was added to increase the contrast difference between the part and background. Figure 5.5 below shows the resulting image.



Figure 5.5 Image from the camera

This image has a very clear contrast difference and it is easy for the measurement to detect where the edge of the part is. Setting the measurement conditions was straightforward as it was only a matter of defining the limits for the acceptable measurement. Figure 5.5 shows the settings for gray edge position measurement.

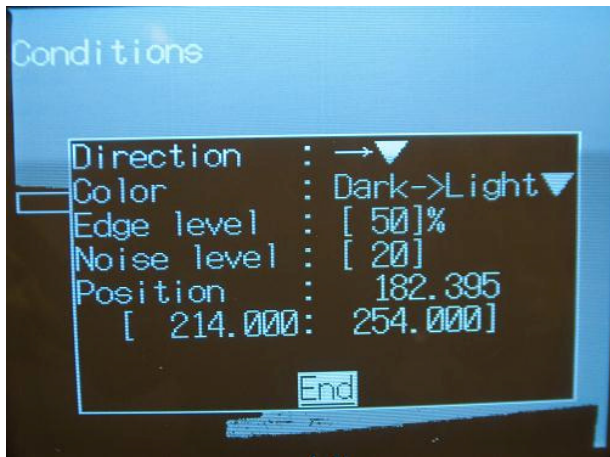


Figure 5.6 Gray edge position measurement settings

Position in the figure shows the current position for the part in pixels. The minimum and maximum limit for the position was set. If the measurement falls between the limits the measurement is judged acceptable.

5.3 Position correction system

There were only two possible choices for fixing the incorrect placement. The choice was to either use an electrical solenoid for pushing the part, or then direct compressed air towards the part. The option of using the robot for mechanically pushing the part to the correct location was omitted since it would complicate its programs too much.

With only two possible choices, still a comparison table was made to logically see the differences between them. Table 5.4 shows the importance of issues related to selecting the method.

Issue	Importance (1-3)
Educational value	3
Versatility	2
Reliability	1

Table 5.4 Importance weighs for selecting position correction system

Educational value and versatility is of high importance as students can learn and modify the system. Reliability would of course be more important if this would be a real factory assembly line.

Table 5.5 shows the points, without weights, for the options.

Correction method	Educational value	Versatility	Reliability
Electrical solenoid	1	1	2
Compressed air	2	2	1

Table 5.5 Points for position correction systems

Compressed air is a more versatile and educationally more interesting choice. On the other hand reliability is higher in using a simple pusher.

The weighed points for the methods are shown below in table 5.6.

Correction method	Educational value	Versatility	Reliability	Total Σ
Electrical solenoid	3	2	1	6
Compressed air	6	4	1	11

Table 5.6 Weighed points for position correction systems

Weighs make the difference clearer. This evaluation ensured the decision of using compressed air in fixing the placement. It is also more appealing for students, as it is a more “showy” method which can expand the student’s view on how to solve problems.

Selected method

The position of the part is corrected using a 3/2 way NC solenoid valve which gives a short pulse of air. Followed by another measurement and if the position is not acceptable, another pulse is given. This cycle is done a maximum of ten times, and after that the part needs to be manually removed to continue normal operation. Figure 5.7 below shows how the air is directed to the part through a 4 mm plastic tube.

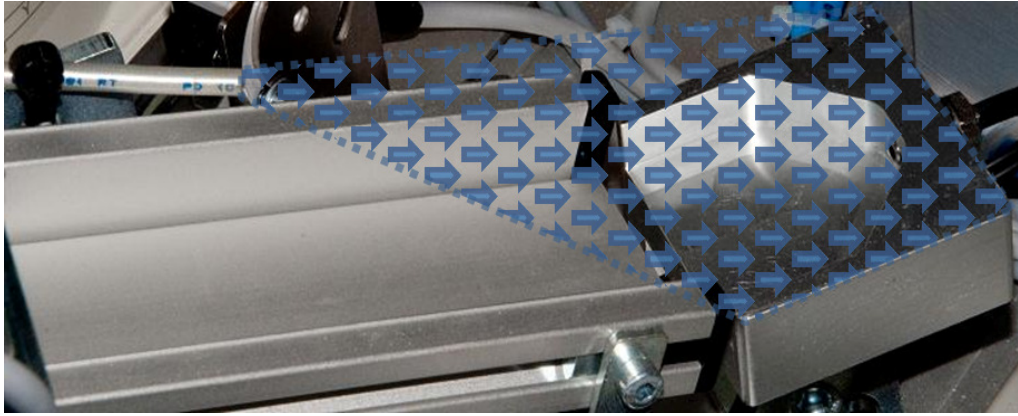


Figure 5.7 Position correction using compressed air

Arrows in the figure show an estimation of the airflow. The airflow is active for a duration of 150 milliseconds. Empirical testing with different settings showed that this time is appropriate.

5.4 Wiring of the devices

The schematic below shows how the wiring was done for the devices. Festo's I/O terminals were used for keeping wiring clear. A 25-pin D-sub connector is connecting the boxes together.

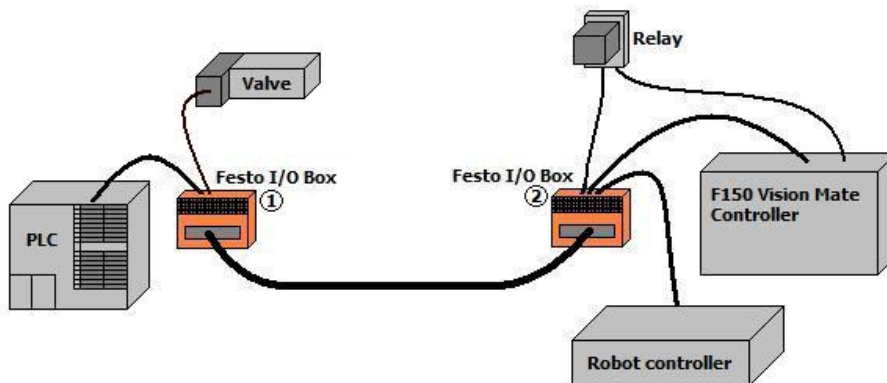


Figure 5.8 Wiring of the devices

Here it can be seen how the inputs and outputs were connected between the devices. A relay is passing on the 24V electric current from the PLC to the machine vision's output terminals. The relay was needed in the configuration because the camera online (I2.0) signal will always be output voltage is given to the output terminal of the controller, regardless of the machine vision software

running status. It was necessary to attach a relay which activates the output terminals when the power is switched on.

5.5 Programming of the PLC and the robot

The first thought was to connect the machine vision to function with the robot only, to create a more simple and reliable system. After studying this possibility it became obvious that it was impossible due to the fact that the robot had only one output and input bit free. Therefore, PLC was needed to create the system.

This chapter is an introduction on how the whole system works to give an idea to follow when reading deeper how individual parts of the program work. The following figure 5.9 shows the main working phases in the system.

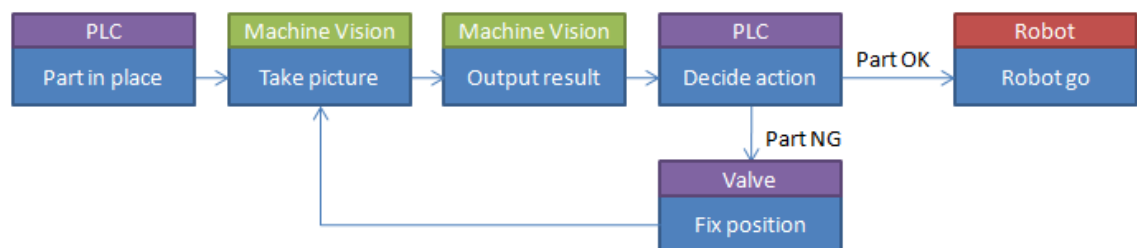
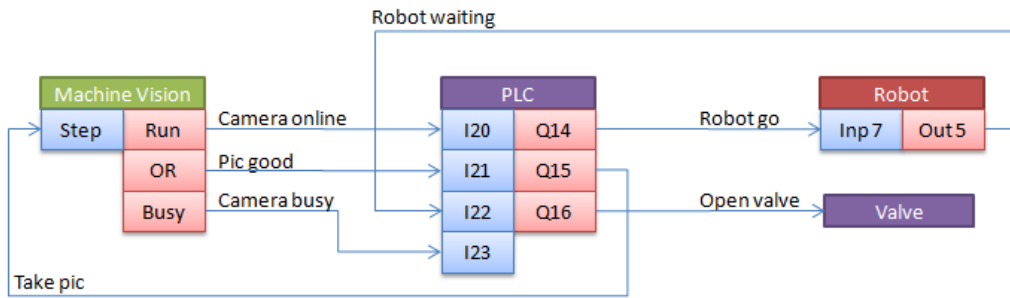


Figure 5.9 The main working phases in the system

First, the system needs to know when to take the picture. That information will be obtained from the PLC that is running the program for the drilling table. After that the picture is taken, and judgement result outputted to the PLC. Logic controller then decides to give the robot a go-signal or opens the valve to correct the position of the part. After closing the valve, picture is taken again, etc.

The following figure 5.10 shows how the different devices communicate with each other. In PLC addresses the abbreviation I means input and Q means output.



Name	PLC address	Dataflow	Purpose
Camera online	I2.0	MV -> PLC	Gives PLC information is the camera activated.
Pic good	I2.1	MV -> PLC	Gives PLC information is the part correctly placed.
Robot waiting	I2.2	Rob -> PLC	Tells the PLC if the robot is waiting to pick up the part.
Camera busy	I2.3	MV -> PLC	Tells the PLC when the camera is not busy.
Robot go	Q1.4	PLC -> Rob	Tells the robot when its clear to pick up the part.
Take pic	Q1.5	PLC -> MV	Gives the machine vision command to evaluate the position of the part.
Open valve	Q1.6	PLC -> Valve	Opens the valve to fix position.

Figure 5.10 Communication between different devices

As the PLC is running the main program, all the other devices are connected directly to its inputs and outputs. The names in the figure are the same which are used in the main program. In the programming chapters signal names will be followed by the PLC I/O address in brackets for ease of reference.

5.5.1 PLC program

The part which was added to the PLC program to make the machine vision system function consists of seven different ladder logic networks. Each of these networks is explained in detail below. Appendix 2 includes the symbol table of the program.

The robot is connected to a sensor that will sense the presence of the part but it cannot be used due to its inability to detect the black cylinder bottom when it does not reach the holder completely. Therefore, it is necessary to use the drilling table program to gain information that the part is present. The following ladder logic networks (figure 5.11) show how this is done.

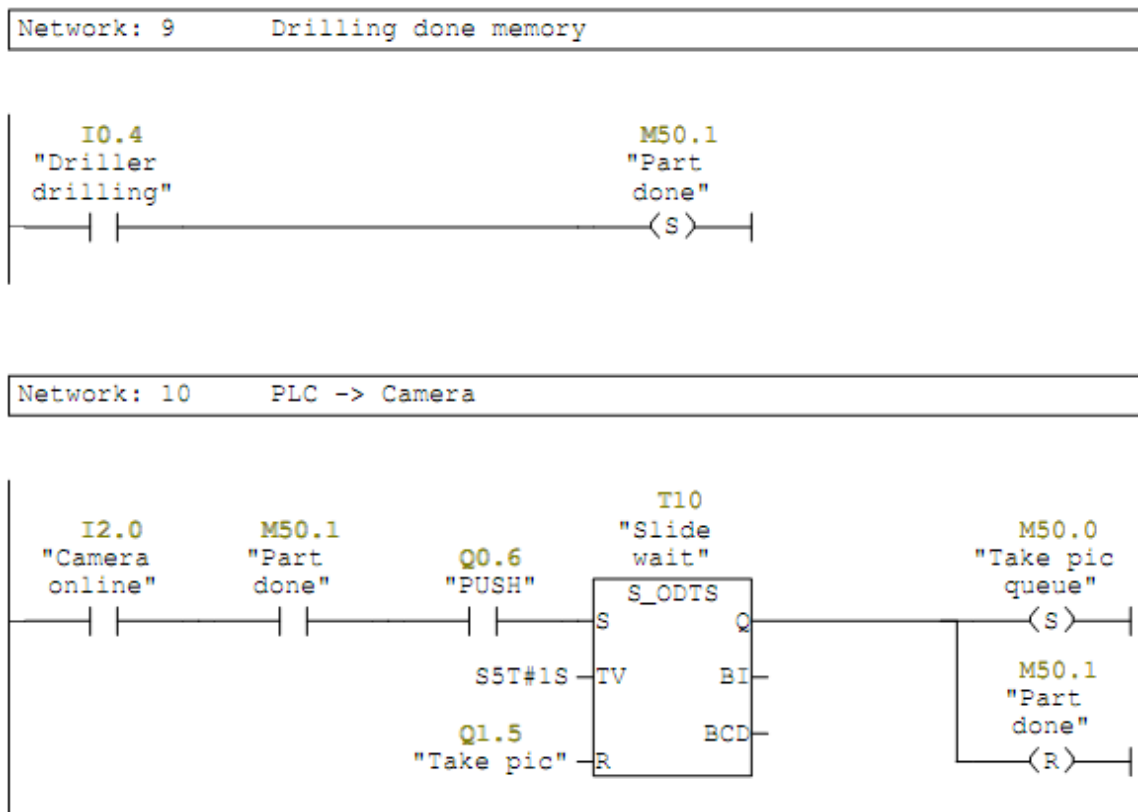


Figure 5.11 PLC program networks 9-10.

When the driller drills (I0.4) it activates a memory (M50.1) that will be used to ensure that a part is actually pushed down the slider, as the pusher will strike even without a part in it.

In network 10 the first contact checks that the machine vision is activated (I2.0), then part drilled memory is checked (M50.1) and pusher strike will activate timer T10. This timer will wait 1 second to make certain that the part has sufficient time to slide down. After 1 second, part done memory (M50.1) is released and take picture queue (M50.0) is activated.

Network 11 (see figure 5.12 below) is responsible for asking the camera to take pictures and to receive judgement results which will result in either giving the robot a go signal, or correcting the position of the part.

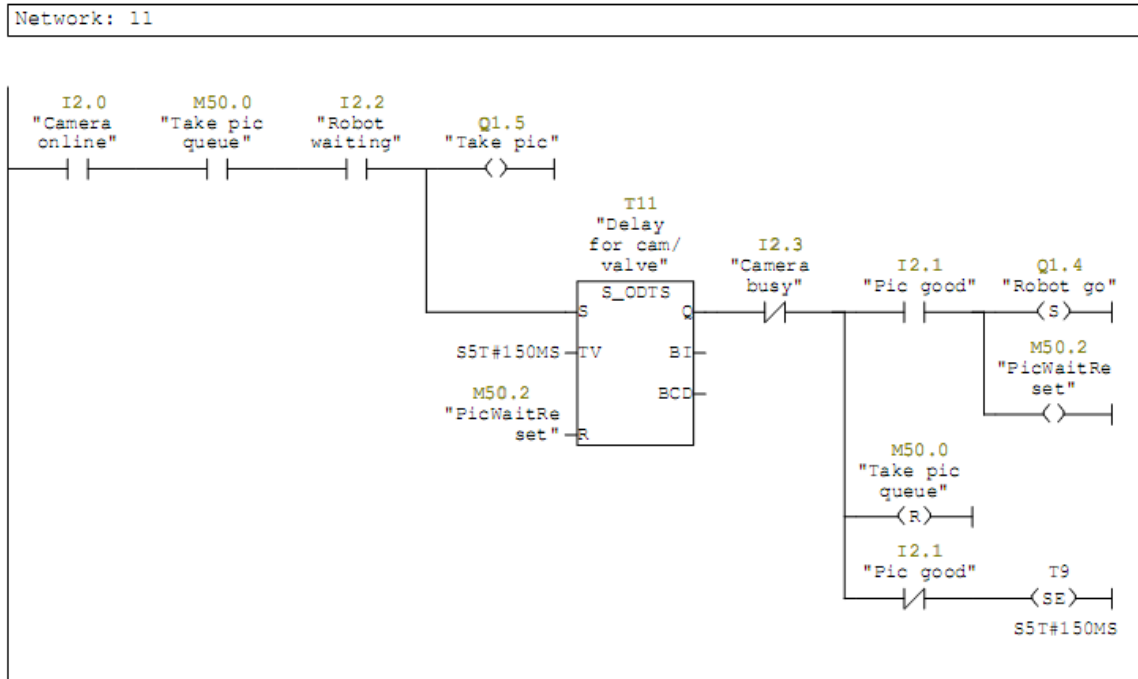


Figure 5.12 PLC program network 11.

The network will not function if the camera is offline (I2.0). The prerequisites for taking the picture are that a picture queue is activated (M50.0) and the robot is in waiting position (I2.2), which means that it is not assembling any part. There is a possibility that the robot obstructs the lighting for the picture, if it is not in the default position. If the robot is working the network will simply wait for the robot to finish its cycle and return to waiting position.

When the PLC outputs the take picture bit (Q1.5) in the same instant timer T11 is activated and it waits for 150 milliseconds and then the result of the judgment is checked. Camera busy (I2.3) is used to ensure that the camera has finished evaluating the picture and is outputting the result. When input pic good (I2.1) is activated robot go signal (Q1.4) is given and the result checking timer T11 is reset with memory M50.2. Take pic queue (M50.0) is reset after obtaining the result. In case of zero bit input in judgement result (I2.1), timer T9 is activated for 150 milliseconds.

Network 13 (figure 5.13 below) consists of a contact, which is activated by timer T9, that takes care of opening the valve.

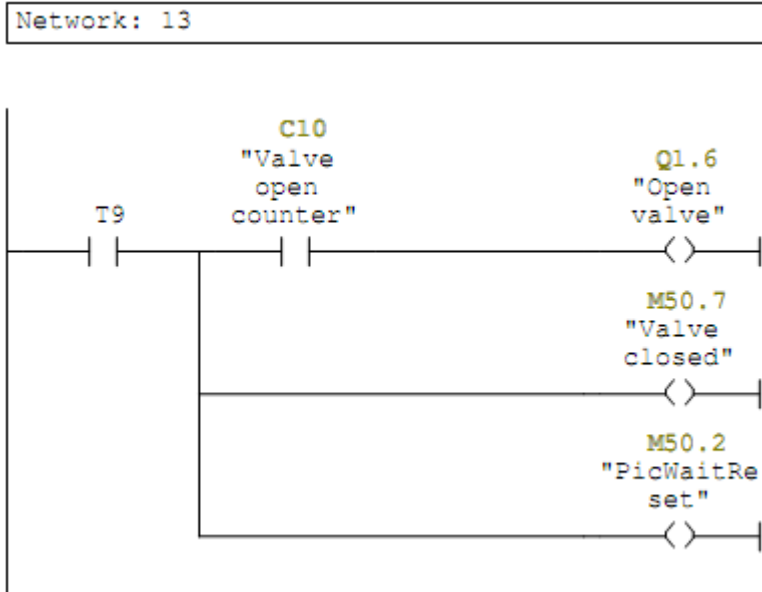


Figure 5.13 PLC program network 13.

T9 is active for 150 milliseconds and will keep open valve output (Q1.6) activated for that time. Counter C10 is activated unless the valve has been opened for ten times with failed judgement results from the machine vision. Memory PicWaitReset (M50.2) is used to reset the T11 timer in network 11 (see figure 5.12).

Valve closed (M50.7) memory is used in network 14 (figure 5.14 below) which is responsible for taking the pictures after the valve has closed.

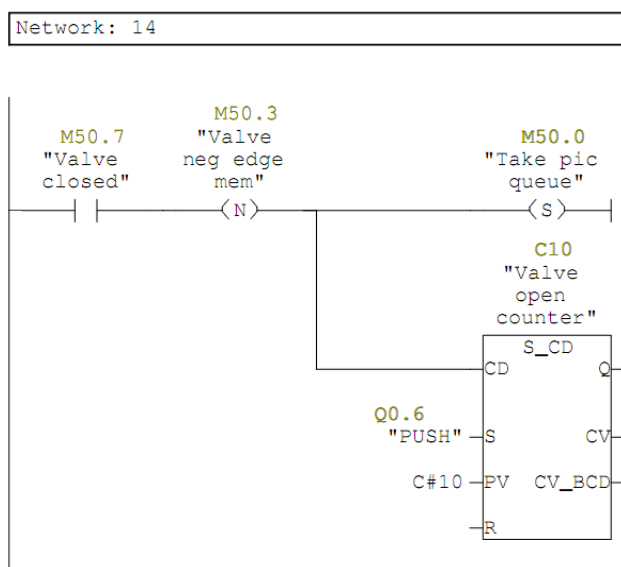


Figure 5.14 PLC program network 14.

This network also has the timer C10 for counting the number of valve openings.

Below (figure 5.15) is network 15 which handles the resetting of the go-signal for the robot.

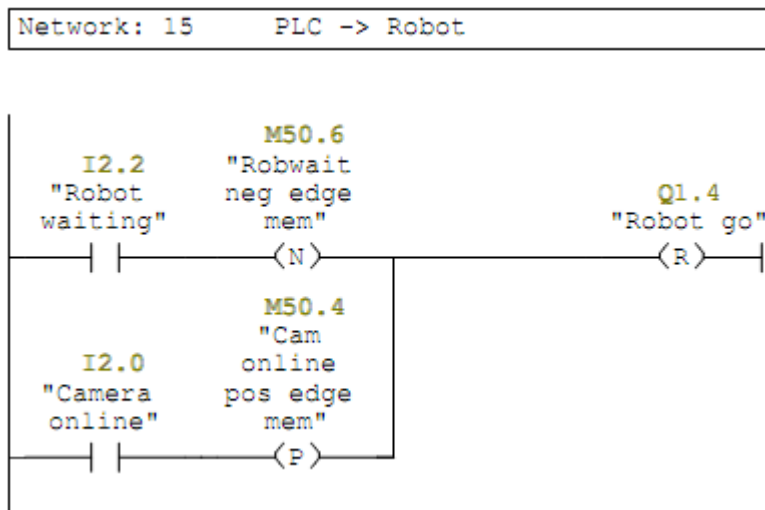


Figure 5.15 PLC program network 15.

Resetting will happen in the case robot ceases waiting (I2.2) and runs its program cycle or when machine vision is suddenly turned on (I2.0).

Finally network 12 will take care that when the machine vision is turned off the robot will always receive a go-signal.

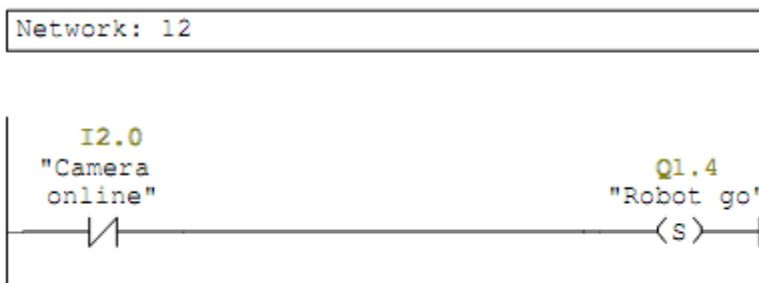


Figure 5.16 PLC program network 12.

This is to ensure that the system will function normally, as it was before installing the machine vision.

5.5.2 Modifications to the robot program

Two things were necessary to add to the program running in the robot, firstly the robot needed to wait for a go-signal from the PLC and secondly the robot needs to tell when it is busy. Below is the code which performs these tasks.

```
2930 *WPART
2940 WAITING = 1
2950 IF PART_AV = 0 THEN *WPART
2960 DLY 2
2970 IF PART_AV = 0 THEN *WPART
2980 GOSUB *CAMCHECK
2990 IP_N_FO = 1
3000 RETURN
3010 '-----
3020 ' | *CAMCHECK (Subroutine) |
3030 ' | checks if the position of the part is correct or not |
3040 '-----
3050 *CAMCHECK
3060 IF PART_OK = 0 THEN *WPART
3070 WAITING = 0
3080 RETURN
```

Figure 5.17 Part of the robot program that was modified

Here can be seen the line 2940 which outputs the “WAITING” signal to the PLC (I2.2) and the subroutine “CAMCHECK” which is checking the go signal from the PLC. As the robot receives the go signal “PART_OK” (Q1.4) the waiting signal is deactivated (line 3070) and the robot starts manipulating the part.

6 CONCLUSION

The purpose was to utilize machine vision to solve a problem consisting of an incorrect placement of a part. The thesis was started with an examination of the setting including detailed examination on; how does the area around the problem work, when and how the problem situation occurs, studying the physics that cause the problem to occur, and thinking of possible alternative solutions.

The machine vision system was successfully integrated as a part of the system and works seamlessly with the logic controller and the robot. It was surprising that much of the attention in the thesis needed to be used for programming the

logic controller and robot. Configuring machine vision was easy. As expected, a significant amount of time was used for finding the correct I/O connections between devices, especially the robot. This thesis supports well the view described in the introduction chapter by Connolly (2003) which states that smart cameras are easy to configure.

After the work was finished an instruction manual on how to configure the machine vision for automation students was made (see appendix 4). It explains in a simple way how to use the machine vision, so that students may quickly understand the steps required for configuring.

The work successfully met its goals; the incorrect positioning is detected, placement fixed, and the robot continues working without interruptions. Evaluating the consistent functioning was sufficiently checked, but the work failed in rigid connection of the camera. Only two months later when I came to check if the system works, somebody had already knocked the camera and the picture was offset so it would not function as it was intended. The work remained unfinished with relation to selecting a more permanent background for the camera image and remains to be used with a blank paper sheet as background.

The work done in the final thesis was interesting as it gave the opportunity to truly work independently and apply knowledge of automation gained through courses. In the start of the work I created a mind map using FreeMind software (see appendix 3) and it helped a lot in structuring and understanding different parts of the work.

The biggest issue while working with the thesis was time management. While doing courses the thesis got much less attention. What mostly disappointed me was the configuration of the machine vision measurements, as it was too easy. I was hoping that it would be more challenging. Working with the robot and PLC was exciting as the working sequence was relatively unorthodox and demanding.

Problems that I encountered during the work taught me a great deal. Machine vision as a theme was fascinating and it gave me a lot of very valuable information. In my opinion the problem solved in the thesis was very simple compared to what could be done using machine vision. When used correctly machine vision can be very productive and save many working hours in many applications.

Future prospects

It would be possible to extend the use of the machine vision within this assembly line. The following lists some views that could be done.

Mount the machine vision on the robot to create a mobile camera. With this system it would be possible to check if the part is correctly placed and also to check if there is sufficient amount of cylinder pistons for the robot to assemble the cylinder. At the moment, the robot does not know if there really exists a piston when it goes to pick it up.

The system could be modified not to use the terminal block but RS232C connection for I/O communication between the machine vision and PLC. This would reduce the amount of wiring and create a more complex process for data transfer that could enhance the skills and knowledge of the students about automation.

Instead of fixing the position the camera could measure the exact location of the part and tell it to the robot which would then pick up the part from that location. This would need good studying of the communication between the machine vision and the robot. Also a deep understanding of programming the robot would be required.

The system could adjust the length of the air burst, which fixes the position, by gaining the information of the part's position from the machine vision. This would create a more accurate position fixing system.

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Ochi, S. et al. 1996. *Charge-coupled device technology*. [e-book] Amsterdam: OPA. Available at: <http://books.google.fi/books?id=fVJ5txTE0mIC> [Accessed 19 May 2010].

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Test slide measurement results

(fix) = Outliers removed

Measurement	Red	Red (fix)	Black	Black (fix)	Silver	Silver (fix)
#1	63	63	64	64	24	24
#2	65	65	81	81	36	36
#3	55	55	60	60	29	29
#4	62	62	71	71	33	33
#5	49	49	57	57	19	-
#6	48	48	73	73	28	28
#7	78	-	63	63	35	35
#8	65	65	49	49	24	24
#9	47	47	38	-	28	28
#10	55	55	64	64	31	31
#11	45	45	95	-	32	32
#12	65	65	46	46	34	34
#13	42	42	70	70	27	27
#14	40	40	38	-	40	40
#15	50	50	76	76	25	25
#16	64	64	64	61	26	26
#17	47	47	65	65	28	28
#18	64	64	70	70	32	32
#19	61	61	73	73	45	-
#20	74	-	60	60	35	35
Average	56,95	54,83	63,85	64,88	30,55	30,39

Symbol table of the PLC program

SIMATIC

rotating_tablelee\

12/15/2009 04:32:37 PM

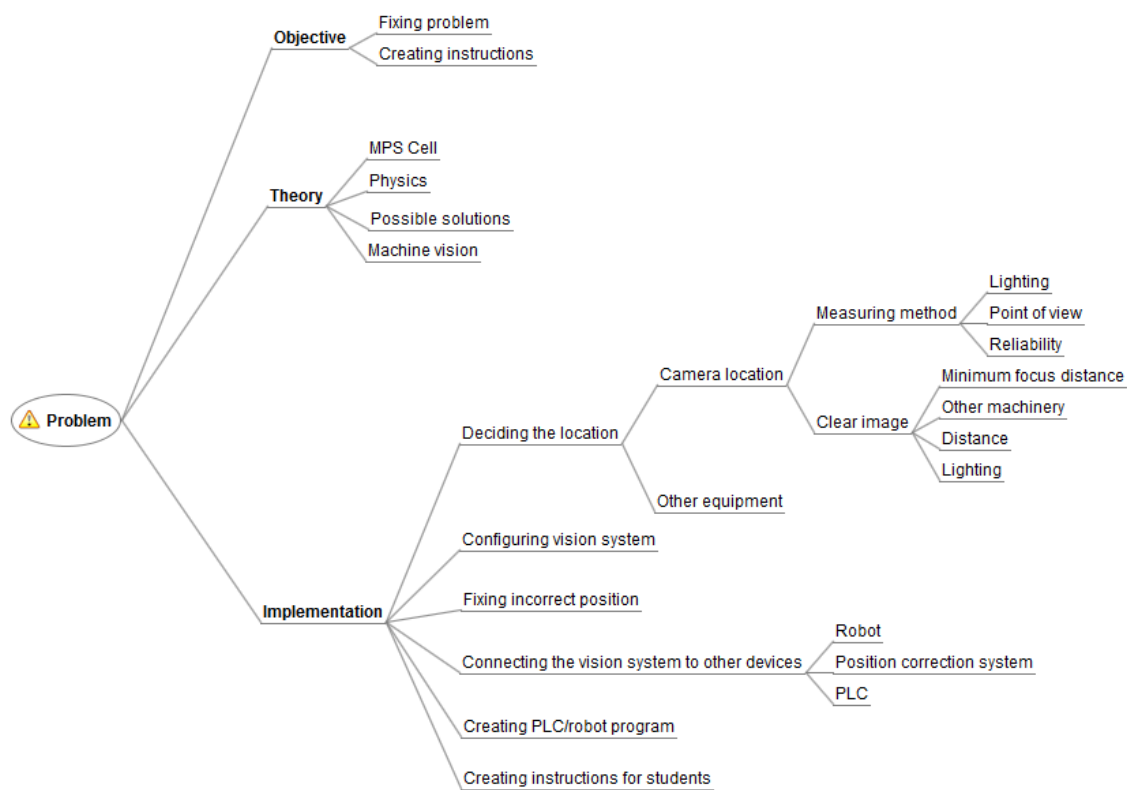
SIMATIC 300(1)\CPU 313C\S7 Program(2)\Symbols

Properties of symbol table

Name: Symbols
 Author:
 Comment:
 Created on: 11/20/2009 06:00:11 PM
 Last modified on: 12/15/2009 02:04:16 PM
 Last filter criterion: All Symbols
 Number of symbols: 20/20
 Last Sorting: Address Descending

Status	Symbol	Address	Data type	Comment
	Delay for cam/valve	T 11	TIMER	
	Slide wait	T 10	TIMER	
	Open valve	Q 1.6	BOOL	
	Take pic	Q 1.5	BOOL	
	Robot go	Q 1.4	BOOL	
	PUSH	Q 0.6	BOOL	
	Valve closed	M 50.7	BOOL	
	Robwait neg edge mem	M 50.6	BOOL	
	Fix pos OK	M 50.5	BOOL	
	Cam online pos edge mem	M 50.4	BOOL	
	Valve neg edge mem	M 50.3	BOOL	
	PicWaitReset	M 50.2	BOOL	
	Part done	M 50.1	BOOL	
	Take pic queue	M 50.0	BOOL	
	Camera busy	I 2.3	BOOL	
	Robot waiting	I 2.2	BOOL	
	Pic good	I 2.1	BOOL	
	Camera online	I 2.0	BOOL	
	Driller drilling	I 0.4	BOOL	
	Valve open counter	C 10	COUNTER	

Mind map for structuring the work



Quick start instructions on how to configure F150-3 Vision Sensor

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1 INTRODUCTION

This instruction manual will give a general idea how to configure F150-3 Vision sensor for measurements. It does not replace the 300 paged Expert menu operation manual but gives an easy start and a general idea on how to apply the vision sensor to use.

1.1 General information about machine vision

Machine vision is technology which belongs to factory automation, it is a system that takes pictures and interprets them to find defects or categorize products. Machine vision systems started to be used widely in the 1980s but the systems were expensive and required a deep knowledge in computer programming. The use of machine vision has increased and continues to increase in the industry due to development of smart cameras which do not need a computer. They possess all the necessary equipment for machine vision system. These smart cameras are small, durable and easy to configure by production engineers.

2 PLACE AND CONNECT DEVICES

This chapter shows a typical machine vision setup and tells the issues you need to think before placing the equipment. F150 Setup manual covers this chapter.

The equipment used in the system are shown and numbered in figure 2.1 below. This figure shows an example of a typical application and connections of machine vision system.

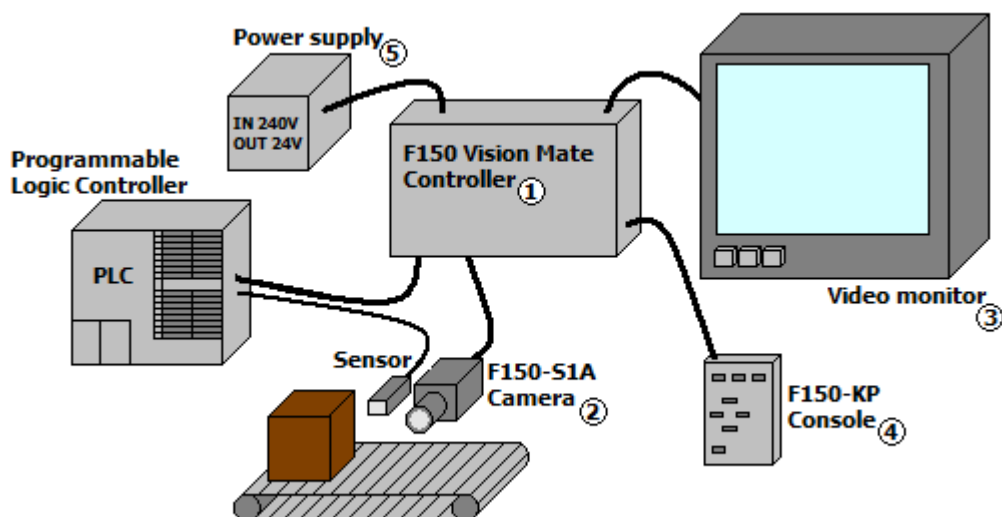


Figure 2.1 Using the F150 to check for package defects.

Devices in the figure are numbered and the following will introduce and explain the essential characteristics and special considerations for the placement of the devices.

1. F150 Vision Mate Controller

The F150 Controller is the core of the system that handles the interpretation of the picture provided by the camera and decides according to set rules if the part is accepted or not. It incorporates the inputs and outputs to sensors and logic controllers, so it should be located in a place that allows easy connection to this equipment. F150 must be installed in a specific orientation and have a minimum clearance of 50 mm above and below to improve heat dissipation. There should be 200 mm space between the controller and power cables to avoid electrical noise.

2. F150-S1A Camera

The camera is responsible for taking the pictures and sending them to the F150 Controller. Special consideration for the placement of the camera must be given due to the importance of clear image and gaining the needed information from the picture. Accidental knocks may change the orientation of the camera so

rigid attaching is important. Camera case is connected to internal circuit 0V line and should not be grounded to avoid noise interference.

3. Ikegami Video Monitor

The video monitor is to be placed in an accessible place to be able to monitor the function of the camera and to adjust the settings of the controller. The monitor is encased in a metal cover which is connected to the internal circuit 0V line and it should not be grounded to avoid interference. Attaching should be done avoiding metal screws/fasteners.

4. F150-KP Console

The console is used to configure the controller to function as needed. It should be readily available for using and have a location where it can be put safely when not in use.

5. S82K-03024 Power supply

Care must be taken in the placement of the power supply as hazardous voltages are involved (230VAC). Ask your supervisor first, as you may not have authorization to handle 230V equipment.

2.1 Before placing the equipment

When choosing the placement for the equipment, think at least the following basic prerequisites:

- Can the equipment function as needed?
- Is there concern that accidental knocks may happen?
- Can other machinery disturb the equipment?
- Does the equipment obstruct access to other equipment?
- Can the equipment placement cause danger to people?

These are just examples of possible questions. Mostly try to use your common sense to assess practical locations.

3 CONFIGURE THE MACHINE VISION

The F150 controller is configured using the console which is shown in figure 3.1 on the right.

- Arrow buttons are used to browse through the options
- ENT button is used to access menus
- ESC button returns to the previous menu
- TRIG button takes a picture and evaluates the result
- SHIFT button is used in conjunction with ENT for additional options



Figure 3.1 Console.

Figure 3.2 below shows the main menu of the controller and necessary options are explained with arrows.

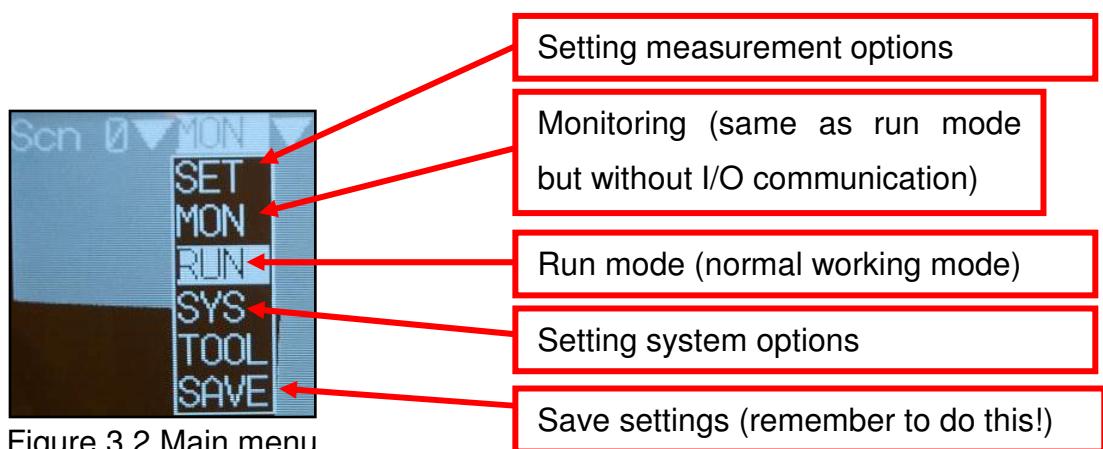


Figure 3.2 Main menu.

3.1 Adjust the image from the camera

Shutter speed needs to be adjusted according to the lighting (low light, slow shutter speed) to make the image bright enough.

1. Firstly select settings from the main menu (figure 3.3 below), and press the enter button.
2. Then select the “camera image” which contains the settings for the image. You can see options for shutter speed, filtering and BGS. Change the shutter speed to a suitable one by testing.
3. Next go to filtering and try if the image quality changes into better when applying any of the filters.
4. After that go to BGS (background suppression) settings and see if you can further improve the image quality.

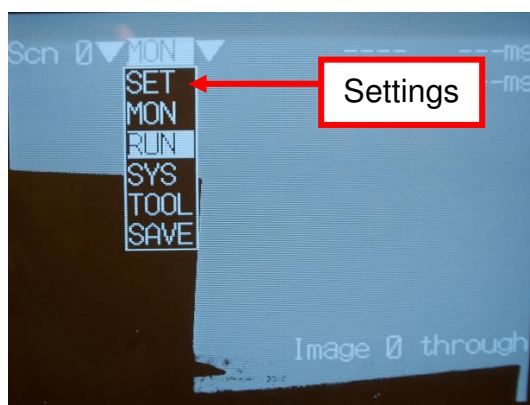


Figure 3.3 Settings menu.

3.2 Select measurement method

F150 contains nine different methods to measure the image. Table 3.1 below shows the measurement methods and a short explanation of the measurement. These measurement methods are explained in detail in the Expert menu operation manual pages 82-120.

Measurement method	Measures	Manual pages
Binary center of gravity and area	Parts area and center of gravity	82-90
Binary center of gravity and axis angle	Area, center of gravity and axis angle of the part (slower than above)	82-90
Gray edge position	Finds the edge of the part	91-95
Edge pitch	Pitch (distance between the midpoints of the parts) of multiple parts using the edges of the parts for measurement	95-98
Gray search	Searches for a part (model that has been preregistered in advance) from the image and compares the part to the model and expresses a correlation value for the similarity	98-105
Precise search	As above but more accurate (and longer processing time)	98-105
Surface defect	Surface area density variations (scratches, holes)	105-108
Density averaging	Density from each pixel (between 0-255) and measures the average density of the image	108-112
Relative search	Searches for a preregistered feature (hole, marking etc) and measures if it is in an acceptable range relative to an edge or another feature	108-120

Table 3.1 Measurement methods

This table shows the manual pages for each measurement method which describes all the detailed steps needed for configuring.

For most methods the configuring principle is the following:

1. Select measurement method.
2. Draw the measurement area (figure 3.4 below).
3. Define acceptable conditions (figure 3.5 below).

Pictures below give an example on how the measurement area drawing and measurement conditions look.



Figure 3.4 Measurement area



Figure 3.5 Measurement settings

3.3 Ensure consistent functioning

Now when the system is familiar and it is known which measurement method to use, the next step is to ensure that the measurements are accurate. The following figure 3.1 shows an example of how you can do this.

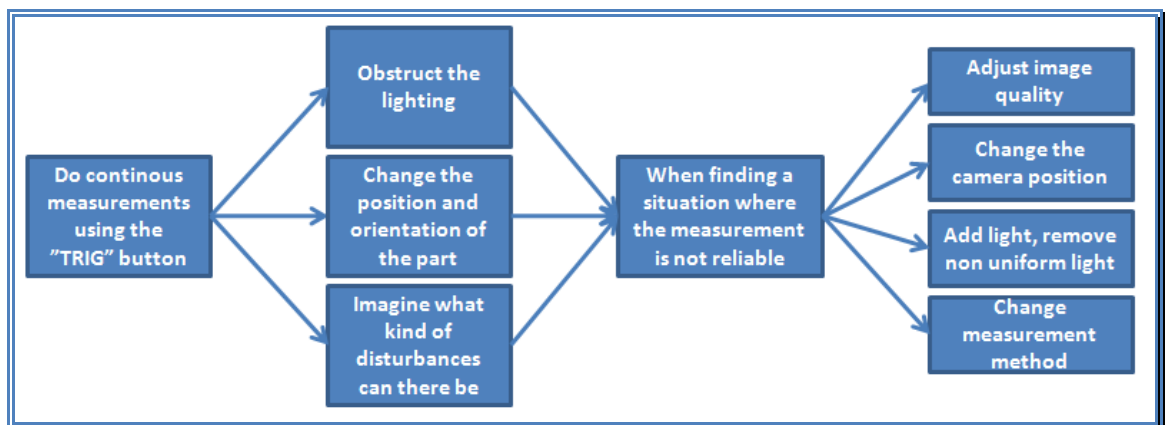


Figure 3.1 Example of systematically ensuring accurate measurements

Some tips for checking consistent functioning:

- Keep in mind that there is no point in creating situations that are very unlike to occur in normal use, stick to probable scenarios.
- When finding the error situation, remember to think how probable it is, that this error would occur.
- It is always a good idea to try to remove all not necessary information from the picture, if the camera does not measure it, it does not need to see it.

- If some measurement method seems to work unreliably with the available equipment, think of another measurement method.

4 CONNECT TO OTHER DEVICES

Wiring the machine vision with PLC and/or robot can be confusing, and it is recommended to draw a figure on a paper and write down all the I/O connections there. It will be much easier to keep track of the wiring. Below there (figure 4.1) is an example configuration of the F150, robot and PLC.

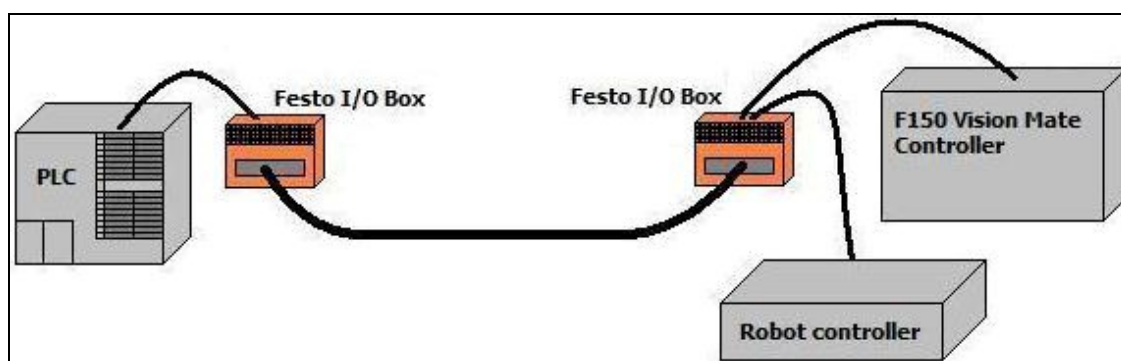


Figure 4.1 Example connections of machine vision system

Note Festo's "orange boxes" that are keeping the wiring tidy between the devices, by means of a 25-pin D-sub cable. Information about how to use the orange box can be found through Moodle or from the address below:

http://www.venlanet.org/timppa/html/common/Festo_IO_box.pdf

4.1 Basics of F150 Terminal block

The top terminals of the F150 will include the most important connections. Figure 4.1 below introduces five basic terminal block connectors.

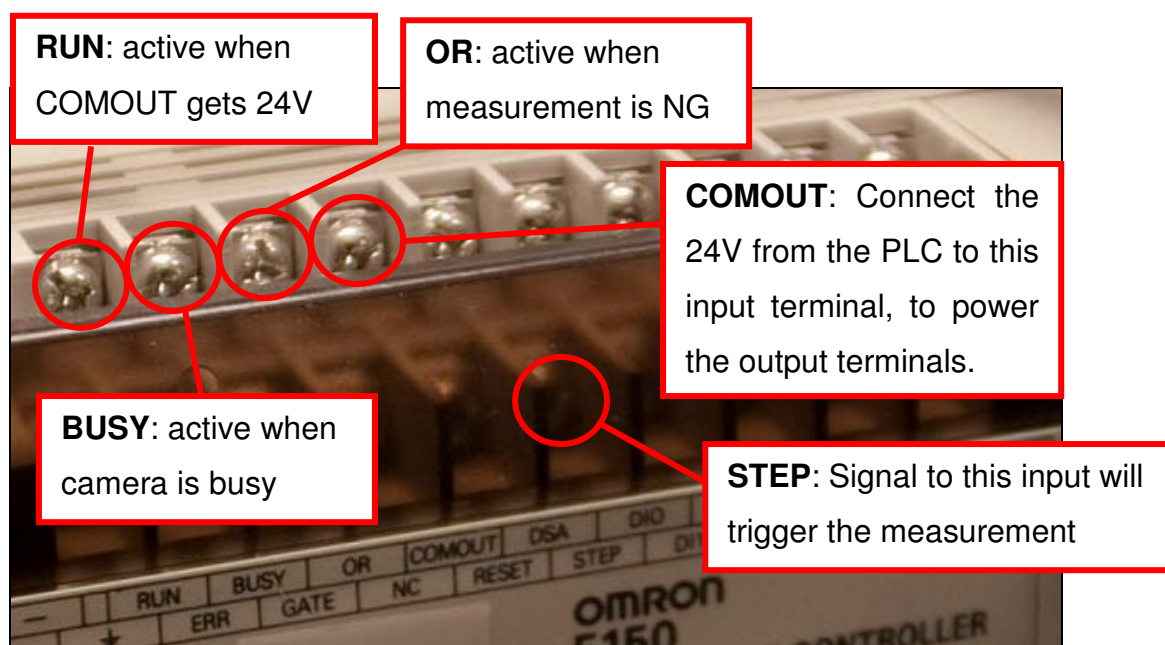


Figure 4.1 Terminal block of the F150.

Notice that:

- You may not need the RUN and BUSY connections if your PLC program does not require that information.
- If you need to use the RUN signal, you will need to route the 24V which is going to COMOUT through a relay. The relay should be activated by the F150 power switch, and it will relay the 24V current from the PLC to the output terminals of F150.
- Default setting is that OR terminal will output a signal when the measurement is NG (not good) but this can be changed from the system settings.

Detailed information about the terminal blocks and additional connectors can be found from the Setup manual pages 29-34, and Expert menu operation manual pages 183-195.

4.2 Machine vision configured

Now the system should be ready to be used with the PLC and/or robot. Continue by creating the programs and enjoy the results of your work.