Sensors And Digitization

Lab 4 - Compact Vision Systems

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Chapter 1

Introduction

1.1 Background of Study

During our course module in sensors and digitization, one of the laboratory tutorials was based on a Compact Vision system. A Compact vision system has the processor in a small compact housing with industrial Input/Output (I/O) rather than in the camera itself. This enables multiple cameras to be connected to the controller over long cable lengths and to share the processor and Input/Output(I/O), making them very cost effective for multi-camera solutions. Compact vision systems provide the flexibility, integration, and ruggedness required for many machine vision applications. A vision system will need components like a camera, lenses, cables, lightning, controller unit, and a monitor.

In the Laboratory tutorial we were to use a compact vision system from KEYENCE. KEYENCE Corporation is a direct sales organization based in Osaka, Japan, that develops and manufactures automation sensors, vision systems, bar-code readers, laser markers, measuring instruments, and digital microscopes. They have built a reputation for providing the best products in this field and having their products being used in many manufacturing industries.

We were to study and get familiar with the compact vision system from Keyence and be able to manipulate it in achieving certain tasks given by our supervisors. The goal at the end of this project was for us to have a broad knowledge on compact vision systems and be able to work with it should we be called upon professionally in the near future.

1.2 Objectives

In order to achieve the laboratory goals,we undertook various steps. We completed each step in a successive order. Below are the steps in which we took

- We read thoroughly the user manual of the controller unit.
- We Installed the vision system
- Performed basic operations by grabbing an image.
- We programmed to detect the edges of the picture taken.
- Performed an advanced operation on an image by using a Measurement Mode program to specific measurements of the image.
- Performed detection of specific parts of the image.

Chapter 2

Hardware And Software Specifications

2.1 Hardware Specifications

The Physical components used for the compact vision system were:

1. Controller Unit(CV-2100)
2. Remote Control Console(OP-42342)
3. Monitor Cable(RCA-RCA, 2m)
4. CCD Camera (CV-020)
5. CV-C3: Camera Cable(3m)
6. Monitor CA-MN80
7. 24 V DC Power Supply
8. Industrial Part and Back-light

2.1.1 Controller Unit (CV-2100)

Features:

- Fastest in its class, Ultra-high-speed processing of 20,000 parts/min.The combination of a new image processing engine, double speed progressive camera, and partial image capturing function produces a minimum processing time of 3 ms (20,000 times/min.*).
- Repeatability of +0.05 or -0.05 pixels The combination of sub-pixel processing and digitalization of image data allows the CV-2100 to achieve high accuracy and repeatability down to +0.05 or -0.05 pixels. Sub-pixel processing allows the display resolution to be reduced to 1/1,000 pixel.
- Digital image transfer. The image data captured onto the CCD is converted to digital data within the camera unit and then transferred to the controller. As a result, the image will not deteriorate and is resistant to noise interference.
- On-screen statistical data processing.Simplified tolerance setting and inspection history analysis.The first in-class statistical function of the CV-2100 allows the user to check the maximum, minimum, and average values of up to 11264 data points. The data is broken down by inspection number and displayed on a histogram and a trend graph, allowing for easy analysis of failed parts and optimization of tolerance settings.
- Basic Inspection tools, Suitable for every inspection need.Features various inspection tools including Area,Pattern search, Multiple searches, Edge angle, Edge width, No.(Number) of edges/Pitch, Stain, Blob, Intensity, Trend edge position, and Trend edge width. Ready to solve all of your application needs.

Specifications:

- Model : CV-2100
- No. of Pixels : 512(h) x 480(V)
- Camera input : 2 cameras
- Processing registration : 100 c/s (varies depending on the setting)
- Program registration : 32 programs.Programs are externally selectable.
- Measurement area : 64 areas/1 program
- Mask area : 4 ares/1 windows
- Area sensor : Window shape: square/circle/ellipse/ring/arc/polygon(up to do-decagon)/edge detection area
- Pattern Search : Multiple searches are available Window shape: square/circle/ellipse/ring/arc/polygon(up to do-decagon)
- Edge Detection : Angle measurement available.Window shape: square/rotating square/perimeter/arc
- Gravity position : Window shape: square/circle/ellipse/ring/arc/polygon(up to do-decagon)
- No.Edges : Window shape: square/rotating square/ring/arc
- Blob (Feature volume) : No. of blobs, gravity, principal axis angle, area, ferret diameter, circumstances length, and circularity
- Stain detection : Window shape: square/circle/ellipse/perimeter/arc/polygon(up to do-decagon)/edge detection area
- Intensity inspection : Window shape: square/circle/ellipse/perimeter/arc/polygon(up to do-decagon)/edge detection area
- Trend edge width : Window shape: square/rotating square/perimeter/arc
- Split Capturing : 2 to 4-split capture processing
- Serial Capturing : Serial capture processing for up to 32 times (Maximum, minimum and average values)
- CCD partial image capturing : 0 to 479 lines. The starting and end lines can be specified arbitrarily
- Display Language : English/Japanese/German selectable
- Power supply voltage : 24 VDC +10 or -10 /
- Ambient temperature : 0 to 40 degrees Celsius (32 to 104 degrees Fahrenheit),No condensation
- Relative humidity : 35 to 85/
- Weight : Approx. 510g

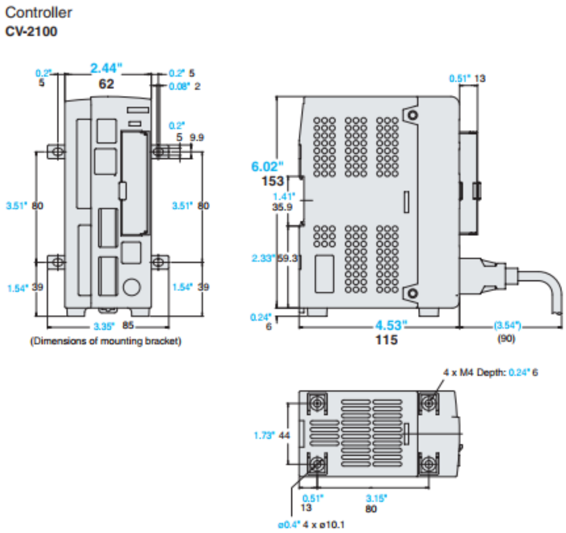

Figure 2.1: Dimensions for Controller Unit CV-2100

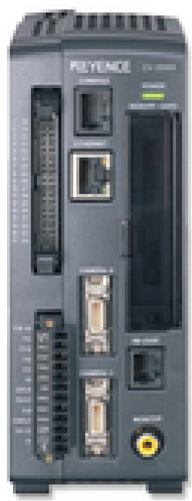

Figure 2.2: Dimensions for Controller Unit CV-2100

2.1.2 Remote Control Console(OP-42342)

Specifications:

- Model : OP-42342
- Overview : Specialized console for the image processing controller.
- Applicable Product: CV-2000/2500/3000

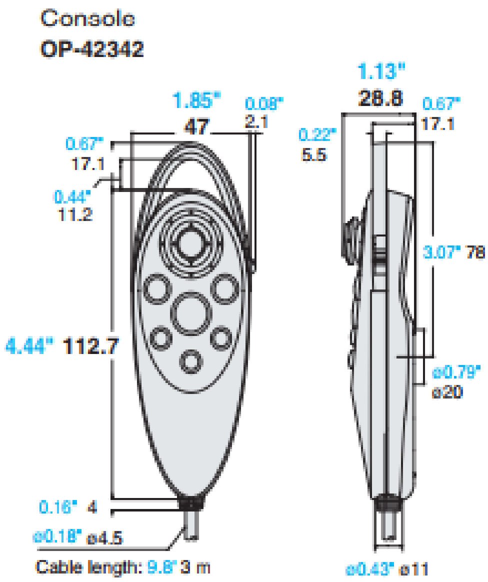

Figure 2.3: Dimensions for remote Control

Figure 2.4: Remote Control Console(OP-42342)

2.1.3 Monitor Cable(RCA-RCA,2m)

We used this to connect the monitor to the Controller Unit. The RCA connector is named from the Radio Corporation of America, who first used it in the 1940s to connect phonographs to amplifiers. It became a popular home-used in the ’50s and is still in use today.

Features:

- Cable Length (2m): Cable length has a negative effect on signal quality. Buy a cable that is only as long as you need, in order to obtain a connection for the best signal quality.
- One side of the cable matches the material used at the other side of the cable to the material used in the connectors.This prevented problems because of an electrolytic reaction.
- Shielding: A well-shielded cable delivers a better signal than one that lacks robust shielding.

Figure 2.5: RCA-RCA cable, 2m

2.1.4 Camera(CV-020)

Specification:

- Model: CV-020
- Image receiving element : 1/3-inch CCD image receiving element, square-pixel,all double-speed reading, 350,000 pixels
- Scanning system: 1/60s progressive, 1/120s interlaced
- Transfer System :Digital Serial Transfer
- Electronic shutter: 1/60, 1/120, 1/240, 1/500, 1/1000, 1/2000, 1/5000, 1/10000, 1/20000 sec.
- Lens mount method : C mount
- Ambient temperature : 0 to 50 degrees Celsius(32 to 122 degrees Fahrenheit)No condensation
- Relative humidity :(35 to 85%) No condensation
- Weight : Approx. 100g

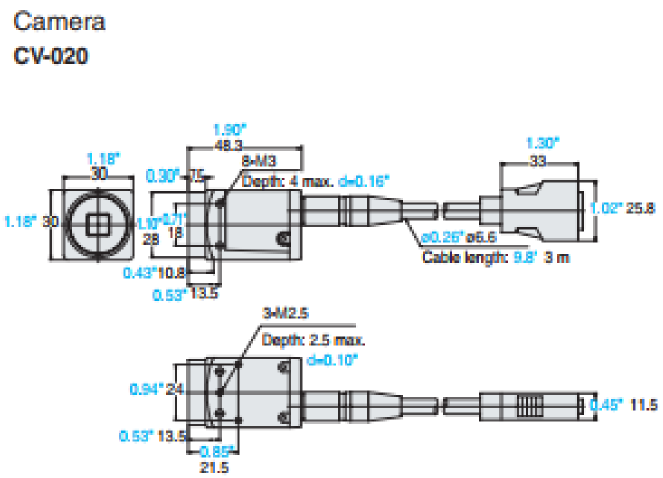

Figure 2.6: Dimensions for Camera

Figure 2.7: Camera (CV-020)

2.1.5 CV-CV3: Camera Cable(3m)

Specifications:

- Model: CV-C3
- Type : Camera Cable
- Applicable product : CV-2000, CV-3000

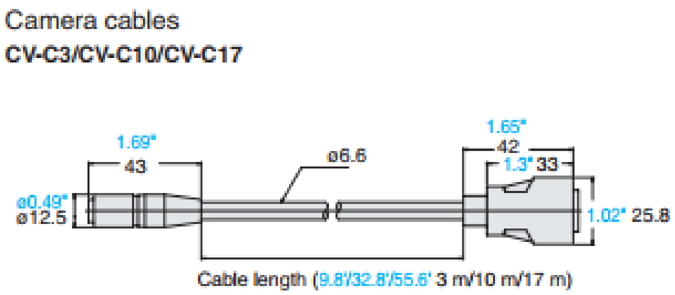

Figure 2.8: Dimensions of Camera Cable CV-C3

Figure 2.9: CV-C3:Camera Cable(3m)

2.1.6 Monitor CA-MN80

Specifications:

- Model : CA MN80
- Display color : a-Si, TFT active matrix method
- No. of dots : 640(W) x480(H) dots
- Active display area: 170.9 mm (W) x 128.2 mm (H) 67.283inches x 5.047inches
- Structure : Panel-mount type, Only the front face is dust-proof and splash-proof equivalent to IP65f.
- Back-light Duration : Approx. 50,000 hours on average (when installed in an upright position at 25 degrees Celsius 77 degrees Fahrenheit)
- Input Signal : NTSC composite signal (1.0Vp-p,75 ohms)
- Connector : RCA pin jack (1 each for input and output)
- Power voltage : 24 VDC +10 or -10 %
- Current consumption : 1 A max
- Ambient temperature : 0 to +40 degrees Celsius, 32 to 104 degrees Fahrenheit
- Relative humidity : 35 to 85 % RH
- Weight : 1,200 g

Figure 2.10: Monitor CA-MN80

2.1.7 24 V DC Power supply

Specifications:

- Brand : DVT
- MPN : ACC-241
- Input : AC = 100-240V, 50-60Hz, Range =85-264V, 0.82-0.33A ,DC : 90-350V, 0.65-0.19A
- Output : 24 V DC, +1 or -1%, 2A
- Environment : Temperature= -25... + 60 degrees Celsius, -13...+140degrees Fahrenheit

Figure 2.11: 24 V DC power Supply

2.1.8 Industrial Parts And Back-light

Description Of Industrial Parts : We took the best image out of the industrial parts captured by the camera and used the taken image to achieve the project goal. This is a metallic material with several holders aligned in a straight line that have caps on their top parts.

Figure 2.12: Industrial Parts

Description Of Back-light : This was our light source. It was a fluorescent tube covered with tempered white glass screen making the reflected light from the tube brighter, allowing the industrial parts placed in front it to be seen by the CCD camera (CV-020), and for an image to be taken.

Figure 2.13: Back-light

2.2 Software Specifications

We used the embedded Keyence software, which was embedded on the digital image controller unit (CV-2100). The software offers a simultaneous real-time data acquisition of both measurement results and helps in capturing images from the controller. It allows measurement values collected on the CV controller to be easily outputted via USB or Ethernet.

2.3 Installation

The installation of the compact vision system was already done in the labs. The cables were all well connected and we just had to place the set ups well.

We plugged in the main power of the system and began the project. We placed the industrial parts in-front of the light source and placed the camera in position to able to grab very good images.

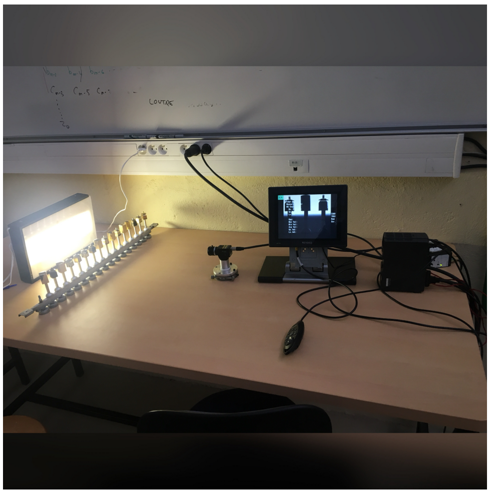

Figure 2.14: Set-Up

Chapter 3

Basic Operation

3.1 Grabbing Images

Before starting to grab images, it was important to study the Basic operations and to set the camera in order to obtain a satisfactory image of the shadow of the industrial parts.
All of the information were found inside the Manual.

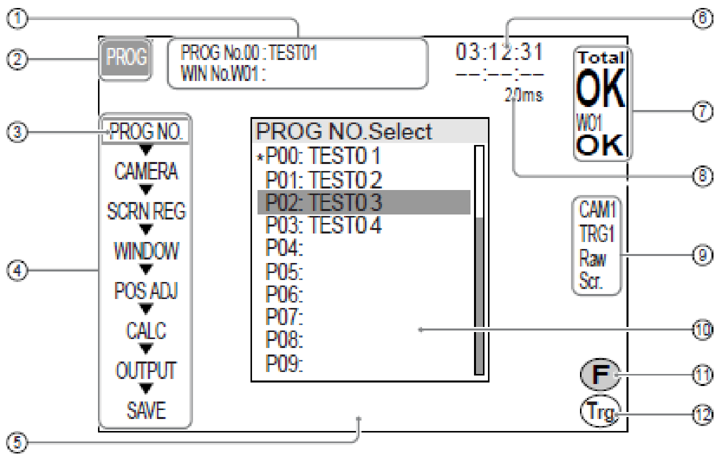

Figure 3.1: Screen Overview

1. **Program number and window name display**
   Displays the program number, window number, and name of the program in progress.
2. **Operation mode display**
   Displays the current operation mode (Program/Run/Test/-Comm.)
3. **Current selected menu**
   Displays in a green frame the menu that is currently selected.
4. **Setting menu**
   Appears only in the Program mode.
5. **Camera image**
   Displays the image that is input from the camera.
6. **Date and time display**
   Displays the date and time at which the input screen was up-dated.
7. **Inspection status display**
   Displays the overall inspection status and the inspection status of the currently displayed window.
8. **Process time**
   Displays the process time of the measurement. The process time is the duration from Trigger input to the end of image processing. To know the accurate process time, select the Run mode or Trial Run mode
9. **Information display**
   Displays information about the cameras connected to the CV-2100 or about the display mode of the screen.
10. **Setup screen**
    Displays detailed setup items.
11. **F (function) display**
    Appears when the currently selected item has a submenu, which appears when you press the [FNC] button of the con-sole.
12. **Trg(trigger) display**
    Appears when a Trigger signal can be input to the CV- 2000 in the Program mode.

3.2 Selecting a program number

In the CV-2100, various settings used for measurements such as camera settings, measurement target range, and evaluation settings can be grouped together under a specific "Program Number." ([PROG NO.]).

To select a program, click on [PROG NO.] when the screen is on. Once [Program Selection] screen appears, point the cursor at any program number that the sample wants to register. For example in our case we choose "P12".
Then press the [FNC] button of the remote control console.

You can save multiple Program Numbers and switch between them as needed. The maximum number of Program Numbers you can save is 32. It is possible to change the type of work piece just by switching the Program No.

Notice that:
➜ To retain a Program Number you have previously saved, select a new Program Number that does not have any setting saved.
➜ An asterisk (*) is displayed in front of the Program Numbers that already have some settings saved.

The manual contains more information about how to name a program, to copy one program to another and to initialize save settings.

3.3 Overview of Camera setting

To modify the camera settings, select [Camera] on the left of the screen below the [Prog No.].
The camera settings that can be altered are as follows:

- ➤ Shutter Speed
- ➤ Capture Method
- ➤ Trigger Setting
- ➤ Gain Adjustment
- ➤ Multi-Measurements
- ➤Image Capture Range
- ➤Out of Range Intensity

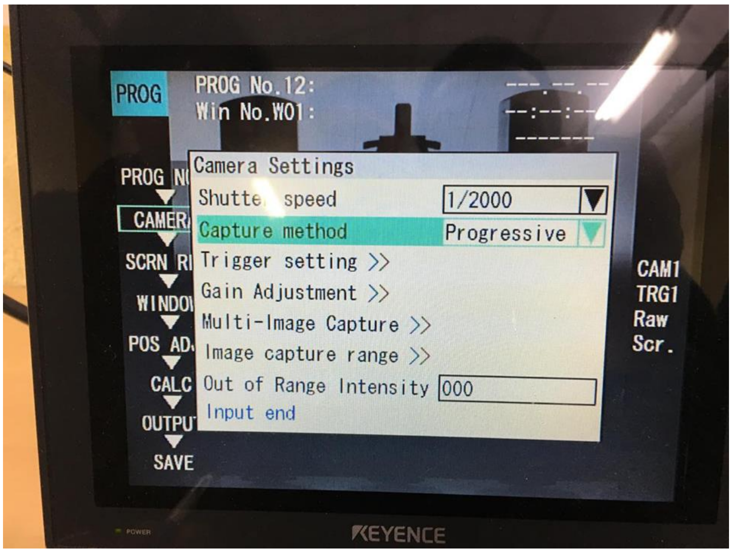

Figure 3.2: camera settings

3.3.1 Selecting a Shutter Speed and a Capture Mode

Process
Select the "Shutter speed" and the "Capture mode" according to the line speed of work pieces and lighting

conditions.
1/2000 is the shutter speed by default.

Interlace mode: Transfers image signals on the CCD of the camera by separating the odd lines and even lines. The image quality for each image is degraded, but with its high transfer rate (approximately 8.3ms), this mode is suited for fast lines..

Progressive mode: Transfers the image signals on the CCD of the camera in bulk starting from the top line. The image quality is high, but the transfer rate is low (approximately 16.7ms). *"Progressive mode" is the mode by default.*

Manipulation

In our case, we took pictures with a shutter speed at 1/2000, 1/240 and 1/10000 all in both progressive and capture mode.

Results :

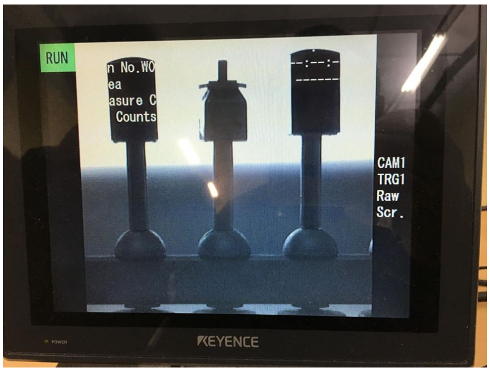

Figure 3.3: Shutter speed=1/240 , Interlace Mode

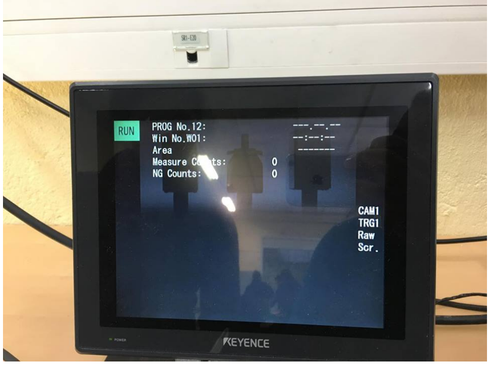

Figure 3.4: Shutter speed=1/240 , Progressive Mode

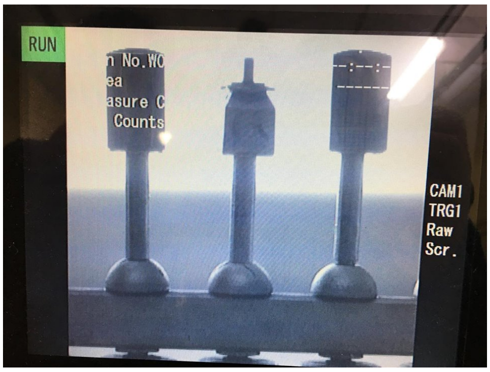

Figure 3.5: Shutter speed=1/2000 , Interlace Mode

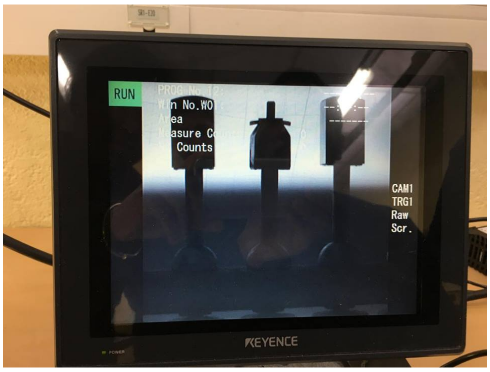

Figure 3.6: Shutter speed=1/2000 , Progressive Mode

Observation and Conclusion

As we can see from the results, it is better to use Interlace mode for a big Shutter speed and in contrary it is better to use Progressive mode for a low shutter speed.
For the rest of our work we kept 1/2000 in Progressive Mode as shutter speed

Adjusting the Contrast for Captured Images:

You can adjust image quality by adjusting the camera sensitivity and gain-adjustment of the captured images. This feature is useful when you need to lighten a dark image or import an image that tends to have black compression or white clipping.

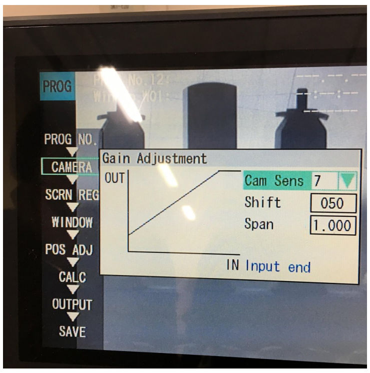

Figure 3.7: Gain Adjustment setting display

Camera Sensitivity

To modify the camera sensitivity, select [Camera] and then within the [Camera Setting] select [Gain Adjustment] where we pick the desired value of the camera sensitivity [cam Sens], the shift and the span depending on your needs.
By default the camera sensitivity is set at 5.

During our work, to observe the change made by the camera sensitivity, we chose to use values 7 and 2.

We notice that the bigger the number, the brighter the image and the smaller the number, the darker the image.

For the rest of the lab, we kept the camera sensitivity at a value of 7.

Shift

This process is similar with Camera sensitivity but in the Gain Adjustment, we modify the shift level for the entire digital signal [Shift].

The range of values you can specify is from -127 to 127 (Default: 0). So to darken the image, specify a negative value and specify a positive value to lighten the image.

For our manipulation we made a variation of the shift at -50, 50 and 0 to observe the changes on the taken image.

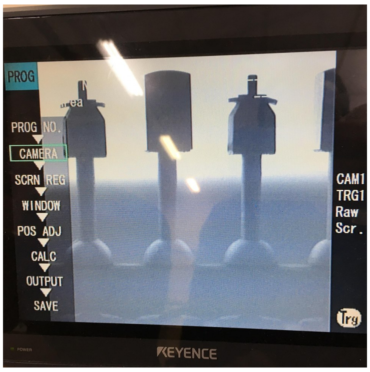

Figure 3.8: shift = 50

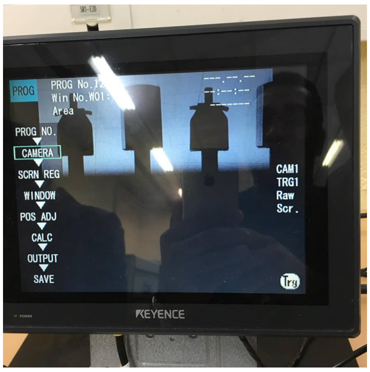

Figure 3.9: shift = -50

Span

Always in the [Gain Adjustment] setting, the [Span] option specifies the degree of adjustment between the black level and the white level.
The range of values you can specify is from 0.5 to 2 (Default: 1).
To increase the number, specify a large value to make the tilt angle of the line acute.
To reduce the number, specify a small value to make the tilt angle of the line blunt.
As you change the value, the image in the background is updated accordingly.

3.3.2 Satisfactory Image

In the next chapter we had to perform a task on an image captured. Having set the camera to our satisfaction, we took what we viewed was the best image and showed clearer details and we used it in the next chapter.

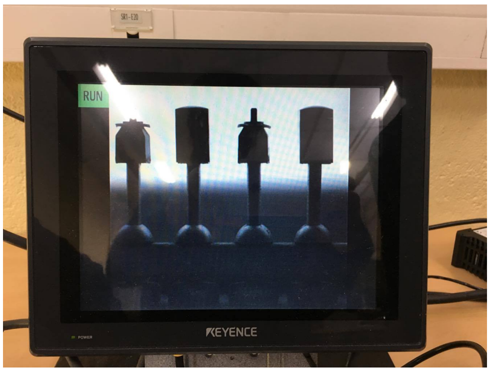

Figure 3.10: Image to be used for the tasks.

Chapter 4

Edge Detection

The edges of the individual holders can be detected using the Edge Pitch Detection Mode on the Compact Vision System. This mode measures the maximum, minimum and average values of the distance between the different edges. Edge detection is not affected by the absolute value of light intensity on the object but on the transition of light to dark. The value of the edge pitch is displayed on the monitor in units of number of pixels.

4.1 Performing Edge Detection

1. To perform edge detection on the holder width of the industrial part, an image is first taken of the holders using the settings programmed into Compact Vision System in the previous chapter.
2. The 'Window Setting' is selected in order to be able to perform the edge detection measurements on the image taken.
3. In the 'Window Setting' menu of the Compact Vision System, the Window Number (Win No) was chosen as Win No 1 because that is where the image taken was placed.
4. Afterwards the measurement window, 'Measure', was selected and ?Edge Pitch? was chosen to be able to measure the maximum, minimum and average distance between the edges.

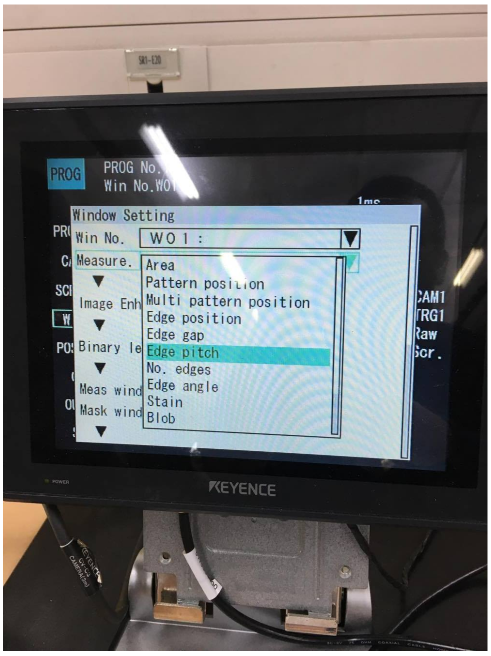

Figure 4.1: Setting the program to use

5. Then 'Pitch' was selected and the type of edge pitch which is to be used for the detection was selected. ?Gap pitch? was then selected from the drop-down menu because the measurement area is a rectangle. With Gap pitch, the width of the object is measured from odd number of edges to an even number in a specific direction.

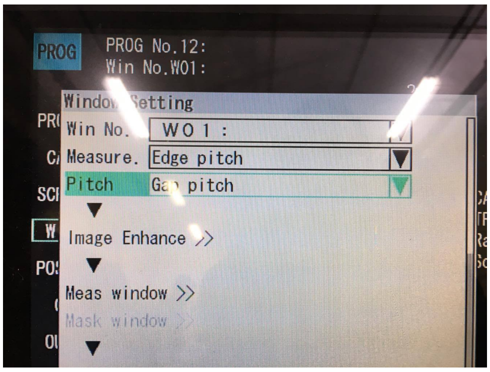

Figure 4.2: setting program

6. For the 'Image Enhancement' menu the default values were maintained by placing each of the processes off. This means no pre-processing will be performed on the image.
7. After, the measurement area was set and this was done in two parts.
8. First 'Meas window' was selected and the desired shape of a rectangle was chosen. Using the remote control console, the measurement area was drawn around the image taken to include all the four holders as this is the area the edges are to be detected from.
9. The second part of defining the measurement area involves hiding the parts within the measurement area that we don?t want to be detected or measured. This is achieved by selecting 'Mask Window'. In the drop-down menu, a maximum of 4 masks can be set. Therefore we drew 4 mask windows between the gaps of each holder in the image, in the measurement window.

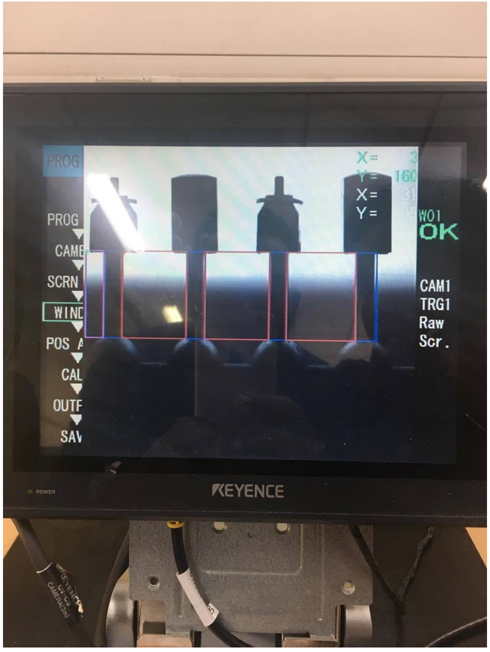

Figure 4.3: Setting Parameters

10. In detection direction menu, 'Det dir', the direction was selected as right.

11. In the edge direction, 'Edge dir' drop-down menu, ?Both? was chosen which detects the transition from light to dark and vice versa.

12. All other settings in the window setting were left at their default settings.

13. 'Input end' was selected after completing the setup of the window settings.

14. Using the remote control console, the image is triggered. When the measurement was within the specified range, an OK message was displayed on the screen. The number of edges, maximum value, minimum value, and average value are displayed on the monitor when the image is triggered.

Figure 4.4: Edge Detected and Measurement given

Chapter 5

Caps Detection

With this part we were to perform a detection of the holders with the caps. To perform this task we used the Blob inspection tool. Blob detection methods are aimed at detecting regions in a digital image that differ in properties, such as brightness or color, compared to surrounding regions. Blob detection was used to obtain regions of interest for further processing.

An application of blob detection could be used in pharmaceutical industry, where it is used to count the number properly shaped tablets and making awareness to those out of shape to be put aside.

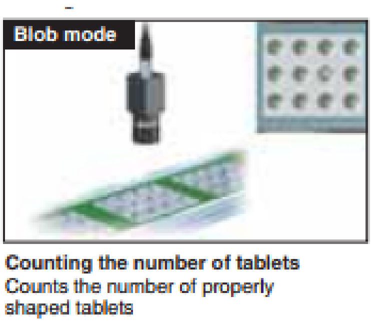

Figure 5.1: Application of Blob Mode

5.1 Performing Cap Detection

1. In ’Window Setting’ for the ’Measure’ menu we used ’Blob’ for this experiment because reading from the manual it seemed like the appropriate one to achieve what we wanted in this experiment.
2. Afterwards we selected ’Area’ from the menu.
3. By selecting the measurement window, we chose the area around the four caps that we wanted to detect.

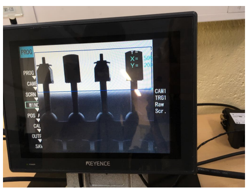

Figure 5.2: Measurement Window

4. Objects with and without caps have different areas. Therefore we performed a first measurement to determine the approximate area of objects with caps and those without the caps.

5. After that we placed the minimum area for the detection above the area of the size without a cap. This therefore excludes the object without a cap from being detected.

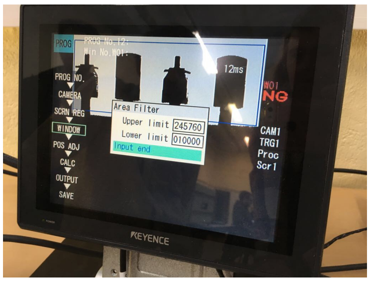

Figure 5.3: Area filter

6. The results were therefore observed in the image below

Figure 5.4: Cap Detected

7. Another test performed by placing the cap close to the best holder and it was also detected.

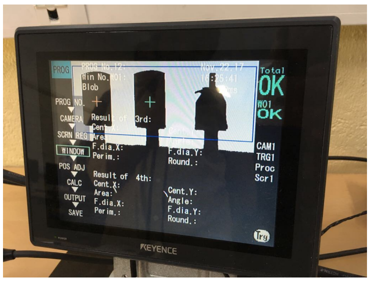

Figure 5.5: Cap detected on another holder

Chapter 6

Conclusion

Having performed various tasks and been able to work with a compact vision system we can say, it really does bring ease of work in aspect of image acquisition. We were able to achieve each goal and we gained much knowledge in this aspect.

With our research we realized the Keyence CV-2100 is no longer been produced by its manufacturers. Advanced types are now been made and as improved capabilities which performs many tasks, be it in packaging web inspection, thread inspection, image processing, sorting and process control, production monitoring and so on.

Applications of compact vision systems includes inspection of different types of medicine capsules in pharmaceutical industries, inspection of plastic cups and printing in food industries, differentiation of tires in automotive indutries and also inspection of flaws on a steel plate.

Figure 6.1: Examples of Applications

with our future research we will educate ourselves with updated versions of different compact vision systems and learn more on it and also perform applications on it.

References

1. **Utilization Guidance for Vision system**

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