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MEI-56606 ASSIGNMENT 1: REPORT

Sorting products on the conveyor belt

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SYSTEM DETAILS

In our solution, system type is PC based. This allows easier integration with other functions outside this conveyor belt. This is helpful if the information from this system were to be, for example, used elsewhere in a factory alongside other machine vision systems. In other words, we wanted to take scalability into account when designing this system to better suit real world environments. PC based system also allows easy integration of the PLC functionality which is required in this case to control the actuators. While smart camera -based system would have enough features and processing power for this application, we feel like the aforementioned benefits of PC based system weigh more when choosing the most suitable system type.

The illumination should be done as bright field illumination. This is because we aren't interested in elevation changes in the objects but rather the patterns and text on the flat surfaces. As for the lighting our preferred option would be axial diffuse light because of this. One example of such light is Advanced illumination DL38144 (for specifications, see appendix A). Ambient light may be an issue if light coming from nearby windows can't be blocked (either with curtains or a plate attached to the conveyor belt). If several conveyor belts need to be equipped with similar systems, it would be cheaper to use standard light ring around or near the camera. Naturally, back lighting isn't possible because the conveyor belt is non-transparent. Also, the conveyor belt is matte so reflections from it shouldn't be an issue. The vision program also has some tolerance for the reflections in the actual objects but reflections can still affect the detection.

Because we are using axial diffuse lighting, we want the light source to be close the objects and the conveyor belt. The light should be positioned in a 90 degree angle directly above the path at which the products come in the belt. The distance from the belt should be as close as possible while allowing the objects to pass under it.

As the light sources we chose led lights. Obviously, too bright lights will cause reflections, so that must be avoided. We don't want to use coloured light because the vision program is optimized to use grayscale images: white light is our best option. Also we aren't interested in UV or IR light so the fact that led lights do not emit them is a good thing.

The camera of our choice would be Firefly MV 0.3 MP Mono USB 2.0 (for specifications, see appendix B). It has a resolution of 752x480 pixels and it uses CMOS-optics. It was also quite inexpensive which is good for the possible system scalability aspect. Since the features in the products aren't really dependent on colour, we thought a monochrome version of the camera would be sufficient. The camera is mounted in 90 degree angle towards the belt, just above the light source. Because the objects move on the conveyor belt, the shutter type needed to be global shutter.

The longest object to classify is 82 mm, whereas the maximum width 35 mm. The actual Field of view has to be larger than this due to possibly rotated (± 10 degrees) or translated (± 25 mm) objects. However, translation doesn't affect the horizontal FOV distance requirement as the conveyor belt rolls the objects into FOV (from left to right), only vertical. The unknown parts may have different dimensions, so some extra margin needs to be added. Overall, a safe width of the field of view can be estimated to be approximately 100 mm. The height can be approximately 70 mm. Because the unknown objects can be bigger than the ones to inspect, it is difficult to provide exact measures but these should be enough for our case.

As our camera doesn't come with a lens, we need a separate one. The lens should be a CS-mount or C-mount with adapter ring. The focal length is calculated below. The camera sensor format is 1/3" which results in $w_d = 4{,}8$ mm and $h_d = 3{,}6$ mm. In this case, D (the working distance) needs to be approximately 155,5 mm. This consists of the most appropriate distance of the light from the object (25,4 mm), the dimensions of the light itself in between the camera and the object (110 mm) and some margin for the lens' distance from the light (20,1 mm).

$f = w_d \frac{D}{w_{FOV}} = 4{,}8 \times \frac{155{,}5}{100} \approx 7{,}5$ and $f = h_d \frac{D}{h_{FOV}} = 3{,}6 \times \frac{155{,}5}{70} \approx 8{,}0$

Out of these two possible focal lengths we choose the smaller one, because it fills the required field of view. It also needs to be rounded up to 8 mm in order to match commonly manufactured focal lengths. Wide angle lens isn't required.

Spatial resolution is 0,13 mm/px. It is calculated simply by dividing 100 mm with 752 pixels. This spatial resolution doesn't allow recognition of single characters in text as they are too small to accurately detect. However, it still allows us to detect logos, markings and large text in the packages which should be enough for this case. The smallest detail to detect can be thought as an 8x8 pixel matrix, so in this case it would be 1,04 mm.

Software could simply be the same as our course: NI vision builder. Other ready-made software packages can also be used as the features required in this application aren't anything too specific and should be available in numerous different programs.

Communication between PC and the camera is done via a regular USB connection (usb2 or usb3) as we don't require large throughput from single images. Communication with the external equipment through a general purpose I/O connector (GPIO) and controlling external devices is done via specialized software (e.g. PLC controller software). Both choices are made because the connections are supported by the camera.

SOURCES

ImageOps, axial diffuse lights. http://www.imageops.com/image-processing/advanced-illumination/LED-illumination-diffuse-illumination.shtml

Flir, machine vision cameras. https://eu.ptgrey.com/firefly-mv-03-mp-mono-usb-20-micron-mt9v022-2-eu

Siltala, N. 2019. MEI-56606 lecture slides.

APPENDIX

Appendix A. Ai DL38144 axial diffuse light specifications

ADVANCED ILLUMINATION

DL38144

4" x 4" Axial Diffuse Illuminator

- Even illumination over the full 100mm x 100mm field of view.
- Designed for large object inspection of specular objects.

Ordering Information

Standard Product:
Shipped Next Day

DL38144-660°

Configured for use with Ai Power Supply

° Standard product requires a dual output power supply.

Optimal working distance:
25.4mm (1")
Effective Working Range:
12.7-50mm (.5"-2")

Standard Product Variation:
Shipped Within Two Weeks

DL38144 - XXX (Spectral wavelength) XX (Optional power Compatibility) X (Optional light Conditioning) XXX (Alternative Connector)

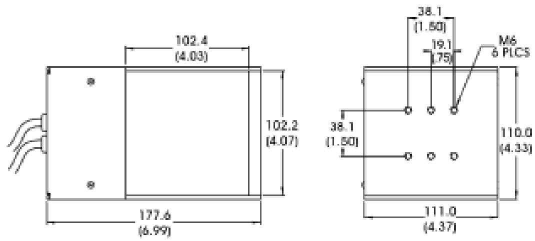
Spectral wavelength	Optional power Compatibility	Optional light Conditioning	Alternative Connector
(UV) 395◊	IC	D (Diffuser)	M12*
(blue) 470†	IS∞		
(green) 520†	C2		
(yellow) 590†	C3		
(orange) 625†	C5		
(red) 660⊗	12		
(infra-red) 880⊗	24		
(white) WHI†			

◊ UV LEDs have a considerably shorter half-life than other LEDs (<1000hrs). For this reason Ai recommends these LEDs be used in strobe mode only. For applications requiring continuous 24v power, contact Ai for assistance.

IC = iCS (requires 24v power supply)
IS = iSU (requires 24v power supply)
C2 = Ai Connector
C3 = Pulsar 710 Connector
C5 = Pulsar 320 Connector
* Available with IC, IS, and 24v options only
† Not available in 12v
∞ - Dual cable light requires dual ISUs
⊗ IS option not available

Dimensional Information

Click for Installation Models & Drawings



DIMENSIONS ARE IN MILLIMETERS (INCHES)

Standard Variation Current Specifications

	blue	green	yellow	orange	red	infra-red	white	
@12	N/A	N/A	N/A	N/A	540	810	N/A	mA
@24	480	480	450	450	460	380	480	mA

Standard Product Information

Product Lifetime:	50,000 hours
Operating Temperature:	0-60° C

advancedillumination.com 07.06.2010

Appendix B. Firefly MV 0.3 MP Mono USB 2.0 camera specifications

MODEL	VERSION	MP	IMAGING SENSOR
FFMV-03M2C-CS	Color	0.3 MP	▪ Micron MT9V022 CMOS, 1/3", 6.0 µm ▪ Global Shutter ▪ 752x480 at 60 FPS
FFMV-03M2M-CS	Mono		

A/D Converter	On chip 10-bit
Image Data Output	8, 16-bit digital data
Image Data Formats	Y8, Y16 (mono), 8-bit and 16-bit raw Bayer data (color)
Partial Image Modes	Pixel binning and region of interest (ROI) modes
Image Processing	Gamma, lookup table, hue, saturation, and sharpness
Gain	Automatic/Manual Gain modes
	0 dB to 12 dB
Gamma	0 to 1
White Balance	Automatic/manual modes, programmable via software
Color Processing	On-camera in YUV or RGB format, or on-PC in Raw format
Digital Interface	6-pin IEEE 1394a for camera control, video data, and power
Transfer Rates	400 Mb/s
GPIO	7-pin JST GPIO connector, 4 pins for trigger and strobe, 1 pin +3.3 V, 1 VEXT pin for external power
External Trigger Modes	IIDC Trigger Modes 0 and 3
Synchronization	Via external trigger or software trigger (on same bus only), or free-running (using standard video formats/modes operating at 30 FPS and 60 FPS only)
Shutter	Global Shutter
	Automatic/Manual/Extended Shutter modes
	0.03 ms to 512 ms (extended shutter mode)
Memory Channels	3 memory channels for custom camera settings
Flash Memory	N/A
Dimensions	44 x 34 x 24.4 mm (excluding lens holder and connectors)
Mass	37 g (without optics or tripod mounting bracket)
Power Consumption	8 to 30 V, 1 W at 12 V via 1394a interface
Camera Specification	IIDC v1.31
Camera Control	via FlyCapture SDK, CSRs, or third party software
Camera Updates	In-field firmware updates
Lens Mount	CS-mount
Temperature	Operating: 0° to 40°C; Storage: -30° to 60°C
Emissions Compliance	CE, FCC, RoHS
Operating System	Windows XP SP1
Warranty	One year

Resolution	752 x 480
Frame Rate	60 FPS
Megapixels	0.3 MP
Chroma	Mono
Sensor Name	Aptina MT9V022
Sensor Type	CMOS
Readout Method	Global shutter
Sensor Format	1/3"
Pixel Size	6.0 µm
Lens Mount	CS-mount
ADC	10-bit
Gain Range	0 dB to 12 dB
Exposure Range	0.031 ms to 512 ms
Trigger Modes	Standard, skip frames
Partial Image Modes	Pixel binning, ROI
Image Processing	Gamma, lookup table, hue, saturation, and sharpness
User Sets	2 memory channels for custom camera settings
Non-isolated I/O Ports	2 bi-directional
Serial Port	1 (over non-isolated I/O)
Auxiliary Output	3.3 V, 150 mA maximum
Interface	USB 2.0
Power Requirements	4.75 to 5.25 V
Power Consumption (Maximum)	<1 W
Dimensions	44 mm x 34 mm x 24.4 mm
Mass	37 grams
Machine Vision Standard	IIDC v1.31
Compliance	CE, FCC, KCC, RoHS. The ECCN for this product is: EAR099.
Temperature (Operating)	0° to 40°C
Temperature (Storage)	-30° to 60°C
Humidity (Operating)	20 to 80% (no condensation)
Humidity (Storage)	20 to 95% (no condensation)
Warranty	1 year