ME5405 Machine Vision

Exercise 2: Image Acquisition

The questions are intended for your exercises. You are encouraged to discuss your solution and any question you may have on this exercise in IVLE forum. – CK Chui

Suppose that you are the engineer responsible for developing a machine vision system to automate the processing of postal parcels. The system comprises of the following components illustrated in Figure 1. Back lighting is used in the system. There is a transparent section made of glass on the conveyer belt. The light is below the glass. The camera above the conveyer belt detects the parcel's silhouette when the parcel is moving on it.

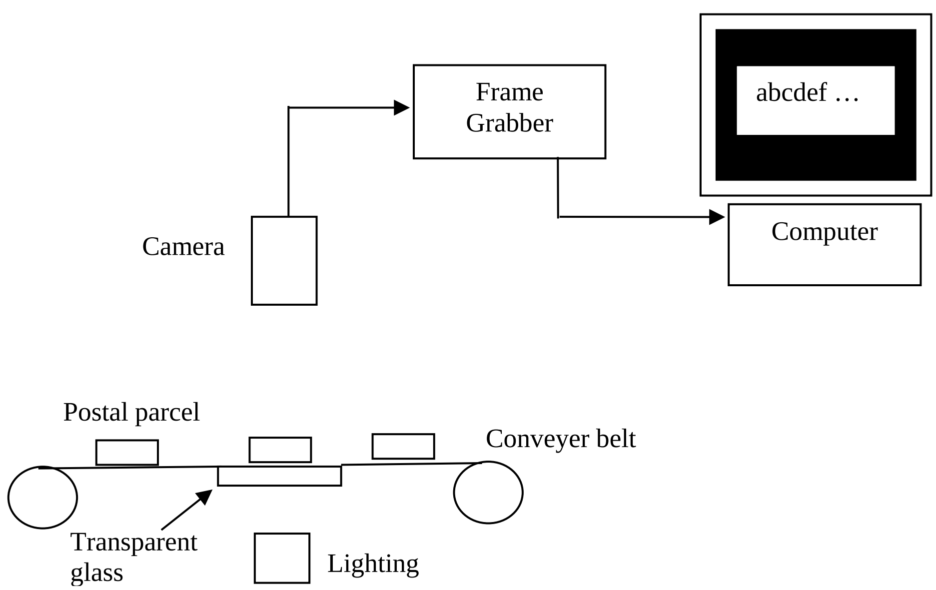

Figure 1. Overview of a machine vision system.

Question 1.
Suppose that the accuracy of the system is defined by the distance travelled in the period of 1 frame. Given that the object (postal parcel) on the conveyer belt is moving at a speed of 0.3 m/s. What is the accuracy of this system?

Question 2.
Assume that the camera can move horizontally. Write an algorithm to "center" the parcel in the image.

Question 3.
Write an algorithm to determine the area of the parcel in the image (in terms of pixels).

Question 4.
The depth of field determines whether the text on the parcel can be read clearly (or sharply). Explain how you can determine quantitatively whether the text on the image will be sharp or blur.

Question 5.
Given that the camera comprises of a rectangular 8.8 x 6.6 mm CCD sensor array with 768 x 493 pixels and a lens with focal length = 300 mm. The frame rate is 30 frames per second.

If the magnification is 10, what is the size of one pixel on the object plane? At what distance, the object will appear completely sharp on the image? Given that the focus length is 300 mm.

Question 6. A CCD camera sensor of dimension 14 x 14 mm, and having 2048 x 2048 elements, is focused on a square, flat area, located 0.5 m away. Suppose that the camera is equipped with a 35-mm lens. How many elements per mm will this camera be able to resolve?

Question 7. Suppose that an object positioned 10 cm to the left of a positive lens is imaged 30 cm to the right of the lens. From the thin lens equation:

$$\frac{1}{10}+\frac{1}{30}=\frac{1}{f} \quad \rightarrow f=+7.5\text{cm}$$

$$m=-\frac{30}{10}=-3$$

The image can be described as real, inverted and magnified.

The following table lists the physical significance of the signs of thin lens parameters.

	+	-
d_o	Real object	Virtual object
d_i	Real image	Virtual image
F	Converging lens	Diverging lens
M	Erect image	Inverted image

Where will the image appear if the object has been re-positioned to 2.5 cm from the lens? Describe the image.

Question 8.
Imagine that you look through a lens at an object and see the object right-side up but its size is only one-third of its normal height.

What is the type of lens? Suppose that the focus length of the lens is *f*. Express the object and image distances in terms of *f*. Construct a ray diagram.

What is the height of retinal image of the object?

Question 9.
Given an optical system comprises of a two-lens combination (compound lens) of focal lengths f_1 and f_2 respectively. The two lenses are separated by a distance d. Suppose that T_1 and T_2 are the translation matrices for the ray in air before and after the two-lens system. T_d is the translation matrix for a ray travelling between the two lenses. S_1 and S_2 are the lens matrix respectively. Determine the system matrix **M**.

Question 10.
Image subtraction is used often in industrial applications for detecting missing components in product assembly. The approach is to store a “golden” image that corresponds to a correct assembly; this image is then subtracted from incoming images of the same product. Ideally, the differences would be zero if the new products are assembled correctly. Difference images for products with missing components would be nonzero in the area where they differ from the golden image.

Suppose that $g(x, y)$ denotes the golden image, and $f(x, y)$ denotes any input image acquired during routine operation of a machine vision system. The resulting image based on simple difference is $d(x, y) = g(x, y) - f(x, y)$.

$f(x, y)$ is “close enough” to the golden image if all the pixels in $d(x, y)$ fall within a specified threshold band $[T_{min}, T_{max}]$ where T_{min} is negative and T_{max} is positive. Usually, the same value of threshold is used for both negative and positive differences, so that we have a band $[-T, T]$ in which all pixels of $d(x, y)$ must fall in order for $f(x, y)$ to be declared acceptable.

What conditions do you think have to be met in practice for this method to work?

(Reference: Book website of Digital Image Processing 3rd Edition by RC Gonzalez and RE Woods, 2010.)