LAUTECH JOURNAL OF ENGINEERING AND TECHNOLOGY 4(1) 2007: 5 – 8

APPLICATION OF RING LIGHT IN AUTOMATIC SURFACE QUALITY INSPECTION

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Abstract

The most important factor for detecting defects in machine vision inspection is illumination. This paper describes the basic lighting concepts and lighting techniques for industrial applications of machine vision. In the paper analytical equations for illumination on the inspected objects using ring-light are determined. Application to the production line shows that ring-light illumination is an effective means of providing constant illumination and perfectly detects defects such as cracks when tested on a number of ceramic tiles with real defects.

Introduction

The most important factor that must be taken into consideration in machine vision system is illumination (Chung et al., 1997; Kim et al., 1998). Many good machine vision applications have failed as a result of poor and uneven illumination which leads to different backgrounds in image captured by camera. This problem however makes it very difficult to find out defects from the inspected object surfaces. Hence in solving this problem in industrial environment constant illumination is required by a special illumination device (Ahlers and Warnecke, 1991).

Several possible lighting schemes have been described in literature in solving illumination problem in machine vision system. This paper is concerned with application of ring-light in machine vision inspection. The paper is organized as follows: A general description of various lighting techniques and their application area is provided in Section 2. Analytical equations for illumination on conveyor surface using ring-light method are determined in Section 3. Experiments / Results on the ring-light illumination schemes are discussed in Section 4. The paper ends in Section 5 with some conclusion.

Lighting Techniques Overview

There are various lighting techniques that could be employed in machine vision application, each depends on the inspected object's surface properties, color, background, and the data needed to extract (High-Tech Digital Product, 2002; Rafael and Safabakhsh, 1982).

Figure 1 shows six of such schemes. The diffuse and directional backlighting illuminating schemes shown in Figure 1(a) and 1(b) are similar; both illuminate the inspected objects from the rear with respect to the camera lens to create a silhouette of the object and hence generates a high contrast image, a black object against a white background. The distinction in the two schemes is the employing of a diffuser and collimating lens placed between the inspected object and the source, respectively.

The two backlighting approaches are suited for applications in which the silhouettes of objects are sufficient for object detection, recognition, and other relevant measurements that could be used for object classification. Some examples of this are detection of irregularities and cracks in glass containers (Jarvis, 1978).

Figure 1(c) illustrates directional front lighting approach. This lighting strategy illuminates an inspected object from the top. The angle of incidence of the collimated light is normally placed at high angle. As the angle of incidence increases, a large portion of the incident light reflects from the flat surface of the test object, thereby reducing the visible contrast of the raised surface defect while information from the inspected object flat surface will be enhanced. The directional front lighting approach can be used for finding small burrs on a flat surface or locating the edge of a hole (Sablatnig and Kropatsch, 1994).

Dark field illumination shown in Figure 1(d) is similar to the directional front lighting. The only difference is the illuminating of the inspected object surface with partly collimated light at low angle. As the camera looks from the top, the defects will appear as bright against a dark background of the flat surface of the target. This illuminating scheme is used to detect the occurrence of surface defects (e.g. bump, scratches, depression, and so on) on any flat inspected object (Hao and Jinwu, 2003; Ginneken et al., 1998; Ikeuchi and Sato, 1991).

Figure 1(e) illustrates illuminating method that uses a spatially modulated light source (Rocker and Keissling, 1975). This scheme involves projecting stripes or grids onto an inspected object. The curvature of the object distorts the light pattern; the distortion is detected in the image and is used to find the object curvature. This technique of lighting may result in some missed edges of an object.

The diffuse front lighting method shown in Figure 1(f) uses a fluorescent lamp with diffuser or an incandescent light with diffuser. This lighting scheme may be employed when imaging highly reflective objects (Sablatnig, 1996).

In the above mentioned lighting schemes, the most significant problems encountered are shadow and non-uniform illumination of different parts of the inspected object. This can make image segmentation difficult and will also present a problem in recognition and classification analysis of the resulting image. In order to ensure good quality of the result for the inspection of ceramic wall tile, ring-shape lighting schemes is implemented to reduce shadows or reflections in the image captured by the camera.

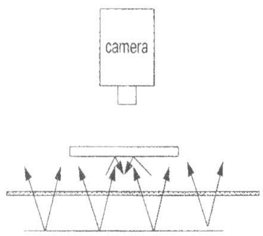
Ring-light illumination

The ideal ring illumination consists of line source shaped like a ring with sufficient number of small point sources or, as a fluorescent ring light (Tomislav and Josip, 2002). In our laboratory, ring-lights method is employed in automated inspection of ceramic wall tile. The scheme is made up of eight small lamps each with luminous intensity of 1044.45cd and arranged on 30 cm diameter ring shown in Figure 2, with the camera placed on the ring axis slightly above the ring.

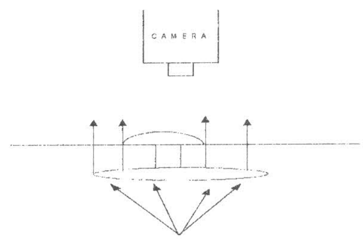
In choosing ring dimensions to achieve uniform illumination on the inspected tile surface placed on the moving conveyor belt below the camera field of view, the ring is assumed to be in the $z = h$ plane. The parametric equation of the ring in the $z = h$ plane is given as

$$x = r_p \cos\alpha$$
$$y = r_p \sin\alpha \qquad (1)$$
$$z = h$$

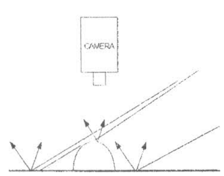
where r_p denote ring radius, and h is the height on which the ring is placed.



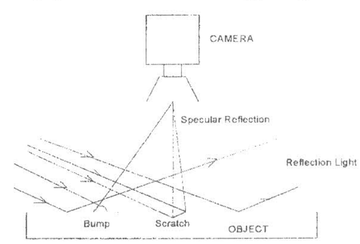
(a) Diffuse Backlighting



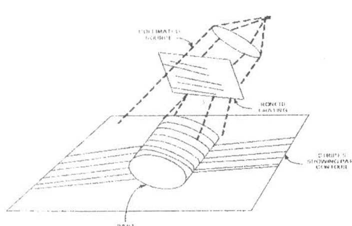
(b) Directional Backlighting



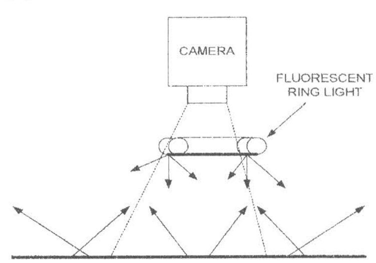
(c) Directional Front Lighting



(d) Dark Field Illumination



(e) Spatially modulated Lighting Scheme



(f) Diffuse Front Lighting

Figure 1: Basic Lighting Schemes

As described by the Lambert's cosine law, illumination is given as (Theraja and Theraja, 2000)

$$E = \frac{d\phi}{dS}\cos\beta = \frac{I}{d^2}\cos\beta \qquad (2)$$

where $\emptyset$ = Flux density

S = Surface area of the working plane

I = Luminous intensity

β = Angle of incidence

d = angular distance of the point source to the working plane

This depends on the distance from the ring element to the point on the inspected tile, and on the angle of incidence. As the illumination scheme is cylindrically symmetrical, illumination is calculated only along the x-axis. Obtained illumination along the x-axis corresponds to the illumination along any line through the origin in the z = 0 plane.

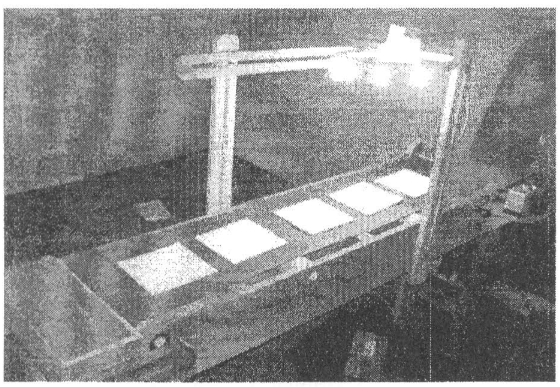


Figure 2: Ring-Shaped Illumination

The point for which illumination is calculated is (r, 0, 0). This is as shown on Figure 3. Because of its cylindrical symmetrical nature, we calculated illumination contribution from only half-ring and obtained the complete illumination by doubling the result.

Illumination from the ring element is

$$dE = \frac{I}{h^2 + r^2 + r_p^2 - 2rr_p\cos\alpha}\cos\beta d\alpha \qquad (3)$$

where angle β is angle of incidence and

$$\cos(\beta) = \frac{h}{\sqrt{(h^2 + r^2 + r_p^2 - 2rr_p\cos\alpha)}} \qquad (4)$$

By combining equations (3) and (4) and integrating along angle α from 0 to π illumination for the point (r, 0, 0) is obtained, and also the illumination for every point on the circle with radius r and center in the origin is calculated.

$$E(r) = 2\int_0^{\pi}\frac{Ih}{\sqrt{(h^2 + r^2 + r_p^2 - 2rr_p\cos\alpha)^3}}d\alpha \qquad (5)$$

The solution to this integral is

$$E(r) = \frac{2Ih}{(h^2+(r+r_p)^2)\sqrt{h^2+(r-r_p)^2}}E\left(\frac{4rr_p}{h^2+(r-r_p)^2}\right) \qquad (6)$$

where E(m) is the elliptic integral of the second kind.

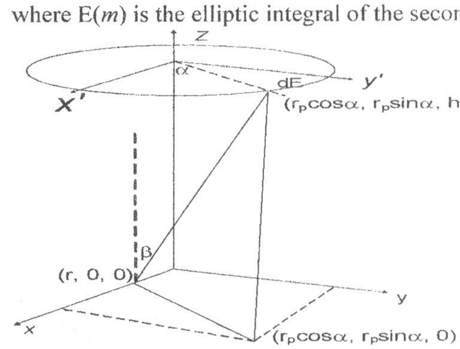


Figure 3: Setup schematic view

Experiments - Results

Experiments were performed to determine the effect of changing of ring height on surface illumination. This was done by keeping the ring radius constant at r_p = 15 cm while changing the ring height from h = 11 cm to h = 49 cm in steps of 4. The results of these experiments are shown in Figure 4. Analysis from Figure 4 shows that, there are peaks in every case, whether the height is raised or lower, and occurs at r = 0 while surface illumination decreases by increasing the ring height.

By setting the ring height at approximately equal to the ring radius uniform illumination is obtained and this enables defect to be detected effectively on the surface of plain tiles of size 200 x 200mm. Figure 5 shows some of the defects detected on a number of tiles when employing ring-light illuminating scheme.

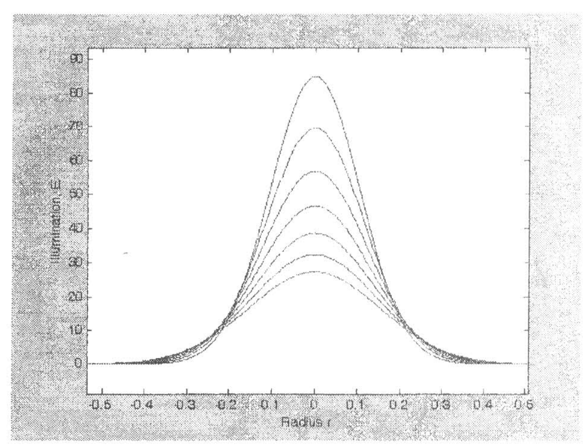
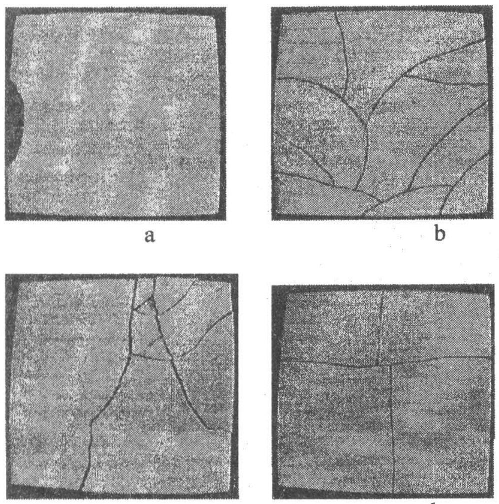


Figure 4: Effect of changing of ring height on illumination



a b c d

Figure 5: Plain white tiles with cracks

Conclusion

The results obtained from the experiments conducted on ring-lights technique shows that the scheme is an effective means of generating uniform illumination on an inspected object. When tested on a limited number of specimen products to detect defects, encouraging results were obtained.

The future work will be conducted on the other lighting methods in machine vision applications.

References

Ahlers, R. J., and Warnecke, H. J., "Industrielle Bildverarbeitung", Addison-Wesley Publishing Company, Bonn, Muenchen, New York, Sidney, Tokyo, 1991.

Chung, Y. K., Kim, K. H., and Kim, H. B., "Extracting of line features for automated inspection of vehicle doors," in: Internat. Conf. on Signal Processing Applications and Technology, San Diego, CA, 1997.

Ginneken, B., Stavridi, M., and Koenderink, J., "Diffuse and specular reflectance from rough surfaces," Appl. Opt., volume 37, pp. 130, 1998.

Hao., S., Ke, X., and Jinwu, X., "Online application of automatic surface quality inspection system to finishing line of cold rolled strips," Journal of University of Science and Technology, Beijing, Volume 10, Number 4, August 2003, pp. 38 - 41.

High-Tech Digital Product, "Imaging components and machine vision systems," High-Tech Digital, Inc., 655 Deep Valley Drive, Suite 305 Rolling Hills Estates, CA 90274 (310) 265 - 8203, 2002.

Ikeuchi, K. and Sato, K., "Determining reflectance properties of an object using range and brightness images," IEEE Trans. Pattern Analysis and Machine Intelligence, vol. 37, pp. 1139, 1991.

Jarvis J. F., "Automatic Visual Inspection of Glass Metal Seals," in: Proceeding Fourth International Conference on Pattern Recognition, pp. 961 - 965, 1978.

Kim, K. H., Kim, Y.W., and Suh, S.W., "Automatic visual inspections system to detect wrongly attached components," in: Internat. Conf. on Signal Processing Applications and Technology, Toronto, Canada, 1998.

Rafael, C. G., and Safabakhsh, R., "Computer vision techniques for industrial applications and robot control," Computer. December 1982, pp. 17 - 30.

Rocher, F., and Keissling, A., "Methods for Analyzing Three-Dimensional Scenes," in: Proc. Internat. Conf. on Artificial Intelligence, pp. 669 - 673, 1975.

Sablatnig, R., and Kropatsch, W. G., "Application Constraints in the Design of an Automatic Reading Devices for Analog Display Instruments," Proc. of the 2nd Workshop on Applications of Computer Vision, pp. 205 - 212, 1994.

Sablatnig, R., "Flexible Automatic Visual Inspection based on the Separation of Detection and Analysis," in: Proc. of ICPR96, pp. 944 - 948, 1996.

Theraja, B. L., and Theraja, A. K., " A Textbook of Electrical Technology," S. Chand and Company Ltd., Ram nagar, New Delhi-110 055, pp. 1526 – 1566, 2000.

Tomislav, P., and Josip, K., "Ring-shaped Illumination," Technical report, University of Zagreb, Faculty of Engineering Croatia, pp. 1 - 7, 2002.