

AN IMAGE ACQUISITION SYSTEM FOR MACHINE VISION APPLICATIONS

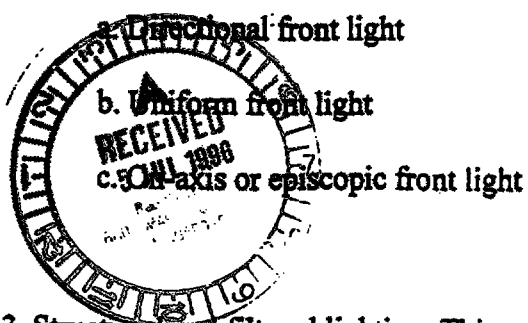
This invention relates generally to a method of image acquisition and lighting techniques for machine vision applications, and more specifically to an image acquisition system and method for acquiring multiple images of an object.

Background of the Invention

Lighting is crucial to the success of machine vision application. There exist a large number of lighting or illumination methods applicable to machine vision. Some of the commonly used lighting methods can be classified into three categories:

1. Back lighting. Light comes from the opposite side of the object as the video source views from. Back light which is bright produces a silhouette of an opaque object. The surface of the object is not lit up. For the case of transparent objects such as plastics and glass, back light is capable of revealing inclusions and scratches. Back lighting provides the highest contrast resulting in a binary image.

2. Front lighting. Light comes from the same side of the object as the video source views from. It is capable of revealing surface features with different shade of gray or colour. Front lighting can be further divided into various configurations.



3. Structured and filtered lighting. This mode of lighting is usually applied in the front lighting way with filters or patterned gratings attached to the light path. For example, a single or multiple sheet of light can be generated and be projected onto the object surface. One application of such a lighting method is to compute the surface height of

the object. This is known as shape from structured light in the art of computer vision. Structured light can also be generated from laser source with appropriate optics. On the other hand, polariser and or colour filters can be used to generate polarized and narrow waveband light.

Most of the time, multiple lighting arrangements are required in an application. For example, back lighting as well as front lighting may be required in a single application. The role of the back light is to highlight the silhouette or contour of the object; whereas front light can reveal the surface reflectance and conditions of the object. These two types of lighting cannot exist together as they will cancel the effect of one another. Due to the fact that multiple lighting arrangements cannot be simultaneously applied to the scene, each of the lighting arrangements has to be applied sequentially. Such a sequential mode of lighting application may not be feasible due to time constraint and also result in increasing system complexity and cost.

Prior arts resort to multiple stations with separate lighting, cameras and optics when multiple lighting techniques are required to inspect the same object. This arrangement is costly in initial setup as well as maintenance. Switching of light sources have also been attempted. For example in the case of both back lighting and front lighting, the first image can be taken with the back light source on while the front light source is off. The second image is taken with the front light on and back light off. This method requires additional dimension of control for the light sources and may incur reliability problem as lights are being turned on and off rapidly.

Summary of the Invention

An aim of the present invention is to ameliorate this problem and to provide an image acquisition system which in a preferred form is able to acquire a plurality of images of an object simultaneously, with each image relating to a different lighting technique. A further aim of the invention is to provide a method for acquiring such images.

According to a first aspect, the present invention provides an image acquisition system including viewing means, separating means operable to separate light incoming from said viewing means into a plurality of light paths, and an image sensor located in each of said light paths. The system is characterised in that it is configured such that each of the image sensors is operable to acquire an image from a predetermined wavelength band of the light in its respective light path.

According to a second aspect, the present invention provides a method of acquiring a plurality of images of an object including the steps of:

- (i) lighting the object using a plurality of light sources each being limited to a predetermined wavelength band;
- (ii) viewing the object through viewing means;
- (iii) separating the incoming light from said viewing means into a plurality of light paths; and
- (v) acquiring an image of said object from a predetermined wavelength band of the light in each of the light paths.

It is provided by a preferred form of the present invention that different lighting methods are differentiated by light sources of different bands of wavelength. These different bands of wavelength produce by the light sources have minimum or no overlap. These different lighting techniques are applied simultaneously to illuminate the object. It is further provided that the image acquisition system viewing the object is capable of separating the different bands of wavelength of light either transmitted or reflected from the object into different paths with different image sensors. The system is arranged such that each of the image sensors captures the image of the object illuminated by different lighting techniques. Different image analysis techniques are then applied to

the images acquired by the image sensors on the different image paths. A preferred form of the invention hence provides a means to view the object illuminated by multiple lighting techniques from a single position.

The image acquisition system according to a preferred form of the present invention includes an objective lens as the viewing means and a beam splitter that splits the incoming light into multiple paths. The objective lens provides a common aperture and field of view for the multiple image paths. Each of the multiple paths are wavelength limited preferably by filters and have minimum overlap response with respect to one another. Image sensors are used to capture the images from each of the image paths. It is further provided that optional filters, such as neutral density filter can be inserted in the different image paths to control the intensity. A frame grabber may be used to digitise the images captured by the image sensors and send them to the processor for image processing and analysis.

It will be convenient to herein after describe an embodiment of the invention in greater detail with reference to the accompanying drawings. The particularity of the drawings is not to be understood as superseding the generality of the preceding broad description of the invention.

Description of the accompanied drawings

Figure 1 is a block diagram of the system

Figure 2 is an illustration of the viewing and lighting techniques with two different types of front light.

Figure 3. is an illustration of the viewing and lighting techniques with both back light and front light.

Figure 4 is the spectral response characteristics of the visible light and the near infrared light.

Figure 5 illustrates the use of uniform top light and a low obliqued light to illuminate marking and shallow dimple on IC respectively.

A Specific Embodiment of the Invention

An image acquisition system is disclosed which consists of an objective lens 20 and a beam splitter 19 to split the incoming light into two image paths 1 and 2. On each of the two paths 1 and 2, there is provided a wavelength filter 11 and an optional general filter 12. An image sensor 13 such as a Charge Coupled Device (CCD) is attached to the image path 1 to produce a video signal of the acquired image. Similarly, on the other image path 2, it is provided a wavelength filter 15 and an optional general filter 16 before the light reaches the image sensor 17. The objective lens 20, the beam splitter 19, the plurality of image paths 1 & 2 and its associated optical components are collectively called the viewing module 3. As illustrated in Figure 1, the multiple lighting methods are collectively indicated as 5.

The two image sensors 13 & 17 generate video signals 41 & 42 which are communicated to a frame grabber 51. The frame grabber 51 is capable of simultaneously acquiring at least two channels of video signals. The video signals 41 & 42 are further digitized such that digital image processing can be carried out by a processor 52. The frame grabber 51 can also be set in a configuration that acquires the multiple images sequentially through the use of an analog video multiplexer 53.

The wavelength filters 11 & 15 situated in image paths 1 and 2 are of different characteristics. The difference in their characteristics will be illustrated by means of examples. The wavelength of the visible light spans from 400nm to 700nm indicated as 81 in Figure 4. In other words, 400nm is perceived as blue while 700nm is red. The spectral response characteristics of most commonly available sensors is from 400nm to 900nm. The most sensitive spectral range is around 550 - 650 nm range. The image sensor 13 & 17 has a better spectral sensitivity in the near infra-red range than the human eye. The near infra-red band is ranged from 700nm to 900nm as indicated as 82 in Figure 4.

Figure 3 illustrates an example where back lighting 26 and uniform front lighting 25 are simultaneously applied to the scene containing the object 30 of interest. The light source that produces the back light 26 is a near infra-red source. Typically, near infra-red light emitting diode (LED) is readily available for this type of application. On the other hand, the light source for producing the front light 25 is of visible light without infra-red component. For those skilled in the art, dichroic filter can be attached to a normal white source such as a tungsten halogen lamp to filter out the infra-red component. The combination of these two lighting methods is able to highlight the contour of the object 30 as well as illuminating the surface features of the object 30. The wavelength filter 11 situated in image path 1 has a characteristics that allows near infra-red light to pass through while visible light is blocked. Hence, the back light 26 will reach the image sensor 13 situated on image path 1 but not the visible front light. The video signal 41 generated by image sensor 13 is therefore a backlighted image of the object 30 revealing its contour or silhouette. The wavelength filter 15 on image path 2 is a short-pass filter which attenuates near infra-red light but passes visible light. Hence, the reflection from the object 30 surface of the visible front light 25 is imaged onto the image sensor 17 of image path 2. The video signal 42 generated by image sensor 17 is hence a front lighted image of the object 30 without the effect of the back light 26. The optional filters 12 & 16 in both image paths 1 & 2 are intended for various purposes such as to attenuate the light intensity. One such filter is known as the neutral density filter. The optional filters 12 & 16 are required because the objective lens 20 is common to both image paths 1 & 2. The aperture of the objective lens 20 is common and cannot be used to control the intensity on two different image paths 1 & 2.

Figure 2 illustrates another example in which two front lighting methods are simultaneously used. In some applications, a low obliqued front light 25 and a uniform top light 26 may be required simultaneously. If two these front lights 25 & 26 were to be applied together, the low obliqued front light 25 will distort the uniformity of the uniform top light 26. Using the present invention, the uniform top light 26 is wavelength limited to visible light wavelength (400nm to 700nm) without near infra-red component (700nm - 900nm). The low oblique light 25 is wavelength limited to

near infra-red without visible light component. Image path 1 is used to view the object 30 illuminated with the uniform top light 26 while image path 2 is to view the low obliqued illuminated image. The application of this example disclosed by the present invention allows both shallow dimple 92 and marking 91 on an integrated circuit (IC) 90 to be inspected concurrently. The low obliqued light 25 will highlight the shallow dimple 92 to produce a highly contrasted region while the uniform top light 26 illuminates the marking 91 on the IC 90 surface evenly. The processor 52 then applies mark inspection algorithms to the uniformly illuminated image and contrast algorithms to detect the location of the shallow dimple 92. For those skilled in the art of machine vision, mark inspection and contrast algorithms are readily understood. Examples of marking inspection algorithms are correlation and shape analysis techniques. Examples of contrast algorithms are differential operation or intensity variance detection.

**Claims:**

1. An image acquisition system including:
viewing means;
separating means operable to separate light incoming from said viewing means into a plurality of light paths; and
an image sensor located in each of said light paths;
wherein the system is configured such that each of the image sensors is operable to acquire an image from a predetermined wavelength band of the light in its respective light path.
2. An image acquisition system according to claim 1, further including filtering means located in at least one of said light paths between said separating means and its respective image sensor, the filtering means being operable to limit the light in that light path to its said predetermined wavelength band.
3. An image acquisition system according to either claim 1 or 2, wherein there is substantially no overlap between the predetermined wavelength bands used to acquire the images from the respective light paths.
4. An image acquisition system according to any preceding claim, wherein said viewing means comprises an objective lens.
5. An image acquisition system according to any preceding claim, wherein the filtering means comprises a wavelength filter.
6. An image acquisition system according to any preceding claim, wherein the separating means comprises a beam splitter.
7. An image acquisition system according to any preceding claim, further including means to regulate the intensity of the light in the respective light paths.
8. An image acquisition system according to claim 7, wherein said intensity regulating means comprises filters located in the respective light paths.
9. An image acquisition system according to any preceding claim, wherein each of the image sensors is operable to generate a video signal from its acquired image.
10. An image acquisition system according to claim 9, further including a frame grabber operable to acquire a plurality of video signals from said image sensors.



11. An image acquisition system according to claim 10, wherein the frame grabber is adapted to digitise the video signals and wherein the image acquisition system further includes processing means operable to process said digital images.

12. An image acquisition system according to either claim 9 or 10, wherein the frame grabber has a plurality of channels and is adapted to receive said plurality of video signals simultaneously.

13. An image acquisition system according to either claims 9 or 10, wherein the frame grabber is operable to acquire said plurality of images sequentially through the use of an analogue video multiplexer.

14. A method of acquiring a plurality of images of an object including the steps of:

(i) lighting the object using a plurality of light sources each being limited to a predetermined wavelength band;

(ii) viewing the object through viewing means;

(iii) separating the incoming light from said viewing means into a plurality of light paths;

(v) acquiring an image of said object from a predetermined wavelength band of the light in each of the light paths.

15. A method according to claim 14, wherein there is substantially no overlap between the wavelength bands used to acquire the images from the respective light paths.

16. A method according to claim 14 or 15, wherein each of the light sources are limited to different wavelength bands.

17. A method according to any one of claims 14 to 16, wherein the wavelength bands of the light are co-ordinated with the wavelength bands used to acquire the images so that the images acquired represent the object illuminated by individual ones of said light sources.

18. A method according to any one of claims 14 to 17, further including the step of filtering the light in each of the light paths so as to enable the images to be acquired from said predetermined wavelength bands of light.

19. A method according to any one of claims 14 to 18, wherein the images are received by a plurality of image sensors which are operable to produce a video signal of said acquired images.



20. A method according to any one of claims 14 to 19, wherein each of the light sources light the object from a different orientation.