Short about active range cameras

Maria Magnusson

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Active range cameras are based on a well-defined light source (i.e. a laser) used together with a sensor, a camera. We here mention five different types.

1: Single spot system with phase shift, see Fig. 1.

2: Single Spot system with triangulation.

3: Sheet-of-light system with triangulation.

4: Gray-coded patterns with triangulation see Fig. 2.

5: Grid-pattern with triangulation, see Fig. 5.

All the five types above work for a stationary scene with varying lighting. Number 3 also applies to the industrially very useful set-up with constant illumination of a laser sheet and a movable scene. Number 3 sheet-of-light and also, to some extent, number 2 single spot are described thoroughly in [1]. For the other three, we here give a brief description.

1 Single spot system with phase shift

Fig. 1 shows an example of a system that provides both distance and intensity information. The instrument has three main components, a transmitter, a scanning mirror, and a receiver. The laser beam is amplitude modulated with a sine wave. It strikes the mirror and is reflected against the object. A small portion of light is reflected back, reflected in the mirror and received by the receiver. The amplitude of the received light is proportional to the reflectance of the object. The difference between the phase of the received light and the phase of reference light is directly proportional to the distance to the object. This gives a distance image. With this instrument, we can combine the intensity and distance information when analyzing a scene.

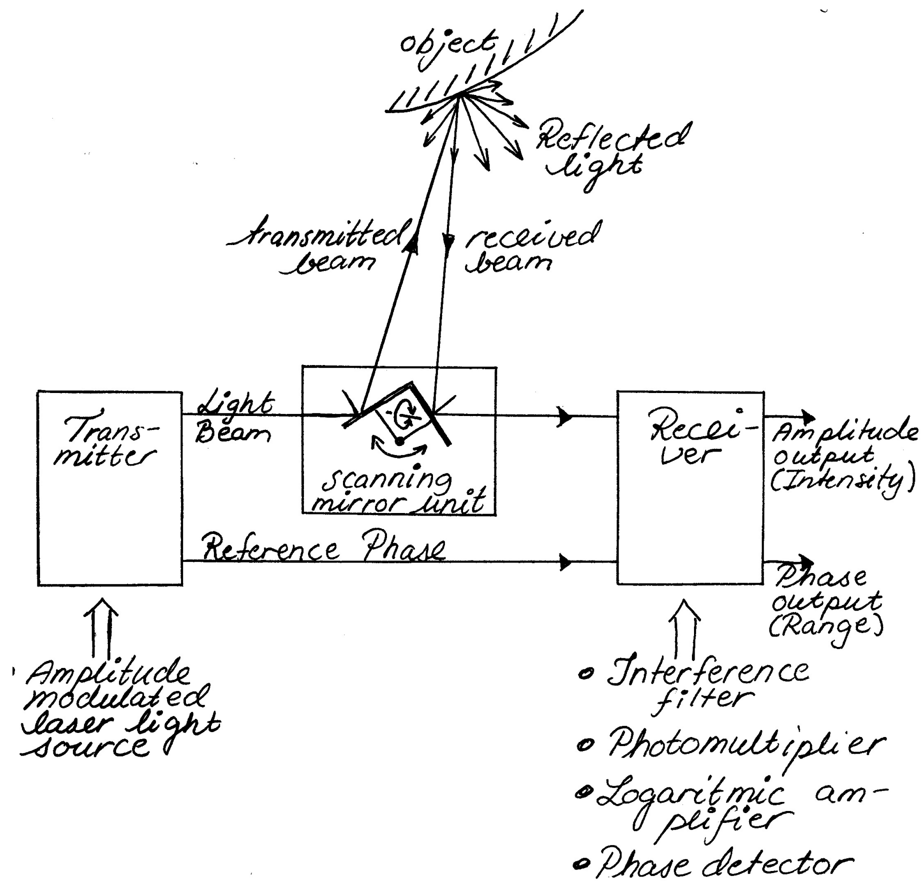

Figure 1: Single spot system with phase shift.

2 Gray-coded patterns with triangulation

The principle of this method is very similar to sheet-of-light as described in [1], but instead of scanning the laser sheet to 2^n different positions across the scene, n consecutive patterns are projected on the scene. Fig. 2 shows the principle of encoding and position detection. An LCD (liquid crystal optical device) generates the patterns, but it also works with simpler devices, such as a slide projector. A set of n binary patterns encode the scene in 2^n regions. Fig. 3 shows the flow of the process. Although the patterns are binary, the camera image will not be binary directly, but must be thresholded (binarizing). You should choose the Gray code instead of the usual binary code. The reason is that the Gray code only changes one binary position at a time as opposed to the binary code. Consequently, one bit error cause only a small error when the Gray code is used, but may give rise to a large error when the binary code is used. A 3-bit binary code and a 3-bit Gray code are shown below.

Binary code:

$$\begin{array}{c} 0: \\ 1: \\ 2: \\ 3: \\ 4: \\ 5: \\ 6: \\ 7: \end{array} \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 1 \\ 0 & 1 & 0 \\ 0 & 1 & 1 \\ 1 & 0 & 0 \\ 1 & 0 & 1 \\ 1 & 1 & 0 \\ 1 & 1 & 1 \end{bmatrix}$$

Gray code:

$$\begin{array}{c} 0: \\ 1: \\ 2: \\ 3: \\ 4: \\ 5: \\ 6: \\ 7: \end{array} \begin{bmatrix} 1 & 0 & 0 \\ 1 & 0 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 0 \\ 0 & 1 & 0 \\ 0 & 1 & 1 \\ 0 & 0 & 1 \\ 0 & 0 & 0 \end{bmatrix}$$

The Gray coded values are then translated to binary sensor coordinate values. Then real world position (x, y) and distance r are obtained from the sensor coordinates in a similar way as for the "sheet-of-light". Fig. 4 shows three ways to perform thresholding of the sensor image.

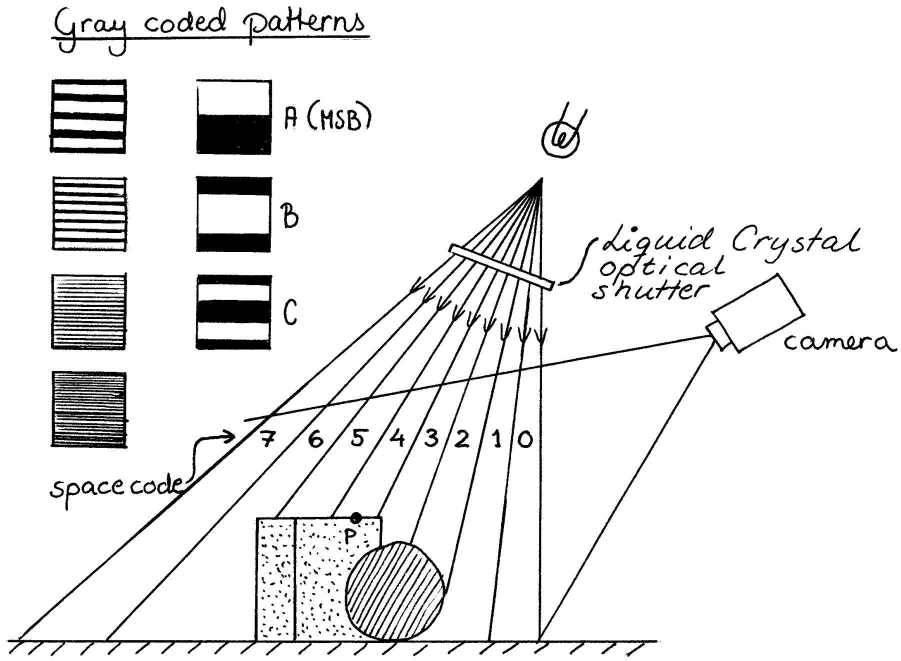

Figure 2: Gray coded patterns projected on the object. (From [2].)

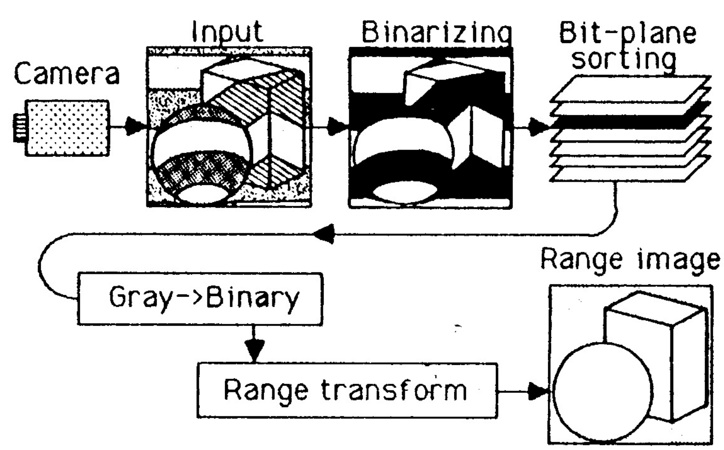

Figure 3: Flow chart for distance measurement with Gray coded patterns. (From [2].)

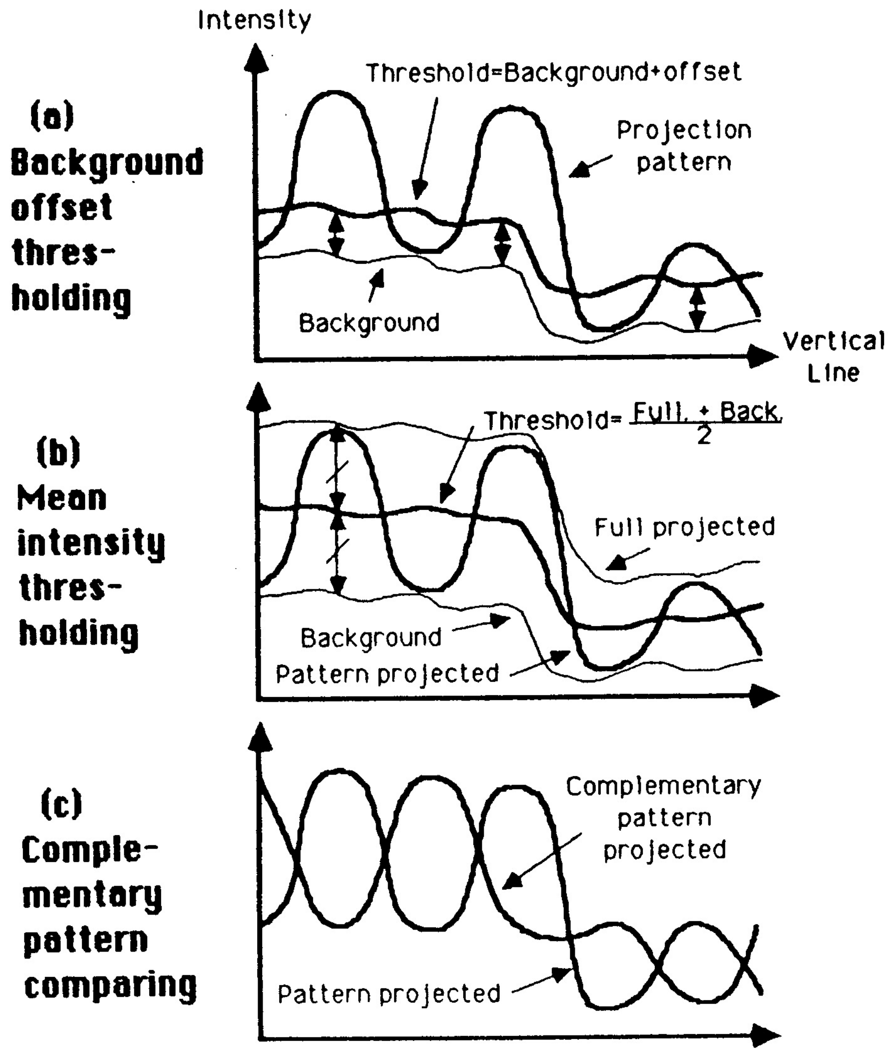

Figure 4: Thresholding of images illuminated with Gray coded patterns. (From [2].)

3 Grid-pattern with triangulation

See Fig. 5. The principle of this method is also very similar to sheet-of-light as described in [1]. A grid pattern is projected onto the object, reflected and received by camera. One advantage is that the scene does not need to be scanned, which saves time. The disadvantage is that it is more difficult to detect a grid pattern on the detector than a single line. A big disadvantage is that restrictions must be set on the appearance of the object. A complicated object can deform the grid pattern in the image so that at it becomes impossible to determine corresponding grid points in the image and the physical grid.

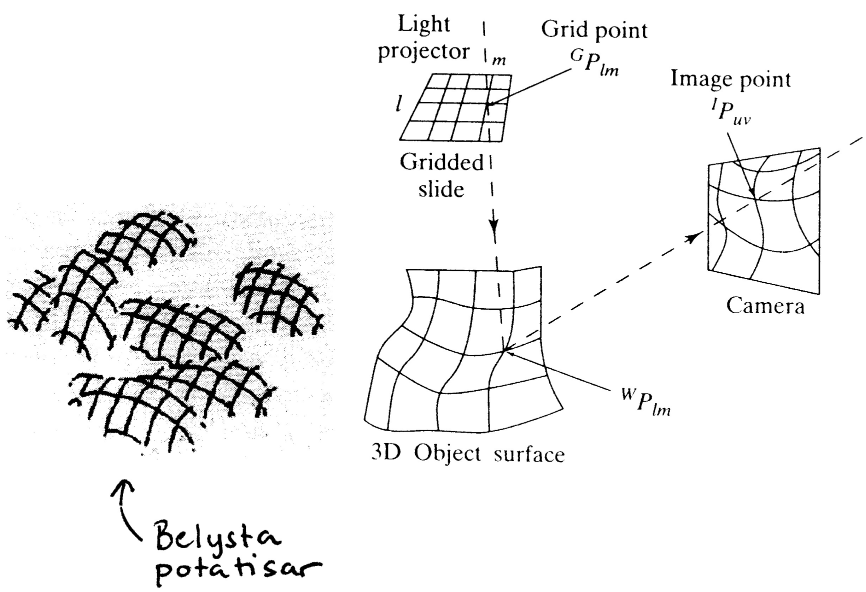

Figure 5: Grid pattern projected on potatoes.

References

[1] Mattias Johannesson, *SIMD architectures for Range and Radar Imaging,* Linköping Studies in Science and Technology. Dissertations No. 399, 1995.

[2] K Sato, H Yamamoto, S Inokuchi, *Tuned Range Finder for High Precision 3D Data,* International Conference on Pattern Recognition, 1986.