거리영상의 획득 및 형상특징 추출

Range Data Acquisition and Shape Feature Extraction

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요 약

본 논문에서는 거리영상의 획득방법 및 입력으로 들어 온 거리영상에서 형상특징을 추출하는 방법을 제안하고자 한다. 제안한 레인지파인더 시스템은 각 화소마다 단지 △R만을 계산함으로써 기존방법에 비해 계산시간을 줄이고자 하며, 얻어진 거리영상에서 깊이값의 부호변화를 고려함으로써 물체의 형상특징도 추출하고자 한다. 끝으로 본 시스템의 유통성을 여러가지 실험에 의해 입증하고자 한다.

Abstract

This paper proposes an acquisition and the representation method of the 3-dimensional information. The proposed range finder system can reduce the computation time by only calculating the △R of each pixel compared to the existing methods.

We also propose a shape feature extraction method by considering the sign change of the acquired range data.

Finally, the effectiveness of this system is demonstrated by several experiments.

I. Introduction

In the field of computer vision, the successful image recognition from the camera-captured images depends on how to obtain the 3-D(3-dimensional) data and how to represent and process the acquired data in the computer. For the better recognition many methods have been proposed so far [1]~[3].

The ways to acquire 3-dimensional data can be classified into the passive methods such as "Shape from X" [4]~[6] and the active ones which include the range finder method [7]~[9].

The problems associated with the former methods have the difficulties in finding correspondence among the multiple images and the latter methods require a separate range measuring medium such as a laser source, an ultra sonic emitter, etc.

However, the range finder system is preferred because it has the advantage that it can take 3-dimensional data directly.

Meantime, the improvement in the range finder system can be achieved when the processing time is reduced.

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In this paper a method to significantly reduce the processing time of the existing range finder system[10] is proposed.

First, the data captured for the reference flat by the horizontally projected laser stripes at the parallel of the camera are saved in the table, then the range data for the object in question is extracted easily by comparing the pixel data value with the reference table values. By utilizing this input/reference table values, computation becomes simpler, hence the processing time is reduced.

Also proposed is the way to recognize the shape of the objects by combining the unique features of the primitives obtained when the captured input range data is scanned row by row and columm by column.

Finally, we have demonstrated the effectiveness of the proposed system through the experiments.

Ⅱ. Acquisition of 3-dimensional information

A basic range finder system consists of a camera which capture the image, a laser source, a cylindrical lens to form structured stripes, a motorized rotating mirror, analysis monitor, a computer including digitizer.

1) Camera calibration

The camera calibration is to determine the correspondence between the real world coodinates in the camera image.

This process is necessary to get the range data through triangulation which requires various parameters such as the focal length of the camera, the distance between the camera and the shaft of the horizontally rotating disk on which the objects to be placed and the angle between the front direction of the camera and the laser stripe plane.

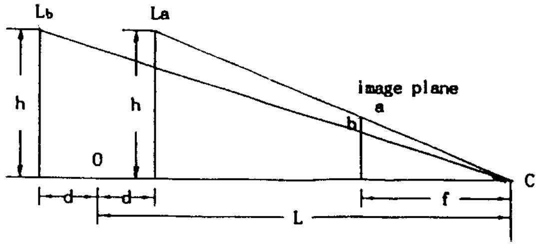


Fig. 1 Camera calibration

Figure 1 shows the following relationship among the parameters :

$$L-d : f=h : a$$
$$L+d : f=h : b \qquad (1)$$

From the above equations we get

$$L=d\times\frac{a+b}{a-b}, \qquad (2)$$

$$f=\frac{2}{h}\times\frac{a+b}{a-b}. \qquad (3)$$

2) Computation of range values

a. Existing method[10]

Figure 2 shows the relationship between the system and the image coordinates. As shown in the figure the shaft of horizontally rotating disk becomes the Z-axis and the center of the disk surface is to be the origin of the 3-dimensional coordinate system. Then the X-axis is the line on the disk surface to the direction of camera and the line from the origin parallel to the image plane becomes the Y-axis.

The coordinates in the image plane are formes such that the center point on the image plane perpendicular to the center of the camera lens is fixed as the origin, C, and the lines on the image plane parallel to the previously mentioned Y-and Z axis from U-and V axis.

Then any point, p on the image plane has the following relationships :

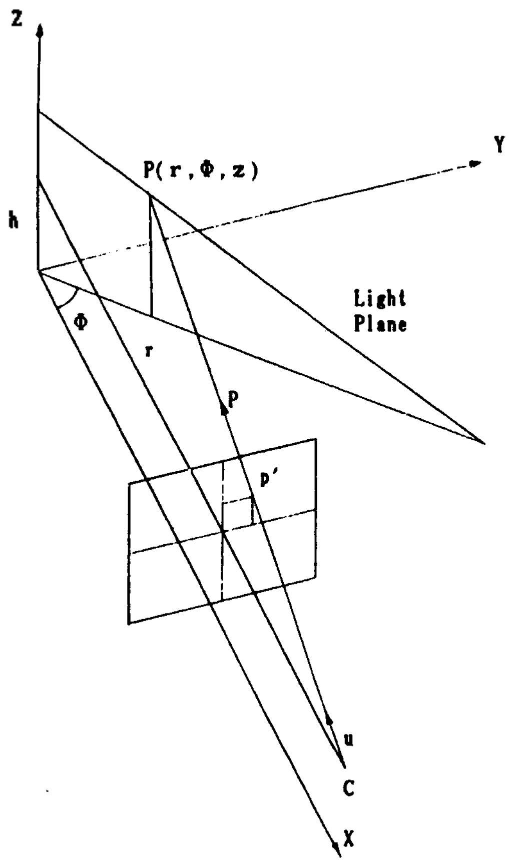


Fig. 2 System & Image coordinates

$$P=C+tU \tag{4}$$

and

$$P=\begin{bmatrix} x \\ y \\ z \end{bmatrix},\ C=\begin{bmatrix} xo \\ yo \\ zo \end{bmatrix}=\begin{bmatrix} L \\ O \\ h \end{bmatrix}$$

$$U=\begin{bmatrix} -f \\ Up \\ Vp \end{bmatrix} \tag{5}$$

From the above

$$x=-tf+L$$
$$y=t\times Up \tag{6}$$
$$z=t\times Vp\times h$$

Also the equation of the stripe plane is

$$y=\tan\Phi\times x \tag{7}$$

These equations can be rearranged by eliminating t and we get

$$x=\frac{L}{1+\frac{f\times\tan\Phi}{Up}}$$

$$y=\frac{L\times\tan\Phi}{1+\frac{f\times\tan\Phi}{Up}}$$

$$z=\frac{\frac{Vp\times L\times\tan\Phi}{Up}}{1+\frac{f\times\tan\Phi}{Up}}+h \tag{8}$$

b. Proposed method

The ways to get the range data by projecting laser include the methods of shooting a spot light into the forms of stripes or a grid type.

The proposed system projects laser stripes called "structured stripes" on the object and compute the range data from it.

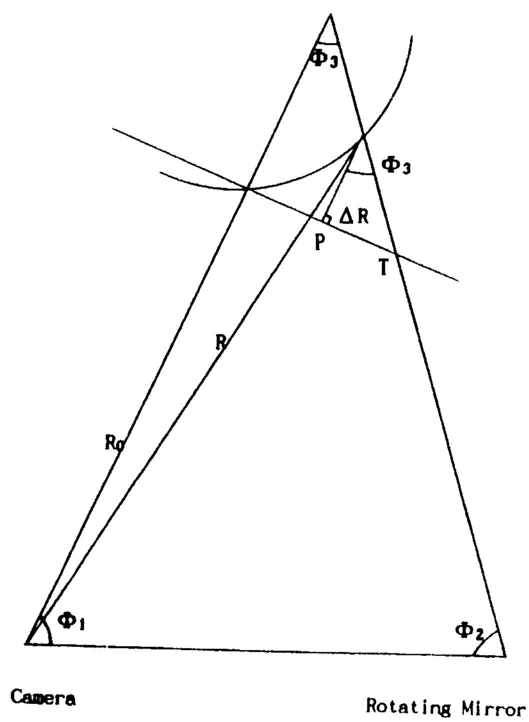


Fig. 3 System and Image coordinates

Figure 3 shows the relationship between the system and the image coordinates. In this system the coordinate system of the physical space is formed such that the optical axis of the camera becomes the z-axis and the optical center on the z-axis is fixed as the origin. From this origin, the x axis is the horizontal line and the vertical line becomes the y-axis, thereby the x-y plane is parallel to the image plane.

In this system, the coordinate system on the image plane shares the same of the physical space.

From the pixel data obtained by the light stripe projection, the coordinate of the point that the light stripe touches with the Y−Z plane of the optical center is obtained.

At the same time the value of Ro which is the distance from the origin to the object is computed from the angle of the rotating mirror. Meantime the reference pixel data table is made with the plane placed parallel to the image plane by projecting the laser stripes repeatedly. This table is used as the reference in computing the range data of the object. At this time it is assumed that the distance value between the camera and the object is unpropotionally larger than the size of the object.

In reality a maximum of 1.5mm discrepancy is measured for the 10cm diameter object at the distance of 1.5mm

$$R \doteqdot Ro + \triangle R \qquad (9)$$

$$Ro = L \times \frac{\sin(\Phi_2 - n\theta)}{\sin(\Phi_1 - n\theta)} \qquad (10)$$

$$\triangle R \doteqdot \frac{To - P}{\tan\Phi_3} \qquad (11)$$

where To : a value from the reference pixel data table

P : measured pixel data of the image coordinate

L : distance between the camera and the mirror

$n\theta$: angle of the mirror rotation

Φ_3 : angle between light stripe and optical axis

In computing the range data by the above method the value of Ro for each object is calculated only once, thereby only the value of $\triangle R$ is computed for each pixel. This is the significant processing time reduction compared with the existing method.

The table shown below gives the comparision between the proposed and existing methods.

Table 1. Comparision between the proposed and existing methods

	Existing method	Proposed method
Method	Calculations(x,y,z) of all surface points	Calculations of only $\triangle R$ values
Numbers of computation terms	multiplication : 3 times division : 2 times addition : 1 time	division : 1 time subtraction : 1 time
Expected time complexity	O(N)	O(N)

Ⅲ. Representation of 3-D Information

To get the shape features, it is confined in this paper that the shapes of the objects are some combinations of the primitives such as spheres, cylinders, cones and planes.

It is based on the report that about 85% of all man-made objects can be represented as some combinations of only four primitives mentioned [1]. Now, for each primitive with the 3×1 mask as shown in figure 4 the value of A+C−2B computed. If this value is greater than the preset thresholed value(TH1) then plus sign, if it is less than TH1 then minus sign, and if they are the same the value zero are given accorrdingly. Then each primitive yeilds a unique sign as shown in

Fig. 4 3×1 Mask

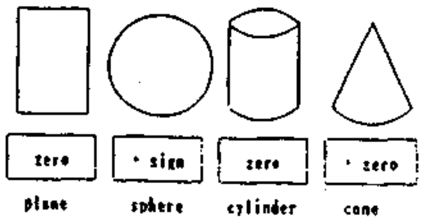


Fig. 5 characteristics of sign values

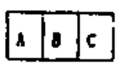


Fig. 6 1×3 Mask

Fig 5.

The reason for the operation of A+C−2B is as follows.

As an example we may have the range values in the window of "123" and "222". From the front the former is slanted 45° and the latter is perpendicular. In this case the values of A+C−2B operations are the same which also corresponds the fact that both are plane surfaces.

In other words, the operation detects plane surface regardless of the degree and orientation of slant.

In this case both plane and cylinder have zero value, so they cannot be distinguished. To differentiate them, we do the same operation with the 1×3 mask as shown in figure 6.

The purpose of these operations is to distingish convexity, concavity and flatness and assign the +, − and 0 signs accordingly.

Also by the curvature of the object the different distribution of + − 0 signs is presented. Consequently, this uniqueness of the distribution of the signs saved in two matrice, the one by horizontal scanning and the other one by vertical scanning yields the shape feature of each object. Here, the mentioned threshold values TH1 and TH2 are the maximum allowable error values and have to be determined experimentally with the real range finder system operations.

Theoritically these threshold values have to be zero.

However they are fixed as small positive values close to zero in considerations of possible noise in the system.

The threshold value is originally the range value of the developed range finder system. This value is optimally selected after repeated experiments to get the best shape feature from the 1×3 and 3×1 window operations.

Ⅳ. Experimental Results and Observation

According to the setup explained previously a laser source is used to get the range data by triangulation and the shape feature of the four single primitive object is extracted.

A 12 volt DC stepping motor of 1.8°/step is used. The mirror moves 0.18°/step and the stripe rotates 0.36°/step through gear reduction. In this way we get about 20~25 stripes for each experimental object. Also the processing time required to extract shape feature of each object from the time of range data acquisition is about 6~8 seconds by the C language programmed IBM PC/AT. Figure 7 shows the range finder system used in the experiment. Figure 8 (a)~(d) show the objects used in the experiment and the corresponding range data are presented in Figure 9. The range data values are computed through triangulation by finding the position of each laser strip with the 256×256 image data captured by the camera. Figure 10 through 11 show the sign matrices computed from the range data in figure

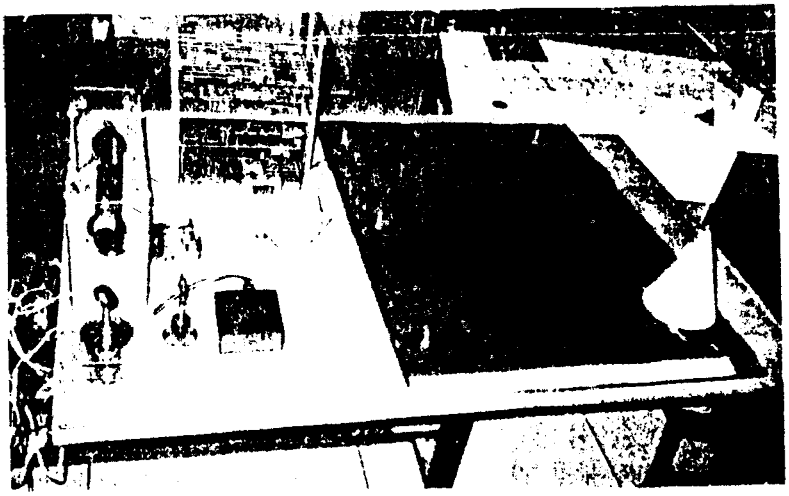
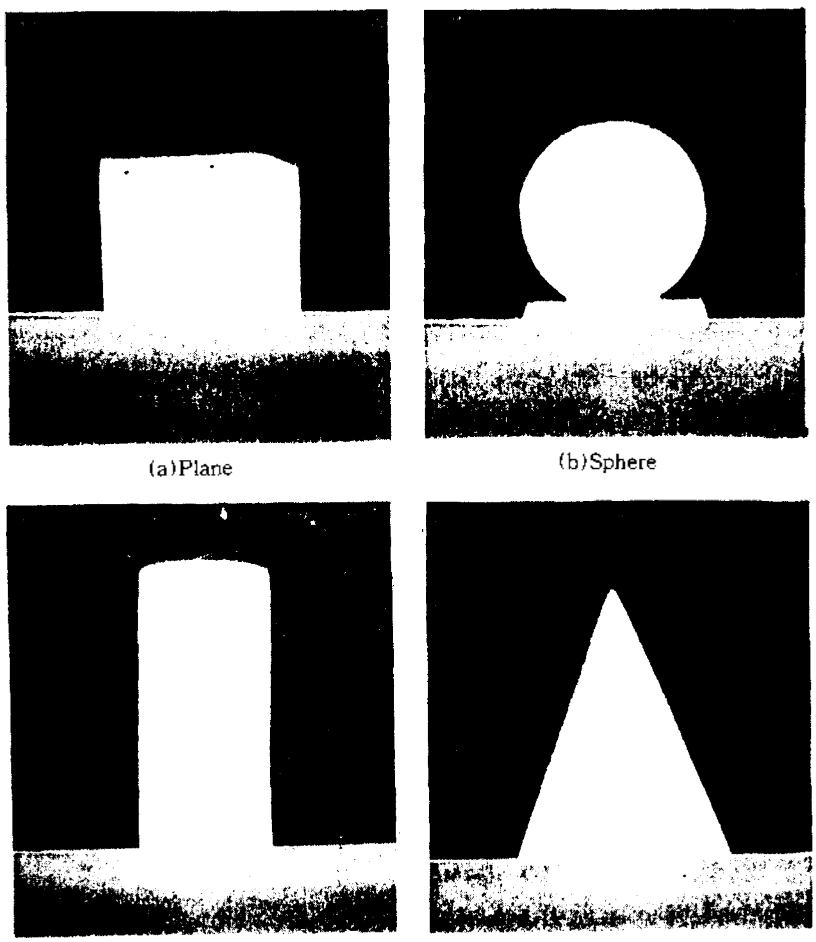


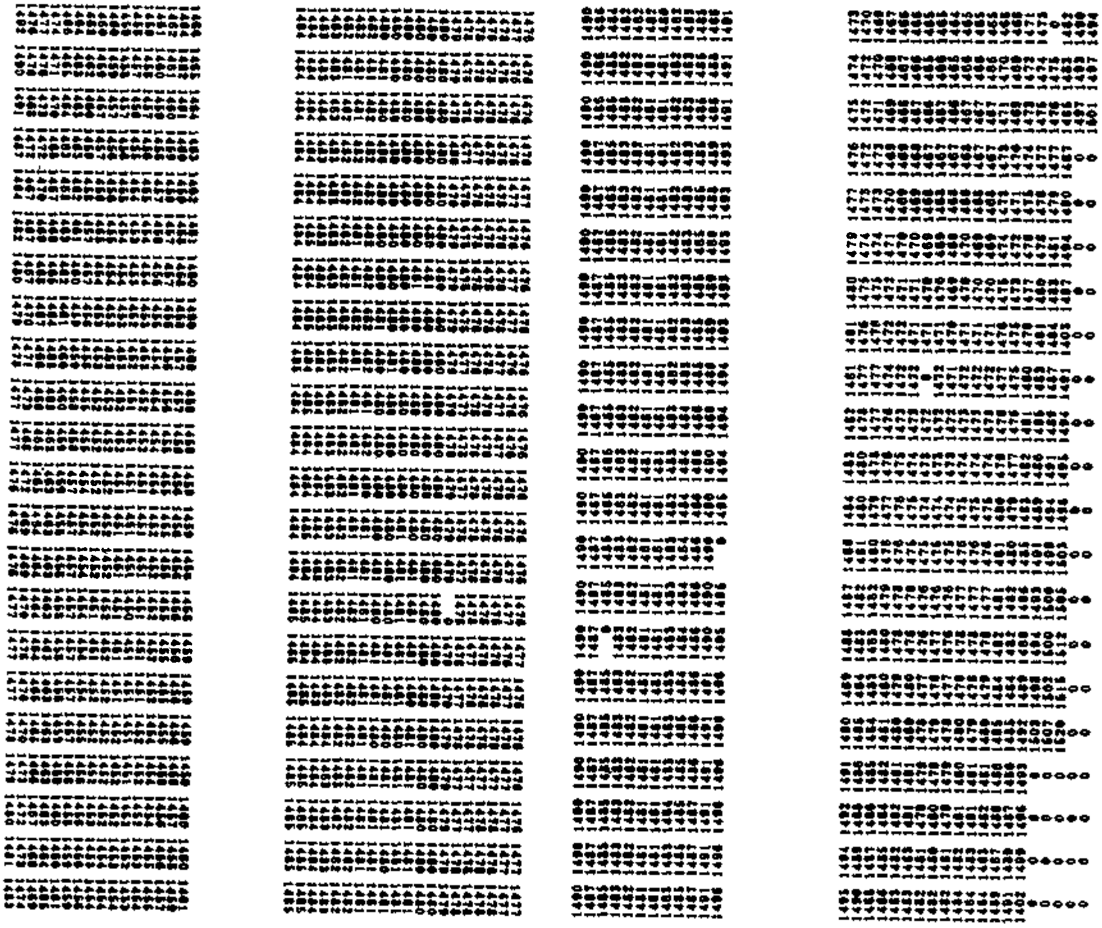
Fig. 7 Developed Range Finder System.



(a)Plane (b)Sphere

(c)Cylinder (d)Cone

Fig. 8 Objects Used in the Experiments



(a)Plane (b)Sphere (c)Cylinder (d)Cone

Fig. 9 Obtained Range Data

9 by scanning horizontally and vertically.

The dots(·) in these figures represent the background of the objects, so the light stripes are not reflected. The experiment has demonstrated that the method developed in this paper successfully expresses the uniqueness of each object by representing the corresponding range data accordingly.

The proposed method cannot be applied in acquiring the range values and in extracting the shape features for the objects whose surface is quite uneven and rugged. It also has the limitation for the complex shape objects in which mutiple primitives are variously combined. Further research is expected in this area.

V. Conclusion

In this paper, a new method of acquiring and representing 3 dimensinal information by the range finder system is presented.

The proposed range finder system computes only $\triangle R$ values for each pixel, thereby significantly reduces processing time.

Also it has been shown that regardless of the range data value density, by taking only the signs from the range data values, the shape feature of each object could be extracted.

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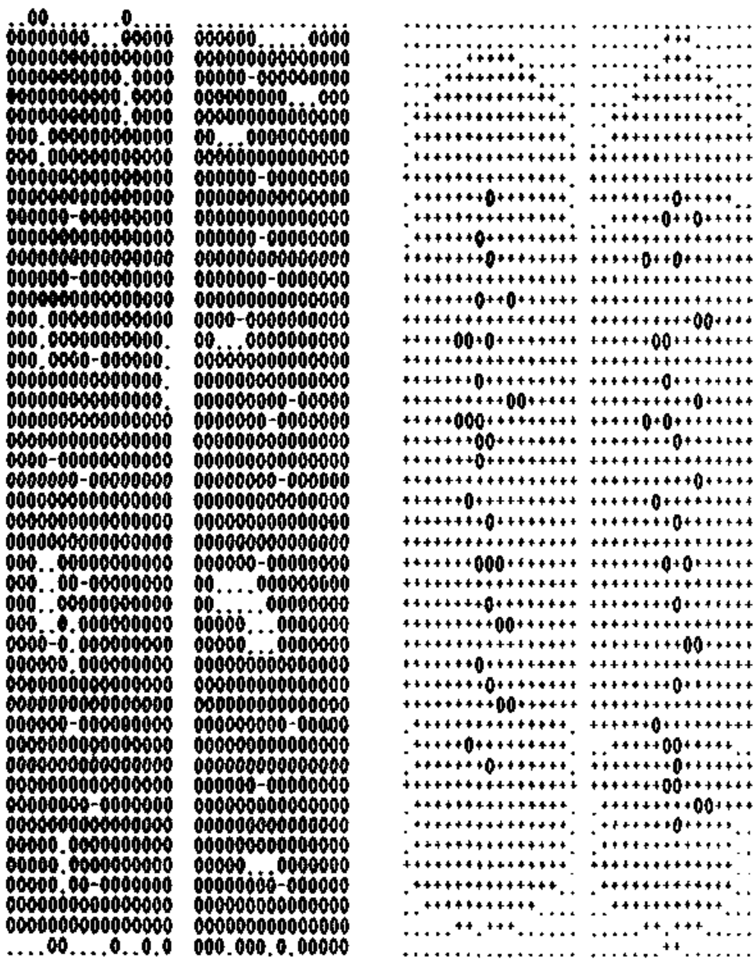

Fig. 10 Sign Change for Plane & Sphere

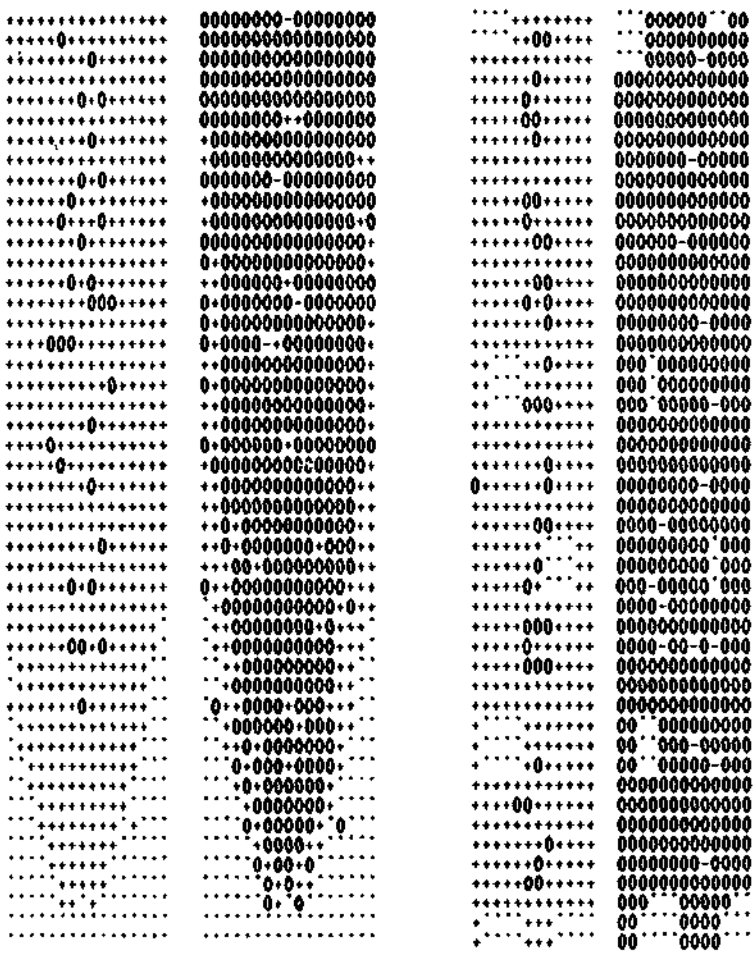

Fig. 11 Sign Change for Cylinder & Cone

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