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RANGE IMAGE SEGMENTATION

ECE 6310, HW08

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METHODOLOGY:

In this lab, we were asked to write a program to segment an image shot from a laser range finder. These camera set-ups give us two images, a range image, and a reflectance image. The range image contains the information required to calculate the distance information in 3D coordinates. The reflectance image contains the data regarding the light reflected back to the sensor. Thus, this acts like a normal greyscale image.

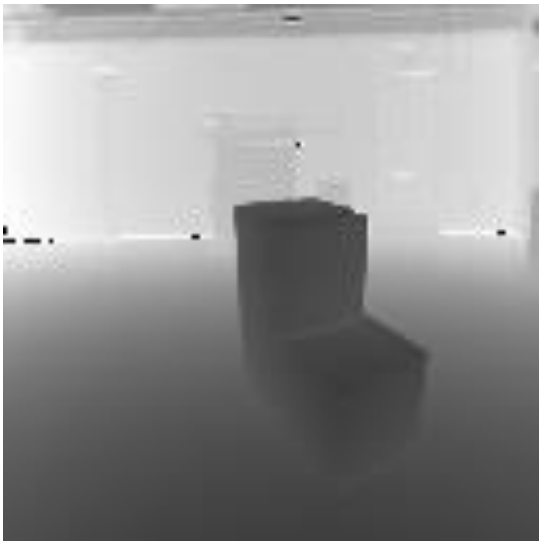

Figure 1. Range Image

Figure 2. Reflectance Image

Conversion to 3D Coordinates:

The "odetics-to-coords.c" file was used to convert the range data at each pixel into 3D coordinates. This script used the model of the laser scanner used to perform this conversion.

Image Thresholding:

To remove the background and keep only the chair, the range image was thresholded to keep pixel values only below **128.** Farther away objects appear white in range images. Thus, this technique is useful in removing backgrounds before segmenting, if wanted.

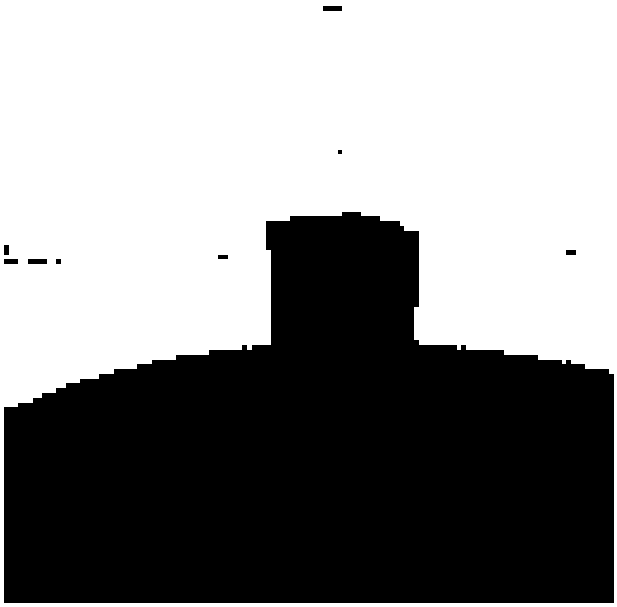

Figure 3. Thresholded Image

Calculation of Surface Normal:

To segment the image into different surfaces, we need to calculate the surface normal. This is the perpendicular vector to two points which lie in the same plane. A block of the image which has closely oriented surface normal can be taken as one "region". The surface normal is calculated by performing the cross product on two pixel vectors of interest.

Given two vectors (a_x, a_y, a_z) and (b_x, b_y, b_z), the surface normal can be calculated as:

$$a \times b = (c_x, c_y, c_z) = (a_y b_z - a_z b_y, \quad a_z b_x - a_x b_z, \quad a_x b_y - a_y b_x)$$

The distance between points to calculate the surface normal was taken as **3.** In a 3x3 window around a seed, the first vector was obtained by subtracting the values of the pixel 3 indices **above** the seed and the seed and the second was the vector by subtracting the pixel 3 indices to the **left** of the seed and the seed

The surface normals were calculated only for the pixels marked in the thresholded image, to save computation.

The needle map of the surface normal is as follows:

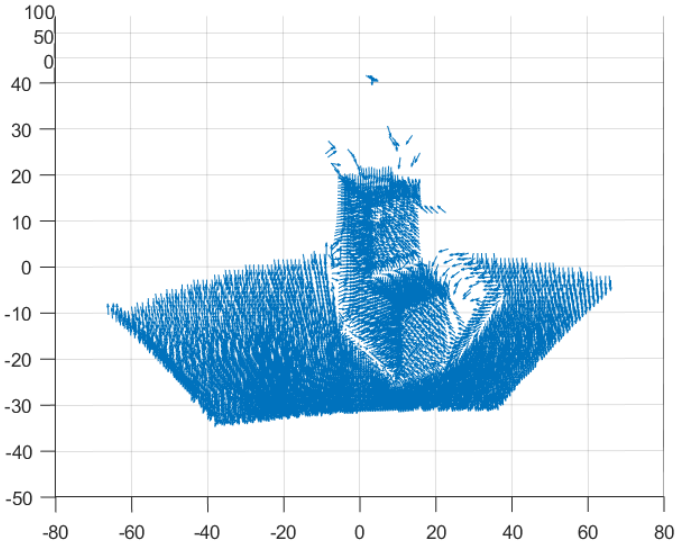

Figure 4. Needle Map of surface normals

Region Growing:

Seed pixels for starting region growing are selected according to the condition that no pixels in a 5x5 window around the proposed seed pixel should be already labeled. If a region with a size below **50 pixels** is returned, it is erased. The predicate for a pixel joining a region is that its surface normal should be oriented within **64°** of the average surface normal of the region it is joining. Such a high value works in this case because the surfaces of the chair have sharp orientation differences. A running average of the surface normal of the pixels of the region is always maintained. The orientation between the surface normal of a new pixel and the average normal is obtained by computing the dot product between them.

The dot product can be calculated as:

$$a.b = |a| * |b| * cos\theta$$

Thus, the orientation would be:

$$\theta = cos^{-1}\left(\frac{a.b}{|a| * |b|}\right)$$

Given two points (a_x, a_y, a_z) and (b_x, b_y, b_z):

$$a.b = a_x b_x + a_y b_y + a_z b_z$$

$$|a| = \sqrt{a_x^2 + a_y^2 + a_z^2}$$

At the end the coordinates of every region seed, its size and the average surface normal components along the X, Y and Z axes were stored.

RESULTS:

Segmented Image:

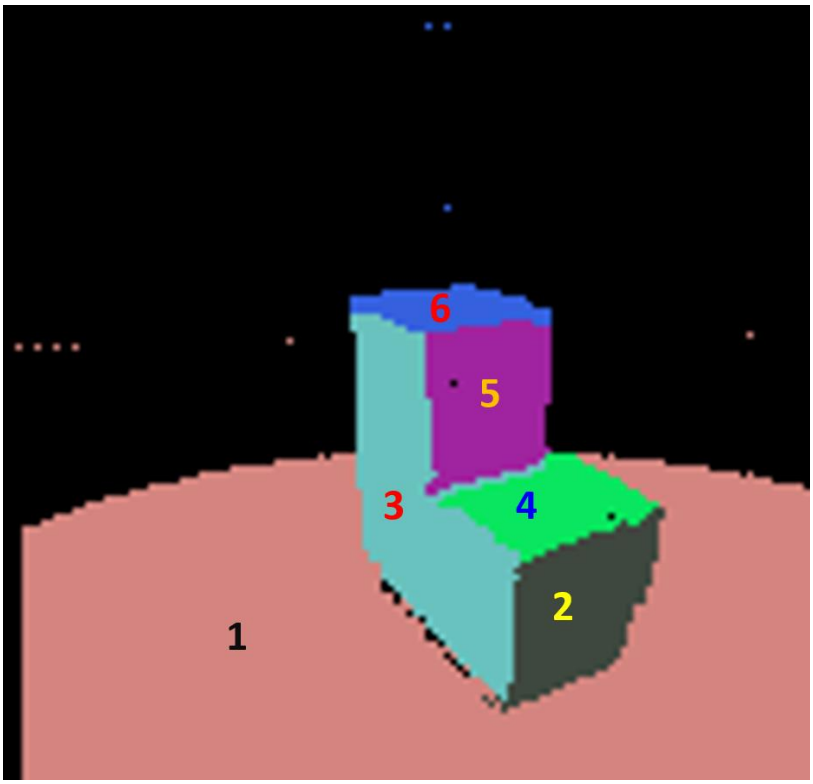

Figure 5. Annotated Segmented Image

As we can see from Figure 4, a total of 6 regions were segmented. The 5 faces of the chair and the ground are the 6 unique regions.

Region 2, seems to have been encroached upon by Region 1, because the surface normals in that region are not very uniform. A few irregularities like these are to be expected.

Region Number	Region Size	Region Seed (r,c)	Average Surface Normal (X)	Average Surface Normal (Y)	Average Surface Normal (Z)
1	166	(46, 71)	2.64	-267.95	47.84
2	850	(53, 55)	147.63	3.88	15.43
3	475	(54, 81)	-2.95	0.41	4.75
4	4921	(74, 50)	0.94	-23.5	7.73
5	311	(76, 88)	0.91	-55.27	-0.46
6	487	(88, 99)	-2.93	4.09	5.37