Depth Image Region Segmentation

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Abstract

Segmentation algorithms separate an image into unique regions determined by characteristics of the pixels within those regions. Image segmentation has applications in Artificial Intelligence, including computer vision, 3D modeling, and robotics. We use two different segmentation algorithms to separate a depth image, which has distance information encoded into each pixel rather than conventional RGB values. Whereas color images are commonly segmented into regions of similar color or luminosity, we segment the depth image into cohesive surfaces. We segment depth images using gradient difference and Laplacian edge detection. When combined together, these two methods offer a chance to reconstruct three dimensional objects from depth data.

1 Introduction

Image processing is a vital component of computer vision and artificial intelligence. Within image processing, image segmentation continues to be a focus of research as machines are expected to be able to have similar visual abilities as humans. Segmentation groups pixels into regions of similar characteristics, which can be used for automated analysis, tracking, and object recognition. Many image segmentation techniques function on color images, grouping pixels by color or perceived luminosity. We explore an alternative - segmentation of depth images.

Depth images contain information about the distance from a point in space to the camera sensor. Whereas traditional RGB images contain a matrix of color pixels, each containing a red, green, and blue value, a depth image only contains a matrix of depth values. Depth images can be visually rendered in greyscale, where a point of maximum distance is represented as white and a point of minimum distance is represented as black. The construction of accurate depth images relies heavily on recent technology, including LIDAR and infrared sensors. Notably, the Microsoft Xbox Kinect sensor has the ability to simultaneously record depth images and color images, providing researchers easy access to rich depth data.

There are two fundamental approaches for segmenting an image: edge-based segmentation and region-based segmentation (Russell and Norvig 2003). Edge-based segmentation locates major discontinuities in the image, indicating separate distinguishable objects, whereas the region-based segmentation identifies different surfaces within those objects by calculating the normal vectors at each point. The remainder of this paper covers background information pertaining to the two methods of segmentation used, describes our specific experimental design, and shares our results.

2 Background

Laplacian Edge Detection

Edge detection distinguishes transitions between pixels by locating large discontinuities in the data of adjacent pixels. In color images, two different objects often have very different luminosities, colors, or patterns; edge detection locates the areas where the pixels experience a rapid change in those values. While pixels in RGB images have various characteristics, depth image pixels only have one piece of data (the depth). Thus, edge detection in depth images locates objects in an image by finding the areas in which the depth data rapidly changes, known as jump discontinuities.

The Marr-Hildreth algorithm is one of the simplest forms of edge detection (Marr and Hildreth 1980). A Gaussian blur convolution is applied to the depth image. The blurred image is subtracted from the original image, resulting in an ”edged” image. Areas with similar values across pixels are relatively unchanged after the blur. The difference between the original image and the blurred image is therefore small over that area, resulting in small values at that location in the edged image. In contrast, areas with large differences in values appear significantly different in the blurred image, and as such have large values at that location in the edged image. When rendered in color, the edged image is dark in continuous areas of the depth image but bright in areas with significant discontinuities.

Gradient Surface Detection

While the Marr-Hildreth algorithm behaves similarly on both color and depth images, it does not take advantage of the different data provided by a depth image. The distance values in a depth image give a pixelated 3D view from a single vantage point, providing volumetric information about the scene. This information is especially valuable when attempting to segment surfaces.

Pulli and Pietikäinen explore several sophisticated approaches in their discussion of depth image segmentation, including fitting continuous differentiable functions, robust estimators, and least squares approximations to the surfaces (Pulli and Pietikäinen 1993). We take a simpler and faster approach, evaluating local normal vectors for each pixel and grouping pixels into surfaces if the normals are sufficiently continuous.

$\varphi or \phi = \tan^{-1}\left(\frac{d_1 - d_2}{2}\right)$

$\vartheta or \theta = ...$

$\psi = \cos^{-1}\left(\cos\theta_1 \cos\theta_2 + \sin\theta_1 \sin\theta_2 \cos\left(\theta_1 - \theta_2\right)\right)$

3 Experiments

In this section, you should describe your experimental setup. What were the questions you were trying to answer? What was the experimental setup (number of trials, parameter settings, etc.)? What were you measuring? You should justify these choices when necessary. The accepted wisdom is that there should be enough detail in this section that I could reproduce your work *exactly* if I were so motivated.

4 Results

Present the results of your experiments. Simply presenting the data is insufficient! You need to analyze your results. What did you discover? What is interesting about your results? Were the results what you expected? Use appropriate visualizations. Prefer graphs and charts to tables as they are easier to read (though tables are often more compact, and can be a better choice if you're squeezed for space). **Always** include information that conveys the uncertainty in your measurements: mean statistics should be plotted with error bars, or reported in tables with a ± range. The 95%-confidence interval is a commonly reported statistic.

5 Conclusions

In this section, briefly summarize your paper — what problem did you start out to study, and what did you find? What is the key result / take-away message? It's also traditional to suggest one or two avenues for further work, but this is optional.

6 Acknowledgements

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References

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