7MR10040: Medical Robotics: Theory and Applications
Semester 1

Assignment 8

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Question 1

The Canny edge detection is a method that is used to detect a wide range of edges in an image. The detection is composed of 5 steps.

1. Noise reduction
2. Gradient calculation
3. Non-maximum suppression
4. Double threshold
5. Edge tracking by Hysteresis

Noise reduction

Using a Gaussian filter, we smooth the image in order to reduce noise. This is done by sampling each pixel and its neighbours using kernels of various sizes. The size of the kernel dictates the quality of the noise reduction. Smaller kernels are better at reducing noise at the cost of time. In a Gaussian filter, the central pixels have a higher weight and their neighbours have lower weights, imitating a normal distribution curve. The central pixel's value is replaced by the weighted average of the neighbouring pixels.

Gradient calculation

Once the noise is reduced, gradient calculation is used as it detects edge intensities and direction by calculating the gradient of the image using edge detection operators. Two examples of these operators are the Prewitt and Sobel filter. Edges are changes in pixel density and these operators highlight the change of pixel density in the image in both the horizontal and the vertical direction. The magnitude and slope are calculated, and they represent the size and orientation of the edge detected.

Non-maximum suppression

In order to thin out the edges in the image, we use non-maximum suppression. To do this, we go through all the points in the gradient intensity matrix and find the pixels with the maximum value in the edge directions. A pixel is stored as an edge if its edge value passes a certain threshold and if it's a local maximum (i.e. greater than its neighbours). Pixels with lower values are disregarded and therefore we achieve thinner edges.

Double threshold

The purpose of double thresholding is to identify 3 kinds of pixels:

1. Strong pixels that have a high enough intensity that we can be sure contribute to the final edge
2. Weak pixels with a low enough intensity that can not be considered as strong, but not low enough to be irrelevant
3. Irrelevant pixels which are the rest

To do this we have a high threshold (anything above this is identified as a strong pixel) and a low threshold (anything below this is identified as an irrelevant pixel). Anything in-between is considered a weak pixel.

Edge tracking by Hysteresis

Following double thresholding, edge tracking by hysteresis transforms weak pixels into strong ones if at least one of the pixels around it is identified as a strong pixel. This helps to ensure that noisy edges are not broken up into multiple edge fragments.

Question 2

Thresholding is a simple and effective method used to segment an image. Using thresholding, we can convert a grayscale image into a binary image. A way of doing this is by replacing each pixel in the image with a black pixel if its intensity is less than a pre-set threshold value or with a white pixel if it is more. The threshold's value can either be chosen manually or automatically. Selecting a threshold automatically is done by separating the image into parts, the foreground and the background and it's a good way to extract useful information from the pixels while minimising background noise.

To apply automatic thresholding, we can use the following steps:

1. Select an initial value which is usually the mean 8-bit value of the original image
2. Divine the image in to two parts. Pixels with values less than the threshold are considered the background and pixels with a greater value are considered the foreground.
3. Calculate the average mean values of the two new parts
4. Calculate the new threshold by averaging the two means
5. Repeat by applying the new threshold to the original image unless the difference between the previous threshold and the new threshold is below a specified value.

Question 3

Dilation and Erosion operations

Dilation is one of the two fundamental operations used in morphological image processing and erosion is the other.
Dilation is used to make objects more visible and to fill in small holes in objects. This is done by adding pixels to the boundaries of objects in the image.
Erosion is used to remove islands and small objects so that only substantive objects remain in the image. This is done by removing pixels on object boundaries.
For both operations, a mask that describes the number of pixels that can be added or removed is required and its size and shape depend on a matrix called the structuring element which is comprised of ones and zeros.
Using these two methods together results in the following terms/operations, which are called opening and closing operations.

Opening and closing operations

We have an opening operation when an erosion is followed by a dilation and a closing operating when a dilation is followed by an erosion. They can be used for morphological noise removal.

The opening operation is used to removal small objects from the foreground in the image by placing them in the background and the closing operation is used to remove small holes in the foreground. They are useful as using erosion or dilation on their own can alter/distort all objects in the image while using them together negates that. Furthermore, these two techniques can be useful in finding specific shapes in images.

Question 4

The required code was uploaded along with this document