 Impact of Image Processing to Medical Imaging

EE4902 Part 2 Assignment 4

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# Introduction

The advancements made in medical imaging technology has paved the way for faster, more accurate and less invasive devices. Techniques such as X-ray, MRI, ultrasound imaging and molecular imaging have allowed medical practitioners to more accurately diagnose and treat patients. No longer confined to photographs in the visible light spectrum and microscope images, modern medical images are now systematic collections of data used to mark, quantify and detect certain phenomena in the human body.

Image processing can be said to have the following steps: (1) Image acquisition (2) Image enhancement and filtering (3) Image segmentation. Image acquisition is the first step and it broadly defines the retrieval of an image using the techniques like X-ray, MRI and ultrasound. Image enhancement and filtering is the broad range of operations performed on the acquired image, including filtering out impulse noise, detecting or extracting certain features like lines, edges and faces, improving the contrast, thresholding. Image segmentation is the division of an image into multiple parts to simplify it into something that is easier to analyze.

# Image Processing Techniques and Applications

The instruments used to acquire the image will not always extract a perfect image. Medical images usually suffer from the following: (1) Low resolution (2) Noise (3) Low contrast (4) Deformation (5) Presence of imaging artifacts.

## Applications in Medical Imaging

X-ray contrast is produced because its penetration through an object differs from its adjacent background tissue. As such, x-ray images have low contrast for soft tissues. Image enhancement techniques such as linear contrast stretching, dynamic histogram equalization or a LoG enhancement can be employed.

Ultrasound is a non-invasive and non-ionizing medical imaging technique. A transmitter sends high frequency sound waves into the body where they bounce off the different tissues and organs to produce distinctive patterns read by a computer. It overcomes the limitations of x-rays in detecting soft tissues, and is hence often used to examine an unborn baby inside its mother’s womb. However, it often produces very noisy images [1]. As the noise is uncorrelated, image averaging, a noise suppression technique, can be used. K images, are taken. The average is taken:

The variance of h is 1/K of noise, which vanishes as .

MRI produces clean and sharp images, though the image quality is affected by metallic implants. Not only that, metallic implants such as pacemakers may not function properly while the subject is in a MRI scan.

## Smoothing Techniques

Smoothing techniques are important as they help remove unwanted noise. Gaussian smoothing is a type of naïve, linear smoothing. A Gaussian kernel is used. The size of determines the amount of smoothing that is done as fluctuations in the image of scales of and smaller are smeared.

However, Gaussian smoothing also blurs out edge lines. Gaussian smoothing has been used for a long time, but this inherent limitation must be overcome by another type of filter. Non-linear filters are ideal because they can target the noise while avoiding edges.

Anisotropic smoothing is a non-linear diffusion equation:

This function slows down diffusion near the edges, where the gradient is large.

## Image Segmentation

Segmentation is the process of creating a structured visual representation from an unstructured one, partitioning an image into meaningful homogeneous regions. It is not concerned with object recognition. A typical example is partitioning a MRI image of the brain into the white and gray matter. Since it replaces continuous intensities with discrete labels, segmentation helps the medical practitioner identify regions better.

### Edge Detection

*Edges* are computed as points that are extrema of the image gradient in the direction of the gradient. It is an important part of image segmentation as it reduces the amount of information in the image while retain shape information of important items. In a noisy image, it is necessary to define the boundary of the target clearly. It is also widely used in the 3D reconstruction of brain imaging. Advances made in science have given engineers a range of tools to use for edge detection, each with their own strengths.

The Sobel and Prewitt operator is a 1 dimensional edge detector that is computationally inexpensive and able to detect edge pixels. A common problem with this method is that multiple edge pixels are obtained, hence methods are used to thin the edge. Edge thresholding is a simple method; however, it still can result in multiple edge pixels. Non-maximal suppression is a better method because it finds the strongest edge pixel in a local neighborhood, and removes all other edge pixels. It also provides directional information on the edge. Sometimes, this method creates disjointed edge lines, hence hysteresis thresholding is used to iteratively label edges as either weak edges or strong edges. Weak edges grow out from strong edges so that the edge line is not broken. The Canny algorithm is a combination of the aforementioned methods: (1) smoothing the image with Gaussian (2) Differentiating the image to obtain edge gradients (3) Non-maximum suppression to find single edge pixels (4) Hysteresis thresholding to find connected edge strings.

Second derivatives may be used to find the zero crossings as edge pixels. A common method is the LoG, where Gaussian smoothing is first applied. Then the Laplacian of the resulting image is found, and then zero crossings are located. A slight modification to the LoG will allow it to be used as an image enhancer, particularly useful for medical images where the doctor may not desire edges, but want to enhance the image sharpness.

### Contour detection

The task of locating objects and boundaries is vital in medical diagnosis and surgical planning. It is often performed manually by clinicians, which are accurate but extremely time consuming. The snake can be used to automate and speed up the process. Contours are obtained from edges, and are often closed. The Active Contour Model (Snake) produces connected contours even if the image is noisy and has broken lines. It finds an object boundary through energy minimization.

# The Future of Image Processing

## Automation

The previous chapter covered how imaging techniques can be used by doctors to identify features for medical diagnosis. Computer vision and automation also allows many menial tasks to be performed, such as the counting of cells in a PAP smear [2]. The steps taken are as follows: (1) Gaussian smoothing to remove noise (2) binary thresholding to identify possible cell nuclei by how dark the image is (3) feature extraction, using the Hough transform to extract circles of a certain radius as cells and count them. Quick and automated counting of cancerous cells in a Pap smear helps speed up screening of cervical cancer and could well prevent many annual deaths.

|  |  |  |  |
| --- | --- | --- | --- |
| Original | Gaussian Blur | Binary Thresholding | Hough Transform |
|  |  |  | ../Drawings/cells.png |

## Machine Learning and Neural Networks

Convolutional Neural Networks (CNN) are relatively new constructs that have been effective in classifying image data and will likely prove beneficial for medical imaging. This technique allows us to pre-train a model and then apply that to a new dataset. Instead of hard-coding the shape of a tumor for instance, the neural network model can be trained to recognize and characterize a tumor based on previous datasets. Predictions and accurate diagnosis can even be made purely by the imaging software without the need for a doctor’s professional judgment.

A key draw of machine learning is the ability to identify trends and make future predictions based on existing datasets. Machine learning in medical imaging may help clinicians identify future threat of disease in patients in the early stages where the signs would normally slip past human detection.

## Wearables

The technology of today is becoming increasingly integrated and connected. No longer is imaging software restricted to being used in a clinical setting with heavy bulky equipment. The future of medical imaging is in wearables. Sensors can be attached to patients that stream data over the cloud in real time. Retinal scanners are diagnostic devices connected to the internet, that are integrated into patients’ personal cameras or mirrors that regularly and non-invasively monitor the patient’s eye [3].

# Conclusion

Many of the methods learnt are actively applied to enhance medical images and segment them to reduce the level of complexity of the image while accentuating important information. While techniques of the past decade have made headway in allowing images to be filtered and enhanced, image processing of the future should focus on feature extraction aided by computer vision and machine learning. Indeed, the future for image processing is in the ability to gain actionable insights, predictions which result in better healthcare for patients.