24-658:HOMEWORK-2

amadala

CARNEGIE MELLON UNIVERSITY

Contents

1) Question1:

Part-a:

Contrast Enhancement

Contrast enhancement is a process that makes the image features stand out more clearly by making optimal use of the colors available on the display or output device. Contrast manipulations involve changing the range of values in an image in order to increase contrast. The goal is to adjust the brightness and enhance the contrast by designing a stretching function or a windowing function. A fast approach based on localized contrast manipulation. It is adaptive, multi-scale, weighted localization, anisotropic.

It is used in television, MR image enhancement, CT image enhancement, laptops, mobile phone etc., for **feature enhancement.**

Filtering

Filtering is a technique for modifying or enhancing an image. For example, you can filter an image to emphasize certain features or remove other features. Image processing operations implemented with filtering include smoothing, sharpening, and edge enhancement. Filtering is a neighborhood operation, in which the value of any given pixel in the output image is determined by applying some algorithm to the values of the pixels in the neighborhood of the corresponding input pixel. A pixel's neighborhood is some set of pixels, defined by their locations relative to that pixel. Linear filtering considers multiple pixels in a linear and space-invariant manner.

Two standard techniques:

– Convolution

– Fourier Transform

In image processing filters are mainly used to suppress either the high frequencies in the image, i.e. smoothing the image, or the low frequencies, i.e. enhancing or detecting edges in the image. It is used for feature emphasis. These days filters are used in photoshop, mobile applications etc.

Segmentation

Segmentation/classification is a process to partition a digital image into multiple regions (sets of pixels). Segmentation is typically used to locate objects and boundaries (lines, curves, etc.) in images. There is no general solution to the image segmentation problem. Segmentation techniques have to be combined with domain knowledge in order to effectively solve an image segmentation problem.

Things involved in segmentation are: Edge detection, Watershed segmentation, Statistical pattern recognition, Region merging, Active surfaces/Front evolution, Fuzzy connectedness, MRF models, Level set methods, Anisotropic Gradient Vector Diffusion (AGVD) .

Medical image segmentation is used to:

– Locate tumors and other pathologies

– Measure tissue volumes

– Computer-guided surgery

– Diagnosis

– Treatment planning

– Study of anatomical structure

Registration

Image registration is the process of aligning two or more images of the same scene. This process involves designating one image as the reference image, also called the fixed image, and applying geometric transformations or local displacements to the other images so that they align with the reference. Images can be misaligned for a variety of reasons. Commonly, images are captured under variable conditions that can change the camera perspective or the content of the scene. Misalignment can also result from lens and sensor distortions or differences between capture devices. Image registration is often used as a preliminary step in other image processing applications. For example, you can use image registration to align satellite images or medical images captured with different diagnostic modalities, such as MRI and SPECT. Image registration enables you to compare common features in different images. For example, you might discover how a river has migrated, how an area became flooded, or whether a tumor is visible in an MRI or SPECT image.

Three criteria: landmark-, segmentation- or intensity based criteria.

Medical image registration has many applications:

– Repeated image acquisition of a subject is often used to obtain time series information that captures disease development, treatment progress and contrast bolus propagation.

– Correlating information obtained from different image modalities

• MRI-CT: MRI has good soft tissue discrimination for lesion identification, while CT provides bone localization useful for surgical guidance.

• PET/SPECT-CT/MRI: Positron emission tomography (PET) and single photon emission computed tomography (SPECT) provide functional information that can be used to locate abnormalities such as tumors, while CT/MRI provided anatomical structure, i.e., PET/MRI (study of brain tumors), and PET/CT (radiation treatment planning).

Part-b:

Edge detection is an image processing technique for finding the boundaries of objects within images. It works by detecting discontinuities in brightness. Edge detection is used for image segmentation and data extraction in areas such as image processing, computer vision, and machine vision.

Common edge detection algorithms include Sobel, Canny, Prewitt, Roberts, and fuzzy logic methods.

Image segmentation using the Sobel method.

Image segmentation using the Canny method.

Image segmentation using a Fuzzy Logic method.

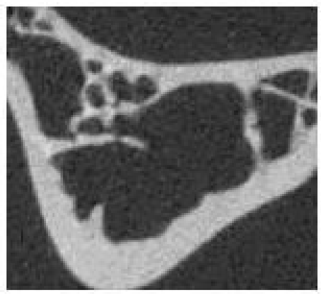
(*Image reference:* https://www.mathworks.com/discovery/edge-detection.html)

Detecting boundaries is based on rapid change in image pixel intensity values. Derivatives are used all over the data and sudden jump or drop is intensities is identified. This zone is categorized as a boundary. The gradient vector and its magnitude of the image intensity are used to detect boundaries.

$$\begin{bmatrix} \frac{\partial \phi}{\partial x} & \frac{\partial \phi}{\partial y} \end{bmatrix} \qquad \left(\frac{\partial \phi}{\partial x}\right)^2 + \left(\frac{\partial \phi}{\partial y}\right)^2$$

2) Question2:

Actual Image:



Actual Image (foot.pgm)

Part-a: Linear filtering

$$\partial_t \phi - \nabla^2 \phi = 0$$

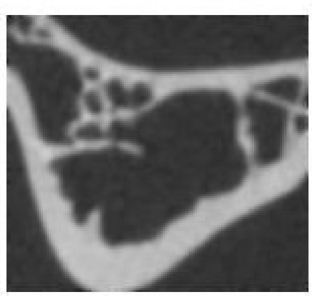
Using FTCS explicit scheme,

$\Delta x = \Delta y = 1$,

Iteration-1:

Let $\Delta t = 0.01$ and t=1s,

No. of time steps = 100

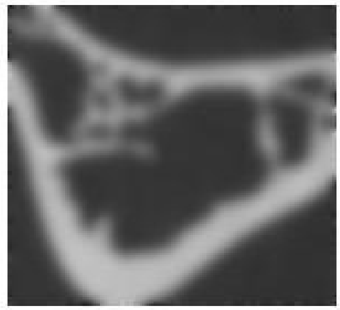


Linear filter – Iteration1

Iteration-2:

Let Δ=0.1 and t = 2s,

No. of time steps = 50



Linear filter – Iteration2

Part-b: Nonlinear filtering

$$\partial_t \phi - div\left(g\left(\left|\nabla\phi\right|\right)\nabla\phi\right) = 0$$

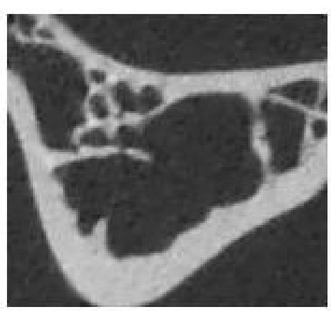
$$g\left(\left|\nabla\phi\right|\right) = \frac{1}{1+\left|\nabla\phi\right|^2 / \lambda^2}$$

Iteration1:

Lambda = 1;

Δt = 0.01;

No. of time steps = 500;



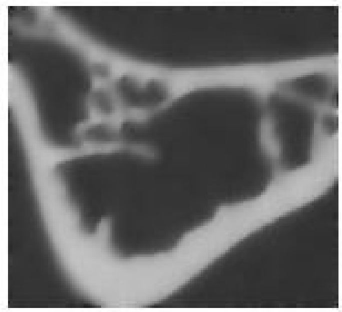
Nonlinear filter – Iteration1

Iteration2:

Lambda = 10;

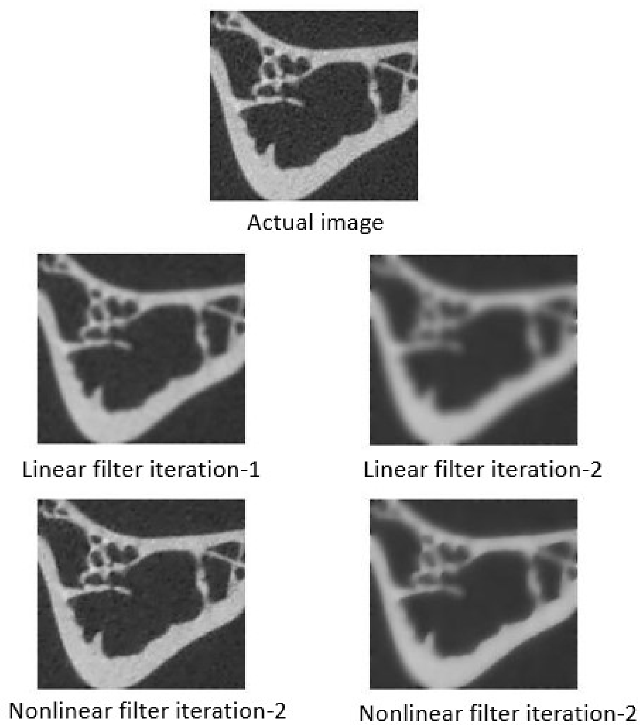
Δt = 0.01;

No. of time steps = 500;



Nonlinear filter – Iteration2

Discussion of results:



From the results, we can notice that linear filter blurs the image whereas nonlinear filter makes it appear much clearer. Nonlinear filter removes the noise whereas linear filter only smoothens the data. Sharpness of image depends on Δt and number of time steps considered. Features are preserved in nonlinear filtering.

References:

http://knightlab.org/rscc/legacy/RSCC_Contrast_Enhancement.pdf

https://www.mathworks.com/help/images/what-is-image-filtering-in-the-spatial-domain.html

https://homepages.inf.ed.ac.uk/rbf/HIPR2/filtops.htm

https://www.mathworks.com/help/images/approaches-to-registering-images.html

https://www.mathworks.com/discovery/edge-detection.html

Lecture slides