의료영상의 본질

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1. Introduction

1.1. Imaging sicence

▪ ▪ ▪ ▪ ▪ The study of mapping of objects and their properties into image space fo rvisualization, and development of ways to understand, improve and productively use them.

1.2. Multidimensional Imaging

Non-invasive visualization(an age-old quest) and analysis of multidimensional, multimodality medical images has expanded into the discipline of its own, separate from any specific application. Techniques created through research in this area are being apllied to growing areas in medial imaging.

1.3. Multidimensional

• 2D−two spatial dimensions, one spatial dimension + time

• 3D – three spatial dimensions, two spatial dimensions + time, two spatial dimensions + different modalities
• 4D – three spatial dimensions + time, two spatial dimensions + different modlities
• 5D – three spatial dimensions + time + different modalities
• nD spatial dimensions + time + different modatlities + vector components, etc.

1.4. Multimodality

• Digital Radiography(standard radiographs stored as digital information)
• X-ray Computed Tomography(conventional CT)
• Fast X-ray Computed Tomography(cine CT, Imatron)
• Magnetic Resonance Imaging(all aspects of MRI, including several sources of signals, 2D modes, 3D modes, fast MRI and MR spectroscopy)
• Positron Emission Tomography(PET)
• Single Photons Emission Computed Tomography (SPECT)
• Ultrasound(all aspects of ultrasound, including B-mode, M-mode, linear arrays)
• Digital Microscopy(Light, Electron and Confocal)

2. Characteristics of Images

2.1. What is an Image?

An image is a real or virtual spatial representation of an object.

• Most 2D images in medical imaging are represented as digital images made up of discrete values.
• Most 3D images are represented as stacks of 2D images(volume images).
• Dimensions beyond the third dimension are represented as collections of images from the previous dimensions(4D a collection of 3D volume images).

2.2. Pixel

A picture element. Most 2D images are referred to as being made of pixels. A pixel contains a single value that is a representation of the structure or parameter being imaged, which has a defined spatial position and size in 2D(x, y). This term is used often in reference to the elements of medical images, but even single 2D images have a third spatial dimensions which is the thickness of the sectioin.

2.3. Voxel

A volume element. Most 3D images are referred to as being made of voxels(a combination of the word 'volume' and the word 'pixel'). Each voxel contains a single value that is a representation of the structure or parameter being imaged, which has a defined spatial position and size in 3D(x, y, z). This term is the more appropriate term to use for the basic element of information in medial images, as eash value generally represented a 3D piece of information.

2.4. Noxel

An N-dimensional element.

3. Images Properties

3.1. Resolution

1) Spatial Resolution

In discrete digital images, each pixel or voxel has specific spatial dimension in the measurement space of the objects which is determined by the image acquisition system and image information mechanism. The spatial dimensions may be different for each of the dimensions represented in the image. The limits to spatial resolution are the smallest dimensions differentiable by the total imaging system.

- Anisotropic : Exhibiting properties with different values when measured along axes in different directions, i.e. having different spatial resolution along the different axes.
- Isotropic : Exhibiting properties with the same values when measured along axes in different direction, i.e. having the same spatial resolution along the different axes.

2) Contrast Resolution

The abilitiy of the imaging system to detect differences in signal intensity(e.g., electron density, proton density) between two structures, which is dependent on the image acquisition system and the energy being measured. This is usually measured as a percentage of the largeest signal difference that can be measured by the imaging system.

3) Temporal Resolution

The amount of time it takes to form the image, again dependent on the imaging modality being used and acquisition system.

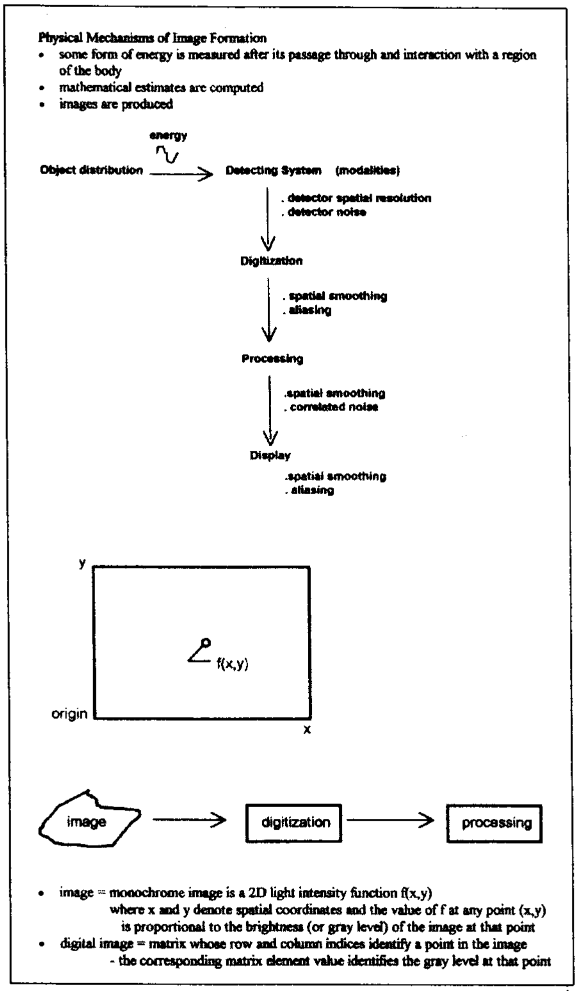
3.2. Dynamic Range

As each value in the discrete image is represented by a value which is measured and computed by the image acquisition system, the range of numbers used to represent discrete image values is called the dynamic range. This is a property of the imaging system and of the numeric scale used to form the images.

4. Characteristics of Modalities

4.1. Imaging Formation

The first step in medical image formation occurs when some form of energy is measured after its passage through a region of the body. Mathematical estimates are computed and images are produces of the 2D and 3D interactions between the energy and the body tissue(absorption, attenuation, nuclear magnetic disturbances, etc.). The instrumentation used to measure the energy is drastically different based on the differences in the type of energy being sampled.



4.2.Digital Radiography

Conventional X-ray projection images are now, in many cases, being stored digitally in place of on standard radiographic film. This is done with both laser scanning of standard films and laser readout of new cartridges. This is also done with real-time imaging systems(cine) in applications like digital subtraction angiography(DSA). Most digital radiography is used for structural imaging, with real-time techniques like DSA providing functional information.

- Energy source : X-rays
- Measured parameters : Transmitted X-rays (attenuation, electron density)
- Dimensionality : 2D(Projection of 3D onto 2D)
- Image Dimensions : (2000×2000×1) to(4000×4000×1)
- Dynamic Range : 0 4096(12 bits)
- Spatial Resolution : (.1mm×.1mm) to .5mm ×.5mm)
- Contrast Resolution : 1% of full range of signal
- Temporal Resolution : 10 msec(exposure time)

4.3. Conventional X-ray Computed Tomography

Conventional X-ray CT scanners utilize single X-ray tube which rotates through a full 360o rotation(every .5 to 1 degrees). These projection images are processed and an image is formed through mathematical reconstruction techniques, including filtered backprojection or Fourier reconstruction. The X-ray beam originates as a point source and is collimated to a single slice, forming a flat fan beam geometry. The detectors are usually solid state detectors(xenon filled chambers). Most CT is used structural imaging, with functional imaging associated with dye distribution used in selective cases.

- Energy source : X-rays
- Measured parameters : Transmitted X-rays(attenuation, electron density)
- Dimensionality

2D within a section(although a section has a thickness)

3D when consecutive, adjacent sections are generated

- Image Dimensions : (512×512×1) to(512×512×100)
- Dynamic Range : 0−2000(10 bits)(Hounsfield Units : -1000 to 1000)
- Spatial Resolution : (.2mm×.2mm×1.5mm) to(.5mm×.5mm×.5mm)
- Contrast Resolution : .5% signal differences
- Temporal Resolution : 1-2 sec

4.4. Spiral X-ray Computed Tomography

Recently, CT vendors have modified the design of third and fourth generation scanners so that no connections are directly hardwired to the X-ray tube from the generator or to the detector array from the computer electronics. Instead, the electrical supply to the X-ray tube and the electrical connections between the moving detector array and the stationary computer are achieved using slip-ring technology. The slip ring is a circular contact with sliding brusches that allows the gantry to rotate continually.

- Energy source : X-rays
- Measured parameters : Transmitted X-rays (attenuation, electron density)
- Dimensionality :

2D within a section(although a section has a thickness)

3D when consecutive, adjacent sections are generated

- Image Dimensions : (512×512×1) to(512×512×100)
- Dynamic Range : 0−4000(10 bits)(Hounsfield Units : -2000 to 2000)
- Spatial Resolution : (.2mm×.2mm×1.5mm) to(.5mm×.5mm×.5mm)
- Contrast Resolution : .5% signal differences
- Temporal Resolution : 1-2 sec

4.5. Electron Beam Computed Tomography

The scanning electron beam sweeps over a curved tungsten ring below the patient producing a rotating source of X-ray. Four stationary tungsten target rings and stationary dual detector arrays combine with a scanning electron beam to produce scan speeds as fast as 1/20th of a second for motion free images or real-time cine display.

- Energy source : X-rays
- Measured parameters : Transmitted X-rays (attenuation, electron density)
- Dimensionality :

2D within a section(although a section has a thickness)

3D when consecutive, adjacent sections are generated

3D when a single section is generated through time

4D when multiple section scans are done through time

- Image Dimensions : (512×512×1) to(512x 512×100)
- Dynamic Range : 0−4000(10 bits)(Hounsfield

Units : -2000 to 2000)

- Spatial Resolution : (.2mm x .2mm x 1.5mm) to(.5mm x .5mm x .5mm)
- Contrast Resolution : .5% signal differences
- Temporal Resolution : 50 msec

4.6. Magnetic Resonance Imaging

Magnetic Resonace Imaging(MRI) technology can produce images with a wide range of characteristics. MRI imaging systems provide mechanisms for complete control of the signal being measured through control of the magnetic field and RF pulse sequences used to alter the spins of protons in the body. Given that MRI is selectively imaging the distribution of protons in the body, it is an excellent tissue imaging system, providing highly detailed structural images. Techniques are being rapidly developed for doing fast MRI imaging, so as to capture functional characteristics as well. MRI can further be used to study the biological makeup of tissues, using a technique called MR spectroscopy.

- Energy source : Electromagnetic energy
- Measured parameters : Emissions of electromagnetic energy from protons
- Dimensionality :
  - 2D within a section(although a section has a thickness)
  - 3D with a single line of signal detected through time,
  - 3D when consecutive, adjacent sections are acquired
  - 3D when a true isotropic volume image set is acqured
  - 3D when a single section is generated through time
  - 4D when multiple section scans are done through time
  - 4D when an isotropic volume is acquired through time
  - 4D when multiple signals are detected for the same spatial image information(i.e. T1, T2, PD, contast)
  - 5D when multiple signals for three spatial dimensions are acquried through time
- Image Dimensions : (256 x 256 x 1) to(256 x 256 x 256)
- Dynamic Range : 0−2047(10 bits) for normal acquisitions. 0−255(8 bits) for 3D acquisitions
- Spatial Resolution : (2mm x 2mm x 5mm) to(1mm x 1mm x 1mm)
- Contrast Resolution : .5% differences in signal
- Temporal Resolution : seconds to minutes(normal), 100 msec(fast)

4.7. Nuclear Medicine Imaging

1) Positron Emission Tomography(PET)

PET uses positron emitting radioisotopes which are injected into the body and which localize in the tissue of interest. These positron emitters then decay, giving off the positron which is turn annihilates into two 511 keV photons. The positron wanders approximately 2mm before annihilation, limiting the spatial resolution to be a minumum of 2mm. The coincident detection of these photons provides the measured signal which can be reconstructed into the image data. PET is functional imaging modality, measuring regional biochemical of metabolic processes, with very poor spatial resolution.

- Energy source : Positron emitting radioisotopes (FDG, Labeled CO2 and O2)
- Measured parameters : Emissions of electromagnetic energy from protons
- Dimensionality :
  2D within a section(although a section has a thickness)
  3D when consecutive, adjacent sections are generated
  3D with a signle section is generated through time
  4D when multiple section scans are done through time
- Image Dimensions : (128×128×15) to(256×256×256)
- Dynamic Range : 0 255(8 bits)(calibrated to activity level)
- Spatial Resolution : (.5mm×.5mm×10mm) to(2mm×2mm×6mm)
- Contrast Resolution : 10% of full range
- Temporal Resolution : 1 to 100 seconds

2) Single Photon Emission Computed Tomography (SPECT)

Other radioisotopes used in nuclear medicine imaging give off single photons, which can be measured with a gamma camera. In SPECT, emission signals from multiple angles of view are acquried with rotating gamma camera and the images are reconstructed similar to what is done with X-ray CT. New SPECT technologies use a tri-headed arranagement of gamma detectors to provide faster scan times and better spatial resolution. SPECT is a functional imaging modality, directly measuring regional biochemical or metabolic processes, with poor spatial resolution.

- Energy source : Various radioisotopes(Technetium 99m)
- Measured parameters : Photon Emissions
- Dimensionality :
  2D within a section(although a section has a thickness)
  3D when consecutive, adjacent sections are generated
  3D with a signle section is generated through time,
  4D when multiple section scans are done through time
- Image Dimensions : (64×64×1) to(128×128×128)
- Dynamic Range : 0 255(8 bits)(calibrated to activity level)
- Spatial Resolution : (.5mm×.5mm×10mm) to(2mm×2mm×5mm)
- Contrast Resolution : 10% of full range
- Temporal Resolution : 1 to 100 seconds

4.8. Ultrasound Imaging

Ultrasound imaging measures the spatial distribution of acoustic properties in the tissue of the body, including velocity, attenuation, impedance, and frequency shift(Doppler). Several transducer technologies are used which directly relate to the spatial resolution of the image data, including sector ultrasound and new linear arrays. The measurements can be used to create structural images or functional images.

- Energy source : High frequency acoustic waves
- Measured parameters : Acoustic echoes, transmitted sound, frequency shifts
- Dimensionality :
  2D within a section(although a section has a thickness)
  3D when consecutive, adjacent sections are generated
  3D when a single section is generated through time
  4D when multiple section scans are done through time
- Image Dimensions : (256×26×1) to(256x 256×100)
- Dynamic Range : 0 2047(10 bits)
- Spatial Resolution : (.2mm×.2mm×1.5mm) to(.5mm×.5mm×2mm)
- Contrast Resolution : .10% of full scale
- Temporal Resolution : 10-30 msec

4.9. MSI or MEG

Magnetic source imaging(MSI) measures the magnetics fields caused by evoked magnetic dipoles in the body, particularly in the brain. MSI technology uses detectors made from spuerconducting Quantum Interference Devices) to measure these magnetic changes due to evoked repsonses. As with EEG, normal maps are created and used to normalize the evoked potential maps so as to locate the positions of the magnetic dipoles, their strength and orientation. These images are currently very poor in spatial resolution, but depict functional information which, again with correlation to other spatial imaging modalities, are becoming useful.

- Energy source : magnetic field
- Measured parameters : magnetic energy(position, strength, orientation)
- Dimensionality :
  2D within a section(although a section has a thickness)
  3D when consecutive, adjacent sections are generated
  3D when a single section is generated through time
  4D when multipole sections are created through time
  nD when then vector components of each electrical dipole are also considered
- Image Dimensions : (128×128×64)
- Dynamic Range : 0 2000(10 bits)(Hounsfield Units : -1000 to 1000)
- Spatial Resolution : (10mm×10mm×10mm)
- Contrast Resolution : .?
- Temporal Resolution : several sconds