1. (a) **Define Medical Imaging and why do use medical imaging techniques?**

**Answer:**

Medical imaging refers to a number of techniques that can be used as non-invasive methods of looking inside the body. This means the body does not have to be opened up surgically for medical practitioners to look at various organs and areas. It can be used to assist diagnosis or treatment of different medical conditions.

Imaging techniques use radiations that form part of the electromagnetic spectrum. It's easy to forget that visible light (that is the colors that we as humans can see) forms only a fraction of the electromagnetic spectrum.

In an ideal world we would be able to diagnose, treat and cure patients without causing any harmful side effects. The use of medical imaging has enabled doctors to see inside a patient without having to cut them open. Medical imaging also helps us learn more about neurobiology and human behaviours.

Medical imaging brings scientists from biology, chemistry and physics together and the technologies developed can often be used in many disciplines.

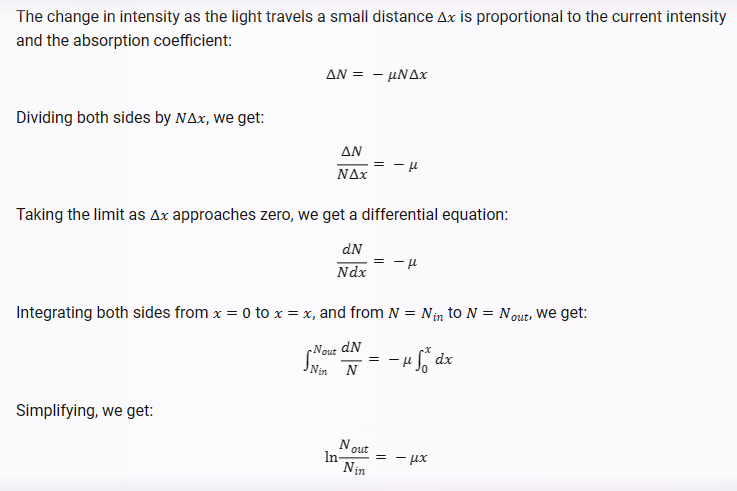
(b) **How do we describe attenuation of X-Rays by body? Explain with necessary mathematical equations and symbols if necessary and prove that, =**

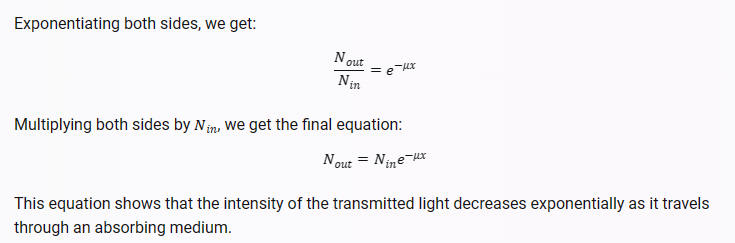
**Answer:**

Attenuation of X-rays by body is the process of reducing the intensity of X-rays as they pass through different tissues in the body. The amount of attenuation depends on the density and thickness of the tissues. The denser and thicker the tissue, the more X-rays are absorbed or scattered, and the less X-rays reach the detector behind the body. This creates a contrast in the X-ray image, where different tissues appear as different shades of grey.

The attenuation of X-rays by body can be described by a mathematical equation:

I=





(c) **Determine and draw the medical diagnostic system.**

**Answer:**

1. (a) **Describe the underlying mechanism for creation of an ultrasound image.**

**Answer:**

The creation of an image from sound is done in three steps – producing a sound wave, receiving echoes, and interpreting those echoes.

**Producing a sound wave**

* A sound wave is typically produced by a piezoelectric transducer encased in a plastic housing.
* Strong, short electrical pulses from the ultrasound machine drive the transducer at the desired frequency.
* The frequencies can be anywhere between 1 and 18 MHz. The sound is focused either by the shape of the transducer, a lens in front of the transducer, or a complex set of control pulses from the ultrasound scanner (Beamforming). This focusing produces an arc-shaped sound wave from the face of the transducer.
* The wave travels into the body and comes into focus at a desired depth. The sound wave is partially reflected from the layers between different tissues or scattered from smaller structures.

**Receiving the echoes**

* The return of the sound waves to the transducer results in the same process as sending the sound wave, except in reverse.
* The returned sound wave vibrates the transducer and the transducer turns the vibrations into electrical pulses that travel to the ultrasonic scanner where they are processed and transformed into a digital image.

**Forming the image:**

To make an image, the ultrasound scanner must determine two things from each received echo:

* How long it took the echo to be received from when the sound was transmitted.
* How strong the echo.
* Once the ultrasonic scanner determines these two things, it can locate which pixel in the image to light up and to what intensity.
* Transforming the received signal into a digital image may be explained by using a blank spreadsheet as an analogy. First picture a long, flat transducer at the top of the sheet. Send pulses down the 'columns' of the spreadsheet (A, B, C, etc.). Listen at each column for any return echoes. When an echo is heard, note how long it took for the echo to return. The longer the wait, the deeper the row (1,2,3, etc.). The strength of the echo determines the brightness setting for that cell (white for a strong echo, black for a weak echo, and varying shades of grey for everything in between.) When all the echoes are recorded on the sheet, we have a greyscale image.

**Displaying the image**

* Images from the ultrasound scanner are transferred and displayed using the DICOM standard. Normally, very little post processing is applied to ultrasound images.

(b) **What precautions we have to take for reducing X-ray radiation?**

**Answer:**

Reduction of radiation risks:

* Keeping a “medical x-ray history” with the names of your radiological exams or procedures, the dates and places where you had them, and the physicians who referred you for those exams
* Making your current healthcare providers aware of your medical x-ray history;
* Asking your healthcare provider about whether or not alternatives to x-ray exams would allow the provider to make a good assessment or provide appropriate treatment for your medical situation
* Providing interpreting physicians and referring physicians with recent x-ray images and radiology reports
* Informing radiologists or x-ray technologists in advance if you are pregnant or think you may be pregnant.

(c) **Compare the Doppler ultrasound and contrast ultrasound system with proper description.**

**Answer:**

| **Aspect** | **Doppler ultrasound** | **Contrast ultrasound** |
| --- | --- | --- |
| Principle | Uses the Doppler effect to measure the frequency shift of the sound waves reflected by moving blood cells1 | [Uses microbubbles as contrast agents that enhance the reflection of sound waves by blood](https://radiologykey.com/doppler-and-contrast-agents/)[2](https://bmccardiovascdisord.biomedcentral.com/articles/10.1186/s12872-020-01840-3) |
| Application | [Useful for evaluating blood flow in vessels and detecting abnormalities such as stenosis, occlusion, or turbulence](https://radiologykey.com/doppler-and-contrast-agents/)[1](https://radiologykey.com/doppler-and-contrast-agents/)[3](https://www.frontiersin.org/articles/10.3389/fonc.2022.872890/full) | Useful for evaluating blood perfusion in tissues and detecting abnormalities such as tumors, inflammation, or ischemia24 |
| Limitations | [Poor sensitivity and specificity for low-flow or complex vascular structures; limited by the angle and direction of the blood flow; does not require contrast agents](https://radiologykey.com/doppler-and-contrast-agents/)[1](https://radiologykey.com/doppler-and-contrast-agents/)[2](https://bmccardiovascdisord.biomedcentral.com/articles/10.1186/s12872-020-01840-3) | [Poor penetration through bone or air; requires contrast agents and specific equipment; may have potential risks or side effects2](https://bmccardiovascdisord.biomedcentral.com/articles/10.1186/s12872-020-01840-3)[5](https://theultrasoundjournal.springeropen.com/articles/10.1186/s13089-022-00274-6) |
| Advantages | Does not use radiation; easy to use and portable; inexpensive; can be performed in real-time12 | [Less direction dependence; higher sensitivity; better contrast of vasculature; not affected by the angle and direction of the blood flow; more comprehensive and dynamic assessment of blood flow2](https://bmccardiovascdisord.biomedcentral.com/articles/10.1186/s12872-020-01840-3)[4](https://bmjopen.bmj.com/content/11/12/e052830) |

1. (a) **Describe the mechanism of B-mode and 2D-mode operations of ultrasound imaging.**

**Answer:**

**B-Mode or 2-D Scan:**

B-mode ultrasound is a technique that uses sound waves to create a two-dimensional image of the internal structures of the body. It is based on the principle that sound waves are reflected and scattered by different tissues and organs, and the echoes are detected by a transducer. The transducer emits and receives sound pulses in a sequence of directions, forming multiple image lines. The echoes are converted into electrical signals, which are processed by a computer to generate a brightness map of the echo-producing features. The brightness of each pixel in the image is proportional to the amplitude of the echo signal. B-mode ultrasound can be used to visualize and measure anatomical structures, such as organs, blood vessels, and tissues.

B-mode ultrasound is also known as brightness mode, because the image is composed of bright dots representing the echoes. The term B-mode was coined to distinguish it from other modes of ultrasound display, such as A-mode (amplitude mode) and M-mode (motion mode). A-mode displays the amplitude of the echoes as a function of time or depth, while M-mode displays the motion of a structure along a single image line over time. B-mode is the most commonly used mode in diagnostic ultrasound, because it provides a realistic and detailed representation of the anatomy.

**2-D or 2 dimensional mode:**

The mechanism of 2D-mode operations of ultrasound imaging is based on the following principles:

* An ultrasound probe emits sound waves into the body and receives the echoes that are reflected or scattered by the tissues and organs.
* The machine calculates the distance from the probe to the tissue or organ boundaries using the speed of sound in tissue (1,540 m/s) and the time of each echo’s return.
* The ultrasound machine displays the distances and intensities of the echoes on the screen, forming a 2D image that represents a cross-sectional view of the scanned area.
* The brightness of the image at each point is related to the strength or amplitude of the echo, giving rise to the term B-mode (brightness mode).
* The position and orientation of the image depend on the angle and location of the probe.

(b) **Explain the speckle noise in ultrasound. Describe a generalized noise model incorporating different kind of noises.**

**Answer:**

Speckle, a multiplicative random noise, is a common phenomenon in ultrasound images, which are produced by the superposition inferring echoes transmitted waveform coming with random phases and amplitudes.

Speckle noise is a type of noise that affects the quality and resolution of ultrasound images. It is caused by the interference of many waves of the same frequency that are reflected by small structures within the tissue.

Speckle noise makes the ultrasound images look grainy and textured, which can reduce the contrast and visibility of the features of interest. Speckle noise can also affect the accuracy of measurements and analysis based on ultrasound images.

A generalized noise model is a mathematical description of the random fluctuations or disturbances that affect a signal or a system. Different kinds of noises have different characteristics, such as distribution, power, frequency, and correlation. A generalized noise model can capture the diversity and complexity of real-world noise scenarios by using appropriate parameters or functions.

One example of a generalized noise model is the symmetric alpha-stable (SαS) model, which can describe noise that ranges from Gaussian to impulsive. The SαS model has two parameters: alpha and gamma. Alpha controls the shape of the noise distribution, and gamma controls the scale or variance of the noise. When alpha is2, the SαS model reduces to the Gaussian model. When alpha is less than 2, the SαS model becomes more impulsive and heavy-tailed.

1. (a) **What is brain scanning technique? Illustrate the working principle of CT.**

**Answer:**

A brain scanning technique is a method of producing images of the brain or other parts of the nervous system. There are different types of brain scanning techniques, each one showing the brain’s structure and functions in a unique way. Some of the most common brain scanning techniques are: **CT, MRI, fMRI, PET, SPECT, DTI, DOT**

* 1. The scanner device incorporates a moving table & a revolving X-ray tube
     1. The table moves the patient back and forth through the revolving X-ray emissions
     2. The X-ray emitter moves (revolves) in a 360o arc around the patient
  2. Instead of film, the CT scanner collects emitted X-rays via a collector
     1. This collector is called a SCINTILLATOR
  3. Scintillator transforms X-ray’s into a proportionally strong electric current
  4. The electric current is then converted into a number of images (“slices”)
     1. Contrast dyes may be used for image enhancement
  5. Tool of choice for most stroke cases

(b) **Compare the X-ray, CT and MRI system based on their advantages, disadvantages and applications.**

**Answer:**

| **Test** | **Technology** | **Advantages** | **Disadvantages** | **Applications** |
| --- | --- | --- | --- | --- |
| X-ray | Uses electromagnetic radiation to create 2D images of bones and some soft tissues. | Fast, easy, inexpensive, and widely available. | Low-quality images with less information and contrast. Exposes the patient to radiation. | Detecting fractures, dislocations, bone cancer, arthritis, osteoporosis, tooth decay, lung infection, enlarged heart, breast cancer, and blocked blood vessels. |
| CT | Uses a 360-degree beam of radiation and a computer to create detailed 3D images of internal structures. | High-quality images with more information and clarity. Provides 360-degree and cross-section views. | Expensive and exposes the patient to higher radiation levels than X-rays. | Seeing internal organs, soft tissues, blood vessels, tumors, complex injuries, and internal bleeding. |
| MRI | Uses a powerful magnet and radio waves to create detailed 3D images of internal structures without radiation exposure. | High-quality images with more information and clarity. Provides cross-section views. No radiation exposure. | Expensive and not widely available. Takes longer than X-rays or CT scans. Can be noisy and claustrophobic. Not suitable for patients with metal implants or devices. | Seeing internal body structures such as the brain, spinal cord, neck, breasts, abdomen, and muscles. |

(c) **Explain the artifacts in CT.**

**Answer:**

Artifacts in CT (Computed Tomography) imaging refer to inconsistencies or distortions in the resulting images that do not accurately represent the true anatomy or structures being imaged. These artifacts can arise due to a variety of reasons, including technical limitations, patient-related factors, and equipment malfunctions. Here are some common types of artifacts in CT imaging:

• **Metallic Artifacts**: When metallic objects such as surgical implants, dental fillings, or jewelry present in the body, they can cause streaking or shading artifacts in the CT images.

• **Beam Hardening:** CT scans involve X-rays of varying energy levels passing through the body. As lower-energy X-rays are preferentially absorbed, higher-energy X-rays dominate, leading to an apparent increase in the average energy of the X-ray beam.

• **Partial Volume Effect**: When a voxel (3D pixel) encompasses two or more different tissue types with varying densities, the CT scanner may struggle to assign a single Hounsfield Unit (HU) value accurately.

• **Motion Artifacts**: Patient movement during the scan, even small involuntary movements like breathing or muscle contractions, can cause blurring or ghosting in the images.

• **Ring Artifacts**: If one or more detector elements in the CT scanner malfunction or have inconsistent sensitivity, it can result in ring-like patterns in the reconstructed images, affecting image quality.

• **Cone Beam Artifacts**: In cone beam CT, which is used in some applications like dental imaging, the X-ray source and detector move in a cone shape around the patient.

• **Noise Artifacts**: Noise in CT images can lead to grainy or speckled appearance. This can be caused by various factors, including low-dose imaging, patient size, and scanner settings.

• **Streak Artifacts from Dense Structures**: High-attenuation structures like bones can lead to streaking artifacts, especially in the presence of strong X-ray beam attenuation.

• **Helical Artifact**: In helical or spiral CT scans, where the patient table moves continuously during the scan, objects with a regular pattern (e.g., zippers on clothing) can cause periodic variations in the images, resembling a helix.

• **Respiratory Artifacts**: Variations in lung density due to breathing can lead to inconsistencies in image quality, especially in the lung regions.

1. (a) **Describe the working principle of MRI.**

**Answer:**

* 1. Magnetic nuclei are abundant in the human body (H,C,Na,P,K) and spin randomly
     1. Since most of the body is H2O, the Hydrogen nucleus is especially prevalent
  2. Patient is placed in a static magnetic field
  3. Magnetized protons (spinning H nuclei) in the patient align in this field like compass needles
  4. Radio frequency (RF) pulses then bombard the magnitized nuclei causing them to flip around
     1. The nuclei absorb the RF energy and enter an excited state
  5. When the magnet is turned off, excited nuclei return to normal state & give off RF energy
     1. The energy given off reflect the number of protons in a “slice” of tissue
  6. Different tissues absorb & give off different amounts of RF energy (different resonances)
  7. The RF energy given off is picked up by the receiver coil & transformed into images
  8. MRI offers the greatest “contrast” in tissue imaging technology (knee, ankle diagnosis)
  9. cost: about $1450 - $2000
  10. time: 30 minutes - 2 hours, depending on the type of study being done

(b) **Mention the advantages and disadvantages of MRI.**

**Answer:**

 Here is a table that summarizes some of the pros and cons of MRI:

| **Advantages** | **Disadvantages** |
| --- | --- |
| Non-invasive, painless, and harmless | Expensive, requires specialized equipment and staff |
| Excellent ability for soft tissue differentiation | Metal implants, pregnancy, allergies to contrast substances, and kidney disease are contraindications |
| Multiplanar imaging, can produce 2D and 3D images | Long scan time, noisy, claustrophobic for some patients |
| Image quality not degraded by bone or air | Not widely available in some regions |

(c) **Write down the difference between MRI and fMRI.**

**Answer:**

Here is a table that summarizes the main differences between MRI and fMRI:

| **MRI** | **fMRI** |
| --- | --- |
| Magnetic Resonance Imaging | Functional Magnetic Resonance Imaging |
| Uses magnetic fields and radio waves to produce detailed images of internal body structures | Measures changes in blood flow to detect brain activity |
| Does not use X-rays or other forms of ionizing radiation | Uses the same MRI machine, but tracks blood flow in different parts of the brain |
| Used for diagnosing medical conditions, such as brain injury, stroke, blood vessel damage, spinal cord injuries, tumors, etc. | Used for research on brain function, such as mapping out the areas of the brain that control certain actions and abilities |
| Can be used for various parts of the body, including the brain | Focused exclusively on the brain |

1. (a) **What is nuclear medicine? Mention the uses of nuclear medicine.**

**Answer:**

Nuclear medicine is a medical specialty that uses radioactive substances, called radiopharmaceuticals, to examine organ function and structure, and to diagnose and treat disease1 Nuclear medicine uses special cameras that can detect the radiation emitted by the radiopharmaceuticals inside the body.

There are two main types of nuclear medicine imaging: **Single Photon Emission Computed Tomography (SPECT)** and **Positron Emission Tomography (PET)** SPECT uses gamma rays, which are a form of light that has a different wavelength than visible light PET uses positrons, which are particles that are the opposite of electrons.

Both SPECT and PET can create three-dimensional images of the distribution of the radiopharmaceuticals in the body. These images can show how different organs and tissues are functioning, and can help detect diseases such as cancer, heart disease, neurological disorders, and infections.

**Some of the uses of nuclear medicine are:**

* To assess **heart function** and **damage**, detect **coronary artery disease**, and evaluate **treatment options** for heart conditions.
* To scan **lungs** for **respiratory** or **blood flow problems.**
* To evaluate **bone fractures** or **breaks**, and evaluate natural and prosthetic **bone joints**
* To detect **abnormalities** in the **brain** and detect certain diseases, such as **Alzheimer’s**, **Parkinson’s**, or **epilepsy**
* To diagnose and treat various types of **cancer**, by locating **tumors**, measuring their **metabolic activity**, and delivering targeted **radiation therapy**
* To diagnose and treat **thyroid disorders**, such as **hyperthyroidism** or **thyroid cancer**
* To diagnose and treat **infections**, such as **osteomyelitis** or **endocarditis**
* To measure the function of the **kidneys**, **liver**, or **gallbladder**

(b) **Write the advantages and disadvantages of DTI (Diffusion tensor imaging) and DOT (Diffuse optical tomography)**

**Answer:**

* DTI uses magnetic resonance imaging (MRI) to measure the diffusion of water molecules along the direction of nerve fibers in the brain and spinal cord. It can provide information about the structure and connectivity of white matter tracts, which are important for brain function Some of the **advantages of DTI are:**
  + It can detect damage or abnormalities in white matter that are not visible in conventional MRI.
  + It can help diagnose and monitor various neurological disorders, such as stroke, multiple sclerosis, Alzheimer’s disease, Parkinson’s disease, epilepsy, and traumatic brain injury.
  + It can provide a 3D visualization of neuronal pathways in the brain.
  + It can be combined with other MRI techniques, such as functional MRI (fMRI), to study the relationship between brain structure and function.

Some of the **disadvantages of DTI** are:

* + It is sensitive to motion artifacts and image distortion, which can affect the accuracy and reliability of the results.
  + It has low spatial resolution, which means it cannot capture the details of small structures or regions in the brain.
  + It requires extensive computing power, man-hours, and expertise to process and analyze the data.
  + It assumes that water diffusion is isotropic (the same in all directions) within each voxel (a small unit of volume), which may not be true in some cases.
* DOT uses near-infrared light to measure the absorption and scattering of light by hemoglobin and other chromophores in biological tissues. It can provide information about the oxygenation and blood flow of tissues, which are related to their metabolic activity. Some of the **advantages of DOT are:**
  + It is non-invasive, safe, and relatively inexpensive compared to other imaging techniques.
  + It can measure both the concentration and the oxygen saturation of hemoglobin, which are important indicators of tissue function.
  + It can be used to monitor dynamic changes in tissue oxygenation and blood flow during various tasks or stimuli.
  + It can be applied to various regions of the body, such as the brain, breast, muscle, or skin.

Some of the **disadvantages of DOT are**:

* + It has low spatial resolution and penetration depth, which means it cannot image deep or complex structures in the body.
  + It is affected by background noise and interference from other sources of light or tissue properties.
  + It requires a priori knowledge or assumptions about the optical properties and geometry of the tissue to reconstruct the images.
  + It is difficult to separate the effects of absorption and scattering on the measured signals.

(c) **Explain the iterative reconstructions methods.**

**Answer:**

Iterative reconstruction methods are a type of image reconstruction algorithms used in CT that can improve the image quality and reduce the radiation dose compared to the conventional filtered back projection method.

Iterative reconstruction methods start with an initial image assumption, and compare it to the measured data from the CT scanner. Then, they update the image based on the difference between the calculated and the actual data, and repeat this process until the image converges to a satisfactory solution.

There are different types of iterative reconstruction methods, such as algebraic reconstruction, statistical reconstruction, and model-based reconstruction. They differ in how they model the system, the noise, and the object, and how they optimize the cost function.

Some of the advantages of iterative reconstruction methods are:

* They can reduce noise and artifacts in the image, especially when the data is sparse or noisy.
* They can preserve or enhance the resolution and contrast of the image, especially for small or low-contrast structures.
* They can lower the radiation dose required to obtain a diagnostic image quality.

1. (a) **With appropriate figure describe the Otsu method of thresholding.**

**Answer:**

Otsu’s method is a technique for automatic image thresholding, which is a process of dividing an image into foreground and background pixels based on pixel intensities. The method finds the optimal threshold value that minimizes the intra-class variance, or equivalently, maximizes the inter-class variance of the two groups of pixels.

The basic steps of Otsu’s method are:

* Compute the histogram and probabilities of each intensity level of the input image.
* Iterate through all possible threshold values and calculate the weighted sum of variances of the two classes.
* Choose the threshold value that minimizes the intra-class variance.

(b) **Describe the watershed segmentation algorithm.**

**Answer:**

The watershed segmentation algorithm is a technique for dividing an image into regions based on the intensity values of the pixels. The algorithm views the image as a topographic surface, where high intensity pixels represent peaks and hills, and low intensity pixels represent valleys. The algorithm then finds the local minima, or the lowest points, in the image and marks them as starting points for flooding the image with different colors. The colors fill up the valleys until they reach the boundaries of the objects or regions in the image. The boundaries are then used to create a segmentation of the image.

The watershed segmentation algorithm can be used for separating objects that are touching each other in an image, such as coins or cells. However, the algorithm may produce over-segmented results due to noise or irregularities in the image. To overcome this problem, marker-based watershed algorithms are used, where the user specifies which regions are foreground and which are background, and the algorithm only floods from those regions.

(c) **Explain Homomorphic transform.**

**Answer:**

A homomorphic transform is a mathematical concept that involves applying a function to a set of values or objects in such a way that the original structure or relation is preserved. For example, if we have two sets A and B, and a function f that maps A to B, then f is a homomorphic transform if there exists an operation ⋅ on both A and B such that

f(x⋅y) = f(x)⋅f(y)

for any x and y in A. This means that the function f preserves the operation ⋅, or is compatible with it.

There are different types of homomorphic transforms such as:

* Group Homomorphism: A group homomorphism is a function that preserves the group structure.
* Ring Homomorphism: A ring homomorphism is a function that preserves the ring structure.
* Field Homomorphism: A field homomorphism is a function that preserves the field structure.
* Module Homomorphism: A module homomorphism is a function that preserves the module structure.
* Algebra Homomorphism: An algebra homomorphism is a function that preserves the algebra structure

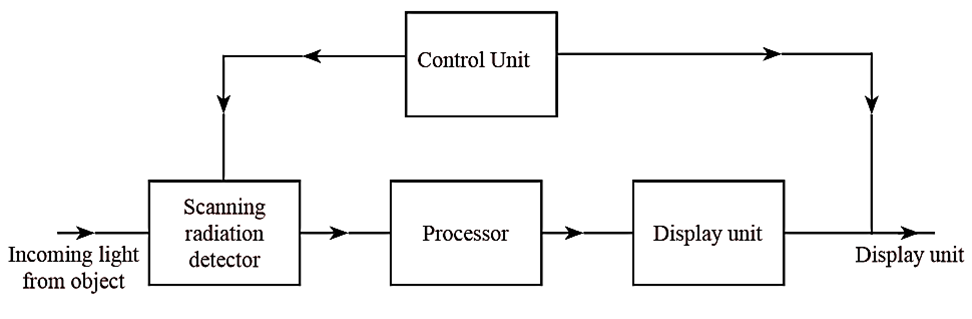
1. (a) **Demonstrate the working principle of medical thermography with proper diagram**

**Answer:**

Medical thermography is a technique that uses infrared cameras to capture the heat patterns of the human body. It can be used for various medical applications, such as detecting inflammation, infection, tumors, vascular disorders, and more.

The working principle of medical thermography is based on the fact that the human body emits infrared radiation that is proportional to its temperature. The infrared camera detects this radiation and converts it into an electrical signal. The signal is then processed by a computer and displayed as a thermal image, which shows the temperature distribution across the body surface.

The thermal image can be displayed in different modes, such as grayscale, color, or isotherm. Grayscale mode shows the temperature variations as shades of gray, where darker areas are colder and lighter areas are warmer. Color mode shows the temperature variations as different colors, where each color represents a certain range of temperature. Isotherm mode shows the temperature variations as contour lines, where each line represents a constant temperature level.



(b) **What can a diagnostic mammography show? Explain with working principle this technique.**

**Answer:**

A diagnostic mammography is a type of X-ray test that is used to examine the breast tissue for any signs of cancer or other abnormalities. It is different from a screening mammography, which is done routinely for women who have no symptoms or signs of breast problems. A diagnostic mammography is done when there is a suspicious finding on a screening mammogram, or when there are symptoms such as a lump, pain, nipple discharge, or changes in the breast size, shape, or skin.

A diagnostic mammography can show the following information:

* The size, shape, and location of any breast lumps or masses
* The presence of microcalcifications, which are tiny deposits of calcium that may indicate cancer or precancerous changes in the breast ducts
* The density of the breast tissue, which can affect the accuracy and interpretation of the mammogram images
* The condition of the breast implants, if any

The working principle of a diagnostic mammography is similar to that of a screening mammography. It uses X-rays to create images of the breast tissue. However, a diagnostic mammography usually involves more X-ray views and more detailed images than a screening mammogram. It may also use special techniques such as magnification, spot compression, or 3D imaging to focus on a specific area of concern.

A diagnostic mammography is performed by a radiologist, who is a doctor specialized in imaging tests. The radiologist will position the breast between two plates that compress it slightly to spread out the tissue and reduce the amount of radiation needed. The X-ray machine will then take pictures of the breast from different angles. The radiologist will examine the images on a computer screen and look for any signs of cancer or other problems. The radiologist may also compare the images with previous mammograms to see if there are any changes over time.

A diagnostic mammography is a safe and effective test that can help diagnose breast cancer and other breast conditions. However, it also has some limitations and risks, such as:

* It may not detect all breast cancers, especially in women with dense breasts or very small tumors
* It may produce false-positive results, which means that it may suggest that there is a problem when there is none
* It may expose the breast to a low dose of radiation, which may slightly increase the risk of developing cancer in the long term
* It may cause some discomfort or pain during the compression of the breast
* It may lead to additional tests or procedures, such as ultrasound or biopsy, if the results are unclear or abnormal.

2018 Question

1. (a) **Write the importance and benefits of medical imaging.**

**Answer:**

In an ideal world we would be able to diagnose, treat and cure patients without causing any harmful side effects. The use of medical imaging has enabled doctors to see inside a patient without having to cut them open. Medical imaging also helps us learn more about neurobiology and human behaviours.

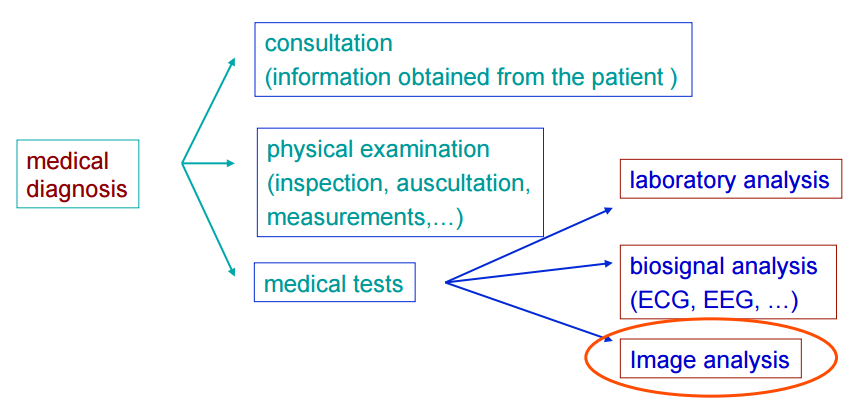
Medical imaging brings scientists from biology, chemistry and physics together and the technologies developed can often be used in many disciplines.

* **Health Benefit:** Medical imaging helps you detect and diagnose disease at its earliest, most treatable stages and guides physicians and patients in determining the most appropriate and effective care.
* **Health Care Costs & Quality:** By catching disease early, reducing the need for invasive, in-patient procedures and facilitating shorter recovery times, medical imaging saves money and improves efficiency in the health care system.
* **Technology & Innovation:** Radiation therapy and medical imaging technologies have revolutionized health care delivery in America and around the world. Extending human vision into the very nature of disease, medical imaging enables a new and more powerful generation of diagnosis and intervention. Radiation therapy offers highly personalized and targeted means of killing cancer cells while leaving healthy ones untouched.
* **Jobs & the Economy:** Medical imaging and radiation therapy is the source of hundreds of thousands of jobs all over the world.

(b) **How can you determine the identity of a possible disease or disorder.**

**Answer:**

Determination of the identity of a possible disease or disorder.



(c) **Differentiate between radiology and radiotherapy. Point out different modalities of medical imaging.**

**Answer:**

Radiology and radiotherapy are both related to the use of radiation in medicine, but they have different purposes and techniques. Here is a table that summarizes some of the main differences between them:

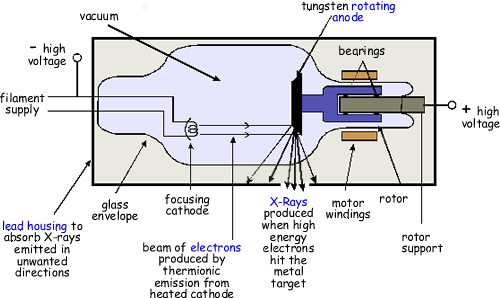
| **Radiology** | **Radiotherapy** |
| --- | --- |
| Uses radiation to produce images of the body, such as X-rays, CT scans, MRI, etc. | Uses radiation to treat cancer and other diseases by killing or shrinking tumors. |
| Has two main specializations: diagnostic radiology and interventional radiology. | Has two main types: external beam radiation therapy and internal radiation therapy. |
| Diagnostic radiologists interpret the images to diagnose illnesses and injuries. | Radiation oncologists prescribe and oversee the radiation treatments for patients. |
| Interventional radiologists perform minimally invasive procedures guided by imaging tools. | Radiation therapists operate the machines that deliver the radiation beams to the patients. |
| Radiology is essential for disease management and monitoring treatment outcomes. | Radiotherapy is one of the main modalities of cancer treatment, along with surgery and chemotherapy. |

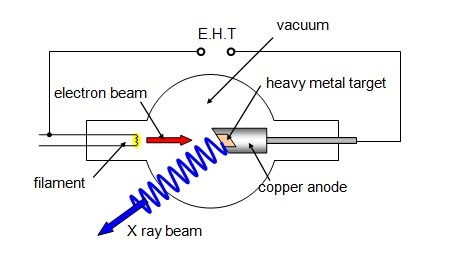
Different modalities of medical imaging:

* Radiography
* Computed Tomography
* Magnetic Resonance Imaging
* Ultrasonography
* Nuclear Medicine
* Endoscopy
* Thermography

1. (a) **Illustrate the X-ray generation technique.**

**Answer:**





(b) **Mention the benefits and risks of X-rays**

**Answer:**

Some of the benefits of X-rays are:

* Medical x-rays have increased our ability to detect disease or injury early enough for a medical problem to be managed, treated, or cured.
* When performed appropriately and early enough, these procedures can improve health and may even save a person’s life.
* They are cheap and easy to use compared to other imaging techniques such as MRI or CT scans.
* They can provide clear and detailed images of bones, teeth, and some organs.
* They can help detect and monitor diseases such as fractures, infections, tumors, and lung problems.
* They can guide interventional procedures such as angiography, biopsy, or stent placement

Some of the risks of X-rays are:

* A small increase in the possibility that a person exposed to x-rays will develop cancer later in life
* The possibility of cataracts and skin burns, but only at extremely high levels of radiation exposure
* They expose you to ionizing radiation, which can damage your cells and DNA and increase your risk of cancer.
* The amount of radiation you receive depends on the type and duration of the X-ray procedure. Some procedures, such as CT scans, deliver higher doses than others.
* The effects of radiation are cumulative, meaning that repeated exposure can add up over time and cause more harm.
* Some people may have allergic reactions to the contrast agents used in some X-ray procedures

(c) **What precautions we have to take for reducing X-ray radiation.**

**Answer:**

Reduction of radiation risks:

* Keeping a “medical x-ray history” with the names of your radiological exams or procedures, the dates and places where you had them, and the physicians who referred you for those exams
* Making your current healthcare providers aware of your medical x-ray history;
* Asking your healthcare provider about whether or not alternatives to x-ray exams would allow the provider to make a good assessment or provide appropriate treatment for your medical situation
* Providing interpreting physicians and referring physicians with recent x-ray images and radiology reports
* Informing radiologists or x-ray technologists in advance if you are pregnant or think you may be pregnant.

1. (a) **What are the potential advantages of ultrasound imaging over other modalities of medical imaging**

**Answer:**

Some of the potential advantages of ultrasound imaging over other modalities of medical imaging are:

- Ultrasound uses non-ionizing sound waves and has not been associated with carcinogenesis - this is particularly important for the evaluation of the fetal and gonads.

- Ultrasound is useful to detect and measure the distance of objects, such as fluid levels, blood flow, and fetal growth.

- Ultrasound can provide clear images of soft tissues that do not show up well in X-ray images, such as muscles, tendons, ligaments, and organs.

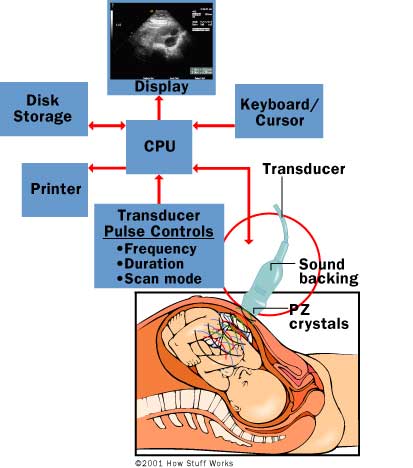
- Ultrasound is relatively inexpensive, portable, and easy to operate compared to other imaging modalities such as CT and MRI.

- Ultrasound can be performed in real-time, allowing dynamic assessment of moving structures and guidance for interventional procedures.

(b) **Describe the basic working mechanism of ultrasound.**

**Answer:**

* The ultrasound machine transmits high-frequency (1 to 18 megahertz) sound pulses into your body using a probe.
* The sound waves travel into your body and hit a boundary between tissues (e.g. between fluid and soft tissue, soft tissue and bone).
* Some of the sound waves get reflected back to the probe, while some travel on further until they reach another boundary and get reflected.
* The reflected waves are picked up by the probe and relayed to the machine.
* The machine calculates the distance from the probe to the tissue or organ (boundaries) using the speed of sound in tissue (5,005 ft/s or1,540 m/s) and the time of each echo's return (usually on the order of millionths of a second).
* The machine displays the distances and intensities of the echoes on the screen, forming a two dimensional image.



(c) **Differentiate among A-mode, B-mode and D-mode operations of ultrasound imaging.**

**Answer:**

| **Mode** | **Description** | **Display** | **Application** |
| --- | --- | --- | --- |
| A-mode | Uses a single transducer to scan the body and plots the echoes as a one-dimensional graph | X-axis: depth, Y-axis: amplitude of echoes | Measuring distances, detecting cysts or tumors |
| B-mode | Uses linear array transducers to scan a plane through the body and converts the echoes into a two-dimensional image | Brightness of pixels: amplitude of echoes | Visualizing anatomy and tissue texture, most common mode for ultrasound imaging |
| D-mode | Uses Doppler effect to measure the frequency shift of echoes due to the movement of blood or tissue and displays it as a color-coded image | Color of pixels: frequency shift of echoes | Measuring blood flow, detecting heart valve problems |

1. (a) **What is brain scanning technique? Illustrate the working principle of CT.**

**Answer:**

(b) **Differentiate between CT and X-ray.**

**Answer:**

| **Parameter** | **CT** | **X-ray** |
| --- | --- | --- |
| Description | A type of advanced X-ray that uses a 360-degree beam and a computer to create detailed 3D images of internal structures. | A type of imaging that uses electromagnetic radiation to create 2D images of bones and some soft tissues. |
| Inventor | Allan Cormack and Godfrey Hounsfield in 1972. | Wilhelm Rontgen in 1895. |
| Use to diagnose | Internal organs, soft tissues, blood vessels, tumors, complex injuries, and internal bleeding. | Fractures, dislocations, bone cancer, arthritis, osteoporosis, tooth decay, lung infection, enlarged heart, breast cancer, and blocked blood vessels. |
| Advantages | High-quality images with more information and clarity. | Inexpensive and widely available. |
| Disadvantages | Expensive and exposes the patient to higher radiation levels. | Low-quality images with less information and contrast. |

(c) **What are the artifacts in CT?**

**Answer:**

Artifacts in CT (Computed Tomography) imaging refer to inconsistencies or distortions

in the resulting images that do not accurately represent the true anatomy or

structures being imaged. These artifacts can arise due to a variety of reasons,

including technical limitations, patient-related factors, and equipment malfunctions.

Here are some common types of artifacts in CT imaging:

• **Metallic Artifacts**: When metallic objects such as surgical implants, dental fillings, or

jewelry present in the body, they can cause streaking or shading artifacts in the

CT images.

• **Beam Hardening**: CT scans involve X-rays of varying energy levels passing through the

body. As lower-energy X-rays are preferentially absorbed, higher-energy X-rays

dominate, leading to an apparent increase in the average energy of the X-ray beam.

• **Partial Volume Effect**: When a voxel (3D pixel) encompasses two or more different

tissue types with varying densities, the CT scanner may struggle to assign a single

Hounsfield Unit (HU) value accurately.

• **Motion Artifacts**: Patient movement during the scan, even small involuntary

movements like breathing or muscle contractions, can cause blurring or ghosting in

the images.

• **Ring Artifacts**: If one or more detector elements in the CT scanner malfunction

or have inconsistent sensitivity, it can result in ring-like patterns in the

reconstructed images, affecting image quality.

• **Cone Beam Artifacts**: In cone beam CT, which is used in some applications like

dental imaging, the X-ray source and detector move in a cone shape around the

patient.

• **Noise Artifacts**: Noise in CT images can lead to grainy or speckled appearance.

This can be caused by various factors, including low-dose imaging, patient size,

and scanner settings.

• **Streak Artifacts from Dense Structures**: High-attenuation structures like bones

can lead to streaking artifacts, especially in the presence of strong X-ray beam

attenuation.

• **Helical Artifact**: In helical or spiral CT scans, where the patient table moves

continuously during the scan, objects with a regular pattern (e.g., zippers on

clothing) can cause periodic variations in the images, resembling a helix.

• **Respiratory Artifacts**: Variations in lung density due to breathing can lead to

inconsistencies in image quality, especially in the lung regions.

1. (a) **Describe the working principle of MRI.**

**Answer:**

1. Magnetic nuclei are abundant in the human body (H,C,Na,P,K) and spin randomly
   * 1. Since most of the body is H2O, the Hydrogen nucleus is especially prevalent
2. Patient is placed in a static magnetic field
3. Magnetized protons (spinning H nuclei) in the patient align in this field like compass needles
4. Radio frequency (RF) pulses then bombard the magnitized nuclei causing them to flip around
   * 1. The nuclei absorb the RF energy and enter an excited state
5. When the magnet is turned off, excited nuclei return to normal state & give off RF energy
   * 1. The energy given off reflect the number of protons in a “slice” of tissue
6. Different tissues absorb & give off different amounts of RF energy (different resonances)
7. The RF energy given off is picked up by the receiver coil & transformed into images
8. MRI offers the greatest “contrast” in tissue imaging technology (knee, ankle diagnosis)
9. cost: about $1450 - $2000
10. time: 30 minutes - 2 hours, depending on the type of study being done

(b) **Mention the advantages and disadvantages of MRI.**

**Answer:**

 Here is a table that summarizes some of the pros and cons of MRI:

| **Advantages** | **Disadvantages** |
| --- | --- |
| Non-invasive, painless, and harmless | Expensive, requires specialized equipment and staff |
| Excellent ability for soft tissue differentiation | Metal implants, pregnancy, allergies to contrast substances, and kidney disease are contraindications |
| Multiplanar imaging, can produce 2D and 3D images | Long scan time, noisy, claustrophobic for some patients |
| Image quality not degraded by bone or air | Not widely available in some regions |

(c) **Write down the difference between MRI and fMRI.**

**Answer:**

Here is a table that summarizes the main differences between MRI and fMRI:

| **MRI** | **fMRI** |
| --- | --- |
| Magnetic Resonance Imaging | Functional Magnetic Resonance Imaging |
| Uses magnetic fields and radio waves to produce detailed images of internal body structures | Measures changes in blood flow to detect brain activity |
| Does not use X-rays or other forms of ionizing radiation | Uses the same MRI machine, but tracks blood flow in different parts of the brain |
| Used for diagnosing medical conditions, such as brain injury, stroke, blood vessel damage, spinal cord injuries, tumors, etc. | Used for research on brain function, such as mapping out the areas of the brain that control certain actions and abilities |
| Can be used for various parts of the body, including the brain | Focused exclusively on the brain |

1. (a) **What is nuclear medicine? Write the uses of nuclear medicine.**

**Answer:**

Nuclear medicine is a medical specialty that uses radioactive substances, called radiopharmaceuticals, to examine organ function and structure, and to diagnose and treat disease1 Nuclear medicine uses special cameras that can detect the radiation emitted by the radiopharmaceuticals inside the body.

There are two main types of nuclear medicine imaging: **Single Photon Emission Computed Tomography (SPECT)** and **Positron Emission Tomography (PET)** SPECT uses gamma rays, which are a form of light that has a different wavelength than visible light PET uses positrons, which are particles that are the opposite of electrons.

Both SPECT and PET can create three-dimensional images of the distribution of the radiopharmaceuticals in the body. These images can show how different organs and tissues are functioning, and can help detect diseases such as cancer, heart disease, neurological disorders, and infections.

**Some of the uses of nuclear medicine are:**

* To assess **heart function** and **damage**, detect **coronary artery disease**, and evaluate **treatment options** for heart conditions.
* To scan **lungs** for **respiratory** or **blood flow problems.**
* To evaluate **bone fractures** or **breaks**, and evaluate natural and prosthetic **bone joints**
* To detect **abnormalities** in the **brain** and detect certain diseases, such as **Alzheimer’s**, **Parkinson’s**, or **epilepsy**
* To diagnose and treat various types of **cancer**, by locating **tumors**, measuring their **metabolic activity**, and delivering targeted **radiation therapy**
* To diagnose and treat **thyroid disorders**, such as **hyperthyroidism** or **thyroid cancer**
* To diagnose and treat **infections**, such as **osteomyelitis** or **endocarditis**
* To measure the function of the **kidneys**, **liver**, or **gallbladder**

(b) **Write the advantages and disadvantages of DTI and DOT**

**Answer:**

* DTI uses magnetic resonance imaging (MRI) to measure the diffusion of water molecules along the direction of nerve fibers in the brain and spinal cord. It can provide information about the structure and connectivity of white matter tracts, which are important for brain function Some of the **advantages of DTI are:**
  + It can detect damage or abnormalities in white matter that are not visible in conventional MRI.
  + It can help diagnose and monitor various neurological disorders, such as stroke, multiple sclerosis, Alzheimer’s disease, Parkinson’s disease, epilepsy, and traumatic brain injury.
  + It can provide a 3D visualization of neuronal pathways in the brain.
  + It can be combined with other MRI techniques, such as functional MRI (fMRI), to study the relationship between brain structure and function.

Some of the **disadvantages of DTI** are:

* + It is sensitive to motion artifacts and image distortion, which can affect the accuracy and reliability of the results.
  + It has low spatial resolution, which means it cannot capture the details of small structures or regions in the brain.
  + It requires extensive computing power, man-hours, and expertise to process and analyze the data.
  + It assumes that water diffusion is isotropic (the same in all directions) within each voxel (a small unit of volume), which may not be true in some cases.
* DOT uses near-infrared light to measure the absorption and scattering of light by hemoglobin and other chromophores in biological tissues. It can provide information about the oxygenation and blood flow of tissues, which are related to their metabolic activity. Some of the **advantages of DOT are:**
  + It is non-invasive, safe, and relatively inexpensive compared to other imaging techniques.
  + It can measure both the concentration and the oxygen saturation of hemoglobin, which are important indicators of tissue function.
  + It can be used to monitor dynamic changes in tissue oxygenation and blood flow during various tasks or stimuli.
  + It can be applied to various regions of the body, such as the brain, breast, muscle, or skin.

Some of the **disadvantages of DOT are**:

* + It has low spatial resolution and penetration depth, which means it cannot image deep or complex structures in the body.
  + It is affected by background noise and interference from other sources of light or tissue properties.
  + It requires a priori knowledge or assumptions about the optical properties and geometry of the tissue to reconstruct the images.
  + It is difficult to separate the effects of absorption and scattering on the measured signals.

(c) **Explain the iterative reconstructions methods.**

**Answer:**

Iterative reconstruction methods are a type of image reconstruction algorithms used in CT that can improve the image quality and reduce the radiation dose compared to the conventional filtered back projection method.

Iterative reconstruction methods start with an initial image assumption, and compare it to the measured data from the CT scanner. Then, they update the image based on the difference between the calculated and the actual data, and repeat this process until the image converges to a satisfactory solution.

There are different types of iterative reconstruction methods, such as algebraic reconstruction, statistical reconstruction, and model-based reconstruction. They differ in how they model the system, the noise, and the object, and how they optimize the cost function.

Some of the advantages of iterative reconstruction methods are:

* They can reduce noise and artifacts in the image, especially when the data is sparse or noisy.
* They can preserve or enhance the resolution and contrast of the image, especially for small or low-contrast structures.

They can lower the radiation dose required to obtain a diagnostic image quality

1. (a) **Point out the advantages and disadvantages of region growing segmentation**

**Answer:**

Region growing segmentation is a technique for dividing an image into regions based on some similarity criterion, such as pixel intensity or color. It starts from some seed points and grows the regions by including neighboring pixels that satisfy the criterion. Here are some advantages and disadvantages of this method:

**Advantages:**

* It can correctly separate the regions that have the same properties we define.
* It can provide good segmentation results if the original images have clear edges.
* The concept is simple and we can choose the seed points and the criteria we want.
* We can use multiple criteria at the same time.

**Disadvantages:**

* The selection of seed points is dependent on the user and may not be optimal.
* It is sensitive to noise and may cause extracted regions to have holes or be disconnected.
* It is not sufficient to segment brain structures accurately and robustly.
* It may be slow to perform if the image has many pixels or regions.

(b) **Describe the watershed segmentation algorithm**

**Answer:**

The watershed segmentation algorithm is a technique for dividing an image into regions based on the intensity values of the pixels. The algorithm views the image as a topographic surface, where high intensity pixels represent peaks and hills, and low intensity pixels represent valleys. The algorithm then finds the local minima, or the lowest points, in the image and marks them as starting points for flooding the image with different colors. The colors fill up the valleys until they reach the boundaries of the objects or regions in the image. The boundaries are then used to create a segmentation of the image.

The watershed segmentation algorithm can be used for separating objects that are touching each other in an image, such as coins or cells. However, the algorithm may produce over-segmented results due to noise or irregularities in the image. To overcome this problem, marker-based watershed algorithms are used, where the user specifies which regions are foreground and which are background, and the algorithm only floods from those regions.

(c) **Explain Homomorphic transform.**

**Answer:**

A homomorphic transform is a mathematical concept that involves applying a function to a set of values or objects in such a way that the original structure or relation is preserved. For example, if we have two sets A and B, and a function f that maps A to B, then f is a homomorphic transform if there exists an operation ⋅ on both A and B such that

f(x⋅y) = f(x)⋅f(y)

for any x and y in A. This means that the function f preserves the operation ⋅, or is compatible with it.

There are different types of homomorphic transforms such as:

* Group Homomorphism: A group homomorphism is a function that preserves the group structure.
* Ring Homomorphism: A ring homomorphism is a function that preserves the ring structure.
* Field Homomorphism: A field homomorphism is a function that preserves the field structure.
* Module Homomorphism: A module homomorphism is a function that preserves the module structure.
* Algebra Homomorphism: An algebra homomorphism is a function that preserves the algebra structure

1. (a) **Differentiate between ECG and EEG. How ECG and EEG signals are produced?**

**Answer:**

Here is a table that summarizes the differences between ECG and EEG:

| **ECG** | **EEG** |
| --- | --- |
| Electrocardiogram | Electroencephalogram |
| Measures the electrical activity of the heart | Measures the electrical activity of the brain |
| Uses electrodes attached to the chest, arms and legs | Uses electrodes attached to the scalp and ears |
| Has an amplitude of 1-5 mV and a bandwidth of 0.05-100 Hz | Has an amplitude of 0.001-0.01 mV and a bandwidth of 0.5-40 Hz |
| Used to diagnose heart problems such as arrhythmias, heart attacks, and heart failure | Used to diagnose brain problems such as epilepsy, tumors, infections, and degenerative diseases |

ECG and EEG signals are produced by the electrical activity of the heart and the brain, respectively. They are measured by electrodes attached to different parts of the body.

ECG signals are generated by the depolarization and repolarization of the cardiac muscle cells, which create a potential difference across the cell membrane. This potential difference propagates through the cardiac tissue and reaches the body surface, where it can be detected by electrodes. The ECG signal reflects the rhythm and function of the heart, as well as its electrical conduction system.

EEG signals are generated by the synchronous activity of large populations of neurons in the brain, which produce postsynaptic potentials that sum up to form a macroscopic electric field. This electric field can be measured by electrodes on the scalp, which record the fluctuations of the potential difference between different brain regions. The EEG signal reflects the state and activity of the brain, as well as its cognitive and emotional processes.

(b) **Describe the feature extraction of EEG signal by Wiener filtering. Also explain the spectral error measure (SEM) for EEG signal**

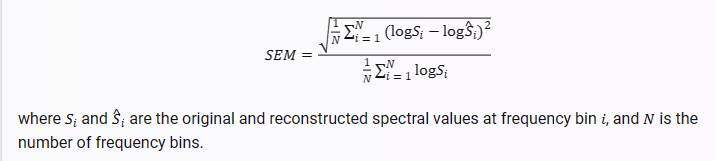
**Answer:**

Feature extraction is a process of transforming the raw EEG signals into a set of features that can be used for further analysis, such as classification, clustering, or visualization. Feature extraction can reduce the dimensionality, noise, and redundancy of the EEG signals, and enhance the relevant information for the specific task.

Wiener filtering is a technique of feature extraction that aims to reduce the effect of noise and artifacts in the EEG signals. Wiener filtering is based on the assumption that the EEG signals can be modeled as a linear combination of a desired signal and an additive noise. The Wiener filter tries to find the optimal linear filter that minimizes the mean squared error between the desired signal and the filtered signal.

Wiener filtering can be applied to single-channel or multi-channel EEG signals. For single-channel EEG signals, Wiener filtering can be performed in the frequency domain, where the Wiener filter is computed as the ratio of the power spectrum of the desired signal and the power spectrum of the observed signal. For multi-channel EEG signals, Wiener filtering can be performed in the spatial domain, where the Wiener filter is computed as a matrix that optimizes the spatial covariance of the desired signal and the observed signal.

Spectral error measure (SEM) is a method to quantify the difference between two spectra of EEG signals, such as the original and the reconstructed spectra. SEM is defined as the root mean square error (RMSE) between the logarithms of the two spectra, normalized by the mean of the logarithms of the original spectrum. Mathematically, SEM can be expressed as:

SEM is useful for evaluating the quality of EEG signal reconstruction, such as in independent component analysis (ICA) or current source density (CSD) transform. A lower SEM value indicates a better reconstruction, meaning that the reconstructed spectrum preserves the shape and magnitude of the original spectrum. SEM can also be used to compare different methods of EEG signal processing and to optimize the parameters for a given method.

2020 Questions:

1. (a) **Write the importance and benefits of medical imaging.**

**Answer:**

In an ideal world we would be able to diagnose, treat and cure patients without causing any harmful side effects. The use of medical imaging has enabled doctors to see inside a patient without having to cut them open. Medical imaging also helps us learn more about neurobiology and human behaviours.

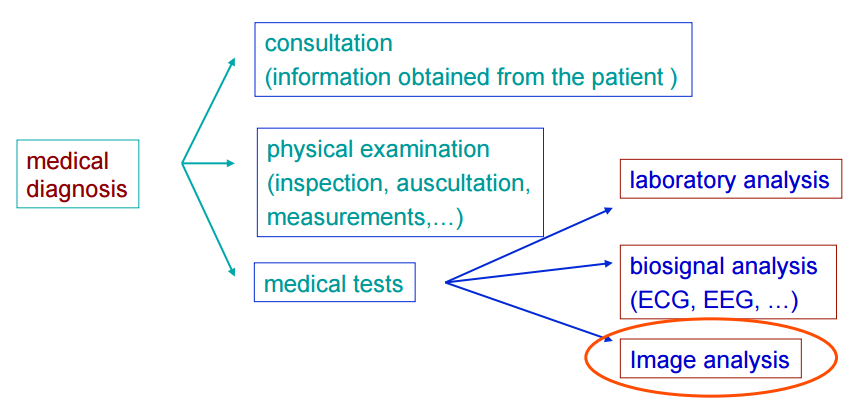
Medical imaging brings scientists from biology, chemistry and physics together and the technologies developed can often be used in many disciplines.

* **Health Benefit:** Medical imaging helps you detect and diagnose disease at its earliest, most treatable stages and guides physicians and patients in determining the most appropriate and effective care.
* **Health Care Costs & Quality:** By catching disease early, reducing the need for invasive, in-patient procedures and facilitating shorter recovery times, medical imaging saves money and improves efficiency in the health care system.
* **Technology & Innovation:** Radiation therapy and medical imaging technologies have revolutionized health care delivery in America and around the world. Extending human vision into the very nature of disease, medical imaging enables a new and more powerful generation of diagnosis and intervention. Radiation therapy offers highly personalized and targeted means of killing cancer cells while leaving healthy ones untouched.
* **Jobs & the Economy:** Medical imaging and radiation therapy is the source of hundreds of thousands of jobs all over the world.

(b) **How can you determine the identify of a possible disease or disorder?**

**Answer:**

Determination of the identity of a possible disease or disorder.



(c) **Differentiate between radiology and radiotherapy. Point out different modalities of medical imaging.**

**Answer:**

Radiology and radiotherapy are both related to the use of radiation in medicine, but they have different purposes and techniques. Here is a table that summarizes some of the main differences between them:

| **Radiology** | **Radiotherapy** |
| --- | --- |
| Uses radiation to produce images of the body, such as X-rays, CT scans, MRI, etc. | Uses radiation to treat cancer and other diseases by killing or shrinking tumors. |
| Has two main specializations: diagnostic radiology and interventional radiology. | Has two main types: external beam radiation therapy and internal radiation therapy. |
| Diagnostic radiologists interpret the images to diagnose illnesses and injuries. | Radiation oncologists prescribe and oversee the radiation treatments for patients. |
| Interventional radiologists perform minimally invasive procedures guided by imaging tools. | Radiation therapists operate the machines that deliver the radiation beams to the patients. |
| Radiology is essential for disease management and monitoring treatment outcomes. | Radiotherapy is one of the main modalities of cancer treatment, along with surgery and chemotherapy. |

Different modalities of medical imaging:

* Radiography
* Computed Tomography
* Magnetic Resonance Imaging
* Ultrasonography
* Nuclear Medicine
* Endoscopy
* Thermography

1. (a) **How ultrasound works? Write the major uses of ultrasound.**

**Answer:**

* The ultrasound machine transmits high-frequency (1 to 18 megahertz) sound pulses into your body using a probe.
* The sound waves travel into your body and hit a boundary between tissues (e.g. between fluid and soft tissue, soft tissue and bone).
* Some of the sound waves get reflected back to the probe, while some travel on further until they reach another boundary and get reflected.
* The reflected waves are picked up by the probe and relayed to the machine.
* The machine calculates the distance from the probe to the tissue or organ (boundaries) using the speed of sound in tissue (5,005 ft/s or1,540 m/s) and the time of each echo's return (usually on the order of millionths of a second).
* The machine displays the distances and intensities of the echoes on the screen, forming a two dimensional image.

**Major Uses of Ultrasound**

* + 1. Obstetrics and Gynecology
       - 1. Measuring the size of the fetus to determine the due date
         2. Checking the position, sex of the baby.
         3. Seeing the number of fetuses in the uterus
         4. Checking the fetus's growth rate by making many measurements over time
         5. Detecting ectopic pregnancy, the life-threatening situation in which the baby is implanted in the mother's Fallopian tubes instead of in the uterus
         6. Determining whether there is an appropriate amount of amniotic fluid cushioning the baby
    2. Cardiology
       - 1. Seeing the inside of the heart to identify abnormal structures or functions
         2. Measuring blood flow through the heart and major blood vessels
    3. Urology
       - 1. Measuring blood flow through the kidney
         2. Seeing kidney stones
         3. Detecting prostate cancer early

(b) **Describe the underlying mechanism for creation of an ultrasound image.**

**Answer:**

The creation of an image from sound is done in three steps – producing a sound wave, receiving echoes, and interpreting those echoes.

**Producing a sound wave**

* + 1. A sound wave is typically produced by a piezoelectric transducer encased in a plastic housing.
    2. Strong, short electrical pulses from the ultrasound machine drive the transducer at the desired frequency.
    3. The frequencies can be anywhere between 1 and 18 MHz. The sound is focused either by the shape of the transducer, a lens in front of the transducer, or a complex set of control pulses from the ultrasound scanner (Beamforming). This focusing produces an arc-shaped sound wave from the face of the transducer.
    4. The wave travels into the body and comes into focus at a desired depth. The sound wave is partially reflected from the layers between different tissues or scattered from smaller structures.

**Receiving the echoes**

* + 1. The return of the sound wave to the transducer results in the same process as sending the sound wave, except in reverse.
    2. The returned sound wave vibrates the transducer and the transducer turns the vibrations into electrical pulses that travel to the ultrasonic scanner where they are processed and transformed into a digital image.

**Forming the image**

To make an image, the ultrasound scanner must determine two things from each received echo:

* + 1. How long it took the echo to be received from when the sound was transmitted.
    2. How strong the echo was.
    3. Once the ultrasonic scanner determines these two things, it can locate which pixel in the image to light up and to what intensity.
    4. Transforming the received signal into a digital image may be explained by using a blank spreadsheet as an analogy. First picture a long, flat transducer at the top of the sheet. Send pulses down the 'columns' of the spreadsheet (A, B, C, etc.). Listen at each column for any return echoes. When an echo is heard, note how long it took for the echo to return. The longer the wait, the deeper the row (1,2,3, etc.). The strength of the echo determines the brightness setting for that cell (white for a strong echo, black for a weak echo, and varying shades of grey for everything in between.) When all the echoes are recorded on the sheet, we have a greyscale image.

**Displaying the image**

Images from the ultrasound scanner are transferred and displayed using the DICOM standard. Normally, very little post processing is applied to ultrasound images.

(c) **Write down the ultrasound advantages and disadvantages.**

**Answer:**

Ultrasound is a medical imaging technology that uses high-frequency sound waves to produce images of structures within the human body. Ultrasound has many advantages and disadvantages, depending on the application and the type of tissue being examined. Here are some of them:

**Advantages of ultrasound:**

- Ultrasound uses non-ionizing sound waves and has not been associated with carcinogenesis - this is particularly important for the evaluation of the fetal and gonads.

- Ultrasound is useful to detect and measure the distance of objects, such as fluid levels, blood flow, and fetal growth.

- Ultrasound can provide clear images of soft tissues that do not show up well in X-ray images, such as muscles, tendons, ligaments, and organs.

- Ultrasound is relatively inexpensive, portable, and easy to operate compared to other imaging modalities such as CT and MRI.

- Ultrasound can be performed in real-time, allowing dynamic assessment of moving structures and guidance for interventional procedures.

**Disadvantages of ultrasound:**

- Ultrasound has poor penetration through bone or air, which limits its use in some areas such as the brain, lungs, and spine.

- Ultrasound images can be difficult to interpret and require experienced operators or radiologists to avoid errors and artifacts.

- Ultrasound has lower resolution and image quality than CT and MRI, which may affect the detection of small or subtle abnormalities.

- Ultrasound is affected by external factors such as noise, temperature, humidity, and interference from other devices, which may degrade the performance of the equipment.

- Ultrasound may cause thermal or mechanical effects on the tissues due to the absorption or scattering of sound energy, which may have potential biological effects or risks.

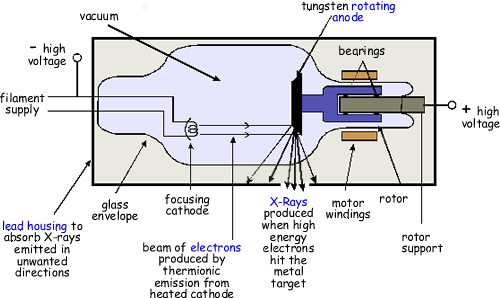
1. (a) **Explain the process of creation of X-ray image.**

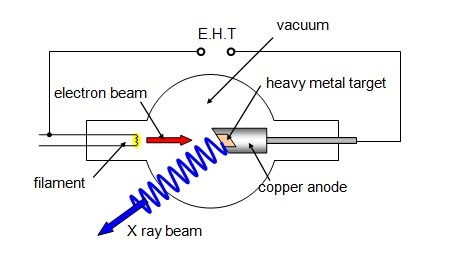
**Answer:**

* 1. X-rays are generated from the interaction of accelerated e-’s & a target metal (tungsten)
  2. Patient is placed between X-ray tube and silver halide film
  3. X-rays passed through the body are absorbed in direct proportion to tissue density
  4. X-rays penetrating the body strike the silver halide film and turn it dark
     1. The more x-rays that penetrate, the darker the area inscribed on the film
  5. Bones & metal absorb or reflect X-rays r inscribed film is “lighter” or “more white”
  6. Soft tissues allow more X-rays to penetrate r inscribed film is “darker”
  7. Visualizing tissues of similar density can be enhanced using “contrast agents”
     1. Contrast agents: dense fluids containing elements of high atomic number (barium, iodine)
     2. Contrast agents absorbs more photons than the surrounding tissue r cavity appears lighter
     3. These contrast agents can be injected, swallowed, or given by enema

(b) **Illustrate the X-ray generation technique.**

**Answer:**





(c) **How the radiation risks can be reduced?**

**Answer:**

Reduction of radiation risks:

* Keeping a “medical x-ray history” with the names of your radiological exams or procedures, the dates and places where you had them, and the physicians who referred you for those exams
* Making your current healthcare providers aware of your medical x-ray history;
* Asking your healthcare provider about whether or not alternatives to x-ray exams would allow the provider to make a good assessment or provide appropriate treatment for your medical situation
* Providing interpreting physicians and referring physicians with recent x-ray images and radiology reports
* Informing radiologists or x-ray technologists in advance if you are pregnant or think you may be pregnant.

1. (a) **What is brain scanning technique? Illustrate the working principle of CT.**

**Answer:**

A brain scanning technique is a method of producing images of the brain or other parts of the nervous system. There are different types of brain scanning techniques, each one showing the brain’s structure and functions in a unique way. Some of the most common brain scanning techniques are: **CT, MRI, fMRI, PET, SPECT, DTI, DOT**

1. The scanner device incorporates a moving table & a revolving X-ray tube
   * 1. The table moves the patient back and forth through the revolving X-ray emissions
     2. The X-ray emitter moves (revolves) in a 360o arc around the patient
2. Instead of film, the CT scanner collects emitted X-rays via a collector
   * 1. This collector is called a SCINTILLATOR
3. Scintillator transforms X-ray’s into a proportionally strong electric current
4. The electric current is then converted into a number of images (“slices”)
   * 1. Contrast dyes may be used for image enhancement
5. Tool of choice for most stroke cases

(b) **Differentiate between CT and X-ray.**

**Answer:**

| **Parameter** | **CT** | **X-ray** |
| --- | --- | --- |
| Description | A type of advanced X-ray that uses a 360-degree beam and a computer to create detailed 3D images of internal structures. | A type of imaging that uses electromagnetic radiation to create 2D images of bones and some soft tissues. |
| Inventor | Allan Cormack and Godfrey Hounsfield in 1972. | Wilhelm Rontgen in 1895. |
| Use to diagnose | Internal organs, soft tissues, blood vessels, tumors, complex injuries, and internal bleeding. | Fractures, dislocations, bone cancer, arthritis, osteoporosis, tooth decay, lung infection, enlarged heart, breast cancer, and blocked blood vessels. |
| Advantages | High-quality images with more information and clarity. | Inexpensive and widely available. |
| Disadvantages | Expensive and exposes the patient to higher radiation levels. | Low-quality images with less information and contrast. |

(c) What are the artifacts in CT?

Answer:

1. (a) Describe the mechanism of producing an image in magnetic resonance imaging (MRI).

(b) **Why MRI is commonly done? Discuss the merits and demerits of MRI.**

**Answer:**

Here are some of the common reasons why MRI is performed:

• **Diagnosis and Evaluation of Medical Conditions**: MRI is widely used to diagnose and assess various medical conditions, including neurological disorders (e.g., brain tumors, multiple sclerosis), musculoskeletal injuries (e.g., ligament tears, joint disorders).

• **Brain and Nervous System Imaging**: MRI is particularly effective for imaging the brain and nervous system. It can detect brain tumors, assess the extent of injuries like concussions.

• **Orthopedic and Musculoskeletal Evaluations**: MRI is used to assess injuries and conditions affecting bones, joints, muscles, tendons, and ligaments. /Cancer Detection and Staging: MRI provides detailed images of soft tissues, making it useful for detecting and staging various types of cancers, such as breast, prostate, liver, and ovarian cancers. / Cardiovascular Imaging: Cardiac MRI is employed to assess the structure and function of the heart, as well as to diagnose conditions like heart defects, cardiomyopathies, and myocardial infarctions (heart attacks).

• **Abdominal and Pelvic Imaging**: MRI is used to visualize abdominal and pelvic organs, including the liver, kidneys, pancreas, uterus, and ovaries. It can detect tumors, cysts, and other abnormalities.

• **Monitoring Treatment Progress**: MRI can be used to monitor the effectiveness of treatments like chemotherapy and radiation therapy by tracking changes in tumor size and appearance.

• **Vascular Imaging**: MR angiography (MRA) is a specialized form of MRI used to visualize blood vessels, aiding in the detection and assessment of conditions such as aneurysms, vascular malformations, and atherosclerosis.

**Some of the merits of MRI are**:

* It does not involve exposure to ionizing radiation, so it is safer than other imaging methods such as X-rays or CT scans.
* It can provide better soft tissue contrast than CT scans and can differentiate better between fat, water, muscle, and other soft tissue.
* It can image any part of the body in any direction, and can produce 3-D images for better understanding.
* It does not require any contrast medium, unless the doctor wants to enhance the visibility of certain structures.
* It can provide information about how the blood moves through certain organs and blood vessels, allowing problems with blood circulation, such as blockages, to be identified.

**Some of the demerits of MRI are:**

* It is a noisy and claustrophobic procedure, which may cause discomfort or anxiety for some patients. Some patients may need sedation or anesthesia to undergo MRI.
* It is a time-consuming and expensive procedure, which may not be available or accessible for everyone.
* It is not suitable for patients with metal implants, devices, or accessories, such as pacemakers, cochlear implants, or braces, as they may interfere with the magnetic field or cause heating or injury.
* It may cause peripheral muscle or nerve stimulation, which may feel like a twitching sensation, due to the changing magnetic fields.
* It may cause allergic reactions or side effects in some patients who receive gadolinium-based contrast agents (GBCAs), such as nausea, headache, or skin rash.

1. (a) **What is nuclear medicine? Write the uses of nuclear medicine.**

**Answer:**

Nuclear medicine is a medical specialty that uses radioactive substances, called radiopharmaceuticals, to examine organ function and structure, and to diagnose and treat disease1 Nuclear medicine uses special cameras that can detect the radiation emitted by the radiopharmaceuticals inside the body.

There are two main types of nuclear medicine imaging: **Single Photon Emission Computed Tomography (SPECT)** and **Positron Emission Tomography (PET)** SPECT uses gamma rays, which are a form of light that has a different wavelength than visible light PET uses positrons, which are particles that are the opposite of electrons.

Both SPECT and PET can create three-dimensional images of the distribution of the radiopharmaceuticals in the body. These images can show how different organs and tissues are functioning, and can help detect diseases such as cancer, heart disease, neurological disorders, and infections.

**Some of the uses of nuclear medicine are:**

* To assess **heart function** and **damage**, detect **coronary artery disease**, and evaluate **treatment options** for heart conditions.
* To scan **lungs** for **respiratory** or **blood flow problems.**
* To evaluate **bone fractures** or **breaks**, and evaluate natural and prosthetic **bone joints**
* To detect **abnormalities** in the **brain** and detect certain diseases, such as **Alzheimer’s**, **Parkinson’s**, or **epilepsy**
* To diagnose and treat various types of **cancer**, by locating **tumors**, measuring their **metabolic activity**, and delivering targeted **radiation therapy**
* To diagnose and treat **thyroid disorders**, such as **hyperthyroidism** or **thyroid cancer**
* To diagnose and treat **infections**, such as **osteomyelitis** or **endocarditis**
* To measure the function of the **kidneys**, **liver**, or **gallbladder**

(b) **What are the differences of nuclear medicine with X-ray and CT imaging?**

**Answer:**

Here is a table that summarizes some of the differences between nuclear medicine, X-ray, and CT imaging:

| **Nuclear medicine** | **X-ray** | **CT** |
| --- | --- | --- |
| Uses small amounts of radioactive substances (radiopharmaceuticals) to diagnose, monitor, and treat diseases. | Uses a wide beam of X-rays to create images of the body’s internal structures. | Uses a narrow beam of X-rays and a detector to create cross-sectional images of the body. |
| Evaluates organ and tissue function as well as structure. | Evaluates anatomy (how the organs look) but not function. | Evaluates anatomy (how the organs look) but not function. |
| Requires a gamma camera or a PET scanner to detect the radiation emitted by the radiopharmaceuticals. | Requires a film or a digital detector to capture the X-rays that pass through the body. | Requires a rotating X-ray tube and a detector array to measure the X-rays that pass through the body at different angles. |
| Involves injecting, inhaling, or swallowing the radiopharmaceuticals before or during the imaging procedure. | Involves exposing the body part of interest to the X-ray beam with or without a contrast agent. | Involves exposing the body part of interest to the X-ray beam with or without a contrast agent. |
| Has a low radiation dose and minimal side effects from the radiopharmaceuticals. | Has a variable radiation dose depending on the type and number of X-rays performed. | Has a higher radiation dose than conventional X-rays but lower than nuclear medicine. |

(c) **Describe SPECT. Write the advantages and disadvantages of DTI and DOT.**

**Answer:**

SPECT stands for **single-photon emission computed tomography**, which is a nuclear medicine imaging technique that uses gamma rays to create 3D pictures of your body’s organs, tissue and bones. SPECT can be used to diagnose or monitor various conditions, such as brain disorders, heart problems and bone disorders.

To perform a SPECT scan, you need to receive an injection or infusion of a radioactive tracer, which is a substance that emits gamma rays and binds to certain types of tissues in your body. A special camera called a gamma camera then rotates around you and detects the gamma rays coming from the tracer. A computer then processes the data and reconstructs a 3D image of the tracer distribution in your body.

Some of the benefits of SPECT are that it can show how your organs are functioning, not just their structure; it can detect changes in blood flow or metabolism before they cause symptoms; and it can provide more information than other imaging tests, such as X-rays or MRI.

DTI stands for **Diffusion Tensor Imaging**, which is a technique that uses magnetic resonance imaging (MRI) to measure the diffusion of water molecules in the brain. This can reveal the structure and orientation of white matter tracts, which are bundles of nerve fibers that connect different brain regions.

DOT stands for **Diffuse Optical Tomography**, which is a technique that uses near-infrared light to measure the absorption and scattering of photons in biological tissues. This can reveal the hemodynamic and metabolic changes in the brain, which are related to neural activity.

Some of the advantages and disadvantages of DTI and DOT are:

| **Technique** | **Advantages** | **Disadvantages** |
| --- | --- | --- |
| DTI | - Able to detect white matter damage that MRI and CAT scans cannot  - Provides detailed information and 3D visualization of white matter tracts  - Can help predict recovery times for concussion patients | - Sensitive to water diffusion, which can cause image distortion and ghosting  - Low spatial resolution, which can result in blurry images  - Extremely sensitive to motion, which can cause misregistration - Requires extensive computing power, man-hours, and expertise |
| DOT | - Non-invasive and safe, as it uses low-intensity light  - Portable and low-cost, as it does not require expensive equipment or shielding  - Can measure both oxygenated and deoxygenated hemoglobin, which reflect blood oxygenation and blood volume | - Limited penetration depth, as light is attenuated by tissue  - Low spatial resolution, as light is scattered by tissue  - Susceptible to noise and artifacts from scalp, skull, and extracerebral tissues |

1. (a) **Point out the advantages and disadvantages of region growing segmentation**

**Answer:**

Region growing segmentation is a technique for dividing an image into regions based on some similarity criterion, such as pixel intensity or color. It starts from some seed points and grows the regions by including neighboring pixels that satisfy the criterion. Here are some advantages and disadvantages of this method:

**Advantages:**

* It can correctly separate the regions that have the same properties we define.
* It can provide good segmentation results if the original images have clear edges.
* The concept is simple and we can choose the seed points and the criteria we want.
* We can use multiple criteria at the same time.

**Disadvantages:**

* The selection of seed points is dependent on the user and may not be optimal.
* It is sensitive to noise and may cause extracted regions to have holes or be disconnected.
* It is not sufficient to segment brain structures accurately and robustly.
* It may be slow to perform if the image has many pixels or regions.

(b) **Write the watershed segmentation algorithm.**

**Answer:**

The watershed segmentation algorithm is a technique for dividing an image into regions based on the intensity values of the pixels. The algorithm views the image as a topographic surface, where high intensity pixels represent peaks and hills, and low intensity pixels represent valleys. The algorithm then finds the local minima, or the lowest points, in the image and marks them as starting points for flooding the image with different colors. The colors fill up the valleys until they reach the boundaries of the objects or regions in the image. The boundaries are then used to create a segmentation of the image.

The watershed segmentation algorithm can be used for separating objects that are touching each other in an image, such as coins or cells. However, the algorithm may produce over-segmented results due to noise or irregularities in the image. To overcome this problem, marker-based watershed algorithms are used, where the user specifies which regions are foreground and which are background, and the algorithm only floods from those regions.

(c) **How tomography is performed? Describe the iterative reconstructions methods.**

**Answer:**

Tomography is a technique that uses penetrating waves, such as X-rays, ultrasound, or light, to create images of cross-sections or slices of an object. The images can provide more detailed information than plain images, and can be used for various purposes, such as diagnosing diseases, monitoring treatments, or studying structures. There are many types of tomography, depending on the source of the waves, the method of data acquisition, and the algorithm of reconstruction.

Iterative reconstruction methods are techniques used to reconstruct images from data acquired by certain imaging devices, such as computed tomography (CT) scanners. These methods use iterative algorithms that compare the measured data with the estimated image and update the image based on the difference. Iterative reconstruction methods can reduce noise and artifacts in the image, especially when the data is noisy or incomplete.

There are different types of iterative reconstruction methods, such as algebraic, statistical, and model-based methods. Each method has its own advantages and disadvantages, depending on the application and the available computational resources. Some examples of iterative reconstruction methods are:

* Algebraic Reconstruction Technique (ART): This method solves a system of linear equations that relate the image pixels to the measured data. It updates one pixel at a time based on the error between the measured and estimated data.
* Sparse Asymptotic Minimum Variance (SAMV): This method is inspired by compressed sensing and uses a sparse representation of the image to achieve super-resolution. It minimizes a cost function that balances the data fidelity and the sparsity of the image.
* Adaptive Statistical Iterative Reconstruction (ASIR): This method is a hybrid approach that combines filtered back projection (FBP) with statistical modeling of the noise. It reduces the noise by applying a correction factor to each pixel based on its local statistics.
* Model-Based Iterative Reconstruction (MBIR): This method uses a sophisticated mathematical model of the imaging system and the noise to estimate the image. It maximizes a likelihood function that measures how well the image fits the data.

1. (a) **Differentiate between ECG and EEG. How ECG and EEG signals are produced?**

**Answer:**

Here is a table that summarizes the differences between ECG and EEG:

| **ECG** | **EEG** |
| --- | --- |
| Electrocardiogram | Electroencephalogram |
| Measures the electrical activity of the heart | Measures the electrical activity of the brain |
| Uses electrodes attached to the chest, arms and legs | Uses electrodes attached to the scalp and ears |
| Has an amplitude of 1-5 mV and a bandwidth of 0.05-100 Hz | Has an amplitude of 0.001-0.01 mV and a bandwidth of 0.5-40 Hz |
| Used to diagnose heart problems such as arrhythmias, heart attacks, and heart failure | Used to diagnose brain problems such as epilepsy, tumors, infections, and degenerative diseases |

ECG and EEG signals are produced by the electrical activity of the heart and the brain, respectively. They are measured by electrodes attached to different parts of the body.

ECG signals are generated by the depolarization and repolarization of the cardiac muscle cells, which create a potential difference across the cell membrane. This potential difference propagates through the cardiac tissue and reaches the body surface, where it can be detected by electrodes. The ECG signal reflects the rhythm and function of the heart, as well as its electrical conduction system.

EEG signals are generated by the synchronous activity of large populations of neurons in the brain, which produce postsynaptic potentials that sum up to form a macroscopic electric field. This electric field can be measured by electrodes on the scalp, which record the fluctuations of the potential difference between different brain regions. The EEG signal reflects the state and activity of the brain, as well as its cognitive and emotional processes.

(b) **Describe the feature extraction of EEG signal by Wiener filtering. Also explain the spectral error measure (SEM) for EEG signal.**

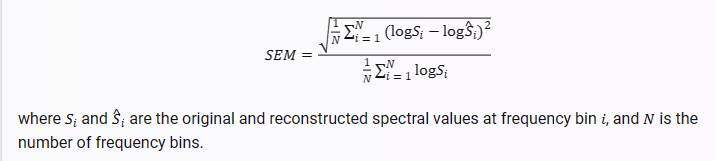
**Answer:**

Feature extraction is a process of transforming the raw EEG signals into a set of features that can be used for further analysis, such as classification, clustering, or visualization. Feature extraction can reduce the dimensionality, noise, and redundancy of the EEG signals, and enhance the relevant information for the specific task.

Wiener filtering is a technique of feature extraction that aims to reduce the effect of noise and artifacts in the EEG signals. Wiener filtering is based on the assumption that the EEG signals can be modeled as a linear combination of a desired signal and an additive noise. The Wiener filter tries to find the optimal linear filter that minimizes the mean squared error between the desired signal and the filtered signal.

Wiener filtering can be applied to single-channel or multi-channel EEG signals. For single-channel EEG signals, Wiener filtering can be performed in the frequency domain, where the Wiener filter is computed as the ratio of the power spectrum of the desired signal and the power spectrum of the observed signal. For multi-channel EEG signals, Wiener filtering can be performed in the spatial domain, where the Wiener filter is computed as a matrix that optimizes the spatial covariance of the desired signal and the observed signal.

Spectral error measure (SEM) is a method to quantify the difference between two spectra of EEG signals, such as the original and the reconstructed spectra. SEM is defined as the root mean square error (RMSE) between the logarithms of the two spectra, normalized by the mean of the logarithms of the original spectrum. Mathematically, SEM can be expressed as:

SEM is useful for evaluating the quality of EEG signal reconstruction, such as in independent component analysis (ICA) or current source density (CSD) transform. A lower SEM value indicates a better reconstruction, meaning that the reconstructed spectrum preserves the shape and magnitude of the original spectrum. SEM can also be used to compare different methods of EEG signal processing and to optimize the parameters for a given method.

Medical Imaging topics  
  
Ultrasound  
X-ray  
CT-scan  
MRI  
FMRI  
ECG  
EEG  
Digital Image Processing  
Image Enhancement

**Q. Histogram modeling, specification and equalization**  
**Histogram modeling** is the process of transforming the pixel values of an image according to a desired probability distribution function (PDF). Histogram specification and histogram equalization are two common methods of histogram modeling.

**Histogram equalization** is a technique that aims to improve the contrast of an image by flattening its histogram, i.e., making it more uniform. Histogram equalization can be done by applying a transformation function that maps the original pixel values to new values based on the cumulative histogram of the image. Histogram equalization can enhance the details of dark or bright regions of an image, but it may also introduce some artifacts or noise.

**Histogram specification**, also known as histogram matching or stretching, is a technique that modifies the histogram of an image to match a given target histogram. Histogram specification can be used to adjust the brightness, contrast, and tonal range of an image according to a reference image or a desired distribution. Histogram specification can be done by applying a transformation function that maps the original pixel values to new values based on the cumulative histograms of both the input and the target images.

**Q. Reconstruction from projection**  
Reconstruction from projection is a technique that can be used to create an image of an object from a series of projections taken at different angles. It is commonly used in imaging methods such as computed tomography (CT), magnetic resonance imaging (MRI), and synthetic-aperture radar (SAR).

There are different algorithms that can be used to perform reconstruction from projection, such as iterative reconstruction, algebraic reconstruction, and transform methods. Each algorithm has its own advantages and disadvantages, depending on the quality and quantity of the projection data, the computational complexity, and the desired accuracy of the reconstructed image.

One example of a transform method is the filtered back projection (FBP) algorithm, which is widely used in CT. It involves applying a filter to each projection to remove noise and blurring, and then back-projecting the filtered projections onto an image plane. The reconstructed image is obtained by summing up all the back-projected images.

Watershed Segmentation Algorithm  
Tomography  
PET  
SPECT

**Q. DICOM**  
DICOM stands for **Digital Imaging and Communications in Medicine**. It is an international standard that specifies the protocols used to facilitate the exchange of medical images and related data in healthcare systems. DICOM is most commonly used for storing and transmitting medical images, enabling the integration of medical imaging devices such as scanners, servers, workstations, printers, network hardware, and picture archiving and communication systems (PACS) from multiple manufacturers. DICOM files can be exchanged between two entities that are capable of receiving image and patient data in DICOM format. The standard includes a file format definition and a network communications protocol that uses TCP/IP to communicate between systems. The National Electrical Manufacturers Association (NEMA) holds the copyright to the published standard which was developed by the DICOM Standards Committee.

Image Restoration  
Brain Scanning Technique  
Mammography  
Nuclear medicine

**Q. Microscopy image**  
A microscopy image is a picture of an object or area that is too small to be seen with the naked eye, taken using a microscope. Microscopes are instruments that use lenses to magnify objects and produce images. There are different types of microscopes, such as optical, electron, and scanning probe microscopes, that use different methods to interact with the sample and create an image.

Microscopy is the technical field of using microscopes to study small objects, such as cells, tissues, crystals, and microorganisms. Microscopy has many applications in biology, medicine, chemistry, physics, and engineering. Microscopy can reveal the structure, function, and interactions of cells and molecules, as well as the properties and behavior of materials at the nanoscale.

DTI  
DOT