ULTRASOUND

An ultrasound is an imaging test that uses sound waves to makes pictures of organ, tissues, and other structures inside your body. Ultrasound works on the principle of **high-frequency sound waves**, typically between **2–10 MHz**, transmitted into the body using a transducer. It allows your health care provider to see into your body without surgery. Ultrasound is also called Ultrasonography or Sonography. Ultrasound images are called sonograms. Unlike X-ray or CT scans, ultrasound does **not use ionizing radiation**, making it safer for patients, including pregnant women and children.

PRINCIPLE:

Ultrasound imaging works based on the principle of **echo reflection of sound waves**.

1. A device called a **transducer (probe)** emits high-frequency sound waves into the body.
2. These sound waves travel through body tissues.
3. When the waves encounter different tissues or boundaries between organs, part of the sound is **reflected back as echoes**.
4. The transducer receives these echoes.
5. The ultrasound machine processes the echoes and converts them into **real-time images** displayed on a monitor.

The **time taken for echoes to return** helps determine the depth and location of structures.

COMPONENTS OF AN ULTRASOUND SYSTEM:

An ultrasound imaging system consists of the following components:

1. Transducer (Probe)

- Produces and receives sound waves.
- Contains **piezoelectric crystals** which convert electrical signals into sound waves and vice versa.

2. Ultrasound Machine

- Generates electrical signals for the probe.
- Processes returning echoes.

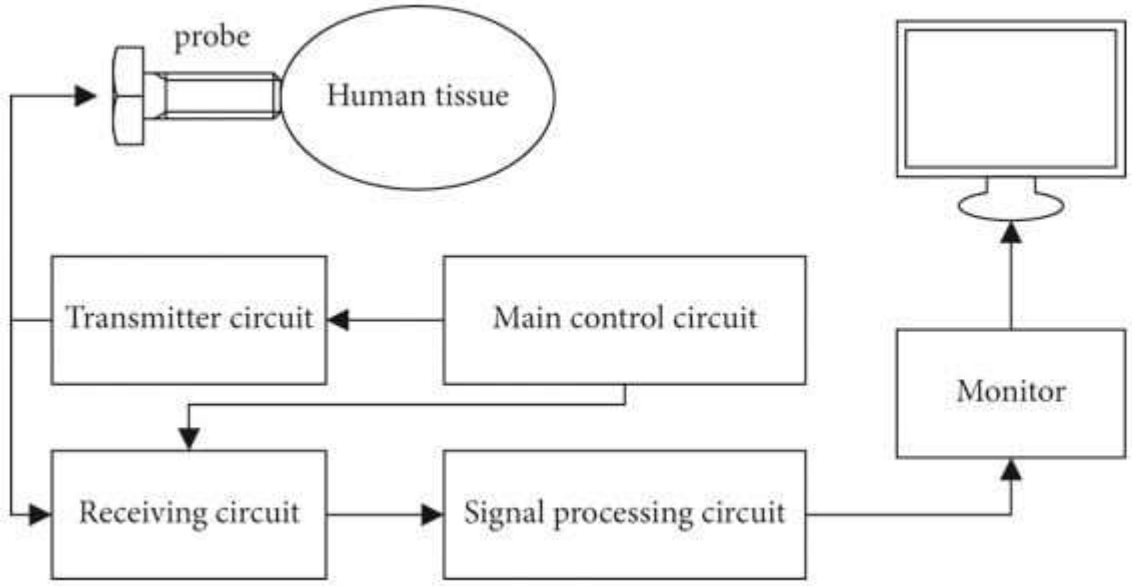
3. Display Monitor

- Shows real-time grayscale images called **sonograms**.

4. Gel

- Applied to the skin to eliminate air between the probe and the body surface.
- Helps sound waves travel efficiently.

BLOCK DIAGRAM:



Types of Ultrasound Imaging

1. **B-mode (Brightness mode)**
   Produces two-dimensional images of internal organs.
2. **Doppler Ultrasound**
   Measures blood flow in vessels.
3. **3D Ultrasound**
   Produces three-dimensional images.
4. **4D Ultrasound**
   Real-time 3D imaging.

Applications of Ultrasound

- Pregnancy monitoring
- Liver disease diagnosis
- Kidney stone detection
- Heart imaging (echocardiography)
- Tumor detection
- Blood flow analysis

ULTRASOUND OF LIVER:

Definition

Liver ultrasound is a non-invasive medical imaging technique that uses high-frequency sound waves to produce images of the liver and surrounding structures in the abdomen. It helps doctors examine the size, shape, texture, and blood flow of the liver and detect diseases such as fatty liver, cirrhosis, tumors, cysts, and infections. It is considered **safe, painless, and radiation-free**.

Types of Liver Ultrasound

1. Standard Liver Ultrasound *(Upper Right Quadrant Abdominal Ultrasound)*

Standard liver ultrasound is the most common type of liver imaging where the ultrasound probe is placed on the upper right side of the abdomen to visualize the liver. Evaluates liver size, shape, internal structure, and presence of masses or cysts. Detects enlargement (hepatomegaly), fatty liver changes, and structural abnormalities.

Working

The probe sends ultrasound waves into the liver tissue, and the returning echoes create a grayscale image of the liver on the monitor.

2.Vascular Ultrasound*(Doppler Ultrasound)*

Vascular ultrasound of the liver, also called **Doppler ultrasound**, is used to study **blood flow in the liver's blood vessels**. Assesses blood flow in liver vessels like the portal vein, hepatic artery, and hepatic veins. Can detect blockages, thrombosis, or abnormal blood flow patterns.

Working

The Doppler technique measures the **change in frequency of sound waves caused by moving blood cells**, which allows doctors to evaluate **blood flow direction and speed**.

3. Elastography Ultrasound*(Transient Elastography)*

Elastography ultrasound is a specialized technique used to measure the **stiffness or elasticity of liver tissue**. Measures tissue stiffness to detect fibrosis or cirrhosis. Useful for monitoring chronic liver diseases like hepatitis.

Working

The ultrasound device sends **mechanical vibrations into the liver tissue** and measures how fast the waves travel through the liver.

- **Soft liver tissue → waves travel slowly**
- **Stiff liver tissue → waves travel faster**

Higher stiffness usually indicates **fibrosis or cirrhosis**.

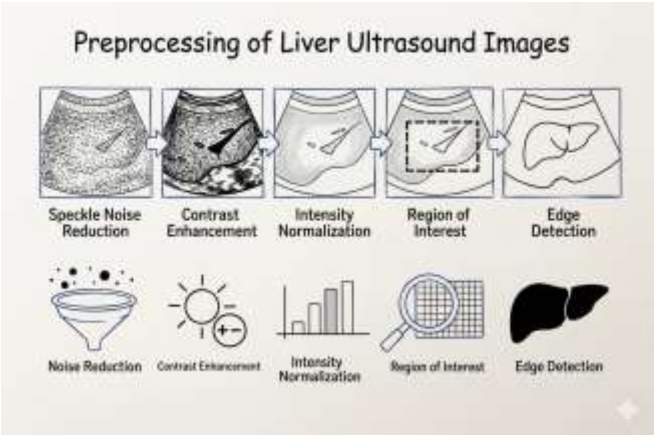
4. Contrast-Enhanced Ultrasound (CEUS)

Contrast-enhanced ultrasound (CEUS) uses a **special contrast agent (microbubble contrast)** injected into the bloodstream to improve the visualization of liver blood vessels and lesions. Helps distinguish between benign and malignant lesions.

Working

The injected contrast agent contains **tiny gas microbubbles** that reflect ultrasound waves strongly, producing **clearer and more detailed images of liver blood flow and tumors**.

Despite its advantages, ultrasound images often contain **speckle noise, low contrast, and artifacts**, which reduce the visibility of small lesions or subtle changes. Preprocessing improves the visibility of liver structures, reduces noise, and prepares images for further **segmentation, feature extraction, and classification** tasks in medical imaging.



Preprocessing of Liver Ultrasound Images

Preprocessing involves several key steps:

1.Speckle Noise Reduction

Speckle noise appears as granular patterns in liver ultrasound images and can mask small lesions. Filters used: **Median filter, Wiener filter, Anisotropic diffusion filter**.

Benefits:

- Preserves edges
- Reduces granular appearance
- Makes lesions and liver parenchyma clearer

2.Contrast Enhancement

Enhances visibility of liver tissues and pathological regions. Techniques: **Histogram Equalization, Contrast-Limited Adaptive Histogram Equalization (CLAHE)**.

Benefits:

- Improves detection of subtle echogenic changes (e.g., early fatty liver or small tumors)
- Helps radiologists and automated systems identify regions of interest

3.Intensity Normalization

Standardizes intensity values across multiple images. Reduces variability caused by different ultrasound machine settings. Ensures consistency in datasets, especially important for **machine learning applications**.

4.Region of Interest (ROI) Extraction

Isolates the liver from surrounding structures (ribs, intestines, diaphragm). Focuses analysis on the liver alone, improving computational efficiency.

5.Edge Detection

Highlights liver boundaries and vascular structures. Techniques: **Canny or Sobel edge detectors**.

Benefits:

- Delineates liver contours
- Helps in accurate tumor or lesion segmentation

Applications in Medical Image Processing

After preprocessing, liver ultrasound images can be used for:

1. **Segmentation**

   Separates liver parenchyma from surrounding tissues. Measures liver volume, shape, and lesion size.

2. **Feature Extraction**

   Computes **texture, intensity, and echogenicity features** for diagnosis. Supports machine learning models to classify **healthy vs diseased liver**.

3. **Computer-Aided Diagnosis (CAD)**

   Preprocessed images improve automated detection of tumors, cysts, and fatty liver. Reduces human error in clinical diagnosis.

4. **Longitudinal Studies**

   Preprocessed images ensure consistency across multiple scans for monitoring disease progression.

ULTRASOUND OF KIDNEY (RENAL ULTRASOUND)

Definition

Kidney ultrasound, also called **renal ultrasound**, is a medical imaging technique that uses **high-frequency sound waves** to create images of the kidneys and urinary system. It helps doctors evaluate the **size, shape, position, and structure of the kidneys** and detect abnormalities such as **kidney stones, cysts, tumors, infections, and blockages**.

It is a **non-invasive, painless, and radiation-free diagnostic method**, making it safe for patients of all ages.

Purpose of Kidney Ultrasound

Kidney ultrasound is performed to:

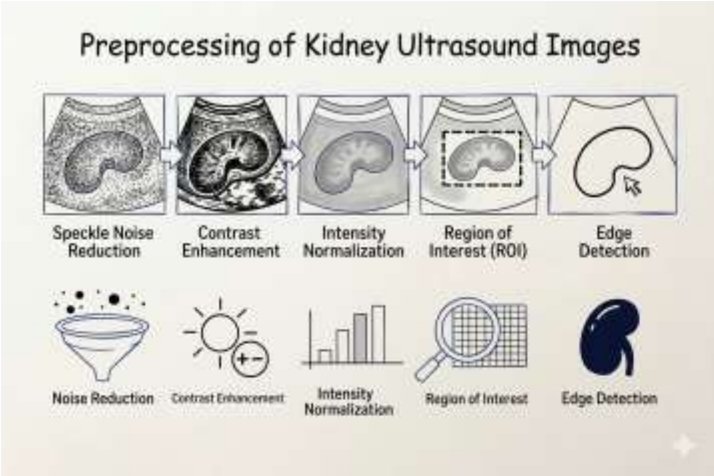
- Detect **kidney stones**
- Identify **kidney cysts**
- Detect **kidney tumors**
- Diagnose **kidney infections**
- Detect **urinary tract obstruction**
- Evaluate **kidney size and structure**
- Monitor **chronic kidney disease**

Procedure of Kidney Ultrasound

1. The patient lies on an **examination table**.
2. A **special gel** is applied on the abdomen or lower back.
3. The ultrasound probe is moved over the kidney area.
4. Sound waves enter the body and create **real-time images of the kidneys**.
5. The images are displayed on the **ultrasound monitor** for analysis.

The procedure usually takes about **15–30 minutes**.

However, raw kidney ultrasound images often contain **speckle noise, low contrast, artifacts, and anatomical complexities**, which can obscure small stones, cysts, or tumors. Therefore, **medical image preprocessing** is performed to enhance image quality and prepare it for **segmentation, feature extraction, and computer-aided diagnosis (CAD)**.



Preprocessing of Kidney Ultrasound Images

Preprocessing kidney ultrasound images involves the following steps:

1.Speckle Noise Reduction

Problem: Ultrasound images of kidneys often have speckle noise, which appears as fine granular patterns.

Techniques:

- Median filter
- Wiener filter
- Anisotropic diffusion

Purpose: Smooths the image while preserving edges, making **stones, cysts, and parenchyma boundaries clearer**.

2.Contrast Enhancement

Problem: Small stones or cysts may not be visible due to low contrast.

Techniques:

- Histogram Equalization
- CLAHE (Contrast-Limited Adaptive Histogram Equalization)

Purpose: Increases visibility of abnormal structures and improves diagnosis accuracy.

3.Intensity Normalization

Problem: Different scans or machines produce images with variable brightness.

Techniques:

- Min-Max normalization
- Z-score standardization

Purpose: Standardizes intensity values for multiple images, essential for **machine learning or automated analysis**.

4.Region of Interest (ROI) Extraction

Problem: Ultrasound images may contain irrelevant background such as surrounding tissues, intestines, or ribs.

Techniques:

- Manual cropping/masking
- Automatic segmentation using thresholding or contour detection

Purpose: Focuses analysis on the kidney, reducing computational effort and improving segmentation accuracy.

5.Edge Detection

Problem: Kidney boundaries and internal structures may be unclear.

Techniques:

- Sobel operator
- Canny edge detector

Purpose: Highlights kidney contours, renal pelvis, and cyst boundaries, aiding **tumor or stone detection**

MAMMOGRAM

A **mammogram** is a specialized medical imaging technique used to examine **breast tissue**. Mammography is mainly used for the **early detection of breast cancer**, which is one of the most common cancers in women.

Mammography can detect very small abnormalities in breast tissue **even before symptoms appear**, making it an important tool for early diagnosis and treatment. Doctors use mammograms to identify **tumors, cysts, calcifications, and other abnormal growths** in the breast.

Principle of Mammography

The working principle of mammography is based on the **absorption of X-rays by different tissues in the breast**.

1. A **low-dose X-ray beam** is directed toward the breast.
2. Different tissues absorb X-rays at different levels.
3. **Dense tissues** such as tumors absorb more X-rays.
4. **Fatty tissues** absorb fewer X-rays.
5. The remaining X-rays pass through the breast and reach a **detector or film**.

6. The detector converts the X-rays into a **grayscale image**.

In the mammogram image:

- **Dense tissues** appear **white**
- **Fatty tissues** appear **dark**
- **Abnormal masses or tumors** appear as bright areas

Types of Mammography

1. Screening Mammography

Screening mammography is performed on women who **do not have symptoms** of breast disease. The purpose is to detect **breast cancer at an early stage** before any signs appear.

Features:

- Used for routine health checkups
- Detects early tumors
- Usually performed for women above **40 years of age**

2.Diagnostic Mammography

Diagnostic mammography is performed when a patient has **symptoms such as breast pain, lumps.**

Applications of Mammography

Mammography is widely used in medical diagnosis for:

- Early detection of **breast cancer**
- Detection of **breast tumors**
- Identification of **microcalcifications**
- Monitoring breast abnormalities
- Evaluating breast lumps
- Screening high-risk patients

Early detection through mammography significantly increases the **chance of successful treatment**.

Advantages of Mammography

1. **Early detection of cancer**
   Mammography can detect tumors before they become noticeable.
2. **Non-invasive procedure**
   No surgery is required.

3. **Quick examination**
   The test usually takes only a few minutes.
4. **High diagnostic accuracy**
   Provides detailed images of breast tissue.
5. **Widely available**
   Available in most hospitals and diagnostic centers.