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Digital Image Processing For Medical Diagnosis: A Review Of Advanced Techniques

Ghazala Shireen, Deepika Makwana

Assistant Professor, Lecturer

Parul Institute of Engineering & Technology-Diploma Studies

Parul University, Vadodara, Gujarat

Abstract: Digital image processing is an important component to contemporary medical diagnosis, as it allows for improved viewing, examination, and understanding of complicated medical data. This review covers advanced imaging modalities such as MRI, CT, ultrasound, X-ray, PET, SPECT, and endoscopy with clinical implementation and fusion of imaging processing methods in concern. These technologies afford highly anatomical and functional details fundamental for non-invasive diagnosis and treatment planning. The paper also notes the role of artificial intelligence and specifically deep learning in automating analysis of images and increasing diagnostic precision while at the same time making personal care feasible. Limitations including scant annotated datasets, no standardization, and expensive computation needs are part of the barriers to the large scale adoption of these technologies. Taking it all together, digital image processing improves a lot for the clinical decision-making, but still, the innovation and standardization are necessary to perfect it for a wide range of healthcare establishments.

Index Terms - pictures, patient, CT scans, ultrasounds, laparoscopic surgeries, radiography high-end gaps, two-dimensional image, high-frequency sound waves, and clinical diagnosis

Introduction

Pictures are the most common and convenient means of conveying or transmitting information.. Pictures concisely convey information about positions, sizes and inter-relationships between objects. They portray spatial information that we can recognize as objects. In the present context, the analysis of pictures that employ an overhead perspective, including the radiation not visible to human eye are considered. Large volumes of data are produced by medical imaging technologies including MRIs, CT scans, ultrasounds, and X-rays, which need to be effectively interpreted. These photos are improved by digital image processing, which enables medical professionals to identify important characteristics that would otherwise be hard to find. Automated and semi-automated diagnosis has been made possible by the field's revolution through the combination of machine learning and deep learning.

The medical image plays an important role in clinical diagnosis and therapy of doctor and teaching and researching etc. [1]

Generally, uniformly sampled data with normal x-y-z spatial spacing (pictures in 2D and volumes in 3D, generally referred to as images) is used for medical image computation. Data is often represented in integral form at each sample point, such as signed and unsigned short (16-bit), however unsigned char (8-bit) and 32-bit float forms are also frequently used. Modality determines the specific interpretation of the data at the sample point; for instance, radio density values are collected by a CT acquisition, whereas T1 or T2-weighted pictures may be collected by an MRI acquisition. Regular time increments may or may not be used in longitudinal, time-varying acquisitions. Fan-like pictures from modalities like curved-array ultrasonography are also frequent and need to be processed using various representational and computational approaches. [5]

1. MEDICAL IMAGING MODALITIES

Medical imaging is a cornerstone of modern diagnostics with non-invasive visualization of internal anatomical and physiological processes. The imaging modalities described below are key to clinical practice. [2]

2.1. Magnetic Resonance Imaging (MRI)

MRI employs strong magnetic fields and radiofrequency pulses to produce high-resolution images of soft tissues. It is particularly valuable for imaging the brain, spinal cord, and musculoskeletal system, with high-contrast resolution and without the need for ionizing radiation. MRI is of utmost importance in diagnosing neurological disorders, musculoskeletal trauma, and cardiovascular abnormalities.

2.2 Computed Tomography (CT)

CT employs X-rays and computer processing to generate cross-sectional images of the body. CT is employed widely to diagnose cancer, assess fractures of the bone, and assess lung disease. CT scans are rapid and deliver high-quality images and are therefore of tremendous utility in emergency departments as well as to direct interventional treatment.

2.3 Ultrasound Imaging

Ultrasound uses high-frequency sound waves to create real-time images of internal organs and tissues. Ultrasound is noninvasive, does not use ionizing radiation, and is used extensively in obstetrics, cardiology, and abdominal imaging. Developments such as Doppler ultrasound allow for measurement of blood flow, further making it diagnostic.

2.4 X-ray Imaging

X-ray imaging is the oldest and most frequent of the diagnostic techniques. It functions by passing X-rays through the body to create images based on tissue density. X-rays are especially effective for the evaluation of bones, for the identification of fractures, and for the evaluation of chest disorders such as pneumonia and tuberculosis.

2.5 Positron Emission Tomography (PET) and Single Photon Emission Computed Tomography (SPECT)

SPECT and PET are nuclear medicine modalities that provide information on tissue and organ function and metabolism. PET scans use radiotracers like fluorodeoxyglucose (FDG) to image regions of high metabolic rate, which in oncology is of critical importance for tumour detection and evaluation of tumour response to treatment. SPECT, although a similar mechanism, uses gamma-emitting radionuclides and will be more likely to find use in cardiology and brain imaging. Modalities are typically used in conjunction with CT or MRI to offer anatomical and functional correlation. [3][4]

3. APPLICATIONS IN MEDICAL DIAGNOSIS

Finding and exposing interior structures that are concealed by the skin and bones is the primary focus of medical imaging. Furthermore, it is employed to examine, identify, diagnose, and treat the sickness or ailment. Magnetic resonance imaging, ultrasound, and CT scanners are used in X-ray imaging. This technique is particularly useful for the specialists to make laparoscopic surgeries for viewing the interior parts without actually opening the body. X-ray imaging uses CT scanner; Experts can examine the body's hidden or obscure third dimension in this way. A CT scanner can reveal internal segments, making it simple to identify and locate cancerous spots. When thinking about MRI, it receives a signal from the body's magnetic particles, converts it into magnetic resonance, and uses a computer to convert the scanned data into images of the interior organs.

3.1 Radiography: Radiography is an imaging method that views non-transparent objects with variable density and composition, like the human body, using electromagnetic radiation, particularly X-rays. An X-ray beam that is heterogeneous is delivered by an X-ray generator and then projected onto the item. A detector picks up the X-rays that pass through the object and superimposes a two-dimensional image of every organ's interior structure.



Fig.1. X-ray image

Fig-1 shows the details of the bones in a human hand can be seen in a standard X-ray scan. For exams such as orthodontic evaluations and dental exams, radiography is utilized. Industrial and medical radiography are both included in radiography. All other radiography is referred to as industrial radiography, while medical radiography is used when the thing being inspected is living, whether it be a human or a creature. Additionally, it is discovered that, without affecting the X-ray content, patient data can be stored on the X-ray image itself.

3.2 Magnetic resonance Imaging (MRI): MRI is a medical imaging method used to visualize the human body's anatomy and physiological processes. MRI scanners create the important medical images of the body through the use of radio waves and magnetic fields. The cross-sectional view of the human head from an MRI scan is displayed in Fig. 2.



Fig.2. MRI image

MRI is widely used in clinical diagnosis, and scanners that use field gradients, magnetic field effects, and radio wave effects to capture images of organs of the human body. It is highly utilized in both biomedical research and diagnostic medicine.

In addition to digital images, MRI scans can generate a range of clinical data. Without exposing the body to radiation, MRI is used to determine and track the stages of disease. Because MRI data is so large, manual segmentation is not necessary.

One current issue with the large spatial, structural, and variable tumours of the human brain is automatic segmentation. Using tiny 3×3 kernels, Convolutional Neural Networks (CNN) are a key tool for investigating brain tumours.

3.3 Endoscopy: "Looking inside" for medical diagnosis is the true meaning of endoscopy. In contrast to other methods, an instrument is used to examine and verify the interior portions of a body pit or empty organ. A cutting tool attached to the endoscope's end allows a specialist to see inside human bodies, and

minor procedures can be carried out if needed. In this sense, the procedure is known as "key hole surgery," and it causes a very small scar on the patient. The endoscopy of the human abdomen is shown in Fig. 3.



Fig.3. Endoscopy image

Each endoscope contains a few bundles of fibres, one of which is used to illuminate the organ's internal structure and the other to gather the reflection of light. The endoscope is a tubular optical device used to examine bodily conditions that are invisible to the human eye. In general, endoscopy is utilized for a number of procedures in plastic surgery, orthopaedic surgery, endoscopic spinal surgery, and pregnancy. Endoscopes are also utilized by the FBI and bomb disposal personnel to conduct surveillance in confined spaces.

3.4 Stereo Endoscope: This type of endoscope has two cameras installed on a single laparoscope. A video screen receives the images from these cameras. A few different presentation techniques are applied to these 2D images in order to identify stereo images. The cameras periodically send out images when they detect a real image.

This makes the image appear to have three-dimensional perspective. Stereoscopic technology helps the clinical and medical fields improve surgical accuracy and operational needs. With a shorter operating time and guarantees patient safety thanks to 2D imaging technology's realistic depth perception.

Other applications of stereoscopic imaging include diabetic retinopathy, digital mammography, anatomy education, and non-invasive surgical procedures.

3.5 Computer Tomography: This method uses digitally processed combinations of several X-ray images. Pictures captured from different edges. This technique allows the user to view internal components without cutting by creating a cross-sectional image of the target object. CT has emerged as a crucial tool in medical imaging to support medical ultrasonography and X-rays. A CT scan image of the human brain in multiple slices is shown in Fig. 4.

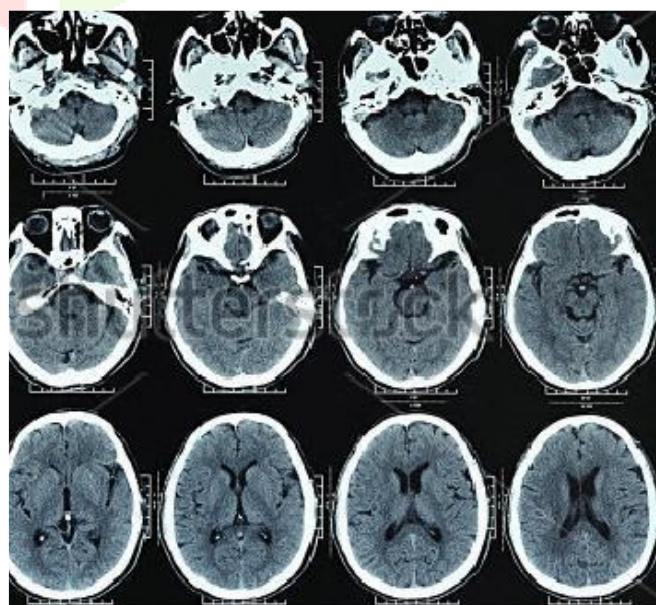
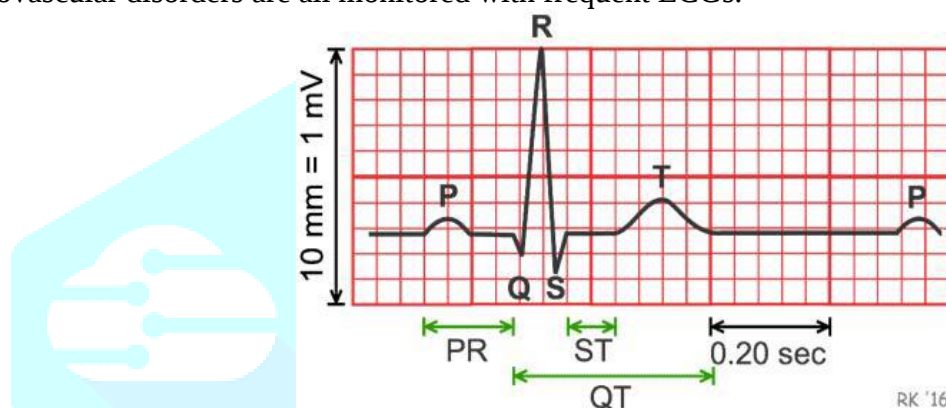


Fig.5. Electro Cardio Graphy

CT scanning of the head is typically performed to identify and detect bone trauma, tumours, calcifications, haemorrhages, and infarction. In order to respond quickly to patients who have had a stroke or other head trauma, ambulances are equipped with small bore multi-sliced CT scanners. This scan can also be used to identify acute or chronic changes in the lungs' internal structure. A test for medical diagnosis To diagnose pulmonary embolism, a CT pulmonary angiogram is utilized. One sensitive technique for diagnosing conditions of the heart and abdomen is CT.

In addition to providing a large volume of data for additional processing and analysis, four-dimensional computed tomography adds a new dimension to patient-related data for radiation therapy.

3.6 Electrocardiography (ECG): ECG uses electrodes that are fixed to record the electrical activity of the heart over a predetermined amount of time. On the body's limbs and chest. These electrodes detect the electrical alterations in the skin brought on by each heartbeat. The main goal of an ECG is to gather data regarding the composition and operation of the heartbeat. Seizures, atrial flutter, cardiac stress testing, fainting or collapse, and suspected pulmonary embolism are some indicators that an ECG should be performed. Patients in critical condition, those undergoing general anaesthesia, and those with sporadic cardiovascular disorders are all monitored with frequent ECGs.



Fourier transformation typically yields poor results. Using digital signal processing, multi-resolution analysis and filtering are used to effectively remove unintentional issues from ECG nodes, and wavelet transform produces an effective filtering effect.

Medical ultrasound: Using ultrasound, medical ultrasound is an indicative imaging method. It is typically used to view internal body structures such as muscles, joints, tendons, vessels, and internal organs. Finding the cause of a disease or outlawing any pathology is its goal.

Ultrasonography, also known as sonography, is widely used in medicine. Using ultrasound to guide interventional procedures like biopsies or fluid collection drainage, it carries out diagnostic and therapeutic procedures. Compared to other medical imaging methods, ultrasound has few advantages. It provides flexible real-time images at a significantly reduced cost. It doesn't employ harmful ionizing radiation techniques.



Fig.6. Ultrasound Scan of foetus

In order to identify stereo images, the cameras periodically send out images when they detect a real image. This makes the image appear to have three-dimensional perspective. Stereoscopic technology helps the

clinical and medical fields improve surgical accuracy and operational needs. With a shorter operating time and guarantees patient safety thanks to 2D imaging technology's realistic depth perception. Other applications of stereoscopic imaging include non-invasive surgical procedures, diabetic retinopathy, digital mammography, and anatomy education. Image processing techniques analyse medical scans like mammograms, CT scans, and dermo copy images for early detection of cancer, identifying abnormal tissue patterns. The diagnosis of neurological disorders, such as Alzheimer's and Parkinson's disease, is facilitated by the use of brain MRIs.

Cardiovascular imaging detects arterial plaques, measures heart function, diagnoses diabetic retinopathy and glaucoma from retinal images, and uses digital histopathology for tumour grading and classification.

4. CHALLENGES AND LIMITATIONS

4.1 Limited Availability of High-Quality Annotated Datasets

The scarcity of well-annotated medical imaging datasets is a significant hurdle in developing accurate AI models. This limitation arises due to:

- **Privacy Concerns and Patient Consent:** Accessing and sharing medical images necessitates strict adherence to patient privacy regulations and obtaining informed consent, which can be complex and time-consuming.
 - **Expert Annotation Requirements:** Annotating medical images demands specialized knowledge, making the process labour-intensive and costly. The shortage of qualified annotators further exacerbates this issue.
- These factors collectively hinder the creation of large, diverse, and high-quality datasets essential for training robust AI models.

4.2 Standardization across Imaging Modalities and Protocols

The inconsistency in imaging protocols across institutions and equipment leads to variability in image quality and format, posing challenges for AI models that require standardized input for reliable performance. Efforts to standardize protocols are ongoing.

Different manufacturers and software versions lead to varying imaging outputs. The inconsistencies in clinical practices and protocols across institutions can be attributed to variations in these practices and protocols.

4.3 Computational Resource Requirements for Deep Learning Models

Deep learning model training for medical image processing is a computationally demanding process that calls for:

- **High-end GPUs and lots of memory:** To manage intricate calculations and big datasets, sophisticated hardware is necessary.
- **Large Financial Investment:** Purchasing and maintaining this kind of hardware can be quite expensive, particularly for smaller organizations.

These specifications restrict the scalability and accessibility of AI solutions in medical imaging, especially in environments with limited resources.

5. CONCLUSION

Digital image processing is very important in increasing medical diagnostics in the sense, it allows precise visualization and analysis of the internal structures, using modalities such as MRI and CT, ultrasound as well as X-ray. The use of AI in a specific is the deep learning has enhanced the diagnostic precision and efficiency. Nevertheless, issues of a limited annotated data, lack of standardization, high computational costs are barriers to wider adoption. It is imperative to address these issues in collaborative research, technology advancement to maximally exploit capabilities of digital imaging in healthcare.

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