INTERNATIONAL ADVANCE JOURNAL OF ENGINEERING, SCIENCE AND MANAGEMENT (IAJESM)
July-December 2023, Submitted in November 2023, iajesm2014@gmail.com, ISSN -2393-8048
Multidisciplinary Indexed/Peer Reviewed Journal. SJIF Impact Factor 2023 =6.753

A Study on The Technologies Used in Medical Imaging

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Abstract

The application of radiofrequency waves causes this alignment to shift, and eventually, the ions will return to the place they were in before the waves were applied. During the process of creating a picture, these shifts in alignment are recorded and then analysed. In order to visualise soft tissue features including muscles, tendons, and joint spaces, magnetic resonance imaging (MRI) is a valuable tool. Despite the fact that there is no risk of radiation exposure, magnetic resonance imaging (MRI) may be hazardous for those who have metal implants due to the use of a powerful magnetic field. Patients who have prosthetic joints, pacemakers, or other forms of implants are included in this category. On the other hand, the treatment of CT photos is challenging because of the anatomical characteristics of the liver as well as the procedures used to gather CT images. As a method of overcoming the challenges that are linked with the abdominal CT scans for automated living and tumour segmentation, the researchers who published their findings in the literature presented a number of different techniques. Deep learning has lately garnered a lot of attention from academics who are studying medical images.

INTRODUCTION

THE TECHNOLOGIES USED IN MEDICAL IMAGING

The technologies that are used in the area of medical imaging are those that are associated with the field of radiography. X-rays and computed tomography scans are very useful instruments; nevertheless, due to the presence of ionising radiation, they should be used in a limited capacity. Cancers, cataracts, cellular mutations, and improper development in foetuses are among potential outcomes that may be attributed to exposure to ionising radiation. Magnetic resonance imaging (MRI), which includes nuclear magnetic resonance (NMR), includes no ionising radiation and offers decreased dangers. When it comes to medical imaging, ultrasound is considered to be one of the safest methods since it creates pictures via the use of ultrasonic vibrations.

An further method of medical imaging that is risk-free is the use of surface-mounted sensors for the purpose of measuring electrical activity. This method is utilised in electroencephalography (EEG) and electrocardiography (ECG), however both technologies provide a change over time graph rather than a graphical picture.

An increasing number of medical imaging systems are using artificial intelligence (AI) in order to improve the capability of interpreting and analysing data. It is now possible to visually diagnose problems that are not yet evident to the human eye with the use of computer vision.

MEDICAL IMAGING: DIVERSE TECHNOLOGIES AND APPLICATIONS

Numerous types of diagnostic medical imaging exist, each of which is distinguished by the physical characteristics of the waves that are used and the technique that is utilised to record the picture. Due to the fact that every imaging technique has its own set of benefits and drawbacks, there is no one imaging technology that absolutely dominates the others. On the basis of these restrictions, radiologists have discovered a certain "niche" that is best suited for each imaging modality:

Ultrasound

In order to capture medical pictures, ultrasonography makes use of sound waves, as the name of the technique suggests. Due to the fact that it does not utilise electromagnetic radiation, it is most likely the most secure method of diagnostic medical imaging. Through the use of a conducting gel, the sound waves are transmitted from the ultrasonic probe into the surrounding body. After striking a variety of anatomical components throughout the body, the waves then return to their original position. It is then possible to examine the photos that have been collected on a monitor once they have been altered. We are able to visualise the flow of blood inside blood vessels by using a specialised kind of ultrasonography that is known as the Doppler.

Radiographs

As a kind of medical diagnostic imaging, radiographs are considered to be the earliest. To a considerable extent, they have been supplanted by more sophisticated medical imaging technologies, which are primarily used for the purpose of visualising bones. The conventional radiograph, on the other hand, may still be helpful in some clinical settings, including the following:

This is a radiograph of the breast which is known as a mammogram. For the purpose of detecting breast cancer in females, it is used as a screening method.

Fluoroscopy is a method that involves the use of radiographs in conjunction with a contrast agent that is either ingested or injected. Through the use of radiography, the course of the contrast agent is traced in order to identify blockages, ulcers, and other pathological processes.

DIFFERENT APPLICATIONS OF DUAL-ENERGY IMAGING

However, the idea of dual-energy imaging is not a novel one. Dual-energy technology has been shown to have benefits in increasing tissue characterisation, as shown by research that dates back to the 1970s and 1980s. On the other hand, the amount of time necessary for data collecting was substantial, which restricted the diagnostic imaging capabilities of dual-energy imaging significantly.

Dual-energy imaging is becoming more popular in the medical field as a result of the introduction of new equipment that has quicker processors. This technology enables more rapid data capture and processing now.

Dual-energy imaging has the potential to be used in the following scenarios:

- To produce better images of blood vessels
- To reduce the number of examinations that a patient is required to undergo
- To detect abnormalities in the body, such as determining the type of kidney stone that could be present in a patient
- To improve image quality in the event that a patient has metal inserts in their body structure
- To generate pictures that are optimally tailored for the purpose of sophisticated three-dimensional reconstruction and visualisation of structures

X -RAY IMAGING TECHNOLOGY

X-rays are a kind of ionising radiation that have a wavelength that typically falls anywhere between 0.01 and 10 nanometers Transmission, absorption, and scattering are the three ways that X-rays might behave when they go through a material. The processes of scattering and absorption are regulated by Lambert-Beer's Law , which states that the attenuation capacity of the substance is a determining factor in both processes:

$$I = I_o e^{-ud}, \qquad (1)$$

Represents the intensity of X-ray photons that have been transmitted, Io represents the starting intensity of X-ray photons, λ represents the linear attenuation coefficient, and d represents the thickness of the matter. A combination of the photoelectric effect, Compton scattering, and Rayleigh scattering is responsible for the majority of the attenuation ability [7]. Both the composition of the matter and the intensity of the X-rays that are incident on it are factors that govern their ratios. Under normal circumstances, the photoelectric effect is the primary mechanism by which X-ray photons are absorbed by an object in a low-energy X-ray area. On the other hand, the Compton scattering phenomenon is the predominant mechanism in low-Z materials and high-energy photons.

Due to the fact that X-rays have a remarkable capacity to penetrate, X-ray imaging has become a very effective medical imaging modality . The development of X-ray imaging has been a driving force behind the advancement of diagnostic radiography technologies. These technologies are used to physically describe the skeleton, including the presence of fractures, luxation, bone disease, and the position of foreign subjects The provision of such imaging information is very helpful in directing the surgical procedure In addition to its uses in the medical field, X-ray imaging is also widely used for non-destructive inspections in the

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industrial and safety sectors. Without a question, the growth of X-ray imaging over the course of more than a century has contributed to the improvement of a broad variety of fields, ranging from basic research to practical applications.

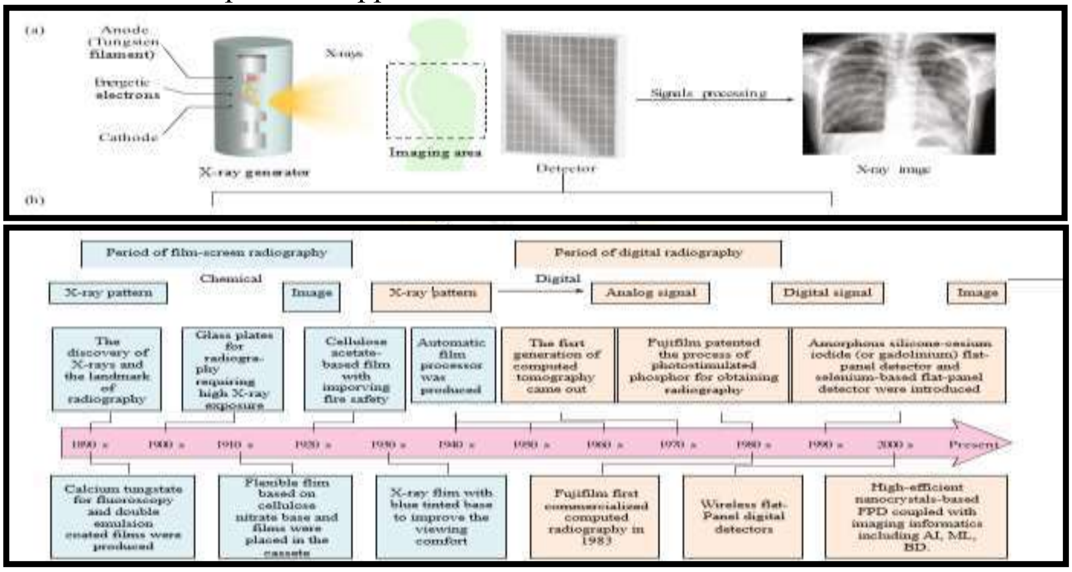

Figure : (a) Schematic illustration of an X-ray imaging system. The system constitutes an X-ray generator and an X-ray detector with a signal processing system. X-ray beam produced by the X-ray generator passes through the object (e.g., patient's chest) to arrive at the Xray detector, followed by the signal processing to produce a visible image. (b) The development of X-ray radiography with the evolution of X-ray detectors. The development can be mainly divided into film-screen radiography and digital radiography. The film-screen radiography converts a latent X-ray pattern into a visible image through tedious chemical processing, whereas digital radiography goes through a series of signal conversions to obtain the X-ray image. ADC: analog-to-digital conversion; DAC: digital-to-analog conversion; AI: artificial intelligence; ML: machine learning; DB: big data.

In most cases, an X-ray imaging system is made up of an X-ray generator and an X-ray imaging detector (as shown in Figure 2(a), left panel) The X-ray generator is constructed up of two electrodes that are encased in a chamber that is then evacuated. In the event that the cathode, which is composed of tungsten filament, is heated to 2200 degrees Celsius by the electric current, it is able to generate energic electrons by a thermionic effect after it has been switched on. The application of an accelerating voltage results in the production of X-rays during the energy changes that occur in electrons that are travelling at a high speed. These electrons collide and interact with the anode material while it is in a vacuum. Bremsstrahlung and distinctive X-rays are produced as a result of the utilisation of the lost energy. Bremsstrahlung is responsible for around eighty percent of the X-ray photons that are released by the diagnostic X-ray generator A number of factors, including cathode materials, accelerating voltage, and filament heating voltage and current, may have an impact on the X-ray spectrum that is produced.

REVIEW LITERATURE

Tarun Chauhan (2022) The fundamental objective of the curriculum curriculum for the radio imaging technology course is to facilitate the distribution of the knowledge, skills, and mentality that are necessary for practice. Students get the opportunity to improve their communication skills by spending more time practicing with volunteer patients. The study of anatomy and physiology, radiography imaging techniques, radiation safety, and radiographic equipment are all topics that students of radiography concentrate on. Estimating knowledge might be effective for bringing to light true deficiencies and limitations in a company as well as suggesting prospective opportunities for improvement inside the business. The report on the present knowledge estimate is more essential than an analysis conducted by a specific qualified expert that is totally resolved by technology. The objective of this study is to assess the level of comprehension that students have about a variety of radiography modalities, as well as their ability to manage and maintain these modalities. Methods: techniques In this study, we employed percentage, mean, and average statistics to analyse the data that was collected prospectively from 94 different samples. There were 94 samples, and the results showed that 49 (52.1%) of them were male and 46 (48.9%) were female. They were divided into four groups according to the standards of their classes: two of them were for students who were in their second and third years of a Bachelor of Science degree, and the other two were for students who were in their first year and final year of a Master of Science degree. According to the findings, students in their third year of the Bachelor of Science programme knowledge the most about radiographic modalities (18.54%), while students in their second year of the programme know the least (16.70%). Following the findings of the study, it is determined that all individuals who are employed in the radiology department are required to have an understanding of the handling, care, and radiographic modalities in terms of safety and precaution. Guidelines were developed, safety standards were adhered to, and instructions on how to make use of the different modalities were followed with care. To evaluate the level of knowledge possessed by radiographers and other members of the staff working in the radiology department, it is advised that they attend class on a consistent basis. It is because of this that, in the case of an emergency, both the patient and the equipment will be safeguarded from any potential injury.

Mohsen El-Bendary's work from 2015 The abbreviation "MIT" stands for "medical imaging techniques," which are non-invasive methods that allow one to view within the body without the need to create incisions during surgery. It served as a useful tool for the diagnosis and treatment of a wide variety of medical conditions. Medical imaging may be accomplished by a variety of techniques, each of which has its own set of benefits and drawbacks. Within the scope of this work, an overview of the concepts, advantages, disadvantages, and applications of these methodologies is provided. There are a number of methods that are cause for worry, including X-ray radiography, X-ray computed tomography (CT), magnetic resonance imaging (MRI), ultrasound, elastography, and optical imaging. A few examples of radioactive imaging techniques are scintigraphy, positron emission tomography (PET) and single photon emission computed tomography (SPECT), thermography, and terahertz imaging. In this section, we will present information on the concepts, benefits, risks, and applications of these technologies. It is planned to conduct a comparison of several approaches with regard to the following aspects: image quality (contrast and spatial resolution), safety (ionising radiation effect and radiation heating influence on the body), and system availability (cost and real-time information).

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The year (2022's) Fahad Muhammad Due to the fact that it assists in the accurate diagnosis and treatment of a broad variety of diseases, radiology is an essential component of modern medical care. The objective of this paper is to investigate the many imaging modalities that are used in radiology and to discuss the significance of these modalities in the creation of accurate diagnoses. In this course, we will discuss the foundations, advantages, and limitations of many modalities that are often used. These modalities include computed tomography (CT), magnetic resonance imaging (MRI), ultrasound, and nuclear medicine. In addition, we will investigate the latest advancements in the industry as well as the technologies that are currently being developed that have the potential to improve diagnostic accuracy. It is possible for medical professionals, such as radiologists, to enhance patient care by optimising their decision-making processes. This may be accomplished by gaining an understanding of the benefits and drawbacks associated with the different imaging modalities.

In the year 2021, Ni Jianfu In addition to its usage in engineering and mineral exploration, the cross-hole electromagnetic wave method, which is sometimes referred to as the radio imaging method (RIM), is a technology that is often used in both of these fields. Despite the fact that the RIM system is capable of collecting data from several frequencies, its applications are still limited to qualitative analysis or the utilisation of a single frequency data type. Following a summary of the multi-frequency information utilisation methods that can be found in a variety of geophysical methods and a demonstration of the theoretical viability of RIM multi-frequency utilisation, three multi-frequency information fusion methods that are suitable for RIM are proposed. These methods are multi-frequency inversion strategies, multi-frequency data fusion, and multi-frequency image fusion. The three strategies for fusing information from several frequencies make full use of the advantages offered by the different frequencies, as shown by an example application study, and they have the potential to improve the imaging output.

ANALYZER-BASED IMAGING

In the procedure known as analyzer-based imaging (ABI), the arrangements are made up of two silicon crystals that are ideal. By positioning itself in front of the imaging object, the first crystal performs the function of a monochromatic-collimator, therefore creating plane waves that are directed towards the imaging object. As the x-ray beam travels through the item, it is redirected as a result of optical refraction and attenuated as a result of absorption and scattering inside the medium. The second crystal, which is a crystal analyzer, is situated behind the object on a revolving cradle (Figure left). It is positioned in alignment with the beam propagation direction in accordance with crystal Bragg4 or Laue angular diffraction, which is why this technique is also known as Diffraction-Enhanced Imaging (DEI). The full width at half maximum (FWHM) of the rocking curve of the crystal is what determines the crystal diffraction properties, also known as the angular acceptance (Figure right). Therefore, the crystal functions as an angular filter, "filtering off" all scattered x-rays. This is because the crystal Bragg diffraction condition is not satisfied by the deflected angles of the scattered x-rays. As a result, the detector can only receive a narrow spatial frequency bandpass ($\lambda = 2d\ sin\theta$, where **R** is a crystal d-spacing and θ is the incident angle) (Figure).

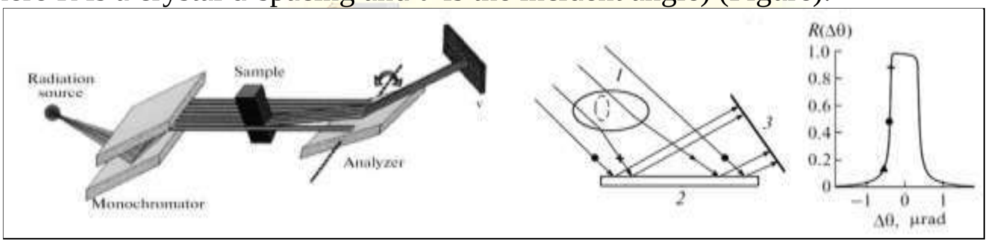

Figure: An explanation of the crystal's "rocking curve" is shown in the left-hand picture of a schematic representation of an analyzer-based PCXI imaging setup

Signals resulting from absorption, scattering, and refraction are all included into the attenuated intensity profile that was obtained. The information contained in this profile pertains to the interaction processes that take place within the item as a function of the crystal angle. Within a few microradians of the slope of the rocking curve of the crystal in reference to the incident beam, it is feasible to detect non-deviated, refracted, and scattered radiation by altering the angle of the analyzer.

THE MFCA-NET TECHNIQUE

MFCA-Net is a technology that is defined as a modified form of the DMSAN approach. The fundamental architecture of the UNet is used as a foundation for this system, nevertheless, it has an original encoder design and improved skipconnection characteristics. To begin, the encoder architecture is modified in order to extract the multiscale features and channel-wise attention approach that are used in the process of updating the features in the skip-connection configuration. By widening the cumulative receptive field of CNN, the multiscale features that are recovered with the help of the Res2Net (R2N) backbone layer, have the potential to represent the multiscale information of the object at a more granular level. It is the multiscale R2N backbone layer that is used to represent the multiscale features, as opposed to the convolution approaches. Following this, the deconvolution operation is utilised in order to reconstruct the low-level multiscale characteristics of the upcoming stage. On the other hand, nonlinear Relu activation is carried out by making use of the high-level features that were obtained from the stage that came before it. This ultimately results in the rich semantic information abstraction which is present at every level.

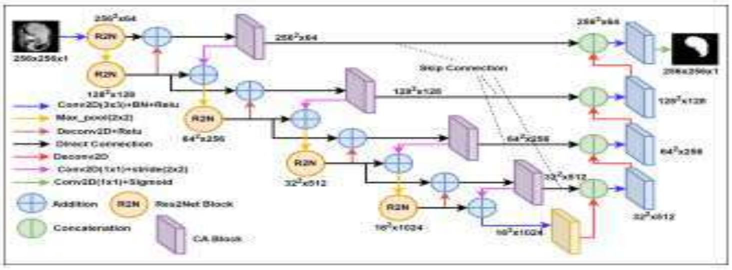

Figure: MFCA-Net architectural proposal

Furthermore, the updated CAB features include significant high-level information that is blended once again with the low-level multiscale features. This is accomplished by using a (1×1) convolution filter with Relu activation, which enhances the contextual details of the low-resolution features. As a consequence of this, the low-resolution feature fusion facilitates an improvement in the learning capabilities of the consecutive network layers. These novel changes not only improve the encoder's capacity to represent high-level and low-level properties, but they also create a wealth of contextual and semantic information pertaining to the hepatic region. Additionally, the network's potential for learning and generalisation is strengthened as a result of these many changes.

CONCLUSION

The fundamental heuristics of fused feature recalibration using the SENet, high-level feature fusion, and local feature reconstruction were used in the presentation of HFRU-Net. This approach harvests the high-level information that is available during the encoding phases and enriches the feature representation in the skip connection. The goal of this technique is to improve the decoder's ability to reconstruct the segmentation map. In order to improve the speed of the network's segmentation, the multiscale ASPP module is additionally used in the bottleneck layer. This is done in order to extract more semantic information from the low-resolution feature map. The usefulness of the model is validated by the utilisation of the LiTS challenge dataset as well as 3DIRCADb. With the use of the 3DIRCADb and LiTS datasets, the HFRUNet was able to obtain a DSC performance of 97.3% and 96.8% for liver segmentation, and 77.9% and 77.4% for tumour segmentation. The tumour burden estimate was calculated using the 3DIRCADb and LiTS datasets, and it was found to be 0.0271 and 0.0345, respectively, in terms of RMSE measures. In addition, the network carried out tests on the 70 CT volume independent LiTS test dataset. The results showed that HFRU-Net obtained a GDC of 95.0% for liver segmentation and 61.6% for tumour segmentation. RMSE for the tumour burden measure was calculated to be 0.052, as was obtained.

FUTURE SCOPE

With the research work that was performed for the thesis, there is potential to build on the principles that have been addressed here in order to develop advanced automated approaches for segmenting the liver and tumours. This list contains potential avenues that might be pursued in order to do more study on the topic:

1. The scope of the research may be broadened even further if data were collected from a variety of hospitals in India for the purpose of segmenting and classifying diseases that are specific to the liver. These diseases include fatty liver, liver cysts, and primary and secondary liver cancer.
2. The scope of the research might be broadened to include an examination of the patient's performance throughout treatment, as well as their survival and recovery from liver cancer.
3. The research may be broadened to include the separation of the liver tumour from the individual Couinaud segments. This would allow for the development of a liver resection that would involve the least amount of invasion and would also allow for the prediction of the stages of liver cancer.
4. It is possible to research the study in order to generalise the recommended techniques for segmenting other medical imaging applications, such as organs, multiorgans, vasculature, and cancers from various organs. This may be done by using a number of medical imaging modalities.
5. Improvements in liver and tumour segmentation performance might be achieved by extending the scope of the research via the use of post-processing techniques.
6. The tactics that are described in the thesis may be utilised to construct successful segmentation systems for general computer vision challenges, in addition to medical imaging applications. This can be accomplished by adjusting the different learning algorithms and data processing pipelines.

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