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A Survey on Medical Imaging Techniques and Applications

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Abstract

Medical imaging is a technique that is utilized for medical purposes, to visualize the internal organs covered by the skin and bones, in order to diagnose and cure disorders. It is a branch of biological imaging that includes radiology, which employs imaging technologies such as X-rays, MRIs, CT scans, PET scans, ultrasound, and many others. It also creates a database of normal physiology and anatomy to aid in the identification of anomalies. This research study examines several medical imaging technologies and their applications. A discussion about the evolution and potential advancements of medical imaging has also been presented.

Keywords: Medical images, image processing, pattern recognition, segmentation, classification

1. Introduction

German professor of physics, Roentgen discovered radioactivity and X-rays in the 18^{th} and 19^{th} centuries in medical imaging technologies [1]. The area of medicine has substantially advanced as a result of these breakthroughs. In the mid-twentieth century, advances in sound wave technology has facilitated the introduction of ultrasound in medicine. After computers entered in the medical field, its extensive use of healthcare, sonography and nuclear medicine technologies were utilised as diagnostic medical imaging modalities or instruments. As a result, imaging technology's existence was heavily reliant on computational skills employed in MRI (Magnetic Resonance Imaging) and CT (Computed Tomography) scans.

The growth of medical imaging has resulted in the creation of new technologies that can address developing concerns. Computing has simplified imaging technology in the

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medical area, which requires a huge number of images created in the radiology profession. All types of images are digital and consist of huge data files. The process of maintaining a massive number of photos is complex. As a result, different technologies have emerged to deal with such a massive volume of photos.

The introduction of PACS (Picture Archiving and Communication System) allows for the integrated storage and viewing of medical images from diverse devices and systems. In the PACS server, the images are stored in DICOM (Digital Imaging and Communication of Medicine) format. The traditional X-rays are being replaced rapidly by CT scans which combines the power of computer with X-ray imaging. The CT scanners take the images in different ways. Advanced version of CT scanners reduces the thickness of image slice and the spiral CT scanners that are arrived, largely reduces the image acquisition time.

The majority of medical imaging is done for diagnostic purposes. Plain radiographs and CT scans aid in the detection of fractures, cancers, lesions, and bone abnormalities on the spot. Medical imaging also helps with treatment planning by allowing surgeons to see the scope of operation ahead of time. Surgeons also use medical imaging technologies to do virtual surgery, whether directly in software or after exporting and producing stereolithographic models.

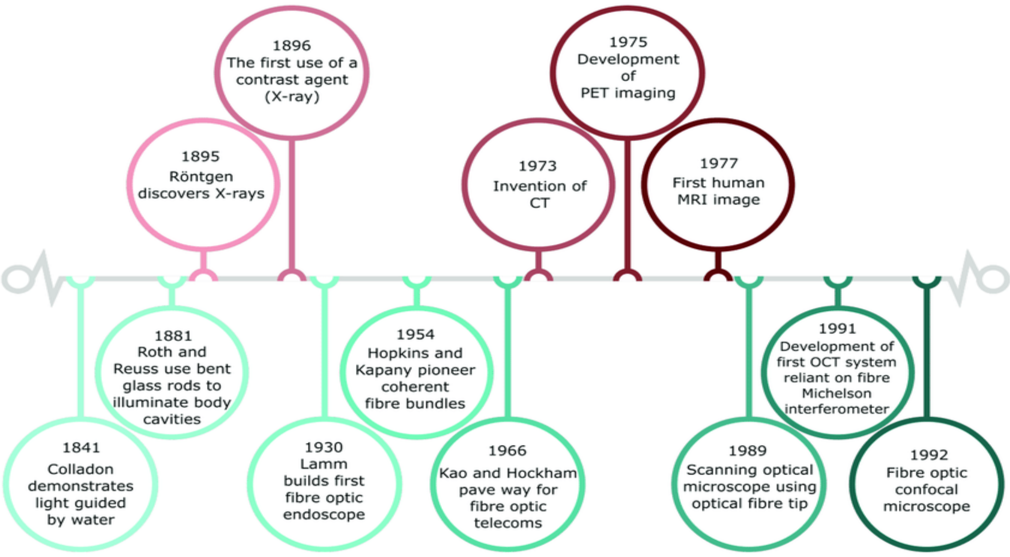

Figure 1. Timeline of Medical Imaging [1]

1.1 Different Techniques in Medical Imaging

Medical Imaging comprises a variety of scientific and diagnostic techniques such as X-rays, ultrasound, Computed Tomography (CT), Magnetic Resonance Imaging (MRI), Positron Emission Tomography (PET), and others. Some imaging techniques, processes, and applications have been presented.

1.1.1 X-rays

In the electromagnetic radiation, X-rays are a big sort of high radiation. The wavelengths of X-rays are lower than UV rays and higher than gamma rays. Wilhelm Conrad Rontgen, a German physicist, discovered X-rays on November 8, 1895. It is commonly used to check for fractures (broken bones). It is also beneficial in a variety of ways, such as chest X-rays to detect pneumonia, and mammogram X-rays to detect breast cancer. The first use of X-rays was to radiograph a needle inserted in the hand in 1986, and in the same year, a surgical procedure was performed utilising X-rays. Marie Curie created radiological automobiles to aid soldiers during World War I in 1914. From the early 1920s until the 1950s, X-ray devices were created to aid with shoe fitting. In the 1950s, the X-ray microscope was invented, and the Chandra X-ray observatory followed in 1999. It catches galaxies, stars, black holes, neutron stars, and other objects.

Figure 2. X-ray scan of chest [2]

1.1.2 CT scan

A CT scan is a medical imaging technology used to produce comprehensive inside pictures of the body. CT scanners employ a revolving X-ray tube and a gantry, to assess the scattering of X-rays by different tissues inside the body. Multiple measurements acquired from various angles are processed in a computer using a tomographic reconstruction technique to create tomography pictures of body. It can also create pictures of non-living items. Allan M. Cormack and Godfrey N. Hounsfield were awarded the Noble Prize in Physiology or Medicine in 1979 for "the creation of Computer-Assisted Tomography." Not just in the medical area, but also in industries, Industrial CT scanning is a procedure that uses

X-ray technology to depict components in 3D both outwardly and inside. CT scanning has also found use in transportation security. In geological research, X-ray CT is employed.

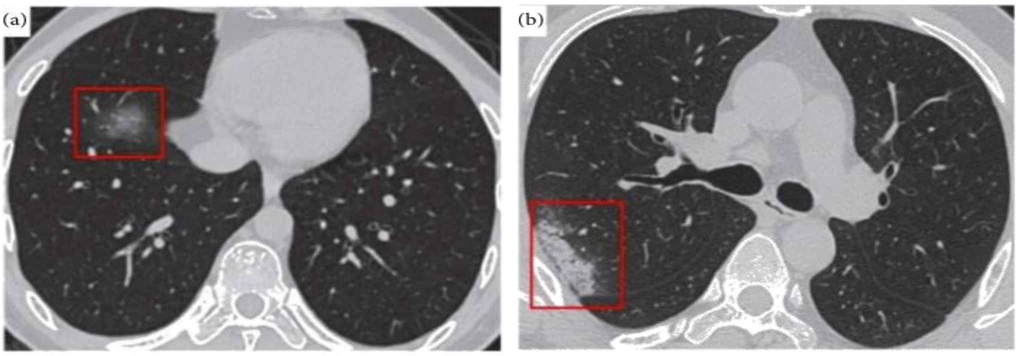

Figure 3. A CT scan in right lower lobe [3]

1.1.3 MRI scan

Magnetic Resonance Imaging examines the organs and its structures of the body using a combination of magnetic and radio waves. In the medical world, MRI scans are used to diagnose everything from injured ligaments to cancers. Examining the brain and spinal cord is really beneficial. MRI, as opposed to CT, that it gives contrast in pictures of soft tissues. MRI, which was developed in the 1970s and 1980s, proved to be a flexible imaging method. Its primary applications are in diagnostic medicine and biological research. Neuronal fibers and blood circulation in the nervous system are captured using diffusion MRI and functional MRI. It's also a research tool for neurological tumors.

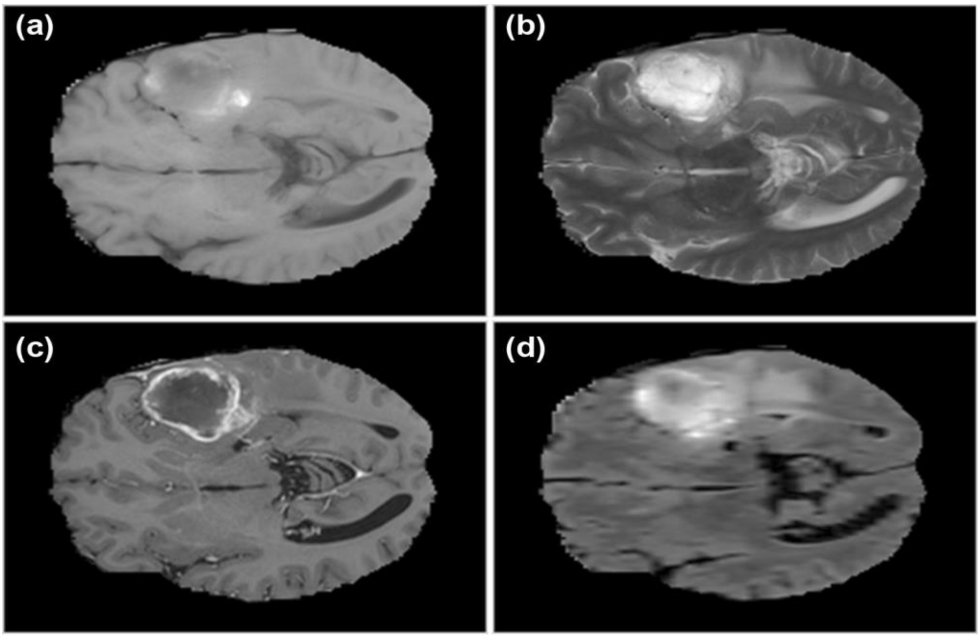

Figure 4. Brain multi-modality MRI images [4]

2. Literature Survey

To prevent separation, David Mata-Mendoza et al., [5] recommended using a hybrid and resilient watermarking technology to certify medical images. The quantization index, in combination with the modulation technique, was used to avoid separation by embedding robust-imperceptible information. The visible-imperceptible watermarking paradigm utilised in medical pictures was used to implant a second watermark in a spatial domain to accomplish authentication. As a result, hybrid digital watermarking combined the two visible-imperceptible and robust-imperceptible properties to avoid disconnection between EPR and medical pictures. Additionally, it performed DICOM image authentication. During the reveal stage, the image source's branding may be seen with the naked eye. Finally, the performance of the suggested method was compared to confirm its contribution. It stood out among the suggestions in terms of toughness and imperceptibility. The embedding strategy would be improved in future work without harming imperceptibility and resilience, as well as other DICOM technologies such as Computed Radiography (CR), MRI, and so on.

Dimitrios Kollias et al., [6] introduced the COV19-CT-DB for COVID-19 detection database, which includes around 7,700 chest 3D CT images. This database contains COVID-19 instances classified according to four COVID-19 severity criteria. He then divided the database into test and validation sections. The first two datasets were utilised for machine learning model validation and training, the third dataset for model assessment. Using the deep learning technique, a CNN-RNN network was built and its results were submitted to the COV19-CT-DB database. The purpose of this study was to propose a baseline approach based on the performance of the examination of COV19-CT-DB diagnostic of the database. The concept was predicated on the future growth of COVID19 diagnostic transparency.

The article [7] presented a standard extraction approach of medical events for the removal of tumor event characteristics. It described the pseudo-data-generation procedure, which is based on the substitution of crucial data and increased the model's migrating learning capacity. In comparison to the CCMNN approach, a significant number of trials on the CCKS2019 and CCKS2020 datasets were conducted. The research goal was accomplished by enhancing the performance of size removes. The pseudo-data-generate method utilised in this article has a high degree of randomization, therefore the created algorithm does not always harm the semantics modal. The semantic substitution was researched on the pseudo-data-generation algorithm in order to increase its quality and performance. This study came in third place in the CCKS2020 electronic medical event assessment challenge and clinical medical event extraction.

Shan Liu et al., [8] discussed the advantages and disadvantages of 2D/3D medical picture registration based on normalised cross-correlation. To solve the normalised cross-correlation, the registration accuracy is rather poor. In the article, the enhanced normalised cross-correlation method was employed. It boosted the edge information, internal details, and added the angle of the gradient vector by employing the alternative operator with the better method. According to the findings of the experiments, the revised normalised cross-correlation method has a greater registration accuracy. In the future, DRR pictures will be created continually with the 2D/3D registration model, which will consume a significant amount of time. DRR is related to graphics rendering, thus using GPU to expedite, process, and optimise the computation performance of the registration model will be considered. Researchers presented a defence to strengthen the Deep Neutral Networks (DNN) and identify hostile samples. Moshe Levy et al., [9] proposed better methods for defending the healthcare DNN from assaults by hardening the system's security and employing digital signatures. It assists medical practitioners and healthcare providers in developing a comprehensive understanding of the hazard posed by hostile samples in image analysis. It also assists medical researchers in avoiding traps such as attackers launching useless attacks, and PACS administrators in making educated decisions to protect their network from potential threats.

Chethana Sridhar et al., [10] described an image compression approach for medical images that employs a recurrent neutral network. This network employed a new picture compression approach known as GenPSOWVQ, which combined GenPSO with wavelet VQ. By combining segments with a genetic algorithm to create a codebook, PSNR, MSE, SSIM, RMSE, SNR, and CR indicators were used in real-time medical imaging to test the proposed system. According to the experimental findings, the suggested GenPSOWVQ produced greater PSNR, SSIMM values, and lower MSE, RMSE, and SNR values for the reduced ratio than the current values. The objective of establishing ideal values will be realised in the future.

Uncertainty qualifications are key elements that undermine confidence in AI. Recent advancements in black-box model dependability have assurances on arbitrary data. The work of Charles Lu et al., [11] was used in these uncertainty qualifying models. It was especially conformal in the prediction of the condition of spinal stenosis in lumbar spine MRI to the deep learning model. They employed a formal prediction set approach to include accurate stenosis severity with user-defined probability. By qualifying a rise in substantial imaging abnormalities, the possible clinical ability and strong uncertainty forecasts may be investigated. The work encourages more research into the unreliability and utility of machine learning systems for healthcare applications. The article [12] proposed a self-supervised form aware mask creation approach using image pseudo-segments. Both the shape and placement of the mask are taken into account in the mask generating model. The square shape mask was widely used for pseudo-segment forms. The location of the masks was in the confined region of the organ for the model's reconstruction performance. The shape also has a significant impact on reconstruction performance. As a result, the mask's location and form will correspond to the image's shape. Finally, the age for mask creation performed better than square and uneven masks. The dataset of created pseudo-generation masks was regarded a substitute for the square and uneven masks in the job of medical picture inpainting.

Aya Hage Chehade et al., [13] used machine learning that utilized feature engineering to categorise histopathological pictures in order to identify different types of colon and lung cancer. The feature sets were collected for picture categorization. The obtained features were combined into a composite feature set that was put into machine learning techniques. The use of computer algorithms based on machine learning and feature engineering to evaluate data and gather key information was beneficial in the medical industry for rapid and accurate tumor identification. It will be difficult to understand the data if a deep learning black box network is deployed. As a result, the authors applied machine learning to improve the interpretability and ease of study of colon and lung cancer using pictures. The data and task features of cardiovascular medical pictures were investigated in paper [14], and the edge region removal was solved utilising the image ring mosaic approach. Depending on the task requirements, a cooperative training network was proposed. The weighted loss function method was introduced, which improved the network performance while aiming to correct imbalances in analysis of medical images. By using cardiac imaging data to overcome several difficulties, the system demonstrated the chance of lesion localisation under weakly supervised situations. The experimental findings confirmed that the suggested deep learning-enabled approach can handle the issues with the least amount of changes to the highlighted infrastructure. Furthermore, SE and SA modules were introduced to improve the efficiency of CAM detection, as well as the fundamental network model's performance can be applicable everywhere.

Table 1. Medical Imaging – Techniques and applications

Reference Name	Applications	Techniques	Future scope	Outcome	Benefits
Mata-Mendoza et al. [5]	*Hybrid & robust watermarking scheme	Quantization index modulation algorithm	Outstands robustness & imperceptibility	Avoids separation	DICOM images in original greyscale
Dimitrios Kollias et al. [6]	*Deep learning *CNN-RNN network	Created COV19-CT-DB	Using database, perform the COVID-19 diagnosis.	Based on COVID-19 CT DB, achieves Baseline approach.	Transparent COVID diagnosis
Gaurav Dhiman et al. [7]	Electronic medical record [CCKS2019 & CCKS2020]	Pseudo-data-generation algorithm	*Improve performance and quality.	Improves tumor size extraction	*Won 3rd place in clinical medical event * Improved performance and quality.
Shan Liu et al. [8]	Normalized cross-correlation algorithm	*Gaussian Laplacian operator *LOG operator *Sobel operator *Multiresolution strategy	Using DRR images, *consume time *computational speed detected	Improved normalized cross-correlation has higher accuracy.	*Higher registration accuracy *Consume time *Computational speed
Moshe Levy et al. [9]	Deep Neutral Networks (DNN)	Adversarial samples	Secure network from attacks.	*Harden security *use of digital signatures	*Understand threat in image analysis. *Avoid pitfalls
Chethana Sridhar et al. [10]	*Recurrent Neutral Network *GenPSO	GenPSOWVQ	*Advanced using ambiguous logic. *Creating optimal values	*Higher values in PSNR, SSIMM *Lower values in MSE, RMSE, SNR	New method GenPSOWVQ was introduced.
Charles Lu et al. [11]	Deep learning	Black –box model	Future studies on *Trustworthiness *Utility of ML	Automated stenosis severity	*Reliability free distribution
Yousef Yeganeh et al. [12]	*Shape aware mask generation *Deep learning	*Pseudo-segments *Superpixel over-segmentation algorithm	Pseudo segment masks substitute to medical inpainting mask	Correlate with shape of image *Mask position *Mask shape	*Higher performance *Considers shape & location of mask
Aya Hage Chehade et al. [13]	*Computer-Aided diagnostic system *Image classification	*Machine Learning *Feature Engineering	*Improve performance *Better interpretability	To identify the types of lung & colon cancers.	XGBoost model's best performance, *accuracy – 99% *F1 score – 98.8%

Panjiang Ma et al. [14]	Deep learning	*Convolutional Neutral Network *Segmentation algorithm.	*Improve the performance *CAM detection *Basic network model	*Resolves capacity *Small changes.	Increases, *Diagnostic accuracy *Decision making ability

3. Conclusion

Medical images are mostly important in the medical profession. The evolution of medical imaging is dependent on computing speed and technical advancements in deeper visibility of fundamental cell level. Many strategies are applied in various ways, which aids in the continuous learning of new hidden objects. AI and ML will be used more and more for medical analysis and diagnosis. This survey research addresses medical imaging techniques, applications, and uses, as well as its future participation in many ways. Future medical imaging technologies may include Digital Twin, the OpenSight AR system which was before the surgical planning tool certified by the US Food and Drug Administration, i.e., 3D printed models which are valuable for patient education and preparing doctors for surgery and so on.

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