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Influence of Artificial Intelligence for Diagnostic Decision making using Radiological Imaging

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Abstract

Artificial intelligence makes lesser human intervention for binary and multi-class decision making which is suitable for the availability of medical data due to the improvements in image acquisition technique. Moreover, the accuracy of prediction and automatic decision making is appreciated. Hence we focus this review on the application of AI for radiological decision making. Initially different radiological techniques are introduced on the science behind imaging the internal body parts and their application for disease diagnosis. Further emphasis on the sequentially flow of decision making after image acquisition is discussed. We hope the application of AI into radiology reduces the human intervention for diagnosis of disease and provide suggestions on further treatment for the condition.

Keywords: Radiological technique; Artificial Intelligence; Opportunities; Challenges.

1. Introduction

Artificial intelligence is a branch of computer science that deals with the constructing smart machines that are capable of performing complicated tasks that usually require human intelligence. It is an interdisciplinary science that has a multiple approach to all the fields. This advancement that has risen out of the artificial intelligence has created a paradigm shift in almost all the sectors of the industries, especially where technology is concerned. It is considered as an endeavor that is designed to replicate and perform human like tasks by the machines. In the medical and health care field, the advance in the computational power and the enormous amount of data that has been generated in the health care sector has advanced the implementation of artificial intelligence. Some of the potential applications include detection of any abnormalities in the tissues, heart rate and blood pressure detection, imaging of biopsy of tissues etc [1]. The artificial intelligence is capable of evaluating both numerical and image-based data. In terms of medical applications, these algorithms from the diagnosis of the artificial intelligence are equivalent to a physician's performance in terms of value and ability.

Using medical images for the diagnosis and treatment in human and animal bodies are regarded as radiology. The radiology involves in variety of techniques such as ultrasound, computed tomography, positron emission tomography, magnetic resonance imaging, x-ray radiography etc.

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With the help of these diagnostic images, the radiologists and the physicians would be able to detect and treat disease. The radiology can be either diagnostic radiology or interventional radiology. The diagnostic radiology helps the physicians and the health care workers to examine and visualize the structures of our body. They usually help in diagnosing a part of the body, monitoring how well the body is responding to a medication or a treatment, and helps in screening of different illness. The interventional radiology helps in guiding procedures. Radiological methods such as CT, MRI, X-ray, ultrasound, fluoroscopy are used by the doctors when inserting a catheter, or any other small instruments into the body. Additionally, they are also helpful in making any small incisions such as cuts inside the body for treatment procedures [2]. The examples include, tumor ablation, feeding tube replacement, breast biopsy, embolization that controls bleeding, vertebroplasty and angioplasty and so on.

The imaging is necessary due to its ability to detect the diseases, very early and helps in improving the chances of survival. For instance, lung computed tomography enables the detect the tumors that are as small as the grain of a rice. It also helps in colon and breast cancer detection. The radiology has improved over the time than it has been once introduced. It has branched off into many specialties and subspecialties such as pediatric radiology, emergency radiology, women's imaging, musculoskeletal imaging and others. The possibility of 3D and 4D technologies are being explored. The sensitivity and the anatomical details of these radiology techniques are steadily increasing.

2. Imaging Techniques

2.1 X-Ray

The X-rays are the most common and most widely used imaging technique. It is also one of the preliminary tests that have to be done before exploring the other tests. In this technique, the part of the body that is images is positioned between the x-ray machine and the photographic x-ray sensor. The x-ray machine sends out electromagnetic radiations which travel throughout the body revealing the structure of the film. The level of radiation employed in the x-ray techniques is usually not harmful. Bones, tumors and calcifications might appear dense and white because they absorb the radiations and blocks them from travelling further. Lesser dense and soft tissues and certain breaks in the bones enable the radiation to pass through them, thus appearing darker in those x-ray images. Several angles are fixed and the image scan be taken. In certain cases, some contrast agents or dyes can be injected and then the x-rays can be taken. This also helps in detecting the needle replacement in the joint when the fluid is eliminated or taken out. This procedure is called as arthrogram that helps in outlying the joints of the structures [3]. However the most common problem associated this technique is the x-ray cannot produce most detailed images which has high resolution (Figure 1a).

2.2 Ultrasound

The ultrasound scan uses sound waves of high frequency that are sent inside off the body and can be echoed off the body. This procedure is usually non-invasive and painless and thus does not require any radiation.it can be used during pregnancy also. They are used to assist in certain types of biopsy also. This technique is mostly used for analyzing and detecting the blood clots, bakers cysts, tear cuffs in the shoulders, in the back of the knee etc. It can also be used to examine liver, kidneys and other organs such as tummy and pelvis etc. It is usually sought for examining the heart and also an unborn baby in the womb. A gel that is lubricating is applied on to the skin and a small handheld probe is used to move over the skin surface. The types of the scan include endoscopic ultrasound scan, internal scan etc. the ultrasound has minimal to no side

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effects and no known risks are associated with the ultrasound techniques. Another advantage of this technique is that no special preparation is necessary for this kind of procedures [4]. Unlike other techniques, these do not involve in radiation. But in the case of endoscopic scan, temporary side effects such as sore throat and bloating are reported. In this type of scans, internal bleeding is also associated (Figure 1b).

2.3 Magnetic Resonance Imaging (MRI)

The magnetic resonance imaging is used in applications where highly detailed images of the internal structures are required. The hydrogen atoms that are plenty in the tissues are kept in the strong magnetic field which is then excited by the resonant magnetic excitation pulse. These hydrogen atoms inherently have a magnetic moment which arises as a result of their nuclear spin. Proper simulation of the electromagnetic radiation can help in orientation of the nuclei in the partial or complete alignment to the applied field. These signals are then detected by the system which then used to generate the image. These MRI scan can be used to detect and image the parts of the bodies such as head, joints, legs and abdomen. They are helpful in producing better soft tissue contrast than the computed tomography technique. This technique can differentiate between muscle, water, soft tissue and fat. The benefits of this technique are they do not involve radiations and they are non-invasive. The contrast agent involved in this technique is less likely to produce an allergic reaction [5]. The disadvantages of this MRI technique are that they could lead to heating of the body due to the radiofrequency energy used. Twitching sensation in the peripheral tissues and nerve simulation are also one of the potential side effects arising from MRI (Figure 1c).

2.4 Computed Tomography (CT)

This technique combines X-ray with a computer technology which then enables to provide more detailed and cross-sectioned images of the body. It helps in capturing the position, size and shape of the body such as organs, tumors and tissues. This process is usually pain-free. An x-ray tube is made to slowly rotate around a patient who is undertaking a scan and the pictures are imaged from all the directions. Then the system associated with the technique combines all the images to produce very clear, two- dimensional images of the organ on the TV screen. The body parts such as brain, spinal cord, abdomen, chest, and pelvis can be used to examine with the help of a CT scan. This CT scan has the advantage of short study time which spans over 15- 20 minutes of duration to produce high-quality images in general. This is mostly adopted due to its accuracy, painless and non-invasive technique [6]. However, the disadvantage of this technique includes the need for the contrast and radiation agent in most cases, especially in the patients affected by the kidney problems. Additionally, this technique includes the usage of ionizing radiation technique, which can cause any damage in the DNA leading to development of cancer in the long- duration exposure (Figure 1d).

2.5 Positron emission tomography (PET)

Positron emission tomography scan is the technique that helps in the imaging of the functioning of the organs and the tissues. It utilizes a radioactive drug which is called as a tracer that helps in the diagnosis of the functions. This scan is reportedly helpful in detection of the disease prior to the detection of the abnormality by any other technique. The radioactive tracers are usually swallowed, injected or inhaled into the vein that is present in the arm and it is completely dependent upon the area of the body being imagined. When they are detected by the scanner, the functionality of the tissue or the organs are evaluated. The areas that are high in the chemical activity collect the tracers due to the problems associated in the organs that enable them to have higher chemical reactivity. Thus it can be used to detect and measure the oxygen flow, blood

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flow, sugar and other criteria present in the functioning of the organ. This is conventionally an outpatient procedure. The problems associated with heart, brain and the nervous systems are detected by this method. This technique is capable of tracking very early changes in the abnormalities of the body parts [7]. However, the risk involved in this type of technique involves allergies, bruising due to the needles, bleeding, swelling and possible kidney malfunctions. It is also not considered safe for the fetuses and the pregnant women are forbidden to access this technique (Figure 1e).

2.6 Scopy

The scopy technique includes capsule technology, endoscopic retrograde cholangiopancreatography, chromoendscopy, endoscopic ultrasound, endoscopic mucosal resection, narrow band imaging, endoscopy and much more. They help in view and operate the internal organs and vessels. They help in performing the key-hole surgery. It delivers detailed images and has proven to be incredible in many medical surgeries. The endoscopic areas can be done in the areas such as gastrointestinal tract, respiratory tract, ears, urinary tract, female reproductive tract etc. They help in investigation, confirmation and diagnosis of these areas. This endoscopy is usually performed when the patient is conscious and the patient will receive a local anesthetic and mostly sedation is often administered. The functional disease such as gastrointestinal tract cannot be detected by this method [8]. The potential side effects of the methods include reaction to sedation, infection, bleeding, perforation and pancreatitis.

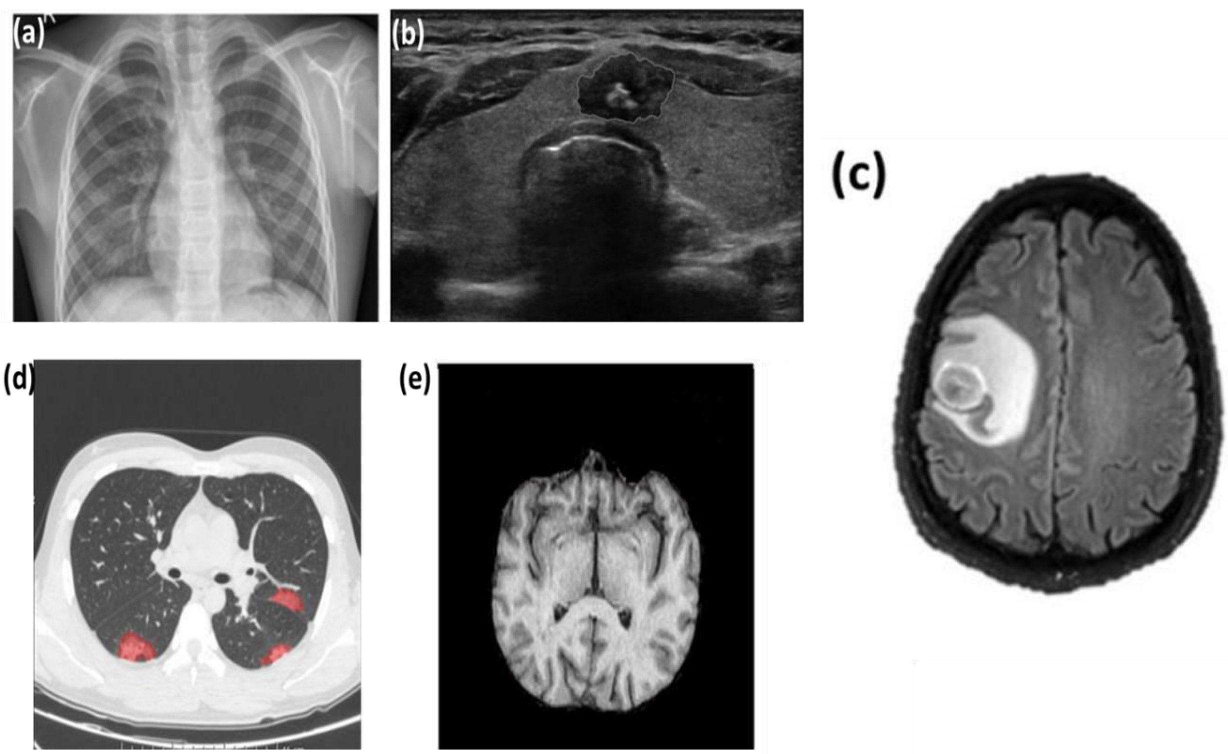

Figure 1: (a) Chest X-ray [3], (b) Thyroid Ultrasound [4], (c) Metastases MRI [5], (d) CT image [6] and (e) PET [7]

3. Artificial Intelligence

There are four sub-sections on making decisions for the diagnosis of disease using any of the above-mentioned imaging techniques.

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3.1 Image Preprocessing

The preprocessing is the method of operations of the images at the lowest level of abstraction. Both the input and out are the intensity images.

3.1.1 Pixel Brightness Transformation

The brightness transformation involves in transformation of the pixels. The properties of the pixels are the major factor in the transformation. Brightness transformation involves in two classes such as grey transformations and brightness transformations. The brightness transformation is done by modifying the pixel brightness by considering for the factors such as original position and the brightness of the images. Conventionally, the sensitivity of the acquisition and the digitalization of the image should not be depending upon the factors such as position of the image, but in practical cases, this assumption is not valid. The linearity of the transformation is assumed in the brightness transformation method, and sometimes the brightness scale is limited. The grey transformation involves in changing the brightness of the images without the regard to its original position of the image. Digital images have a very limited amount of grey levels thus the grey scale levels are little easy to realize either in hardware or software. 265 bytes of memory are required for this technique [9]. The image signal is generally passed through in image displays thus enabling simple grey scale transformations in real time applications. This exact principle is used in the color displays. If the contrast is enhanced, the transformed images are more easily interpreted.

3.1.2 Geometric Transformation

In image analysis and computer graphics, geometric transformations are often employed. When an image is captured, a number of geometric distortions occur and they can be eliminated by the geometric transformations. When two different images are attempted to be matched, the geometric transformation is required. 2D geometric transformations are considered sufficient for digital numbers. A good example of geometric transformation is the attempt to match an image taken before a year and after a year and both of them do not match in position preciselyit is mandatory to execute the geometric transformation and then subtract the one image form the other. This geometric transformation involves in two steps such as pixel co-ordination transformation that maps the input image's co-ordination of the input image to the output image. The second step involves in identification of a point in the digital raster that then matches the transformed point to match its brightness points [10]. It is generally computed as interpolation of all the points in the neighborhood. This geometric transformation enables the preprocessing techniques, and only the pixel in the neighborhood is required for the classification. The boundary between the point and the local operations are regarded as the geometric operations.

3.1.3 Image Smoothing

Frameworks of local preprocessing methods that are intended to suppress the image noise are called as image smoothing. In the image data, it employs redundancy. By averaging the brightness of these values in the neighborhood, smoothing is enabled. It is based on the common idea that from the points in the neighborhood that exhibits same properties to the processed points, average is computed. But when smoothing is performed the sharp edges of the images are blurred and the smoothing methods that preserve the edges are often opted for smoothing. Averaging of the images in the neighborhood with many noises is employed in many cases.

Impulsive noises, degradations that look like thin stripes can be effectively eliminated by the local smoothing methods. But this method may not effectively work on the large blobs or thick stripes. When image restoration techniques are utilized, the complicated degradation of the

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images can be inhibited. When the noises in the images are smaller in size than the object of the study, the results are good [11]. One of the main serious disadvantages of this technique is blurring of the edges and the images. Most alternative techniques are aimed at overcoming the blurring of the edges and they are non-linear operations.

3.1.4 Image Sharpening

The motive of the image sharpening is to mark the edges and the corners steeper. The sharpened image is intended for human visualization. The frequency domain helps in the interpretation of the image sharpening. Laplace technique is much often employed for this technique. Combinations of harmonic functions such as Laplace results in higher frequency, the higher magnitude of its derivative. A similar technique called unsharp masking is utilized in the industrial applications such as printing. The gradient operators that are sheer measure of the edge sheerness can be categorized into three main sections such as operators approximating derivatives of the image function using differences, operators based on the zero crossings of the image function second derivative, and operators which attempt to match an image function to a parametric model of edges. Laplace operator, Prewitt operator, Robert operator, sobel operator, robinson operator, kirsch operator is the variety of operators proposed and employed in the image sharpening techniques. Individual gradient operators, examines small local neighborhoods and can be expressed by convolution masks [12]. Operations that are able to detect the edge directions can be represented by collection of masks, each corresponding to different directions.

3.1.5 Edge Detection

A collection of mandatory local pre-processing methods that are used to locate the sharp edges in the intensity function is referred as edge detection. This function changes abruptly in the edge pixels. This edge is a fundamental property that is attached to the individual pixel. It can be calculated from the behavior of image function in a pixel's neighborhood. Two vector components such as magnitude and direction are the vector variables. The magnitude of the gradient is the edge gradient and the direction of the edge is usually rotated with respect to the gradient direction from Ψ- 90 degrees. This gradient direction enables the direction of maximum growth of function. To find the region boundaries, edges are often employed in the image analysis [13]. The condition includes region should have homogeneous brightness and the pixels where the function of the image varies. And in the ideal case, the pixels should consist without noise and with high edge magnitude. Roof edges are employed for the objects with the thin lines in the images. The edge detectors are conventionally tuned for certain types of edge profile. A Laplacian or linear differential operator is used when the edge magnitudes are required without regard to their orientations.

3.2 Segmentation

3.2.1 Obsolete technique

The obsolete technique for the segmentation of the images was first developed in the late 1900s but now it is not currently employed widely. The multi-resolution methods involves in adjusting a lot of glitches and are resolution appropriate. There are many methods and models such asmulti resolution methods, deformable models, coupled surface, and geodesic minimal math. A robust estimation of the image estimation can be addressed using this multi-resolution method. A deformable model describes the boundaries of any objects and it has been extensively used in the segmentation of the anatomic parts, in the images that are obtained for medical examination.

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During the deformation, the internal forces derived from the curve of the surface helps in smoothing the curve [14]. The coupled surface helps in segmenting the volumetric layer which is of the limited wideness that are faced in the medical imaging techniques. In geodesic minimalistic path, the computation is done on the basis of the arguments that are dispersed in the appearance.

3.2.2 Ancient Technique

The ancient techniques are old but are still widely used in many applications. These techniques includeregion-based segmentation, automatic and semi-automatic segmentation, target tracking, markov random field approach, graph cut approach, appearance models, atlas based segmentations. These are simple yet powerful techniques and can be categorized into local and global thresholding. Global threshold works by separating an image with one threshold. Local threshold functions depend on the sub image's local characteristics. The selection of the threshold is basically dependent upon the size, histogram, shape, separation of class and posterior entropy of the images [15]. For the pixel labelling, the contribution picture's feature are excerpted from the segmentation. For the appearance of spotless, supple images graph cuts are involved. To convert artless and confined segmentations, both boundary and regional information are used. For the images that are segmented with no well-defined boundaries, that distinctly separates between the region and the pixel intensities, atlas-based segmentations are used.

3.2.3 Recent Technique

These segmentation techniques are very new in medical imaging studies and diagnosis. These images have few uncertainties and unpredictability. To deal such uncertainties, intelligent techniques such as neural network, fuzzy set, artificial intelligence, intuitionistic fuzzy set etc. in medical imagings are used by the researchers. The segmentation techniques are huge in number such as active shape model, artificial neural network segmentation, and segmentation using artificial intelligence, and clustering. The active shape model involves in distorting the previously established ad existing object into a new image. While segmentation is done with the artificial intelligence, a raw input image is used and segmented into non-overlapping regions. When these images are homogeneous, the union of any two segments results in heterogeneous images. Clustering involves in the integration of the segments. Various data points in a cluster can be coupled by expectation maximization. The limitations of the lustering include statistical representations [16]. To overcome the limitations, intuitionistic fuzzy c-mean technique was developed. These concepts are then successfully incorporated in the medical images. It is helpful in clustering the non- similar regions of the images that are medically helpful to catch the irregularity in the images.

3.3 Feature Extraction

For medical pictures it is nearly impossible to obtain best approach for the feature extraction. The techniques for the feature extraction are discussed in the following subsections:

3.3.1 Gray Level Based

In an image matrix, the gray level length-based matrix is the encoding method of denoting string of symbols. This is a set of collinear, consecutive pictures that has the same grey levels. The number of pixels in the run is denoted as the run level. For the texture feature extraction, a run length matrix is used. The thickness of the text in a precise direction is confined by the run

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length statistics [17]. It is further specified by the defined direction, number of occurrence and length in the particular direction. local binary pattern, GLCM, GLRLM, Haralick features.

3.3.2 Filter Based

The filter-based feature extraction involves in many methods such as gabor texture features, symbolic dynamic filtering, learning vector, quantization and so on out of which gabor feature extraction method is based on gabor filter. They are related to gabor wavelets and are designed with an thought of human visual system. It is used for edge detection and it is a linear filter. They are just a cluster of wavelets [18]. After the distribution of the collected energy distributions, the pictures may be taken out.

3.3.3 Component Analysis Based

Principal component analysis and independent component analysis are the types involved in component analysis-based feature extraction. The principal component analysis is the best suited method for low dimensional principal analysis and it is also considered to be the best method for feature extraction. They are mainly opted for reducing the dimensionality during the analysis of the classifications. When the high dimensional data are analyzed, it is recommended to identify the superfluous structures and eliminate them form the data structures. The independent component analysis sis used for the feature extraction when there is accumulation of contributing feature is observed. It is generally connected to contribution by the dispersion [19]. The output of this technique is usually independent component vectors and hence it is categorized as unsupervised learning.

3.4 Classification

The classification of the images can be classified into binary classification, multiclass classification, multi-labelled classification and hierarchical classification.

3.4.1 Binary Classification

The binary classification consists of only two classes. A study was conducted that involved in the deep learning of an image from the CT scan of a patient who was affected with Covid-19. The existence of infection, false negatives, have been labeled and are controlled which could affect the virus spread from prevention, decisions on health monitoring and discharging the patients [20].

3.4.2 Multi-Class Classification

The multiclass classification faces numerous challenges and issues. However, one output can be obtained for each sample. In the case of Covid-19, four sub class of this classification are studied such as determining the suspicion and confirmation of the information. Another study approached the problem with deep squeeze net with bayers optimization, that helped detecting the covid. An assesmnet stated that this study had 98.3 % accuracy in detecting and distinguishing the normal, pneumonia and covid cases. A patch-based technique with convolution neural network has also been studied. As per the studies, pre-processing is considered to be an important aspect that ensures the performance of a segment in the cross-data base. To restructure the data classes as a pre-processing method, fuzzy color technique was also employed [21].

3.4.3 Multi-labelled Classification

Many studies have been reported the application s multi labeled classification such as application of the artificial intelligence in the detection of the covid -19,that emphasizes on the AI in marinating the spread of Covid, x-ray images in the accurate detection in binary classification and also multiclass classification. The accuracy of this particular model was observed to be 98.08% for the binary classes and 87.02% for multi-classification [22].

3.4.4 Hierarchical Classification

Hierarchicalclassification can be converted into flat classification. In this hierarchical classification, the learning output is identifying over a special class taxonomy. It can be categorized into sub classes and super classes [23]. The performance of this classification is converged into structural similarity index and universal quality index metrics.

4. Conclusion

AI has the most positive attitude towards radiology in a vision from acquisition till decision based on classification of healthy and unhealthy images. The sequential flow process of preprocessing the radiological image suitable for characteristic feature extraction makes them accurate for classification. The availability of numerous choices of preprocessing, specific region segmentation from the original image, various feature extraction and classification techniques are suitable to apply in any imaging modalities. Hence the utilization of AI in clinical practice may reduce the burden on physician.

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