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Medical Imaging and its Associated Analysis

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Abstract: This paper proposes the study and development of the digital image parameters for the detection of potential abnormalities. This paper explores a wide range of imaging modalities and focuses at fusing anatomical, functional and molecular information. More and more fields of human's life are becoming computerized nowadays. The role of imaging in healthcare is continuously increasing. Recent innovations in medical imaging technology have created a lot of imaging data, which is revolutionizing diagnosis, therapy planning and follow-up, as well as clinical, preclinical and biomedical research. The diagnostic interpretation of medical images is a multi-step task.

Keywords: Medical Imaging, Analysis, Health care, Tomography, Magnetic Resonance.

I. INTRODUCTION

Medical Imaging is the technique used to create images of the human body for clinical purposes such as medical procedures seeking to reveal, diagnose or examine disease and medical science including the study of normal anatomy and physiology. Many of the techniques developed for medical imaging also have scientific and industrial applications. Medical imaging is often perceived to designate the set of techniques that non-invasively produce images of the internal aspect of the body. In this restricted sense, medical imaging can be seen as the solution of mathematical inverse problems. This means that cause (the properties of living tissue) is inferred from effect (the observed signal). Before discussing the medical imaging in detail, it is necessary to provide some basic information about digital imaging. Two classes of digital images can be distinguished as analog and digital images respectively. Both types fall into non temporal multimedia type. Analog images are painted or created through photographic process. Analog images are characterized by continuous and smooth transition of tones. This means that between each two different points at the picture there is an infinite number of tonal values. It is possible to transform an analog image into digital. A digital image $a[m,n]$ described in a 2D discrete space is derived from an analog image $a(x,y)$ in a 2D continuous space through a sampling process that is frequently referred to as digitization. The 2D continuous image $a(x,y)$ is divided into N rows and M columns. The intersection of a row and a column is termed as a pixel. The diagnostic interpretation of medical images is a multi-step task where the aim is the detection of potential abnormalities. It is accurately achieved when the clinician integrates two processes. The first is the image perception to recognize unique image patterns and the second is the identification of the relationship between perceived patterns and possible diagnoses. The success of these two steps relies heavily on the clinician's skill to do the needful. On-going Medical Image Analysis projects cover a wide range of imaging modalities (Magnetic Resonance Imaging, Positron Emission Tomography, Computerised Tomography, ultrasound, optical imaging) and aims at fusing anatomical, functional and molecular information. An **image** defined in the "real world" is considered to be a function of two real variables, for example, a (x,y) with a as the amplitude (e.g. intensity) of the image at the real coordinate position (x,y). An image may be considered to contain sub-images sometimes referred to as Regions-Of-Interest (ROIs), or simply regions. This concept reflects the fact that images frequently contain collections of objects each of which can be the basis for a region**.**The use of images in human communication is hardly new – our cave-dwelling ancestors painted pictures on the walls of their caves, and the use of maps and building plans to convey information almost certainly dates back to pre-Roman times. But the twentieth century has witnessed unparalleled growth in the number, availability and importance of images in all walks of life. Images now play a crucial role in fields as diverse as medicine, journalism, advertising, design, education and entertainment.

1.1 ANALOG IMAGES

Two classes of digital images can be distinguished – analog and digital images. Both types fall into non-temporal multimedia type. Analog images are painted or created through photographic process. During this process, the image is captured by a camera on a film that becomes a negative. We have a positive when the film is developed no processing is required from this moment. When the photography is made on a transparent medium then we are dealing with a diapositive (slide). Analog images are characterized by continuous, smooth transition of tones. This means that between each two different points at the picture there is an infinite number of tonal values. It is possible to transform an analog image into digital

1.2 DIGITAL IMAGES

A digital image $a[m,n]$ described in a 2D discrete space is derived from an analog image $a(x,y)$ in a 2D continuous space through a sampling process that is frequently referred to as digitization. The effect of digitization is shown in Figure 1. The 2D continuous image $a(x,y)$ is divided into N rows and M columns. The intersection of a row and a column is termed a pixel. The value assigned to the integer coordinates $[m,n]$ with $\{m=0,1,2,...,M-1\}$ and $\{n=0,1,2,...,N-1\}$ is $a[m,n]$. In fact, in most cases $a(x,y)$ which we might consider to be the physical signal that impinges on the face of a 2D sensor--is actually a function of many variables including depth (z), color (λ), and time (t). A digital image can be captured with a digital camera, scanner or created with a graphic program. Transition from digital to analog image also takes place by devices as computer monitor, projector or printing device. The image shown in Figure 1 has been divided into N = 16 rows and M = 16 columns. The value assigned to every pixel is the average brightness in the pixel rounded to the nearest integer value. The process of representing the amplitude of the 2D signal at a given coordinate as an integer value with L different gray levels is usually referred to as amplitude quantization or simply quantization.

II. METHODOLOGY OF MEDICAL IMAGING

Medical imaging constitutes and consists of a sub-discipline of biomedical engineering, medical physics or medicine depending on the context. Research and development in the area of instrumentation, image acquisition, modelling and quantification are usually included in biomedical engineering, medical physics and computer science whereas research into the application and interpretation of medical images is usually included in radiology and the medical sub-disciplines relevant to medical conditions under investigation or area of medical science like neuroscience, cardiology, psychiatry, psychology, etc. Medical imaging is often perceived to designate the set of techniques that non-invasively produce images of the internal aspect of the body. In this restricted sense, medical imaging can be seen as the solution of mathematical inverse problems. The techniques involved in medical imaging are Medical Radiography. Medical Radiographs are further sub divided in to projectional radiographs which is often used to determine the type and extent of a fracture as well as for detecting pathological changes in the lungs and other organs respectively. Fluoroscopy produces real-time images of internal structures of the body in a similar fashion to radiography, but employs a constant input of x-rays, at a lower dose rate. Tomography is the method of imaging a single plane, or slice, of an object. Computed Tomography (CT) scan also known as a CAT scan, is a helical tomography (latest generation), which traditionally produces a 2D image of the structures in a thin section of the body. MRI stands for Magnetic Resonance Imaging and unlike CT Scan, MRI does not involve the use of ionizing radiation. Medical ultrasonography uses high frequency broadband sound waves in the megahertz range that are reflected by tissue to varying degrees to produce (up to 3D) images.

2.1 MEDICAL IMAGING

Medical Imaging is the technique used to create images of the human body (or parts and function thereof) for clinical purposes such as medical procedures seeking to reveal, diagnose or examine disease and medical science including the study of normal anatomy and physiology. As a field of scientific investigation, medical imaging constitutes a sub-discipline of biomedical engineering, medical physics or medicine depending on the context: Research and development in the area of instrumentation, image acquisition, modeling and quantification are usually included in biomedical engineering, medical physics and computer science; research into the application and interpretation of medical images is usually included in radiology and the medical sub-disciplines relevant to medical conditions under investigation or area of medical science like neuroscience, cardiology, psychiatry, psychology, etc. Many of the techniques developed for medical imaging also have scientific and industrial applications. Medical imaging is often perceived to designate the set of techniques that non-invasively produce images of the internal aspect of the body. In this restricted sense, medical imaging can be seen as the solution of mathematical inverse problems. This means that cause (the properties of living tissue) is inferred from effect (the observed signal). For example, in the case of ultrasonography the probe consists of ultrasonic pressure waves and echoes inside the tissue show the internal structure. In the case of projection radiography, the probe is X-ray radiation which is absorbed at different rates in different tissue types such as bone, muscle and fat.

2.2 MEDICAL RADIOGRAPHS

Although X-rays were discovered over a century ago, they are still in common use. During examination, the patient is placed between an X-ray source and a detector. Different tissues absorb x-rays with different force thus the X-rays penetrating through the patient have different energy depending on tissue densities. Dense tissues, e.g. bones, block and soft tissues give no resistance to the X-rays. Parts of the detector that are behind tissue that absorbs 100% X-rays produce white areas on the image. The “softer” a tissue, the darker becomes the image in parts that represent this tissue. Many different X-ray detectors can be used during medical examination. Two forms of radiographic images are in use in medical imaging and they are projection radiography and fluoroscopy.

2.2.1 RADIOGRAPHY

They are often used to determine the type and extent of a fracture as well as for detecting pathological changes in the lungs. With the use of radio-opaque contrast media, such as barium, they can also be used to visualize the structure of the stomach and intestines. This can help diagnose ulcers or certain types of colon cancer.

2.2.2 FLUOROSCOPY

It produces real-time images of internal structures of the body in a similar fashion to radiography, but employs a constant input of x-rays, at a lower dose rate. Contrast media, such as barium, iodine, and air are used to visualize internal organs as they work. Fluoroscopy is also used in image-guided procedures when constant feedback during a procedure is required. An image receptor is required to convert the radiation into an image after it has passed through the area of interest. Early on this was a fluorescing screen, which gave way to an Image Amplifier which was a large vacuum tube that had the receiving end coated with cesium iodide, and a mirror at the opposite end. Eventually the mirror was replaced with a TV camera.

2.3 TOMOGRAPHY

Tomography is the method of imaging a single plane, or slice, of an object. Pictures created during tomography are called tomograms and they create a specific class of X-ray images. There are several forms of tomography like linear tomography, poly tomography, zonography, orthopantomography, computed tomography

2.3.1 LINEAR TOMOGRAPHY

This is the most basic form of tomography. The X-ray tube moved from point "A" to point "B" above the patient, while the receiver moves simultaneously under the patient from point "B" to point "A." The fulcrum, or pivot point, is set to the area of interest. In this manner, the points above and below the focal plane are blurred out, just as the background is blurred when panning a camera during exposure. No longer carried out and replaced by computed tomography.

2.3.2 POLY TOMOGRAPHY

This was a complex form of tomography. With this technique, a number of geometrical movements were programmed, such as hypocycloidic, circular and elliptical. Philips Medical Systems produced one such device called the ‘Polytome’. This unit was still in use into the 1990s, as its resulting images for small or difficult physiology, such as the inner ear, was still difficult to image with CTs at that time. As the resolution of CTs got better, this procedure was taken over by the CT.

2.3.3 ZONOGRAPHY

This is a variant of linear tomography, where a limited arc of movement is used. It is still used in some centers for visualizing the kidney during an Intra Venous Urogram (IVU).

2.3.4 ORTHOPANTOMOGRAPHY

This makes use of a complex movement to allow the radiographic examination of the mandible, as if it were a flat bone. It is often referred to as a "Panorex", but this is incorrect, as it is a trademark of a specific company's equipment.

2.3.5 COMPUTED TOMOGRAPHY

A CT scan, also known as a CAT scan, is a helical tomography (latest generation), which traditionally produces a 2D image of the structures in a thin section of the body. It has a greater ionizing radiation dose burden than projection radiography; repeated scans must be limited to avoid health effects.

2.4 MAGNETIC RESONANCE IMAGING

A magnetic resonance imaging instrument (MRI scanner), or nuclear magnetic resonance (NMR) imaging scanner as it was originally known, uses powerful magnets to polarize and excite hydrogen nuclei (single protons) in water molecules in human tissue, producing a detectable signal which is spatially encoded, resulting in images of the body. It uses three magnetic field namely a very strong static magnetic field to polarize hydrogen nuclei, a weaker time varying field for spatial encoding and a weak radio frequency field for manipulation of the hydrogen nuclei to produce measurable signals.

2.5 NUCLEAR MEDICINE

Nuclear medicine encompasses both diagnostic imaging and treatment of disease, and may also be referred to as molecular medicine or molecular imaging & therapeutics. It uses certain properties of isotopes and the energetic particles emitted from radioactive material to diagnose or treat various pathology. Different from the typical concept of anatomic radiology, nuclear medicine enables assessment of physiology. This function-based approach to medical evaluation has useful applications in most subspecialties, notably oncology, neurology, and cardiology.

2.5.1 SINGLE POSITION EMISSION COMPUTED TOMOGRAPHY

A 3D tomographic technique known as SPECT uses gamma camera data from many projections and can be reconstructed in different planes. Gamma cameras are used in nuclear medicine to detect regions of biologic activity that may be associated with disease. Relatively short lived isotope is administered to the patient. Isotopes are often preferentially absorbed by biologically active tissue in the body, and can be used to identify tumors or fracture points in bone. Images are acquired after collimated photons are detected by a crystal that gives off a light signal, which is in turn amplified and converted into count data.

2.5.2 POSITRON EMISSION TOMOGRAPHY

It uses coincidence detection to image functional processes. Short-lived positron emitting isotope, such as ^{18}F, is incorporated with an organic substance such as glucose, creating ^{18}F-fluorodeoxyglucose, which can be used as a marker of metabolic utilization. Images of activity distribution throughout the body can show rapidly growing tissue like tumour, metastasis, or infection. PET images can be viewed in comparison to CT scans to determine an anatomic correlate. Modern scanners combine PET with a CT, or even MRI, to optimize the image reconstruction involved with positron imaging.

Fig.1: X-ray Image of Human Hand

Fig.2: X-ray image of human skull

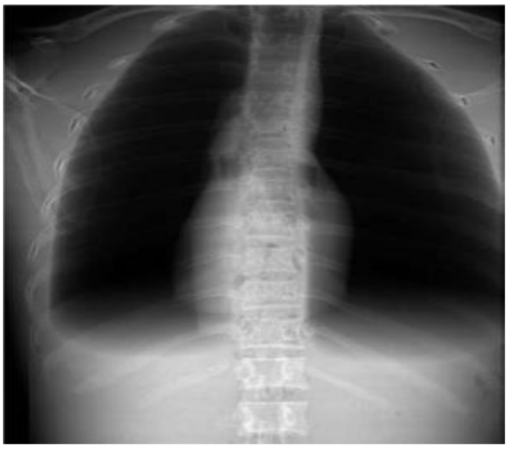

Fig.3: X-ray image of human chest

Fig.4: A rotational fluoroscopy image of a hepatic artery injection

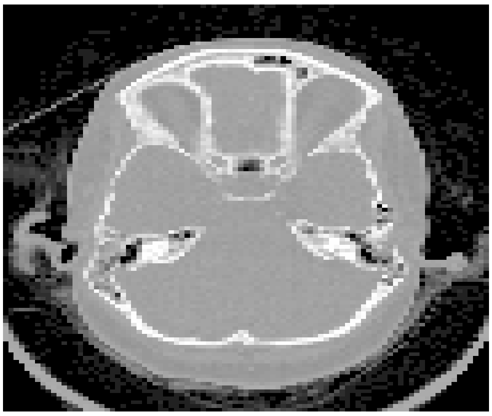

Fig.5: Brain CT Scan

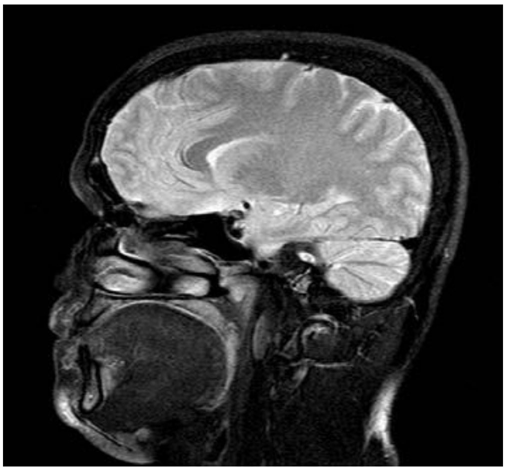

Fig.6: Brain MRI 1

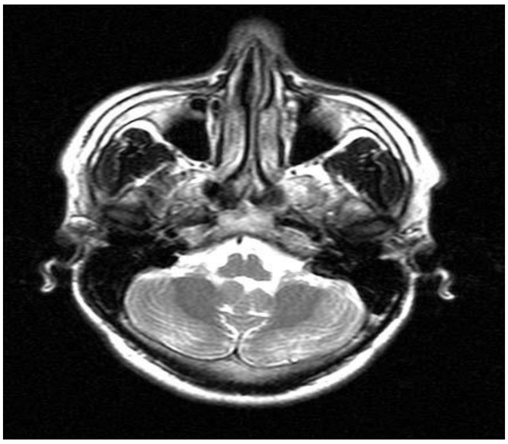

Fig.7: Brain MRI 2

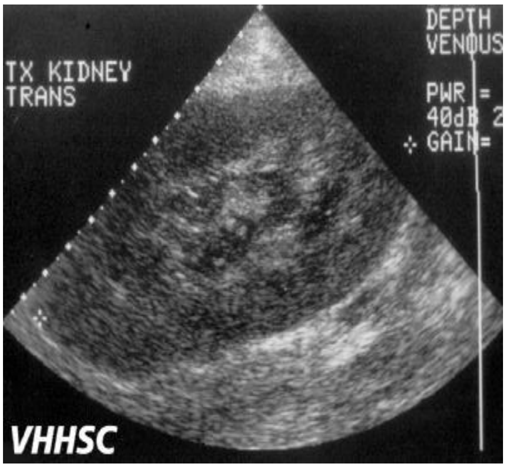

Fig.8: Ultrasound of Kidney

Fig.9: X-ray images of Human neck

Fig.10: X-ray images of Human knee

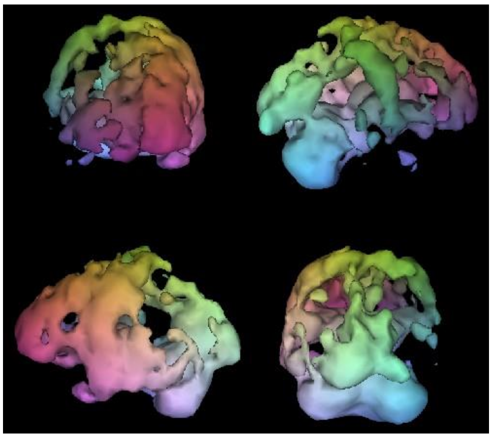

Fig.11: Brain SPECT Showing Alzheimer's disease

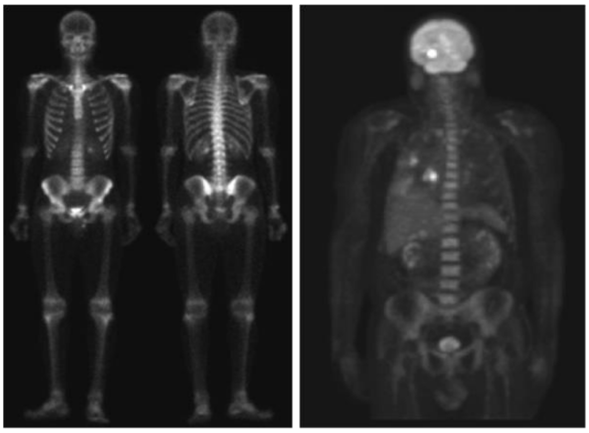

Fig.12: PET scan

III. MEDICAL IMAGING DISCUSSIONS

The review of medical imaging techniques unveil large diversity of medical image classes and technology used in medical diagnosis. Nevertheless, all these images have some common characteristics which distinguish them from general images.

3.1 LOW RESOLUTION

All the mentioned classes of medical images are characterized with very restricted size. Images from different classes have different sizes. Largest are the X-ray images, which can have size up to 2048 pixels vertically and horizontally. Other medical images are much smaller, for example Computerized Tomography are smaller than 512×512 pixels, Magnetic Resonance images up to 256×256 pixels and USG images 700×500 or less.

3.2 LOE CONTRAST

Medical images have also limited bit depth. X-ray images have bit depth equal 12 bit and USG images only 8 bits. The matter is not so clear with Magnetic Resonance images. Image format used here can store 2^{16} (bit depth equal 16) tones of gray but, in fact, there are much fewer tones – about 2^{9} (bit depth equal 9).

3.3 HIGH FIDELITY

Medical images create a particular class of digital images, where the information carried by them is extremely important. High fidelity of compression and any other processing is required or the diagnosis could be erroneous. The loss of information may mislead not only when a physician personally examines the image but also when software is used for analyzing the image.

3.4 MAGNIFICATION

Due to small resolutions of medical images, their psychical size on a display device also will be rather small. Because of this, it is difficult to perform measurements by hand during diagnosis or even to read the image by a physician. Thus, magnification of the image is often very desirable and this means that also a zoomed-in image should be maximally true, legible and clear.

3.5 IMPERFECTION

Medical Images often suffer from high level of noise, geometric deformations and presence of imaging artifacts.

3.6 CHALLENGES IN MEDICAL IMAGING

General image processing whether it is applied to robotics, computer vision, medicine etc. will use imaging geometry, linear transforms, shift invariance, frequency domain, segmentation, histogram analysis etc. that apply to any image modality and any application. While these classic approaches to general images and to general applications are important, the special nature of medical images and medical applications requires special treatments. Medical images typically suffer from one or more of the following imperfections. These imperfections can be inherent to the imaging modality (e.g., X-rays offer low contrast for soft tissues, ultrasound produces very noisy images, and metallic implants will cause imaging artifacts in MRI) or the result of a deliberate trade-off during acquisition. Quality of medical imaging is limited by factors like The movement of a patient, Insufficient performance of method of acquisition, Out-of-focus lens, Poor illumination, Coarse quantization and reconstruction errors associated with noise of imaging devices, Distortion and burring associated with relatively long acquisition time (due to anatomical motion), Beam hardening. All these factors account for the differences between medical and non medical approaches that affect the way in which images are processed and analysed.

3.7 MEDICAL IMAGING AND ANALYSIS

Analysis of medical images is essential in modern medicine. With the increasing amount of patient data, new challenges and opportunities arise for different phases of the clinical routine, such as diagnosis, surgery and therapy.Large amount of medical images per case together with the growing importance of medical imaging in clinical practice, have continuously increased the workload of the radiologist, which explains the need for computer-assisted medical image analysis. Intelligent processing of such multi-dimensional images has become crucial in conventional or computer-aided interpretation for radiological and diagnostic applications. Medical image analysis concentrates on the development of techniques to supplement the mostly qualitative and frequently subjective assessment of medical images by human experts. Regardless of its application area it encompasses incorporation of prior knowledge, classification of features, matching of model to sub-images, description of shape, and many other problems and approaches of artificial intelligence. The diagnostic interpretation of medical images is a multi-step task where the aim is the detection of potential abnormalities. This goal is accurately achieved when the clinician integrates two processes. The first is the **image perception** to recognize unique image patterns and the second is the **identification** of the relationship between perceived patterns and possible diagnoses. The success of these two steps relies heavily on the clinician's skill. On-going Medical Image Analysis projects cover a wide range of imaging modalities (Magnetic Resonance Imaging, Positron Emission Tomography, Computerised Tomography, ultrasound, optical imaging) and aim at fusing anatomical, functional and molecular information.

IV RESULTS

We can distinguish many different types of digital images. Firstly all the digital images are divided into recorded and synthesized images. Analog images scanned by digital scanner belongs to the first group and to the second group are classed all images created with graphical computer programs. The second possible classification of digital images divides them into vector images and raster images. Both of the groups can contain recorded as well as synthesized images. Vector images are mostly created with graphic software. Analog images can be recorded only to a raster image, but then they can be converted to vector image. The opposite conversion which is also known as rasterization is also possible. Vector images are treated as a set of mathematically described shapes and most often are used in creating drawings like logos, cartoons or technical drawings. Raster image (bitmap) is defined as set of pixels filled with color identified by a single discrete value. This kind of image is usually used for photographs.

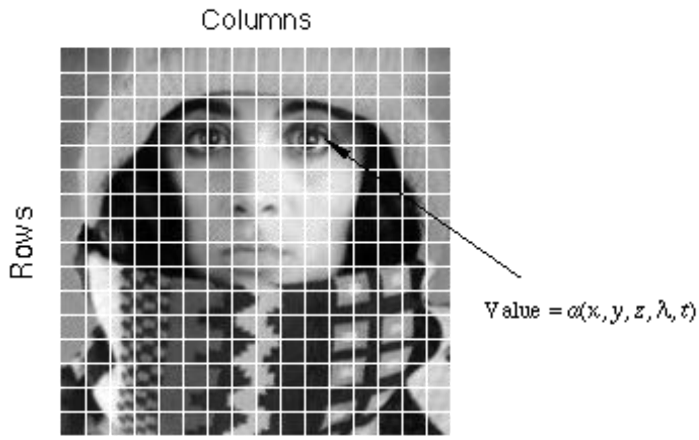

Fig.13: Digitization of continuous images

4.2 SIGNIFICANCE OF DIGITAL IMAGES

1] **Color Mode:** A digital image can have one of three modes: binary, grayscale or color. A binary (bilevel) image is in which there are only two possible values for each pixel. A grayscale image means that its each pixel can contain only a tint of gray color. Bit depth, called also color depth or pixel depth, stands for how many bits are destined for description of color for each pixel. Higher color depth means that more colors are available in the image, but at the same time, it means that more disk space is needed for storage of the image. Monochrome images use only one bit per pixel, and grayscale images engage usually 8 bits, which gives 256 gray levels. Color images can have pixel depth equal 4, 8 or 16 bits; full color can be achieved with 24 or 32 bits.

2] **Resolution:** The resolution of a digital image is the number of pixel within a unit of measure. Typically, the resolution is measured in pixels per inch (ppi). The higher the image resolution the better is its quality. The image resolution can also be understood as dimension of the pixel array specified with two integers: number of pixel columns × number of pixel rows.

3] **File Format:** A digital image can be stored in one of many file formats. Some formats are bounded with one specific program, but there are also common formats that are being understood by different graphic programs. For e.g, JPEG, PNG, BMP, GIF and so on. There is a very close relation between file formats and compression. Images stored in a particular format are usually compressed in order to reduce the size of the file.

4] **Compression Method:** The last characteristic of a digital image is compression method used to reduce size of file containing the image. Each format supports one or few compression methods; there are also formats that store uncompressed data.

V. CONCLUSION

The medical images are segmented and different parameters are taken into consideration like colour modes, resolution, compression, etc. any medical image i.e. ultrasound, x-ray etc. is processed using the MATLAB code in order to detect the error as all images consists of some errors. The critical problem like cancer, tumor, etc. can be analyzed easily using diagnostic interpretation and image perception.

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