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A Study of Application of Digital Image Processing in Medical Field and Medical Image Segmentation by Edge Detection

Tanusree Saha, Kumar Vishal

Abstract- There has been a lot of recent development in the domain of image processing and associated imaging techniques. Medical imaging is about the practice to capture images of different fragments of the body for diagnostic or investigative purposes. The number of imaging procedures performed each week is in the millions. This study presents the promising image processing methods currently in use in the medical field. The rapid expansion of medical imaging can be attributed to advancements in image processing methods, including image recognition, enhancement, and analysis. Utilised in the diagnosis and treatment of patients, image processing techniques have proven to be of immense benefit to surgeons and physicians. The explosion of clinical medical devices is largely attributable to the blend of hardware and image processing techniques, both of which have contributed significantly to medical progress. In recent years, Image segmentation via edge detection plays a vital role by extracting important features of the images like corners, lines and curves to recognized object boundaries which in turns helps the medical expertise to detect diseases in medical analysis and patient care.

Keywords: Non-Intrusive Techniques; Human Anatomy; Digital Image Processing; Diagnosis

I. INTRODUCTION

Information technology (IT) has permeated every facet of modern life, and its effects in medicine and healthcare have become apparent in recent years. The goal of medical imaging is to provide a visual representation of the anatomical structures and physiological processes occurring within a patient's body for the purposes of diagnosis, treatment, and research. Through Picture Archiving and Communication Systems, Digital Imaging and Communications in Medical (DICOM), and other communication networks and protocols facilitate the efficient processing, evaluation, and dissemination of these visual representations to a global audience [4]. Biomedical images, or pictures of the human body used for medical purposes, are an essential part of the medical sciences.

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******Correspondence Author(s)*

Tanusree Saha*, Research Scholar, Department of Computer Science & IT, Magadh University, Bodh Gaya, Bihar, & Assistant Professor, Department of IT, JIS College of Engineering, India. E-mail: tanusreesah@gmail.com, ORCID ID: 0000-0001-6011-1237

Dr. Kumar Vishal, Assistant Professor, Department of Mathematics, Magadh University, Bodh Gaya (Bihar), India. E-mail: kumarvishal.bhu@gmail.com, ORCID ID: 0000-0002-5055-1447

Any one-dimensional algorithm can be applied to this two-dimensional digital image by first applying it to the rows of the matrix, and then to the columns. These biomedical pictures show not only individual body parts and organs but also molecular structures. To decipher and extract useful information from these images, image processing methods are crucial. Physicians were aided in their ability to diagnose illness, locate abnormalities, and treat patients by means of digital imaging technology [3][16][17].

II. Image Categorization

In the field of digital imaging, there are two primary image formats. A raster image is an array of pixels, which are small squares of data that are sampled frequently. There are two phases to the digitization process: sampling and quantization. Quantization reduces a signal's range of possible values from an infinite number to a finite number, while sampling reduces a continuous quantity in time and space domain to discrete quantities. The vast tonal range and inaccessibility of digital images is their defining characteristic. The resolution of digital images is always the same because of the size of the pixels used to create them. When digital images are resized, quality is lost because some of the original data is lost in the process. Digital photographs are widely used because of the high quality of their colour tones. The device used to acquire the image determines the resolution. Digital pictures can be saved in a wide variety of formats; some common ones are BMP, TIFF, PCX, and PNG [1,2].

Basic Image Processing Operations as follows:

- Image Acquisition: This primary process involves the collection of images through the use of sensors and a variety of modalities of images, and is represented through a matrix.
- Enhancing an image by reducing noise and makes it easier to examine microscopic details of medical images like MRI, ultrasound, X-Ray etc. and their techniques.
- Medical images taken in natural light can have their colors altered and corrected without the need for artificial lighting thanks to this feature.
- Medical image segmentation relies heavily on edge detection as a pre-processing system for identifying internal human anatomy like lungs, organ systems, tissues, ribs etc.
- Image Smoothing is a technique used to lessen the visual disturbances in diagnostic pictures.

- Restoring Images used to recover restorative images such as X-Ray images, ultra sound images, and CT scan images, MRI etc.

Advantages of applying image processing techniques [10] in the medical field:

- Data stored digitally cannot be altered and always appears authentic even after being copied numerous times.
- Digital processing is an effective method for helping doctors finds the most relevant images quickly.
- The image is shown instantly after it is captured.
- The enhanced/intensified images are simple to interpret for physicians.
- It quantifies changes over time.
- Image comparisons can be performed quickly

A. X-RAY IMAGING

Radiography, or X-Ray imaging, a medical imaging method used to create images of internal body structures like bones and organs. A wide variety of medical conditions can be diagnosed with this painless, non-invasive procedure. In radiography, the patient is positioned so that an X-ray machine can produce and then pass radiation through their body. A digital sensor or photographic film records the X-rays' detection, producing an image of the body's internal structures. More dense objects appear whiter on the X-Ray image because they absorb more radiation than less dense ones, which causes the latter to appear darker. Bone fractures, lung infections, and gastrointestinal disorders are just some of the many medical conditions that can be diagnosed with radiography. Diseases like breast and lung cancer can be screened for and tracked with its help. Human chest X-Ray shown in Figure. 2 are fairly typical. Ever since the discovery of X-rays by the German scientist Roentgen, human body components have been photographed for diagnostic purposes. Electrons are generated in the cathode through a thermal emission process and accelerated by a potential difference ranging from 50 to 150 KV within an X-ray tube. X-rays are generated through the interaction of electrons with the anode. A mere 1% of the energy is transformed into X-rays; the remainder is converted to heat. X-ray devices generate two-dimensional blueprints of the anatomical structure under investigation. An organ in motion is imaged through the utilisation of a fluoroscopy instrument. Photo captures are capable of being viewed, stored, and transmitted through a variety of devices. In order to generate images, computed radiography (CT) employs image receptors. X-rays are emitted in the presence of a storage phosphor device that covers a screen. Mammography images are utilised to differentiate various medical conditions from breast tissues. Mammography imaging is energy-efficient in comparison to imaging of bone structure. The range of potential differences utilised is 15 to 40 kV [5].

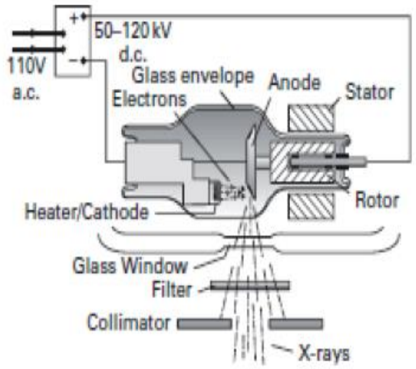

Figure 1: X-Ray Tubes

Figure 2: Chest X-Ray Image

B. MAGNETIC RESONANCE IMAGING (MRI)

MRI is a medical imaging technique which generates high-resolution pictures of the body's internal anatomy by merging magnetic field with radio waves and a computer [8][19]. It is a common diagnostic tool because patients don't feel any discomfort or there is no harm during imaging. In magnetic resonance imaging, the patient relaxes on table that moves into a giant cylindrical magnet. Hydrogen atoms in the body have protons that align with the magnetic field. After sending radio waves into the body, the MRI machine picks up the signal emitted by the protons. This signal is then used by the computer to render accurate pictures of the body's internal anatomy. Tumors, brain and spinal cord injuries, joint and musculoskeletal disorders, and heart and vascular conditions are all diagnoses that benefit from the use of magnetic resonance imaging (MRI). It's also put to use in functional imaging, which gives the doctor a look at how the brain's various regions are doing their jobs. MRI is helpful for diagnosing complex medical conditions because it can produce detailed images of the body's inner structures in multiple planes (sagittal, coronal, and axial) without rendering any harmful levels of radiation or involve any sort of invasive procedure. A cross-sectional MRI scan image of a human skull is shown in Figure. 4.Scanners based on MRI technology use radio waves, magnetic fields, and field gradients to create internal human organs images for clinical diagnosis. With the data produced by MRI being small 3, 3 kernels, Convolution Neural Networks (CNN) play an important role in investigating brain tumours [9].

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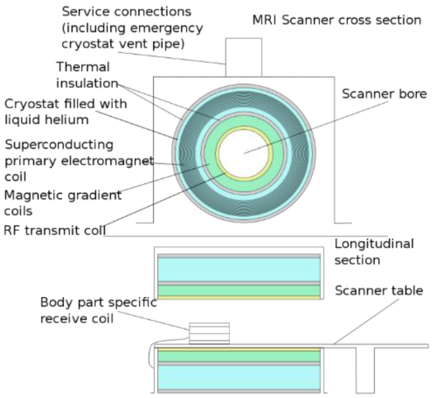

Figure 3: Diagram of Construction of a Cylindrical Superconducting MR Scanner

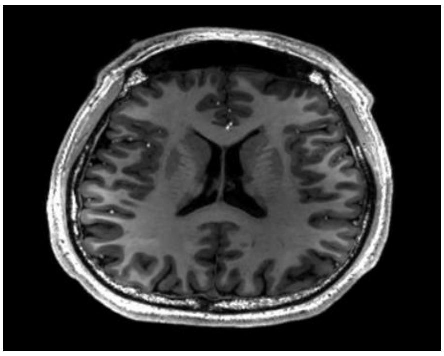

Figure 4: MRI of Human Brain

C. COMPUTER TOMOGRAPHY

Medical imaging using X-Rays and a computer is known as computer tomography (CT), and it is used to produce detailed images of the body's inner structures. Varieties of medical conditions can be diagnosed with this painless, non-invasive procedure. Through the procedure of CT scan, the patient lies on table that moves into a doughnut-shaped machine. The patient is positioned in the centre, and the machine rotates around them, sending X-Rays through their body. The information is fed into a computer, which produces internal images of human body with high-resolution. Tumours, injuries, infections, and vascular disease are some of the many medical conditions that can be diagnosed with a CT scan. Diseases like lung cancer and heart disease can be detected and tracked with its help. Figure 4 depicting A CT scan of a human brain showing multiple brain slices [14].

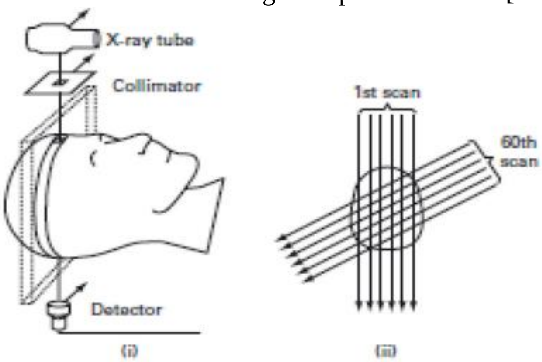

Figure 5: CT Scanner

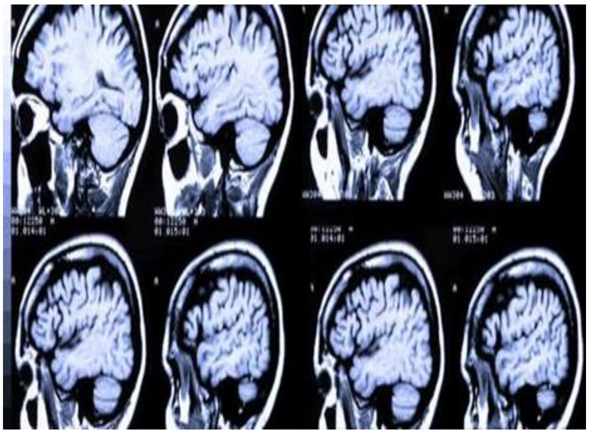

Figure 6: A CT Scan of a Human Brain in Multiple Slices

D. NUCLEAR MEDICINE

This imaging modality employs radioisotopes to generate pictures of the functions of various structures such as kidney, heart and liver. Pharmaceutical materials mark radioisotopes so that they can be steered to certain organs.

The photons generated by the patient are detected and converted into signals by the detectors. These signals are turned into digital images that may be interpreted. Nuclear medicine scanning modes include planar, tomographic, and positron emission to name a few. Planar emission generates two-dimensional pictures. Both tomographic and positron emissions generate 3D pictures. Figure 7 depicting the process of Nuclear Medicine imaging [13].

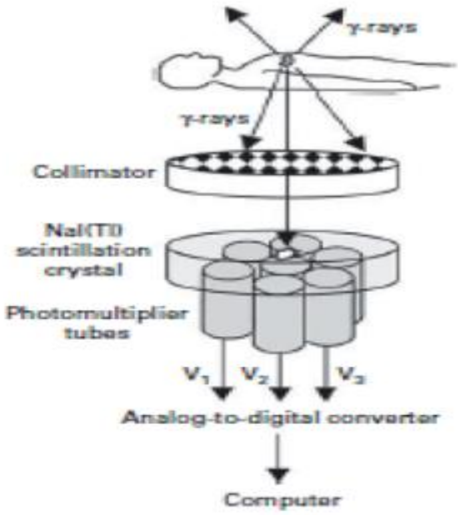

Figure 7: Nuclear Medicine Imaging

E. MEDICAL ULTRASONOGRAPHY

Medical ultrasound [7], also known as diagnostic sonography, generates images of the internal structures of the body using high-frequency sound pulses. A diverse range of medical conditions can be identified through the utilisation of this non-invasive and painless method.

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In order to perform ultrasound, a transducer, which is a compact hand-held instrument, is applied to the skin over the area of interest. The transducer generates echoes through the emission of high-frequency sound waves that subsequently reflect off the internal structures of the body. The transducer captures these echoes in order to generate visual representations of the internal structures of the body that are displayed on a screen. Ultrasound capabilities extend to the diagnosis of malignancy, liver and kidney disease, and complications that may arise during pregnancy. Additionally, it serves as an instrument for guiding needle aspirations and biopsies in the medical field. In Figure 9, ultrasound images of a maturing foetus are displayed. An automated technique that joins and separates the foetal image by employing morphological operators, which are a category of nonlinear image processing filters.

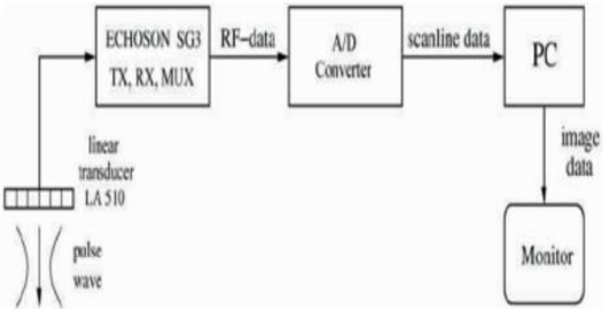

Figure 8: Ultra Sound Imaging

Figure 9: Ultrasound Imaging of a Developing Fetus

F. Electrocardiography (ECG)

The electrocardiogram (ECG) [6][18] is a diagnostic tool used to assess cardiac function. It is a painless, non-invasive method used for diagnosis of various heart conditions. During an electrocardiogram, small electrodes are adhered to the skin of the arms, chest, and legs. Electrical signals generated by the heartbeat are recorded by a device connected to the electrodes. The recording shows the heart's rhythm and can help find electrical problems in the heart. Arrhythmias, heart attacks, and heart failure are just some of the heart conditions that the electrocardiogram (ECG) is used to diagnose. It can also be used to detect changes in the heart's electrical activity and evaluate the efficacy of treatments for these conditions. Using digital signal processing, Multi Resolution study and filtering techniques are used to remove the accidental troubles caused by ECG nodes efficiently, and the Wavelet Transform is used to obtain an effective filtering effect. Figure 10: An Electrocardiogram (ECG) of a Human Heart.

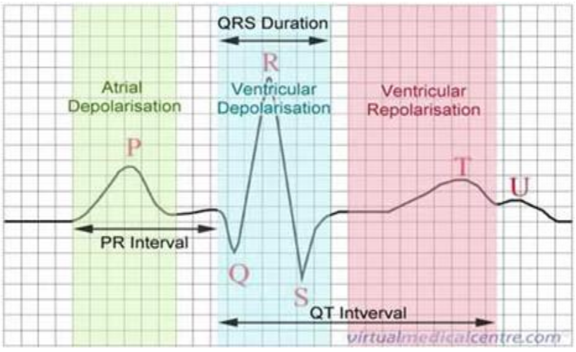

Figure 10: An Electrocardiogram (ECG) of a Human Heart

III. Fundamental of Digital Image Processing

i. Image enhancement.
ii. Image Segmentation.

Image enhancement is a technique to increase clarity and quality of images. With the support of computer software and different tools, this technique combines objective and subjective improvements. Image enhancement technique incorporates local and points operations. The regional input pixel values determine how the local processes work. Two different kinds of enhancement techniques that are widely used, namely Spatial and Transform domain approaches [12]. The physical approaches operate at the pixel level or spatial domain, whereas the transform method operates on Fourier and then spatial domain. Image Segmentation: It is a process of dividing an image into various components. The main goal for this is to simplify the image for analysis and elucidation. Using Edge detection, Image segmentation is done for improving the image perceptibility and quality by using computer-aided software [11]. In digital image processing, A sharp change in the brightness of an image is referred to as an edge. Methods that approximate gradients and derivatives are utilized in edge detection to identify these regions. Some common Edge Detection [15][20] techniques are:

Roberts Kernel: The method by which the distinctions between two adjacent pixels are ascertained is referred to as forward differences. This method assists in locating boundaries in images with high levels of noise. For calculation, a first-order fractional derivative and cross-gradient operator are applied. The equations are given as follows:

$$\frac{df}{dx} = f(i+1, j+1) - f(i, j) \qquad \text{.......Equation 1.}$$

$$\frac{df}{dx} = f(i+1, j) - f(i, j+1) \qquad \text{.....Equation 2.}$$

Two 2*2 matrices are being used to apply fractional derivative. Roberts's masks are as follows:

$$Gx = \begin{bmatrix} -1 & 0 \\ 0 & 1 \end{bmatrix} \text{ and } Gy = \begin{bmatrix} 0 & -1 \\ 1 & 0 \end{bmatrix}$$

Prewitt kernel: This technique of edge detection has been implemented based on the idea of central difference. It is improved compared to Roberts's operator. The matric has arrangement of pixels [i, j] as:

$$\begin{bmatrix} a0 & a1 & a2 \\ a7 & i,j & a3 \\ a6 & a5 & a4 \end{bmatrix}$$

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Compute the fractional derivative of the Prewitt operator as:

$$Gx = (a2 + pa3 + a4) - (a0 + ca7 + a6) \quad \text{.......Equation 3}$$

where p is constant and representing the pixels closed to the centre of the image. Gx and Gy are the calculations at [i, j]. When p equals 1, the Prewitt kernel is calculated as:

$$Gx = \begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix} \text{ and } Gy = \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix}$$

Sobel kernel: This method may rely on the central difference, which, on average, gravitates towards the central pixels. The formulation for this method is a 3 x 3 matrix applied to the first derivative of the Gaussian kernel. This method is computed as follows:

$$Gx = (c2 + 2c3 + c4) - (c0 + 2c7 + c6)$$

and

$$Gy = (c6 + 2c5 + c4) - (c0 + 2c1 + c2)$$

The Sobel masks are the following:

$$Gx = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix} \text{ and } Gy = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$$

IV. EXPERIMENTAL RESULT OF EDGE DETECTION TECHNIQUES

In this section, a comparison of the efficacy of several edge detection methods, including Roberts, Sobel, Prewitt, and Laplacian Canny Edge Detector, is presented. The edge detection methods were implemented utilising Co-Lab and evaluated on a chest x-ray image of a human. The purpose of these procedures is to generate a pristine edge map through the extraction of the principal edge characteristics of the image. Figure 11, 12, 13, 14 presents both the original image and the image generated through the implementation of various edge detection techniques respectively.

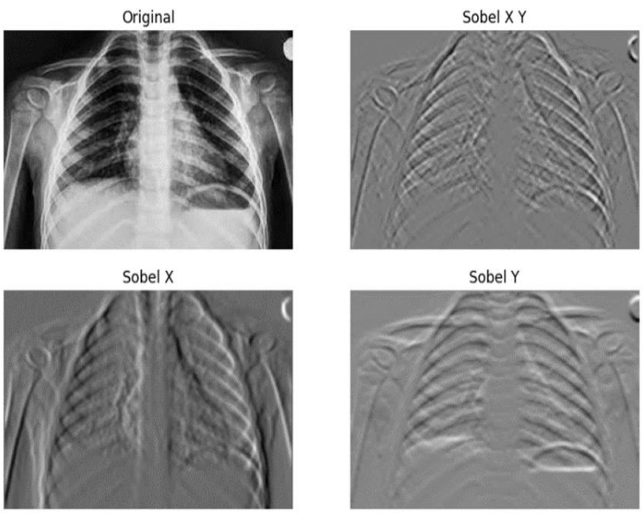

Figure 11: Sobel Edge Detection

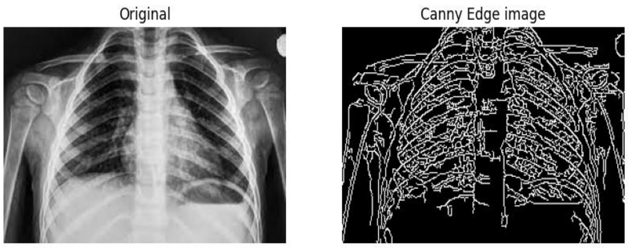

Figure 12: Canny Edge Detection

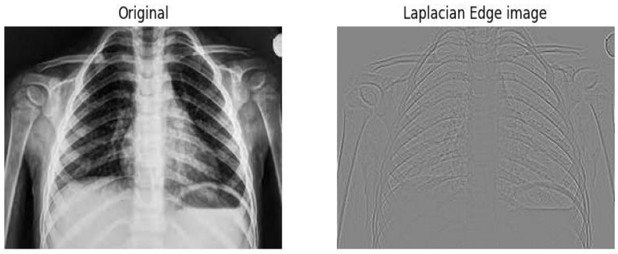

Figure 13: Laplacian Edge Detection

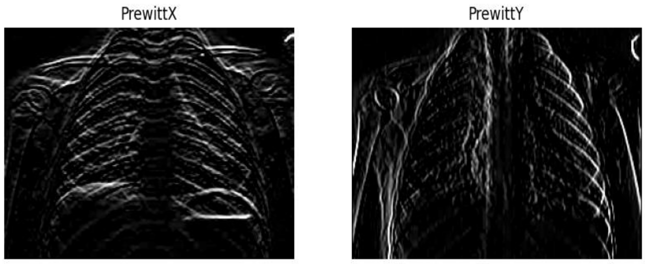

Figure 14: Prewitt Edge Detection

Sobel and Prewitt Laplacian results actually deviated and Canny produce almost same edge map. It has been observed from the figure that canny result is superior by far to the other results.

V. CONCLUSION

Multimodal image processing methods are gradually replacing the more traditional single-modality approaches. The computational methods integrate imaging with other forms of data. The advent of digital image processing has greatly facilitated many facets of our lives, including work and study. As digital image processing moves into the field of algorithmic research with the help of neural networks, fuzzy logic, artificial intelligence, associated image processing expertise will be carried out to full fill the purpose. The enlargement of AI and Deep Learning has led to the gradual proposal of image enhancement algorithms which is based on deep convolution neural networks. The method is fast and accurate enough to meet the requirements of digital image processing.

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Ethical Approval and Consent to Participate	No, the article does not require ethical approval and consent to participate with evidence.
Availability of Data and Material	Not relevant.
Authors Contributions	All authors having equal contribution for this article.

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AUTHORS PROFILE

Tanusree Saha, M. Tech, pursuing Ph.D. from Magadh University Bodh Gaya, currently working as Assistant Professor, JIS, College of Engineering, Kalyani. Perused M. Tech Degree from West Bengal University of Technology. Having 13 years of teaching experience and 3 years of research experience in the field of Digital Image Processing and allied technology. Have guided several UG level projects till date through the journey as teaching professional. A certificated AWS cloud Foundation Educator since 2021. Apart from Digital Image Processing research domain, also working on Machine Learning, Artificial Intelligence based projects. Till date have published more than 18+ IPR-Patent. Received AWS Educator excellence award in consecutive two years [2022 &2023] by AWS academy. Life members of FOSET, ISTE and CSI.

Dr. Kumar Vishal originally hails from Aurangabad district in Bihar. He has done his Ph. D. from Banaras Hindu University, Varanasi, Uttar Pradesh. He is currently working as an Assistant Professor at the P. G. Department of Mathematics, Magadh University, Bodh-Gaya and also as the In-charge of Department of Computer Science, Magadh University, Bodh-Gaya. He has published several national and international journals of high repute and attended several seminars/conferences/workshops of state and national level. His area of research is majorly in the field of Nonlinear Dynamics, Fractional Calculus. He has significant contribution in the domain of mathematics through his research publication.