

DIAGNOSES OF MEDICAL IMAGE USING NANO DIGITAL TOPOLOGY

K. Bhuvaneswari and J. Sheeba Priyadharshini

Department of Mathematics,
Mother Teresa Women's University,
Kodaikanal - 624101, Tamil Nadu, INDIA

E-mail : drkbmaths@gmail.com, jsheeba02@gmail.com

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Abstract: In this paper the new concept of nano topological boundary approach is introduced to identify the bone fracture in it digital images.

Keywords and Phrases: Bone Fracture Detection, Nano Topology, Black Points, White Points, Boundary Point, Medical Image, Image Segmentation.

2010 Mathematics Subject Classification: 54A05.

1. Introduction

X-ray medical imaging plays a vital role in diagnosis of bone fracture in human body. The X-ray image helps the medical practitioners in decision making and effective management of injuries. In order to improve diagnosis results, the stored digital images are further analyzed using medical image processing. The most common ailment of the human bone is fracture. Bone fractures are nothing but the cracks which occur due to accidents. There are many types of bone fractures such as normal, transverse, comminuted, oblique, spiral, segmented, avulsed, impacted, torus and greenstick [3, 4].

Medical image processing is a field of science that is gaining wide acceptance in healthcare industry due to its technological advances and software breakthroughs. Among the various diseases, bone fracture detection and treatment, which affects many people of all ages, is growing important in modern society. Bone fracture is common problem even in most developed countries and the number of fractures is increasing rapidly. Bone fracture can occur due to a simple accident or different

types of diseases. So, quick and accurate diagnosis can be crucial to the success of any prescribed treatment. In practice, doctors and radiologists rely mainly on X-ray images to determine whether a fracture has occurred and the precise nature of the fracture. Manual inspection or conventional system of X-rays for fracture detection is a tedious and time consuming process. A tired radiologist has found to miss a fracture image among healthy ones. Depending on the experts alone for such a critical matter has caused intolerable errors and hence, the idea of automatic diagnosis procedure has always been an appealing one. Over the last two decades, digital topology has proved to be a very strong aid in image analysis and image processing. Rosenfeld et al., [2] first presented the fundamentals of digital topology, which provides a sound mathematical basis for image processing operations such as image thinning, border following, contour filling and object counting. Whenever spatial relations are modeled on a computer, a digital topology is needed. Rough set theory introduced by Pawlak [6] in 1982 is a mathematical tool that supports also the uncertainty reasoning but qualitatively. In Pawlak's study, any rough set is replaced by the crisp sets called lower and upper approximations of it. The lower approximation consists of all objects which surely belongs to the set and the upper approximation contains all object which possibly belongs to the set. The difference between the upper and the lower approximation constitutes the boundary region of the rough/nano set. The purpose of this paper is concentrated on developing a nano image processing based efficient system for a quick and accurate classification of bone fractures based on the information gained from the X-ray/CT images.

2. Preliminaries

Definition 2.1. [3] *The elements of a two-dimensional image array are called pixels. The elements of a three-dimensional image array are called voxels. Each pixel or voxel is associated with a lattice point in the plane or in 3D-space.*

Definition 2.2. [3] *Two lattice points in the plane are said to be 8-adjacent if they are distinct and each coordinate of one differs from the corresponding coordinate of the other by at most 1.*

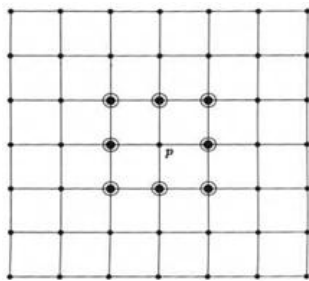


Figure 2.1: 8-Adjacent

Definition 2.3. [3] Two lattice points in the plane are said to be 4-adjacent if they are 8-adjacent and differ in at most one of their coordinates. That is any pixel $p(x,y)$ has two vertical and two horizontal neighbors, given by:
 $(x+1, y), (x-1, y), (x, y+1), (x, y-1)$

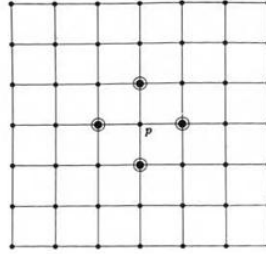


Figure 2.2: 4-Adjacent

Definition 2.4. [3] A two dimensional unit cell is a square with sides of length one whose corners are all lattice points. A one dimensional unit cell is a straight line segment of length 1 joining two lattice points. A 0-dimensional unit cell is a lattice point

Definition 2.5. [3] A lattice point associated with a pixel or voxel that has value 1 is called black point ($\bullet$) A lattice point associated with a pixel or voxel with value 0 is called a white point (0).

Definition 2.6. [3] A digital picture is a quadruple (V, m, n, B) , where $V = \mathbb{Z}^2$, $B \subseteq V$ and where $(m, n) = (4, 8)$ or $(8, 4)$ if $V = \mathbb{Z}^2$. The elements of V are called the points of the digital picture. The points in B are called the black points of the picture; the points in $V - B$ are called the white points of the picture.

Definition 2.7. [3] Two black points in a digital picture (V, m, n, B) are said to be adjacent if they are m -adjacent and two white points or a white point and a black point are said to be adjacent if they are n -adjacent. A Straight line segment that joins two adjacent points is called an adjacency.

Definition 2.8. [3] A set S of black and/or white points in a digital picture is connected if S cannot be partitioned into two subsets that are not adjacent to each other.

Definition 2.9. [3] A component of a set of black and/or white points S is a non-empty connected subset of S which is not adjacent to any other point in S . In a (m, n) digital picture a component of a set of black points is an m -component, whereas a component of a set of white points is an n -component.

Definition 2.10. [3] A component of the set of all black points of a digital picture

is called black component, and a component of the set of all white points is called a white component. In a finite digital picture there is a unique infinite white component, which is called the background.

Definition 2.11. [7] Let U be a certain set called the universe, and let R be an equivalence relation on U named as indiscernibility relation. The pair $A = (U, R)$ will be called an approximation space. If $x, y \in U$ and $(x, y) \in R$ we say that x and y are indistinguishable in A . Let $X \subseteq U$.

- (i). The lower approximation of a set X with respect to R is the set of all objects, which can be for certain classified as X with respect to R (are certainly X with respect to R) and it is denoted by $R(X)$. That is, $R(X) = \cup\{Y \in U/R : Y \subseteq X\}$.
- (ii). The upper approximation of a set X with respect to R is the set of all objects which can be possibly classified as X with respect to R (are possibly X in view of R) and it is denoted by $R(X)$. That is, $R(X) = \cup\{Y \in U/R : Y \cap X \neq \emptyset\}$.
- (iii). The boundary region of a set X with respect to R is the set of all objects, which can be classified neither as X nor as not- X with respect to R and it is denoted by $B N_R(X) = R(X) - R(X)$.

Definition 2.12. [7] Let U be a certain set called the universe, and let R be an equivalence relation on U named as indiscernibility relation. Let $X \subseteq U$.

- (i). A set X is crisp (exact with respect to R), if the boundary region of X is empty. That is $R(X) = R(X)$.
- (ii). A set X is rough (inexact with respect to R), if the boundary region of X is nonempty. That is $R(X) \neq R(X)$.

3. Nano Image Processing Techniques

In this paper, bone fracture detection system is implemented with five steps procedures. The X-ray images are obtained from radiology websites that contains normal as well as fractured bone images. A typical computer aided diagnosis systems that depend on medical images contains image processing tools for noise removal, enhancement and feature extraction play a crucial role in the success of such systems. In the first step, applying preprocessing techniques such as RGB to grayscale conversion and enhance them by using sharpening technique to sharp the bone region in the images. After preprocessing, it converts the image into digital image that is (m, n) connected component digital picture. Then nano approximation techniques applied to a converted digital picture. And finally the image segmented through the nano approximation space. In this step segmented image classifies the fracture and non-fractures. The general block diagram of the proposed system is illustrated in Figure 3.1 and the following subsections are discussed these steps in detail.

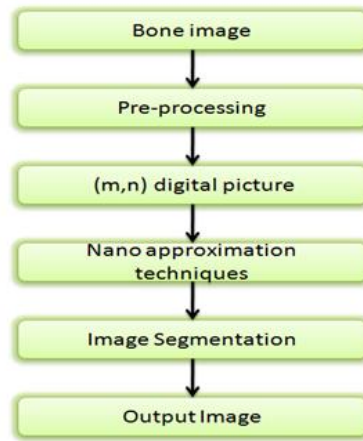


Figure 3.1

3.1. Input Image

Input X-ray image or image acquisition is the very first step of the proposed system. Therefore, this work depends on X-ray/CT images to diagnose bone fractures. The initial step is the image acquisition to get the data in the form of digital X-ray images that are required in this research. Image acquisition can be broadly into the action of retrieving an image from some hardware source. JPG format is used for input X-ray images in this research work because this is ease to process in image processing algorithms.

After this step, image preprocessing is required because there is need to enhance the input X-ray image by removing noise or sharpening image edges and get soft focus (blurring) effect for further processes. Figure 3.2 shows the scanning X-ray image of bone.



Figure 3.2 (a). Normal arm bone

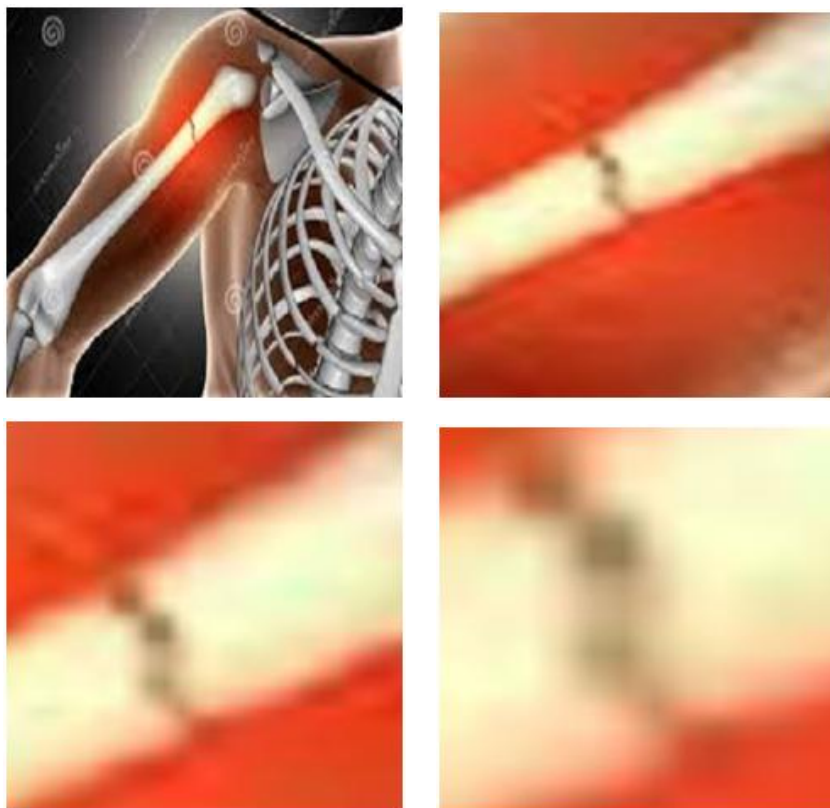


Figure 3.2 (b). Fractured arm bone

3.2. Image Preprocessing

Pre-processing is an essential stage since it controls the suitability of the results for the successive stages. Image enhancement technique can be used as preprocess or post process portion. Image sharpening refers to any enhancement technique that highlights edges and fine details in an image. In this step, image preprocessing is carried out by the following procedure. The input X-ray/CT image is RGB image. Firstly, this image is converted into gray scale image which is single layer image to speed up the processing time and less computation. The digital X-ray images of bone fracture needs to be pre-processed to improve the quality of image before analysis. In the pre-processing stage, noise removal, shading correction and contrast enhancements are performed on the X-ray/CT images. These stages consist of the procedures that enhance the features of an input X-ray/CT image so that resulting image improves the performance of the subsequent stages of the proposed system. Figure 3.3 shows the preprocessed image of the bone.



Figure 3.3

3.3. Digital Picture

Digital image processing deals with manipulation of digital images through a digital computer. It is a subfield of signals and systems but focus particularly on images. Digital image processing focuses on developing a computer system that is able to perform processing on an image. The starting point of research on digital topology was the simple but important idea of using different adjacency relations for black and white points, a device which as far as was first recommended by Duda, Hart, and Munson [1]. The digital image processing deals with developing a digital system that performs operations on an digital image. In other words, an image can be defined by a two-dimensional array specifically arranged in rows and columns. Digital Image is composed of a finite number of elements, each of which elements have a particular value at a particular location. These elements are referred to as picture elements, image elements and pixels. A Pixel is most widely used to denote the elements of a Digital Image. A pixel p at coordinates (x, y) has four horizontal and vertical neighbors whose coordinates are given by $(x + 1, y)$, $(x - 1, y)$, $(x, y + 1)$, $(x, y - 1)$. This set of pixels, called the 4-neighbors of p , is denoted by $N_4(p)$. Each pixel is a unit distance from (x, y) , and some of the neighbors of p lie outside the digital image if (x, y) is on the border of the image. Connectivity between pixels is a fundamental concept that simplifies the definition of numerous digital image concepts, such as regions and boundaries. To establish if two pixels are connected, it must be determined if they are neighbors. Here Figures 3.4 (a) and 3.4 (b) should have the same connectivity paradoxes as the original pattern of Figures 3.2 (a) and 3.2 (b). This is achieved by testing each pixels adjacency relation. In Figures 3.4 (a) and 3.4 (b), the black points and white points are shown as $\bullet$ and $\circ$ respectively. Figure 3.4 shows digital representation of the binary images given in Figure 3.3.

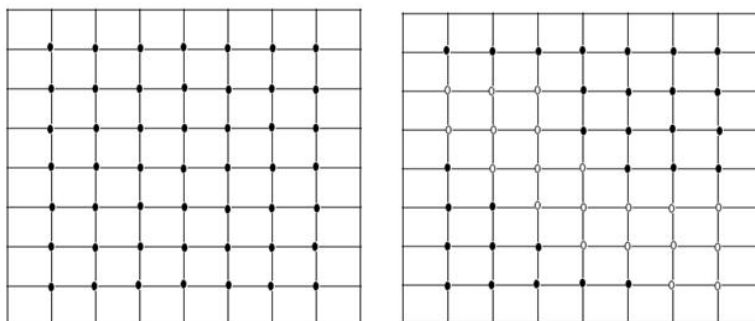


Figure 3.4 (a). Connectivity Paradoxes of normal arm bone

Figure 3.4 (b). Connectivity Paradoxes of fractured arm bone

3.4. Nano Approximation Techniques

Rough set theory is the approximation space whose topology is generated by the equivalence classes of R . The partition characterizes a topological space, called approximation space $K = (U, R)$, where U is a set called the universe and R is an equivalence relation.

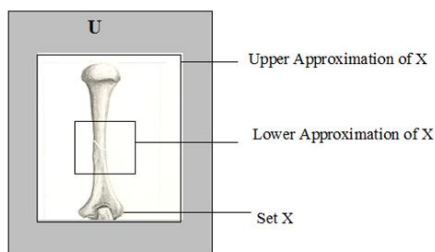


Figure 3.5 An Example arm bone image of representing a nano topology

The equivalence classes of R are also known as the granules, elementary sets or blocks; rough sets have been successfully employed for various image processing tasks including image segmentation, enhancement and classification. Figure 3.5 shows an example of representing a rough set. There is an object X , and two squares. A first square which include the object is upper approximation ($\bar{N}$), and a next square which included the object is lower approximation (N^0). In this situation, rough set theory offers a tool to deal with inconsistencies.

The digital image (medical image) segmentation using rough sets shows the result exactly. A lower approximation of a nano topology (N^0) is composed of all the elementary sets included in X , and upper approximation of a nano topology ($\bar{N}$), is composed of all the elementary sets which have non-empty set intersection with X . Here the set of all white points and black points denoted the upper approximation

and lower approximation of a digital picture respectively. A block point is called a nano boundary points if it is adjacent to one or more white points and it is denoted by N_{BND} . In a finite digital picture there is a unique infinite white component, which is called the nano background of a digital picture. The nano boundary point shows the fracture outline of the bone image. Fig 3.6 shows the disconnectedness of black points that is black points separated as two black components. In this case the binary digital picture was identified by the transformation of some black points to white ones. In Figures 3.6 the boundary points are shown as $\square$. Figure 3.6 shows nano representation of the image given in Figure 3.3.

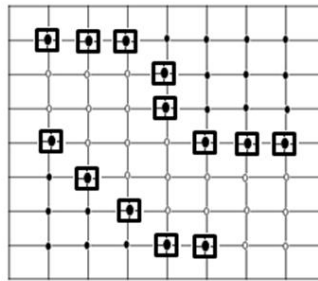


Figure 3.6

3.5. Image Segmentation

In the domain of image processing, image segmentation has become one of the key applications that are involved in most of the image based operations. Image segmentation refers to the process of breaking or partitioning any image. Image segmentation is the process of splitting an image space into non-overlapping and meaningful homogeneous regions. Image segmentation also faces some problems and issues when segmenting process becomes much more complicated. Previously lot of work has proved that Rough-set theory can be a useful method to overcome such complications during image segmentation. Therefore, Rough-set in image segmentation can be very useful. Rough-set based image segmentation provides a stable and better framework for image segmentation. The segmentation of medical images is challenging due to the poor image contrast and artifacts that result in missing or diffuse organ/tissue boundaries. The basic idea behind segmentation-based rough sets is that while some cases may be clearly labeled as being in a set X , and some cases may be clearly labeled as not being in X . Let the universe U is an image consisting of a collection of pixels. Then if we partition U into a collection of arrays, each array can be considered as a unit cell. Here the digital images segmented by the nano boundary approximations. Figure 3.7 gives the output of the digital image.



Figure 3.7

4. Conclusion

This work presents a connection between theoretical results in nano topology and applied ones in digital imaging and also presented some results that show how the choice of the nano topology used can be crucial in preserving the desired properties of the initial bone image. We aim in the future to implement some theoretical and practical results and to take advantage in many applications.

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