

# Calculation of Geometric Properties of Compact Bone

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**ABSTRACT:** Bone disease and fracture healing affect the geometry of the bone cross sections. This variation can be used as a diagnosis tool to evaluate the normal and abnormal health condition. In this work we conduct an analysis which is using image processing to find the geometric properties of compact bone. Two verification examples were considered (black rectangular and compact bone in Femur). Images were converted to binary image to make the defining of the object easy to be done. The results in the first example show excellent agreement and the error is less than 1%. In the second case the results show almost the same change with the length of the Femur bone and they were close. The accuracy cannot be verified because the bone used by Khalil et al 1981 is different than the bone we used (bones differ from person to person due to age, length, weight, and health condition). The compact bone gives the bone its strength. The change in the geometrical properties of the bones gives us good indication about the health condition of the bone.

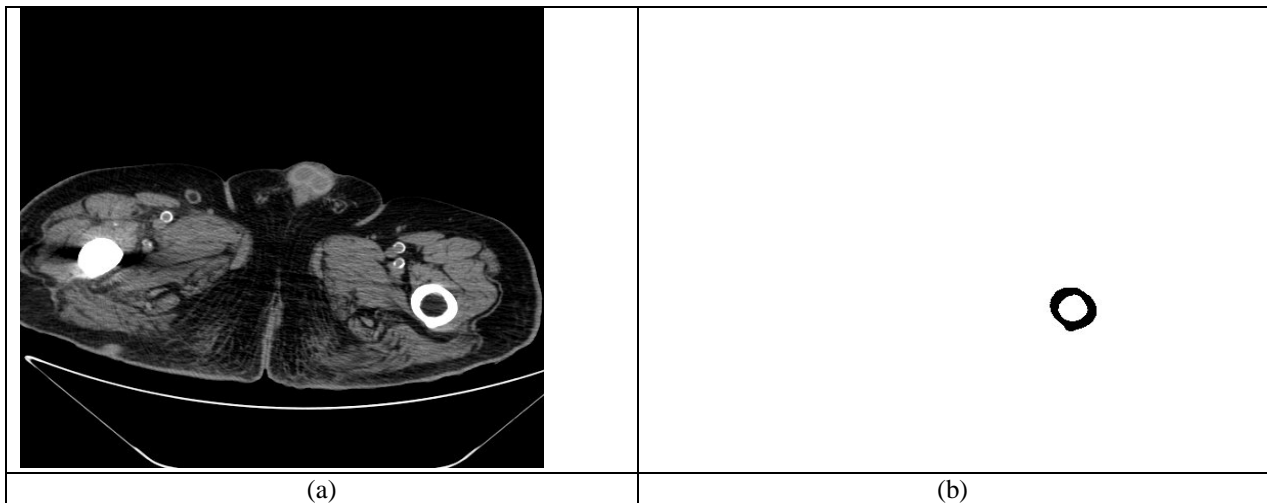
**KEYWORDS:** Bones, Image Processing, Binary Image, Geometrical Properties, Compact Bone.

## I. INTRODUCTION

Many engineering practice involves the calculation of geometric properties (area, centroid, moment of inertia, and angle of rotation of the principle axis). Approximation methods were used to estimate those properties by discretization and fitting the curvature to standard geometrical shapes (square, rectangular, etc). This approximation leads to percentage of error which can be accumulated with other errors in the engineering analysis and may cause the solution to be divergent or we will have a solution with relatively accepted engineering error.

In this work we will use the image processing to calculate the geometric properties of any irregular shape. Electronic images are constructed from small elements called pixels. Those pixels contain the information about the color and the location in the image. Images can be converted to mathematical model (matrix). Each pixel will be converted to a number which is related to its color and its location in the matrix represent its coordinate in the original image. In order to simplify the calculation the images will be converted to binary image (black, white or empty). The matrix related to the binary image will consist of zero and one (zero for white and one for black) [1].

The theory of finding the geometric properties follows the standard procedures (first and second moments of area) which are well known for all engineers. The irregular shapes we are going to deal with in this paper cannot be discretized into elements of standard shapes. Such shape can be found in Biomechanics application (bones, nerves, air throat, etc). Data received from CT scan or MRI are in DICOM image formats (gray image). Those data can be converted to binary images after identifying the region of interest by using thresholding. Thresholding will group the pixels which have the same grayscale value. Deleting and improving the result image will make it ready for the calculation of the geometric properties. Figure (1) shows the image of a section of the femur bone obtained by CT scan before and after converting the image to binary image [2]. The work in this paper is divided into two stages. 1) Text- Detection 2) Inpainting. Text detection is done by applying morphological open-close and close-open filters and combining the images. Thereafter, gradient is applied to detect the edges followed by thresholding and morphological dilation, erosion operation. Then, connected component labelling is performed to label each object separately. Finally, the set of selection criteria is applied to filter out non-text regions. After text detection, text inpainting is accomplished by using exemplar based Inpainting algorithm.

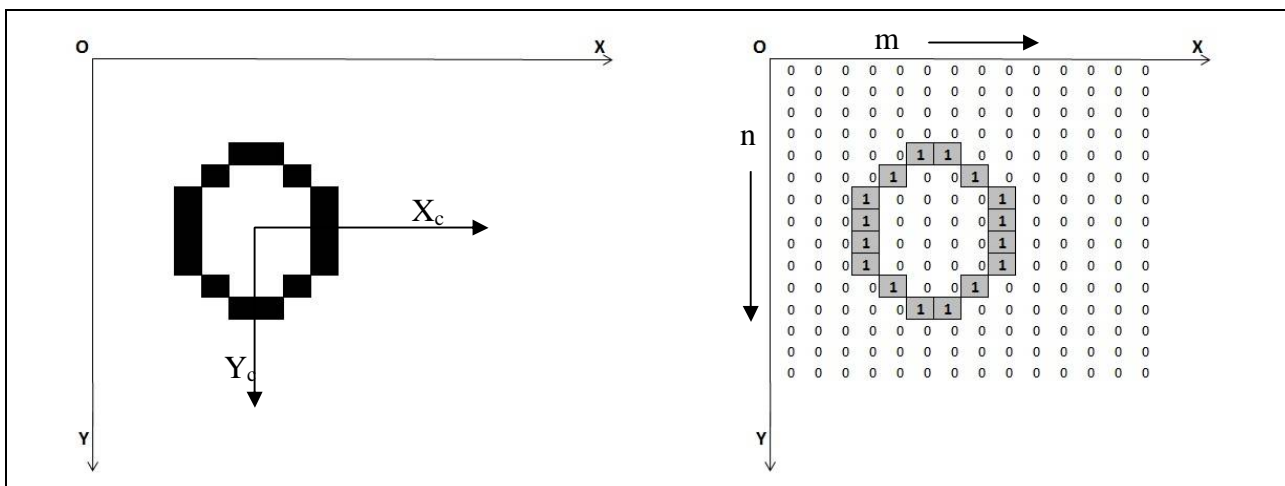


**Figure: (1)** DICOME image obtained by CT scan. (a) before processing and (b) after processing

## II. GEOMETRICAL PROPERTIES CALCULATION

Binary image are made of pixels that has two values. Thos values are often called “foreground” and “background”. In the binary image the foreground is 1 and the background is 0. The object in the binary image will be constructed from pixels with 1 value. It will become easy to isolate the object and count the number of pixels which has 1 value.

Binary image can be obtained by adjusting a grayscale image by identifying the region of interest (ROI). The later can be obtained by using thresholding operation. The thresholding will group all the pixels which has grayscale value within a specific range (for bones the grayscale range is 1250 to 2635). By converting the grayscale image to binary all objects which has different values will be deleted. The Binary Image can be represented by a matrix in which each pixel has a value of 1 or 0 and its location in the matrix (m n) represent the coordinate of that pixel in the original image Figure (2).



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## III. AREA

The area of an object in a binary image can be found by calculating the number of pixels that has the value of 1. The shape of the pixel is square and its dimension can be found by dividing the size of the image by the number of pixels. This value will be used to convert the length in pixels to mm. Area of the object can be found by multiplying the total number of pixels which belongs to the object by the area of the pixel.

$$\text{Correction factor (f)} = \frac{\text{length of image in mm}}{\text{length of image in pixels}}$$

$$\text{Area of square with the dimension 1 pixel length (a)} = b^2$$

Where, (b) is the pixel length in mm.

$$\text{Area of the object (A)} = N * a$$

Where, N is the total number of pixels which belong to the object

## IV. CENTROID

The centroid of irregular object can be found by using the first moment of area. If we consider that the object is constructed from a defined number of square elements (pixels) then the multiplication of the area of each element by the distance from its centroid to certain coordinate will identify the first moment of area of that element. The coordinate system from the binary image will be defined as the upper side (X-axis) and the left side (Y-axis) as shown in fig (2).

$$\text{First moment of area about X-axis} = \sum_1^N a * ((n-1) * f + \frac{b}{2})$$

$$\text{First moment of area about Y-axis} = \sum_1^N a * ((m-1) * f + \frac{b}{2})$$

Where,

m & n are the number of row and column.

The centroid coordinate can be found by dividing the first moment of area by the object area.

$$X_c = \frac{\text{First moment of area about Y-axis}}{\text{Area of the object}}$$

$$Y_c = \frac{\text{First moment of area about X-axis}}{\text{Area of the object}}$$

## V. MOMENT OF INERTIA

The moment of inertia can be found by calculating the moment of inertia of each square element about its centroid. The moment of inertia for each element is transferred to the coordinate system (X or Y axis) by using the parallel axis theorem. The moment of inertia of the object about the coordinate system is found by the summation of all the moments of inertia of all elements. The moment of inertia of the object about its centroid axis can be found by using the parallel axis theorem.

$$\text{Moments of inertia about X-axis } (I_x) = \sum_1^N \left( \frac{b^4}{12} \right) + a * (n-1) * f + \frac{b}{2}$$

$$\text{Moments of inertia about Y-axis } (I_y) = \sum_1^N \left( \frac{b^4}{12} \right) + a * (m-1) * f + \frac{b}{2}$$

$$\text{Product of inertia } (I_{xy}) = \sum_1^N a * ((m-1) * f + \frac{b}{2}) * ((n-1) * f + \frac{b}{2})$$

$$\text{Moment of inertia about } X_c \text{-axis } (I_{xc}) = I_x - a * Y_c^2$$

$$\text{Moment of inertia about } Y_c \text{-axis } (I_{yc}) = I_y - a * X_c^2$$

$$\text{Product of inertia about the centroid } (I_{xcyc}) = I_{xy} - a * X_c * Y_c$$

Maximum and minimum moments of inertia

$$I_{max \& min} = \left( \frac{I_{xc} + I_{yc}}{2} \right) \pm \sqrt{\frac{(I_{xc} - I_{yc})^2}{4} + (I_{xcyc})^2}$$

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$$\text{Angle of rotation of principle axis}(\theta) = \frac{1}{2} * \tan^{-1} \left( \frac{2 * I_{xcyc}}{I_{yc} - I_{xc}} \right)$$

## VI. VERIFICATION EXAMPLE

The above procedure will be verified by using two examples.

The first case study is an image of rectangular shape area. The dimension of the rectangular is 6.69 cm width and 6.59 mm height (253 pixel and 248 pixel).

Correction factor (f) =  $0.02644 \frac{cm}{pixel}$

Pixel area (cm<sup>2</sup>) =  $6.9907 * 10^{-4} cm^2$

The table below show the results obtained from the image processing procedure and the standards formula for the rectangular shape.

Table (1) Comparison between the analytical and image processing results.

No	Parameter	Analytical results	Image processing results
1	Area	43.8864	43.8627
2	Centroid (Xc)	3.345	3.3447
3	Centroid (Yc)	3.28	3.2786
4	Moment of Inertia (I <sub>xc</sub> )	157.3824	157.1593
5	Moment of Inertia I <sub>yc</sub>	163.682	163.5603
6	Product of inertia (I <sub>xcyc</sub> )	0	$2.4954 * 10^{-11}$
7	Max moment of inertia (I <sub>max</sub> )	163.682	163.5603
8	Min moment of inertia (I <sub>min</sub> )	157.3824	157.1593

The second case study is an 82 DICOM images obtained from CT scan for the right Femur. The results are compared with those obtained by **Khalil et al (1980)**. The following figures show the comparison between different geometric parameters.

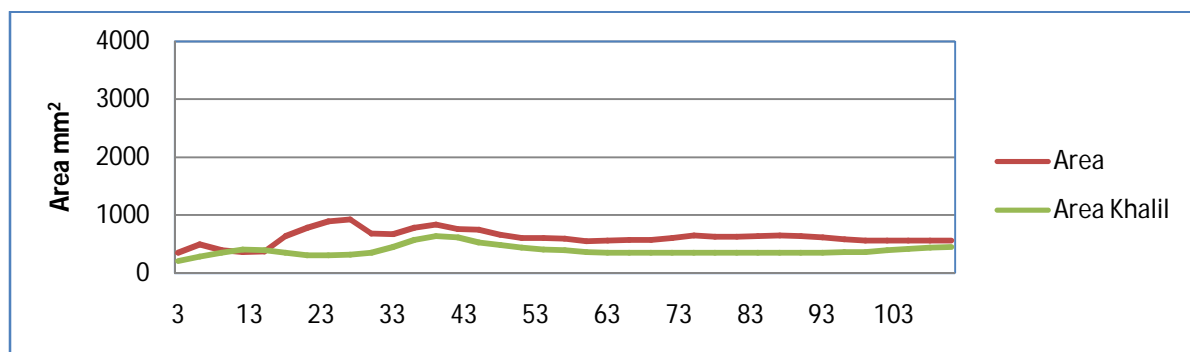


Figure (3): Area variation along Femur bone.

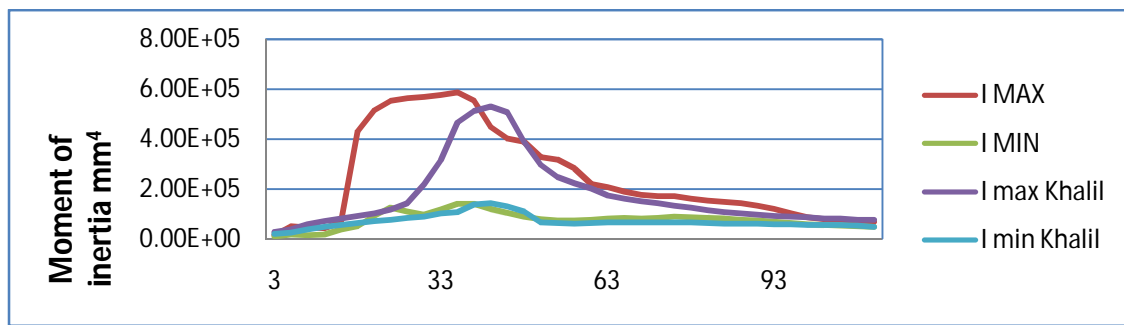
The variation in the area of the compact bone follow the expected manner increasing from zero to some point where the cross sectional area is maximum and then decrease due to the change in the shape of the bone and its value remain almost constant in the bone shaft because the shape change is relatively low.

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**Figure (4):** Moment of inertia comparison between present study and Khalil et al (1980).

## VII. MATERIALS

Samples (10 bones) were collected from different cows. CT-Scan test was made for the bones. The images obtained from the test were stored in DICOM format. CT-Scan device type GE Medical Systems\Discovery CT 750 HD was used and the images were taken with the same setting (KVP 120, slice thickness 2.5 mm, and tube current 120 mA). The number of images depends on the bone length (200-300).

## VIII. RESULT AND DISCUSSION

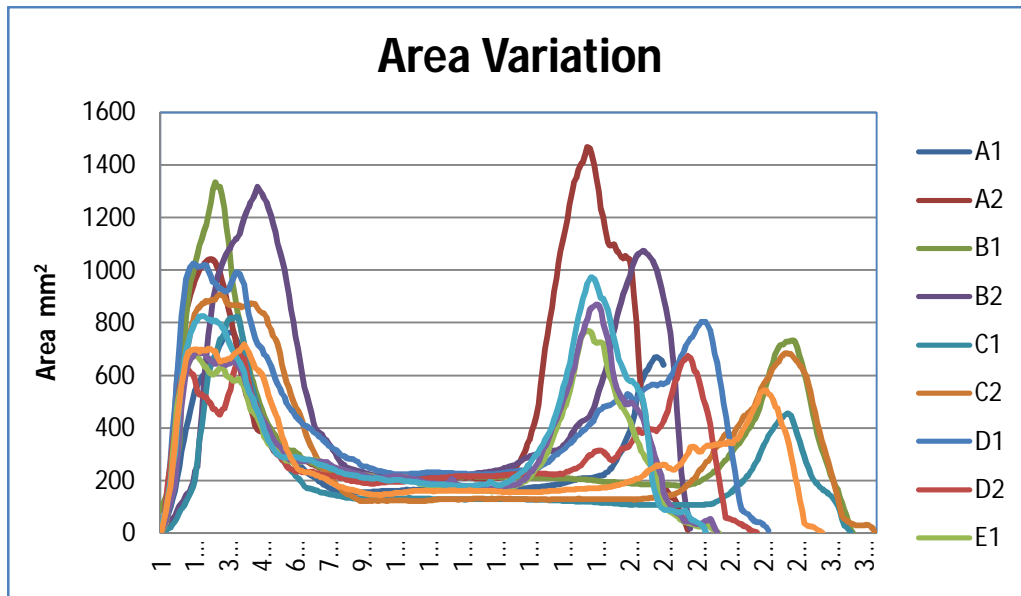
The images of the bones were processed by using J-Image program. They were converted to 8-bit binary image format. Thresholding was performed to identify the region of interest and other objects were deleted. Mat lab program was used to apply the prescribed procedure to evaluate the geometrical properties of each section. Compact bone area variation of all the samples are shown in the figure (5). The area increases as we move to the right. Although, the compact bone form only a thin layer in the bone ends but its area is higher than the mid shaft, this increase is due to the large size of bone end. This increase continue to certain point and the area start to decrease. This decrease is due to the decrease in the entire sections area. The compact area become nearly constant in the bone shaft because the changes in the geometry of the shaft are very small. Area start to increases when the other end is reached. This increase is due to the increase in the entire section area and at a certain point the area start to decrease as a results of the decrease in the cross-section of the bone.

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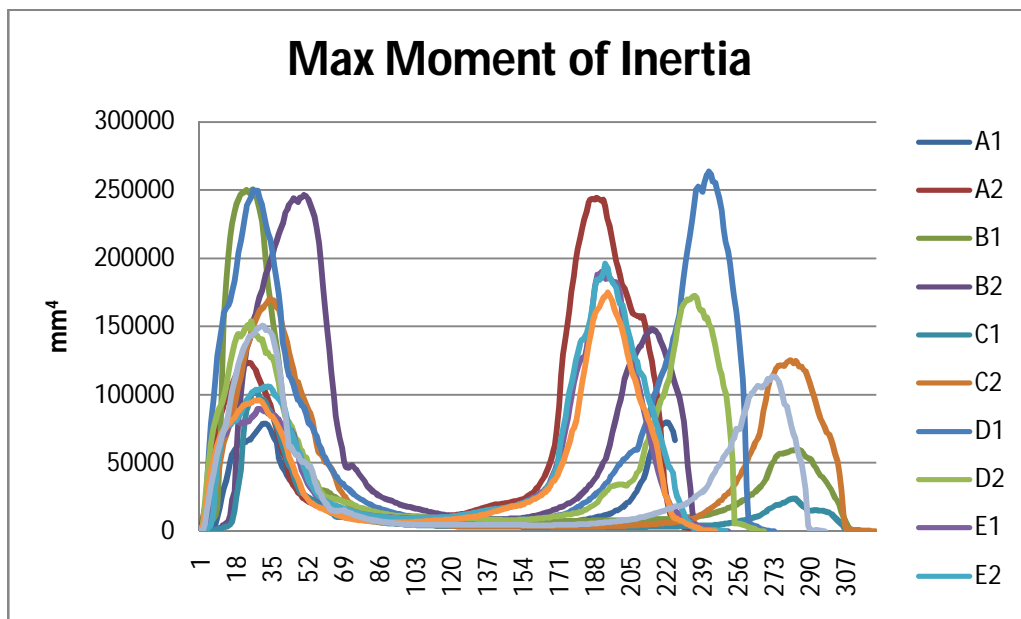
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**Figure (5):** Compact Bone area variation along the bone.

The bone cross section irregularity results a two principle axis (maximum and minimum). The area moment of inertia are calculated on bone directions. The variation in the maximum and minimum moment of inertia are presented in figures 6 and 7. The variation follow the same as the area variation along the bone.



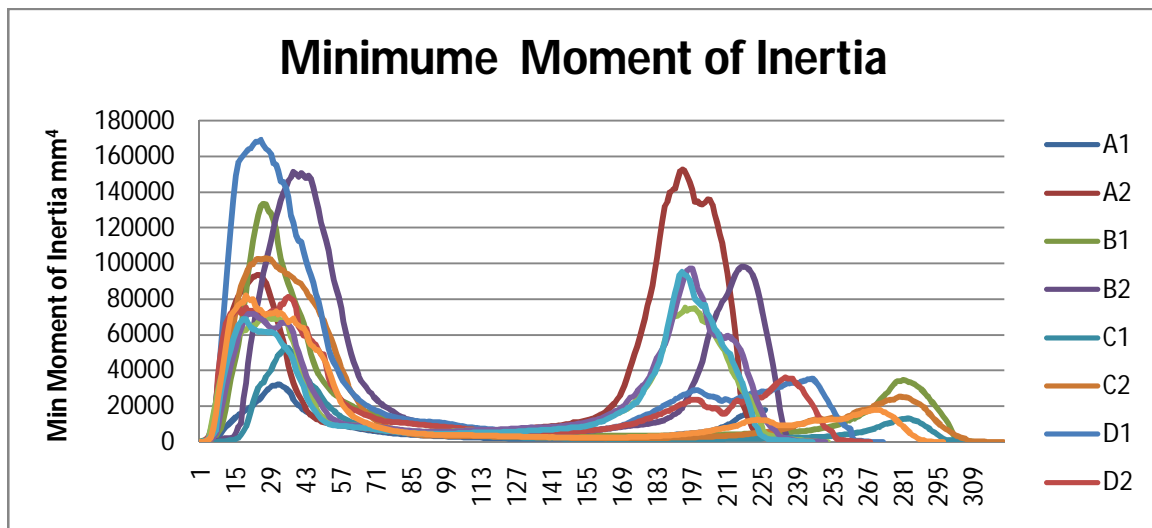
**Figure (6):** Compact Bone Maximum moment of inertia variation along the bone.

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**Figure (7):** Compact Bone Minimum Moment of inertia variation along the bone.

## IX. CONCLUSION

The Image processing technique is a powerful tool which can be used to solve many engineering problems. In the first case study the accuracy was excellent (less than 1%). The deviation in results in the second case is due to the different femur bones used. Also Khalil et al (1980) used 59 section to draw the variation of the geometric properties along the full length of the bone while in this work 82 DICOME images (sections) used to describe the variation of the geometric properties along part of the femur bones. There was good agreement with the previous work done by Khalil et al (1980) and the behavior of the variation is the same. Many bone disease affects the geometry of the bone and those changes can be identified by the changes in these properties and in fracture healing the geometry of the fractured section will change as the bone heal. The determination of the geometrical properties can be used as indication about the pathological health condition of the bone.

## CONFLICT OF INTREST

No outside funding or grants in support of our research for or preparation of the work is received. And no personal or institutional financial support is related to the study. Furthermore, we have had full control of all primary data and we agree to allow the journal to review the data if recommended. Therefore, we accompany this submission with Authorship Responsibility and Disclosure Regarding Commercial Interest form.

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## REFERENCES

- 1 R. C. Gonzalez and R. E. Woods, Digital Image Processing. PrenticeHall, 3rd ed., 2007.
- 2 Dhananjay K Teckedath, Image Processing, Third edition. Nandu Publishers, Mumbai.

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(An ISO 3297: 2007 Certified Organization)

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- 3 I.Weiss, "Projective invariants of shapes," in Proc. Computer Vision and Pattern Recognition CVPR '88, pp. 1125–1134, IEEE Computer Society, 1988.
- 4 Anil K Jain, Digital Image Processing, Prentice Hall, Englewood Cliffs, New Jersey, USA.
- 5 Flusser, J.; Suk, T.; Saic, S., Recognition of blurred images by the method of moments, Image Processing, IEEE Transactions.
- 6 Dr. T.C. Manjunath, Ph.D, Detection of Shapes of Objects Using Sophisticated Image Processing Techniques, International Journal of Computer Science & Emerging Technologies. Volume 1, Issue 4, December 2010.
- 7 M.-K. Hu, "Visual pattern recognition by moment invariants," IRE Trans. Information Theory, vol. 8, no. 2, pp. 179–187, 1962.
- 8 D.B. Khalil, D. C. Viano and L. A. Taber, Vibrational Characteristics of the Embalmed Human Femur. Journal of sound and Vibration, vol 75, pp 417-436, 1981.
- 9 Shaker S. Hassan and Ameen M. Al Juboori. "Natural Frequency Change due to Disrupting the Organic Materials inside Bone Matrix". Journal of Advanced in Natural and Applied Science, 2016 December 10(17): pages 210-216. 2016 December10 (17): pages 210-216.
- 10 Shaker S. Hassan and Ameen M. Al Juboori. "Acidic Medium Effect on the Natural Frequency of Bones". Journal of Applied science research. 2017March; 13(3): pages 27-34.