How to Cite:
Aashikathulzuberiya, J., Sathik, M. M., & Nisha, S. S. (2022). Three dimensional reconstruction of the spine computed tomography (CT) images from 2D CT slices. *International Journal of Health Sciences*, *6*(S3), 2521–2531. https://doi.org/10.53730/ijhs.v6nS3.6075

Three dimensional reconstruction of the spine computed tomography (CT) images from 2D CT slices

Aashikathulzuberiya J.
Ph.D Research Scholar, Sadakathullah Appa College | Manonmaniam Sundaranar University, Abishekapatti, Tirunelveli, Tamil Nadu 627012, India

Mohamed Sathik M.
Principal & Research Supervisor, Sadakathullah Appa College | Manonmaniam Sundaranar University, Abishekapatti, Tirunelveli, Tamil Nadu 627012, India

Shajun Nisha S.
Assistant Professor and Head, PG & Research Department of ComputerScience, Sadakathullah Appa College | Manonmaniam Sundaranar University, Abishekapatti, Tirunelveli, Tamil Nadu 627012, India

***Abstract*---**In medical field, imaging techniques are used for diagnosis of different disease and carrying out treatments. Number of people affected by spinal disorders is increasing nowadays. The Spine details obtained from a Computed Tomography (CT) imaging plays a significant role in screening of spine conditions, disorders and also useful for planning of surgeries. Spine has a complex structure as it consists of vertebrae, intervertebral disks, spinal cord. Surgeons face challenges while working with the computer aided system for training of surgeries. This can be made ease by creating a Three dimensional image models as it provide detailed view of the internal parts of the spine. In this paper, a method for developing three dimensional image from two dimensional slices for spine CT images is presented. The Global thresholding and a mathematical morphological technique is applied in the presented method. It is concluded that segmented and mathematical morphological technique applied reconstruction produce better results than the direct reconstruction of images from the segmented image. The visualization and the quantitative results state the method is effective and better. The results are evaluated using the metrics like Accuracy, Sensitivity, Specificity and Dice.

***Keywords*---**computed tomography (CT), spine disorders, spine CT images, reconstruction, accuracy.

***Corresponding author**: Aashikathulzuberiya, J.; Email: aashikameera@gmail.com*
Manuscript submitted: 18 Dec 2021, Manuscript revised: 27 March 2022, Accepted for publication: 09 April 2022

Introduction

Computer based technology holds an important role in the medical field. Even it plays a vital part in performance of surgery. In Medical field there are different imaging techniques used for diagnosing and treating the diseases and carry out a surgery or operation. The term CT refers to "computed tomography". Computed Tomography (CT) is a violation free screening technique that guides doctors. During screening process the body is, invaded through radiations. CT is a computer based imaging process in which x- rays, a thin light emission beams also called as narrow beam is focused on a patient and immediately turned around the body, creating signals that are prepared by the machine's system to produce cross-sectional picture or slices of the body. The images or slices generated by this process are called as tomographic images. These contain more definite data than traditional x-beams. While comparing to the traditional x – rays the CT images contain more definite and detailed data. When number of cross-sectional slices are gathered, the slices can be digitally "stacked" together carefully to frame a three-dimensional image of the patient. The three dimensional image helps to identify the anomalies and basic structures.

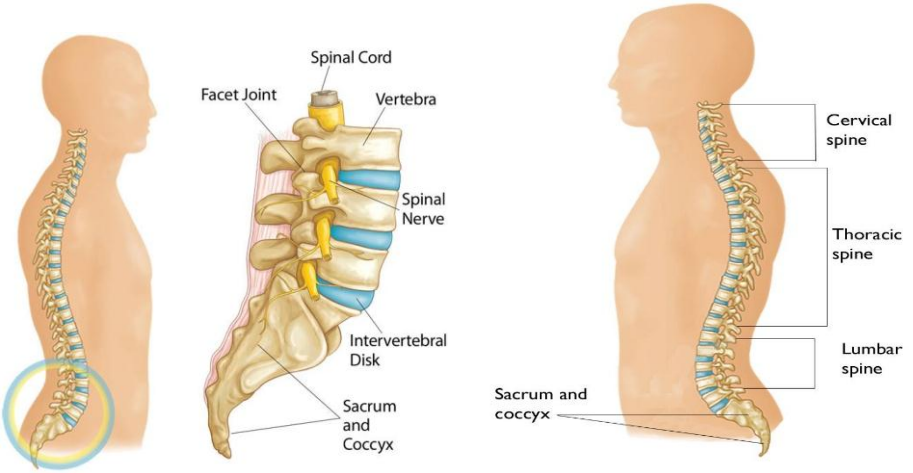


Fig 1.Spine Structure

Spine related medical issues and abnormalities are seen in many peoples of different age groups. Scoliosis, Spondylolisthesis, Kyphosis, Spondylosis are examples of spinal deformity and spine disorders (Athertya et.al.,2012). CT is suggested for screening the region specific deformities in spinal column like spine deformity as CT provides images with more details for evaluating bone injuries or disorders. Screening the patient with the use of CT provides detailed information of the abnormality. The three dimensional representation of CT images provide more information than two dimensional images for diagnosis of disease using the morphological features and changes.

The entire column is split as 33 vertebrae grouped into different regions namely, cervical, thoracic, lumbar, sacrum and coccyx (Reddy ,2003). The movement is provided by the intervertebral discs. The distribution of vertebrae is such that the

thoracic region has the maximum number equaling 12 which is followed by the cervical, ranging 7 vertebrae. The Lumbar spine constitutes 5 below which the sacrum and coccyx have fused ones with 5 and 4 in number respectively.

Outline of the paper

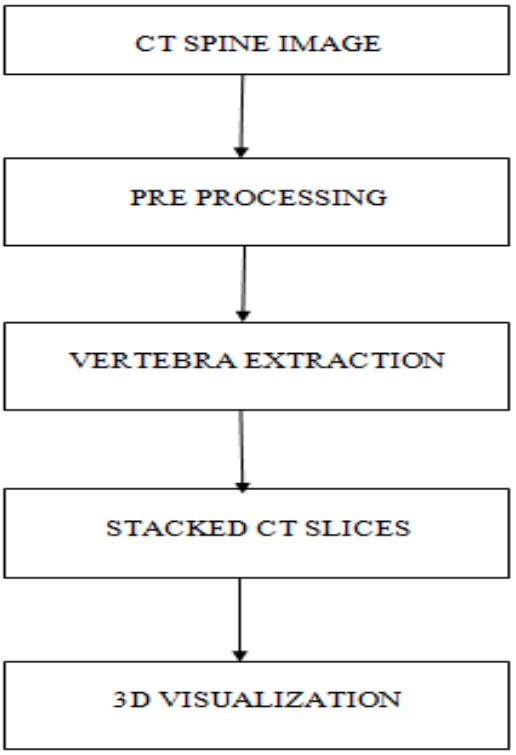


Fig 2. Outline of the paper

Organization of the paper

The remaining portion of the paper is structured as follows, Section II comprises literature review, Section III describes methodologies, Section IV includes Experimental results, Performance analysis and Section V discusses conclusions.

Related works

(Justin Novosad et al., 2004) proposed a novel three dimensional (3-D) reconstruction technique for the quantitative 3-D analysis of lateral bending motion. The algorithm was developed by using a small calibration object and an explicit calibration algorithm of a single X-ray image. This method allows the physicians to visualize the lateral view of the spine in a lateral bending position when only an anterior–posterior view was acquired. To improve accuracy of the 3-D reconstruction results, the author developed a novel geometric constraint to reduce pose error. (Wei et al.,2009) designed a femur 3D reconstruction technique by using a template model and 2D X-ray images. The reconstruction is carried out

by using Non Uniform Rational B-spline (NURBS) by defining central points on the X-Ray image.

(Neculai Archip et al.,2002) presented a knowledge-based approach with anatomical structures map (ASM) and a task-oriented architecture for the spinal cord identification in CT images of the thorax. (Jongwon Lee et al., 2011) presented a framework for segmentation of the lumbar pedicle CT images and provide the segmented output in 3-D voxel sets. The spinal pedicle edge is segmented based on the segmented vertebra and canal reference. To eliminate the fault edges, morphological operations are used in the spinal pedicle edge. (Patrik Kamencay et al.,2014) presented a 3D reconstruction algorithm for CT slices. The proposed algorithm is based on the integrating the SURF (Speeded-Up Robust Features) descriptor and SSD (Sum of Squared Differences) algorithm. It is combined with the Mean-Shift segmentation algorithm to obtain perfect 3D model.

Methodology

The 3D reconstruction of the Spine CT images is obtained by stacking the 2D slices after applying the segmentation technique. The outline of the proposed work is given in figure 2. Spine CT image is the input of the proposed work. The input image is axial or sagittal oriented data. Vertebrae are the region of interest. It can be any of the 4 regions of the vertebral column such as Cervical, Thoracic, Lumbar, Sacrum or Coccyx. The region has to be extracted from the soft tissue background.

Pre-processing

The Image is first converted to grayscale image. The input image is filtered from noise and smoothened to achieve a clear picture of the vertebral component. The median filter is used to remove the noise from input images. The filtered image is then converted into binary image to differentiate the bone region and soft tissue region. To make the image better, the contrast is adjusted by applying a mask of 5 X 5 matrixes. Thus the image is smoothened.

Vertebra extraction

Morphological operations are set of operations that works on images based on shape of the image. In the presented work the Morphological operation 'Erode' is carried out with the structuring element 'disk' to remove the unwanted pixels in the region of interest. In (Athertya et.al.,2012) author stated that the Global thresholding method is effective segmentation by comparing three different algorithms for CT images. Global thresholding method is applied for the segmentation to obtain the region of interest. Thus all the CT slices are processed and prepared for stacking

Stacked CT slices

The output CT Slices which are obtained after segmentation are stacked to achieve a reconstructed image. Isosurface reconstruction is utilized as it is

visualized in three dimensional domain whereas two dimensional domain uses the isoline method (Kloetzli et.al., 2008). After the reconstruction step the volume function or element should be carried out. Marching cube algorithm is employed to balance the missing gradient vectors in reconstruction phase and visualize the image. Marching Cube algorithm is used in medical visualization of dicom images and 3d visualizations. It creates a polygonal mesh from voxel model (Lorensen et.al., 1987). The concept in Marching cube is to traverse or move all the cubes created by the neighbor slices and creates set of triangles for the output isosurface inside the cube. Based on the thickness of input slices the cube dimensions are defined.

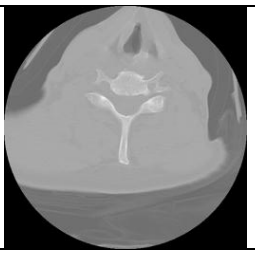
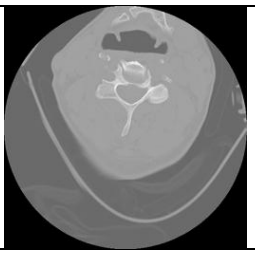
3D visualization

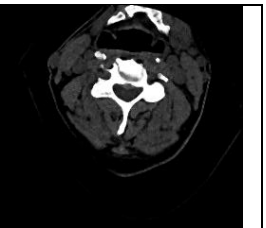
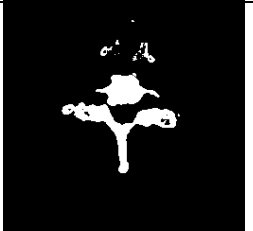
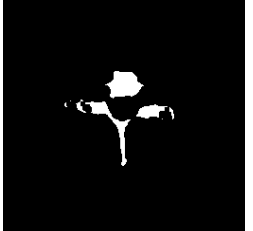
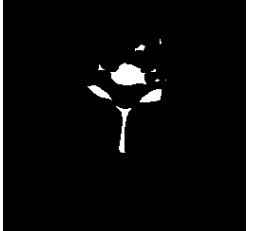
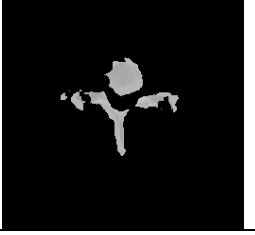
Visualization is the final step. Volumetric rendering is an efficient rendering to visualize images in three dimensional model. Voxels are used for volume representation which holds the visual functions and properties. Volumetric rendering is used to view number of images slices in a single picture. The rendering technique helps user to convert the voxels from pixel (Upson et.al.,1989). Thus volume rendering is used to project the processed image slices into 3D image model.

Experimental analysis

In this presented work, the datase (https://biomedia.doc.ic.ac.uk/data/spine/) used is collected from BioMedIA website. The dataset consist of spine focused CT images of 125 patients with different pathologies. The data has been acquired at the Department of Radiology at the University of Washington. Spine-5 dataset from BioMedIA is used in our work. Filtering technique, Binary image, Morphological operation, Segmentation techniques are applied on number of CT input slices and the results are tabulated in the following Table 1. The performance metrics such as Accuracy, Sensitivity, Specificity and Dice are calculated to evaluate the obtained results. The Performance metrics are presented in graphical representation from Fig 3 to 6.

Table 1
Result of Images on applying Median filter, Binary image, Erode image, Segmented image, Segmented image after reconstruction

Original image				

Median filter image				
Binary image				
Erode image				
Segmented image				
Segmented image after reconstruction				

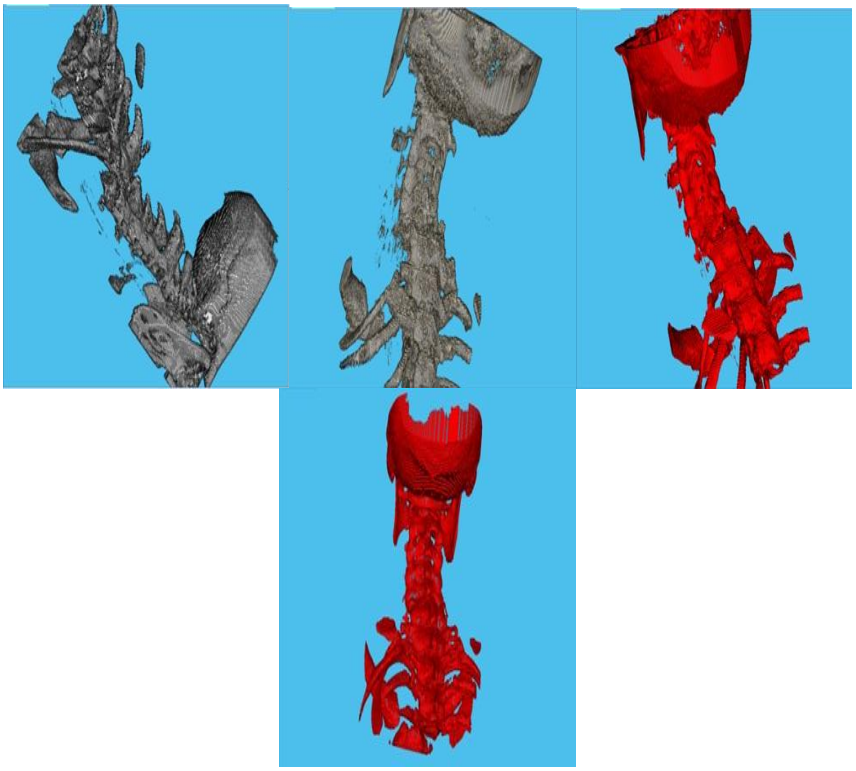


Fig 6. 3D Reconstructed Spine - Volume Rendering Results

Table 2
Values of accuracy, sensitivity, specificity, DSC

Methods	Accuracy	Sensitivity	Specificity	DSC
Mathematical morphology + Reconstruction	0.8069	0.7927	0.7952	0.8027
Reconstruction	0.7725	0.7685	0.7638	0.7747

Accuracy: The accuracy is the percentage of correctly classified instances (Baratloo et.al.2015).

$$\text{Accuracy} = (TP + TN) / (TP + TN + FP + FN)$$

TP, FN, FP and TN represent true positives, false negatives, false positives and true negatives.

Sensitivity: Sensitivity is used to measure how good a test can identify true positives (Baratloo et.al.2015).

$$\text{Sensitivity} = TP / TP + FN$$

Specificity: Specificity is used to calculate how well a test can identify true negatives (Baratloo et.al.2015).

Specificity = TN / TN + FP

Dice: Dice or Dice coefficient, is used to measures the similarity between two sets of data (Moore et.al., 2022)

Dice = 2 TP / (2 TP + FP + FN)

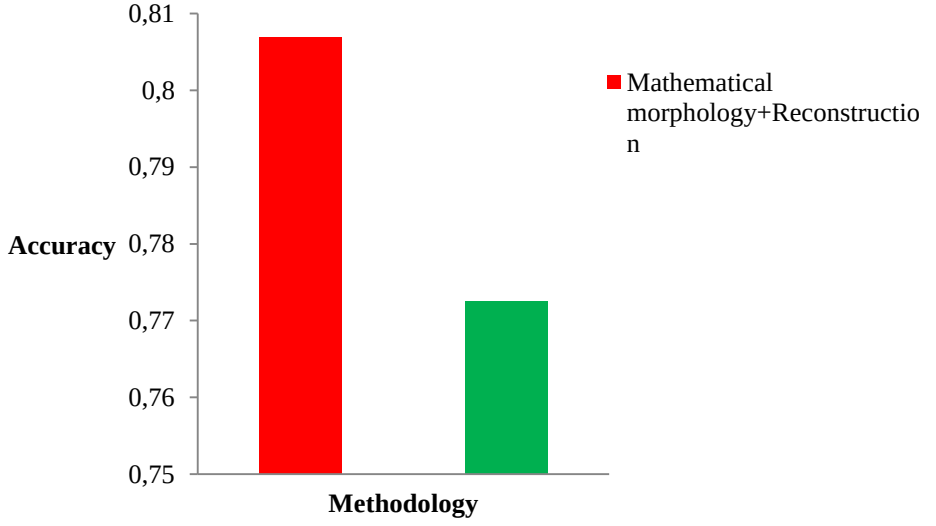


Fig 3. Graphical Representation of Accuracy

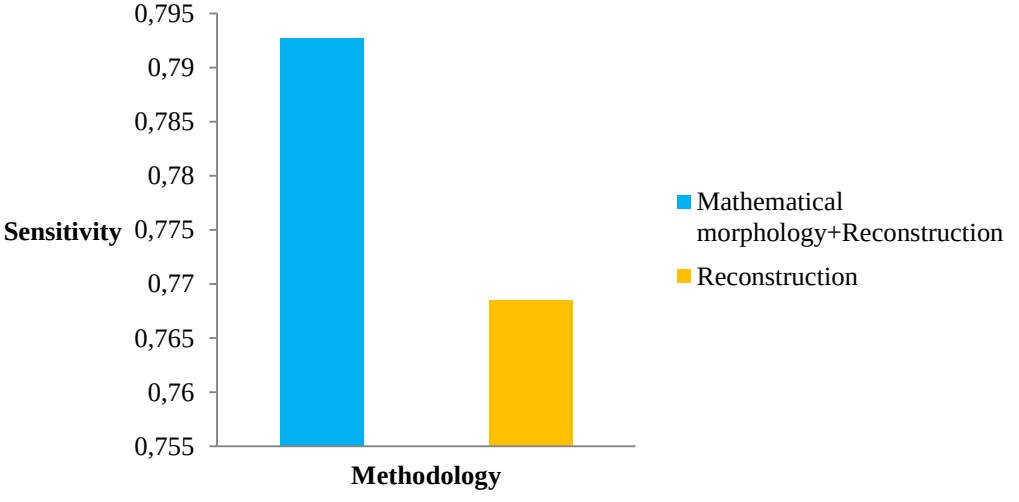


Fig 4. Graphical Representation of Sensitivity

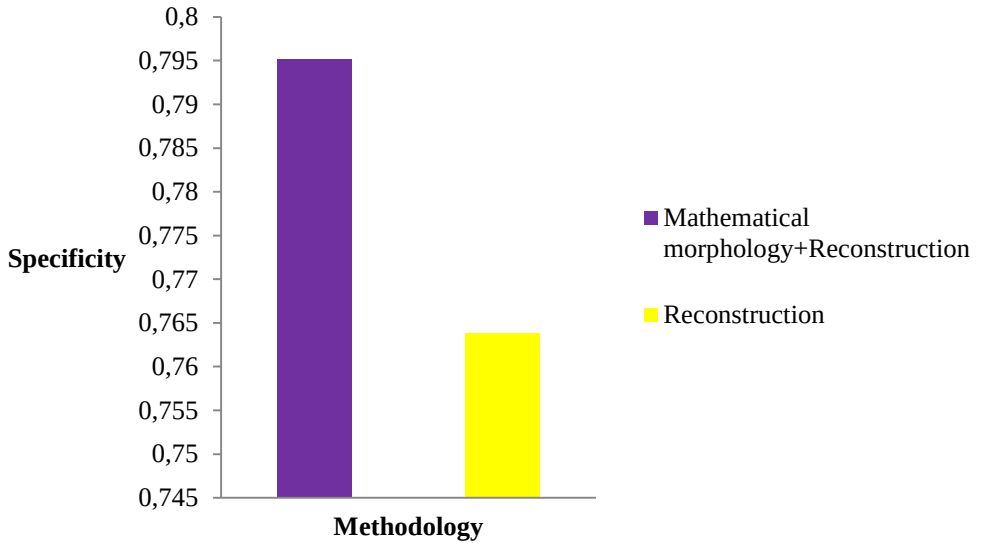


Fig 5. Graphical Representation of Specificity

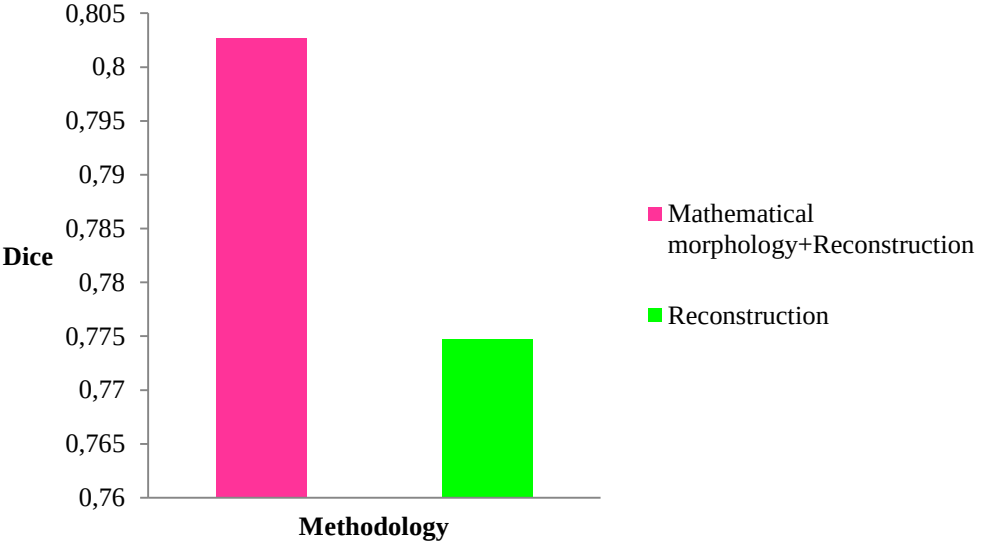


Fig 6. Graphical Representation of Dice

Conclusion

The developed method is applied on number of CT spine images. In the proposed method the image is enhanced and then it is segmented. Mathematical morphology method is used on the segmented image. Thus the region of interest is obtained. Mathematical morphology applied images are used to reconstruct three dimensional image. Future work includes developing three dimensional

reconstruction algorithm for better result in viewing the CT image and interactive visualization model for planning of surgery.

References

Praksam Reddy.L., ”Fundamentals Of Medical Physiology”,3rd edition, pp. 72-87,2003.

Justin Novosad, Farida Cheriet, Yvan Petit, and Hubert Labelle,”Three-Dimensional (3-D) Reconstruction of the Spine From a Single X-Ray Image and Prior Vertebra Models”, IEEE Transactions on biomedical engineering, Vol. 51, No. 9, pp. 1628-1639,September 2004.

Wei Wei;Wang Guorong;Chen Hua;"3D Reconstruction of a Femur Shaft using a Model and Two 2D X-ray Images" IEEE Proceedings of 2009 4th International Conference on Computer Science & Education.

Neculai Archip; Pierre-Jean Erard; Michael Egmont-Petersen; Jean- Marie Haefliger;"A Knowledge-Based Approach to Automatic Detection of the Spinal Cord in CT Images"IEEE Transactions on Medical Imaging, VOL. 21, NO. 12, December 2002.

Jongwon Lee; Sungmin Kim; Young Soo Kim; Wan Kyun Chung; “Automated Segmentation of the Lumbar Pedicle in CT Images for Spinal Fusion surgery” IEEE Transactions on Biomedical Engineering, Vol:58, Issue:7, pp. 2051-2063. July 2011.

Kamencay, P., Zachariasova, M., Hudec, R., Benco, M., & Radil, R. (2014, July). 3D image reconstruction from 2D CT slices. In 2014 3DTV-Conference: The True Vision-Capture, Transmission and Display of 3D Video (3DTV-CON) (pp. 1-4). IEEE.

Jiyo.S.Athertya, Dr.S.Poonguzhali,”3D CT Image Reconstruction of the Vertebral Column”, ICRTIT-2012, ISBN: 978-1-4673-1601-9/12/$31.00 , 2012 IEEE.

Kloetzli, J., Olano, M., & Rheingans, P. (2008, February). Interactive volume isosurface rendering using bt volumes. In Proceedings of the 2008 symposium on Interactive 3D graphics and games (pp. 45-52).

W.E.Lorensen, H.E.Cline, “Marching Cubes: A high resolution 3D surface construction algorithm”, Computer graphics, 1987.

Upson, C. Stellar Computer, Newton, MA, USA Faulhaber, T.A., Jr. ; Kamins, D. ; Laidlaw, D. ; Schlegel, D. ; Vroom, J. ; Gurwitz, R. ; van Dam, A.(1989), "The application visualization system: a computational environment for scientific visualization", Computer Graphics and Applications, IEEE, Vol :9, Issue : 4, pp 30-42.

Dataset https://biomedia.doc.ic.ac.uk/data/spine/

B. Glocker, D. Zikic, E. Konukoglu, D.R. Haynor, A. Criminisi, “Vertebrae Localization in Pathological Spine CT via Dense Classification from Sparse Annotations”, International Conference on Medical Image Computing and Computer Assisted Intervention (MICCAI), Nagoya, Japan, September 2013.

B. Glocker, J. Feulner, A. Criminisi, D.R. Haynor, E. Konukoglu, “Automatic Localization and Identification of Vertebrae in Arbitrary Field-of-View CT Scans”, International Conference on Medical Image Computing and Computer Assisted Intervention (MICCAI), Nice, France, October 2012.

Baratloo, Alireza et al. “Part 1: Simple Definition and Calculation of Accuracy, Sensitivity and Specificity.” Emergency (Tehran, Iran) vol. 3,2 (2015): 48-9.

Moore, C., Bell, D. Dice similarity coefficient. Reference article, Radiopaedia.org. (accessed on 12 Apr 2022) https://doi.org/10.53347/rID-75056