

# 3D Modeling of X-Ray Images using Virtual Reality

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**Abstract** - Nowadays, advanced medical imaging is a widely accepted scientific discipline in the healthcare industry due to technological advances and software breakthroughs. Traditionally using digital images of X-Ray for diagnosing diseases in healthcare is very common. Many researchers have proposed different methods like X-Ray, CT-scan, and MRI for bone implantation. But the problem is while implantation it does not get the actual size as original, so it causes a bad impact on the health and the person suffers from pain. Therefore, to solve this problem, the proposed system uses a canny edge detection that can sketch the edges of knee bone present in an x-ray image with the size of the bone for implantation by using a virtual reality technique. The system will convert the 2D image to 3D and then the 3D model will be shown in a VR headset. So, we can get a clear visualization of the image. This model provides accurate measurements and detailed visualization of bones in virtual reality with 95.58% accuracy. Virtual reality-based visualization using X-ray images is more effective than CT-Scan in improving radiologists' accuracy and efficiency in diagnosing certain medical conditions, leading to a preference for X-ray images in certain diagnostic scenarios.

**Keywords:** Canny Edge detection, Image Processing, Digital Image, Digital, X-Ray, VR, Knee Arthroplasty, Google Cardboard.

## 1. Introduction

Medical imaging technology dates back to the 18th and 19th centuries, when Becquerel found radiation and x-rays, respectively. Both findings significantly enhanced medical practice. The practical implementation of ultrasound in medicine was made feasible by advances in the use of sound waves in the mid-twentieth century, and then came computers, which changed the game completely. Sonography, nuclear medicine technology, and radiography were used as diagnostic medical imaging methods or instruments prior to the widespread use of computer technology in health care. Bone serves as the human body's skeleton, allowing body parts to move and protecting organs. One of the largest and most complex bones in the body is the knee bone. Real life knee bone replacement problem is very serious. Replacing the knee

bone or joint with a made artificial joint, known as prosthesis, requires a surgery. Damaged cartilage and bone are taken out of the knee joint during this procedure. The knee is then implanted with man-made bone.

The preferred method for evaluation and therapy planning in orthopedics continues to be traditional X-ray images, despite the growing accessibility of 3D image acquisition techniques like computed tomography (CT). However, X-rays only show a 2D projection of the anatomy of interest, making it difficult for a human viewer to evaluate its 3D characteristics like the anatomical form. (eg. the surgeon). The goal of this project is to create computer-assisted methods for creating 3D models from a single or a small number of X-rays that describe an anatomy's patient-specific form and bone density distribution. The final aim of these patient-specific models is to provide critical 3D information purely based on 2D X-rays, enabling exact joint replacement planning, follow-up, and biomechanical analysis.

The term "CT scan" is frequently used to refer to computed tomography. A CT scan is a diagnostic imaging process that creates pictures of the inside of the body using a mix of X-rays and computer technology. Any portion of the body, including the bones, muscles, fat, organs, and blood systems, is shown in depth. Compared to traditional X-rays, CT images are more comprehensive. A beam of energy is directed at the bodily portion being examined in conventional X-rays. After the energy beam travels through the epidermis, bone, muscle, and other tissues, it varies and is captured by a plate behind the body component. While a normal X-ray can provide a lot of information, internal organs and other tissues cannot be seen in great depth.

Virtual reality, also known as VR, is a digital environment that was created decades ago but has only recently begun to take off. This is due to the fact that the technology has only recently become compact, potent, and widely accessible. Because of these factors, virtual reality is now beginning to be applied in the classroom. A new media tool called virtual reality (VR) offers the potential to make learning more engaging for pupils. But more significantly, it can also be a choice to give all pupils more chances and experiences. For example, learners with bodily disabilities or

students attending institutions with limited resources can now take virtual excursions to locations they were previously unable to visit.

## 2. Literature Survey

This section presents recent developments in related areas and an analysis of the work to identify the limits and scope of further work to improve the system.

The article begins by highlighting the importance of 3D modeling in medical imaging and the limitations of traditional 2D X-ray imaging. The author then presents a review of various techniques for 3D modeling of X-ray images, including volume rendering, surface rendering, and hybrid methods. The article also discusses the challenges faced by researchers in this field, such as the need for accurate segmentation of images and the need for efficient algorithms for 3D reconstruction. The author concludes the article by highlighting the potential of 3D modeling in medical imaging and the need for further research in this field [2].

The paper presents a comprehensive review of various methods for 3D reconstruction of 2D X-ray images. The authors begin by discussing the limitations of traditional 2D X-ray imaging and the importance of 3D reconstruction in medical imaging. The paper then presents a review of various techniques for 3D reconstruction of X-ray images, including the voxel-based approach, the surface-based approach, and the hybrid approach. The authors also discuss the challenges faced by researchers in this field, such as the need for accurate image segmentation and the need for efficient algorithms for 3D reconstruction. They further describe various applications of 3D reconstruction in medical imaging, such as diagnosis, surgical planning, and treatment monitoring. The paper concludes by highlighting the potential of 3D reconstruction in medical imaging and the need for further research in this field [3].

Given paper presents a novel approach to naturalistic 2D-to-3D conversion, which aims to generate high-quality 3D images from 2D images that resemble the natural 3D scenes as much as possible. The authors first introduce the concept of naturalistic 2D-to-3D conversion and discuss the challenges faced by existing methods, such as the lack of accurate depth information and the difficulty in modeling natural scene structures. The paper then presents a new approach based on a multi-stage framework that involves 2D image segmentation, depth estimation, and 3D scene reconstruction. The approach utilizes various cues, such as texture, shading, and perspective, to estimate the depth of the scene and generate a high-quality 3D image. The authors also evaluate their approach on a variety of test images and compare it with existing methods.

The results demonstrate that the proposed approach achieves superior performance in terms of both subjective and objective measures [4].

The article presents a method for converting 2D medical image files in DICOM format into 3D models using image processing techniques and analyzing the results with Python programming. The article begins by highlighting the importance of 3D models in medical imaging and the challenges faced by medical professionals in analyzing 2D medical images. The authors then describe the steps involved in converting DICOM files into 3D models, which include image preprocessing, segmentation, and 3D reconstruction. The authors also discuss the use of Python programming in analyzing the results of 3D reconstruction, such as calculating volume, surface area, and other relevant measurements. They provide code examples in Python for carrying out these analyses. The article also describes the evaluation of their method on various medical images and compares the results with existing methods. The authors demonstrate that their method produces high-quality 3D models and accurate measurements, making it a useful tool for medical professionals. The article provides a good overview of the method, and the code examples in Python make it easy to implement. However, more information on the evaluation process, including the size of the dataset and the comparison with other methods, would have been useful [5].

The paper presents a new method for reconstructing a 3D femur model from biplane X-ray images. The authors propose a novel method based on Laplacian surface deformation for reconstructing a 3D femur model. The method involves first segmenting the femur from the biplane X-ray images using a thresholding technique. Then, the segmented contours are used to generate a 3D surface mesh of the femur using the Marching Cubes algorithm. The surface mesh is then deformed using a Laplacian surface deformation method, which ensures that the resulting 3D model is smooth and preserves the surface details of the original femur. The authors validate their method on a dataset of 10 femur specimens and compare their results with those obtained using other methods. The results demonstrate that the proposed method produces more accurate and detailed 3D femur models than the other methods. The authors have also provided a comprehensive evaluation of their method and compared it with other methods, which enhances the credibility of their approach. However, the authors could have provided more information on the limitations and potential future directions of their method [6].

The article presents a method for constructing a 3D model of knee joint motion based on MRI image registration. The authors describe the process of acquiring MRI images of

the knee joint during motion and segmenting the images to obtain the 3D geometry of the bones and soft tissue. They then propose a registration method to align the segmented MRI images at different time points, which is crucial for constructing the 3D model of knee joint motion. The registration method is based on a hybrid approach that combines intensity-based and feature-based registration methods. The authors also introduce a motion analysis framework to quantify the motion of the knee joint based on the 3D model. The authors evaluate their method on a dataset of six subjects and demonstrate that the proposed method can accurately reconstruct the 3D model of knee joint motion and quantify the motion parameters, such as translation and rotation [7].

The paper proposes a method for 3D reconstruction of leg bones from X-ray images using CNN-based feature analysis. The paper was published in the journal *Computers in Biology and Medicine* in 2021. The authors propose a method that involves first segmenting the leg bones from the X-ray images using a U-Net based segmentation network. Then, the segmented bones are used to generate a 3D surface mesh of the bones using the Marching Cubes algorithm. The authors propose a novel feature analysis method based on a convolutional neural network (CNN) to improve the accuracy of the 3D reconstruction. The CNN is trained to learn the features that represent the structure and shape of the leg bones from a set of labeled X-ray images. The learned features are then used to refine the surface mesh generated from the segmented X-ray images, resulting in a more accurate 3D model of the leg bones. The authors evaluate their method on a dataset of 50 leg bones and compare their results with those obtained using other methods. The results demonstrate that the proposed method produces more accurate and detailed 3D models of the leg bones than the other methods [8].

The authors describe the process of 3D printing and its benefits in medical applications. They highlight the advantages of using 3D printed models in preoperative planning, surgical training, and medical education. The paper focuses on the conversion of 2D medical scan data, specifically computed tomography (CT) and magnetic resonance imaging (MRI) scans, into 3D printed models. The authors discuss the steps involved in the conversion process, which includes image acquisition, segmentation, conversion to a 3D model, and finally, 3D printing. They highlight the importance of accurate segmentation and discuss various software tools that can be used for this purpose. The authors also discuss the challenges associated with 3D printing, such as the need for high-resolution imaging and the limitations of current printing technologies. However, the paper could have provided more detailed information on the challenges associated with 3D printing, as well as potential solutions to

these challenges. Additionally, the paper could have provided more information on the limitations of 3D printed models and the need for further research in this area [9].

The paper discusses the process of constructing a 3D model from 2D DICOM images, which are commonly used in medical imaging. The authors describe the challenges associated with this process, including image segmentation and the need for accurate alignment of the images. The authors propose a method for constructing a 3D model using a combination of image processing techniques and 3D reconstruction algorithms. They describe the steps involved in this process, which includes image pre-processing, segmentation, feature extraction, registration, and finally, 3D reconstruction. The authors evaluate the performance of their proposed method using a set of DICOM images and compare the results with those obtained using other methods. They demonstrate that their proposed method produces more accurate and detailed 3D models compared to other methods [10].

The paper describes a method for creating patient-specific 3D bone models from 2D radiographs for use in image-guided orthopedic surgery. The authors describe the challenges associated with this process, including the need for accurate alignment and registration of the 2D radiographs. The authors propose a method for constructing a 3D bone model using a combination of image processing techniques and 3D reconstruction algorithms. The steps involved in this process include image pre-processing, segmentation, feature extraction, registration, and finally, 3D reconstruction. The authors evaluate the performance of their proposed method using a set of radiographs and compare the results with those obtained using other methods. They demonstrate that their proposed method produces more accurate and detailed 3D bone models compared to other methods [11].

### 3. Terminologies

#### A) Python

Python is a high-level, general-purpose programming language. His design philosophy uses clear indentation to emphasize code readability. Python is dynamically typed and garbage collected. It supports multiple programming paradigms, including structured programming, object oriented programming, and functional programming.

#### B) Unity

Unity is a cross-platform game engine developed by Unity Technologies and first announced and released as a Mac OS X game engine at the Apple Worldwide Developers Conference in June 2005. The engine has since been gradually

expanded to support various desktop, mobile, console and virtual reality platforms.

### C) Google Cardboard SDK

The open-source Cardboard SDK lets you create immersive, cross-platform VR experiences for Android and iOS. Create entirely new VR experiences or enhance existing apps that support VR with essential VR features such as motion tracking, stereoscopic rendering, and user interaction.

### D) Google Cardboard Goggle

Get it, fold it, take a look inside, and immerse yourself in the world of Cardboard. It's a VR experience that starts with a simple viewer that anyone can create or buy. Once you have it, you can explore the multitude of apps that surround you. And with so many viewers available, you're sure to find one that's right for you.

### E) Inkscape

Inkscape is a free and open source vector graphics editor primarily for creating vector graphics in scalable vector graphics format. Other formats can be imported and exported. Inkscape can render primitive vector shapes and text.

### F) Blender

Blender is a free and open source 3D computer graphics software toolset used to create animated films, visual effects, art, 3D printed models, motion graphics, 3D interactive applications, virtual reality and early video games.

### G) Gaussian Filter

Gaussian Filtering is commonly used in image processing. It is applied to images to reduce noise. We will create 2D Gaussian Kernel in this article. The 2D Gaussian Kernel follows the Gaussian distribution which is shown in formula. Where  $y$  is the vertical distance from the origin,  $x$  is the horizontal distance from the origin, and  $\sigma$  is the standard deviation.

### H) Sobel Operator

The Sobel operator, also known as the Sobel-Feldman operator or Sobel filter, is used in image processing and computer vision, particularly in edge detection algorithms to emphasise edges. It is a discrete differentiation operator that computes a gradient approximation of the image intensity function. The Sobel-Feldman operator produces either the corresponding gradient vector or the norm of this vector at each point in the image.

### I) Digital X-Ray

Injuries to the musculoskeletal system, cancer, clogged arteries, stomach pain, sinusitis, spinal issues, and other abnormalities are just a few of the diseases and injuries that can be diagnosed with digital X-Rays.

### J) Canny Edge Detection

With the use of the Canny edge detection technology, the amount of data that needs to be processed can be drastically reduced while still extracting meaningful structural information from various vision objects. It is frequently used in many computer vision systems. According to Canny, the prerequisites for applying edge detection to various vision systems are largely the same. Thus, a solution for edge detection that meets these needs can be used in a variety of contexts.

### K) Arthroplasty

It is a surgical procedure to restore joint function. The joint can be restored by resurfacing the bones. An artificial joint (called a prosthesis) may also be used. Different types of arthritis can affect the joints. Osteoarthritis, or degenerative joint disease, is the loss of cartilage or cushion in a joint and is the most common reason for arthroplasty.

### L) Image processing

It is the process of converting an image into digital form and performing certain operations in order to extract useful information from it. An image processing system typically treats all images as 2D signals using certain predetermined signal processing methods.

## 4. Proposed Methodology

### A) Noise Reduction

Canny edge detection is a well-liked method of image processing that finds edges in pictures. Before finding edges, the Canny edge detection algorithm reduces picture noise as one of its phases. This is crucial because noise might result in misleading edges or make it challenging to recognize real edges. A Gaussian filter is frequently used to reduce noise in the Canny edge detection process. The image is given a Gaussian function via the convolution kernel that makes up the Gaussian filter.

The two-dimensional Gaussian kernel of size  $(2k+1) \times (2k+1)$  used in image processing. This equation can be expressed as a matrix as follows:

$$H_{ij} = \frac{1}{2\pi\sigma^2} \exp\left(-\frac{(i-(k+1))^2 + (j-(k+1))^2}{2\sigma^2}\right); 1 \leq i, j \leq (2k+1) \dots(1)$$

Where H is the Gaussian kernel matrix of size (2k+1) x (2k+1), sigma is the standard deviation of the Gaussian function, and D is a matrix of distances between each pixel in the kernel and the center pixel.

To compute the distances, we can define a matrix X of size (2k+1) x (2k+1) where each element X(i,j) represents the column index of the pixel. Similarly, we can define a matrix Y of size (2k+1) x (2k+1) where each element Y(i,j) represents the row index of the pixel.

### B) Gradient calculation

Gradient calculation is a fundamental operation in image processing and computer vision. The gradient of an image represents the direction and magnitude of the change in pixel intensities across the image. The gradient is often used in edge detection, feature extraction, and object recognition. The gradient of an image can be computed using different methods, but one of the most common methods is the Sobel operator. The Sobel operator calculates the gradient by convolving the image with two 3x3 kernels, one for the horizontal direction and one for the vertical direction. The kernels are designed to detect changes in pixel intensities in the corresponding direction.

The horizontal Sobel kernel has the following formula:

$$S_x = [-1 \ 0 \ 1; -2 \ 0 \ 2; -1 \ 0 \ 1] \quad (2)$$

The vertical Sobel kernel has the following formula:

$$S_y = [-1 \ -2 \ -1; 0 \ 0 \ 0; 1 \ 2 \ 1] \quad (3)$$

To calculate the gradient, we first convolve the image with the horizontal Sobel kernel and then with the vertical Sobel kernel. The resulting convolved images represent the gradient in the horizontal and vertical directions, respectively. The magnitude and direction of the gradient at each pixel can then be computed using the following formulas:

$$\text{Magnitude} = \text{sqrt}(G_x^2 + G_y^2) \dots(4)$$

$$\text{Direction} = \text{atan2}(G_y, G_x) \dots(5)$$

Where Gx and Gy are the convolved images in the horizontal and vertical directions.

The sqrt() function computes the square root of the sum of the squares of the two images, which gives the magnitude of the gradient.

The atan2() function computes the arctangent of the ratio of the vertical gradient to the horizontal gradient, which gives the direction of the gradient.

## 5. Implementation

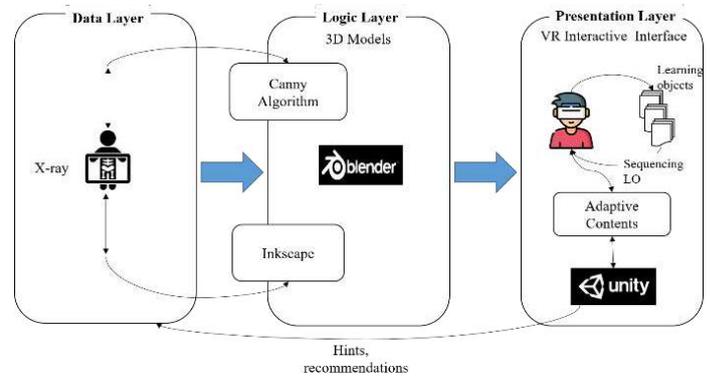


Fig. 1: Architecture of the proposed system

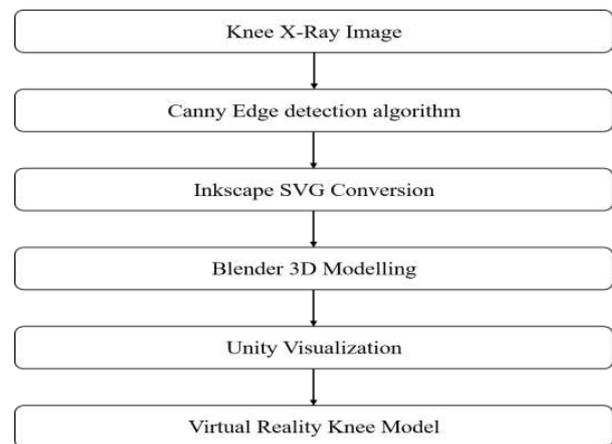


Fig. 2: Model Flow Architecture

The proposed system can be used to improve medical diagnosis and treatment planning. By creating 3D models of X-ray images using virtual reality, medical professionals can gain a better understanding of the patient's condition, leading to more accurate diagnoses and treatment plans. Here are the implementation stages as follows:

### A) Data Layer

According to figure we will first collect X-ray images of the patient's body part that needs to be modeled. These images can be taken using traditional X-ray machine the X-rays is recommended for complex cases of the bone. In this step we are collecting the X-ray image of the bone where it will check image quality of the X-ray image. The image will be processed in the Logical layer with the help of the Canny Edge Detection Algorithm.

## B) Logic Layer

The 3D models' accuracy may be impacted by noise and artefacts in the X-ray pictures, So to avoid this the clarity and sharpness of the X-ray pictures can be increased by removing these artefacts using pre-processing techniques such as noise reduction. We identified the necessary edges of the bone in this stage using a canny edge detection method and this result picture in the PNG format here. The image may then be transformed into an SVG file using Inkscape, which is a scalable vector format and to trace the edges raise threshold.

We have to import the SVG file into a 3D modelling tool like Blender. With the help of the blender tool, a 2D scan of the X-ray may be converted to 3D Model. In Blender tool have feature to get the coordinates of the 3D Model which will require for the measurement. The 3D model must be extruding in a way that it can be loaded into a VR development platform, such Unity, as the last stage. OBJ is one of the popular 3D file formats.

## C) Presentation Layer

In this Stage it will import the 3D model created in Blender into a virtual reality platform such as Unity. Unity is a cross-platform game engine that allows you to create interactive 3D and 2D content for various platforms including VR headsets. Once the 3D model is imported into Unity, it can be viewed and interacted with using a VR headset.

## 6. Result

Appropriate results are obtained using this proposed approach.



Fig. 3: Input Image (Knee X-Ray)

The first step is to collect a dataset of X-ray images that will be used for developing the 3D modeling system. This dataset should include a variety of images from different

patients and anatomical structures. Here we have taken knee bone X-ray.



Fig. 4: Canny Edge Detection

The X-ray images may contain noise and artifacts that can affect the accuracy of the 3D models. Pre-processing techniques such as noise reduction and image enhancement can be applied to remove these artifacts and improve the quality and sharpness of the X-ray images. In this step using canny edge detection algorithm we have found out required edges of bone. Here our image is in png format.



Fig. 5: Converting to .SVG format

The canny edge detection algorithm output can be saved as an image file (such as PNG) and imported into a vector graphics software, such as Inkscape. The software can then trace the edges increase threshold and convert the image into an SVG file, which is a scalable vector format.



Fig. 6: 3D Model in Blender

The SVG file can be imported into a 3D modeling software, such as Blender. The software can be used to extrude the 2D image into a 3D model that represents the Knee anatomy. The final step is to export the 3D model in a format that can be imported into a VR development platform, such as Unity. Common 3D file formats include OBJ. Here we have found out actual size of the given bone.



Fig. 7: Watch in VR

The final step is to export the 3D model in a format that can be imported into a VR development platform, such as Unity. Using VR Google cardboard we can visualize actual bone.

In this system, we have used a canny edge detection algorithm to find edges the accuracy of algorithm is 94.58%. We have converted image to SVG so accuracy is increased by 1%. So final accuracy of this system is 95.58%.

Table 1: System Comparison

System Comparison	Accuracy
Bone Fracture Detection and Classification using Deep Learning Approach [23]	94.58%
Automatic detection of fracture in femur bones using image processing [25]	87.5%
Bone Fracture Detection Using Opencv [27]	66.7%
<b>Proposed System</b>	<b>95.58%</b>

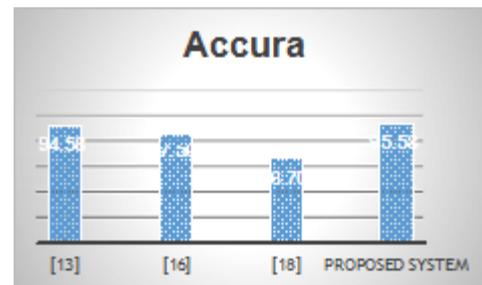


Fig. 8: System Comparison

## 6. Conclusion

The proposed system aims to address the problem of inaccurate bone implantation by using a canny edge detection technique to sketch the edges of the knee bone in an X-ray image and then converting it into a 3D model that can be viewed in a VR headset. This model provides accurate measurements and detailed visualization of bones with a high level of accuracy. The use of virtual reality- based visualization using X-ray images can be more effective than CT-Scan in improving radiologists' accuracy and efficiency in diagnosing certain medical conditions. However, it is important to note that the choice of imaging modality depends on the specific diagnostic scenario, and each imaging technique has its advantages and limitations. Overall, the proposed system can be a promising approach to improve the accuracy and precision of bone implantation procedures, potentially leading to better health outcomes for patients.

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