CM2006 Project Proposal

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Nov 2021

1 Use cases of our project

The idea of the project is to build 3D-CT images of femur bones. Femoral head necrosis is a common bone disease. 3D-CT images could be used to diagnose the stages of femoral head necrosis. Basically, femoral head necrosis is caused by avascular necrosis which results in the death of bone cells and fat cells in femur bones. The changes in a bone structure such as the collapse of the femoral head would clearly show in the 3D-CT image.

1.1 The need of the visualization tool

The 3D-CT image would be used in the following clinical scenarios.

The diagnosis of femoral head necrosis: The necrosis of the femoral head in each stage would have different shapes and boundaries in images. Figure 1 and Figure 2 show the changes in bone structures. In Picture D and E from Figure 2, the femoral head is almost broken. In Picture C and D, the depression of the femoral head could be recognized. Also in one staging criteria, when the depression of the femoral head is higher than 2mm patients would be diagnosed as stage 3. The 3D-CT image will conclude the surface and volume of the femoral head which helps doctors with diagnosis.

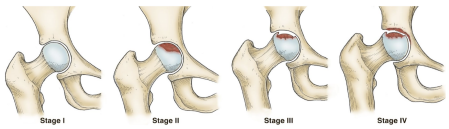

Figure 1: Five Stages of Femoral Head Necrosis

Formulation of the surgical plan for femoral head:
In the implantation surgery of the femoral nail, the position of the femoral nail matters. A 3D-CT image could be used to simulate the position of femoral nails inside the bone. Also, it is important to follow the movement or the loosening of the implant after surgery.

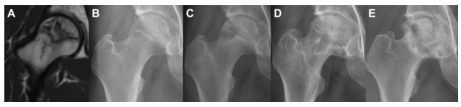

Figure 2: The MRI Image of Five Stages of Femoral Head Necrosis

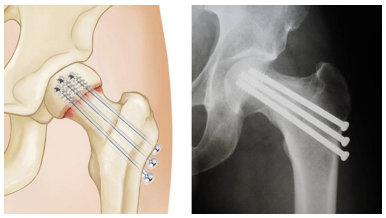

Figure 3: A Schematic Diagram of Femoral Surgery

Joint replacement surgery plan:
The joint replacement surgery is required to be accurate. For patients, there would be less discomfort during the knee movement due to slight deviations in the installation angle. So 3D-CT image could be used to build a 3D model of bones before the surgery. For example, the length between the femoral head with tissues might be calculated with the help of a 3D-CT model.

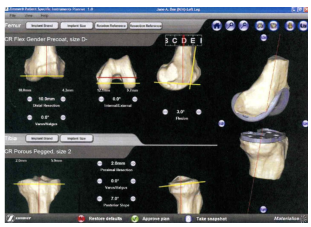

Figure 4: A 2D Model Used to Plan Surgery

1.2 The future users of the tool

Most of users of this project are surgeons and doctors who specialize in femur bones.

2 Selection of basic tools of the project

2.1 Surface reconstruction

In order to generate meshes from the data, we plan to use marching cubes technique. We also plan to try 3D flying edges algorithm if it is possible.

Marching cubes: In the MC method, it is assumed that the original data is a discrete three-dimensional spatial regular data field. Images produced by tomography (CT) and nuclear magnetic resonance (MRI) used for medical diagnosis belong to this type. In our project, we plan to use some CT images, so MC method is very suitable for our project. In vtk, the correspond function of MC method is *vtkMarchingCubes*.

After generating the meshes, we plan to implement smoothing and vertex clustering with Mean Curvature Flow and Quadric Error Metrics respectively.

2.2 Surface rendering

We choose Blinn-Phong model in our project because this model overcome some constrains of Phong model. In Phong model, the value of the highlight emission is determined by the reflection vector and the observation vector. When the angle θ between the two exceeds 90, there is no high light reflection component. Therefore, Phong model does not reflect the actual lighting conditions well. This situation is illustrated in figure 5.

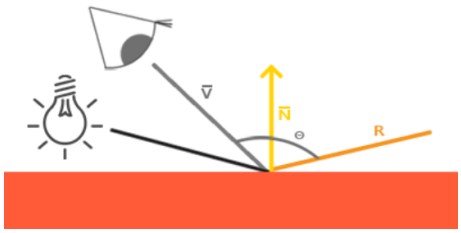

Figure 5: The angle between reflection and observation exceeds 90

2.3 Volume rendering

We will try to define different transfer functions for different parts of our image, e.g., bones, vessels and other tissues. We also plan to implement some other techniques like empty space skipping, ray tracing, etc.

2.4 Interaction methods and other applications

Some interaction methods will be implemented, including zoom, rotation, translation and clip planes, advanced clip planes, virtual resection, distance/area measurement, annotation, etc. Stereo rendering and animation will be applied in our project.