A Simulation of Human Heart

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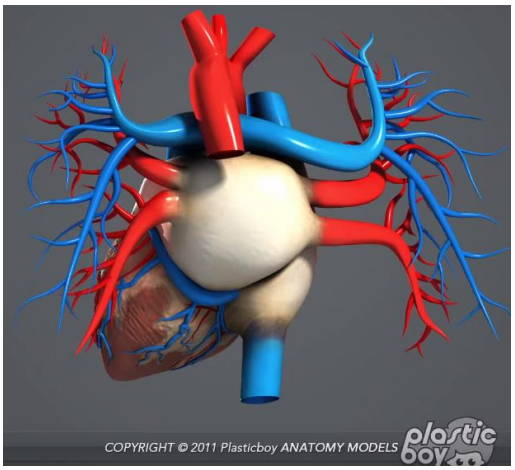
I. Introduction

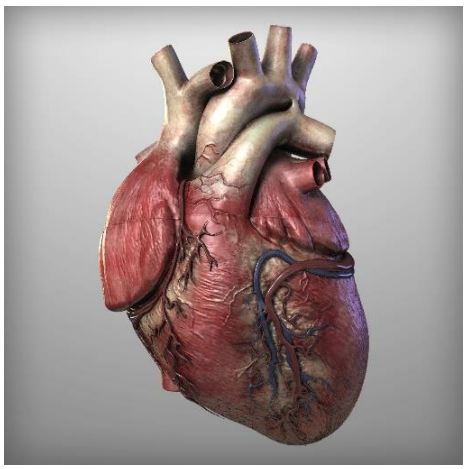
The project is focusing on simulating the working mechanism of the human hear. By using computer graphics technologies, the biological phenomena can be present on the screen other than going through all the anatomical procedures or just reading the plain bibliography. The real-time running demonstration can provide users with interactive experience with the human organ, which, in a way that the cases in the real life cannot offer.

The goal of this project is to provide a real-time simulation of human heart. Therefore the project could serve with good educational purposes not only for medical personnel, but it could also be a good learning tool for assisting students. Another motivation of this project is that this imitation procedure the human heart could also be a starting point of building a real-time model of the whole human blood circulatory system. The heart is modeled as a mass spring system and in this case is not a stationary model, whereas it is pumping and releasing with steady beating rate which can be configured in the program's user interface.

II. Related work

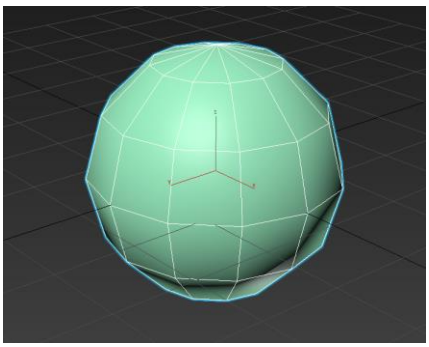
Currently most of the work that have being done for simulating the human heart are about modeling a stationary heart which is surely beautiful shaded but does not pump blood and is modeled not driven by the physics laws. The other type of the heart that mostly being modeled is with the movements of the heart, but they are just simple animations without physics simulation, let alone using fluid simulation.

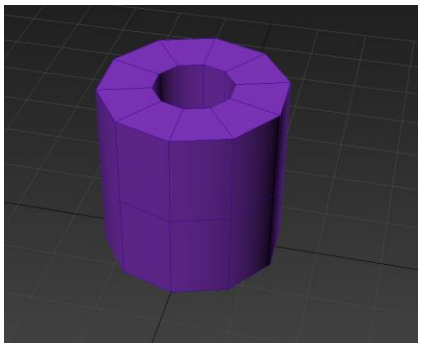




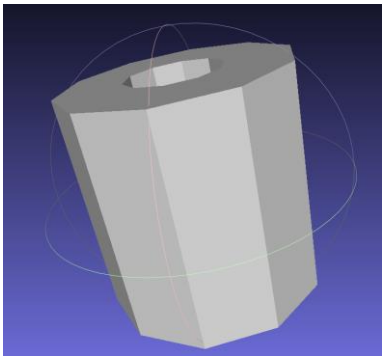
III. METHOD

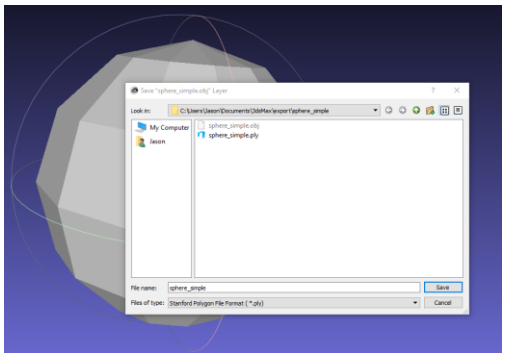
The project is using mass spring system as its underlying basis. A more complicated case would be using FEM models. But it requires more knowledge about continuum mechanics and numerical analysis, which are fairly difficult for me currently. But mass spring system is a subset of the particle system, so that implementing this is more specific which also requires many quantitative and programming skills.



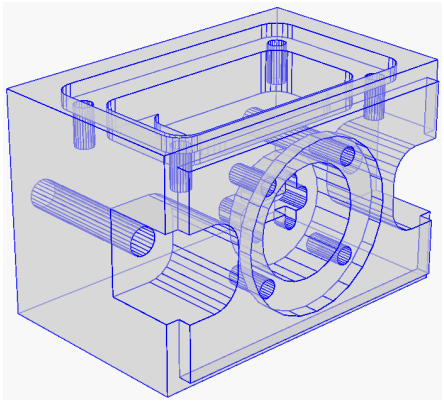


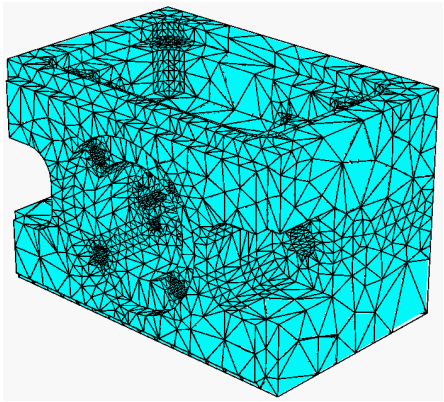
Firstly, the models are all created by using 3ds Max, including several simple primitive meshes, low and high fake heart meshes and the real heart mesh. The original design was more focusing on using Maya because I thought the project may be more animation intensive. It is true. But what Maya does are more Key Frame Animation related and it is not suitable for my program. The only thing therefore I need is just the meshes. Meanwhile I need to create my own physics simulation, add physics laws by myself.





The MeshLab is a great tool for translating the .obj files into .ply meshes that can be recognized by the TetGen program. By using TetGen, hollow meshes can be transformed so that the tetrahedral meshes can be used by my mass spring system which requires the particles in each tetrahedron primitive to be connected by the internal structures. Nevertheless, only this kind of work cannot ensure the models to be animated with the desired deformations. Because the quick jitters of those particles inside the model can lead the animation to be really odd. The system is not stable anymore if the damping effect is not added into the system.



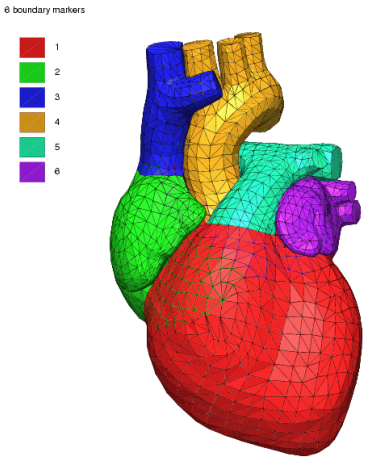


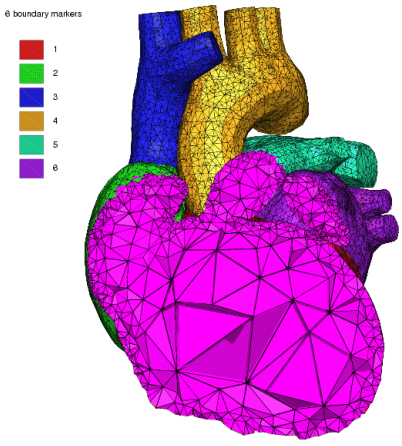
Heterogeneous Spring Rest Length Variation. This method is adding a fixed value to each spring in the system. So that when the heart rate timer is started, the length of each spring is elongated or shortened by this fixed length. With the damping effect added into the particle system, the movement of the model is pretty stable. Homogeneous Spring Rest Length Variation is another method which is pretty much doing the same job. But it is elongating and shortening the springs by multiplying and dividing a fixed value, which is in a way that homogeneously modifying the length of the spring.

IV. FUTURE WORK

The current progress of the project is completing the shading for the model by using VBO and triangle VAO. So that the performance of the program is fairly raised comparing the way that is using OpenGL rendering pipeline.

Future work could be separating the TetGen meshes to be several groups so that the program could have more control on the different parts of the model to let them behave slightly or drastically different. Another job for this project in the future could be adding more realistic texture and lighting effects.





V. Conclusion

The project is exploring the mass spring system and many possibilities are discovered in this project for animating tetrahedral meshes. Because the project is fairly complicated, the real heart meshes is not working so realistic currently. More techniques should be applied in the future work. But it is pretty sure that if the meshes are separated into different groups and by controlling more parameters on the real heart mesh, a more realistic result would be generated. As well as using a better texture on the mesh. However, the project is successfully delivered before the end of the semester and it is working pretty well either with good performance at the same time with good results when using fairly symmetrical tetrahedral meshes.