

Using Quaternions for Skeleton Animation

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May 11, 2016

Abstract

In computer animation, the rotations of objects can be described in many ways. However, quaternions are one of the best methods for rotating and moving objects. In this project, I used quaternions to rotate bones of skeleton.

1 Introduction

There are many different ways to rotate an object or represent its orientation. One of the most intuitive ways is using the Euler angles. Based on Euler's rotation theorem any rotation can be described using three rotation angles along three axes x, y and z. However, from the description, it's obvious that the process can not be smooth since we have to rotate 3 times to get the rotation about the access we want. In addition, gimbal lock can happen during the rotation using Euler angles

To avoid problems mentioned and much more, quaternions became so popular in many areas in computer animation. Quaternions can describe objects orientation in a very simple mathematical notation in three dimensions. They can make stable and smooth results.

2 Quaternion

Quaternion defines by two components, the axis of rotation which is $u = (u_x, u_y, u_z)$ and the amount of rotation which will occur about this axis θ .

Suppose we want to rotate point $p = (p_x, p_y, p_z)$ with respect to u axis. Quaternion can be represent as:

$$q = \cos \frac{\theta}{2} + (u_x i + u_y j + u_z k) \sin \frac{\theta}{2} \quad (1)$$

To apply rotation on p , we can easily do :

$$p' = qpq^{-1} \quad (2)$$

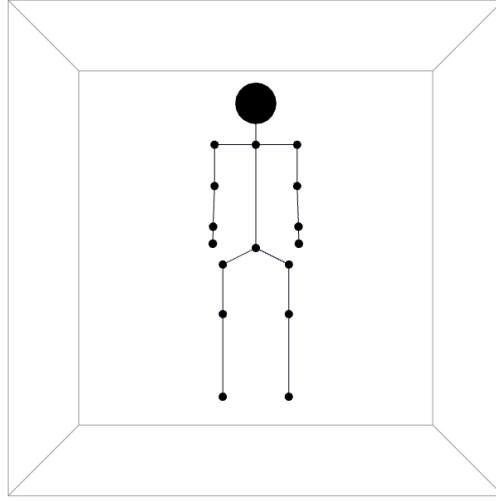


Figure 1:

in which p' is the new position of the point after the rotation. Also, to find the q^{-1} we can just negate the imaginary part of q which will be :

$$q^{-1} = \cos \frac{\theta}{2} - (u_x i + u_y j + u_z k) \sin \frac{\theta}{2} \quad (3)$$

I have to note that to do the products in equation (2), p have to have the same dimension as q and q' , therefor we can just add a theta element to the vector p with a value of zero.

3 Skeleton Animation

For my project, I chose Skeleton in order to apply quaternion implementation and rotate the bones. As you can see in Figure 1 I made skeleton using simple OpenGL functions and tree structure.

Each bone holds properties as below:

```
float pos[3];
float v_base[3];
float len;
myQuaternion q;
int parentId;
int leftId;
int rightId;
int centerId;
int id;
```

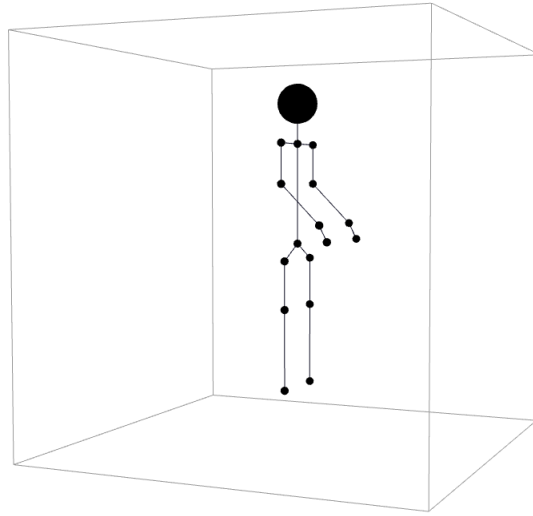


Figure 2:

The most important parameters are `pos` which holds the position of each bones at the starting point of the bone , `v_base` is the array that has bone's orientation and `q` which is the quaternion that we get using the orientation of bone.

I also implemented the class called `myQuaternion` which contains the functions we need to use for rotation using quaternion. These functions are : `quaternionProduct()` , `rotateVector()`, `normalizeQuat()` and constructors that make initial quaternion.

Here are the steps I went through to rotate the bone that I was interested in:

Recursively:

- Accumulative rotations: multiplying quaternion together as we go down to the tree of bones (used `quaternionProduct()`)
- Using cumulative quaternion I rotate the bone with orientation of `v_base` (used `rotateVector()`)
- Accumulate positions using the new orientation of bone and length of bones
- Update the position of each bone
- Do the same process for child bones

It has to be noted that the orientation vectors and quaternions have to be normalized throughout the process.

4 Results

You can find the result in the video that I provided. As you can see the rotations are very smooth and it can be run in real time. However, skeleton animation requires a lot of effort to make the skeleton move naturally. I tried to make at least the hands working naturally and to do so I had to define the time for each bone to start moving and the initial orientation of them should be set individually. You can find the snap shot of it in Figure 2.

As a future work I want to use blender and human model to apply the quaternion rotation on it. Also I want to work more on the bones initial conditions and other properties that each bone should have to make it more natural.

5 References

Tutorials :

- http://www.gamasutra.com/view/feature/131686/rotating_objects_using_quaternions.php
- <http://www.3dgep.com/understanding-quaternions>

Jake B.Kuipers's book on Quaternions and Rotation Sequences