Mathematics

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Abstract

3D math is all about measuring locations, distances,and angles precisely and mathematically in 3D space. The most frequently used framework to perform such calculations using a computer is called the Cartesian coordinate system.

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1 Introduction

The purpose of this article is to have a look at how mathematics is used in computer games. I'll use examples from computer games you've probably already played. There are lots of different types of computer games, and I'll talk about how maths is used in some of the following examples:

The First Person Shooter (FPS) is a type of game where you run around 3D levels carrying a big gun shooting stuff. Examples of this sort of game include Doom , Quake , Half Life , Unreal or Goldeneye . There are other games that look very similar, but aren't first person shooters, for instance Zelda: Ocarina of Time or Mario 64 .

The Strategy games are divided into two main types, Real Time Strategy (RTS), and Turn Based Strategy (not usually called TBS for some reason). These games usually involve building and managing a city or civilization and also fighting wars by controlling troops. Examples of real time strategy games are Age of Empires , Command &; Conquer , Tiberian Sun . Examples of turn based strategy games are Civilization and Alpha Centauri .

Simulation games are games that try to make something as realistic as possible. For instance, Flight Sims are computer games which try to realistically simulate flying an aeroplane or helicopter. Two games of this sort are Microsoft Flight Simulator and Red Baron . Space sims are like flight sims, but with spaceships instead of planes. For instance, Wing Commander or X-Wing vs. Tie Fighter . Racing games are games which simulate driving different sort of cars. For instance, Need for Speed , NASCAR Racing , Gran Turismo or Driver .

There are some exercises which you can do (if you want) throughout this article. The answers are at the end of the article, but do have a go at solving them on your own first. If there are any bits of this article you don't understand, you should either ask a question on the NRICH web board, or send an email to me at dog@fcbob.demon.co.uk
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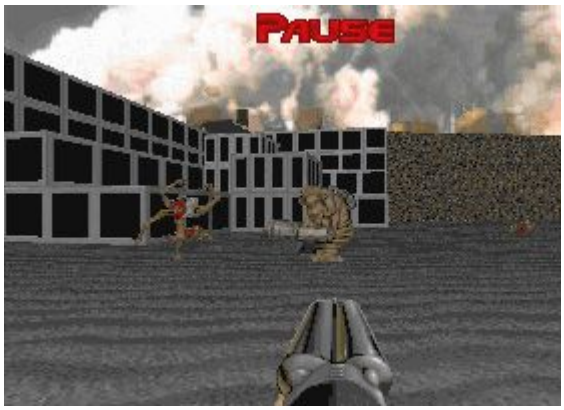
If you find any of the article patronising, I apologise, my excuse is that the article is aimed at people of many different ages so there might well be bits you already know. If you already understand one bit, you can just skip through until you get to something more interesting.

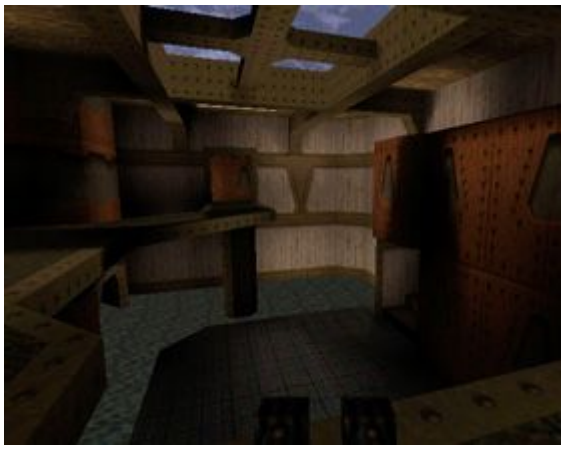
2 First Person Shooters
The most amazing things about FPS are their incredible graphics. They look almost real, none of this would have been possible without the use of advanced maths. Here are some pictures from the early games (Wolfenstein) to the most recent games (Quake III Arena). All

of the following screen shots are from games by iD software.

Wolfenstein, one of the earliest FPS games



Doom, the next breakthrough in graphics



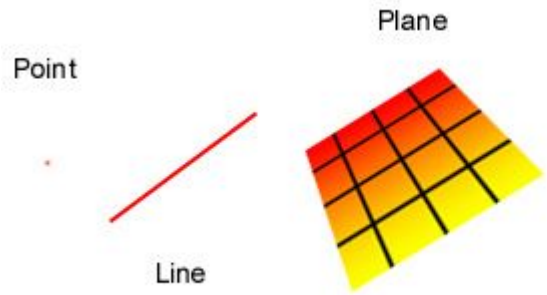
Quake, this was a huge leap in the quality of graphics in computer games

Quake III, one of the newest FPS games around

To begin to explain how these games work, you need to know a bit about geometry , vectors and transformations .

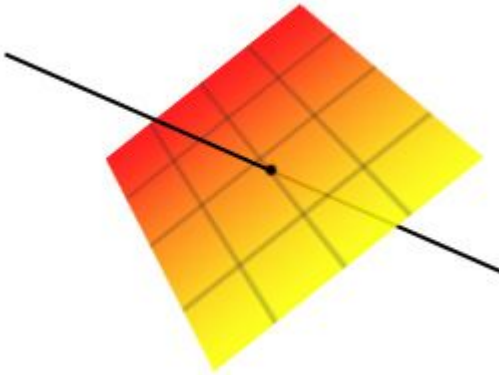
2.1 Geometry, Vectors and Transformations

Geometry is the study of shapes of various sort. The simplest shape is the point . (It's quite difficult to explain what a point is, it is basically just a position, for instance, the very end of your nose is a point). Another simple shape is a straight line . A straight line is just the simplest shape joining two points together. A plane is a more complicated shape, it is a flat sheet, like a piece of paper or a wall. There are more complicated shapes, called solids , like a cube or a sphere. Here are some pictures of these things.



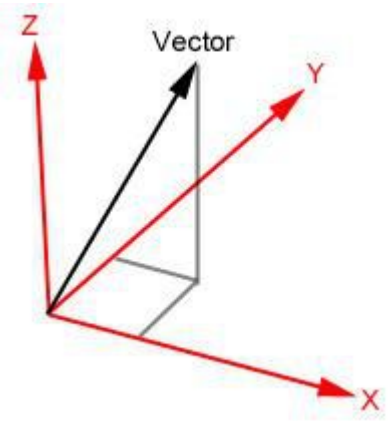
Simple geometric figures

If you have a line and a plane, you can find the point where the line cuts through the plane. In fact, sometimes you can't find the intersection, because they don't meet and sometimes the line is inside the plane so they meet at every point on the line , but this doesn't happen in the cases we're interested in. We call this the intersection of the line and the plane. Here is a picture of what this looks like.



Intersection of a line and a plane

A vector is a mathematical way of representing a point. A vector is 3 numbers, usually called x, y and z. You can think of these numbers as how far you have to go in 3 different directions to get to a point. For instance, put one arm out pointing to the right, and the other pointing straight forward. I can now give you a vector and you'll be able to find the point I'm talking about. For instance, if I say x=3, y=1, z=5, you find the point by walking 3 metres in the direction of your right hand, then 1 metre in the direction of your left hand, and then getting a ladder and climbing up 5 metres. Here is a picture of a vector.



Picture of a vector and directions

Vectors are written as (x,y,z), for instance (1,2,3) means move 1 in the x-direction, 2 in the y-direction and 3 in the z-direction.

One confusing thing about vectors is that they are sometimes used to represent a point, and sometimes they are used to represent a direction. The vector (1,0,0) can mean both ``the point you get to if you move 1 unit in the x-direction from the starting point'', or it can mean ``move 1 unit in the x-direction from where you are now''.

References

http://www.delorie.com/djgpp
http://www.talula.demon.co.uk/allegro
Here are some links on programming games:
http://www.gamasutra.com
http://www.gamedev.net
This is a brilliant page on path finding:
http://www-cs-students.stanford.edu/~amitp/gameprog.html
Here are some very comprehensive notes on 3D graphics (very hard!):
http://www.cc.gatech.edu/gvu/multimedia/nsfmmedia/cware/graphics/toc.html