Principles of Computer Game Design and Implementation

Lecture 6

We already knew

- Game history
- game design information
- Game engine

What’s Next

- Mathematical concepts (lecture 6-10)
- Collision detection and resolution (lecture 11-16)
- Game AI (lecture 17 -)

Mathematical Concepts

3D modelling, model manipulation and rendering require Maths and Physics

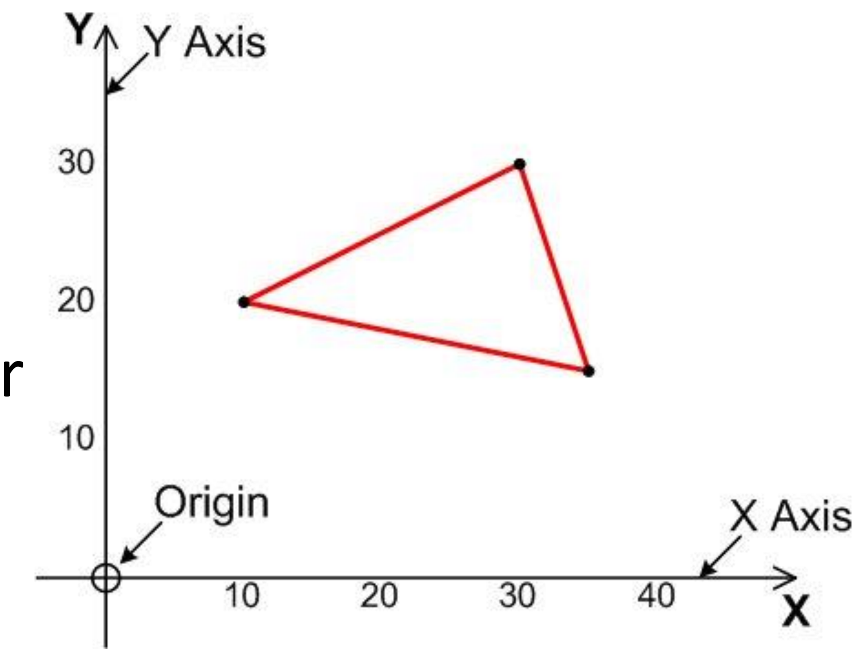
- Typical tasks:
  - How to position objects?
  - How to move and rotate objects
  - How do objects interact?

2D Space

- We will start with a 2D space (simpler) and look at issues involved in
  - Modelling
  - Rendering
  - Transforming the model / view

2D Geometry

- Representation with two ***axes***, usually X (horizontal) and Y (vertical)
- ***Origin*** of the graph and of the 2D space is where the axes cross (X = Y = 0)
- Points are identified by their coordinates

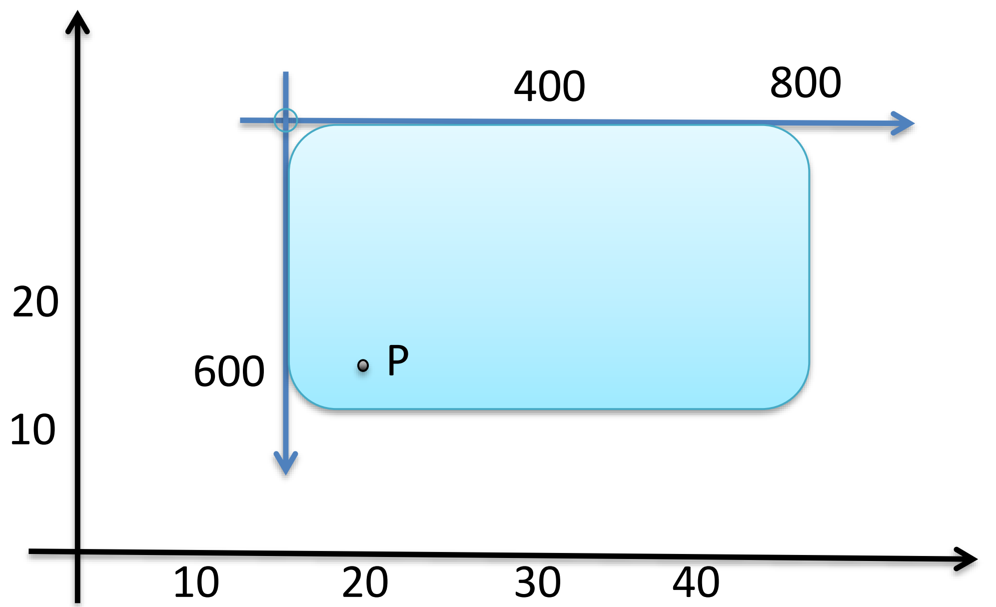


Viewports

- A ***viewport*** (or ***window***) is a rectangle of pixels representing a view into ***world space***
- A viewport has its own coordinate system, which may not match that of the geometry.
  - The axes will usually be X horizontal & Y vertical
    - But don't have to be – rotated viewports
  - The *scale* of the axes may be different
  - The *direction* of the Y axis may differ.
    - E.g. the geometry may be stored with Y up, but the viewport has Y down.
  - The origin (usually in the corners or centre of the viewport) may not match the geometry origin.

Example

- Example of changing coordinate system from world space to viewport space:



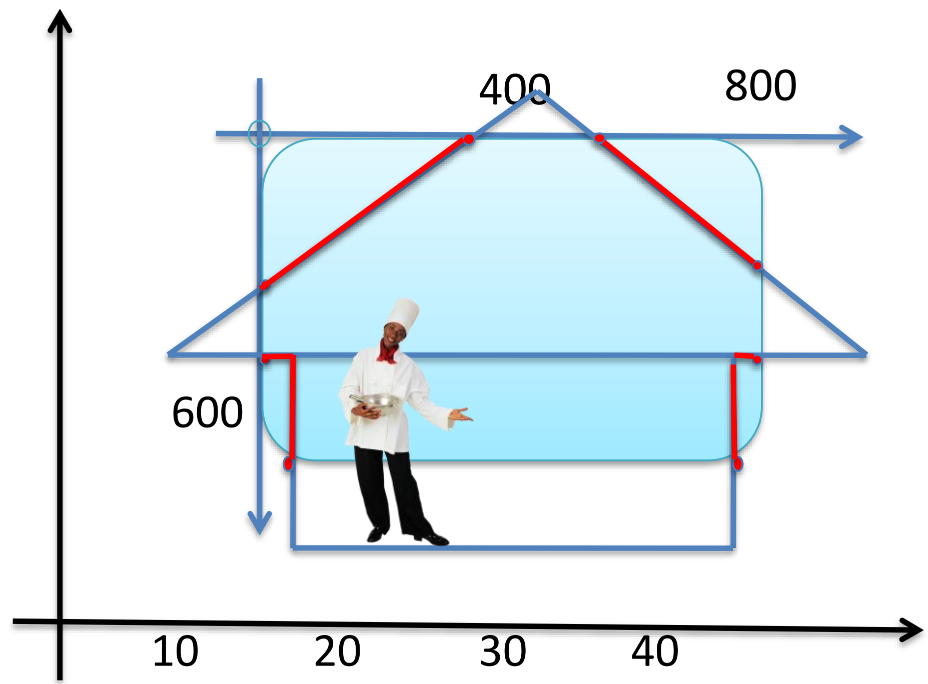
P = (20,15) in world space. Where is P' in viewport space?

Rendering

- ***Rendering*** is the process of converting geometry into screen pixels
- To render a point:
  - Convert vertex coordinates into viewport space
  - Set the colour of the pixel at those coordinates
  - The colour might be stored with the geometry, or we can use a fixed colour (e.g. black)

Rendering Lines and Shapes

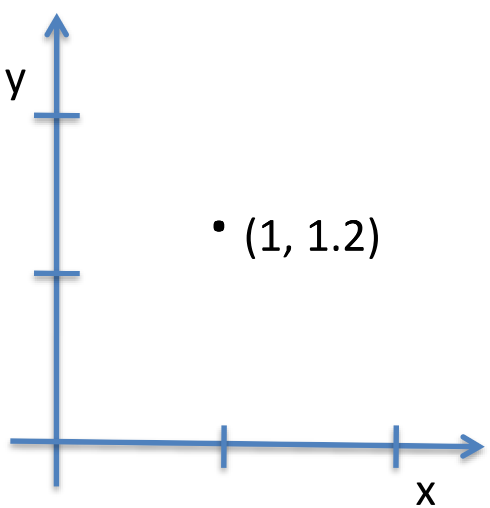
- Need to determine which part of the line is visible, where it meets the viewport edge and how to crop it.

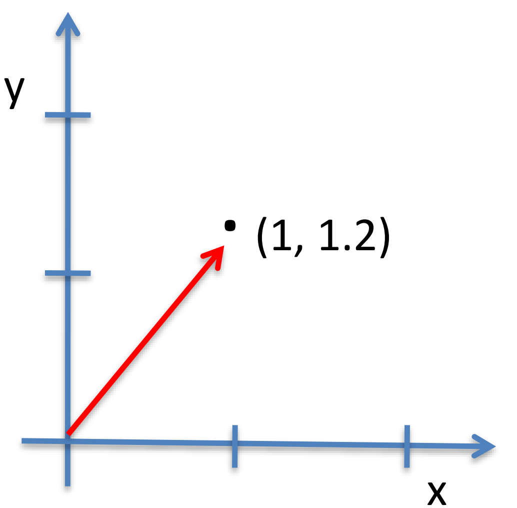


- In “Ye good old days” this was rather difficult
- With support from rendering libraries easy

Points and Vectors

- Point: a **location** in space
- Vector: a **direction** in space





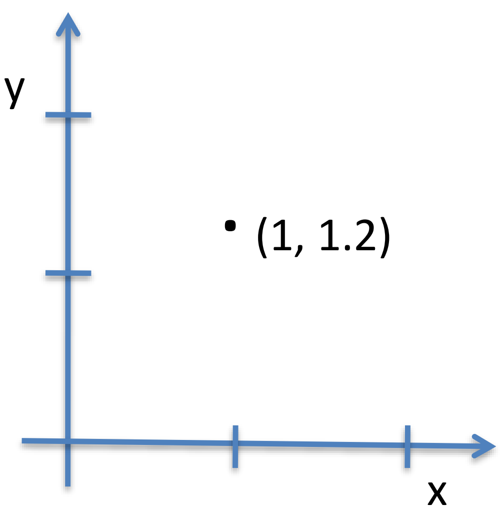
What’s the Difference?

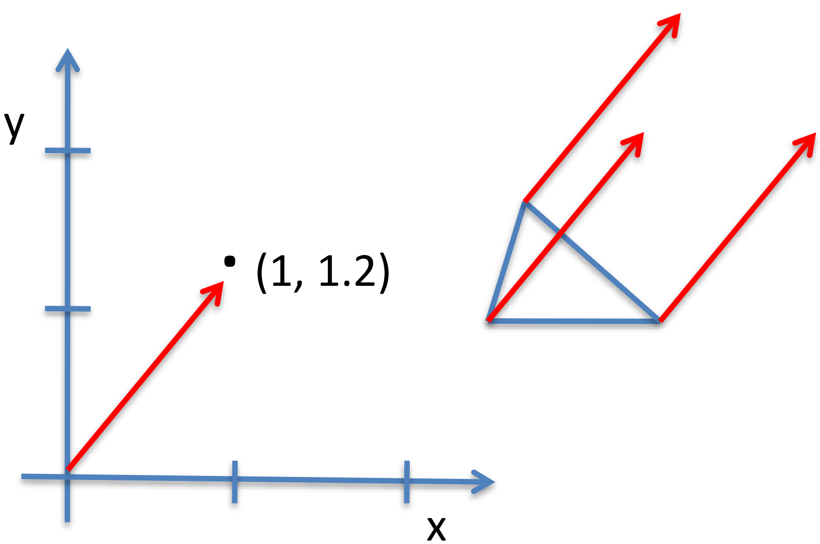
- The only difference is “meaning”

- But think about
  - “move a picture to the right
  - “move a picture up”
  - “move a picture in the direction …”
    - Vectors specify the direction

Moving an Object

- ***Translation*** of an object
  - Moving without rotating or reflecting
  - *Apply* a vector to all points of an object
  - Vector specifies **direction** and **magnitude** of translation

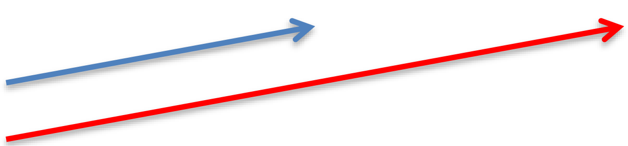




Vectors

A **vector** is a *directed line segment*

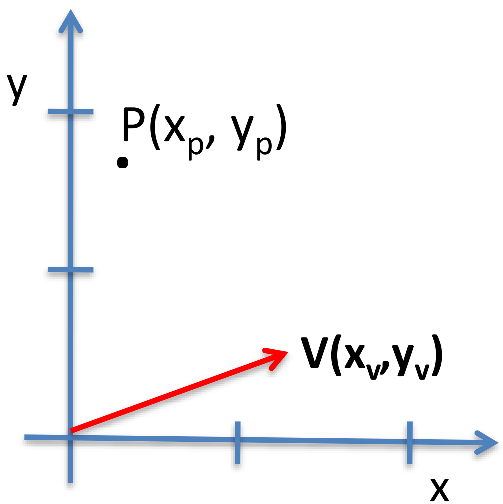
- The length of the segment is called the *length or magnitude* of vector.
- The direction of the segment is called the *direction* of vector.
- Notations: vectors are usually denoted in bold type, e.g., **a**, **u**, **F**, or underlined, $\underline{a}$, $\underline{u}$, $\underline{F}$.

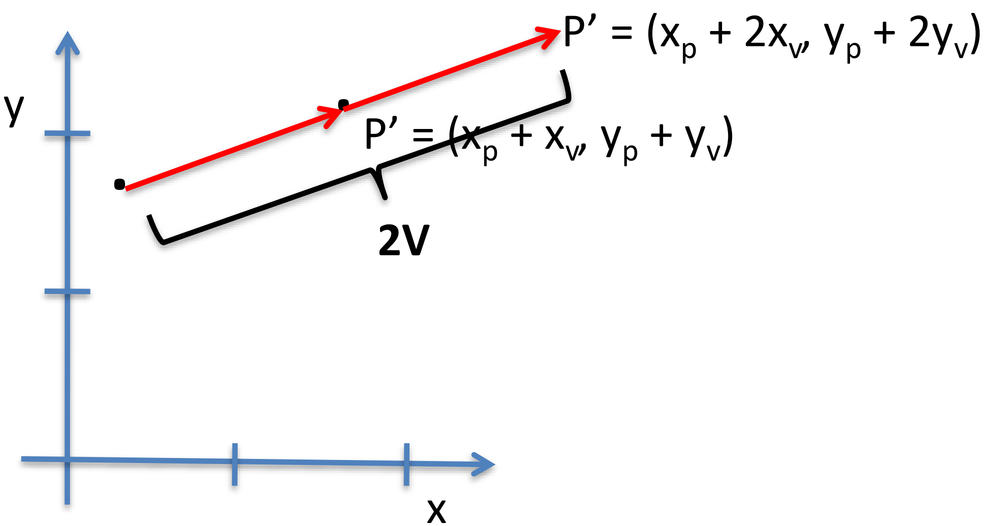


Same direction,
red is twice as long

Translation Recipe

- In order to translate (move) an object in the direction given by a vector **V**, move all points.





$\mathbf{V = (x_v, y_v)}$

$P = (x_P, y_p)$

$$P' = (x_p + x_v, y_p + y_v)$$

Multiplying a Vector by a Number

- Multiplying a vector by a positive **scalar** (positive number) does not change the direction but changes the magnitude
- Multiplying by a negative number reverses the direction and changes the magnitude

In Coordinates

- $\mathbf{V}=(x,y)$ a vector, λ a number

$$\lambda \cdot \mathbf{V} = (\lambda x, \lambda y)$$

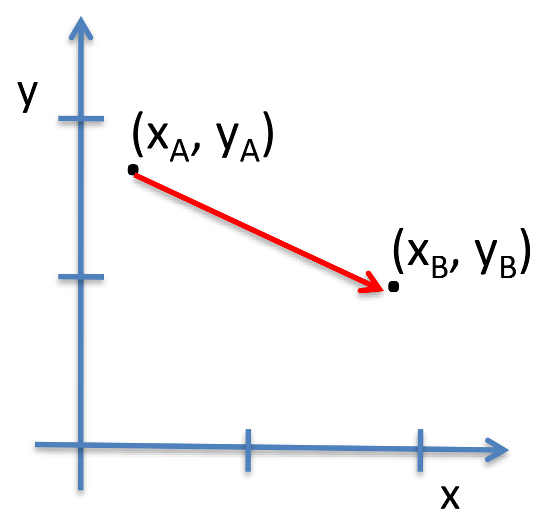
Example:

$$2 \bullet (2, 5) = (4, 10)$$
$$0.7 \bullet (2, 5) = (1.4, 3.5)$$
$$-2 \bullet (2, 5) = (-4, -10)$$

From A to B

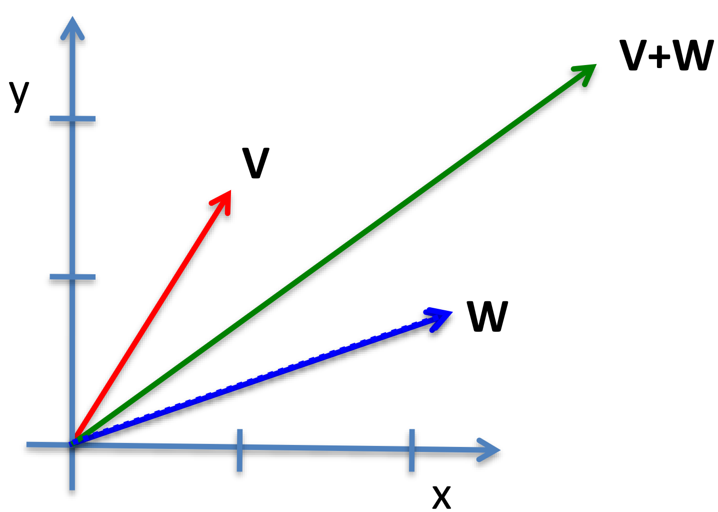
- Which vector should be applied to move a point from (x_A,y_A) to (x_B,y_B)?

  $-(x_B - x_A, y_B-y_A)$



Sum of Two Vectors

- Two vectors **V** and **W** are added by placing the beginning of **W** at the end of **V**.



In Coordinates

Let

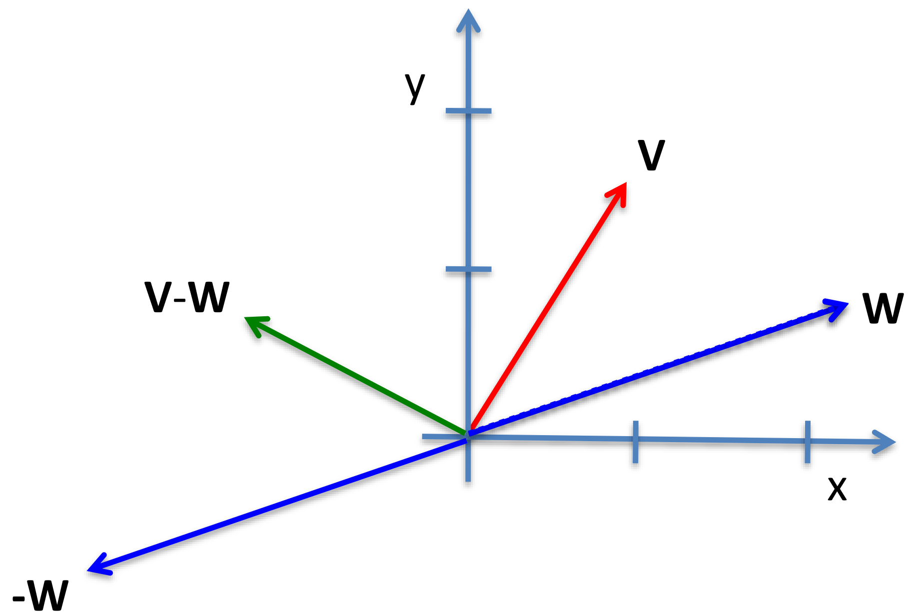
- $\mathbf{V} = (x_v, y_v)$
- $\mathbf{W} = (x_w, y_w)$

Then

$$\mathbf{V} + \mathbf{W} = (x_v + x_w,\ y_v + y_w)$$

Vector Difference

- **V** – **W** = **V** + (-1)•**W**



In Coordinates

Let

- $\mathbf{V} = (x_v, y_v)$
- $\mathbf{W} = (x_w, y_w)$

Then

$$\mathbf{V} - \mathbf{W} = (x_v - x_w,\ y_v - y_w)$$

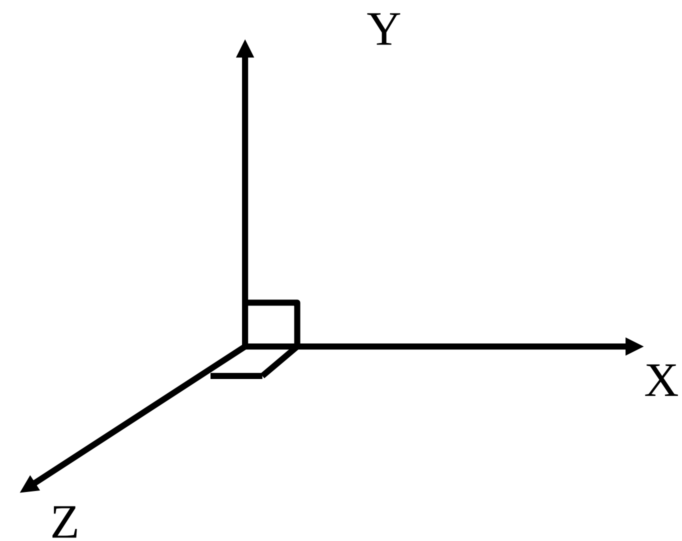
Applications

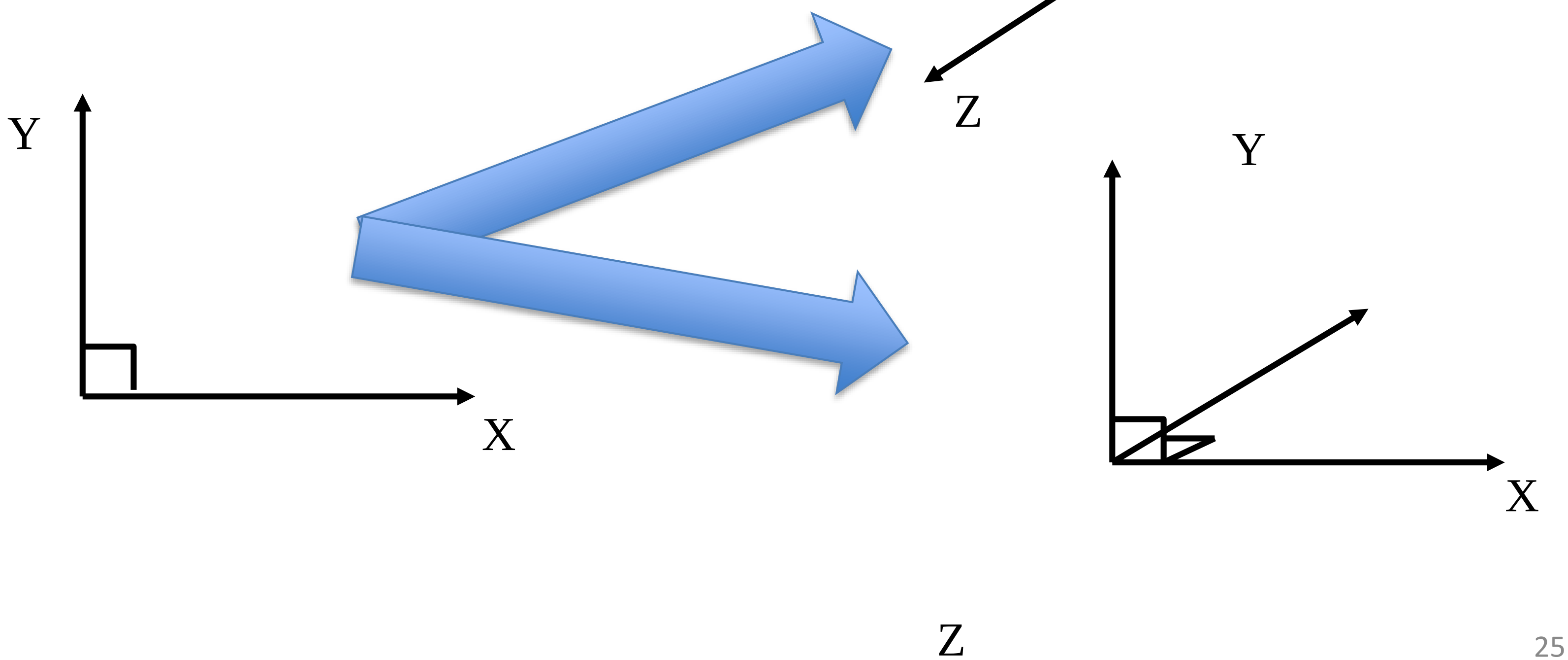
- Apply vector **V** to an object then apply **W**
  - Apply **V** + **W**
  - Representing motion as a combination of two

- If **V** takes you to A, **W** takes you to B, what takes from A to B?
  - Apply **W** – **V**
  - Shooting, targeting

From 2D to 3D

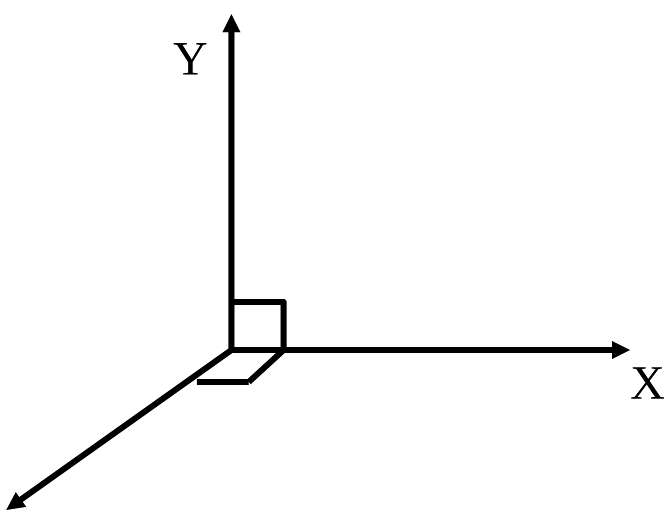
- 3D geometry adds an extra axis over 2D geometry
  - This “Z” axis represents “depth”
  - Can choose the “direction” of Z



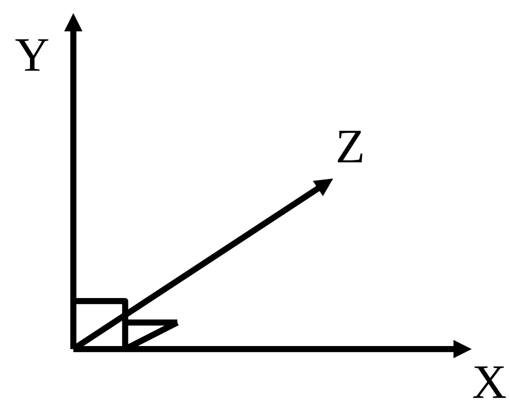


“Handedness”

- Use thumb (X), index finger (Y) & middle finger (Z) to represent the axes
- Use your left hand and the axes are left-handed, otherwise they are right-handed



Right-Handed System
(Z comes out of the screen)



Left-Handed System
(Z goes in to the screen)

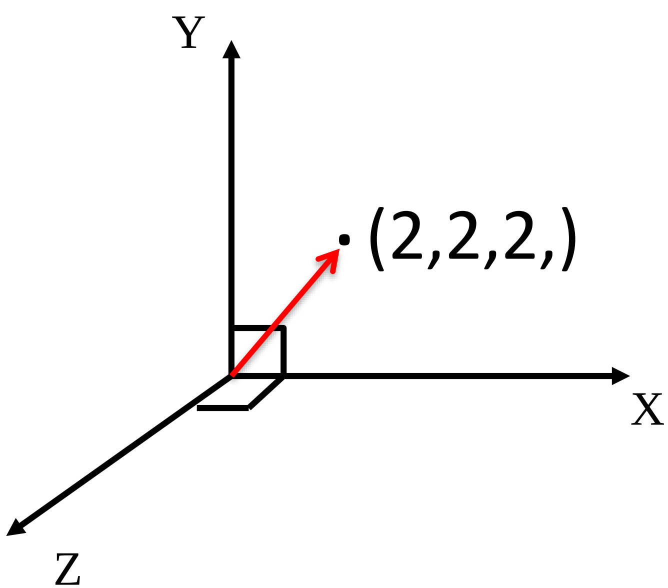
Left- vs Right-Handed

- In mathematics, traditionally, right-handed axes are used
- In computing:
  - DirectX and several graphics applications use left-handed axes
  - OpenGL use right-handed

Neither is better, just a choice

Vectors in 3D

- Still a directed interval
- x, y and z coordinates define a vector



- $\mathbf{V}=(x_v,y_v,z_v)$ a vector, λ a number
  $$\lambda\cdot\mathbf{V} = (\lambda x_v, \lambda y_v, \lambda z_v)$$
- $\mathbf{V} = (x_v, y_v, z_v)$; $\mathbf{W} = (x_w, y_w, z_w)$
  $$\mathbf{V} + \mathbf{W} = (x_v+x_w, y_v+y_w, z_v+z_w)$$
- $\mathbf{V} = (x_v, y_v, z_v)$; $\mathbf{W} = (x_w, y_w, z_w)$
  $$\mathbf{V} - \mathbf{W} = (x_v-x_w, y_v-y_w, z_v-z_w)$$

Vectors in jMonkeyEngine

- jME defines two classes for vectors
  - Vector3f
  - Vector2f
- Constructors
  - Vector2f(float x, float y)
  - Vector3f(float x, float y, float z)

- Lots of useful methods (see javadoc)

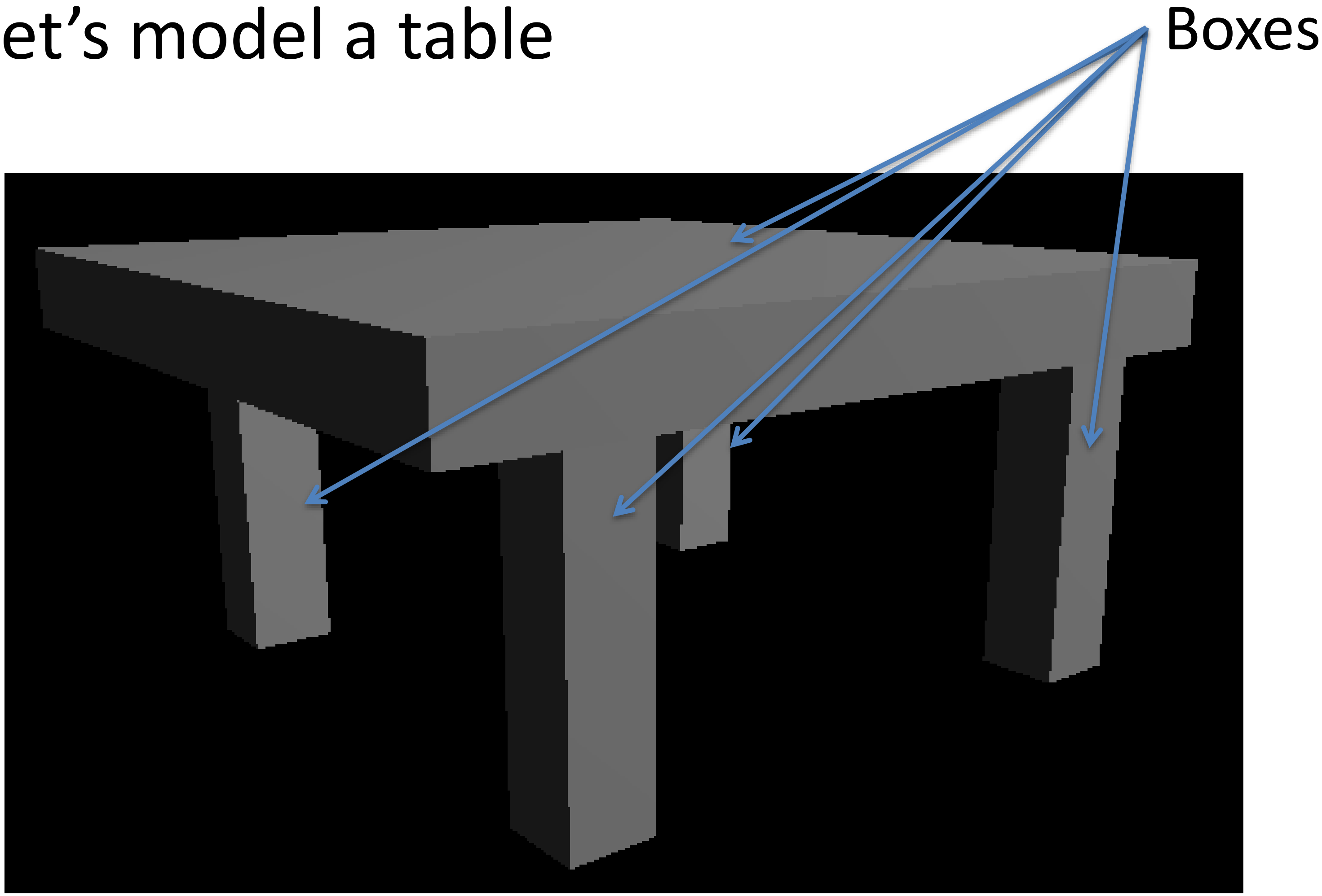
Translation (setting position) in JME

```
protected void simpleInitApp() {
    Geometry box =...;

    Vector3f v= new Vector3f(1,2,0);
    box.setLocalTranslation(v);

    rootNode.attachChild(box);
}
```

Position of an object

Translation And the Scene Graph

- Let's model a table



Boxes for Tabletop and Legs

```
Box tableTop = new Box(10, 1, 10);
Box leg1 = new Box(1,5,1);
…
Geometry gTableTop  = new
    Geometry("TableTop", tableTop);
gTableTop.setMaterial(mat);
Geometry gLeg1 = new
    Geometry("Leg1", leg1);
gLeg1.setMaterial(mat);
…
```

Beware of Floats

- If you think that the table top is too thick and change

```
Box tableTop = new Box(10, 1, 10);
```

Double

to

```
Box tableTop = new Box(10, 0.3, 10);
```

you will see an error:

```
The constructor Box(int, double,
  int) is undefined
```

Use the “f” word! ☺

```
Box tableTop = new Box(10,
0.3f, 10);
```

float

Many jME methods take “single precision” float numbers as input

No need “double precision”

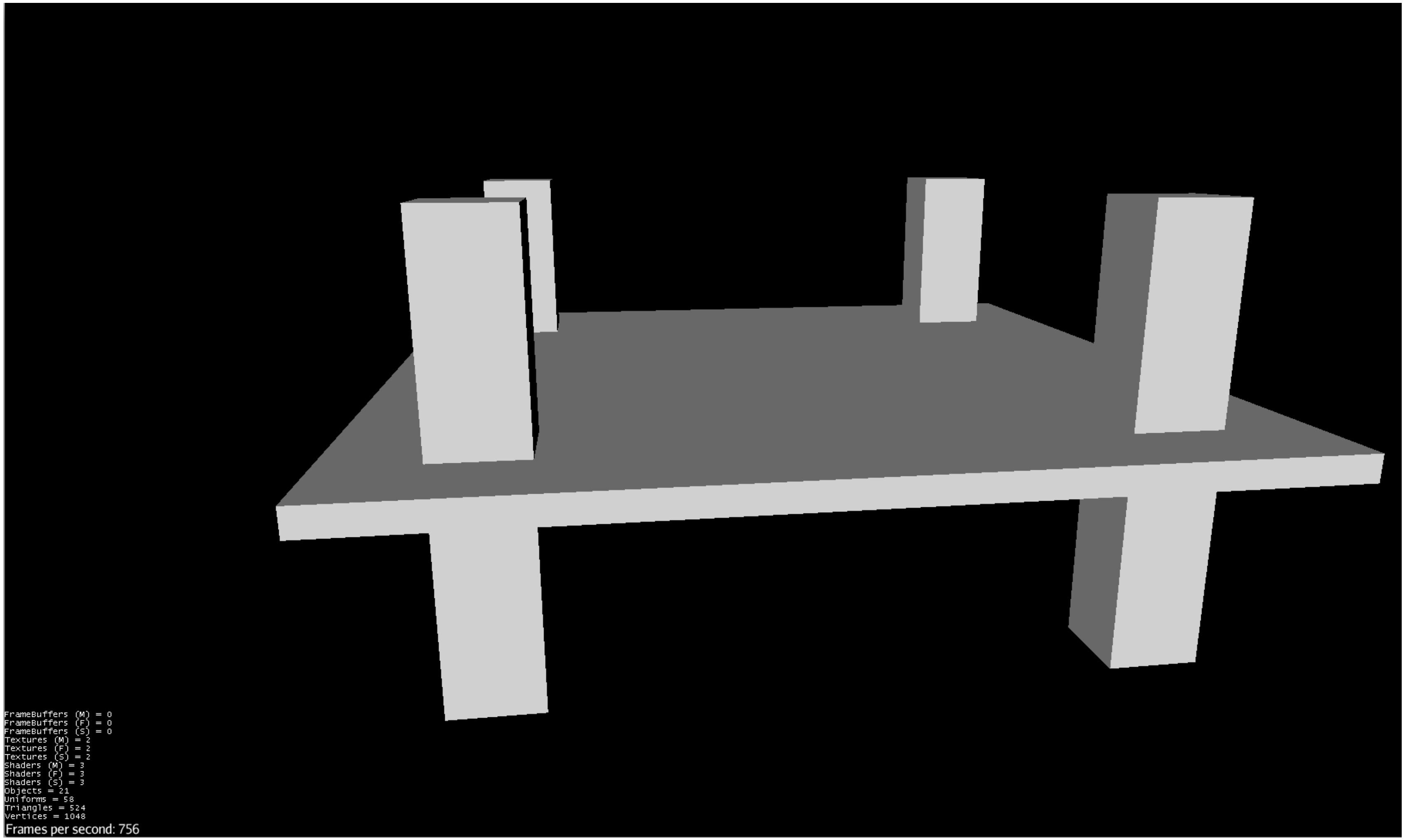
Position the legs

…

```
leg1.setLocalTranslation( 7, 0, 7);
leg2.setLocalTranslation(-7, 0, 7);
leg3.setLocalTranslation( 7, 0,-7);
leg4.setLocalTranslation(-7, 0,-7);
```

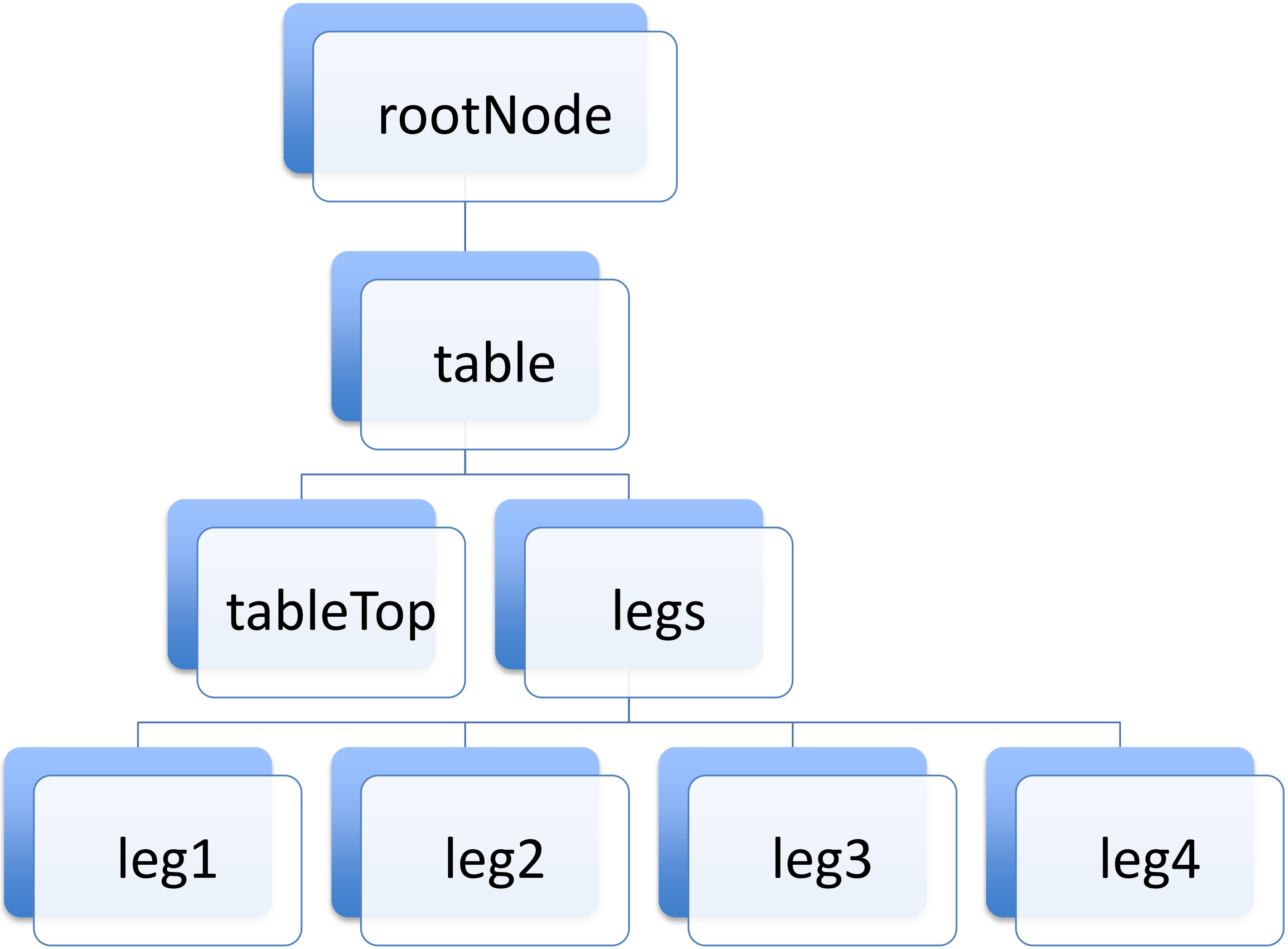
Attach all to rootNode

Oops…



FrameBuffers (M) = 0
FrameBuffers (F) = 0
FrameBuffers (S) = 0
Textures (M) = 2
Textures (F) = 2
Textures (S) = 2
Shaders (M) = 3
Shaders (F) = 3
Shaders (S) = 3
Objects = 21
Uniforms = 58
Triangles = 524
Vertices = 1048
Frames per second: 756

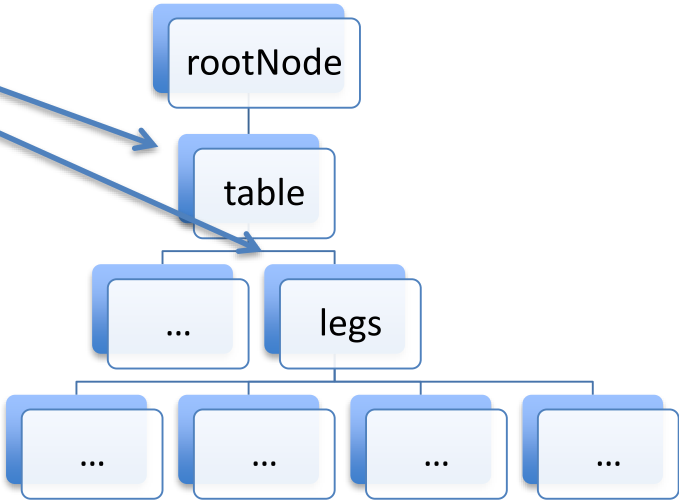
A Better Scene Graph



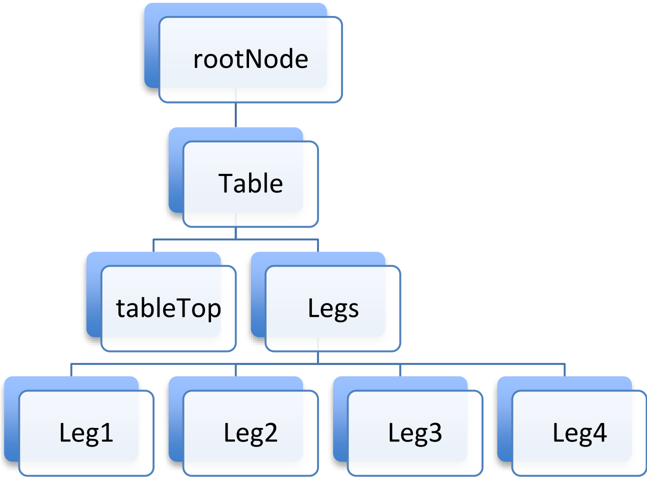
What are “table” and “legs”

- Internal nodes

```
Node table = new
  Node("Table");
Node legs = new
  Node("Legs");
…
```



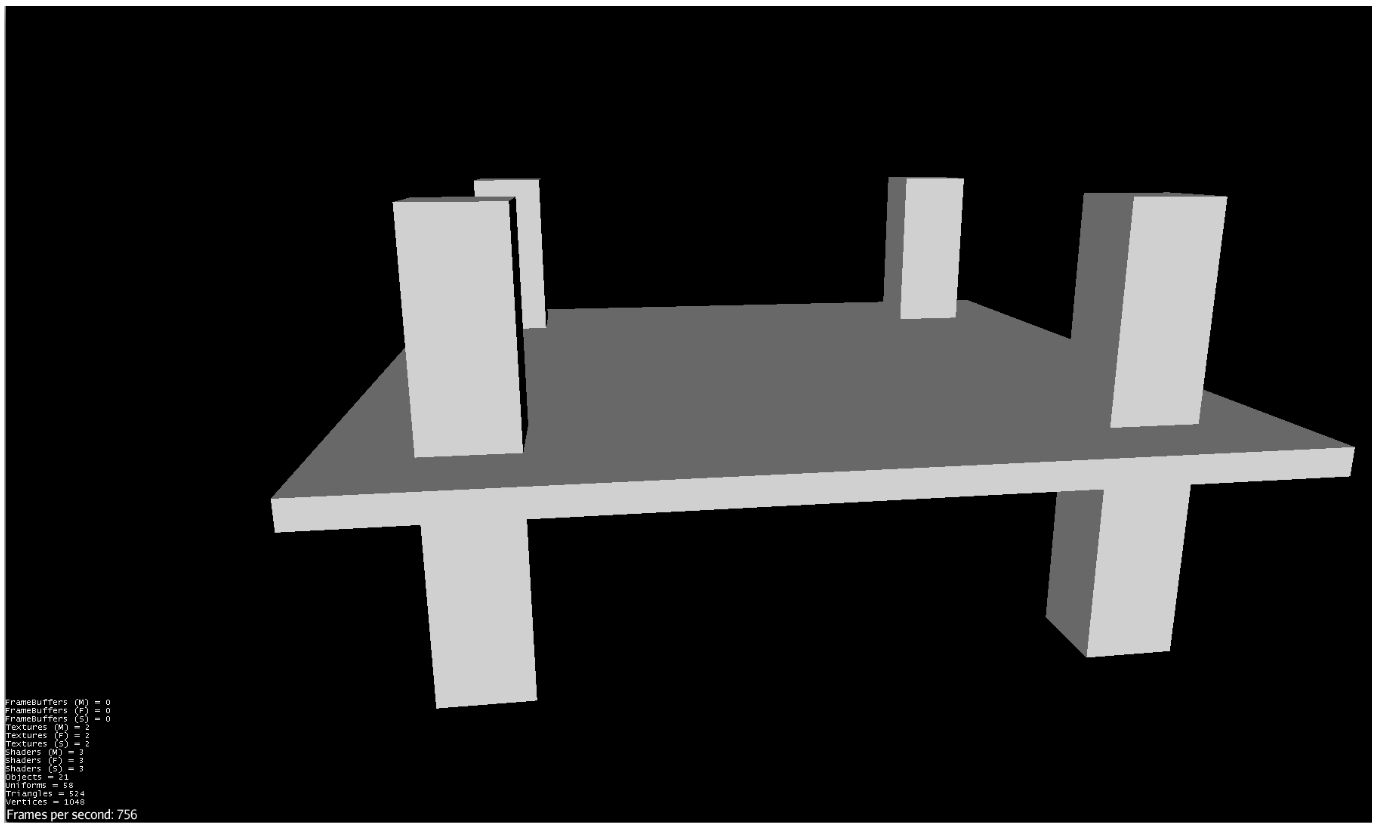
Putting it Together




```
legs.attachChild(gLeg1);
legs.attachChild(gLeg2);
legs.attachChild(gLeg3);
legs.attachChild(gLeg4);

table.attachChild(tableTop);
table.attachChild(legs)

rootNode.attachChild(table);
```

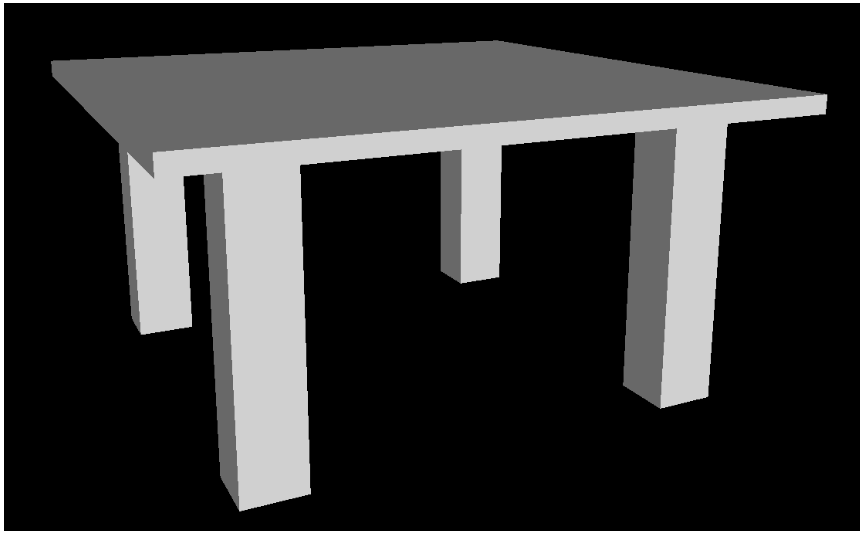
But Does It Change the Picture?

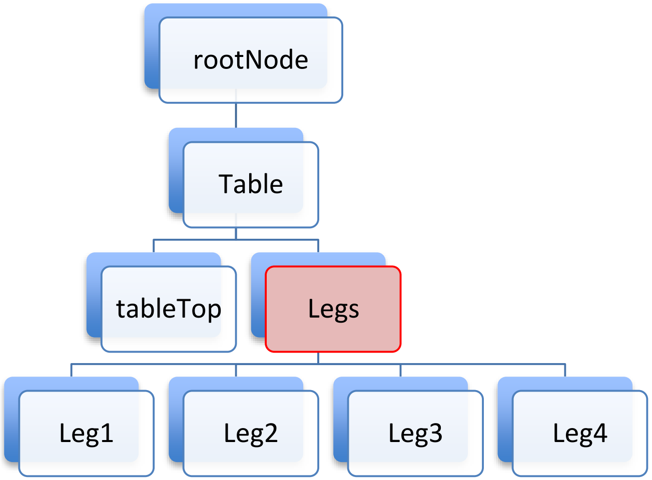
No



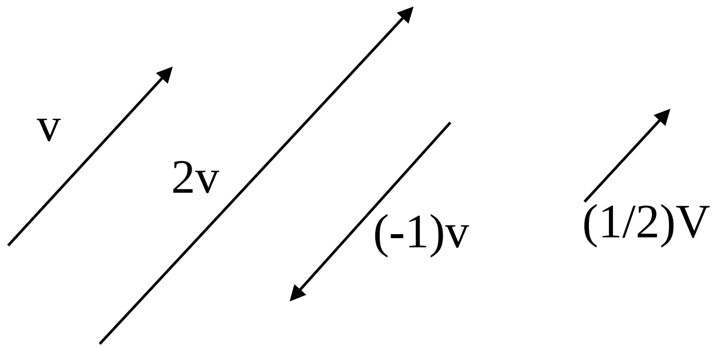
Transforms Are in All Nodes!

```
legs.move(0,-5f,0);
```

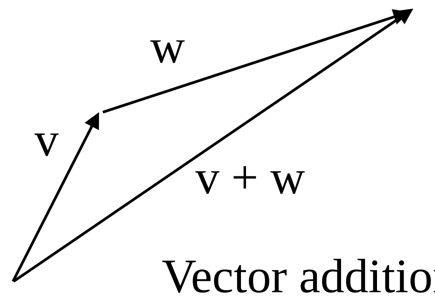




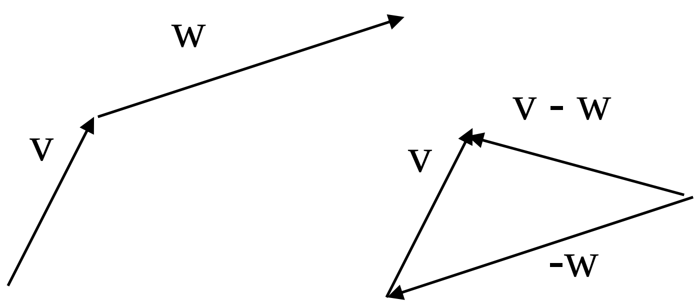
Summary: Manipulation of Vectors



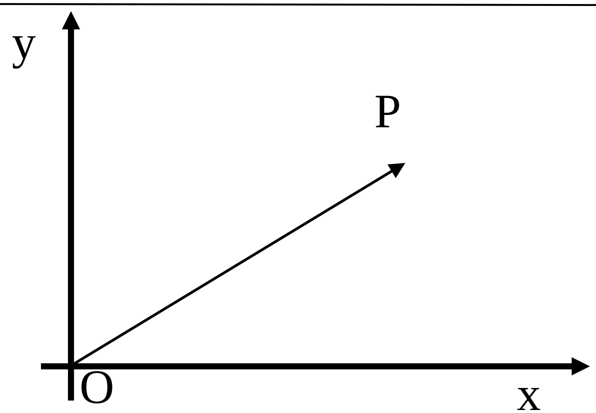
Scalar multiplication of
vectors (they remain parallel)



Vector addition
sum v + w



Vector difference
v - w = v + (-w)



Vector $\overrightarrow{OP}$

Summary: Vector Arithmetic

- $\mathbf{V}=(x_v,y_v,z_v)$ a vector, λ a number

$$\lambda \cdot \mathbf{V} = (\lambda x_v, \lambda y_v, \lambda z_v)$$

- $\mathbf{V} = (x_v, y_v, z_v)$; $\mathbf{W} = (x_w, y_w, z_w)$

$$\mathbf{V} + \mathbf{W} = (x_v+x_w, y_v+y_w, z_v+z_w)$$

$$\mathbf{V} - \mathbf{W} = (x_v-x_w, y_v-y_w, z_v-z_w)$$

*What about a product of **V** and **W**?*
And why?

Summary: Vector Algebra

- $\mathbf{a} + \mathbf{b} = \mathbf{b} + \mathbf{a}$ (commutative law)
- $(\mathbf{a} + \mathbf{b}) + \mathbf{c} = \mathbf{a} + (\mathbf{b} + \mathbf{c})$ (associative law)
- $\mathbf{a} + \mathbf{0} = \mathbf{a}$
- $\mathbf{a} + (-\mathbf{a}) = \mathbf{0}$
- $\lambda\,(\mu\mathbf{a}) = (\lambda\,\mu)\mathbf{a}$
- $(\lambda + \mu)\mathbf{a} = \lambda\,\mathbf{a} + \mu\mathbf{a}$
- $\lambda(\mathbf{a} + \mathbf{b}) = \lambda\,\mathbf{a} + \lambda\,\mathbf{b}$
- $1\,\mathbf{a} = \mathbf{a}$