Reality is Virtual

Gravity in 1, 2 and 3 Dimensions

Gravity in One Dimension

In one dimensional gravity each Boxel has two sides – a right side and a left side. Accurate diagrams of gravity in one dimension would show lines without and thickness. But for clarity the diagrams of gravity in one dimension below are given a vertical thickness. The figure below shows an isolated yellow Mass "M".

								M				

Figure 1 - Mass M in one dimension

The figure below shows the force of gravity at unit distance for a mass of 1000 units. Gravitational field change vectors are shown below, pointing in the direction of the force of gravitational attraction. The magnitude of the change is given below the vector. It is the change in mass divided by the distance squared. As the change in M's mass was 1000, the magnitude of the gravitational field change is 1000/1^2 = 1000.

							→	M	←			
							m/1		m/1			
							1000		1000			

Figure 2 - GFC spreads out by one unit in both directions

Next the same line of space is one and two simulation cycles later, with corresponding gravitational force vectors.

						→	→	M	←	←		
						m/2^2	m/1		m/1	m/2^2		
						250	1000		1000	250		

				→	→	→	M	←	←	←	
				m/3^2	m/2^2	m/1		m/1	m/2^2	m/3^2	
				111	250	1000		1000	250	111	

Figure 3 - GFC spreading out during two additional cycles

Then we include an additional mass. The next sequence of cycles shows the spreading of gravitational force form a blue mass of 1000 over sequential simulation cycles.

				M				M			

			→	M	←			M			
			m/1		m/1						
			1000		1000						

		→	→	M	←	←		M			
		m/2^2	m/1		m/1	m/2^2					
		250	1000		1000	250					

	→	→	→	M	←	←	←	M			
	m/3^2	m/2^2	m/1		m/1	m/2^2	m/3^2				
	111	250	1000		1000	250	111				

Figure 4 - GFC spreading out during multiple cycles

Next we show both sequences with the magnitude of the gravitational force from each of the Boxels. The blue Boxel gravitational strengths are on the first line, the yellow Boxel's gravitational strengths are on the second line.

→	→	→	M	←	←	←	←	←	←	←
m/3^2	m/2^2	m/1		m/1	m/2^2	m/3^2	m/4^2	m/5^2	m/6^2	m/7^2
111	250	1000		1000	250	111	62.5	40	28	20

→	→	→	→	→	→	→	M	←	←	←
m/7^2	*m/6^2*	*m/5^2*	*m/4^2*	*m/3^2*	*m/2^2*	*m/1*		*m/1*	*m/2^2*	*m/3^2*
20	*28*	*40*	*62.5*	*111*	*250*	*1000*		*1000*	*250*	*111*

Figure 5 - Yellow and Blue GFC Progression

Then we combine numerically the gravitational forces from each, adding them together when they point in the same direction and subtracting them when they point in opposite directions.

→	→	→	→	←		→	←	←	←	←
111 +20= **131**	250 +28 = **278**	1000 +40= **1040**	62.5	1000 - 111= **889**	0	1000 - 111= **889**	62.5	1000 +40= **1040**	28 +250= **278**	20 +111= **131**

Figure 6 - Net Gravitational Field Strength

What do we observe?

- Gravity is an attractive force of gravity and is strongest near the two objects.
- Gravity is balanced out at a point midway between them
- Each object feels gravitational attraction towards the other object

Good – these are what we expect and consistent with how gravity really works.

There are additional points.

- Gravity is spreading out one Boxel per simulation cycle – the speed of light; and
- The force of gravity is being treated as single valued for the entire Boxel

Now let's add in another complication – we move one object over by one Boxel. This results in a decrease in gravitational strength spreading outward from where the object used to be located and an increase in gravitational strength spreading outward from where the object is now located.

For example imagine a unit of mass of 1000 moving from one Boxel A to the next Boxel, Boxel B. To accomplish this we subtract a mass of 1000 from Boxel A and simultaneously add a mass of 1000 to Boxel B. We let the mass changes expand like before, the distance of one Boxel length per simulation cycle. The effect of gravity that used to be coming from Boxel A is erased outwards, one Boxel length at a time. The effect of gravity originating from Boxel B spreads outward one Boxel length at a time as well.

Too many GFCs at the same time

Each Boxel has the capacity to handle a finite number of gravitational force changes during one simulation cycle. If the number of changes hitting a Boxel at the same time exceeds this amount something has to give.

To illustrate - first we show a single blue mass with a GFC spreading outward.

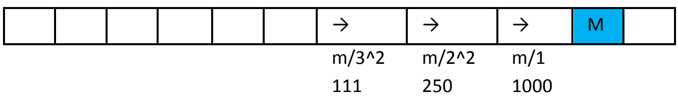

Figure 7 - Blue mass GFC spreading outward

A yellow mass is added at the same time the blue's gravitational force is passing through.

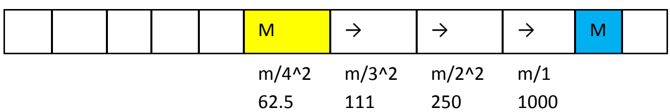

Figure 8 - Yellow mass appears as Blue GFC passes through

In the next diagram we color the GFC from the yellow mass yellow, and the GFC from the blue mass in blue. In a few more simulation cycles the situation is now:

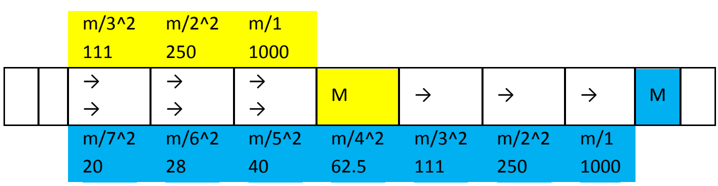

Figure 9 - Blue and Yellow GFC changes continue

Three more cycles pass (above), and then a Green Mass is also added (below).

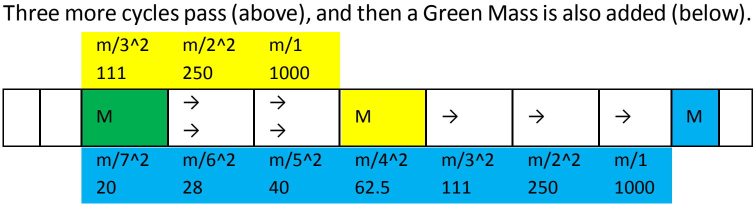

Figure 10 - Green Mass is added

With the green mass there will now be three gravitational field change vectors moving together in lock step, each maintaining its own distance measurement (R) with its original mass quantity (M).

If the maximum number of concurrent GFCs hitting a Boxel at the same time was two we would have to do something to reduce the count. One approach is to combine the two most similar. But combining the two most similar "GFC" we impact the simulation the least. But which two are the most similar? If we could find two vectors whose distances (R) were equal:

$$R_1 = R_2$$

Then we could combine the two vectors as the denominator of the magnitudes would be the same:

$$\frac{M_1 + M_2}{R^2} = \frac{M_1}{(R_1)^2} + \frac{M_2}{(R_2)^2}$$

Unfortunately in one dimensions we will never have two vectors with the same distance (R) value entering the same side of the boxel. So the best we can do is to select the pair of vectors that are most compatible, whose combination would result in the smallest numerical error. We can identify the two most similar vectors by finding the pair that has the smallest value for:

$$\left(\frac{M_1 + M_2}{R^2}\right) - \left(\frac{M_1}{(R_1)^2} + \frac{M_2}{(R_2)^2}\right)$$

A computer algorithm or method to accomplish this would sort all of the vectors in ascending "R" order; compute this expression for each pair of GFCs, and then chose the pair with the smallest value. This needs to be done for all of the GFC entering the left side of the Boxel, and separately for all of the GFC entering the right side of the Boxel, as illustrated below.

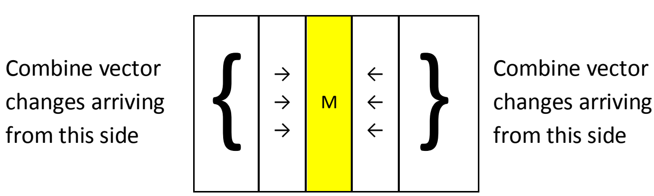

Figure 11 - Combine Vectors to reduce computational load

Gravity in Two Dimensions

Just as in one dimension, the change in the gravitational field change vector expands one boxel length per simulation cycle. In two dimensions the changes spread outward in all directions from the boxel with the change in mass as shown in the figure below.

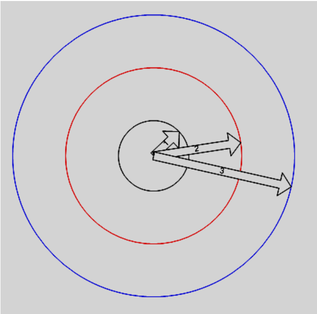

Figure 12 - GFC expanding outward over three simulation cycles

But how can we implement this in a boxel structure? Boxels represent square volumes of space (in 2 dimensions). Below are diagrams that show the spreading of a GFC over three simulation cycles in an array of Boxels. Yellow Boxels are "in range" of the gravitational force for the indicated Simulation Cycle.

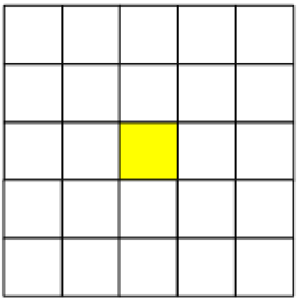

Figure 13 - Simulation Cycle #1 - Object with Mass Added

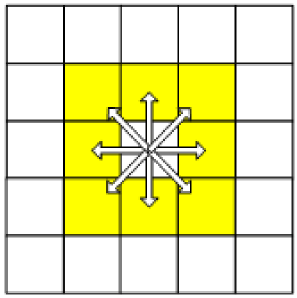

Figure 14 - Simulation Cycle #2 – GFC spreads out another unit

There are eight adjacent Boxels. The Boxel that was given mass last cycle looks in all directions to each of the eight adjacent Boxels to see if they are now within range of the gravitational force. All those now in range turn yellow, the original Boxel is no longer in range so it turns white.

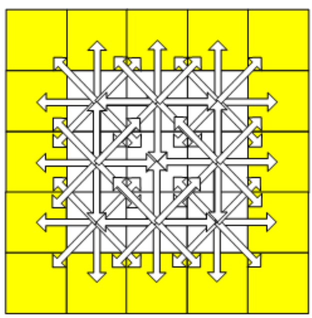

Figure 15 - Simulation Cycle #3 - GFC spreads out another unit

In the third simulation cycle (the third diagram) each of the eight Boxels who received gravity last cycle are now checking to see if any of the eight Boxels around them are now in the range of gravitational force.

The first time a Boxel turns yellow the force of gravity from the expanding GFC is calculated for the center of the Boxel. That value is added into the total gravitational force for this Boxel.

Gravity in Two Dimensions – Is the Boxel in Range?

Look at the figure below which shows Boxels labeled 0, 1, 2, 3, and 4. The red circle represents the distance gravity has traveled as of the second simulation cycle. You can readily see that Boxel labeled 0 is inside of the red circle, the Boxel labeled 4 is outside the red circle. Boxels labeled 1, 2 and 3 overlap the red circle and are in range for the second simulation cycle.

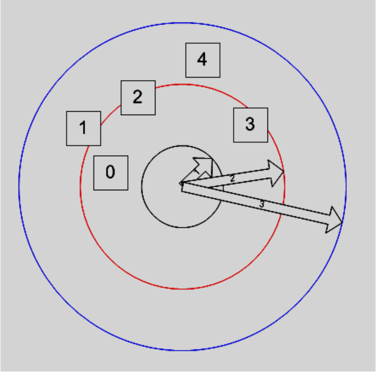

Figure 16 - Overlap of Boxels and GFCs

We have the coordinates of the four edges of each Boxel, and we have the simulation cycle. What computer algorithm (method) can we use to determine if a Boxel is in range?

One part of the calculation is determining distance. Calculating distance from the origin to a point (x, y) is given by the Pythagorean Theorem, or:

$$Distance = \sqrt{x^2 + y^2}$$

We calculate the distance from the origin to each of the four corners of the Boxels. Then we compare that with the distance that the force of gravity has travelled for this simulation interval. The table below summarizes the results of this calculation for each of the 5 Boxels shown in the figure above.

Table 1 - GFC Properties in each Boxel

Boxel #	# Corners inside of Red GFC	# Corners outside of Red GFC	Boxel overlaps range of Red GFC?
0	4	0	No
1	1	3	Yes
2	2	2	Yes
3	3	1	Yes
4	0	4	No

A careful review shows that a Boxel that is "in-range" if it has at least one corner inside of the Red GFC and one corner outside of the Red GFC. The figure below illustrates the distance calculation for a Boxel with one corner inside and three corners outside.

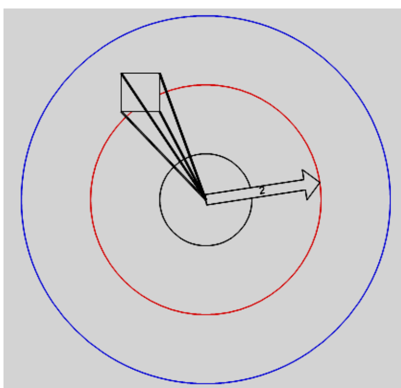

Figure 17 - Computing the distance to the Boxel Vertices

When a Boxel is determined to be in range of the GFC then the force of gravity attributed to that GFC needs to be added in. First, the distance from the center of the Boxel to the origin of the GFC is calculated.

$$Distance^2 = (Boxel_x - GFC_x)^2 + \left(Boxel_y - GFC_y\right)^2$$

Then, the distance (actually, Distance squared) is used in the Universal Law of Gravitation to determine the force of gravity on a mass of "1" at that distance, i.e.

$$Gravitational\ Magnitude = \frac{1 \text{ x } Mass}{Distance^2}$$

Now, this is where it gets tricky. The Gravitational Magnitude computed above is the strength of the force of Gravity along a line the runs from the center of the Boxel to the center of the origin of the Gravitational Force change. But the simulation keeps track of everything using vectors – pairs of X and Y components.

We need to resolve the force of gravity into X and Y directions. We do this by projecting the magnitude of the gravity along both of these directions. We know that the force of gravity will be in the same proportion as are the X and Y distances between the two points. First we calculate a proportionality constant, i.e.

$$Proportionality = \frac{Magnitude}{Distance}$$

With the proportionality constant we now calculate the force of gravity along the X and Y directions as follows:

$$Gravity_X = -Proportionality\left\{X_{Center\ of\ Boxel} - X_{Center\ of\ Mass}\right\}$$
$$Gravity_Y = -Proportionality\left\{XY_{Center\ of\ Boxel} - Y_{Center\ of\ Mass}\right\}$$

Then we add this gravitational force into the total accumulated gravitational force field of each Boxel, i.e.

$$NEW\ [Total\ Gravitational\ Force_x = OLD\ [Total\ Gravitational\ Force_x\ ] + Gravity_X$$

$$NEW\ [Total\ Gravitational\ Force_y\ ] = OLD\ [Total\ Gravitational\ Force_y\ ] + Gravity_y$$

Gravity in Three Dimensions

Going from gravity in two dimensions to gravity in three dimensions is much easier than going from one dimension to two dimensions. The table below summarizes the key elements.

Table 2 - Gravity in 1, 2 and 3 Dimensions

Aspect	One Dimension	Two Dimensions	Three Dimensions
Shape of the outward moving gravitational force	Two Points	Circle	Sphere
Number of adjacent Boxels to check to see if now in range?	$3^1 - 1 = 2$	$3^2 - 1 = 8$	$3^3 - 1 = 26$
In calculating $Distance^2$	x^2	$x^2 + y^2$	$x^2 + y^2 + z^2$
Number of vertices to check to determine if a Boxel is in range?	$2^1 = 2$	$2^2 = 4$	$2^3 = 4$

While in two dimensions we only needed X and Y, in three dimensions we need X, Y and Z. The distance formula in three dimensions is:

$$Distance^2 = (Boxel_x - GFC_x)^2 + \left(Boxel_y - GFC_y\right)^2 \\ + (Boxel_z - GFC_z)^2$$

The equivalent equations for projecting the force of gravity into X, Y and Z are:

$$Gravity_x = Proportionality \text{ x } (Boxel_x - GFC_x)$$
$$Gravity_y = Proportionality \text{ x } \left(Boxel_y - GFC_y\right)$$
$$Gravity_z = Proportionality \text{ x } (Boxel_z - GFC_z)$$

Dark Matter Or Too Many GFCs?

What to do when there are too many GFCs coming in to handle? After identifying the ones that are coming from the same, or nearly the same direction, combine them. If you use the use the distance of the closer one in the combined result you will be overstating the force of gravity, a little.

While in the Solar System the force of gravity from the Sun, the planets and moons dwarfs the effect of gravity from more distant locales, so this approach will have no discernable effect. But outside of the solar system, in the galactic environs, this simplification might well resemble the effect ordinarily attributed to dark matter. I am still researching this idea.