Gravitation Simulation Program

Installing the Program

The program will run with QB64 GL1.2 and higher. Use the URL to download the zip file and extract the folder “Gravitation Simulation” into your QB64 folder. (When extracting the folder, be careful that the extraction method doesn't create a further level of folder with the same name). You will need to move (or copy) the “falcon.h” file to the QB64 folder if you don't already have one there. From the IDE, load the program “GravitationSimulation.bas” and make sure that you have the Run Option “Save EXE in source folder” checked. Your screen size should be 1440 x 900 or greater.

https://www.dropbox.com/s/ga2bq4m0btixnru/Gravitation Simulation.zip?dl=1

Using the Program

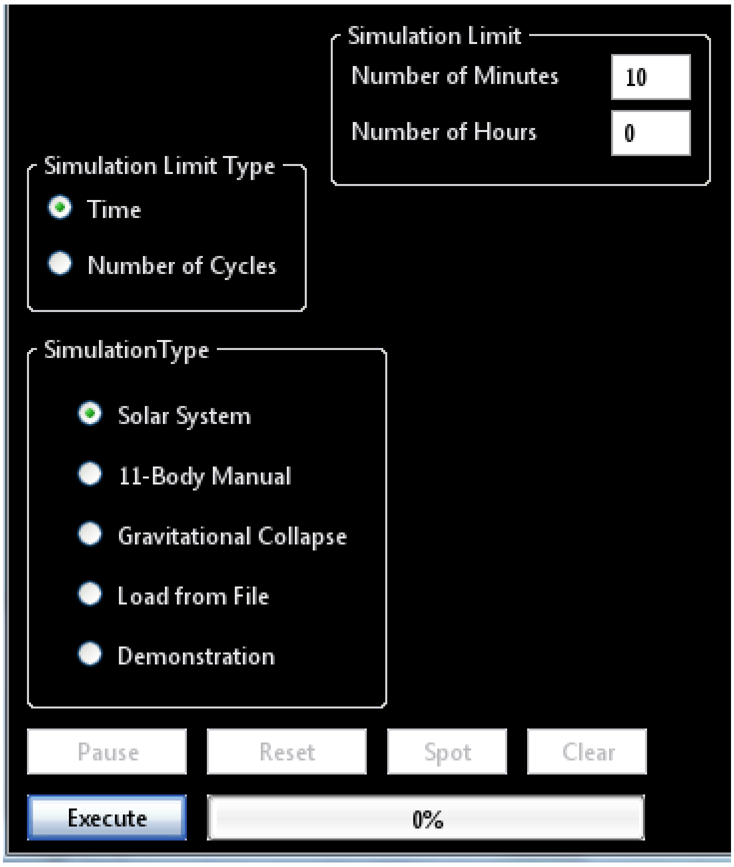
The program simulates the behaviour of bodies with mass moving under Newtonian mechanics with gravitational attraction between all bodies governed by Newton's inverse-square law. At the start of the program there are a number of options which you may try. When an option has been selected, the simulation can be started and then the program calculates the positions of all the bodies in time and displays the simulated positions on the screen.

All calculations are carried out in three dimensions, and so there has to be a translation of the 3-D data into 2-D for display. The QB64 statement _MAPTRIANGLE(3D) would have been most appropriate for this translation, but unfortunately this could not be used with this program. The program uses QB64 InForm which gives the program a semi-professional look (at least I suppose that it does!), and makes User Interfacing extremely easy. An original (non-InForm) version of the program has previously appeared on the QB64.net site.

Program Home Screen

The program starts at the User Input Interface (shown above). Selections can be made and simulation data changed as desired.

In the bottom left, most of the choices can be selected.



In the "Simulation Type" frame, you can choose between 4 simulation scenarios and a demo. The Solar System models the Sun, the eight planets and a number of other bodies. The "11-body Manual" setting allows you to input your own data. The "Gravitational Collapse" setting allows you to simulate a larger number of bodies collapsing by gravitation (will a 'Solar System' form?). The "Load from File" setting allows you to use data from a previous run. The "Demonstration" setting gives an animated demo of what the program can do.

The selected method can be then simulated by clicking on the 'Execute' button.

Simulation Limit Type

You can set how long the computer will run the simulation for. You can set either a fixed time (the default and most obvious setting) or you can set a given number of simulation cycles.

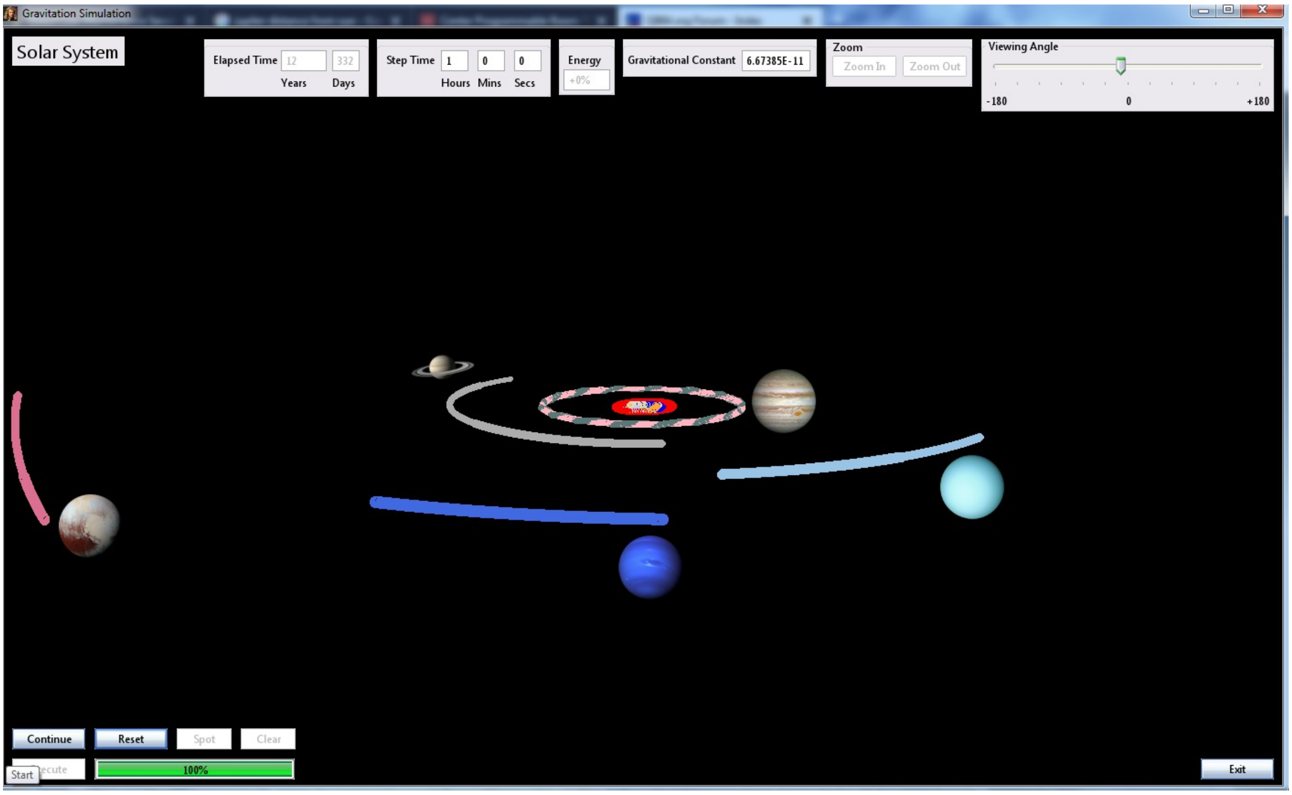
Simulation Limit

Here you set how long (or the number of cycles, if selected) the simulation runs for. When the simulation is running, the progress is given in the bar to the right of the 'Execute' button.

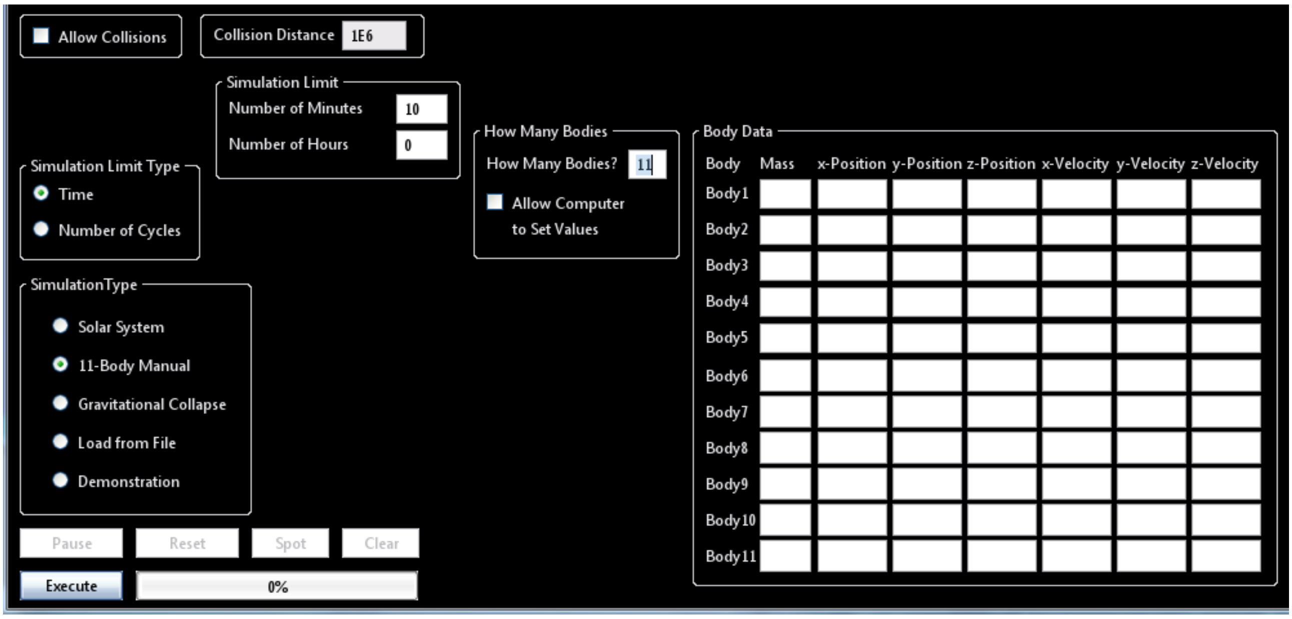
<u>The Solar System Simulation</u>

Here, the workings of the Solar System are (very accurately) modelled. The Sun, the eight planets, The Moon, Pluto (yes, it got downgraded!) and Jupiter's moon Elara are simulated. Starting data were taken from JPL Ephemeris data 7th June 2013. If the default program parameters are used, the graphical output is as shown in the image. In the image given here, the outer planet images have been added as identifiers. The scale of the graphical output has been set so that the path of Pluto can be seen. If the program is allowed to run, it will show that the orbits of all the planets are accurately given.

The times taken to circle the sun (each planet's 'year') are very close to those observed, and the eccentricities and tilt to the ecliptic are as expected, within reason. Of course, the program uses only Newtonian gravitation, and considers no other forces. As well as giving good results for the planets orbiting the sun, the Earth's moon has the correct periodicity in the Earth-Moon circulation (although the two bodies are so close that they cannot be separated in the graphical output), and Jupiter's moon Elara circles her mother planet with the correct period.



<u>11-Body Manual Mode</u>



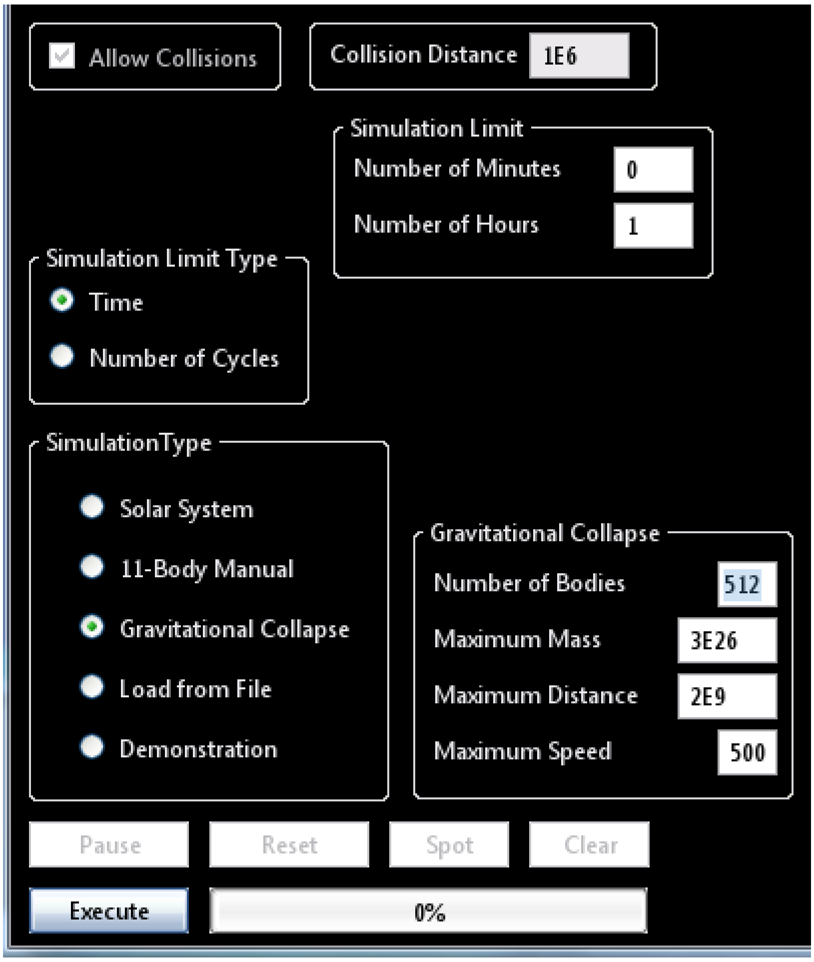
With this mode selected, the User can input the starting data of up to 11 bodies and then run the simulation. For each body, its mass, the x-, y- and z- starting positions and the x-, y- and z- starting velocities are input via the table. In the 3D space, x- is from Left to Right, y- is from Bottom to Top, and z- is from Into to Out Of the screen. Distances are in km, whereas speeds are in m/s. The number of bodies can be set from 2 to 11.

Please note that all inputs into textboxes must be followed by 'Return', as the CR is the prompt which tells the computer how to manipulate the data.

Inputting data manually has to be done with care and skill. If no consideration is given, it is likely that either the bodies are accelerated quickly off the screen or they collapse very quickly, and in both such cases it might appear that nothing happened. For the novice user, checking the “Allow Computer to Set Values"” checkbox may be advisable.

There is also the possibility to allow collisions. If this checkbox is checked, the simulation will allow two bodies to coalesce if they approach closer than a given distance. This Collision Distance (in km) is also settable. If you run the simulation with both “Allow Computer to Set Values"” and “Allow Collisions” checked, some somewhat amusing outputs are obtained.

Gravitational Collapse Mode



In this mode, you can simulate up to 512 bodies which are set in a spherical array, and then see how the resulting gravitational collapse proceeds. With the maximum of 512 bodies, the computational process is very slow – about 100 simulation cycles per minute. This is because the number of calculations per cycle is in the many thousands. Collisions occur in this mode, and the maximum body mass, distance (km) and speed (m/s) are settable. In the past, I have found that proto-solar-systems can form, but again some skill is required in setting and running this type of simulation. Of course, the limit of just 512 bodies means that this gives nothing like a real gravitational collapse situation. A further problem is that this simulation will proceed very slowly before anything interesting happens. If you wish to run this type of simulation, you may need to set it running in the background for a number of hours.

Load From File Mode

When a run has been completed, a file is saved of the body data. Subsequently, in this mode you can run another simulation using this as the starting point.

Demonstration Mode

In this mode, you cannot input any data but the computer runs a simple demonstration which shows what things can be done and what happens.

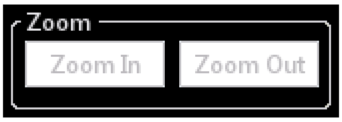
Simulation Parameters Which Can Be Adjusted

As well as the mode and body data, other parameters can be adjusted.

Simulation Step Time

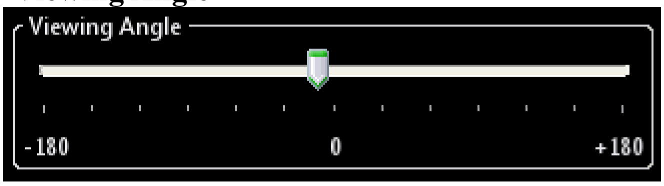
You can set the Step Time used in each calculation. This is the 'deltaT' used at each step of the simulation. This should be set at a value which gives a reasonable computation speed, but which does not adversely affect computational accuracy. For example, in the Solar System simulation, a Step Time of 1hr is used as default. The Moon and Earth circulate at 28 days, and so a step time of 1hr will be quite accurate.

Zoom



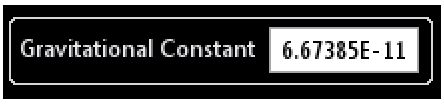
When a simulation is running, you can zoom in or zoom out, depending upon which is the most interesting view.

Viewing Angle



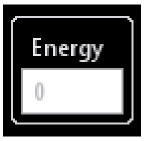
The viewing angle can be adjusted through 360^{o} to get the best visualisation. This is only useful if there is some axis of rotation, for example with the Solar System.

Gravitational Constant



If desired, you may change the gravitational constant. However, it is a constant! Interestingly, the Wiki value for this constant changed from when I created the previous program in 2013 to now – from 6.67385E-11 to 6.67408E-11, so even at this advanced stage they can't get it accurate to 4 decimal places. The units are $m^3kg^{-1}s^{-2}$ (SI).

Energy / Number of Bodies

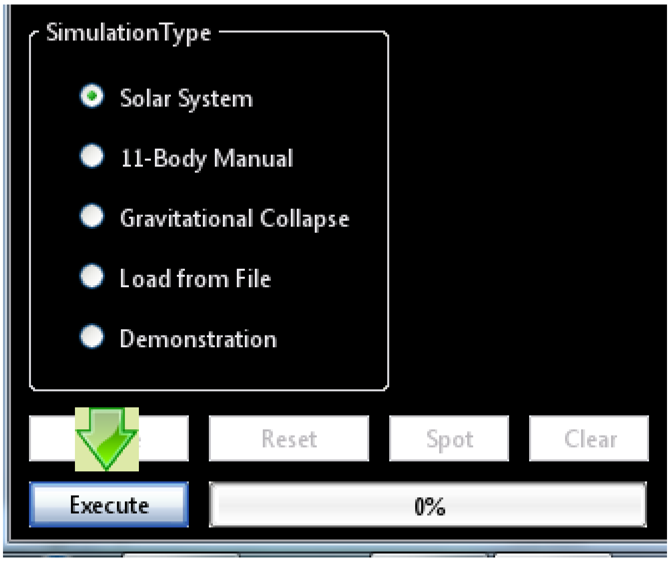


This display indicates the change in total energy (kinetic plus gravitational potential) compared to that at the beginning of the run. You will find for the Solar System that this stays at zero, which is a confirmation that the quantised computation code is a good description of the real system. In situations where collisions are allowed, you will find that this will deviate from zero. Clicking on the word "Energy" will change this display to the number of bodies, which again will change when collisions are allowed. The display is updated every 3s.

The Simulation Step Time, Viewing Angle, Gravitational Constant and Energy Display can be changed before and during execution. The Zoom can only be changed during execution.

Simulation Controls and Displays

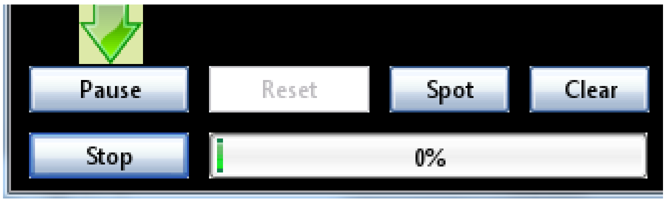
Execute Button



When you have selected the Simulation Type and set any further parameters, Click on Execute to start the simulation.

While the simulation is running, this button changes to 'Stop', and clicking on this will terminate the simulation and save a file. Esc will have the same effect as clicking Stop.

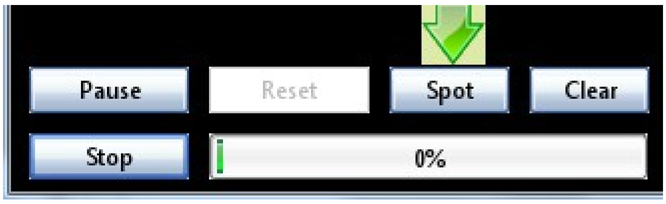
Pause Button



A running simulation can be suspended by clicking on 'Pause'. Clicking again will resume the simulation.

When a simulation has been completed, this button displays 'Continue', and clicking this will carry on from where the simulation stopped with the same conditions and for the same time.

Spot/Trace Button



Clicking on this button will change the display between leaving a trace and not.

When the display leaves a Trace, the 'Clear' button can be clicked at any time to remove the trace.

Reset Button

When a simulation has been completed or has been stopped, clicking on the 'Reset' button will take the program back to the Home screen, where you can choose to do another simulation.

Exit Button

Clicking on this button at any time will quit the program. If you exit while a simulation is running, that simulation will not be saved. Pressing Esc when a simulation is not running will also exit.

Elapsed Time Display

While a simulation is running, the elapsed time of the simulation is shown in this display. For example, if the Solar System mode is used you will see that this elapsed time agrees with each planet's year when they have completed one revolution. This display is updated every 3s.

<u>The InForm Program</u>

QB64 InForm is a remarkable achievement. In this program, when the simulation is running a very great deal of computer power is required. Yet the User is able to change some parameters whilst this is running, and the screen is continuously updated with the graphical output. This is achieved in InForm by essentially allowing two simultaneous computing loops (a 'sort-of multithreading'). The computational part of the program runs without any _LIMIT statement, whereas the InForm part runs at a set frame rate (30 per second is used). At every 30 InForm cycles (once per second), a copy of the computational data is taken and used to update the display. Further, at every 90 steps of the InForm cycle (3s), the Elapsed Time and Energy, as well as some other functions, are updated. This infrequent sampling is used so as to minimise CPU effort. The computational part of the program uses about one core's-worth of CPU, whilst the InForm loop uses an additional half of one core's-worth. Nevertheless, it has been found that the computational speed is slowed down compared to the previous non-Inform version. In the Solar System mode, the non-InForm program achieved 284866 loop cycles per minute whereas this was 208333 per minute with InForm, and in the 512-body Gravitational Collapse mode, non-InForm was 157 per minute, InForm 100 per minute. The reduction in processing rate is acceptable for the additional benefits which InForm delivers.