ThreeBody Help

February 5, 2012

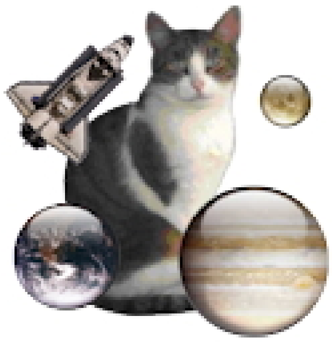

Figure 1: **ThreeBody** Version 3.01

Contents

1 What is the use of ThreeBody ?

This program illustrates the 3 bodies problem. This is a classic problem in celestial mechanics: determine the trajectories of 3 planets linked only by universal gravitation. Although his statement is simple, it's interesting to note that there is no explicit solution like in the problem of two bodies, where we known, since Newton, that the trajectories are conic (ellipse, parabola or hyperbola).

In the case of three-body problem nothing can be said in general as regards the asymptotic behavior of the system for arbitrary initial conditions. The computers do not answer to this problem since it cannot work for an infinite time (or at least for periods representing the approximate longevity of the solar system, billions of years) , and computers have a limited accuracy, leading to an accumulation of errors that makes their long-term calculations very uncertain.

1.1 What is new in version 3.

1.1.1 New initial conditions.

This new version of **ThreeBody** enhances remarkable cases of 3-body problem.

To the 2 cases available in previous versions:

- **The case of "Lagrange"** where the trajectories are periodic, discovered in 18th century by **Joseph Louis, comte de Lagrange** (Giuseppe Lodovico Lagrangia Italian, born January 25, 1736 in Turin - died April 10, 1813 in Paris).

- **The 8 periodic orbit case.** This remarkable periodic orbit was discovered by **Moore** in 1993 and rediscovered by **Chenciner et Montgomery** in 2001.

  Montgomery 2001 states "numerical experiments done by **Heggie** suggest that the probability of an eight is somewhere between one per galaxy and one per universe." Heggie 2000 describes a series of scattering experiments and states if the coordinates of the initial central particle are changed by as much as about 0.13 (in standard units), the 8-like behavior does not persist after about T = 100.

We added 2 new interesting cases:

- **Pythagorean Problem.** These initial conditions for the Pythagorean Problem are given on www.sverre.com and discussed in **Aarseth's** book. The masses are in the ratio 3:4:5, on the apexes of a right triangle. In 1893 the mathematician **Meissel** conjectured these initial conditions would produce a periodic orbit. **Burrau** in 1913 and **Szebehely** and **Peters** in 1967 investigated this intriguing configuration numerically.

- **Criss-Cross Orbit**. This periodic orbit is described in a 2005 paper by **Moore and Nauenberg**. It was first obtained by **Henon** in 1976, rediscovered by **Moore** in 1993, and more recently rigorously proved to be a member of a family of retrograde orbits. The authors state similar orbits exist for different mass ratios - *can you find one?*

1.1.2 A new presentation.

The program works in 2 different modes:

- **Mode Introduction**. At the start **ThreeBody** in this mode which is a simple kinetic animation with three planets and a spaceship on a sky background. The movement of three planets is not a calculated (with Newton Law) move. Simply the biggest planet describe an ellipse, the middle size planet describe a circle around the big one and the smallest planet describe also a circle, but around the middle sized planet.

- **Calculation mode**.To enter this mode you must choose the initial conditions, then start the calculation. The calculation is done using a **Runge et Kutta** method of 4th order with variable step size. Although this numerical method is accurate, as it may be noticed in some case, that after a while, it accumulates errors.

A more playful look. Finally we gave a more entertaining look using the entire screen. It can thus serve as animated wallpaper.

1.1.3 Added recent files menu.

2 Installing ThreeBody (on Windows).

ThreeBody is distributed as a compressed installer: **SetUpThreeBody.zip**. After decompression, the execution of **SetUpThreeBody.exe** installs the executable program **ThreeBody.exe**. The folder **ThreeBody_3.0.0** is also installed in the folder **Documents.**

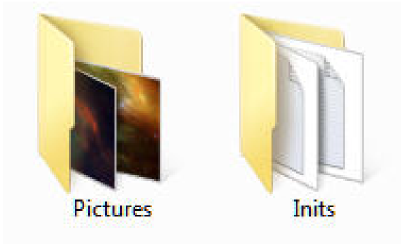

Figure 2: Contents of folder **ThreeBody_3.0.0**: This folder contains the application **ThreeBody** and 2 folders. The folder **Pictures** contains images of sky, the folder **Inits** is supposed to keep the conditions of the calculation files.

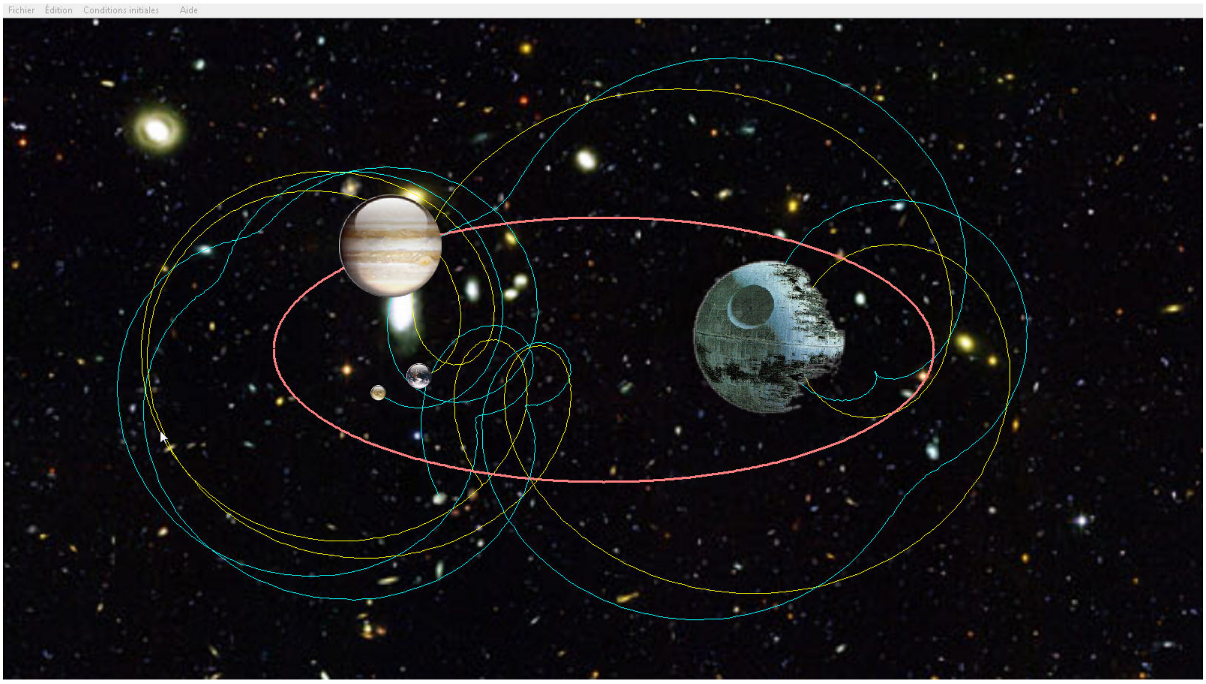

Figure 3: **ThreeBody** in Mode Introduction.

3 Use of ThreeBody .

3.1 Mode Introduction.

At startup, ThreeBody is in **Mode Introduction** (see figure [3]) which is a simple kinetic animation with three planets and a spaceship on a sky background. The movement of three planets is not a calculated (with Newton Law) move. Simply the biggest planet describe an ellipse, the middle size planet describe a circle around the big one and the smallest planet describe also a circle, but around the middle sized planet.

3.1.1 Changing the sky, the spacecraft and the trajectories appearance.

You can change lhe sky, the spacecraft and the trajectories appearance by using dialog **Preferences**. You can access this dialog by the menu **Help→Preferences** (see figure [4]).

- **Sky choice**. By clicking the button **(...)** you can choose a sky picture in the folder **Pictures**.
- **Spacecraft choic**. By clicking the corresponding radio button.
- **For each planet** you can be displayed or not its **trajectory**, choose the **color** by clicking on the picture and the '**thickness** with the **Up/Down** button.
- **For the 2 small planets**, you can set the number of rotations they perform during the course of the ellipse by the primary planet.
- **Start delay**. This is the time after which the simulation begins after the start of the **Calculation mode**. This can be useful if you wish to make a screenshot.

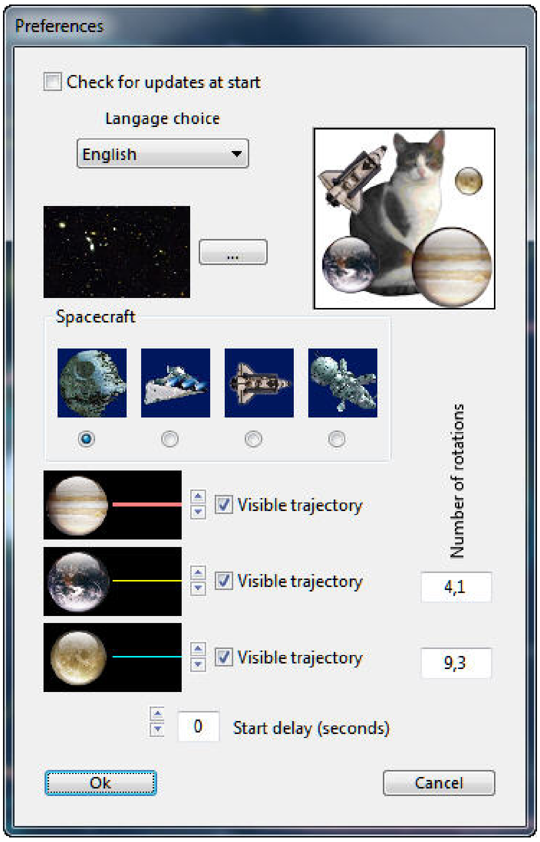

Figure 4: **Preferences dialog**. With this dialog you can also chose for **checking updates at each start** of the program (the menu **Help→Check for update** will do it manually) and allows to **choose the langage** of the interface (*English, German or French*).

3.2 Calculation mode

3.2.1 Initial conditions choice

To set the initial conditions you use the menu **Initiales Conditions**. You have choice between 6 types of conditions:

- **Lagrange**. *Planets of equal masses placed on an equilateral triangle.*
- **The 8 orbits**. *Planets of equal masses.*
- **Criss-cross orbits**. *Planets of equal masses.*
- **The Pythagorean problem**. *The planets are placed on top of a triangle and their mass are 3, 4, 5.*
- **Sun-Earth-Jupiter orbits**. *To illustrate the significant mass of Jupiter.*
- **From a file**. *From initial conditions saved.*

3.2.2 Choice of calculation conditions

When the initial conditions are chosen, dialog **Conditions of calculation** appears (see figure [5]).

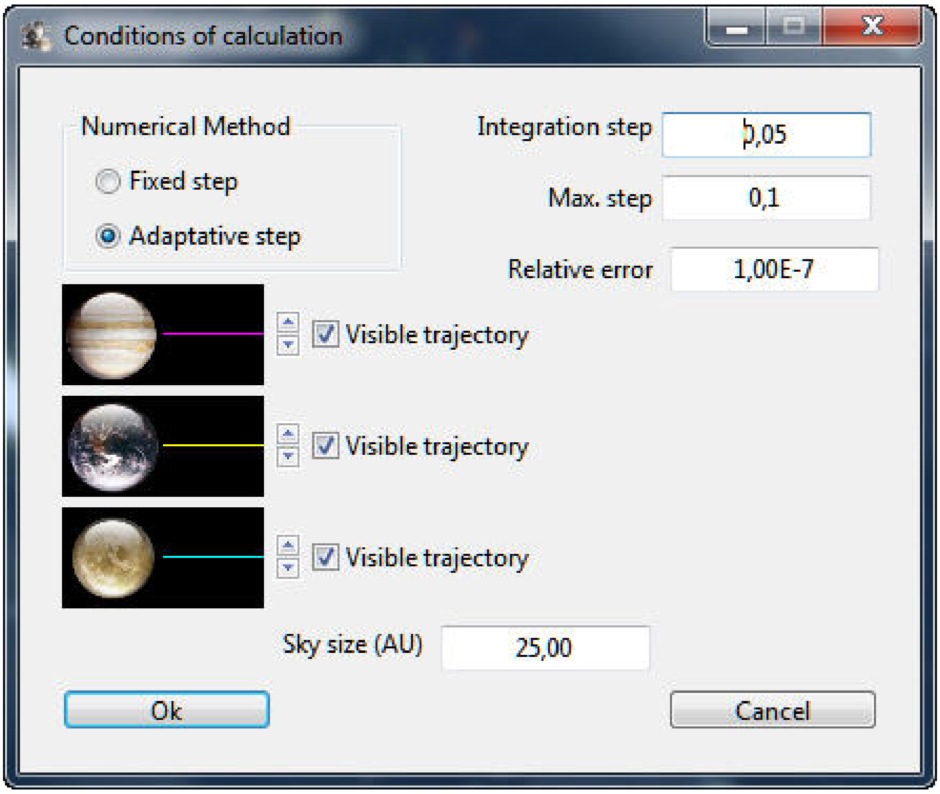

Figure 5: **Dialog Conditions of calculation**. **The unit of time** is the year (≈ 365,25 days), **the unit of length** is the astronomic unit (1 AU ≈ 150 million km). We can choose between the **Runge and Kutta method** with *fixed or adaptative step, the initial time step, the maximal time step and the maximum allowable relative error* which determine the vatiable step. The *"Sky size"* scale the sky to your screen. You may also *specify the trajectories appearance*, like in the dialog **Preferences** (see figure [4]).

Note that the menu **Initial Conditions→Conditions of calculation** apparaît. It provides again access to dialog **Conditions of calculation**.

3.2.3 Parameter changes

But the **dialog Conditions of calculation** does not change the parameters that are set in standard cases (*mass, position, speed*). When the *dialog Conditions of calculation closes*, the planets appear on the screen in their original positions. We can then modify their positions, masses and velocities by clicking one of them: the dialog **Parameter changes** then appears (see figure [6]).

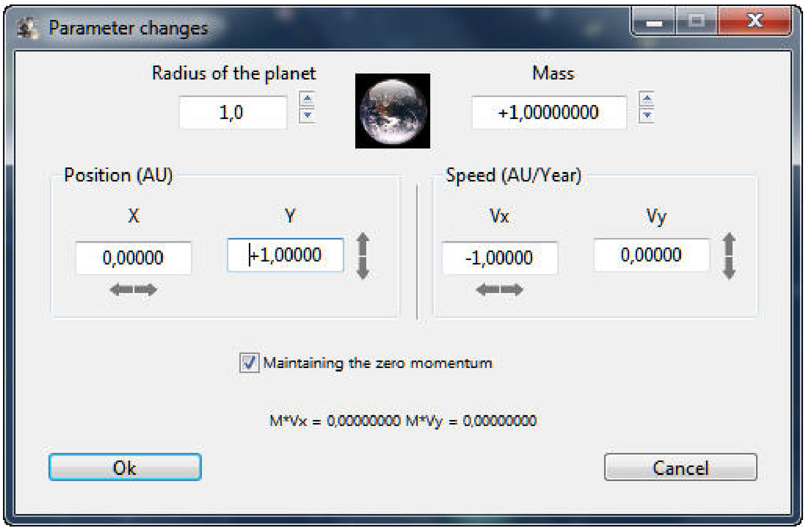

Figure 6: **Dialog Parameter changes**. You can modify the **mass**, la **position** and **velocity** of the chosen planet. If the box **Maintain zero momentum** is checked, this property is maintained. It can also change the radius of the planet is a purely aesthetic parameter has no influence on the calculation. You can also change the radius of the planet, but it's a purely aesthetic parameter with no influence on the calculation.

3.3 Start, stop the calculation and return to menu Introduction.

These operations are initiated by the menu **Action**:

- **Action→Start**. Starts or restarts it (after stopping) calculation. Time window appears (see figure [7]).
- **Action→Stop**. Stops the computation.
- **Action→Introduction**. Back to Introduction mode.

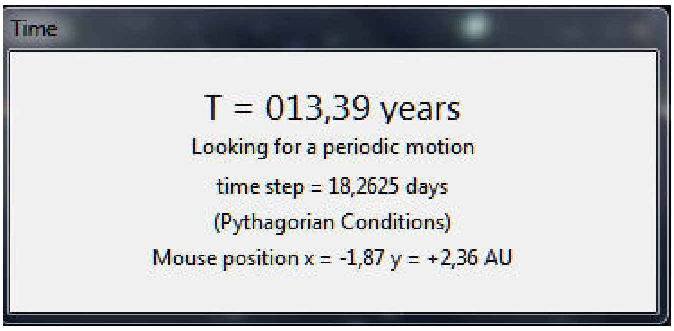

Figure 7: **Time window**. This window shows the ellapsed time in years, the instantaneous time step of calculation, recalls the initial conditions chosen. It also gives the position of the mouse in the "Sky".

3.4 Saving conditions of the calculation and picture.

3.4.1 Saving conditions of the calculation.

Menu **File→Save conditions of calculation...**. When the calculation conditions or parameters have changed, it is possible to save the calculation conditions. It is recommended to save this file in the folder **Inits** (see figure [2]).

3.4.2 Saving the image.

Menu **File→Saving picture**.

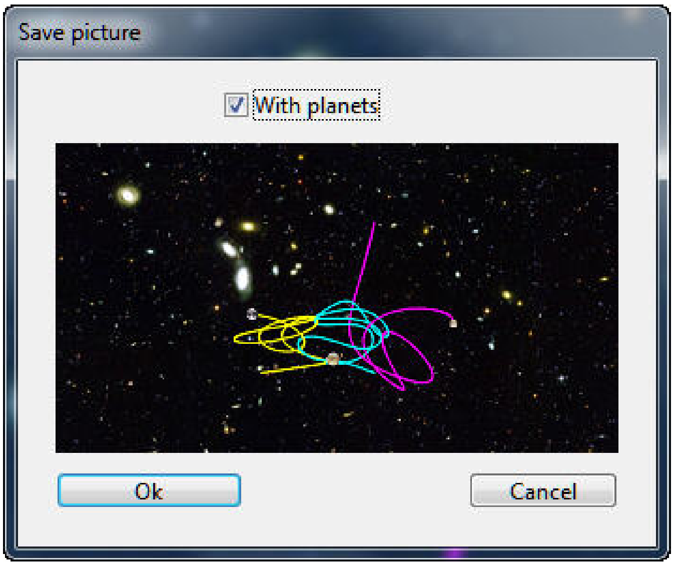

Figure 8: **Save picture**. You can save the image of the trajectories as .jpg files. You can add the image of the planets by checking the box **With the planets**.