The Lagrange points - more than simply solutions to a differential equation

Trojan simulation program

While undertaking research for this WiS! article I came across the following Trojan simulation program. It originally comes from Helmut Jahns from the VdS section Computer Astronomy, who spontaneously stated his willingness to present his program here and in the context of this article. Mr. Jahns also kindly stated his willingness to answer any questions about his program that teachers or students may have. Thank you on behalf of the WiS! team! (N. Fischer)

Calculating the positions of planets, asteroids and comets is a classical exercise in astronomy. The orbital elements, which can be found in the respective catalogues and databases for each object, provide the basis of these calculations. In principle these orbital elements enable positions to be calculated at any point in time. In practice this can only take place with limitations: Disturbances due to the gravitational force of other planets add up over time such that the positions are only accurate enough for a limited period of time.

One resource to use is numerical integration. This is used to calculate the positions of celestial bodies fully taking into account all types of gravity-related parasitic drag. The Integrator Pro program was created because almost all of the astronomy software that is available both commercially and as freeware does not offer numerical integration.

Integrator Pro performs two tasks:

1. Calculates the positions of the celestial bodies in our planetary system in order to set these objects in a telescope with the aid of a celestial chart or GoTo control.

2. Explores the dynamics of celestial bodies in our planetary system.

As a result of other planets interfering in the orbits, the orbital elements are not constant and are subject to changes over time. This variation can be calculated for any object using Integrator Pro and can be visualised from various angles. It can be used to investigate special celestial mechanic phenomena (e.g. catching a comet, movement of Trojans or resonances between asteroids).

Integrator Pro can be downloaded free of charge from the webpage of the VdS section Computer Astronomy.

Find out more on www.esa.int/education
About the program itself:

You do not need to enter the parameters of the Trojans manually. Integrator Pro comes with an asteroid file called ASTORB.DAT that already contains all of the required path data. When the program is launched only the planets including the Moon and Pluto are loaded. Asteroids must be loaded separately:

1. In the menu go to "Anwendung→Laden→Asteroid laden" [Application→Load→Load asteroid]. A small dialogue box appears.
2. Enter the name of the Trojan asteroid in this field, e.g. Hektor, and confirm using the "Laden" [Load] button. The message "Hektor geladen" [Hektor loaded] appears in the status bar below in the main window.

Repeat the two steps for every Trojan asteroid that you would like to investigate (e.g. with Patroclus, Agamemnon and Troilus). It is quite practical (but not necessary), to work with several objects at the same time.

We recommend increasing the calculation speed by removing the inner planets from the simulation. This does not distort the result for Trojans.

3. In the menu go to "Vorbereiten→Storplaneten wahlen" [Prepare→Select interfering planets] and check that only Jupiter, Saturn, Uranus and Neptune are selected. Click on "OK" to confirm.

After you have included the desired asteroids, you can configure the long-term integration.

In our example we would like to illustrate the movement of the Trojans around the Lagrange points, i.e. we will use two space coordinates for the x and the y axis of the screen: rx and ry. The movement of the Trojans can however only be tracked in a meaningful way if you are located in a coordinate system that is co-rotating with Jupiter, i.e. the connecting line between the Sun and Jupiter is assumed to be stationary.

The graphic parameters that ensure that this is configured exactly are as follows:

4. In the menu go to "Vorbereiten→Phasenraum konfigurieren" [Prepare→Configure phase space]. A dialogue box will open. You can define the parameters for the graphic here.
5. Select the parameter "rx" for the x axis (scroll down if required).
6. Select the parameter "ry" for the y axis.
7. As the “Objekt” [object] select all of the asteroids that you want to investigate (select more than one by holding down the Ctrl key)
8. An index element is located at the bottom right. Please select the "Korotation" [Co-rotation] index, insert the tick next to "korotierendes Bezugssystem" [co-rotating reference system] and under this select Jupiter.

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9. In the “Kenndaten” [characteristics] area at lower left please enter e.g. 200 years as the time period and 10 days for the “Schrittweite” [step size] h.

10. Click on "Hinzufügen" [Add] and click "OK" to confirm.

After all of the objects have been loaded and the graphic has been configured, you can start the calculations:

11. In the menu under "Rechnen→Langzeitintegration starten" [Calculate→Start long-term integration].

Depending on the outcome of the calculation a window appears with graphics showing the paths of the Trojans around their Lagrange points.

Please note that the kidney-shaped paths that are generally depicted in textbooks are only made by very few of the Trojans. In the majority of cases they are interlooping paths which only have a kidney shape as an envelope.

Please further note that only the paths around L4 and L5 are stable. Ongoing position corrections are required for space travel projects in L2, but I guess this has no doubt been known for some time.

While writing this I have been reminded of the fact that at first glance the program is not so easy to use. I have often wondered if it can be simplified.

For this reason, please use the four examples in the Help function that are intended to facilitate initial use of the programme.

Helmut Jahns