Dynamics Solver – a (very) brief tutorial

Content

1. Introduction

Dynamics Solver (hereinafter *DS*) is a *free software*, which can be downloaded from the author's webpage [1].

DS is intended to solve *initial and boundary-value problems for continuous and discrete dynamical systems*:

- single ordinary differential equations of arbitrary order,
- systems of any number of first-order ordinary differential equations,
- a rather large class of functional-differential equations and systems,
- iterated maps and recurrences in arbitrary dimensions,
- any problem that can be written in one of the aforementioned forms.

No programming is necessary: everything can be entered in user-friendly dialog boxes and complex graphics (and numerical) results can be easily and quickly obtained. The program has a powerful built-in compiler that automatically translates a large class of mathematical expressions written in a standard format into an internal code that can be executed very fast.
DS is a powerful tool to study differential equations, (continuous and discrete) nonlinear dynamical systems, deterministic chaos, mechanics, etc. For instance, you can draw phase space portraits (including an optional direction field), Poincaré maps, Ljapunov exponents, histograms, bifurcation diagrams, attraction basins, etc. The results can be watched (in perspective or not) from any direction and particular subspaces can be analyzed. Very different kinds of results may be obtained in different graphics and text formats displayed in one or more windows. It is also possible to generate animated output. There are many programs to draw geometrical figures, but most of them are not appropriate to draw the figures that physicists often need when preparing lectures or research papers. DS can be used to draw segments, arcs of circles and ellipses, arrows, arbitrary parametric curves in two and three dimensions, a large class of fractals, and points and lines from external data files.

The following sections show briefly the most basic using of DS. A detailed manual can be found in the ***dsdoc.pdf*** file in Tools map of our electronic material. The user is referred to the rest of the manual and help file to find both a complete description of each feature and a systematic discussion of the way in which a problem can be set up and input into DS. You may want to read any section from the program help system: you will be able to load the examples by clicking with the mouse in their name.

2. Installing and start Dynamics Solver

Unfortunately there is no DS version for Linux platform.
For Windows platforms you can download the appropriate (32 bits, or 64 bits) version of DS on the Getting Dynamics Solver page of [1].
After download on your PC execute the *dslvr???.exe* program and the installing will be performed in few very simple steps.

To *start* DS you can choose from the following possibilities:

- select it from the Start/Programs/Dynamics Solver menu,
- double click on the Desktop icon  of DS,
- run any *.ds "problem file" (for example in our electronic material).

If there is another instance of DS running when the program is started directly with no problem file appended after its file specification, or when the same problem file is being analyzed by another copy of the program, the following dialog will open:

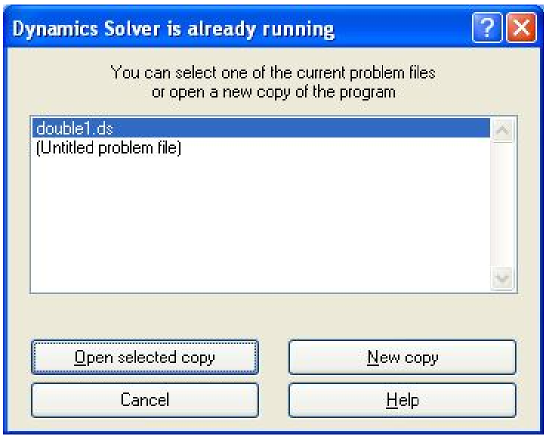

Figure 1.

You can select there one of the problem files which are already open or start a new copy of the program. It is also possible to cancel the operation. To start always a new copy of the program you may disable the **Check previous instances entry** of the **Preferences/Other** dialog box which opens when using the **Configuration/Preferences** menu.

To exit Dynamics Solver, use the following procedure:
1. If the program is solving a problem, stop the solution by pressing **Esc** (or use the **Go/Stop**! menu or the corresponding  toolbar button).
2. Press **Alt+F4** (or use the **File/Quit** menu). If the current problem file has been changed you will get a warning and the opportunity to save the changes (see also Saving and Loading a Problem).

WARNING! If during the running of a problem file *.ds one makes any changes in it then at logging out the following dialog box is appearing:

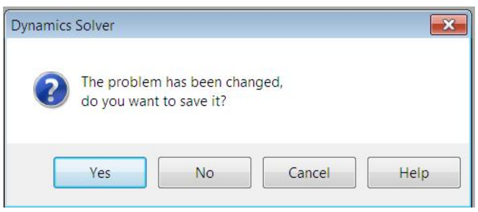

Figure 2.

If button **Yes** is chosen then the problem file is overwritten with its new version. (Generally it is not advisable). Therefore it is worth clicking button **No**. Then the original file will be saved. However, if you want to save both the original version and the new one too then click the button **Cancel** and use the **File/Save as...** function for saving the new version of the problem file with a new name.

3. Identification our dynamical system (input)

In DS each problem can be saved to and retrieved from a disk file with extension *.ds. This "problem file" can also be edited and used as a template for related problems. One can extend the program by providing more integration methods or additional mathematical functions. Problem files *.ds are simple ASCII text files which contain all the information about the dynamic model and they can be edited with any of TextEditors. (It is very instructive to look into a problem file to see what kind of information is stored in it.).

For the identification of a dynamic system the following are necessary

- Type of the mathematical model (**Edit/Type...**),
- Declaration of the independent variables (generally the time or the number of steps) and the dependent variables of the model.(**Edit/Variables...**),
- Controlling function of the dynamics (in case of continuous systems the functions which give the time derivative of the dependent variables.) (**Edit/Equations...**),
- The parameters of the controlling functions (**Edit/Parameters...**),
- The initial or the boundary conditions (**Edit/Initial conditions...**, or **Edit/Boundary conditions...**),
- The range of the independent variable (**Edit/Range...**).

In the present e-learning material the models in the problem files has already been declared, so if you use them it is worth changing only the parameters (**Edit/Parameters...,** or with  toolbar button), the initial conditions (**Edit/Initial conditions...,** or with  toolbar button) and maybe the range of the independent variable (**Edit/Range...**) or the graphic visualization.

4. Graphics and text output of simulation

The best Dynamics Solver feature is the ability to show the results of integration in graphics format. To take advantage of this possibility, one or more graphics windows must be created. Press **Shift+Ctrl+G** (or use the **Output/New graph window** menu entry) to create a new graphics window. The Expressions sheet of the Graphics Output dialog box will open:

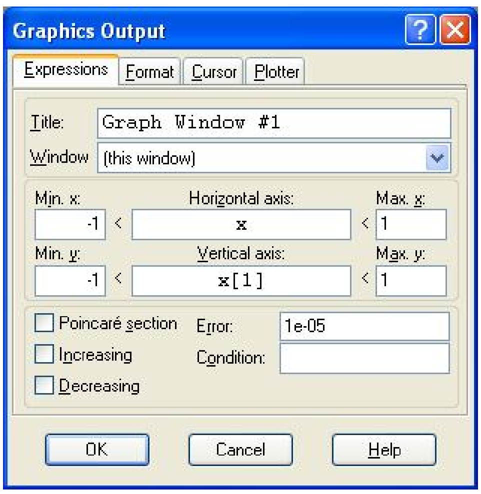

Figure 3.

In the present e-learning material the graphic displays of the models in the problem files has already been declared so only the boundaries of the displayed areas can be varied (the **Min** and **Max** values in the **Expression** sheet of figure 3.) and in the case of stroboscopic patterns the frequency of plotting can be changed (clicking the **Format** tab the **Frequency** can be changed)

A more exact picture of the chaotic attractor can be obtained by applying a *stroboscopic mapping*. An essential feature of the Dynamics Solver, that the repetition time of the graphic displaying (Δt_{plot}) can be prescribed during the simulation. In the menu **Edit/Range** the range of the independent variable (generally the time t) (*First value* and *Last value*) and the step (*Step*) can be prescribed. *Frequency* which determines the repetition time ($\Delta t_{plot} = Frequency \cdot Step$) can be prescribed in **Format** sheet of the **Graphics Output** dialog window of the **Output/New graph** menu. Using stroboscopic mapping, the graphic plotting occurs always at the same phase $\Theta = \frac{2\pi}{T_p} t$ of the driving force. If a repetition time Δt_{plot} is prescribed than the plotting takes place per phase $\Delta\Theta = \frac{2\pi}{T_p} \Delta t_{plot}$. If every plotting must have the same phase than $\frac{\Delta t_{plot}}{T_p} = \frac{Frequency \cdot Step}{T_p}$ should be integer, suggested value is 1 (plot in every same phase).
Practically this means that if the parameter T_p (chosen in **Edit/Parameters** window) and the value of *Step* (chosen in **Edit/Range** window) are given than parameter *Frequency* have to fulfil the condition $\frac{Frequency \cdot Step}{T_p} = \text{integer}$.

This paragraph shows a very important and useful property of the Dynamics Solver, namely that *cycle parameters* can be used in it. In window **Edit/Parameters** can define two cycle parameters in the two fields of the *Repeated solutions and phase portraits* (as defaults *nx* and *ny*). These cycle parameters can be used for changing of the parameters of a model in an arbitrary interval by for-next type cycles. For example in a *bifurcation diagram* has been drawn with varying x_0 control parameter. In the **Edit/Equations** window x_0 was substituted everywhere with the term *(xa+(xf-xa)/N*nx)* in the controlling function *dw/dt.* In the term *(xa+(xf-xa)/N*nx)* the cycle parameter *nx* runs over the integers 0…N, so the term (essentially the control parameter x_0) covers the interval [*xa;xf*] where limits of the interval (*xa* and *xf*) can be chosen freely.

The mouse cursor in the graphic windows is transformed into a mouse pointer the instantaneous position of which is displayed at left side of the bottom status line. An important possibility of the program that with a double clicking on the cross hair cursor the initial position of the motion can be fixed. (The flashing cursor ⊕ denotes the initial position at the graphic area.) If there is more than one graphic window on the screen then the cursor can be activated by clicking to the window chosen. Then we can work in this window (e.g. its content can be deleted with the toolbar button , the colour of the graphics and the line thickness can be fixed with toolbar button ) Warning! Clicking button  the content of all the windows are deleted.)

The ranges displayed in a graphics window can be selected in the **Graphics Output** dialog box and you can also zoom in a window piece in the following different way.

If you want to select a rectangular piece of a window and amplify it to fill the window:
1. Locate the mouse at one of the new rectangle corners,
2. While holding down the **Shift** key and the left mouse button, move the pointer to the other corner on the same rectangle diagonal. The pointer location will be displayed, as usual, on the right panel of the status (bottom) line, Furthermore, the two corners of the new window will be displayed in the format *(x1,y1)-(x2,y2)* inside the rectangle that is currently selected.
3. If you release the left mouse button before the **Shift** key, the rectangle will be the new window. If, on the contrary, the **Shift** key is released before the left button, the previous window ranges will be retained.

The **Status line** is the last line in the main window. It is used to display:
1. In the left panel: numerical results, information and help lines, or the kind of graphics element being edited.
2. In the middle panel: the coordinates of the cursor indicating the initial condition (or the angle values of some graphics elements).
3. In the right panel: the coordinates of the mouse pointer.

You can get numerical information about the solution while it is being drawn on the screen.

Press **Shift+Ctrl+S** (or use the **Output/Status** line menu entry or the corresponding toolbar button) to open the **Numerical Output in Status Line** dialog box:

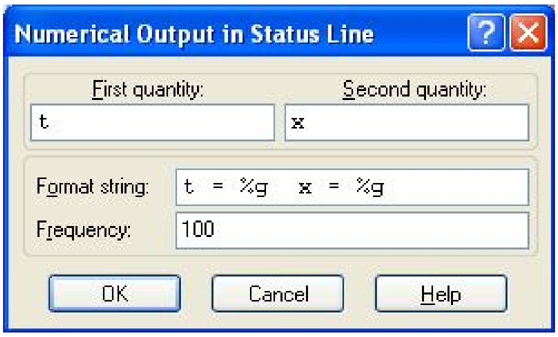

Figure 4.

5. Running simulation

To start solving a problem, press **Shift+Enter** or use the **Go/Start** menu or press toolbar button. First, DS will try to compile all the expressions defined in the problem. In the event of an error, you will be prompted to correct it. A Compiler Error dialog displaying the type and probable location of the error will be opened. You can then correct it and continue solving the problem, or stop the compilation at this point.
After a successful compilation, the different kinds of output will start (refer to Output Parameters). Most of the menus are disabled while the computation is being performed, but you can, for instance, erase one (or all) windows as described in Erasing and Refreshing Windows.

To stop the solution, press **Esc** or use the **Go/Stop** menu or press toolbar button. Please note that, to have the possibility of a smooth continuation, the **Esc** key is only read after each solution point is computed. (This can suppose several, or even many, points plotted on the screen and, thus, the action is not always immediate if Interpolation is on (in the Range dialog) and Step low, or if Max. h (in the Method dialog) is high, or if the Tolerance is very low.)
In fact, the integration halts when any of the following things happens:

- The user presses the **Esc** key or uses the **Go/Stop** menu entry or press  toolbar button.
- An error happens.
- The **Last value** is reached by the independent variable.
- The absolute value of any dependent variable reaches the Infinity value.
- The first argument of a break or stop function in an expression is not equal to zero.
- The first argument of a continue function in an expression is equal to zero.

After stopping the solution with button  the running can be started again from the original initial position, while clicking button  the simulation can be continued from the last value of the independent variable.

References

[1] http://tp.lc.ehu.es/jma/ds/ds.html