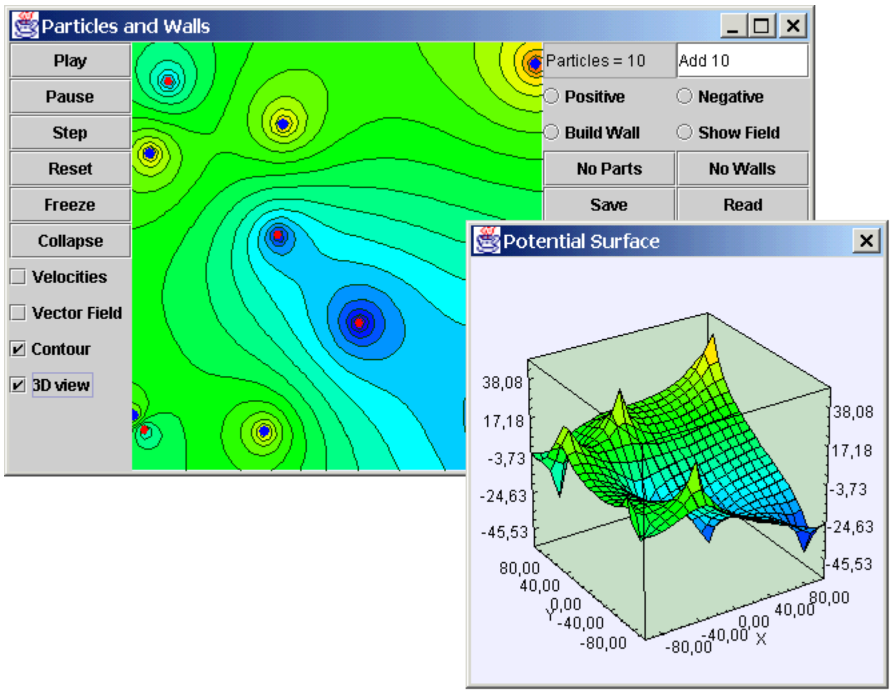
Easy Java Simulations
The Manual

Version 3.4 - September 2005



Francisco Esquembre

Contents

CHAPTER 1

A first contact

We describe in this chapter how to create an interactive simulation in Java using *Easy Java Simulations* (*Ejs* for short). In order to get a general perspective of the complete process, we will inspect, run and finally modify, slightly but meaningfully, an already existing simulation. This will help us identify the parts that make a simulation, as well as become acquainted with our authoring tool. [1]

1.1 About *Easy Java Simulations*

Every technical work requires the right tool. *Easy Java Simulations* is an authoring tool that has been specifically designed for the creation of interactive simulations in Java. Though it is important not to confuse the final product with the tool used to create it, and, in principle, the simulations we will create with *Ejs* can also be built with the help of any modern computer programming language, this tool originates from the specific expertise accumulated along several years of experience in the creation of computer simulations, and will therefore be very useful to simplify our task, both from the technical and from the conceptual point of view.

From the technical point of view because *Ejs* greatly simplifies the creation of the *view* of a simulation, that is, the graphical part of it, a process that usually requires

[1]Readers of the OSP Guide (see http://www.opensourcephysics.org) may skip this chapter. The information contained in it has been already covered in the chapter about *Ejs* of the guide.

an advanced level of technical know-how on programming computer graphics. From the conceptual point of view, because *Ejs* provides a simplified structure for the creation of the *model* of the simulation, that is, the scientific description of the phenomenon under study.

Obviously, part of the task still depends on us. Ours is the responsibility for the design of the view and for providing the variables and algorithms that describe the model of the simulation. We will soon learn how to use *Ejs* to build a view. For the model, we will learn to declare the variables that describe its state and to write the Java code needed to specify the algorithms of the model. Stated in different words, we will learn to program the computer to solve our model.

If you have never programmed a computer, let me tell you that it is a fascinating experience. And, actually, it is not difficult in itself. All that is needed is to follow a set of basic rules determined by the syntax of the programming language, Java in our case, and, obviously, to have a clear idea of what we want to program. It can be compared to writing in a given human language. No need to say that one can attempt to write simple essays or complete literary creations.

With this software tool, we can create models of different complexity, from the very simple to the far-from-trivial. Once more, *Easy Java Simulations* has some built-in features that will make our task easier, also when writing our algorithms. For instance, *Ejs* will allow us to solve numerically complex systems of ordinary differential equations in a very comfortable way, as well as it will automatically take care of a number of internal issues of technical nature (such as multitasking, to name one) which, if manually done, would require the help of an expert programmer.

But let us proceed little by little.

1.2 Installing and running *Ejs*

Easy Java Simulations can be run under any operating system that supports a Java Virtual Machine, and it works exactly the same in all cases. Only what this section describes can be different depending on the operating system you use in your computer.

Though we will illustrate the process assuming you are using the Microsoft Windows operating system, the explanations should be clear enough for users of different software platforms, with obvious changes.

Nevertheless, you will find detailed installation and start-up instructions for the most popular operating systems in the Web pages for *Ejs*, `http://fem.um.es/Ejs`.

1.2.1 Installation

Let's start our work! First of all, we must install the software we need in our computer. The steps needed for this are the following:

1. Copy the files for *Ejs* to you hard disk.
2. Install the Java 2 Standard Edition *Development Kit* (JDK) in your computer.
3. Inform *Ejs* where to find the JDK.

All the software required to run *Ejs* is completely free and can be found in the Web server of *Ejs*.

The installation of *Ejs* consists in uncompressing a single ZIP file that you will most likely have downloaded from the Web server. It is recommended that neither this directory, nor any of its parents, contains white spaces in its name. We will assume that you uncompressed this file in the root directory of your hard disk, thus creating a new directory called, say, **C:\Ejs**. But any other directory will serve as well. [2]

The installation of the JDK follows a standard process established by Sun Microsystems (the company that created Java) which, under Windows, consists in running a simple installation program. The version recommended at the time of this writing is 1.5.0_04, although any release later than 1.4.2 should work just fine. The only important decision you need to take during the installation is to choose the directory where Java files will be copied to. We recommend that you just accept the directory suggested by the installation program. In the case of version 1.5.0_04, this defaults (in English-based computers) to **C:\Program files\Java\jdk1.5.0_04**.

Easy Java Simulations requires the Java Development Kit to run. Please, do not confuse this with the Java Runtime Environment (JRE), sometimes called the Java *plug-in*. The JRE is a simpler set of Java utilities that allows your browser to run Java *applets* (a Java applet is an application that runs inside an HTML page) and certain applications, but does not include, for instance, the Java compiler. Thus, although you might be able to run *Ejs*' interface, you won't be able to generate simulations. Hence, please make sure that you download the (larger) JDK.

It is possible that your computer has already a copy of the JDK installed in it. For instance, if you use an operating system that ships with a Java Virtual Machine, such as Mac OS X or some distributions of Linux. In this case, we still recommend that you check the version of Java you got. If it is too old, you should consider updating to a more recent version.

[2]In Unix-like systems, the directory may be uncompressed as read-only. In this case, please enable write permissions for the whole **Ejs** directory.

The last step you need to complete is to let *Ejs* know in which directory you installed the JDK. [3] The way to do this depends on which method you will use to launch *Ejs*.

The recommended method to run *Easy Java Simulations* is to use *Ejs*' console. In this case, once you run the console (usually by double-clicking on the **EjsConsole.jar** file), you will just need to write the installation directory you used for the JDK in the console's "Java (JDK)" text field. We describe this in detail in Subsection 1.2.3 below.

Alternatively, for operating system purists, *Ejs*' installation includes three script files (one for each major operating system: Windows, Mac OS X, and Linux) that will help you run *Ejs* from the command line. If you choose this method, you will need to edit the script file for your operating system and modify the variable `JAVAROOT` defined in the first few lines of this script to point to the installation directory of the JDK.

Thus, for instance, if you are using Windows and have used the suggested installation directory, then you may not even need to do anything at all. If, on the contrary, you installed the JDK in the directory, say, **C:\jdk1.5.0_04**, then you must edit the file called **Ejs.bat** that you will find in the directory where you installed *Ejs*, and modify the line in this file that reads:

```
set JAVAROOT=C:\Program files\Java\jdk1.5.0_04
```

so that it reads as follows:

```
set JAVAROOT=C:\jdk1.5.0_04
```

Virtually all the reported installation problems have their origin in *Ejs* not finding the JDK because this environment variable is not properly set.

There are some options that you may want to configure before running *Ejs*. The most interesting one is, perhaps, the language for the interface. *Ejs* offers an interface in several different languages from which you need to choose *before* running it. You can choose that of the operating system installation itself, English, Spanish, and Traditional Chinese from the console. If you can't obtain *Ejs*' interface in the language you want, try editing the script file for your operating system and modifying the self-explanatory commands in there.

All in all, if you followed the installation instructions provided and cannot get *Ejs* to run as described in Subsection 1.2.3, please e-mail us at `fem@um.es`. Send a simple description of the problem, including any error message you may have gotten in the process. We'll try to help.

[3]This step is not necessary in Mac OS X.

1.2.2 Directory structure

We need to say some words about the organizational structure of the files in the **Ejs** directory. Once you have created this directory in your hard disk, please inspect it with the file browser of your operating system.

You will find in it a set of three files, all with the same name, **Ejs**, if only they have different suffixes (*extensions* is the technical word). These files, **Ejs.bat**, **Ejs.macosx**, and **Ejs.linux** are those used to run *Ejs* under the different major operating systems. You will also find the JAR file for *Ejs*' console, **EjsConsole.jar**. These four files are covered in the next subsection. Finally, there are also two files called **LaunchBuilder.bat** and **LaunchBuilder.sh** in this directory. They are used to run a utility program called **LaunchBuilder**, which we will cover in Subsection 4.5.1.

Besides those files, you will also find two directories called **data** and **Simulations**. The first directory contains the program files for *Ejs*, and you should not touch it. The second directory will be your working directory and you can modify its contents at your will, with one important exception: do not touch the directory called **_library** that you will find in it.

This directory contains the library of files required for the simulations that we will create. Because of its importance and also so that it does not interfere with the files and directories that you may create in the directory **Simulations**, we have given this library a directory name that starts with the character "_". It is therefore forbidden (if this sounds too strict, let's say it is very dangerous) to use this character as the first letter of the name of any simulation file that you may create in the future.

You will also find other subdirectories of **Simulations** that begin with the character "_". We have included, for instance, a directory called **_examples** with many sample simulations (and auxiliary files for them) that may be useful for you to inspect and run. Depending on the distribution you got, there might be additional sample directories.

The usual operation with *Easy Java Simulations* takes place in the directory **Simulations**. We will save our simulation files in it and *Ejs* will also generate there the files needed for the simulations to run. As you work with *Ejs*, this directory will contain more and more files (it may even become crowded!). You can do whatever you think appropriate with your files, but recall not to delete, move, nor rename the **_library** directory (or, even better, do not touch any directory or file whose name starts with the character "_").

1.2.3 Running *Easy Java Simulations*

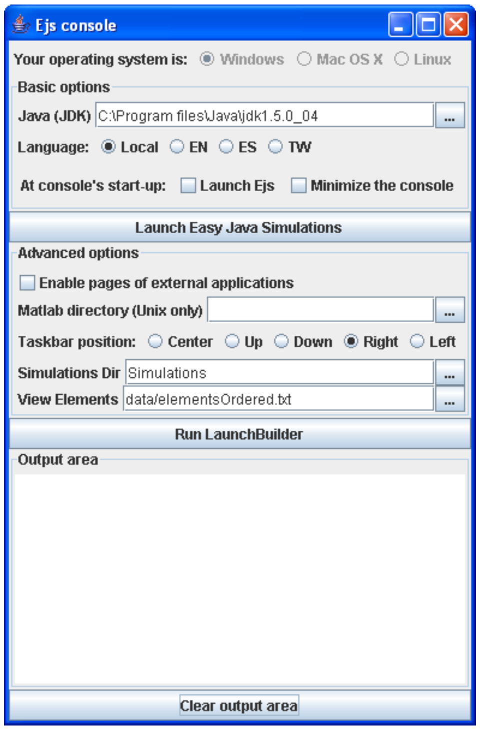
Please return now to the **Ejs** directory. As we already mentioned, there are two ways of running *Easy Java Simulations*.

Using the console (recommended)

To run *Ejs* from the console, we need to run the console file **EjsConsole.jar** first. This is a self-executable JAR file. Thus, if your system is properly configured (usually Windows and Mac OS X systems are, once you have installed the JDK on them), you just need to double-click this file. If you cannot make it run this way, open a system prompt, change the current directory to **Ejs**, and type the following: [4]

```
java -jar EjsConsole.jar
```

You should get a window like that of Figure 1.1.


Ejs console

Your operating system is: [✓ Windows] Mac OS X Linux

Basic options

Java (JDK): C:\Program files\Java\jdk1.5.0_04

Language: [✓ Local] EN ES TW

At console's start-up: ☐ Launch Ejs ☐ Minimize the console

Advanced options

☐ Enable pages of external applications

Matlab directory (Unix only):

Taskbar position: Center Up Down [✓ Right] Left

Simulations Dir: Simulations

View Elements: data/elementsOrdered.txt

Figure 1.1. *Easy Java Simulations*' start-up console under Windows.

Notice that the console includes a text field labeled "Java (JDK)", near the top. This field can be left empty in Mac OS X computers, but in Windows and Linux,

[4]You may need to fully qualify the `java` command if it is not in your system PATH for binaries.

you must write there the location of your JDK. The figure shows the default value for Windows systems.

If the “Java (JDK)” text field doesn’t point to the directory where you installed the JDK, either type the correct installation directory in this field, or use the button to its right to bring-in a file browser, and use it to select the JDK installation directory.

Then, click on the “Launch Easy Java Simulations” button and *Ejs*’ window should appear.

Again, there are some options that you may want to configure before running *Ejs*. The console offers you an easy way to select them. Also, the console includes a button that runs **LaunchBuilder**. This utility program is described in Subsection 4.5.1.

Notice that the console includes a text area in which *Ejs* will print whatever messages it produces.

Using the script file

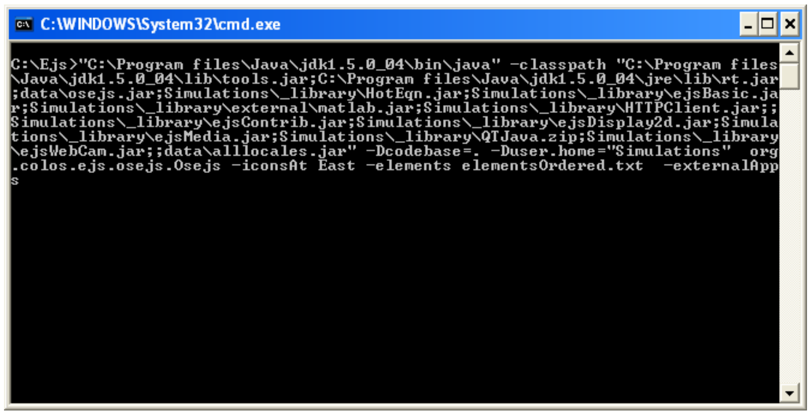
Among the files called **Ejs**, select the one that corresponds to your operating system and run it.

- Under Windows, use the file called **Ejs.bat** and double-click on it to run it.
- The start-up file for *Ejs* under Mac OS X has the name **Ejs.macosx**. To run it, you’ll need to open a terminal (also know as shell) window, change the current directory to **Ejs** and type “`./Ejs.macosx`”. Before this, however, make sure that this file has execution permission. For this, write in the terminal window the command “`chmod +x Ejs.macosx`”.
- The file called **Ejs.linux** corresponds to Linux operating systems. The steps to run this file are the same as for Mac OS X.

If everything went well, in a few seconds you will find two windows in your screen.

The first of these is the operating system window from which *Ejs* is run and contains just a few (rather strange) sentences. See Figure 1.2. This window will not be of interest for us, except for the fact that it will display any message that *Ejs* produces. You can minimize it (but do not close it!) or just place it where it won’t disturb and ignore it (except for messages).

The second window is *Ejs* user interface itself..



```
C:\Ejs>"C:\Program files\Java\jdk1.5.0_04\bin\java" -classpath "C:\Program files
\Java\jdk1.5.0_04\lib\tools.jar;C:\Program files\Java\jdk1.5.0_04\jre\lib\rt.jar
;data\osejs.jar;Simulations\_library\HotEqn.jar;Simulations\_library\ejsBasic.ja
r;Simulations\_library\external\matlab.jar;Simulations\_library\HTTPClient.jar;;
Simulations\_library\ejsContrib.jar;Simulations\_library\ejsDisplay2d.jar;Simula
tions\_library\ejsMedia.jar;Simulations\_library\QTJava.zip;Simulations\_library
\ejsWebCam.jar;;data\alllocales.jar" -Dcodebase=. -Duser.home="Simulations"  org
.colos.ejs.osejs.Osejs -iconsAt East -elements elementsOrdered.txt  -externalApp
s
```

Figure 1.2. Terminal window that launches *Easy Java Simulations* under Windows.

The interface of *Easy Java Simulations*

Figure 1.3 shows the interface of *Easy Java Simulations*, to which we have added some notes. From now on, we will just concentrate on it, and minimize (or just ignore) either the console or the terminal window we used to launch *Ejs*.

You will notice that *Ejs* interface is rather basic. This was a design decision. It often happens (at least it happens to us) that the first look at a software program with an enormous amount of icons in its taskbar, causes fear rather than ease. Recall that *Easy Java Simulations* has the adjective *Easy* in its name and we want this to be appreciated (specially when used by students) from the very first moment. However, despite its austere aspect, *Ejs* has all it needs to have. The program will be displaying its capabilities as we need them.

We'll start exploring the interface by looking at the set of icons to the right, what is called in the figure the taskbar. You may be surprised by the place chosen to locate this taskbar. Usually, this bar (that provides tasks such as loading and saving our files, for instance) appears at the top of most program windows.

Well, it is an option. We first decided to place it on the right-hand side because it seemed to us that this was the place where it would leave more free space for the real work. Actually, once we got used to it, we think it is a very comfortable place to have it.

The taskbar shows the following icons:

“New”. Clicking this icon clears the current simulation (if there is one) and returns *Ejs* to its original initial state.

“Open”. This icon lets you load an existing simulation file.

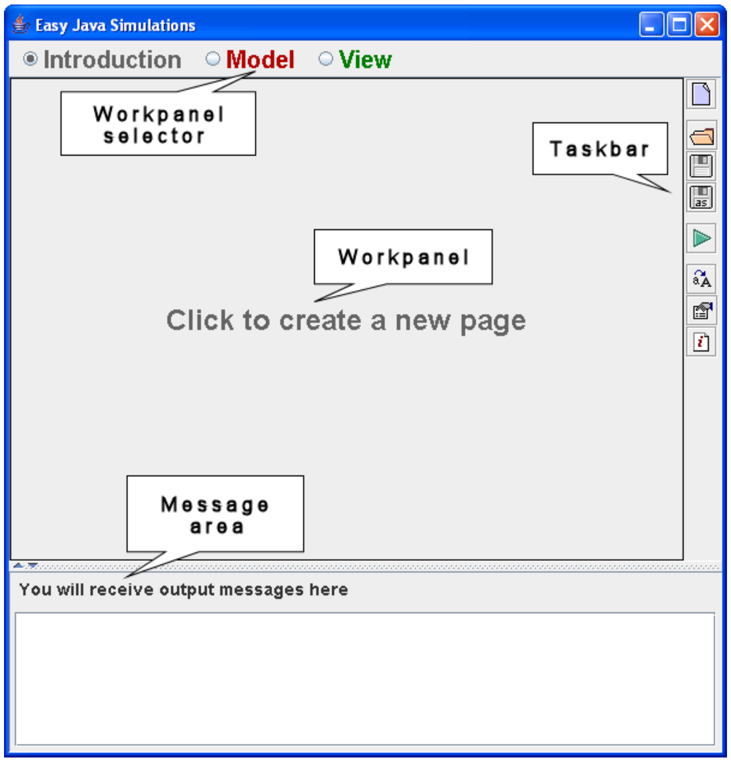


Figure 1.3. *Easy Java Simulations* user interface (with annotations).

“Save”. This is used to save the current simulation on disk in the same file from which it was loaded.

“Save as”. This icon also lets you save the current simulation on disk, but in a file different from the one currently in use.

“Run”. When this icon is clicked, *Ejs* generates and runs the simulation currently loaded. It then changes its color to red (returning to green when you exit the simulation).

“Font”. This icon lets you change the type and size of the font used in the text areas of *Ejs*.

“Options”. This allows you to modify some options that change the appearance and behavior of *Ejs*. See Subsection 4.3.

“Information”. This icon shows information about *Easy Java Simulations*.

We will show how to use these icons as we need them for our work, though their meaning and use should be rather natural.

Coming back to Figure 1.3, please notice that there is a blank area at the lower part of the window with a header that reads "You will receive output messages here". This means exactly what it promises. This is a message area that *Ejs* will use to display information about the results of the actions we ask it to take.

Let us turn now our attention to the most important part of the interface, the workpanel, the central area of the interface, and the three radio buttons on top on it, labeled "Introduction", "Model" and "View". When you select one of these buttons, the central area of *Ejs* displays the panel associated to the edition of the corresponding part of the simulation. Obviously, these parts are the introduction, the model and the view.

1.3 Working with a simulation

Now that we are familiar with the interface, we will use it to work with an existing simulation. Click with the mouse on the "Open" icon and a dialog window, similar to the one shown in Figure 1.4, will appear. This window will show you the files contained in your **Simulations** directory.

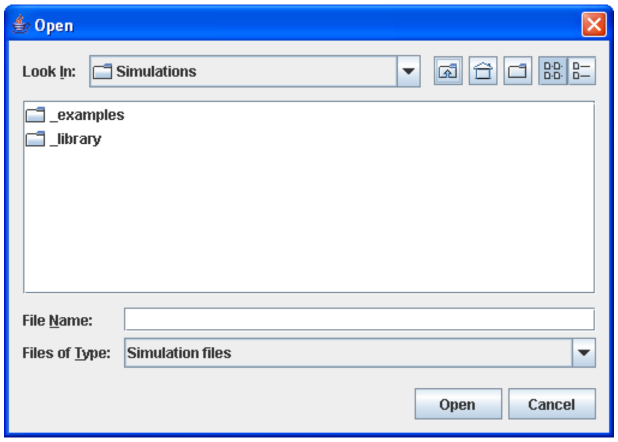
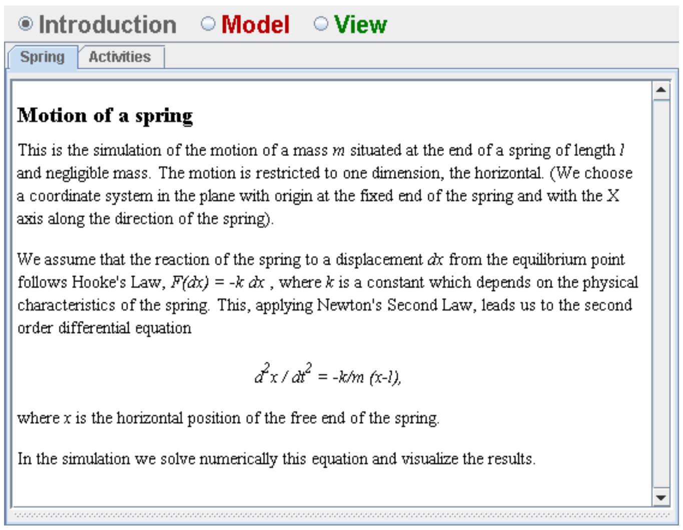


Figure 1.4. Contents of the **Simulations** directory.

Open the directory **_examples/Manual/FirstContact**. You will find there the simulation file **Spring.xml**. Select it and click the "Open" button in this dialog window; *Ejs* will then load this simulation. Notice that the message area of *Ejs* will display a confirmation message ("File successfully read...") and that the title of *Ejs* window will change to include the name of the file just loaded.

1.3.1 The introduction

Figure 1.5 shows the aspect of the workpanel of *Ejs* with the short introduction that we prepared for this simulation.



Motion of a spring

This is the simulation of the motion of a mass *m* situated at the end of a spring of length *l* and negligible mass. The motion is restricted to one dimension, the horizontal. (We choose a coordinate system in the plane with origin at the fixed end of the spring and with the X axis along the direction of the spring).

We assume that the reaction of the spring to a displacement *dx* from the equilibrium point follows Hooke's Law, *F(dx) = -k dx* , where *k* is a constant which depends on the physical characteristics of the spring. This, applying Newton's Second Law, leads us to the second order differential equation

$$d^2x / dt^2 = -k/m\ (x-l),$$

where *x* is the horizontal position of the free end of the spring.

In the simulation we solve numerically this equation and visualize the results.

Figure 1.5. Introduction pages for the simulation of a spring.

You can read the second introduction page by clicking on the corresponding tab. As user of an existing simulation, this panel allows you to read the narrative that the author included as prelude or as instructions of use for the simulation. Later in this chapter we will learn how to modify these pages.

1.3.2 The view

Besides the changes to the interface of *Ejs* itself, you will notice that two new windows have appeared on the screen. These windows, which are displayed in Figure 1.6, correspond to the interface of the simulation we loaded and make what we call its view.

We can investigate how this view has been built. If we select the panel for the view in *Ejs* (clicking the corresponding radio button), we will see in the central area two frames which display several icons, see Figure 1.7. The frame on the right-hand side shows the set of graphical elements of *Ejs* that can be used to build a view, grouped by functionality. The frame on the left displays the actual construction chosen for this particular simulation.

In a first approach, we can consider this panel as an advanced drawing tool specialized in the visualization of scientific phenomena and its data. Obviously, if

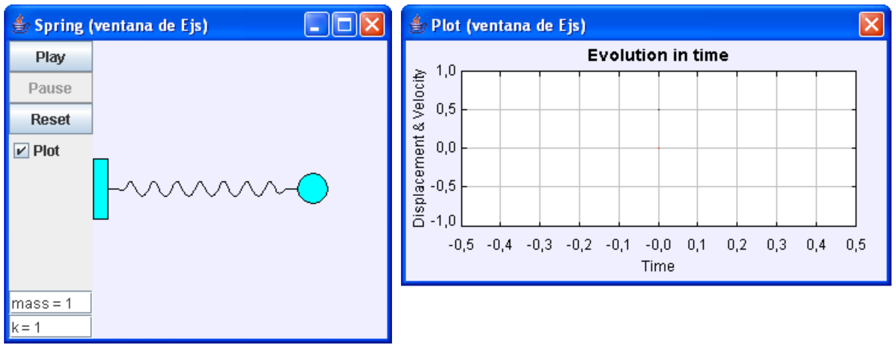


Figure 1.6. Visualization of the phenomenon (left) and panel for plots (right) for the simulation of a spring.

we want to create nice drawings, we'll need to learn all the drawing tools at hand, and an important part of the task of learning how to use *Easy Java Simulations* consists in learning which elements exist and what they can do for us.

1.3.3 The model

To proceed in this first inspection of the simulation, please click now the radio button for the model. The central panel will now show a set of five subpanels, each containing a part of the model (see Figure 1.8). You can explore these subpanels on your own, you will probably guess what each of them does. We'll be doing this soon, but we are now interested in running the simulation.

1.3.4 Running the simulation

A warning: do not try to run the simulation clicking on the buttons of the windows that appeared when we loaded the simulation! These windows are actually static and only serve us to get an idea of how the final simulation will look like. (More precisely, they are there to help the author build the view, during the creation of the simulation). You can distinguish these static windows from others that will soon appear because the static ones have a note between parentheses in their title that reads “Ejs window”.

To run the simulation correctly, you need to click on the *Run* icon in *Ejs* taskbar. Then, after a few seconds (the fewer, the faster your computer is) *Ejs* will display some reassuring messages in its message area and two new windows, very similar to the previous ones, will appear, if only this time their title won't tell they are “Ejs windows”.

Now, you can interact with the simulation. Click the “Play” button and the

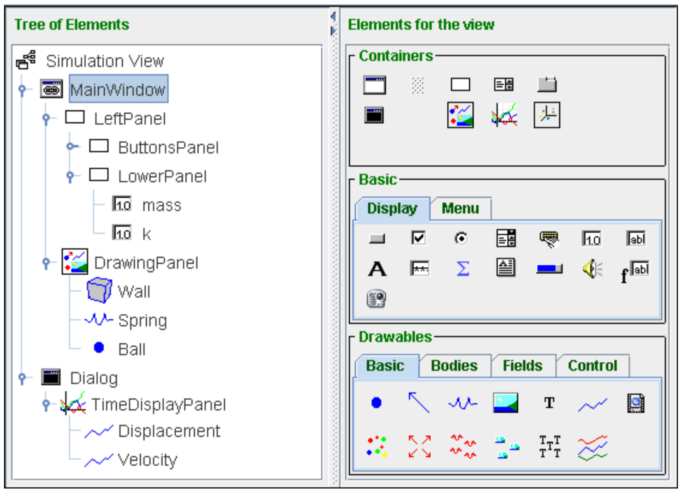


Figure 1.7. Tree of elements for the simulation (left) and set of graphical elements of *Ejs* (right).

spring will start oscillating, since it starts from a non-equilibrium position. The dialog window on the right will plot the graph of the displacement of the ball at the end of the spring with respect to the equilibrium (the graph in black) and of its velocity in the X axis (the graph in red), as Figure 1.9 shows.

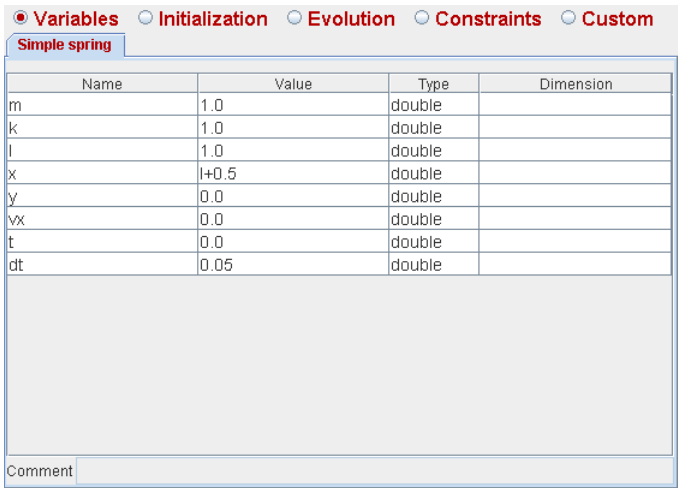
You can now work with the simulation to show some of the characteristics of simple harmonic motion. In particular, you can illustrate the dependence (or independence) of the period with respect to the parameters of the system and to its initial conditions. You can also modify the values of the mass and the elasticity constant of the spring using the input fields provided by the interface. You can place the spring in different initial positions just by clicking the ball at its end and dragging it to the position you want. You can measure the period by clicking the mouse on the plotting panel so that a yellow box appears displaying the coordinates of the point you clicked upon.

You now have a small *laboratory* to work with your students on the motion of a spring.

1.3.5 Publishing the simulation on a Web server

If this simulation is of interest for you, you will probably like to be able to publish it on the Internet so that other people (your students, for instance) can run it in a remote way.

Now, this is one of the greatest benefits from the fact that *Easy Java Simulations* is based on Java: you already have all you need! Indeed, if you inspect the directory



Name	Value	Type	Dimension
m	1.0	double	
k	1.0	double	
l	1.0	double	
x	l+0.5	double	
y	0.0	double	
vx	0.0	double	
t	0.0	double	
dt	0.05	double	

Figure 1.8. Subpanels of the model. The panel for the definition of variables is currently shown.

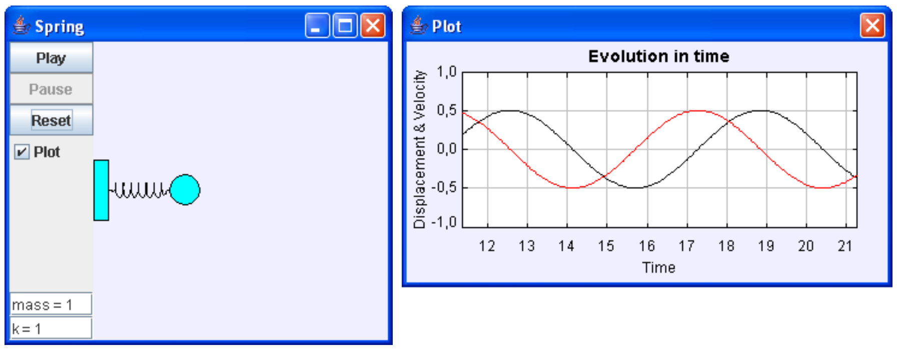
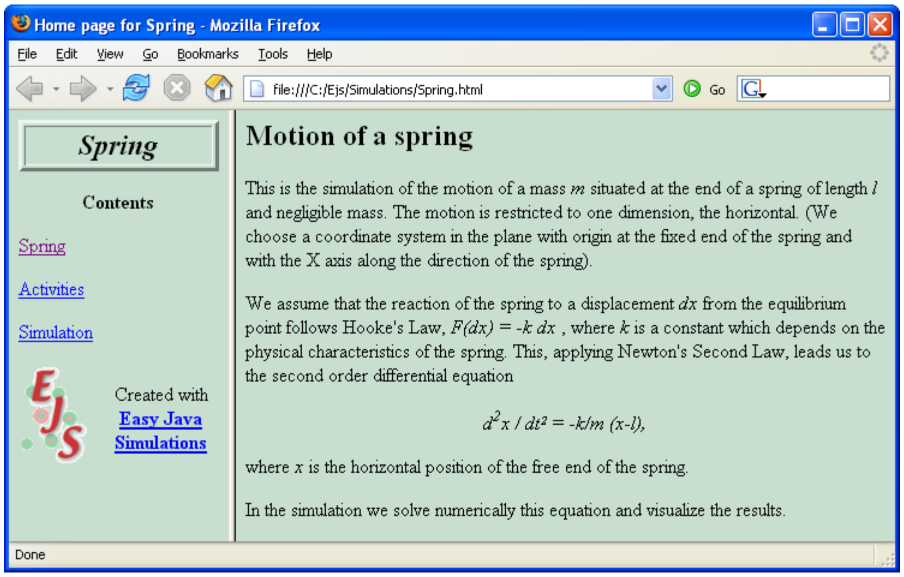


Figure 1.9. The simulation as it runs.

Simulations, you will see in it a set of files, of different type, whose names all start with the word "Spring" (well, one of them starts with the word "spring"). Open the one called **Spring.html** with your favorite Web browser and you will get something similar to what Figure 1.10 displays.

Explore the links offered by this Web page and you will see that *Ejs* has used the introduction pages of the simulation to create the corresponding HTML pages, and that it has added to them a new page that includes the simulation itself in form of a Java applet, see Figure 1.11. It is important to remember that the simulation will only appear correctly if your browser is capable of displaying applets of Java version 1.4.2 or later. (If the simulation doesn't appear in your browser as shown in Figure 1.11, you'll need to install the necessary Java plug-in or JRE. You'll find the instructions for this on the Web pages for *Ejs*, at `http://fem.um.es/Ejs`.)


Home page for Spring - Mozilla Firefox
File Edit View Go Bookmarks Tools Help
file:///C:/Ejs/Simulations/Spring.html
Go
Spring
Contents
Spring
Activities
Simulation
Created with Easy Java Simulations
Done

Motion of a spring

This is the simulation of the motion of a mass *m* situated at the end of a spring of length *l* and negligible mass. The motion is restricted to one dimension, the horizontal. (We choose a coordinate system in the plane with origin at the fixed end of the spring and with the X axis along the direction of the spring).

We assume that the reaction of the spring to a displacement *dx* from the equilibrium point follows Hooke's Law, *F(dx) = -k dx* , where *k* is a constant which depends on the physical characteristics of the spring. This, applying Newton's Second Law, leads us to the second order differential equation

$$d^2x / dt^2 = -k/m\ (x-l),$$

where *x* is the horizontal position of the free end of the spring.

In the simulation we solve numerically this equation and visualize the results.

Figure 1.10. Main *Ejs*-generated Web page for the simulation of the spring.

You will notice that only the window that visualizes the spring appears inside the HTML page. The window that plots the graphs appears separately. This is because the first window was selected by the author, during the design of the interface, as the main window. See Subsection 3.4.3 for more details.

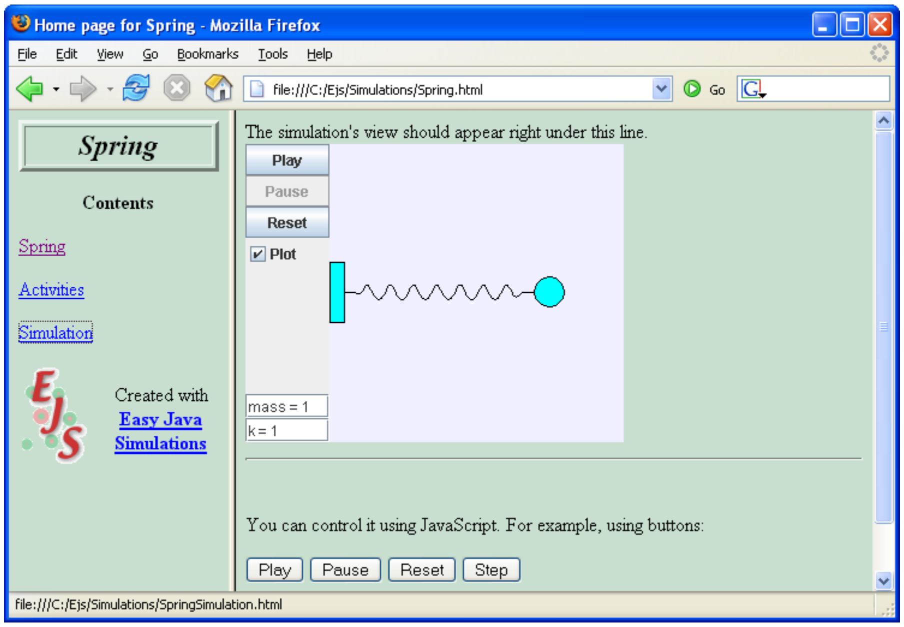
If you want to publish this simulation on a Web server of your own, you only need to copy in it all the files that appeared in your **Simulations** directory (remember that all of them start by the word “Spring”, either upper or lowercase), and, this is important, also the directory that contains the library of *Ejs*: **_library**. Once copied, you can delete your files (but not the library!) from this directory, if you want to keep it clean. Anyway, you can always re-create them repeating what you did along this section.

If you want to learn more about the contents of these HTML pages, please read Section 4.4.

1.4 Inspecting the simulation

Now that you know how to use a simulation previously created with *Ejs*, you may have two questions in mind:

- Could I know what the computer does to simulate the motion of the spring?


Home page for Spring - Mozilla Firefox
File Edit View Go Bookmarks Tools Help
file:///C:/Ejs/Simulations/Spring.html
Go
Spring
Contents
Spring
Activities
Simulation
Created with
Easy Java
Simulations
Play
Pause
Reset
Plot
mass = 1
k = 1
Play
Pause
Reset
Step
file:///C:/Ejs/Simulations/SpringSimulation.html

The simulation's view should appear right under this line.

You can control it using JavaScript. For example, using buttons:

Figure 1.11. The simulation of the spring in applet form.

- Even more interesting, could I modify this simulation to include other types of motions, or to plot different graphs?

These are the two questions that, because their answers are positive, make of *Easy Java Simulations* a very special tool. You can surely find on the Internet many applets that simulate scientific processes. However, very few of them will allow you to see their "secrets", that is, how they have been done. And those that allow you this, will surely do it by providing the full Java code of the applet, something which is only useful for expert Java programmers (which can also understand the phenomenon).

Ejs on the contrary, because it was designed to be used by people that don't need to be Java programmers, allows you to understand and customize the simulation in a much simpler and efficient way. We'll show this in the present and next section by inspecting and modifying our example in a substantial way.

1.4.1 Inspecting the model

Let's go back to the model by clicking the corresponding radio button. We already saw, in Figure 1.8, that this panel contains five subpanels.

Declaration of variables

The first of these, labeled “Variables” and visible in Figure 1.8, displays the table of variables needed for our model. When programming, we use the term *variables* either for the parameters, the state variables or the inputs and outputs of the model. Every numerical value (or of any other type, such as boolean or text) is called a variable, even if its value remains constant all along the simulation.

For the model of our example, these variables are the following:

`m`, the mass of the ball at the end of the spring,

`k`, the elastic constant of the spring,

`l`, the length of the spring in equilibrium,

`x`, the horizontal coordinate of the end of the spring,

`y`, the vertical coordinate (which must remain constant),

`vx`, the velocity of the horizontal motion,

`t`, the variable that represents the time of the simulation,

`dt`, the increment of time for each step of the simulation.

As we can see, some variables correspond to parameters of the system (`m`, `k` and `l`), others describe the state of it (`x`, `y` and `vx`), and others are variables needed for the simulation itself (`t` and `dt`).

Initialization of the model

Variables need to be initialized. The table of Figure 1.8 provides an initial value for each of our variables, thus specifying the precise initial state of the system. In occasions, however, we will need a more complex initialization (for instance, if some preliminary computation is required). For these cases, we can use the second subpanel of the model. This is not necessary for our model, though, and we will leave this panel empty (we don’t display it either).

Evolution of the model

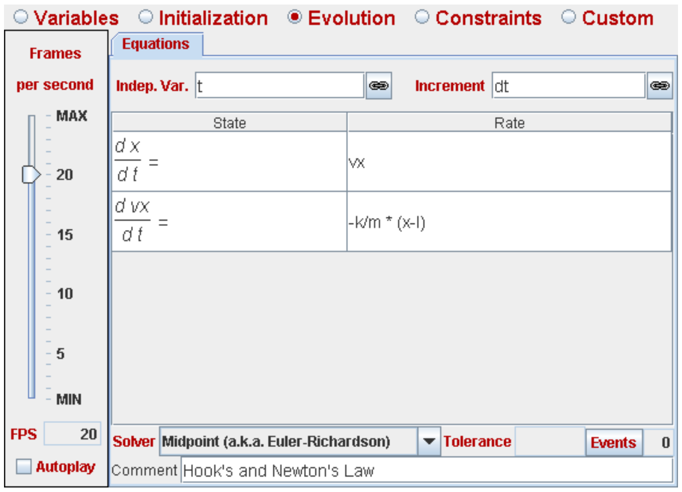
Next panel, labeled “Evolution”, is of special importance. It is used to indicate the simulation what to do when the evolution runs. The panel can contain two types of pages: a first type in which the author must directly write the Java code that implements the desired algorithm, and a second one, the type that this example is using, specially indicated for models that can be described using systems of ordinary differential equations.

In our model, the differential equation that rules the motion is obtained from applying Newton's Second Law, $F = m\,a$, and the basic assumption that the response of the spring to a displacement dx obeys Hooke's Law, $F = -k\,dx$. We therefore obtain the second order differential equation:

$$\ddot{x} = -\frac{k}{\mathrm{m}}\,(x - l), \tag{1.1}$$

where x is the horizontal coordinate of the end of the spring. (We are choosing a coordinate system with its origin placed at the fixed end of the spring and the X axis along it).

To enter this second order equation in the editor for differential equations of *Ejs* we need to rewrite it as a system of first order differential equations, which we achieve by using the variable $v_x = \dot{x}$. All this results in the formulation displayed in Figure 1.12. [5]



Variables Initialization [✓ Evolution] Constraints Custom

Indep. Var. t   Increment dt

State	Rate
$\frac{d\,x}{d\,t}$ =	vx
$\frac{d\,vx}{d\,t}$ =	-k/m * (x-l)

FPS 20

Solver Midpoint (a.k.a. Euler-Richardson)   Tolerance   Events 0

Comment Hook's and Newton's Law

Figure 1.12. Evolution panel with the differential equations for our spring.

Actually, this form of writing the previous second order differential equation may be easier to understand for students not familiar with the concept of differential equations. Note in the figure that we have selected `t` as the independent variable and that we are asking the editor to provide a solution for the equation for an increment of time given by `dt`.

With this information, when the simulation is created, the editor will generate all the code needed for the numerical computation of the solution of the equation,

[5]Note that the products require the character "*".

using for this the numerical method indicated in the field right below the equations. For this relatively simple problem, we have chosen the so-called Euler–Richardson method, a method of order two that provides a reasonable ratio speed/precision (for this problem).

The field called "Tolerance", that appears here empty, is only required when the method of numerical solution is of the type called *adaptive*, see Subsection 2.5.3. The field "Events" tells us that there are no events defined for this differential equation. We'll discuss events in Subsection 2.5.4.

Solving differential equations numerically is a sophisticated task, although it can be automated in an effective way. This is precisely what *Easy Java Simulations* offers: you write the equations in this editor and *Ejs* automatically generates the corresponding code.

Before proceeding, we need to turn our attention to the left frame of this subpanel. In it we instruct *Ejs* to play 20 steps of the simulation per second (or, in different words, to display 20 frames per second). This, together with the value of 0.05 that we used for the variable `dt` will result in a simulation that runs approximately in real time (although this is not absolutely necessary). Notice also that there is a checkbox called "Autoplay", that is now unchecked. This box must be checked if we want the simulation to start automatically playing the evolution when it is run.

Constraints among variables

The subpanel labeled "Constraints" is used to write the Java code needed to establish fixed relationships among variables of the system. We call these relationships *constraints*. In our model, the panel (not shown here) is empty since there are no constraints among variables.

Custom methods

The last subpanel of the model is labeled "Custom". This panel can be used by the author of the simulation to define his/her own Java methods [6] Differently to the rest of panels of the model, that play a well-defined role in the structure of the simulation, methods created in this panel must be explicitly used by the author in any of the other parts of the simulation. Again, in our example, this panel is empty and is not displayed.

[6] "Method" is the name that Java gives to what other programming languages call functions or subroutines. The object-oriented nature of Java turns these methods into something even more powerful than that. However, given the simplified use of Java that we chose for *Ejs*, this definition will be sufficient for us.

The model as a whole

We can now describe the integral behavior of all subpanels of the model. To start the simulation, *Ejs* declares the variables and initializes them, using for this both the initial value as specified in the table of variables, and whatever code the user may have written in the initialization panel. At this moment (ignoring for once the left-to-right order), *Ejs* also executes whatever code the user may have written in the constraint pages. The reason for this is that the constraints contain equations that can modify the initial value of certain variables, as will be explained in Subsection 1.5.1 and, in more detail, in Chapter 2.

Next, when the simulation plays, *Ejs* executes the code provided by the evolution panel and, immediately after, also the possible constraints. Once this is done, the system will be ready for a new step of the evolution, which it will repeat at the prescribed speed (number of images per second).

Notice that, as we mentioned already, methods in the panel "Custom" are not automatically included in this process.

1.4.2 Inspecting the view

Specifying the view of the simulation takes two steps. In the first place, we need to build the tree of elements displayed in the left frame of Figure 1.7. This tree is graphically descriptive of the components of the view because each element appears next to an icon representative of its function. Usually, the author also gives each element an illustrative name (at least, we do so), which also facilitates the comprehension.

The second step, less evident but also easy to accomplish, consists in editing the so-called *properties* of each element. Properties are internal values of the element that determine how the element looks and behaves on the screen. We may be interested in editing the properties of an element either to change any of its static graphical peculiarities (such as the color or font, for instance), or to instruct it to use the variables of the model to modify its dynamic aspect (position or size) on the screen. This second possibility is what turns the simulation into a really dynamic, interactive visualization of the phenomenon under study. Let us see how we used it in this particular example.

Select the panel for the view and, in the tree of elements of our simulation, click on the element called `Ball` to select it. The graphical aspect of this element is precisely that of a filled ellipse, and corresponds to the ball that you can see at the end of the spring. Once selected (you will see a colored frame around its name), click again on it, but this time with the right button of the mouse. The menu of Figure 1.13 will appear.

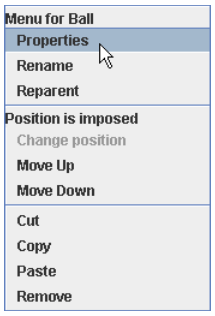
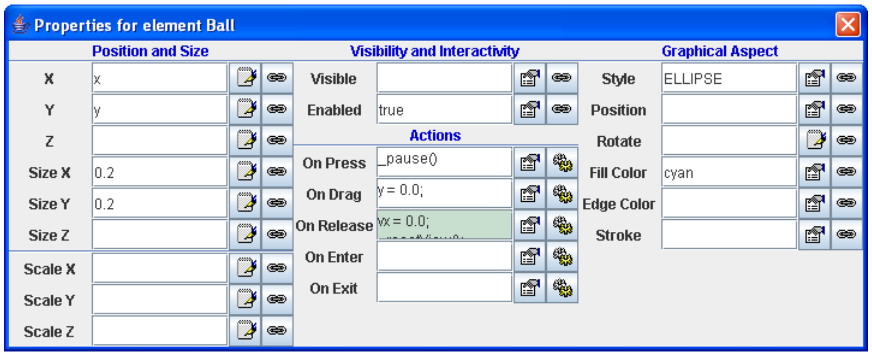


Figure 1.13. Popup menu for the element `Ball` of the view.

Select the option "Properties" (the one highlighted in the figure) and the window displayed in Figure 1.14 will appear. (Double-clicking directly on the `Ball` element is a short cut for this option.)


Properties for element Ball

Position and Size

X	x
Y	y
Z	
Size X	0.2
Size Y	0.2
Size Z	
Scale X	
Scale Y	
Scale Z	

Visibility and Interactivity

Visible	
Enabled	true

Actions

On Press	_pause()
On Drag	y = 0.0;
On Release	vx = 0.0;
On Enter	
On Exit	

Graphical Aspect

Style	ELLIPSE
Position	
Rotate	
Fill Color	cyan
Edge Color	
Stroke	

Figure 1.14. Table of properties for the element `Ball` of the view.

This window displays the table of properties of the element. In our case, the static values indicate that the ball will be displayed filled with the color cyan (a sort of light blue), in the form of an ellipse of size (0.2,0.2) (which finally results in a circle being drawn), and that the element is enabled, that is, that it will respond to user interaction if (s)he clicks on it with the mouse.

You can also notice, and this is the most interesting thing, that other properties of the element are associated to variables of the model, or use expressions that use them. For instance, the position of the element is associated to the point (`x`,`y`), where `x` and `y` are the corresponding variables of the model. This association is a two-way link. In one direction it means that, every time the value of these variables changes during the execution of the model, the element will be informed and the corresponding properties updated to the new values, causing the ball to move at the simulation's pace. In the other direction, if the user interacts with the ball to modify its position, then, in an automatic way, the value of the variables of the model associated to these properties will also be modified. In this simple manner, associating variables of the model to properties of the view elements, we can easily build complete dynamic, interactive simulations.

Finally, the way the element `Ball` must react when it is interacted by the user has been established associating to the (so called) *action* properties of the element expressions that use variables of the model, or methods of it. We can see in Figure 1.14 that the action produced "On Press"ing the element is associated to the predefined method `_pause()`. (This method just pauses the simulation). The action produced "On Drag"ing the element evaluates the sentence `y = 0.0;`, which keeps the spring in a horizontal position. Finally, the action produced "On Release" of the element evaluates the code: [7]

```
vx = 0.0;
_resetView();
```

We can use for this code any valid Java expression that involves the variables of the model and even any Java method that we may have defined in the "Custom" subpanel of the model.

According to the code written in these three action properties, the sequence of the interaction with the element `Ball` is the following:

1. When the ball is first clicked, the simulation is paused (if it was playing). This is necessary because it is rather uncomfortable to try to reposition a ball while it is moving because of the effect of the evolution of the system.

2. When moving the ball, we force the `y` coordinate to keep the value 0. This way, even if the user inadvertently tries to move the ball in the vertical direction, the spring remains horizontal.

3. When the ball is finally released, the system will freeze the ball (`vx = 0`), clean the graphs (`_resetView()`) and leave the system ready to start a new simulation run with the new initial conditions.

You can also inspect the properties of the other elements to become familiar with some of the different types of elements that *Ejs* offers and their properties. Of particular interest are the elements called `Displacement` and `Velocity`.

[7] Code in action properties can span more than one line. When this happens, the field adopts a different background color. If the code is not clearly visible, click on the first button to its right, 📝, and an editor window will display it more clearly.

1.5 Modifying the simulation

We have already used one of the big peculiarities of *Easy Java Simulations*, the fact that it lets us see how the simulation works. In this section we will use the other important characteristic of it, the possibility of modifying the simulation to adapt it to our preferences or to include new possibilities.

Very often, when we explore a program created by another person, right after learning the possibilities that the program offers, we come to the universal question: "What if...?" (or a variant of this one: "Is it possible to...?"). Unless the author has taken into account all different possibilities (which is unlikely), the answer may cause us a small disappointment.

This doesn't need to be the case with *Easy Java Simulations*. The tool not only lets us see the interiors of the author's creation, but also allows us to contribute to it adapting or enriching the model and the view according to our needs. We will illustrate this process by extending our simulation in the following way:

1. We will modify the model so that it includes both friction and an external force, turning our originally free spring into a forced, damped oscillator. The resulting second order differential equation is:

$$\ddot{x} = -\frac{k}{m}(x-l) - \frac{b}{m}\dot{x} + \frac{1}{m} f_e(t) \tag{1.2}$$

   where b is the so-called coefficient of dynamic friction and $f_e(t)$ is an external force applied to the system. We'll use in particular an oscillatory force of the form $f_e(t) = A\,\sin(\omega\, t)$, that allows us to explore interesting phenomena such as resonance.

2. We will modify the view so that it also displays a diagram of the phase space; that is, of velocity versus displacement.

3. We will compute and plot the potential and kinetic energies of the system and their sum.

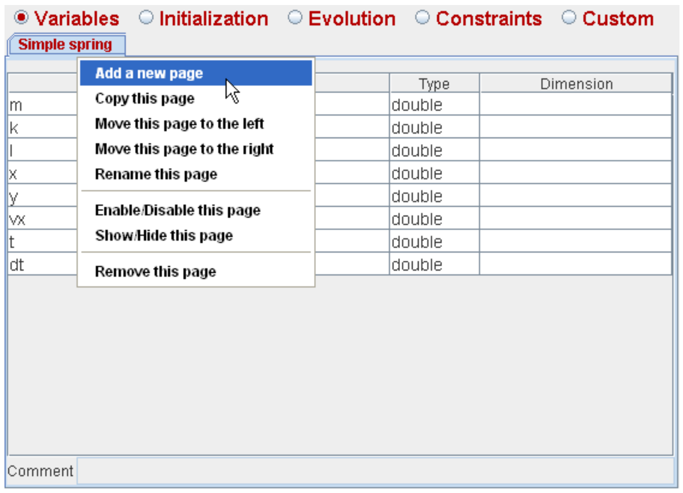
1.5.1 Modifying the model

We begin by modifying the model according to our new needs. Please select again, in *Ejs*' interface, the panel for the model and, inside it, the subpanel for variables. We are going to add some new variables to our model.

Even though we could simply add the new variables to the existing table, it is sometimes preferable, for clarity, to keep several separated tables of variables. This has only organizational purposes; actually, all variables can be used in exactly the same way, independently of the page in which they have been defined.

Adding new variables

Click with the right button on the upper tab of the page (where the label “Simple spring” is) and a popup menu will appear, as Figure 1.15 shows.



	Type	Dimension
m	double	
k	double	
l	double	
x	double	
y	double	
vx	double	
t	double	
dt	double	

Figure 1.15. Popup menu for the page of variables.

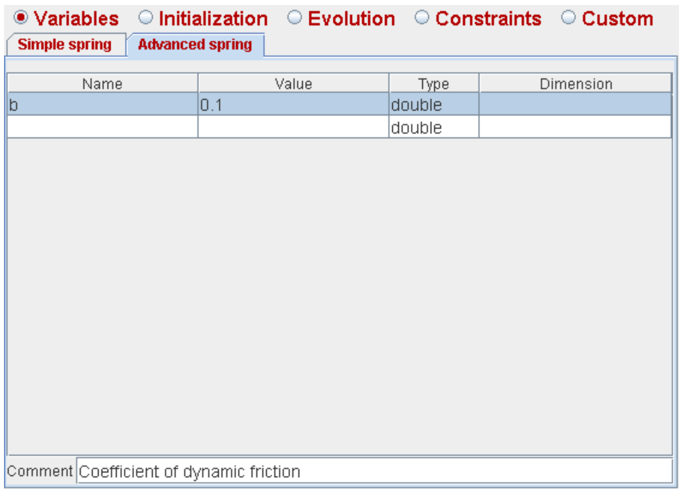
In this menu, select the “Add a new page” option (the one highlighted in the figure) and the program will add a new page with an empty table for variables. (*Ejs* will first prompt you for a name for the new page, you can choose, for instance, “Advanced spring”.)

In this new table, initially empty, click on the first (and only) cell of the column “Name” and type `b`. In the next column, “Value”, type `0.1`. This will be our coefficient of dynamic friction. You can write a comment about it in the text field situated at the lower part of the table. The table will look as in Figure 1.16.

In a similar way, please create new variables called `amplitude` and `frequency`, with values 0.2 and 2.0, respectively. Finally, create three new variables called `potentialEnergy`, `kineticEnergy` and `totalEnergy`, for the potential and kinetic energy and their sum, respectively. Do not assign to these variables any initial value (we’ll soon see why this is not necessary).

You can comment all these variables, if you want to do so. The final result can be seen in Figure 1.17. [8]

[8] Do not worry about the extra blank row at the end of the table, *Ejs* ignores it. But it you want, you can delete this empty row by right-clicking on it and selecting the option “Remove this variable” from the popup menu that appears.



Name	Value	Type	Dimension
b	0.1	double	
		double	

Comment Coefficient of dynamic friction

Figure 1.16. Adding the coefficient of dynamic friction `b` to our model.

Modifying the equations of the evolution

Let's go now to the evolution page and edit the right-hand side of the second differential equation so that it reads now:

```
-k/m*(x-l) - b*vx/m + externalForce(t)/m
```

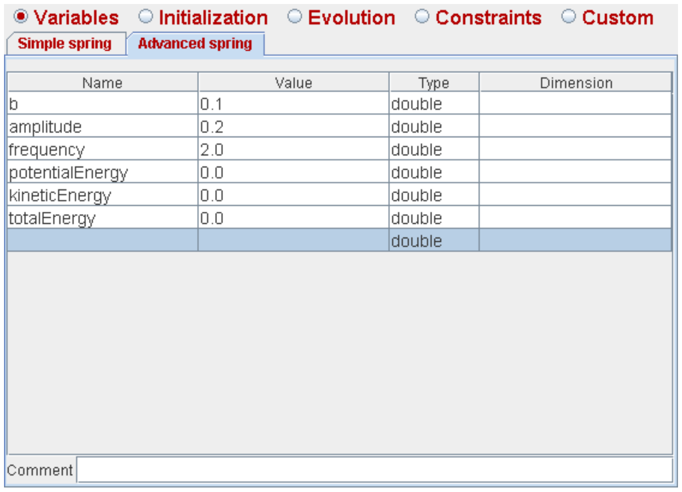
The result is shown in Figure 1.18. Notice that we are using in this expression the method `externalForce()`, that is not yet defined. We'll need to create it as a custom method, when we get to this panel.

Adding the computation of the energy

But, before this, select the subpanel for the constraints. Click on the message "Click to create a new page" and give the new page the name "Energies". In the editor that appears, write the following code:

```
potentialEnergy = 0.5*k*(x-l)*(x-l);
kineticEnergy = 0.5*m*vx*vx;
totalEnergy = potentialEnergy + kineticEnergy;
```

Please, play special attention and copy this code *exactly* as it appears above! (The multiplication character "*" and the semicolon ";" are particularly easy to forget.) Compilers of computer languages are inflexible concerning syntax errors. Any small mistake when typing the code can result in the compiler issuing a (sometimes very



Name	Value	Type	Dimension
b	0.1	double	
amplitude	0.2	double	
frequency	2.0	double	
potentialEnergy	0.0	double	
kineticEnergy	0.0	double	
totalEnergy	0.0	double	
		double	

Comment

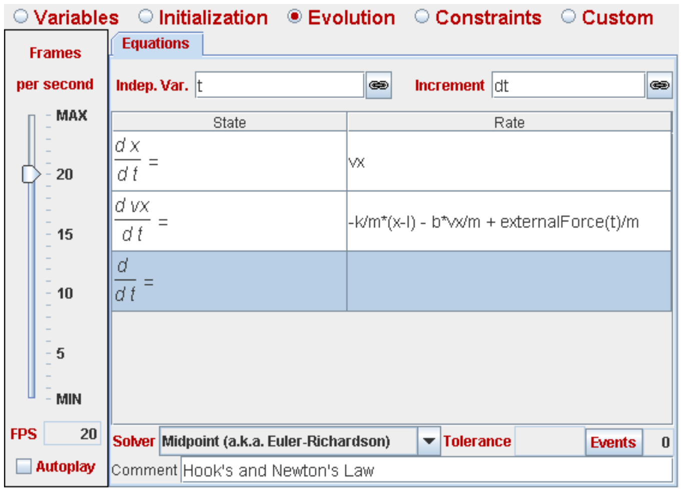
Figure 1.17. The complete table for the new variables.

long) sequence of error messages. The appendices (which are distributed separately from this manual, visit `http://fem.um.es/Ejs`) include some instructions to understand these messages but, for the moment, we will assume that you copied this code correctly. The result (once we add a short comment to this page) is shown in Figure 1.19.

This is the first time that we use constraints. You may remember that we defined the constraints as “fixed relationships among variables”. In our model, the potential and kinetic energy respond to the expressions $E_p = \frac{1}{2}kx^2$ and $E_k = \frac{1}{2}m{v_x}^2$. The code we wrote above is the translation of these equations to Java code.

Now comes a subtle point. One of the questions most frequently asked by new users of *Ejs* is: “why don’t we write these equations into a page of the evolution, instead of one of constraints?” The reason is that this relationship among variables must *always* hold, even if the evolution is not running. It could very well happen that the simulation is paused and the user interacts with the simulation to reposition the ball. If we write the code to compute the energy in the evolution, the values for the energy will not be properly updated, since the evolution is not evaluated (because the simulation is not playing). To prevent this situation we need to write these equations in a constraint page.

Constraint pages are always automatically executed after the initialization (at the beginning of the simulation), after every step of the evolution (when the simulation is playing) and each time the user interacts with the simulation. Therefore, any relationship among variables that we code in here, will always be verified.



Indep. Var. t   Increment dt

State	Rate
d x / d t =	vx
d vx / d t =	-k/m*(x-l) - b*vx/m + externalForce(t)/m
d / d t =	

Solver Midpoint (a.k.a. Euler-Richardson)   Tolerance

Comment Hook's and Newton's Law

Figure 1.18. The new differential equations of the model.

Coding the external force

Recall finally that, to complete our model, we still need to specify the expression for the external force. [9] To this end, go to the “Custom” subpanel and click on it to create a new page called “External force”.

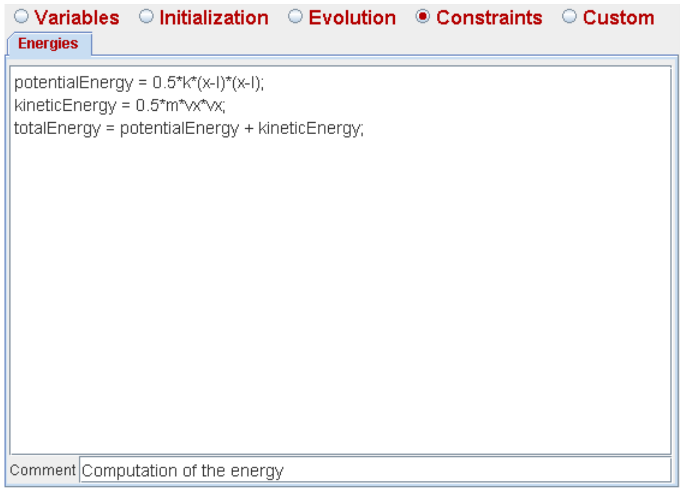
The new page will be created with the code necessary to create a standard method. Edit this code to read as follows (see also Figure 1.20):

```
public double externalForce (double time) {
  return amplitude * Math.sin(frequency*time);
}
```

This code illustrates the syntax for a method that returns a (double precision) numeric value. (The expression `Math.sin` corresponds to a call to the sine function of the mathematical library of Java.) Notice that this method accepts a parameter, `time`, that can be used as another variable inside the body of the method (`time` is then called a local variable), and that it uses the (global) variables `amplitude` and `frequency`. The use of the parameter `time` is important; it would be a mistake to define the method as follows:

```
public double externalForce () {
  return amplitude * Math.sin(frequency*t);
}
```

[9]Even when we could have written the expression for this force directly in the corresponding cell of the differential equation, it will be simpler for our students or users to interpret the model if we write it separately.



```
potentialEnergy = 0.5*k*(x-l)*(x-l);
kineticEnergy = 0.5*m*vx*vx;
totalEnergy = potentialEnergy + kineticEnergy;
```

Comment: Computation of the energy

Figure 1.19. Constraint equations for the computation of the energy.

which uses directly the global variable `t`. This is incorrect because `t` is a variable that changes during the process of solution of the differential equation (while `amplitude` and `frequency` do not), and this affects the precision of the numerical algorithm for the solution. Thus, as a general rule, we must state that:

> If a global variable can change during the resolution of a differential equation, this variable must be included as one of the parameters sent to any method called from the cells of the equation editor.

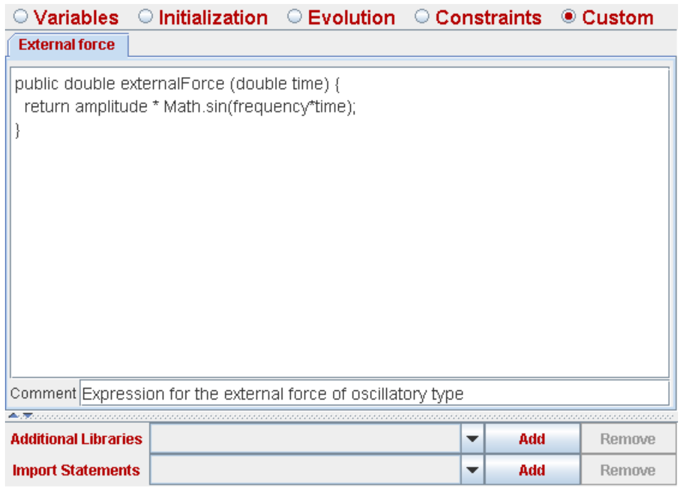
This is exactly what we did. Our new model is ready.

> You will notice in Figure 1.20 that the "Custom" panel of the model includes some extra controls at its bottom. Although *Ejs* tries to provide all the programming tools that a typical user may need, experienced Java programmers may always want to go a step further and, for example, reuse any previous Java code or libraries that they may have created previously. These controls allow just this, as will be explained in detail in Section 2.7.

1.5.2 Modifying the view

Lets us now enrich the visualization of our phenomenon with the graph of the phase space, velocity versus displacement. For this, select the panel for the view and, in the right-hand frame, from the upper set of elements called "Containers", click on the icon for "PlottingPanel", . [10] When you click on it, the icon will be highlighted

[10]If you doubt about which icon is the right one, place the cursor over it and wait a second until a tip appears revealing the type of the element selected and displaying a brief description of it.



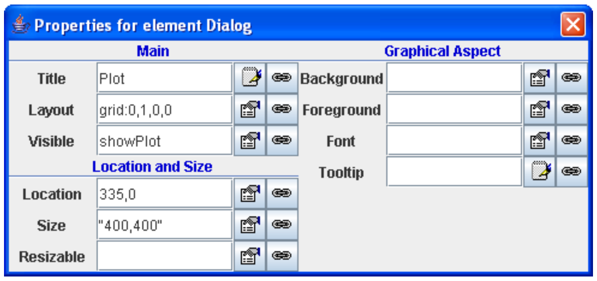
```
public double externalForce (double time) {
  return amplitude * Math.sin(frequency*time);
}
```

Comment: Expression for the external force of oscillatory type

Figure 1.20. Custom method with the expression for the external force.

with a colored background and the cursor will change to a magic wand, . With this wand, go to the tree of elements and click on the element called `Dialog`. You are then asking *Ejs* to create an element of type "PlottingPanel" inside the window `Dialog`. This window is prepared to accept this type of "children".

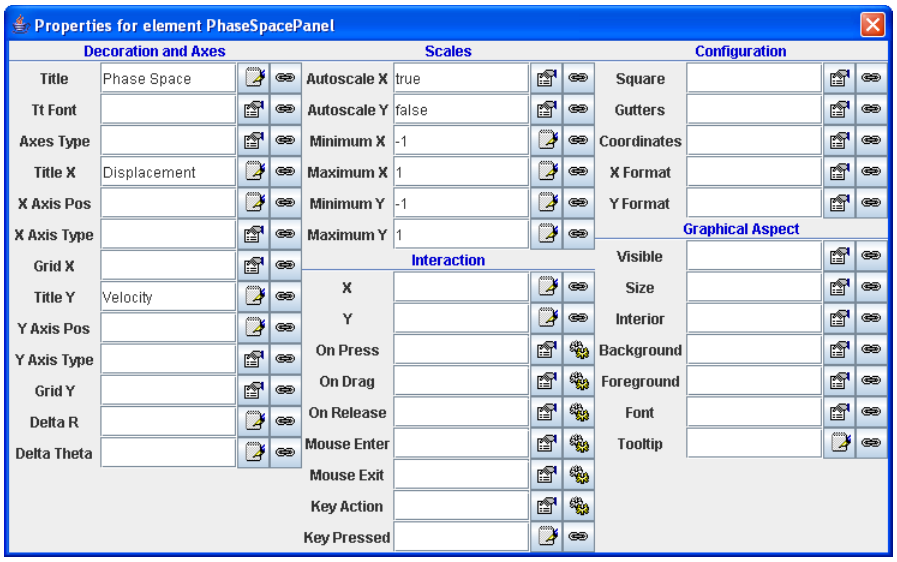
When you do this (give the new element the name `PhaseSpacePanel`), a new panel with axes will appear inside the window with the plots, sharing the available space with the previous plotting panel. Get rid of the magic wand by clicking with it on any blank space of the tree of elements' frame. Then, since both plotting panels (the old and the new one) look too small, double-click on the tree element called `Dialog` to bring-in its property editor and modify the one called "Size", changing it from the current value of `400,200` to the value `400,400` (it may also appear as `‘‘400,400’’`), thus doubling its height. The table of properties for this dialog window will look as in Figure 1.21.



Title	Plot	Background	
Layout	grid:0,1,0,0	Foreground	
Visible	showPlot	Font	
Location	335,0	Tooltip	
Size	"400,400"		
Resizable			

Figure 1.21. Properties for the dialog window.

Edit now the properties of the new element `PhaseSpacePanel` so that they appear as in Figure 1.22.



Properties for element PhaseSpacePanel

Decoration and Axes

Title	Phase Space
Tt Font	
Axes Type	
Title X	Displacement
X Axis Pos	
X Axis Type	
Grid X	
Title Y	Velocity
Y Axis Pos	
Y Axis Type	
Grid Y	
Delta R	
Delta Theta	

Scales

Autoscale X	true
Autoscale Y	false
Minimum X	-1
Maximum X	1
Minimum Y	-1
Maximum Y	1

Interaction

X	
Y	
On Press	
On Drag	
On Release	
Mouse Enter	
Mouse Exit	
Key Action	
Key Pressed	

Configuration

Square	
Gutters	
Coordinates	
X Format	
Y Format	

Graphical Aspect

Visible	
Size	
Interior	
Background	
Foreground	
Font	
Tooltip	

Figure 1.22. Properties for the element `PhaseSpacePanel`.

Notice that, when you type on the text field of a property to modify it, the background color of the field turns yellow. This is *Ejs*' way of telling you that the value won't be accepted until you hit the "return" key. In this very moment, the background will turn white again. For this reason, never leave any field with the yellow background!

An exception to this rule are the fields of action properties. These fields are special: any edition on them is automatically accepted, and they only change color (to a sort of light green) to warn you that they span more than one line. These editors can obviously be left colored.

The window with the plots will finally look as in Figure 1.23.

Adding the graph of velocity versus displacement

The plotting panel we added is only the container for the graph we want to add. The graph is visualized using an element of the type called "Trace", with icon , which you can find on the subpanel of drawing elements (or "Drawables") called "Basic".

Click on this icon to select it and to get the magic wand again, and use it to create an element of this type, named `PhaseSpace`, inside `PhaseSpacePanel`. Once you do this, edit the properties of the new element and give to its properties "X" and "Y" the values `x-l` (recall `l` is the length of the spring at rest) and `vx`, respectively.

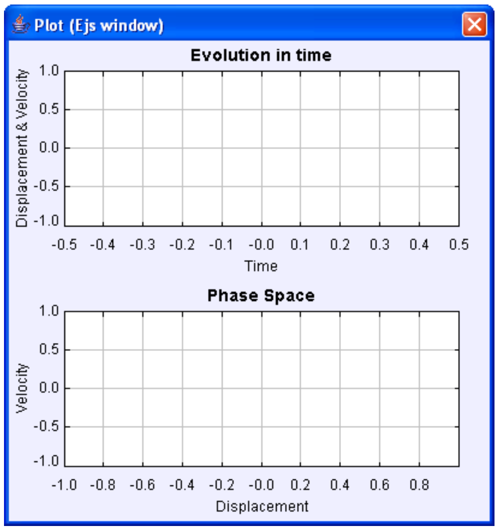


Figure 1.23. Dialog window with two plotting panels.

This is all we need to do to display the phase space graph.

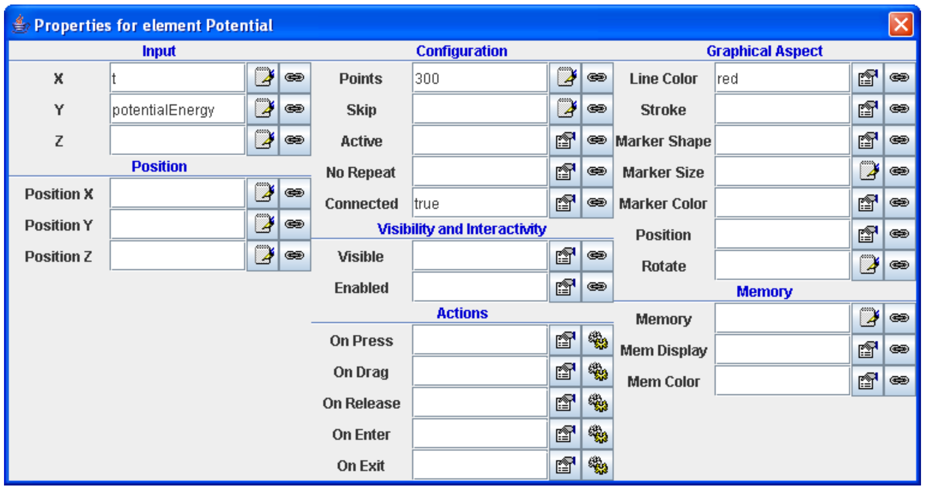
As this example shows, the value of a property can also be specified using an expression in which one or more variables of the model appear. In this case, however, the bi-directionality of the connection between model variables and view properties is lost, it only works in the obvious direction.

Plotting the energy

The process we carried out for the phase space graph is very similar to what we need to do to display a graph of the three energies we computed in the model. Create another plotting panel, called `EnergyPanel`, in the `Dialog` window and increase again the vertical size of this window (changing the “Size” property to `400,600`). Edit the new panel and change the property “Title” to `Evolution of the energy`, and the properties “Title X” and “Title Y” to `Time` and `Energy`, respectively. Leave the other properties as they appear originally.

Use the magic wand to create three elements of type “Trace” called `Potential`, `Kinetic` and `Total`, inside `EnergyPanel`. Edit the properties of these three traces associating the property “X” to the variable `t` in all three cases, and the property “Y” to the variables `potentialEnergy`, `kineticEnergy` and `totalEnergy`, respectively.

Additionally, for all three traces, type the fixed value `300` in the field for the property called “Points” (this value indicates that the traces should only display the last 300 points of data they have received) and choose a different value for the property called “Line Color” of each of the traces, so that you can distinguish the graphs. To obtain a panel with the available colors, click on the icon immediately to the right of the text field for this property. We chose (for no particular reason) the color red for the potential energy, green for the kinetic energy and blue for the total energy. As an example, Figure 1.24 shows the panel of properties for the element `Potential`.



Properties for element Potential

Input

X	t
Y	potentialEnergy
Z	

Position

Position X	
Position Y	
Position Z	

Configuration

Points	300
Skip	
Active	
No Repeat	
Connected	true

Visibility and Interactivity

Visible	
Enabled	

Actions

On Press	
On Drag	
On Release	
On Enter	
On Exit	

Graphical Aspect

Line Color	red
Stroke	
Marker Shape	
Marker Size	
Marker Color	
Position	
Rotate	

Memory

Memory	
Mem Display	
Mem Color	

Figure 1.24. Properties of the trace `Potential`.

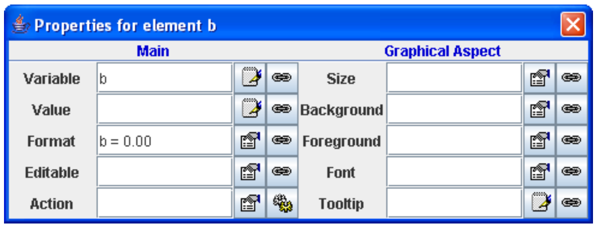
Displaying the new parameters

Finally, we will add new elements of the type “NumberField” so that the user can visualize and edit the values of the variables `b`, `amplitude` and `frequency`. They will be located below those already existing for the mass and the elastic constant of the spring.

You can find this type of element, with icon , in the “Display” tab of the “Basic” central panel of the right frame. Select this icon and, with the magic wand, click on the element of the tree called `LowerPanel` to create three new elements with names identical to the variables we want to display, that is, `b`, `amplitude` and `frequency`. This coincidence on names doesn’t cause any problem. Names of variables in the model must be unique, but they do not conflict with similar names for the elements of the view.

We must finally edit the properties of these elements so that they fulfill their work. We’ll show you how to do this for the first of them. Bring the panel of properties for the new element `b` into view and edit the properties as in Figure 1.25.

The association of the property “Variable” with the variable of the model `b` tells



Properties for element b

Main		Graphical Aspect	
Variable	b	Size	
Value		Background	
Format	b = 0.00	Foreground	
Editable		Font	
Action		Tooltip	

Figure 1.25. Properties for the number field for `b`.

the element that the value displayed or edited in this field is that of `b`. The property called "Format", to which we assigned the value `b = 0.00`, has a special meaning. It doesn't indicate that `b` should take the value of 0, but is interpreted by the element as an instruction to display the value of `b` with the prefix "b = " and with two decimal digits (hence the value 0.00).

That's all, do the same for the other two number fields, associating the same properties to `amplitude` and `amp = 0.00`, and to `frequency` and `freq = 0.00`, respectively. To facilitate the association of properties with variables of the model, you can use the icon 🔗 that appears to the right of the text field for the corresponding property. If you click on this icon, a list of all the variables of the model that can be associated to this property will be offered to you. You can then comfortably select the one you want with the mouse.

1.5.3 An improved laboratory

Our simulation is now ready! This is a perfect moment to save our changes. [11] Because we don't want to overwrite the original simulation (we may be interested in preserving it), we will save this new one in a different file. Click then on the "Save as" icon of *Ejs*' taskbar. A dialog window will appear as shown in Figure 1.26, that will allow you to chose the name of the file for the new simulation.

Type the name **MySpringAdvanced.xml** in the field called "File Name" and click the "Save" button of this dialog window. *Ejs* will then save the new file and will notify you in the message area.

We can now run the simulation. Click the "Run" icon and you will obtain results similar to those of Figure 1.27.

We have thus created a complete laboratory to explore the behavior of simple harmonic motion plus damping and external forces. You can use this laboratory with

[11] Actually, we should have done this earlier. If you are used to work with computers, you'll know that they have the bad habit of stopping (*hanging* is the slang word for this) with no apparent reason and with no previous warning. We therefore recommend you to learn to save your work from time to time.

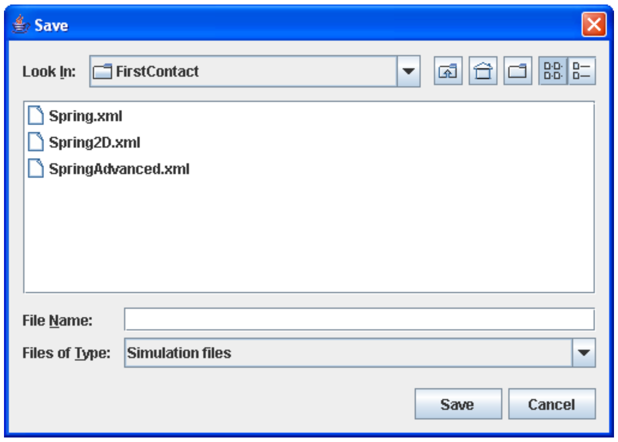


Figure 1.26. Saving our simulation.

your students to explore interesting phenomena such as resonance (try a value for the frequency close to $\sqrt{k/m}$). Besides the file **MySpringAdvanced.xml** that you just created, you will find this simulation in the **_examples/Manual/FirstContact** directory, with the name **AdvancedSpring.xml**.

Modifying the introduction

You might want to modify now the introduction for the simulation. Select the panel for the "Introduction" and add a new page or edit the existing ones. Use for this the popup menu for each page and select the option "Edit/View this page". A simple visual editor for HTML pages will then appear to help you edit the HTML code. See Figure 1.28.

HTML pages are text pages that include special instructions, or tags, that allow Web browsers to give a nice format to the text as well as to include several types of multimedia elements. The editor allows you to work in a WYSIWYG (what you see is what you get) mode. However, if you know HTML already and want to work directly on the code (which, sometimes, is preferable), select the option that appears highlighted in Figure 1.28.

You can write as many introduction pages as you want. As we saw earlier, each of the pages will turn into a link in the main HTML page that *Ejs* generates for the simulation. A second possibility is to delay until the last moment the edition of the introduction and, once the HTML pages have been generated by *Ejs*, copy the simulation and their pages to a different directory (for instance, that of the Web server from which they will be published) and modify them using your favorite HTML editor. If this is the option of your choice, we insist that you do this work in a directory other that **Simulations**. Otherwise, if you ever run your simulation

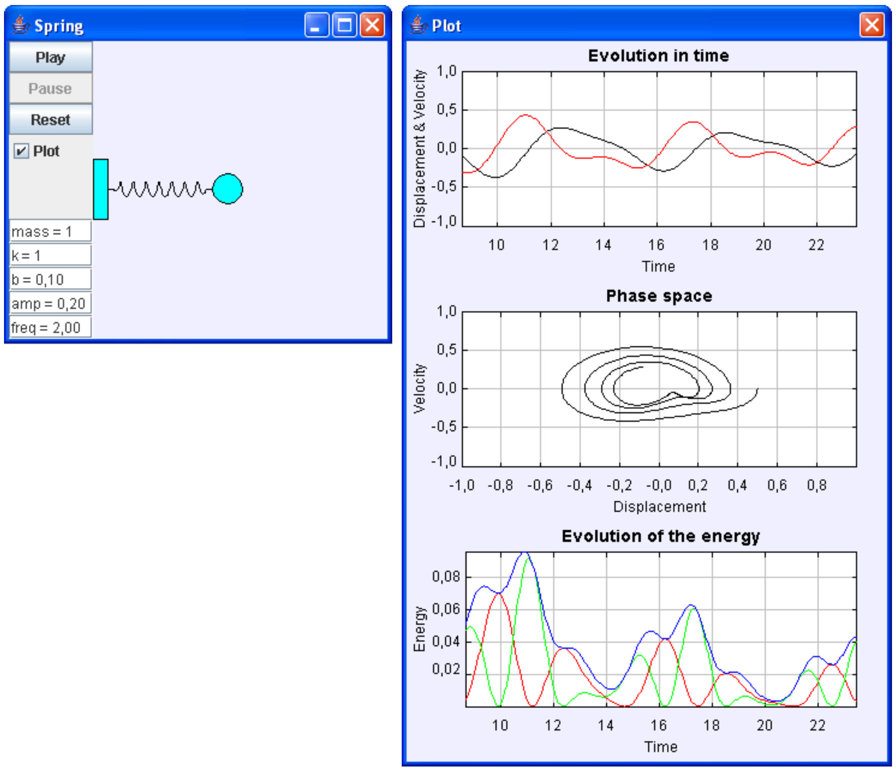


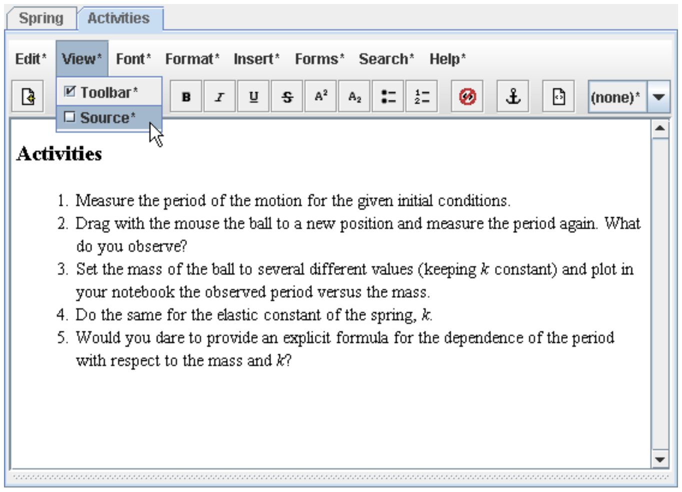
Figure 1.27. The improved simulation in action.

again from within *Ejs*, you will loose whatever edition you have made, because *Ejs* will overwrite the edited pages!

1.6 A global vision

We end this chapter taking an overview of what we did in it. We first learned to install and run *Easy Java Simulations*. Next, we loaded one of the examples included in the **_examples** directory and run it. We checked that, besides running the simulation as an independent Java application, *Ejs* also generates a complete set of Web pages, ready to be published, that contain the simulation in form of a Java applet. We then learned to distinguish and to explore the different parts that make a simulation, and, finally, we even modified these parts to improve the simulation, adding new functionality.

The three parts of a simulation are the introduction, the model and the view. Each of these parts has its function and its own panel in *Ejs*' interface with a particular look and feel.



Activities

1. Measure the period of the motion for the given initial conditions.
2. Drag with the mouse the ball to a new position and measure the period again. What do you observe?
3. Set the mass of the ball to several different values (keeping k constant) and plot in your notebook the observed period versus the mass.
4. Do the same for the elastic constant of the spring, k.
5. Would you dare to provide an explicit formula for the dependence of the period with respect to the mass and k?

Figure 1.28. Improving the introduction.

The introduction contains an editor for HTML code needed to create the multimedia narrative that wraps the simulation. We can create the pages we need with this editor, either working in WYSIWYG mode or writing directly the HTML code.

The model contains a series of subpanels needed for the specification of the different parts of it: definition of variables, initialization, evolution of the system, constraints or relationships among variables, and custom methods. Each panel provides edition tools that facilitate the job of creation.

Finally, the view contains a set of predefined elements that can be used as individual building blocks to construct a structure in form of a tree for the interface of our simulation. These elements, that are added through a procedure of click and create (our magic wand), have in turn a set of properties that indicate how each element looks and behaves, and that, when associated to variables from the model (or expressions that use them), turn the simulation into a true dynamic and interactive visualization of the phenomenon under study.

Well, and this is all! Though the chapter is a bit long because we accompanied the description with many details and instructions, the process can be summarized in the few paragraphs above. Obviously, learning to manipulate with fluency the interface of *Easy Java Simulations* requires a bit of practice, as well as the familiarization with all the possibilities that exist. In particular, with respect to the creation of the view, you'll need to learn the many several types of elements offered and what each of them can do for you.

The rest of this manual will give more information about all these possibilities. Also, the examples provided with *Ejs* are a great source of information. If you are anxious to start exploring our simulations and create your own ones, and if you think you got a sufficiently general overview of the way *Ejs* works (this was precisely the goal of this chapter), you can go directly to explore some examples, returning later to the other chapters of this manual when you need to improve your knowledge about *Ejs*.

Exercises

Exercise 1.1. Modify the example of the spring to remove the restriction that the motion is only horizontal. Introduce also a second external force along the Y axis of the form $A_2 \cos(\omega_2 t + \phi)$ (ϕ is the phase difference between both external oscillatory forces) and explore the different resulting motions.

Exercise 1.2. Include new elements of the type “NumberField” for the values of the velocities in X and Y for the simulation of the previous exercise. Modify the code for the “On Release” action of the ball to allow initial conditions that do not start from rest.

You'll find this exercise solved in the **_examples/Manual/FirstContact** directory with the name **Spring2D.xml**.

CHAPTER 2

Creating models

In this chapter we cover in detail the different parts that make the model of a simulation and explain the support that *Easy Java Simulations* offers for their implementation. This chapter can be considered as a complete reference for the use of the panel of *Ejs* for the description of the model.

2.1 Definition of a model

Let's start with a bit of theory. We create the model of a phenomenon when we define its relevant magnitudes, set their values at a given initial instant of time, and establish the rules that govern how these magnitudes change.

We use the term "magnitude" here to refer either to state variables (the variables that describe the state of the phenomenon), or to parameters, or to any other input or output quantities of the model. When we work with our simulation, we'll always refer to these magnitudes as *variables*.

Actually, a variable can hold a value that changes along the execution of the simulation or one that doesn't. In other words, it can represent a constant or variable magnitude, but this won't prevent us from using this terminology. [1]

[1]It is possible that a magnitude considered constant at one initial implementation, changes later, either because we change the model and the role that this variable plays in it, or because we allow

This way, the state of a model is completely determined by the value of its variables at a given instant of time. This state can change because of two reasons:

- The internal dynamics of the simulation, which we will call *evolution*.
- The influence of external agents. In our case (since we are using simulations that do not read data from the real world, for instance), because of the interaction of the user with the simulation, to changes the value of one or more of the variables of the model.

Changes directly caused by any of these reasons may cause other changes in an indirect way. This is actually the case when there exist variables in the model whose values explicitly depend on the values of those who where modified. In this situation, we say that there exist *constraints* among the variables affected.

All these changes are ruled by equations that describe the laws under which the evolution takes place, or that state the interdependence of the variables. These equations must be made explicit by using mathematical formulas or logical computer algorithms.

So, finally, in order to specify the model of a simulation, we need to establish:

- the variables of the model,
- their initial state,
- the evolution equations, and
- the constraint equations.

2.1.1 Variables and the initial state of a model

First of all, we need to **declare the variables** of our model. This is a crucial process from which a good or a bad simulation can result: we need to choose the right reference system, the magnitudes that allow us to write simpler formulas,...

In order to illustrate what follows, we will assume that the variables of our model are called $x_1, x_2, \ldots, x_n$. Obviously, if we want our model to be more easily understood, it is customary to give meaningful names to the variables, such as position, velocity, number of individuals of a species, concentration of a chemical element, etc., which are in turn simplified using easy to identify shorter acronyms. However, since our exposition is general, we will assume this naming mechanism with subscripts.

the user to interact with the simulation to modify the magnitude. Thus, the term variable turns out finally to be appropriate.

In the second place, we need to set the initial state by giving the right value to each of the variables. This can be done, in the majority of cases, by simply typing the desired value. In occasions, however, the initial value of some variables can only be obtained by making some previous computations. We call this process (by either of both methods) **initializing the model**.

2.1.2 Evolution equations

Continuing with the terminology introduced above, the system can evolve in an autonomous way from the current state, $x_1, x_2, \ldots, x_n$, to a new state $x_1^*, x_2^*, \ldots, x_n^*$, thus simulating the passing of time (which, by the way, can or cannot be one of our variables—although it frequently is). We call the equations that rule this transition *evolution equations*, which can be written using one or more expressions of the form

$$x_i^* = f_i(x_1, x_2, \ldots, x_n) \tag{2.1}$$

Sometimes, these laws have a direct mathematical formulation, as in the case of the so-called discrete systems. In other situations, they derive from the discretization of continuous models which are described by differential equations. In many cases, however, the formulation (2.1) (so typically mathematical) requires of a combination of numerical techniques and of logical algorithms that conforms an elaborated computer algorithm.

But, as a conclusion, we will state that simulating the evolution in time of the model consists in computing, from the current state $x_1, x_2, \ldots, x_n$, the new values $x_1^*, x_2^*, \ldots, x_n^*$, take these as the new state of the model, and iterate this process indefinitely while the simulation runs.

Thus, the third step that we need consists in **writing the evolution equations**.

2.1.3 Constraint equations

The last step consists in **writing the constraint equations**. As we mentioned above, changes in the variables directly caused by evolution equations can have indirect effects on other variables. This indirect changes are determined by what we will call constraint equations, which can be made explicit by one or more of expressions of the form

$$x_i = g_i(x_1, x_2, \ldots, x_{i-1}, x_{i+1}, \ldots, x_n) \tag{2.2}$$

where, as you can see, a variable should only appear at one side of the equation.

These expressions indicate that, if one or several of the variables on the right-hand side change, then equation (2.2) must be evaluated so that the variable on the left is consequently modified. Similarly to evolution equations, this theoretical formulation can require in practice the need to write a sophisticated algorithm, partially logical, partially numerical.

It is a common temptation to consider constraint equations as part of the evolution. That is, if the changes are caused primarily by the evolution,. . . why not include these relationships as part of it?

That would be, however, a bad practice. The reason is that there is a second source for changes, namely the direct interaction of the user with the simulation. Indeed, if constraints interrelationships among variables must always be valid, then they should also hold when the user changes any of these variables, even if the simulation is paused (that is, if the evolution is not taking place). For this, it is convenient to identify clearly and to write separately both types of equations. This will allow the computer to know which equations it must evaluate in each case (see Subsection 2.1.4 below).

A useful (though perhaps not always valid) criterion to distinguish both types of equations is to examine the expression we use to compute the value of a variable at a given instant of time and, if this value depends on the current value of the same variable, then this is most likely an evolution equation. If, on the contrary, the value of the variable can be computed exclusively from the value of other variables, then it is a constraint.

2.1.4 Running the model

Once we complete the four steps described above, the model is precisely defined. If we now run the simulation, the following events will take place: [2]

1. The variables are created and their values set according to what the initialization states.

2. The constraint equations are evaluated, since the initial value of some variables may depend on the initial values of others.

   In this moment, the model is found to be in its initial state, and the simulation waits until an evolution step takes place or the user interacts with it.

3. In the first case, the evolution equations are evaluated and, immediately after, the constraints. A new state of the model at a *new* instant of time is then reached.

4. In the second case, when the user changes a variable, constraint equations are evaluated and we obtain a new state of the model at the *same* instant of time.

[2]See, however, the more complete description, which includes the view, in Section 3.3.

A coherent model should take care that there exist no contradictions among their different parts. In particular, the values given to a variable during the initialization or the evolution should not be different to what it results from any constraint that affects this variable. However, if this actually happens, *Ejs* will solve the contradiction by giving always priority to (that is, evaluating in the last place) the constraint.

Because of the multitasking form in which simulations are run in *Ejs*, it is possible that the user interacts with the simulation right when it is in the middle of one evolution step. Although this doesn't necessarily need to be bad in itself, it can occasionally produce undesired effects, such as the change of the value of a parameter in the middle of an algorithm. In these situations, it is preferable to ask the user to pause the simulation (using a control that allows him/her to do this) before interacting with it.

This is the scheme, simple but effective, that *Ejs* uses for the creation of the model of our simulations.

2.2 Interface for the model in *Easy Java Simulations*

Let us now describe the structure that *Ejs* provides for this task. The panel in *Ejs* dedicated to the creation of the model displays five radio buttons (see Figure 2.1), one for each of the four steps described in the previous section, plus an extra one, labeled "Custom", whose use will be explained in Section 2.7.

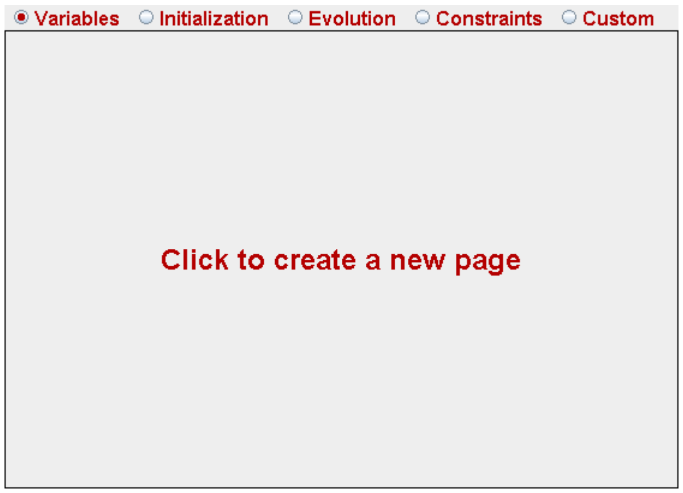
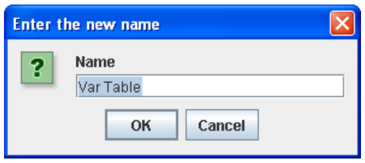


Figure 2.1. Panel of *Easy Java Simulations* for the model.

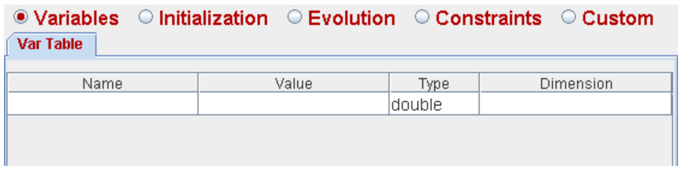
Each radio button allows us to visualize the corresponding subpanel in the central working area of *Ejs*. The aspect of these subpanels is, in principle, rather similar, displaying a message that invites us to create a new page. If you click on this message, the system will effectively create a new page, asking first for a name for it, as Figure 2.2 shows. Although *Ejs* always proposes a generic name for the new pages, we recommend that you use descriptive names for them. You can type any name you want, with no restrictions. The only recommendation is that these names are different and not too long.



Var Table

Figure 2.2. Asking for the name of a new page.

Once you type the new name and click "Ok", a new page will appear. The aspect of this page depends on the subpanel you are working on. Figure 2.3 shows a partial view of a new page for variables.



Name	Value	Type	Dimension
		double	

Figure 2.3. Partial view of a new page for variables.

Notice that the new page has a header tab with its name on it. This system of tabs is very convenient to organize the pages when there are more than one in a panel. The reason to create several pages in the same panel is just to group variables or algorithms with similar purposes or meaning in separated pages, thus helping clarify the model. *Ejs* actually uses all these pages in the same way, processing them from left to right.

Each page offers an option popup menu that appears right-clicking the mouse on its header tab. See Figure 2.4.

You can use the options in this menu to create a new empty page for this panel, to copy, rename or remove the current one, or to change the order of the pages. There are finally two other options that require a small explanation.

The option to enable and disable the page can be used when we want *Ejs* not to use a page that we have created, but without removing it. This can be useful when we are testing different algorithms for the same model and we want to compare them by enabling and disabling them in turns.

On the other hand, the option to show and hide a page is used (very rarely, that's the truth) for pedagogical reasons, when the author wants to hide pages with

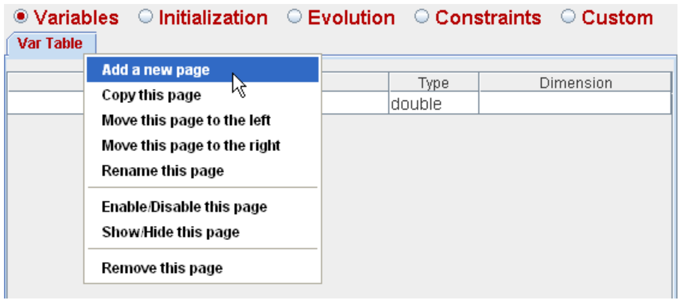


Figure 2.4. Popup menu for a page.

difficult to understand algorithms that (s)he doesn't want to expose the students to, at least in a first approach. The "Options" icon (see also Subsection 4.3) in *Ejs*'s taskbar offers the possibility of making completely invisible the pages defined as hidden. Later on, when the students are ready to understand the pages, the author can ask them to use this option to make them visible again.

When any of these two options is used, the name on the header tab will append a letter between parentheses indicating the status of the page, (D) for disabled, (H) for hidden. Disabled pages are ignored by *Ejs* when it generates the simulation. Hidden pages, on the contrary, are perfectly valid.

This way of working is common to all subpanels, the rest of the chapter describes each of these subpanels in more detail.

2.3 Declaration of variables

Let's start with the first step of the creation of a model: the declaration of variables. Variables are easy to define, we just need to give them a valid name, specify the *type* of each of them and, for the case of arrays (vectors or matrices), also specify their *dimension*. Optionally, we can also give an initial value to each variable. Let us describe each of these points in detail.

2.3.1 Types of variables

Even when in mathematical formulas we frequently use the so-called real numbers (integers, rationals and irrationals) [3] without distinguishing among them, when we write a computer program we do make distinctions among different types of variables,

[3]In some problems we may use complex numbers. However, Java doesn't support them natively, hence any computation with complex numbers must be done accessing explicitly the corresponding real and imaginary parts of the numbers.

depending on the use we plan to do of them and on the computer memory required to hold their possible values.

Thus, for instance, variables that will only hold integer values require considerably less memory and the computations that involve only integer numbers perform faster because modern computers implement optimized routines for integer arithmetic.

Java language implements the following basic types of variables:

- `boolean`, for variables of boolean type, that is, those which can hold only two values: `true` or `false`.
- `byte`, `short`, `int`, and `long`, for integer values.
- `float` and `double`, for the so-called floating-point numbers (what we would call real numbers).
- `char` and `String`, for characters and texts, respectively.

As an object-oriented programming language, Java introduces also a new type called `Object` as the basis of a whole new world of advanced constructions called classes.

Nevertheless, except in the occasions in which it is absolutely essential to do the computations using the minimal possible type of variable so that to optimize memory usage, we can choose to work only with the standard type for each category. This will be our case, and *Ejs* will only make use of variables of types `boolean`, `int`, `double`, `String`, and (to open the world of object-orientation) `Object`.

Although *Ejs* was not designed as a tool for professional programmers, it leaves a door open for them to use directly object-oriented constructions by accepting also variables of type `Object`. These can also be used for simple, still useful, things, such as to create colors (objects of the class `java.awt.Color`) that change along with the state of the model.

2.3.2 Creation of variables

Each new page of the panel labeled “Variables” contains a copy of the editor for variables, that takes the form of a table. See Figure 2.5.

To add a variable, we write its name in the first column of the edition row and select its type using the selector of the third column. If we want to give the variable an initial value, we only need to type it in the corresponding column. On the lower part of the editor there exists also a comment field in which we can type a short description of the role the variable plays in the model. This can be useful to facilitate the comprehension of the model.

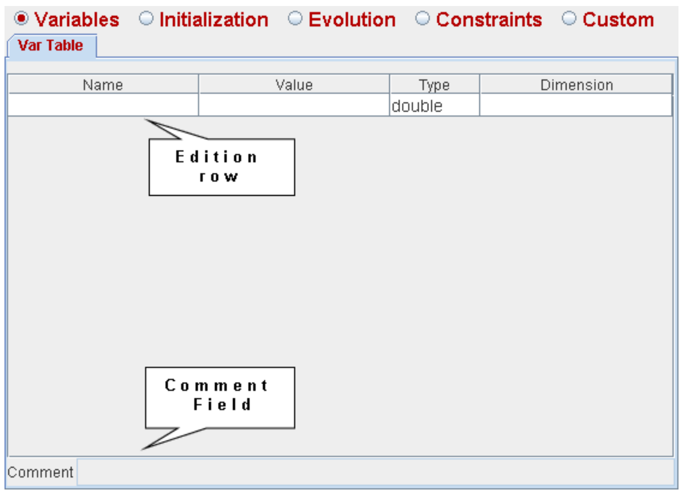


Figure 2.5. Table for the edition of variables (with annotations).

If the variable is an array, [4] we must indicate its dimension as well. *Ejs* can work both with simple and multidimensional variables. If the field of the "Dimension" column is left empty, then a simple variable will be created, that is, just one variable of the given type. If, on the contrary, we type in this field one or more integer numbers (it's important that these numbers are integer!) between square brackets, then *Ejs* will create a set of variables of the given type, where each of the numbers among square brackets indicates a dimension.

Hence, for instance, if we type `[50]` in this field, *Ejs* will create a unidimensional array (or vector) with 50 coordinates, reserving memory space for 50 individual variables of the type indicated. If we write `[10][100]`, it will create a two-dimensional matrix of 10 rows, each of them with 100 elements. The integer number used to indicate a dimension can be either a constant or a variable of type `int` that has been previously defined.

It is important to notice that, if a dimension of an array is indicated using an integer variable, the array will be created using (for the corresponding dimension) the value that the variable holds at the moment of the initialization of the array. Any later change in the value of the variable will not directly affect the dimension of the matrix.

Each time you create a new variable, a new edition row will automatically appear to accept more variables. But we can also insert a variable between two existing ones using the popup menu for each row (different from the popup menu for the page) that appears when you right-click on the corresponding row. The options of this menu can be seen in Figure 2.6.

[4] We use the term array to refer both to vectors and to matrices of any number of dimensions.

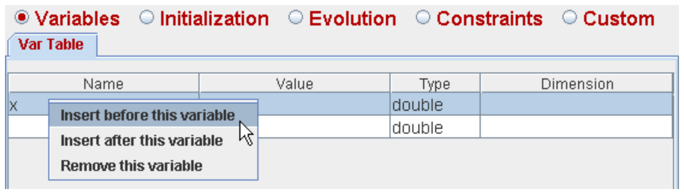


Figure 2.6. Pop-up menu for each variable.

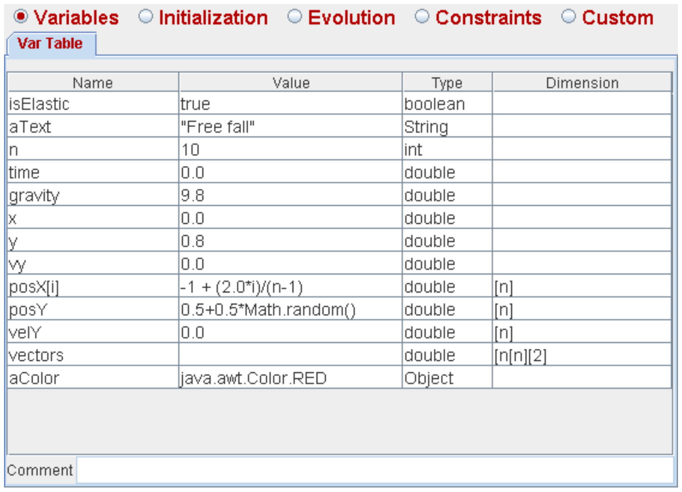
2.3.3 Initial value for a variable

A variable can be initialized writing a constant value or a simple expression in the corresponding field of the "Value" column. By default, *Ejs* gives each variable a default (zero for numeric variables) value, which we can then edit. This is not mandatory, though, and we can even leave this field empty. In this case, we will need to initialize the variable in the initialization panel (see Section 2.4) or as a result of a constraint.

If we provide an initial value for an array, all the elements of the array will be initialized to the same value. If we want to provide a different value to each of the elements of an array, usually a value that is an expression of the index of each element, we must explicitly include the index or indexes in the name of the variable and use them in the expression for the value.

Thus, for instance, the definition of the following variables will appear in the editor as in the table of Figure 2.7.

- `isElastic`: boolean, simple, initialized to `true`.
- `aText`: variable of type String, simple, initialized to "Free fall" (double-quotes are mandatory!).
- `n`: integer, simple, initialized to 10.
- `time`, `gravity`, `x`, `y`, and `vy`: double precision real variables, simple and initialized to 0, except `gravity` and `y`, which are initialized to 9.8 and 0.8, respectively.
- `posX`, `posY` and `velY`: unidimensional arrays (vectors) of `n` (that is, 10) elements of double precision, initialized to equally spaced values from -1 to +1 the first one, and with random values between 0.5 and 1 the second.
- `vectors`: three-dimensional matrix with 10 rows, each with 10 cells and each cell with 2 elements of type `double`, not initialized.
- `aColor`: An object, simple, initialized to the predefined (by Java) color red.



Name	Value	Type	Dimension
isElastic	true	boolean	
aText	"Free fall"	String	
n	10	int	
time	0.0	double	
gravity	9.8	double	
x	0.0	double	
y	0.8	double	
vy	0.0	double	
posX[i]	-1 + (2.0*i)/(n-1)	double	[n]
posY	0.5+0.5*Math.random()	double	[n]
velY	0.0	double	[n]
vectors		double	[n[n][2]
aColor	java.awt.Color.RED	Object	

Comment

Figure 2.7. Sample declaration of variables.

Notice in particular the expression that uses the function `random()` from Java mathematical library (see Section 2.7) and the form in which the elements of the array `posX` are initialized with equally spaced values from -1 to 1, using the ad-hoc variable `i`.

In the expression of the right-hand field for `posX`, we are using that the first element of an array in Java has the index 0, and the last one, the size of the array minus one. Also, it was necessary for us to write the expression `(2.0*i)` between parentheses to make sure that Java doesn't use integer arithmetic to evaluate this expression, which it does when it has the opportunity to, and that would result in values different to what we expect. Recall these two principles and you will save yourself some troubles!

With respect to the initial value of `aColor`, this example illustrates the use we can do of the (literally) hundreds of classes in Java. This manual doesn't try to teach you Java in all its extension, but this is actually one of the few classes that can be really useful for us, for instance, to make our objects change color dynamically. Once we have declared the variable this way, we can give `aColor` the value of the color we want using a sentence such as :

```
aColor = new java.awt.Color(255,0,0);
```

where the parameters of this invocation to the class `java.awt.Color` must be three integer numbers between 0 and 255 that indicate the levels of red, green and blue, respectively, for the color we want. In the case shown, the color created is, again, red. If you want to get semi-transparent colors (which is rarely really necessary and causes the computer to run slower), you can include a fourth parameter indicating the level of transparency.

2.3.4 Using the variables

When, later on, we want to use a simple variable in a Java expression, we only need to write its name. If we want to use an element of an array, we need to indicate which element we refer to. [5] For this, if the array is unidimensional, we write the name of the array and, between square brackets, an integer number that indicates the position of the element in the array. If the array has more than one dimension, we must specify as many integers between square brackets as needed.

> Once more, recall that the first element of an array has the index 0, and the last one, the size of the array minus one. Forgetting this (for many, a bit strange) way of numbering, is a frequent source of severe errors during the execution of a simulation. Thus, in the case shown above, trying to use the element `posX[10]` will cause what is known as an *exception*, that is, a long complaint of the Java virtual machine. This errors, unfortunately, are not detected during the compilation, which makes them even more of a nuisance.

Correct examples of use of the variables defined above are the following:

```
isElastic = false; time = 3.5; posY[0] = 1.0; posY[n-1] = 4.2;
vectors[9][9][1]=5.0;
```

while next ones are incorrect:

```
n = 1.5; x[0] = 0.1; posX[10] = 1.0; posY[0][0] = 1.0;
vectors[9][9] = 5.0;
```

2.3.5 Naming conventions

Along the process of creating the simulation, we will need to provide a name for several different elements of it: pages for the different panels, variables, custom methods (see Section 2.7) and elements of the view (Chapter 3).

Names for pages you create have no restrictions, since they are only used for organizational purposes. You can even use (if there is a good reason for it) the same name for different pages. But the names for the other elements do need to follow some rules in order to avoid conflicts among them (and to help keep clarity, as well). Thus, we will respect the following conventions:

1. The name of each variable or custom method must be unique in the model. The name of view elements must be unique in the view (even when it can coincide with a name used in the model).

[5] Java doesn't natively support matrix algebra.

2. Names are constructed by a combination of alphanumerical characters (from "a" to "z", from "A" to "Z", and from "0" to "9") with no limit of length. The first character must be alphabetical.

3. Although not strictly compulsory, the first character of the names of variables and of custom methods of the model will be lowercase. For view elements, on the contrary, the first character will be uppercase.

4. It is recommended to use descriptive names. If we need to write more than one word, there must be no blank spaces among them; words can be joined, for instance, by using uppercase for the first letter of the second and consecutive words. Thus, instead of `cm`, we will write `centerOfMasses`.

5. It is forbidden to use names that start with the character "_", since *Ejs* can use some such names for internal tasks.

Finally, the following words cannot be used because they are reserved words either by Java or by *Ejs*: [6]

Palabras reservadas: *boolean, break, byte, case, catch, char, continue, default, do, double, else, float, for, getSimulation, getView, if, import, initialize, instanceof, int, long, Object, package, private, public, reset, return, short, static, step, String, switch, synchronized, throws, try, update, void, while.*

2.4 Initializing the model

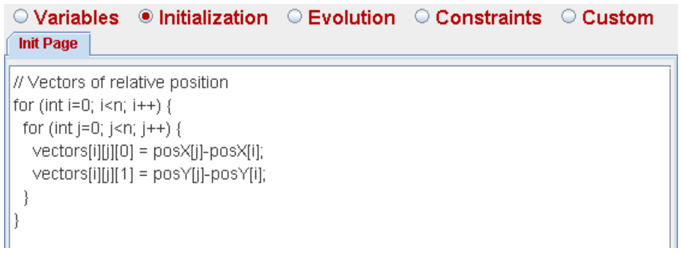
As we have seen in the previous section, we can initialize the variables of the model with constant values or with simple expressions, using the field in the column "Value" of the table of variables. However, we sometimes require initializations which are a bit more complex. For instance, if we want to give elaborated values to the elements of an array, or if we want to do some previous computations. In these situations, we can use the second of the subpanels of the model, "Initialization".

We can create in this panel one or more pages of an editor where we can write the Java code that does these computations. This code will be executed once, when the simulation starts. For instance, we can give values to the elements of the array `vectors` in the example above using the code shown in Figure 2.8. [7]

Although the algorithm we write in these pages can be as sophisticated as the problem requires, the process is rather simple in itself: just add as many pages as you wish and write in them the Java code you need. This code only needs to contain

[6]This list may grow as new releases of Java introduce new features.

[7]This code is not actually very interesting in itself. It is included only for illustrative purposes.

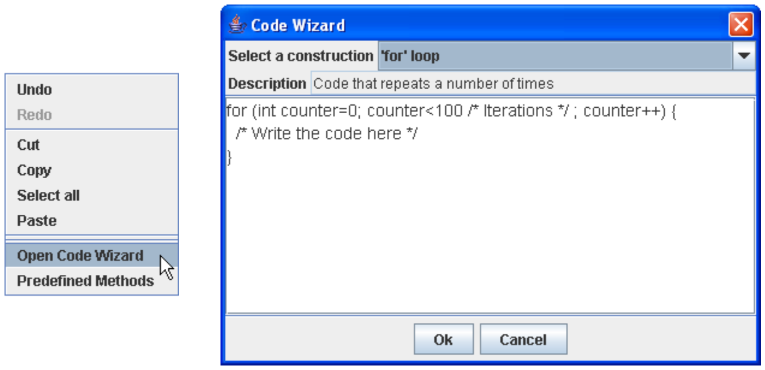


```
// Vectors of relative position
for (int i=0; i<n; i++) {
  for (int j=0; j<n; j++) {
    vectors[i][j][0] = posX[j]-posX[i];
    vectors[i][j][1] = posY[j]-posY[i];
  }
}
```

Figure 2.8. Sample initialization code.

the Java expressions and sentences that your algorithm requires, thus avoiding other technicalities of Java (such as method declaration). Recall that, if there are more than one initialization pages, *Ejs* will process them always from left to right. If you want to change the order in which a given page appears, use the popup menu for it.

The editor for the code (the white edition area) has its own popup menu, displayed in Figure 2.9. This menu offers the typical edition options, but also a simple code assistant that will help you introduce standard Java constructions, such as loops and conditional statements. It also offers an option that displays some of the predefined methods of *Ejs* (see Subsection 2.7.3).



```
for (int counter=0; counter<100 /* Iterations */ ; counter++) {
  /* Write the code here */
}
```

Figure 2.9. Popup menu (left) and code assistant (right).

You will finally observe that the lower part of the editor includes a text field in which you can write a short comment about the code of the page. Documenting the code, either with comments inside the code,[8] or using this text field, is an effort that will be very much appreciated both by your users and by yourself when, after some time, you need to re-read your own code.

[8]Lines which start with a double slash, `//`, are considered comments.

2.5 Evolution equations

The interface for this subpanel, that we see in Figure 2.10, is a bit more elaborated.

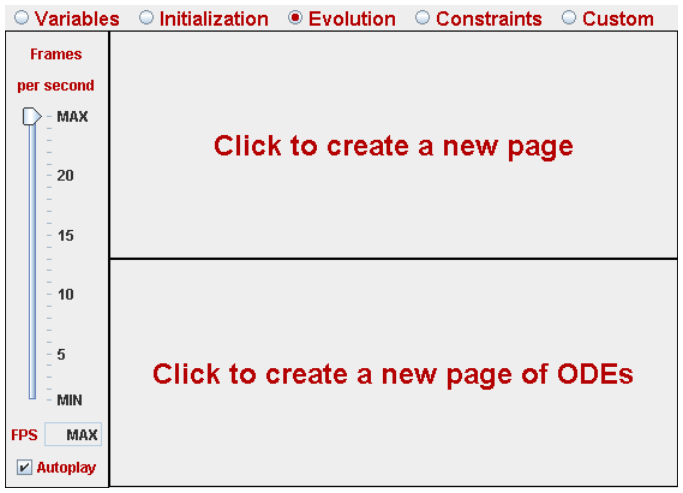


Figure 2.10. Panel for the evolution of the model.

2.5.1 Setting the parameters for the evolution

To the left of the panel we see a slider that lets us modify a value called "Frames per second" ("FPS" for short) that is also shown in the field immediately below it. This parameter tells *Ejs* how many times per second it should execute the evolution equations.

The value we can see in the image corresponds to the symbolic value "MAX" (for maximum), which tells *Ejs* that it should run the evolution as fast as it can. However, even when this may seem to you in principle the most desirable thing, in many situations it is not so. Modern computers can be so fast that this may prevent us from appreciating properly the evolution of the phenomenon under study. In these cases, you can use this slider to set a smaller FPS number.

The change from the value "MAX" to the one immediately below it (24) is actually qualitatively important. A value of 10 FPS can be enough for simple processes. If accompanied by a value of 0.1 seconds for your time step (if you have such a variable), it will approximately display a simulation running in real time. Finally, the `_setDelay()` predefined method (see Subsection 2.7.3) allows you a finer control of the speed of execution of a simulation.

Below these controls, and still on the left of the panel, you will see a checkbox labeled "Autoplay", which appears activated in the image. This tells *Ejs* that the evolution should start automatically when the simulation is run. You can leave the checkbox selected if this is what you want. In many situations, however, you may prefer that the evolution doesn't start automatically; for instance, if you prefer that your users can first manipulate the interface of the simulation to select appropriate initial conditions for your model. In these cases, you must click on the "Autoplay" box to deactivate it and, obviously, provide an alternative way of starting the evolution.

The easiest way for this is to include a button in your simulation's view that, when clicked, will invoke the predefined method `_play()` (see Subection 2.7.3 and Chapter 3).

2.5.2 Editors for the evolution

Differently to the rest of subpanels in the model, the central area of the evolution subpanel is divided into two parts. The upper one invites us to create a page (for Java code), while the lower one allows us to create a page with an editor for ODEs, that is, ordinary differential equations. [9] This corresponds to the fact that the evolution of a model can be described in two, complementary ways.

In principle, the implementation of the evolution equations will simply consist in the transcription of expressions (2.1) to Java code. That would certainly be the case for the so-called discrete models, in which variables change in time steps of previously defined duration. However, many of the processes that we will study are based in continuous models, in which time is considered as a continuous magnitude. In these cases, since the computer is essentially a discrete machine, evolution equations may derive, at least in part, from the numerical resolution (which implies the discretization) of systems of ordinary differential equations, a task that implies writing rather sophisticated code.

Even when it is possible that you prefer to write this type of code by yourself (for instance, if your interest is precisely the teaching of this type of numerical methods), *Ejs* includes the possibility of typing these equations in a specialized editor that will automatically generate, when the simulation is created, the Java code required to implement some of the most popular methods for numerical solution of ordinary differential equations.

Hence, when you come to work on the evolution, you need to start choosing which of the two editors you want to use, the one for plain Java code or the one

[9] These differential equations are called *ordinary* to distinguish them from *partial* differential equations.

specialized in ODE. Obviously, since your model may require using both types of editors, the popup menu for these pages allows you to create as many additional pages of both types as you may need.

2.5.3 Editing ordinary differential equations

The editor for plain Java code is identical to the one described in Section 2.4, so we don't need to talk about it here. Figure 2.11 shows the editor for ordinary differential equations.

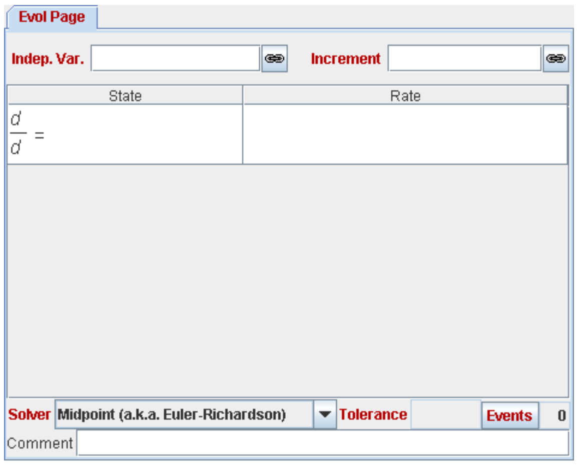


Figure 2.11. Editor for ordinary differential equations.

This editor allows us to introduce systems of explicit, first-order ordinary differential equations. That is, these in which the first derivative of a variable of the model is expressed as an explicit function of itself and the other variables. This apparent limitation still allows us to solve a great deal of differential problems with this editor, in particular because the variables that are differentiated can be either simple variables or vectors, i.e. unidimensional arrays. In both cases, for obvious reasons, the variables need to be of `double` type.

The fact that the differential equations need to be of first order is no restriction in itself, since any system of equations of higher order can be rewritten as another system of first order, introducing some auxiliary variables. The fact that expressions need to be explicit may require, we admit it, to elaborate a bit our equations, or carefully choosing our variables.

We will illustrate the process using an example that involves both simple and dimensioned variables. We will be using the variables we declared in Section 2.3. Thus, suppose, to begin with, that we want to solve the second-order differential equation:

$$\ddot{y}(t) = -g, \tag{2.3}$$

which corresponds to a body in free-fall, where variable y represents the position in height of the body and $g = 9.8\,m/s^2$ is the acceleration due to gravity on the Earth's surface. [10] Using v_y as an auxiliary variable, the equation can be rewritten as the system:

$$\begin{array}{rcl} \dot{y}(t) & = & v_y(t) \\ \dot{v_y}(t) & = & -g \end{array} \tag{2.4}$$

Similarly, suppose that the vector variable **posY** represents the position in height of a set of bodies that fall freely, so we are faced with the vector system of ODEs (using **velY** as auxiliary variable):

$$\begin{array}{rcl} \dot{\mathbf{posY}}(t) & = & \mathbf{velY}(t) \\ \dot{\mathbf{velY}}(t) & = & -\mathbf{g} \end{array} \tag{2.5}$$

where $\mathbf{g}$ denotes a vector with all its components equal to g.

Declaring an ODE

Before typing these equations in *Ejs*' editor, we must first select the independent variable for our system. Usually (and also in this example) this variable is the time. Even when we have written time in the equations above as t, in our set of sample variables, the name we chose for it was `time`. This will be therefore the value that we must type in the field of the editor devoted for the independent variable. We can either directly type this value in the field, or use the icon that appears to the right of it, ⚭, that (since the independent variable must always be a simple, double variable) will show the list of all simple variables of type `double`.

In the second place, we must indicate the integration step that we want our editor to use to solve the differential equation. This value can either be a constant or a variable of type `double`, and indicates the increment that the independent variable must experiment, in each step of the evolution, at the end of the process of numerical resolution of the differential equation. Thus, for instance, if we type in this field the value, say, 0.01, in each step of the evolution, *Ejs* will solve the equation advancing from the current state of the system at time t, to a later state at time $t + 0.01$. Notice that, as part of the solution of the system, the independent variable `time` will be augmented by the given increment. For this reason, all the differential equations that use the same independent variable need to be written in the same page.

[10] Obviously, this differential equation can be easily solved analytically, but we will ignore this.

Once we have introduced these data, the editor looks as in Figure 2.12. Notice how the variable `time` appears automatically in the denominator of the differential expression of the first row of the table.

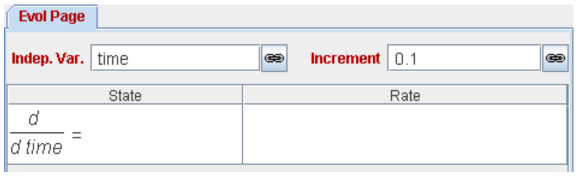


Figure 2.12. Introduction of the independent variable and its increment.

We now need to edit one row of the table for each of the differential equations of our system. The process for simple (non-dimensioned) variables consists in double-clicking on the left cell of each row and typing in there the variable that we want to differentiate, and then double-clicking on the right cell of the same row and typing the expression for the corresponding derivative. The editor takes care of displaying the differential expression in a familiar way. Thus, for instance, for equations (2.4), the result must look like in Figure 2.13.

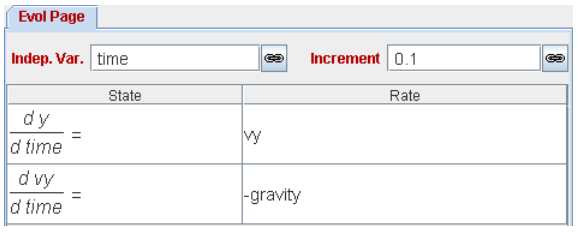


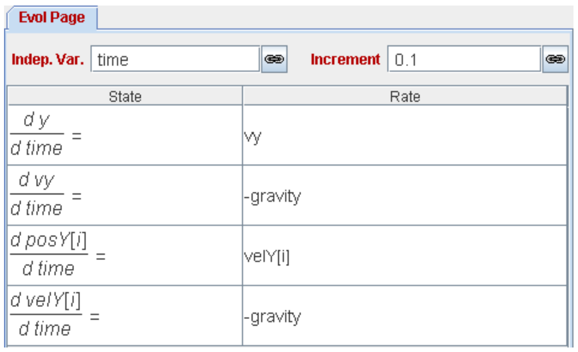
Figure 2.13. Differential equations for simple variables.

To facilitate the editing process, we can alternatively use the popup menu for this table. If we right-click on a cell, a popup menu will appear that will allow us to select the variables that we want to type, as well as other standard options for table maintenance.

The mechanism to introduce the derivative of vectors is very similar, but with one small difference. Since the editor can only really differentiate (for technical reasons) simple variables, we must include the index of the array in the differential expression, both on the left and the right-hand side. We can choose for the index any name that doesn't conflict with a global variable. The typical name is `i`, variable that we can consider as local. [11] If we use the popup menu for the cell to choose the variable to differentiate and the one selected is a vector, then *Ejs* will automatically add this index. The result of the edition of equation (2.5) (together with those

[11]A local variable is one that is defined and used only inside a given block of code.

already edited for (2.4)) are displayed in Figure 2.14. This concludes the definition of the differential equations for our example.



Indep. Var. time Increment 0.1

State	Rate
$\frac{d\,y}{d\,time} =$	vy
$\frac{d\,vy}{d\,time} =$	-gravity
$\frac{d\,posY[i]}{d\,time} =$	velY[i]
$\frac{d\,velY[i]}{d\,time} =$	-gravity

Figure 2.14. Differential equations for simple variables and for vectors.

Using custom methods in an ODE

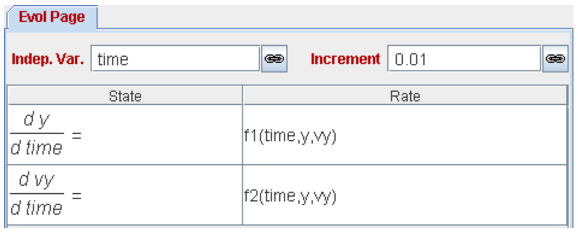
In this example, the expressions on the right-hand side of the equations were rather simple. However, it could very well happen that these expression are longer to write or that they require a more complex algorithm. In these cases, it is more appropriated to define a custom Java method (see Section 2.7) that makes the computations separately and invoke this method from the right-hand side cell of our equation.

When we choose to do this, it is very important that the methods that appear in these expressions are *self-contained*. With this we mean that, if the expression depends on one or more of the variables that are being differentiated, or on the independent variable, then all of them must appear as parameters of the invoked method. The reason for this is that (almost all) the algorithms of numerical integration used to solve the equations compute intermediate states of the system, in order to improve their precision. Including all the variables involved as parameters allows them to do these computations correctly.

For instance, if we wanted to do this for our equation (2.4), the editor should look as in Figure 2.15, where we should previously declare, in the "Custom" subpanel, the following methods: [12]

```
double f1 (double t, double pos, double vel) { return vel; }
double f2 (double t, double pos, double vel) { return -gravity; }
```

[12]The simplicity of these equations would allow us to declare `f1` and `f2` with less parameters. However, it is a good practice to get used to include as parameters all the variables that could possibly appear in the expressions, in case we change later the dynamics of the problem.



Indep. Var. time Increment 0.01

State	Rate
$\frac{d\,y}{d\,time} =$	f1(time,y,vy)
$\frac{d\,vy}{d\,time} =$	f2(time,y,vy)

Figure 2.15. Differential equations using custom methods.

Although we will see in detail the generic syntax of custom methods in Section 2.7, it is important to underline here the following peculiarities:

- It is a good programming practice to use for the parameters names different to those of the global variables, thus stressing that their values (at the intermediate states computed by the solver) can be different.
- The method can still use for its algorithms any other global variable, as long as this variable doesn't appear differentiated in this system of differential equations.
- These methods don't need to be declared public (see Section 2.7), unless they will also be used by the view (which is actually rather unusual).

For the case of dimensioned variables it is very usual that the index is also included as a parameter of the method invoked. This is the case when the expression in the right cell depends on the element of the matrix that is being differentiated.

Choosing the numerical algorithm

Immediately below the table that defines the differential equations, we can see a selector that allows us to choose the numerical algorithm that we want to use to solve our equations. The algorithms offered are currently: [13]

Euler This is a method of order 1, and therefore of very low precision. This method is included only for pedagogical reasons, since it is easy to understand by students.

Euler–Richardson This is a method or order 2 with a ratio speed/precision appropriated for simple problems. We typically recommend to start always with this method and, if you observe that the results lack precision, use a more powerful method (that also requires more computing time).

[13]We may add new algorithms in the future.

Runge–Kutta This is the clasical Runge-Kutta method of order 4. A very popular method with more than reasonable precision.

Runge–Kutta–Fehlberg This is a method with adaptive step size. It consists in a sophistication of the previous one that automatically adjusts the integration step to obtain an error smaller than a predefined value called tolerance. If you select this method, you'll need to indicate the tolerance in the field that will be enabled for this purpose.

To the right of the tolerance field you will see the elements of the interface that help us include events for our differential equations. Events are discussed in the next subsection.

Commenting the page

Notice, finally, that each page of equations offers a text field where you can write a short comment for it.

2.5.4 Events of a differential equation

Sometimes, when we are implementing the evolution of our simulation through the solution of a system of differential equations, we want the computer to detect that a given condition which depends on the variables of the system has taken place, allowing us then to make some corrections to adjust the simulation.

For instance, suppose that the falling body that we are simulating using equations (2.4) is an elastic ball that we have thrown against the floor. The numerical solution of these equations doesn't take into account, by itself, the fact that the computed solution will eventually take the ball to a position below ground, that is, $y(t) < 0$. As the method for numerical solution advances at constants step of time, it is very likely that the exact moment of the collision of the ball with the floor doesn't coincide with any of the solution steps of the algorithm, taking the ball to a, let's put it this way, 'illegal state'. Instead of this, we would have preferred that the computer had detected the problem and had momentaneously stopped at the precise instant of the collision, applying then the code necessary to simulate the rebounding of the ball against the floor, and continuing the simulation from these new initial conditions. This is the archetypical example of what we call an event.

More precisely, we define an event as the change of sign of a real-valued function of the state variables (the variables that we differentiate) and of the independent variable of an ODE. (Events caused only by the independent variable are traditionally called *time events*, while those caused by the other variables are called *state* *events*). To simplify the discussion that follows and, since actually all variables depend on the independent variable, we will denote by $h(t)$ the function that changes sign in the event.

Operational definition of event

Finding the instant of time at which the event takes places consists therefore in finding the solution of the equation $h(t) = 0$. We will assume that the usual state of the system implies $h(t) \geq 0$ and that the event takes place when $h(t + \delta t) < 0$ (δt is the increment we set for the independent variable of this ODE). Notice that we take as valid a state of the system that verifies $h(t) = 0$. [14] It is only when at the next instant of time the system becomes illegal that we consider that the event has taken place.

This is, however, the theoretical approach. In practice, the numerical resolution of differential equations can only be done in an approximate way. Even more, small round-off errors during the computations can produce states where $h(t) < 0$, with $h(t)$ extremely small, even when the system is actually legal.

For these reasons, we must slightly modify our definition so that it becomes more operational. The definition of event that we will use is established through the following procedure:

1. Each valid state of the system at instant t has associated to it a non-negative number $h(t)$. Because of possible round-off errors in the computation of this number, a state will still be considered valid if $h(t) > -\epsilon$, where ϵ is a small positive tolerance.

2. If the evolution step takes the system to a state such that $h(t + \delta t) \leq -\epsilon$, then the method of numerical solution will consider that an event has taken place in the interval $[t, t + \delta t]$. Then,

   (a) The method will search for a point t' in this interval that verifies $|h(t')| < \epsilon$. In this search, the first point to check will be t itself (this is done to improve the treatment of simultaneous events).

   (b) When it finds this point, the method of resolution will invoke a user-defined action. The result of this action must bring the system back to a state such that either $h(t + \delta t) > -\epsilon$ immediately (evolving from the new conditions set by the action) or, at least, this will become true in a finite number of iterations of this same process (starting again from point 1).

[14] In our example, the ball can be lying on the ground without the need to rebound.

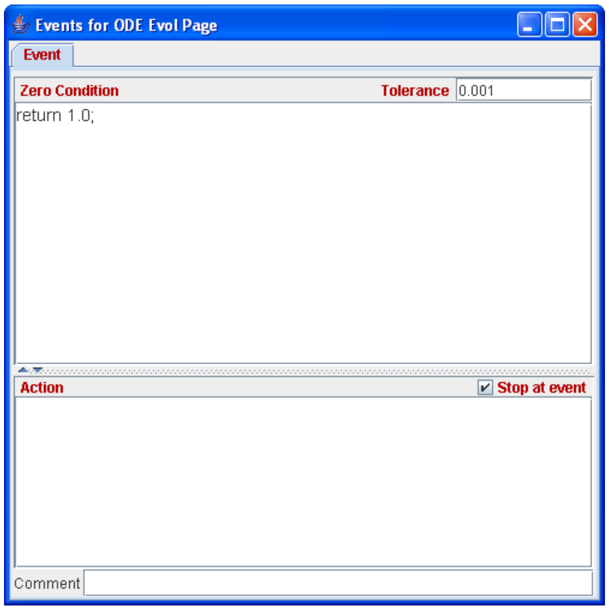
Thus, with this definition, an event is specified by providing: (a) the function h which depends on the state, (b) the desired tolerance, and (c) the action to invoke at the event instant.

Although the function h doesn't need to be continuous (this allows for greater flexibility when specifying events), it must be defined so that the procedure indicated above can work. That is, if $h(t)$ is a legal state and $h(t+\delta t) \leq -\epsilon$, then there must exist a point t' in $[t, t+\delta t]$ such that $|h(t')| < \epsilon$.

Creating events for an ODE

Notice that the editor for differential equations includes a button labeled "Events" and a field that indicates that, by default, there are no events defined for this equation. Clicking the button "Events" will bring in an independent window with an editor with a behavior similar to that found in other parts of the model, and which we can use to create as many pages of events for our differential equation as we want.

There exist, however, some differences. Observe in Figure 2.16 that a page for the edition of events appears divided into two sections (besides the text field for comments).



Tolerance: 0.001

```
return 1.0;
```

Stop at event: [✓]

Figure 2.16. A page for an event of our differential equation.

In the upper section of this page we need to indicate how to detect the event. For this, we need to write the code that computes the function $h(t)$ from the values of the state and the independent variable of our ODE. This code must end, necessarily, returning a value of type double. To help us remember this, the editor writes by default the next code (which, by the way, causes no event at all):

```
return 1.0;
```

In the "Tolerance" field on the upper right corner of this section we need to indicate the value for the tolerance that we want for this event (this is the ϵ in the discussion above).

The lower section is used to tell the computer what to do when it detects (and then precisely locates) an event. Recall that this action must solve, or at least simplify, the situation that triggered the event. In the upper-right corner of this second section we find a checkbox labeled "Stop at event", currently activated, that tells the computer whether it should return from the solution of the ODE at the instant of the event or not. Notice that, if checked, this causes the real increment of the independent variable to be smaller that the one originally desired. But still, checking this option may be useful if you want to appreciate the exact moment of the event.

A technical tip: the code for the action doesn't need to return any value explicitly using a `return` statement, the checkbox "Stop at event" takes care of this. However, if the code for the action has any `return` statement in its body, for instance to interrupt the execution of the code at any given point (never as the last sentence of the code), the value returned must be a boolean. This boolean will indicate, if true, that the event must interrupt the computation of the solution at the moment of the event.

We can use our example of the falling ball to construct a sample event. For this, edit the code of the upper section of the page so that it reads:

```
return y;
```

This indicates that the event will take place when the ball reaches the level of the ground, $y = 0$. The default value for the tolerance is adequate. As action for the event, write the code:

```
vy = -vy;
```

which simulates a totally elastic rebounding at the instant the event takes place. Leave the box "Stop at event" checked, so that the system visualizes the instant of the rebounding.

Final considerations about events

The creation of the function for the “Zero condition” and of the “Action” are totally under the responsibility of the user. He or she must consider carefully the process that they will cause according to the procedure described above.

Notice that the event editor allows us to define more than one events for the same differential equation. When there are more than one events defined, the editor will look for those that take place in the same interval $[t, t + \delta t]$, and, among these, which one takes place first, executing the action associated to this one. If two events take place simultaneously, the editor can invoke the corresponding actions in any order. The user should bear this possibility in mind and try to avoid infinite loops, in which one event causes a second event, which in turn reproduces the first one, and so indefinitely. This would cause the computer to hang.

A second problem arises from the so-called *Zeno-type* problems. [15] This takes place when the system reaches a state in which a big number of events take place with increasingly smaller gaps of time between two consecutive ones. This causes the computer to spend all its time solving events instead of simulating the process, which slows down the simulation so that it even seems that it has stopped.

Zeno-type problems can appear in apparently innocent problems. Try an inelastic rebounding of the ball and you will get one! Just be warned. See an example of how we solved this one in the **_examples/Events/BouncingBall.xml** sample file.

Finally, since the method for the solution of events checks the state of the system in several different instants of time when looking for the precise (well, actually approximate) moment of the event, it is difficult to predict how many times the system will execute the code for the function h and with which states of the system.

However, in order to facilitate the creation of elaborated events, the system makes the following compromise with you. If,

(a) the function $h(t)$ of a given event returns a value less than or equal to the tolerance, and

(b) this event is the one that finally triggers its action (when there are more than one events defined, this could not be the case, even if the first condition holds),

then the action of the event will be called immediately after the evaluation of the corresponding function h. That is, the function of this same event will not be called with a different state of the system before invoking the action.

[15] Do you remember Zeno, the one of the paradox of Aquiles and the turtle?: “Aquiles will never catch the turtle because when Aquiles covers the distance that separates him from the turtle, it has already moved a little bit. And when Aquiles covers this new distance, again the turtle has moved further. And so, infinitely many times. . . ”

We can benefit from this compromise, for instance, to set the value of certain global variables, during the evaluation of the function h, which will be used in the corresponding action for the event. In the **_examples/Events/BallsInBox.xml** example file, you can see how we used this compromise to build an event that handles a situation with collisions among many balls.

2.6 Constraint equations

The panel for the creation of constraint equations behaves exactly the same way as the panel for the initialization does (although, obviously, the role of these pages is different). The only thing we need to do is to write the code that transcribe constraints equations (2.2) into sentences of Java language.

2.7 Custom methods and additional libraries

The last radio button of the model is labeled "Custom". The main purpose of the corresponding subpanel is to allow us to create our own methods (what other programming languages call functions or subroutines) that we may need in other parts of the simulation. A second use of this subpanel is to let advanced users access their own libraries of Java classes packed in JAR or ZIP archives. We will refer to them as *additional libraries* (additional to *Ejs* itself).

Accordingly, the interface for this panel is divided in two parts, as Figure 2.17 shows. The bigger upper part lets us create our custom methods. The lower part is used to add additional Java libraries.

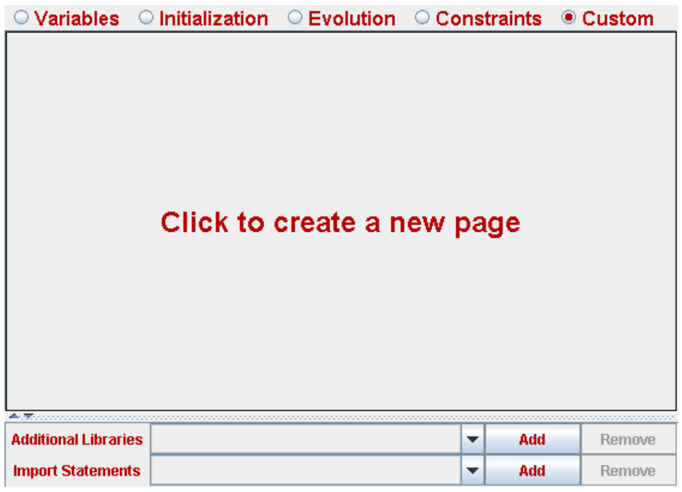


Figure 2.17. Subpanel for custom methods and additional libraries.

We cover first custom methods and leave for Subsection 2.7.2 the description of how to access your own Java libraries.

2.7.1 Custom methods

Custom methods are frequently used to group portions of code with the intention of making other parts of the model (or the view) simpler, either because the resulting model is easier to read and hence to understand, or because it reuses code that appears in several parts of the model. A second utility of custom methods is that of preparing actions that can be invoked as response of user interaction with the interface of the simulation (by using them in *action* properties of view elements, see Chapter 3).

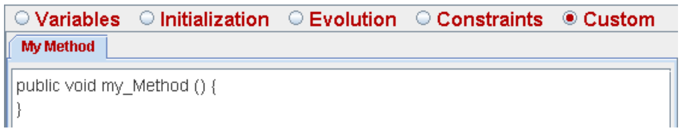
The look and feel and the way of working of the panel for custom methods is very similar to those for the initialization and constraints. There exist, however, two important differences.

The first one lies in the use that *Ejs* makes of what we write in these pages. To be more precise, *Ejs* makes **no** explicit use of it. Differently to the code that we may have written in any of the other editors, that played a defined role in the life of the simulation, methods defined here will not be used unless we explicitly invoke them from another part of the simulation.

The second difference is that we have an even greater degree of freedom (if this is possible) to write Java code in this panel. The only requisite in that what we write conforms valid Java methods. You can create methods as complex as you want, that take several parameters and have return values of any type.

Creating custom methods

When we create a new page in this panel called, say, “My Method”, *Ejs* helps us including in the page the initial skeleton for the method. See Figure 2.18.



```
public void my_Method () {
}
```

Figure 2.18. Initial page for a custom method.

Creating a Java method requires, besides writing the necessary code, providing a name for it, indicating the type of the returned value (if any), and specifying the method’s *accessibility*. We also need to indicate whether the method accepts parameters or not, and their type.

With respect to the method's name, we can choose whichever we want, respecting the conventions that we established in Subsection 2.3.5.

The term 'accessibility' refers to which other parts of the simulation can use the method. If the method is declared as 'public' (this is the purpose of the `public` keyword which we see in Figure 2.18) then the method is universally visible. It can be used anywhere in the model and in the view. It also results visible from *outside* the simulation by using JavaScript. (This will be explained in detail in Chapter 4.) If the method is not declared as public (either using the keyword `private` or just nothing) then the method can only be used inside the model. There is actually no powerful reason that prevents us from declaring all our custom methods public, except perhaps reducing the offer to final users which don't know what every method does and for whom it could even be confusing to see so many methods available.

The return value of the method makes reference to whether the method returns a value (thus acting as a function) or not (a subroutine). If it doesn't return any value, then we must indicate the special type `void`. If it does, we must indicate the type of value returned, which can be any valid Java type, either simple or dimensioned. If this is the case, the execution of the method must always end with a `return` sentence that indicates the value effectively returned. The code that accompanied Figure 2.15, for instance, illustrates this.

Finally, parameters are indicated by a comma-separated list of pairs *type name* which declare local variables that can be used in the method's body. This list must be written between the parentheses that follow the method's name. If a method accepts parameters, then it must be always invoked using the exact same number and type of variables. If a method requires no parameters, then we can leave the list of parameters empty.

You can change any aspect of the basic declaration provided by *Ejs* when it creates the new page: the accessibility, the type of the return value, the list of parameters (initially empty) and even the method's name (which will then be used only to decorate the page header tab). You can also declare more than one methods in the same page.

For example, the following methods compute the exponential of the cosine of a double value, and the conjugate of a complex number (specified by a double[2] array), respectively:

```
double expCos (double x) { return Math.exp (Math.cos(x)); }

double[] conjugate (double[] complex) {
  return new double[]{complex[0],-complex[1]};
}
```

2.7.2 Using your own Java libraries

Advanced users may have legacy code that they want to reuse. These code is usually already compiled and has been packed in compressed Java archives, also known as JAR files.

Using Java classes in packed in JAR files is straightforward. There are only three steps required for this:

1. Place a copy of the JAR file in an accessible place. A good place is anywhere under the **Simulations** directory.
2. Use the "Additional libraries" control to add this JAR file to the libraries *Ejs* will use to run your simulation.
3. Use your classes normally in the code. Classes you use need to be fully qualified. Alternatively, you can use the "Import statements" control to ask *Ejs* to add `import` statements to the generated Java code.

We illustrate these three steps with a simple example.

Suppose you have created a Java class which provides a static method that computes the norm of a vector (given as a double array). The code of this class may looks as follows:

```
package mylibrary.math;

public class VectorMath {
  static public double norm (double[] vector) {
    double norm2 = 0;
    for (int i=0; i<vector.length; i++) norm2 += vector[i]*vector[i];
    return Math.sqrt(norm2);
  }
}
```

Suppose, also, that this class file has been compiled and included in a JAR file called **myLibrary.jar**.

To use this class from within *Ejs*, you would typically do the following:

1. Copy **myLibrary.jar** to the **Simulations** directory.
2. Go to the "Custom" subpanel of the model and, on the "Additional libraries" control, click on the "Add" button. In the file dialog that will appear, select the file **myLibrary.jar** and click "Ok". The "Additional libraries" control will change to reflect that this library has been added. See Figure 2.19.

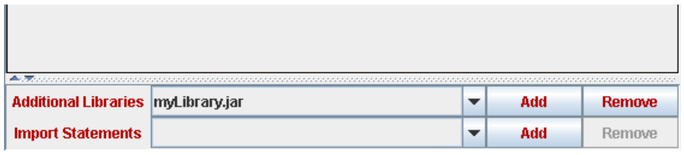

Additional Libraries myLibrary.jar Add Remove
Import Statements Add Remove

Figure 2.19. Adding a new additional libraries.

3. Now, you can just type, in any of the code editors of *Ejs*, the following code:

```
_println ("Norm = " +
   mylibrary.math.VectorMath.norm (new double[]{1,1,1}));
```

If you run the simulation, the console will read "Norm = 1.7320508075688772".

As you see, we fully qualified (`mylibrary.math.VectorMath`) the `VectorMath` class in our code. Obviously, if we only need to use the methods from this class once, this is just fine.

However, if we need to make frequent use of methods in this class, we can avoid having to fully qualify them every time by adding a, so called, *import statement*. For this, click on the "Add" button of the "Import statements" control and type `mylibrary.math.VectorMath` in the input dialog that appears. The control will reflect the change (see Figure 2.20).

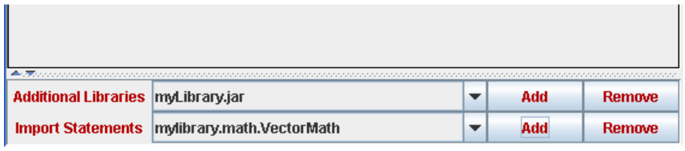

Additional Libraries myLibrary.jar Add Remove
Import Statements mylibrary.math.VectorMath Add Remove

Figure 2.20. Adding an import statement.

Now the code above can be written simply as:

```
_println ("Norm = "+VectorMath.norm (new double[]{1,1,1}) );
```

2.7.3 Predefined methods

A special type of methods are those that control the execution of the simulation itself. For instance, to pause or play the evolution, to modify the speed at which it plays, to play it step by step, or to return the simulation to its initial state, among others. Maybe, the most sophisticated of them are those that allow you to save the state of the simulation in a disk file and read it later across the Internet.

Because implementing these methods requires specific knowledge of the way *Ejs* works internally, they are provided by the system for your perusal. These methods can be used as any other method, either by themselves or in the body of other methods. The tables that follow list these methods, grouped by category, and the effect that each of them causes.

Methods that control the execution of the simulation
`void _play()` Starts the evolution of the simulation.
`void _pause()` Stops the evolution of the simulation.
`void _step()` Executes one step of the evolution of the simulation.
`void _setFPS(int fps)` Sets the number of frames per second for the simulation (which will modify the settings of the slider of the evolution panel) to the integer value `fps`.
`void _setDelay(int delay)` This method is, so to say, the reciprocal of the previous one. It allows to control the number of milliseconds that *Ejs* must wait when it finishes one step of the evolution, before executing the next one. Obviously, this affects the number of frames per second of the simulation.
`void _reset()` This initializes all model variables to the values set in the tables of variables, it also executes the pages of initialization code (followed by those of constraints) and clears the view. This brings back the simulation to its exact initial state.
`void _initialize()` This method can be considered as a soft reset. It executes the initialization pages (plus constraints), but doesn't use the initialization values of the tables of variables. This can be useful when we want to initialize the simulation while respecting the values of some variables that the user has modified using the interface of the simulation.
`boolean _isPlaying()` This method returns a true boolean if the evolution is playing and a false one if it is not. This method is typically used to enable and disable some view elements depending on whether the simulation is playing or not.
`boolean _isPaused()` This method returns a true boolean if the evolution is paused and a false one if it is not. It is the opposite of the previous one and its use is similar to that one.

Methods specific for the view
`void _resetView()` It resets all the view elements to their original state. The precise meaning of this depends on each type of element. For instance, the result of this method on an element of type "Trace" will clear all the points drawn so far, including the memory (if it has memory).
`void _clearView()` Clears all the elements of the view. Again, the precise meaning of this depends on each type of elements. In general, this method can be considered as a softer version of the previous one. For instance, the result of this method on an element of type "Trace" will clear the points drawn so far in the current trace, but will respect the traces in memory (if it has memory).

`void _print(String text)` Prints the provided text in the view of the simulation if this contains an element of the type “TextArea”. If this is not the case, the message will appear on the console from which the program was launched or on the Java console of the Web browser that is running the applet.
`void _println(String text)` Prints the indicated text, followed by a (so-called) carriage return and a new line, so that the next message will appear at the beginning of a new line. The text will appear as with the method `_print`.
`void _println()` Prints a blank line, followed by a carriage return and a new line. Works similarly to the method `_print`.
`void _clearMessages()` Clears the text area of the view. If the view has no such element, the method has no effect at all.
`String _format(double value, String format)` Returns a String with the provided numerical value written according to the format indicated. The possible values for the format are the same as those for the “Format” properties that several view elements exhibit. See for instance the HTML reference page for the element of type “NumberField”.
`void _alert(String element, String title, String message)` Displays a dialog, with the given title, that shows the given message. The `element` parameter must be the name of an element of the view on top of which the dialog will appear. If `null` the dialog will appear on top of the element set using the `_setParentComponent()` method or, if this is not set, at the center of the computer screen. The view can’t be accessed until the message is acknowledged.
`void _setParentComponent(String element)` Sets the element of the view on top of which subsequent alert dialogs will appear.

`org.opensourcephysics.ejs.control.ControlElement`
`_view.getElement(String element)`
Gets the ControlElement object for the given element of the view. Consult the JavaDoc documentation for `ControlElement` for more information.

`java.awt.Component _view.getVisual(String element)` Gets the `java.awt.Component` wrapped by a given element of the view. See `_view.getComponent()` for an explanation.
`java.awt.Component _view.getComponent(String element)` Gets the `java.awt.Component` wrapped by a given element of the view. Usually, the component and the visual of an element are the same. There are occasions in which they are different. For example, for a TextArea, the visual is the JTextArea and the component a ScrollPane. It is wise to check the class before using it.
`java.awt.Container _view.getContainer(String element)` Gets the `java.awt.Container` wrapped by a given container element of the view. Usually, the container and the component of a container element are the same. There are occasions in which they are different. For example, for a Frame, the component is the JFrame and the container is its content pane. It is wise to check the class before using the object returned.
`Object _view.getObject(String element, String objectName)` Some view elements define particular objects in its interior (the function of a ControlFunction is a good example). This method gets the object with the given name defined inside the given element of the view. Elements should document which objects they contain.

`org.opensourcephysics.ejs.Function`
`  _view.getFunction(String element, String functionName)`
Some view elements define `org.opensourcephysics.ejs.Function` objects in its interior (the function of a ControlFunction is a good example). This method gets the object with the given name defined inside the given element of the view. Elements should document which functions they define.

Methods for input and output
`boolean _isApplet()` Whether the simulation is running as an applet.
`String _getParameter(String name)` When the simulation runs as an applet, this method can be used to retrieve the value of a given `<param>` tag of the applet. The name of the parameter is given by `name`. If the parameter of the applet is not set, this method returns `null`. If the simulation runs as an application, this method looks for a pair of arguments (of the Java start-up command for the application) of the form `"-name value"` (where `name` is the argument of this method). If found, the method return returns the value of `value`. This method can therefore be used to read parameters from either the `<applet>` HTML tag or the start-up command, using exactly the same program logic for both, applet and application form.
`String[] _getArguments(String name)` When the simulation runs as an application, this method returns the array of arguments that was specified at the Java start-up command. If the simulation runs as an applet, this method returns `null`.
`boolean _saveText(String filename, String text)` Saves the given text to the specified file. The method returns `true` if everything went well, and `false` if there was any problem (then you might also get an error message in the console from which you run *Ejs*). If the filename starts with the prefix "ejs:", then the text is written to a temporary memory location. This means that data can be later read as if they had been stored in a file (using the `readText` method), but only during the same working session of the simulation, since data will be lost when the simulation ends. This possibility of saving temporarily to memory is useful when the application is running as an applet, since (for security reasons) an (unsigned) applet can not save to the hard disk. However, this possibility of saving to memory can be used without problems. If any other case, the text is written to a file on the hard disk. Security restrictions apply. This means that, again, if the simulation is running as an applet, then the applet needs to be signed or the method will trigger a security exception. You'll need to consult a specialized book to learn how to sign Java applets (*Ejs* can't -for security reasons- do this for you, sorry.)
`boolean _saveText(String filename, StringBuffer textBuffer)` A variant of the previous method that uses a `StringBuffer`. (`StringBuffer` is a Java class that works faster when you need to handle many small texts.)

`String _readText(String filename)`

It reads text from the file `filename`. Returns `null` if it was not successful.

If the name of the file starts with the prefix “url:”, then the method will interpret the rest of the name as a location on the Internet relative to the location of the simulation itself and will try to connect to this location and read the data from the corresponding Web server. If, moreover, the rest of the name starts with the prefix “http:”, then the Internet location will be considered as an absolute URL. These options are specially interesting when we call this method from an HTML page using JavaScript (see Subsection 4.4.1).

Finally, if the name starts with the prefix “ejs:”, *Ejs* will try to read the data from the specified memory location (see `_saveText()`).

`boolean _saveImage(String filename, String element)`

Saves the image of a given element of the view to the specified file. The method returns `true` if everything went well, and `false` if there was any problem (then you might also get an error message in *Ejs*’ console).

The `filename` parameter is used as in `_saveText()` above. Moreover, if the filename has an extension, this extension is used as the format in which to save the image file, and the system tries to do so. Different systems may support different graphic formats. Currently, only PNG and JPEG formats are guarantied to be supported by all Java Virtual Machines (JPEG is used by default). We have added support for GIF format, but it only works well with images with less than 256 different colors on it.

`boolean _saveState(String filename)`

Saves the state of all model variables in the specified file. If successful, it returns a true boolean; if it encounters any problem, it returns `false`. The parameter `filename` indicates the name of the file where to store the data, and is used as in `_saveText()` above. The file is created as a binary file. To create text files, use the method `_saveText()` described above.

`boolean _readState(String filename)`

It reads the value of all model variables from the file `filename`. This file must have been created using a previous call to the `_saveState()` method from the same simulation, that is, with exactly the same variables, declared in the same exact order. Returns a true boolean if successful and a false if it is not.

The `filename` parameter is used as in `_readText()` above.

`boolean _saveVariables(String filename, String variablesList)`

Similar to `_saveState()`, but only saves the variables specified in the given list. This must be a String with the names of the variables you want to save, separated by either spaces, commas, or semicolons. The parameter `filename` indicates the name of the file where to store the data, and is used as in `_saveText()` above. The file is created as a binary file. To create text files, use the method `_saveText()` described above.

`boolean _saveVariables(String filename, java.util.ArrayList variablesList)`

Similar to `_saveState()`, but only saves the variables specified in the given list. The parameter `filename` indicates the name of the file where to store the data, and is used as in `_saveText()` above. The file is created as a binary file. To create text files, use the method `_saveText()` described above.

`boolean _readVariables(String filename, String variablesList)`

Similar to `_readState()`, but only reads the variables specified in the given list. The data file must have been created with a matching call to `_saveVariables()`. The list of variables must be a String with the names of the variables you want to read, separated by either spaces, commas, or semicolons. The parameter `filename` indicates the name of the file where to read the data from, and is used as in `_readText()` above.

`boolean _readVariables(String filename, java.util.ArrayList variablesList)` Similar to `_readState()`, but only saves the variables specified in the given list. The data file must have been created with a matching call to `_saveVariables()`. The parameter `filename` indicates the name of the file where to read the data from, and is used as in `_saveText()` above.

Methods to access variables using JavaScript
`boolean _setVariables(String command)` This method is used to set the value of one or more variables of the model. The parameter `command` must consist on a semicolon-separated list of instructions of the type `variable=value`. As in, for example, `_setVariables("x = 1.0; y = 0.0")`. If the variable is a unidimensional array (a vector), it is still possible to use this method, separating the values of the different array elements by commas, as in `_setVariables("posX = -0.5,0.0,0.5")`. This method is not designed to be used from within *Ejs*, but from HTML pages using JavaScript. See Subsection 4.4.2.
`boolean _setVariables(String command, String sep, String arraySep)` This is a variant of the previous methods in which it is possible to specify the characters that separate variables and array elements. This may be necessary when you want to assign a value to variables of type String which contain commas or semicolons..
`String _getVariable(String variable)` This method is the counterpart of `_setVariables`. Given the name of a variable, it returns a String with its value. The user must extract the value of the variable (using the right type) from this String.

2.7.4 Methods from Java mathematical library

Even when these methods are not properly from *Ejs*, but belong to Java mathematical library, we find it useful to end this section providing a list of them, since they are of frequent use when writing code. These method must be invoked adding to their names the prefix “Math.”. Thus, for instance, to compute the sine of 0.5 (radians) we must write:

```
Math.sin(0.5).
```

Methods of the mathematical library of Java
`double abs(double x)` Returns the absolute value of `x`.
`double acos(double x)` Returns the inverse function of the cosine, $\cos^{-1}(x)$, from 0 to π.
`double asin(double x)` Returns the inverse function of the sine, $\sin^{-1}(x)$, from $-\pi/2$ to $\pi/2$.
`double atan(double x)` Returns the inverse function of the tangent, $\tan^{-1}(x)$, from $-\pi/2$ to $\pi/2$.
`double ceil(double x)` Returns the smallest integer greater than or equal to `x`.

`double cos(double x)` Returns the cosine of `x`.
`double exp(double x)` Returns the exponential of `x` with basis e, e^x.
`double floor(double x)` Returns the greatest integer smaller than or equal to `x`.
`double log(double x)` Returns the natural logarithm (with basis e) of `x`.
`double max(double x, double y)` Returns the greatest of the numbers `x` and `y`.
`int max(int x, int y)` Returns the greatest of the integer numbers `x` and `y`.
`double min(double x, double y)` Returns the smallest of the numbers `x` and `y`.
`int min(int x, int y)` Returns the smallest of the integer numbers `x` and `y`.
`double pow(double x, double y)` Returns `x` to the power of `y`. More precisely, $e^{y \log x}$.
`double random()` Returns a random number between 0.0 and 1.0 (0.0 is excluded).
`double rint(double x)` Returns the integer number (in form of `double`) closest to `x`.
`long round(double x)` Returns the integer number (in form of long integer) closest to `x`.
`double sin(double x)` Returns the sine of `x`.
`double sqrt(double x)` Returns the square root of `x`.
`double tan(double x)` Returns the tangent of `x`.
`double atan2(double x, double y)` Returns the argument of the complex number `x+yi`.

Exercises

In the **_examples/Manual/Model** subdirectory of your **Simulations** directory, you will find the model that we have developed under the name **FreeFall.xml**. Run it with *Ejs* and you will obtain a total of 11 free-falling balls. However, only one of them will rebound.

Exercise 2.1. Check that, since the rebounding is totally elastic, the ball always bounces back to the initial height, even if you let the simulation run for a long period of time. To better visualize this, add to the simulation a plotting panel and plot in it a trace with the height of the ball.

Exercise 2.2. Create new variables for the potential, kinetic and total energies of the ball that rebounds, use constraints to compute these energies and investigate how well is the energy preserved.

Exercise 2.3. Try to create an event so that all balls rebound when they reach the ground, and check again if the energy for the whole set is still preserved.

You will find the solution to these exercises in the cited subdirectory.

CHAPTER 3

Building a view

There is no doubt. The creation of the graphical user interface, or view, is the part of the simulation that requires a deeper knowledge of advanced programming techniques. Usually, the graphical tools provided by a high-level programming language have general applicability and, because of this, no specialization for any particular task. Hence, an important technical effort is required to apply these tools for a use as specific as the one we want.

However, the current degree of development of computer graphics makes it impossible to conceive a simulation without an advanced graphic visualization. Moreover, if the simulation is to be used for pedagogical purposes, we also need to provide it with a high level of interactivity.

For all these reasons, *Easy Java Simulations* uses its own powerful library. A library that is specialized in the visualization of scientific processes and data, and whose use has been simplified as much as possible. This library is based on the standard Java library called *Swing* and on the *Open Source Physics* tools created by Wolfgang Christian at Davidson College, [1] but it also adds its own developments. All these sets of Java classes are supported by Java 2 and its plug-ins (version 1.4.2 or later), so they can visualized by most modern Web browsers.

[1]Davidson College is a reputed institution of higher education located in North Carolina, in the USA. For more information, visit the Web site http://www.opensourcephysics.org.

We will introduce these elements in a simplified, though effective, way that is sufficient for our purposes.

3.1 Graphical interfaces

We will create a graphical user interface for our simulation through the construction of a tree-like structure of selected graphical elements. The process can be compared to playing with one of these block-construction games.

We call graphical element, or simply *element*, each of these building blocks, a piece of the interface that occupies an area of the computer screen and that performs a specific task on which this element is specialized on. There are elements of several types: panels, labels, buttons, particles, arrows,... and an important part of the game consists in learning which elements exist and how to use all their possibilities.

The graphical aspect of each element is very much determined by its type. However, each element has a set of inner characteristics, called *properties*, that we can modify so that the element looks and behaves according to our needs. These properties are usually set using constant values, but they can also be changed dynamically, thus creating the animations we want. Moreover, some elements have a special type of properties, called *actions*, that allow us to define the response of the interface to the user interaction with these elements (for instance when clicking the mouse or typing on the keyboard). This provides the required interactivity.

In this chapter we will show the common principles of use of these elements to build sophisticated user interfaces, without getting into details about any particular type of element. The names of the element types are rather descriptive of their natural use. However, the best way to learn how to use them is through examples, and consulting the reference pages that you will find in the web server of *Ejs*, `http://fem.um.es/Ejs`.

In order to continue with our general description, we need to mention now only a big classification of the elements in three groups: containers, basic elements and drawing elements (or drawables).

3.1.1 Containers

A container is a graphical element that can host other elements in its area of the screen. When this happens, we call the container element the *parent*, and the element contained the *child*. Since a container can be both parent and child, we can form a complete hierarchical structure of graphical elements with the form of a tree, whose root (which is not really an element) we will refer to as the `Simulation View`.

As the first child of this root, we will usually create what we call the *main window*, which is the window that first appears on the computer screen when we run the simulation as an application, or the one that appears embedded in the HTML page, when we run the simulation as an applet.

> The elements that need to interact with the rest of windows of the operating system are containers of a special group generically called windows. There exist two concrete types of these: frames and dialogs. See the corresponding entry in the reference pages.

There are, in turn, two main families of containers: containers that can host basic elements and other containers, and containers for drawing elements.

The first group is used, together with basic elements, to configure the skeleton of the simulation's view, providing the user with elements to control the simulation and to modify the value of the variables of the model. In this group of containers we list windows, toolbars, standard panels, split panels, and tabbed panels.

The second group is used, together with drawing elements, to create animations or to visualize graphs of the simulated phenomenon. The group comprises two-dimensional drawing panels, plotting panels (2D panels with coordinate axes), and three-dimensional drawing panels.

The *Layout* property

Maybe the most important property of a container of the first group mentioned above is the *layout*. When an element is added to a container, the parent assigns to the child appropriated position and size according to the available space, the child requirements, and of, so to call it, the container's own policy of space distribution or layout. Some layouts allow the child to choose its relative position inside the parent, but in most of them position is a consequence of the "order of birth" of the child.

> Containers of the second group mentioned above define their own system of coordinates that allows their children (which must be drawing elements) to specify their position using user coordinates. For this reasons these containers have no layout property.

We need to admit that the first time a new user is faced with layouts, they always seem an unnecessary nuisance: "Why can't I just place a child exactly here with a fixed, prescribed size?". The answer appears naturally when the user resizes or adds new elements to a view (which happens rather frequently). Then, the original sizes and positions are almost always inadequate. Using layout policies in the containers of our view instructs them how to proceed in these situations to distribute the new available space in a form that is congruent with the previous one. After a bit of practice, the use of layout policies becomes not only simple, but it even appears as the natural way of designing the interface.

Even when Java provides a great deal of layout policies (and allows the programmer to create new ones), we will only use the following layouts:

Flow It distributes the children in one row, from left to right, in a way much similar to how words appear in a paragraph. Children can be left, right, or center justified.

Border Maybe the most frequently used layout, distributes its children in one of five possible locations: up, down, left, right and center, from which each child must choose a different one.

Grid The second most popular, places its children in a rectangular table with as many equally sized rows as columns as indicated.

Horizontal box This distribution works similarly to a grid with only one row, if only it doesn't force all its children to have the same size.

Vertical box This works as a single-columned grid, with children of possible different height.

For all these layouts it is possible to provide two additional parameters that indicate how much it should separate children among them, both horizontal and vertically.

3.1.2 Basic elements

The group of basic elements is made of a set of interface elements that can be used to decorate the view, to visualize and edit variables of the model, and also to invoke control actions (that is, methods that manipulate the model).

You will find the elements in this group rather familiar, since they appear in practically all computer programs that you may use. The group includes labels, buttons, sliders, text fields, etc. These basic elements can be added to any of the containers of the first group of Subsection 3.1.1, but can not host other elements. That is, they are not containers themselves.

There are two exceptions to this assertion. The tab of basic elements labeled "Menu" contains all the elements you need to create menus for your view. In this tab, you will also find the "MenuBar" and "Menu" types, which are, in purity, containers.

3.1.3 Drawing elements

The set of drawing elements is one of the main contributions to *Ejs* of the *Open Source Physics* project. It consists of a set of view elements that can be included in dedicated containers (these of the second group of Subsection 3.1.1) to create animated graphics that visualize the different states of the model.

These animated graphics can range from the simple to the sophisticated, and be drawn in two or three dimensions, including particles, arrows, springs, GIF images, polygons, vector fields, contour maps, three-dimensional bodies, and even more.

3.1.4 Creation of the view

Thus, finally, the creation of the view consists in generating a structure, or tree, of elements that serves our purposes. This tree must include elements that visualize the state of the model, elements for the interaction of the user with the simulation, and containers that host all other elements.

3.2 Association between variables and properties

As we mentioned above, graphical elements have certain internal values, which we call properties, that can be customized to make the element behave in a particular way.

Since we are mainly interested in the dynamical visualization of the state of our models and in providing the required interactivity to our simulations, what we really want is to use our model variables as value for some of the properties and as arguments for the actions of the view elements. This process, which we call *associating* or *linking* objects of the model with properties of the view, is what turns our simulation into a really dynamic, interactive application.

In traditional programming, these links are created using calls to predefined methods of the graphic components. The main problem is that, since the standard graphical library was created, as we said before, to support any general use, the methods we are talking about are of rather low level, which demands high technical skills from the user.

Easy Java Simulations dramatically simplifies this situation, in the first place, by adapting the graphical elements it offers to the use we expect of them, but also allowing us to establish the required links through a simple process of edition of the properties of each element. In this process, the only thing we need to do is to indicate in the so-called panel of properties of the element, which object of the model must be associated to which property. In most occasions this can simply be done by choosing from a list of possible values the one we want for the link. With this information, *Ejs* will generate the code required to ensure that, later, when the simulation runs, all the necessary calls to the low-level routines are done correctly for this connection between model and view to work properly.

Linking is a two-way, dynamic process. With this we mean that at any time during the execution of the simulation, the element property will hold the value of the model variable to which it has been associated. Thus, if the evolution of the model changes this value, the element will automatically reflect the change. But also, in a reciprocal way, if a property changes as result of the interaction of the user with the view (by introducing a value, moving a slider,. . .), the variable of the model will immediately receive the new input value.

The configuration of the so-called action properties of the elements with code expressions that modify model variables or that use model methods, allows in turn the control of the simulation by the user, who will be able to execute the code interactively (by clicking a button for instance).

This mechanism turns out to be, as we will see, both simple and effective to create advanced user interfaces for our simulations.

3.3 How a simulation runs

Once we have established the associations between model and view that we need, the simulation will be ready to be run. With this information, *Ejs* generates the code necessary for the correct behavior of the future simulation. We can now complete the description of the execution of a simulation generated by *Ejs* that we started in Subsection 2.1.4.

When a simulation runs, this is exactly what takes place behind the scenes:

1. The variables are created and their values set according to what the initialization states.

2. The constraint equations are evaluated, since the initial value of some variables may depend on the initial values of others.

3. The view of the simulation is created and it appears on the computer screen. All the associations that we may have created are used to instruct the view elements how to correctly visualize the state of the model, and how to properly respond to user interaction.

   At this moment, the model is found to be in its initial state, the view reflects this state, and the simulation waits until an evolution step takes place or the user interacts with it.

4. In the first case, the evolution equations are evaluated and, immediately after, the constraints. A new state of the model at a *new* instant of time is then reached. The view is then updated through the links with the model.

5. In the second case, if the user changes a variable associated to a model variable, this is consequently modified, or, if the user invokes a control action, the corresponding code is executed. In any of both cases, constraint equations are evaluated immediately after. We then obtain a new state of the model at the *same* instant of time and the view is updated using the links with the model.

3.4 Interface of *Easy Java Simulations* for the view

The interface of *Ejs* for this panel is shown in Figure 3.1.

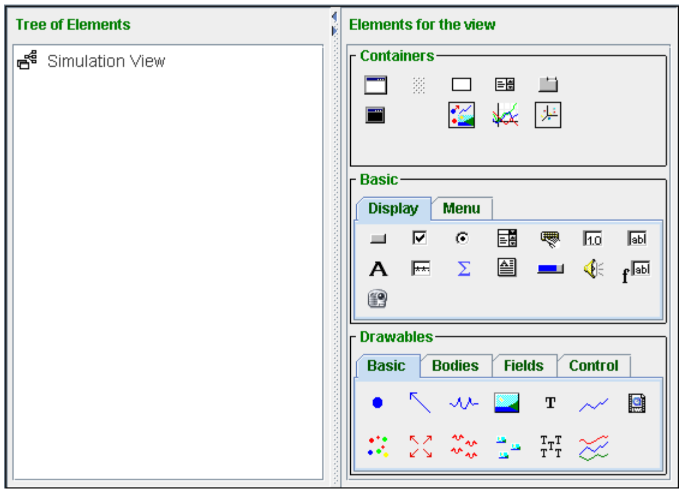


Figure 3.1. *Ejs* interface for the view.

The left-hand side of the working area of *Ejs* is now occupied by a panel that displays the (initially empty) tree of elements that forms the view. The node called `Simulation View` shown corresponds to the root of this tree. When we add new elements to our view, this panel will be displaying them reflecting the corresponding tree-form structure.

The right-hand side of the working area displays a panel with three sections in vertical. Each section contains a set of icons, grouped according to the classification that we did in Section 3.1. Each icon represents one of the types of elements that we can use to create the view. Whenever the number of icons is high, the section groups them in subpanels with identification tabs.

You can explore the icons by placing the mouse on top of each of them and waiting, without clicking, for a second, until a small tip appears indicating the name of the type and a short description of its function. See Figure 3.2.

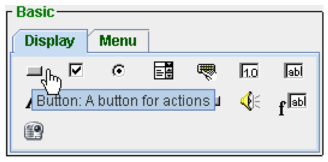


Figure 3.2. Detail of the information for the type “Button”.

3.4.1 Types of elements

We make in this paragraph a short introduction of the main types of elements offered by *Ejs*. Please notice that we don't cover all the types, but leave the complete list for the reference you will find on the Web pages for *Ejs*.

Containers

Frame The main characteristic of frames is that they know how to deal with the windows environment of your operating system. In particular they can be minimized and maximized in the usual way. Each view must have at least a first element of this type in which to place other elements, we will call this first frame the main window.

Dialog Window dialogs, or simply dialogs, are also independent windows, but, differently to frames, they can not be minimized (though they can be hidden). Besides this, they have the ability to always display on top of the frame that precedes them in the tree of elements, which can be useful in simulations with more than one windows.

Panel Panels are the most basic type of container, and hence the first candidates to use when we just want to group other elements.

SplitPanel This is a container that has two clearly separated resizable areas.

TabbedPanel This is a container that displays only one of its several children at a time, organizing them using tabs.

DrawingPanel This is a basic container for two-dimensional drawings.

PlottingPanel Similar to the previous one, it adds a system of cartesian or polar axes.

DrawingPanel3D This is a three-dimensional version of DrawingPanel.

Basic elements

Button Element in form of a button, used to invoke actions.

CheckBox A button that allows to select one of two possible boolean states, true or false.

RadioButton Similar to the previous one, it has the particularity that it works in group with all other radio buttons in the same container. Then, selecting any of the buttons, automatically unselects all the others.

ComboBox An element in form of a list that allows selecting one of several options.

Slider Allows to visualize and modify a numerical value, within a given range, in a graphical way .

NumberField Allows to visualize and modify a numerical value using the keyboard.

TextField Allows to visualize and modify a value of type `String` using the keyboard.

Label Used to write labels for decorative or informational purposes.

Drawables

Particle Draws an interactive ellipse or rectangle in a given position and with a given size.

Arrow Draws an interactive arrow or segment.

Spring Draws an interactive spring.

Image Draws an interactive GIF image or animated image.

Text Draws an interactive text.

Trace Draws a polygonal line created by accumulation of successive points, thus forming the trace of a motion.

Sets Draw sets with several of the corresponding elements.

Polygon Draws a polygonal line from the coordinates of its vertex.

Surface Draws a parametric surface from the coordinates of the points of a regular grid on the surface. There exist particular elements for some surfaces such as spheres, cylinders and other bodies.

ContourPlot Draws a contour map of a scalar field.

GridPlot Alternative (simpler) visualization of a scalar field.

VectorField Visualizes a vector field.

SurfacePlot Draws in 3D the graph of a scalar field.

3.4.2 Adding elements to the view

The creation of new view elements follows the next four steps.

Choosing the type of element to create

For this, just click on the icon for the type you want to create. When you do this, the background of the icon will change color, indicating that it has been selected. Moreover, the cursor will change to a hand when you are on top of an icon, and to a magic wand when the icon is selected. See Figure 3.3.

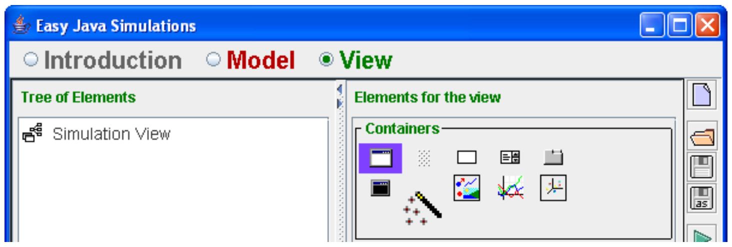


Figure 3.3. Choosing the icon for an element of type "Frame".

Choosing the parent for the new element

That is, the container that will host the new element. For this, click with the magic wand on a container element (that you created previously) in the tree of elements. If the new element is a frame or a dialog, which require no parent, you need to click directly on the root node, the one called "Simulation View". This is precisely the case that Figure 3.4 illustrates.

Choosing a name for the new element

Each element needs a name for it. *Ejs* will propose one based on the type of element that you are creating (see Figure 3.5), you can either accept it or choose a more representative name according to the role of the element in the interface. Recall, however, the naming conventions that we established in Subsection 2.3.5.

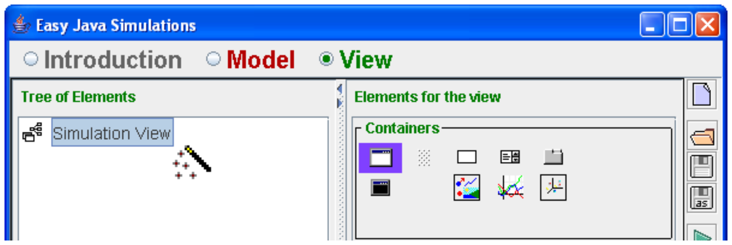
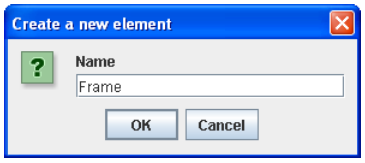


Figure 3.4. Choosing the parent for the new element.

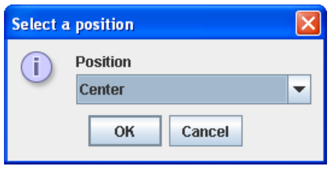


Name: Frame

Figure 3.5. Choosing a name for the new element.

If necessary, choosing a position for the new element

This is only necessary when the parent is using the `border` layout policy, as we explained in Subsection 3.1.1. In this case, a dialog such as the one shown in Figure 3.6 will appear [2] offering one of the five possible positions: up, down, left, right, and center. Choose the one you want and click “OK”.



Position: Center

Figure 3.6. Choosing a position for the new element.

And this is all! The element is created, placed at the corresponding position, and the tree of elements is updated to include the new element.

3.4.3 Modifying the tree of elements

Once we have created the tree of elements for our view, or even when we are still building it, we may want to modify its structure. This can be necessary to correct any possible mistake or to improve the initial configuration including new functionality.

[2]This figure doesn’t correspond to the previous one, since a frame doesn’t need to choose a position.

For this, each element in the tree has a popup menu that can be invoked by right-clicking with the mouse on the element. Figure 3.7 shows the view of the example of Section 3.6 with the popup menu for one of its elements. This menu can vary a little bit depending on the precise element that we choose, but the image shows a typical case. [3]

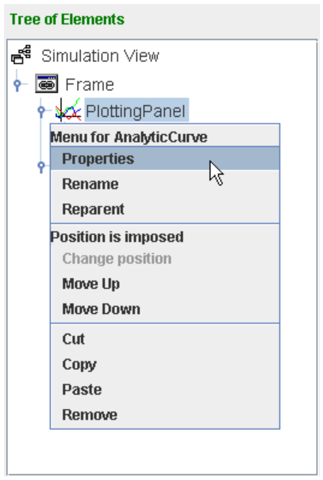


Figure 3.7. Popup menu for a new element.

The first entry in the menu is the one most frequently used. (Actually, it is so frequently used, that *Ejs* provides a shortcut for it. If you double-click on an element on the tree, this option is selected –even when the popup menu is not shown.) This option allows us to modify the properties of the element and will be described in detail in the next section.

The second option allows us to change the name of the element, and the third one, its parent. In both cases, a dialog window will appear to allow us to choose a different name or parent, respectively.

In a second group, there appear the options that allow us to change the position of the element inside its parent. A label tells us the current position of the element. This position may have been chosen by ourselves (if the layout policy of the parent is `border`) or be "imposed" by the parent according to the order of creation of its children. In the first case, to change the position we will need to use the option called "Change position". In the second case, this option will be disabled and we will need to use the other two options to change the relative order of the element with respect to its "brothers". The tree of elements will always reflect the actual order.

There exist a final group of options, cautiously separated from the others, that

[3]Because of its special nature, the popup menu for the root of the tree contains only the "Paste" option.

is used to cut, copy, paste, and remove the element. Be careful, *Ejs* will not ask for confirmation if you choose any of these options! (And there is no "Undo", either.)

A special option, only for frames

A special option, that only appears in menus for elements of type "Frame", is the one called "Main Window". Perhaps you noticed that, although the icon for the "Frame" class is ▭, the icon that appears associated to the first of the frames of a tree looks slightly different, ▣. This has a special meaning.

When the simulation is run in form of an applet, that is, inside an HTML page (see Chapter 4), one of the windows of the view appears inside this page, while all others will appear separately. We call this window the *main* window. A second property of this window is that, when the simulation runs as an independent application, closing the main window will end the simulation.

The icon ▣ identifies this window and the option "Main Window" of the menu for a frame element (see Figure 3.8) will allow you to choose which of the frames (if there are more than one) will be the main window.

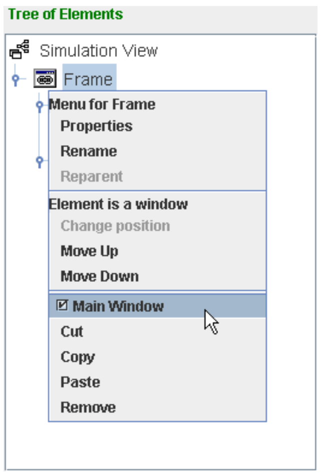


Figure 3.8. Detail of the "Main Window" option.

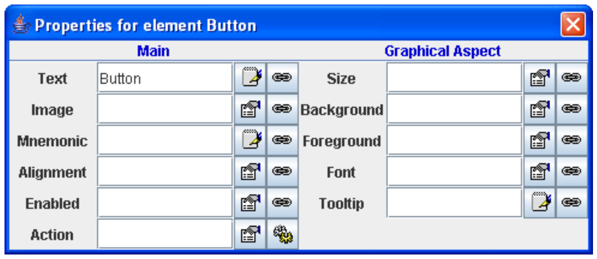
3.5 Editing properties

When we create new elements, they appear with default values for their properties. As we said already, properties are internal values that determine how the elements look and behave. We can modify these properties using the panel for the edition of properties of each element. For this, we need to select the first of the options of the popup menu for the element, "Properties", or double-click on the element's node in the tree of elements. Figure 3.9 shows the panel of properties for an element of the class "Button".

3.5.1 Choosing constant values

The way to modify a property is, in principle, straightforward: you just need to click on the corresponding entry field and type the desired value for the property.

However, it is sometimes difficult to remember the correct format for some of these values, specially if the property is one of the technical ones (such as color,



Properties for element Button

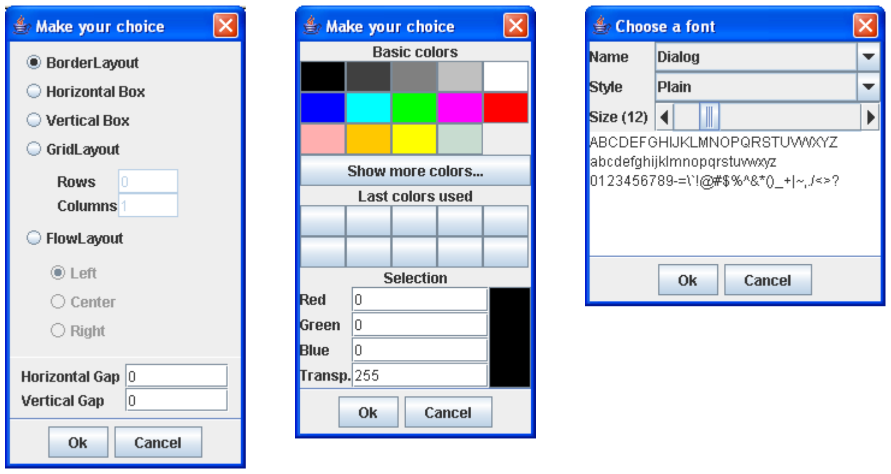
Main		Graphical Aspect	
Text	Button	Size	
Image		Background	
Mnemonic		Foreground	
Alignment		Font	
Enabled		Tooltip	
Action			

Figure 3.9. Panel of properties for an element of type "Button".

layout or font, for instance). To help with this, input fields of the properties have a button to its right that helps us choose the right value. (There exist a second button which we will discuss in a minute.)

If the icon that appears on this button is 📝, then there is no editor that facilitates the task; but most likely you don't need it either, since this is a property that requires just a numeric or text field for which you can simply type the value you want.

If the icon on the button is, on the contrary, 🗂, then *Ejs* provides an editor specialized in this property. We recommend you to use it. Figure 3.10 shows the specialized editors for the layout, color and font properties, respectively, from left to right. All of them work in a natural way.



Make your choice

- [✓ BorderLayout]
- Horizontal Box
- Vertical Box
- GridLayout
  - Rows: 0
  - Columns: 1
- FlowLayout
  - [✓ Left]
  - Center
  - Right

Horizontal Gap: 0
Vertical Gap: 0

Ok Cancel

Make your choice

Basic colors

Show more colors...

Last colors used

Selection

Red: 0
Green: 0
Blue: 0
Transp.: 255

Ok Cancel

Choose a font

Name: Dialog
Style: Plain
Size (12)

ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz
0123456789-=\`!@#$%^&*()_+|~,./<>?

Ok Cancel

Figure 3.10. Specialized editors for the layout, color and font properties.

Many of the elements, and particularly drawables, are interactive. This means that (when enabled) their values, positions, sizes, etc. can be changed interactively. In this case, interacting with the element (for instance, dragging it with the mouse), changes their properties. This is particularly useful to easily position or size windows and also to create drawings interactively.

3.5.2 Association with variables and use of methods of the model

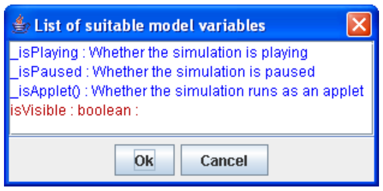
As we said in Section 3.2, properties can also be set through their association with variables of the model, with Java expressions that use them, or, in the case of action properties, using Java sentences that involve variables and methods from the model. These associations are the essence of the interactivity of the simulation.

This process is also easy to accomplish. You just need to type the variable or the Java expression in the corresponding property field.

To facilitate this task, though, there exists a second column of buttons, one for each property, in the table of properties. These buttons display one of the two icons: 🔗 or ⚙.

If you click on a button with the icon 🔗, a dialog window will appear, listing all the variables of the model that can be associated to the property that you are editing. It is possible that not all variables of the model are listed, since, for instance, a property of numeric type can not be associated to a variable of type `String`. Choose among the offered variables the one you want and click "Ok".

Thus, for instance, if we click on this second button for the property "Enabled" of the panel in Figure 3.9, whose value needs a boolean, we will obtain a list of all boolean variables of the model. If our model only defines the boolean `isVisible`, we will obtain the list of Figure 3.11.



_isPlaying : Whether the simulation is playing
_isPaused : Whether the simulation is paused
_isApplet() : Whether the simulation runs as an applet
isVisible : boolean :

Figure 3.11. List of all possible boolean variables.

Observe that, as this example shows, this list can also include, besides the variables that our model define, some variables and methods predefined by *Ejs*. These are displayed in a different color. (In this concrete example, `_isPlaying` is a boolean variable that is true if the evolution of the simulation is playing and false if it is not. The variable `_isPaused` is the negation of `_isPlaying`. Finally, `_isApplet()` is a method that returns a true boolean if the simulation runs as an applet, and false if it runs as an application.)

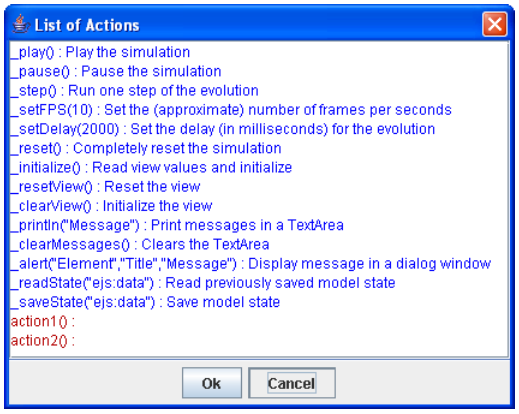
Any connection between a model variable and an element's property works right from the start. With this we mean that the connection will of course work when the simulation runs, but also under *Ejs*. You can appreciate that properties associated to model variables use the values of the variables specified in the corresponding "Value" cells of the table of variables. If you change any of these values, the view will readily reflect this change.

But the connection also works the other way round. If you interact with a view element and change one of its connected properties, the value in the "Value" cell will be updated too. This can be useful to set initial conditions of your simulation in an interactive way.

There is only one exception for this rule. If the "Value" column for the variable affected by this interaction contains an expression (instead of a constant value), *Ejs* will ask you for confirmation before replacing the expression with the constant value obtained from the interaction.

Finally, if the button on the second column exhibits the icon, this tells us that the property is one of the so-called *action* properties. That is, that it can be used to define an action that will be invoked when the user interacts with the element in a given way (which depends on the type of element and on the property chosen).

If we click on a button with this icon, a dialog will display all custom methods defined by the model (see Subsection 2.7.1), together with some of the predefined methods defined by *Ejs* (Subsection 2.7.3) in different color, to help us choose one of them. Thus, if the model defines the methods `action1()` and `action2()`, and we click on the second button of the property "Action" of Figure 3.9, the result will be like in Figure 3.12.



```
_play() : Play the simulation
_pause() : Pause the simulation
_step() : Run one step of the evolution
_setFPS(10) : Set the (approximate) number of frames per seconds
_setDelay(2000) : Set the delay (in milliseconds) for the evolution
_reset() : Completely reset the simulation
_initialize() : Read view values and initialize
_resetView() : Reset the view
_clearView() : Initialize the view
_println("Message") : Print messages in a TextArea
_clearMessages() : Clears the TextArea
_alert("Element","Title","Message") : Display message in a dialog window
_readState("ejs:data") : Read previously saved model state
_saveState("ejs:data") : Save model state
action1() :
action2() :
```

Figure 3.12. List of model methods for an action.

The action can consist in a simple call to any of the model or predefined methods or can include directly Java sentences that perform the action. It can even consist of a combination of both. Clicking on the first icon to the right of the input field of an action property brings in a simple editor specialized on edition of Java code that will help us write our code more comfortably.

3.5.3 The color codes of the property fields

Property fields, that is, the text fields where you type in the values for the properties, implement a simple color code.

Fields for properties that are not action properties are always displayed in white background. When you edit them, however, their background turns yellow, so to warn you that you are modifying them, but that the value has not yet been applied to the property. Only when you hit return, thus accepting the value, gets the background white again. For this reason, don't leave yellow backgrounds behind!

Actions properties are different. Since their values are only really used when the simulation is generated, whatever you type in the corresponding field is immediately valid. For this reason, their background never turns yellow. However, since (differently to all other properties) the code you write for an action property can span more than one line, whenever this happens, the background of the field changes color to a sort of dim green, to warn you that there are possibly more lines than those you can see in the field. You can therefore leave green backgrounds behind. And we recommend that you always use the editor provided to view and modify the corresponding code.

3.5.4 Special case: properties of type `String`

When we assign manually the value of a property, it is possible that there exist a small ambiguity in the case of properties that require text values. Indeed, suppose that we edit the "Title" property for a frame and write in it the value "graph", and suppose that we have defined a variable of `String` type in our model which is called precisely `graph`. In this situation, what should *Ejs* do? Should it use the text "graph" for the title of the frame, or should it use the value of the variable `graph` for it?

Even if you think that the example is a bit forced, it sometimes happens. In principle, *Ejs* will almost always do what we expect it to do, but if this is not the case, we need to solve the problem either changing the name of the variable of the model or using the following additional rules:

- If we write the text between quotes (simple or double), we force the element to use the text literally. In our example, we should write either '`graph`' or "`graph`".

- If we write the text between per cent characters, `%`, we will force the element to consider the text as the name of a variable. In our example, we would need to write `%graph%`.

The use of these rules helps *Ejs* to completely solve the ambiguity. The specialized editors make automatic use of these rules.

3.6 Learning more about view elements

Well, this is actually all you need to know, in general, about building views with *Easy Java Simulations*! Of course, you will need to learn more about the different types of elements that exist and how they can be used, together with the possible values of their properties, to achieve several visualizations and interactive capabilities. But this is learned in a more effective and nicer way through examples.

For this reason, we end here the general description and refer to the examples distributed with *Ejs* to see practical cases of use. Recall also that on the Web server of *Ejs* you will find a set of HTML pages describing all the elements that *Ejs* offers. Do not hesitate to explore these pages on your own to learn more about a given type of element.

We end this chapter with a concrete example of use that also has interest in itself. Although, usually, the model of the simulation contains the greatest part of its dynamic information, the view we build with *Ejs* can have its *own life* by itself. The degree of utility of it will depend on the capabilities of the graphical elements that we use to build it.

We will illustrate this life of the view by constructing a simple function plotter using an element called "AnalyticCurve" as the main component of the view. This plotter will visualize the graph of a function $f(x)$ which depends on three parameters. To reinforce all that we explained in this chapter, we will guide you through all the process.

Main window

Let's start with an empty simulation. For this, click the "New" icon, 🗋, in *Ejs* taskbar; this will delete any previous simulation.

Now, choose the panel for the "View" and create an element of type "Frame". For this, click on the first icon of the subpanel for containers, 🗔, and click with the magic wand the root node of the tree of elements, the one called `Simulation View`. Accept for the new element the proposed name `Frame`. The result will look as in Figure 3.13.

Now edit the properties of the frame to change its title to `Function plotter`. The panel of properties will look as in Figure 3.14.

> Notice that, as we said in Subsection 3.5.3, when you modify a field, it takes a yellow background (except for action properties). Don't forget to hit the return key of your keyboard to accept the value, so that the background looks white again. Only then will the change really affect the element's property.

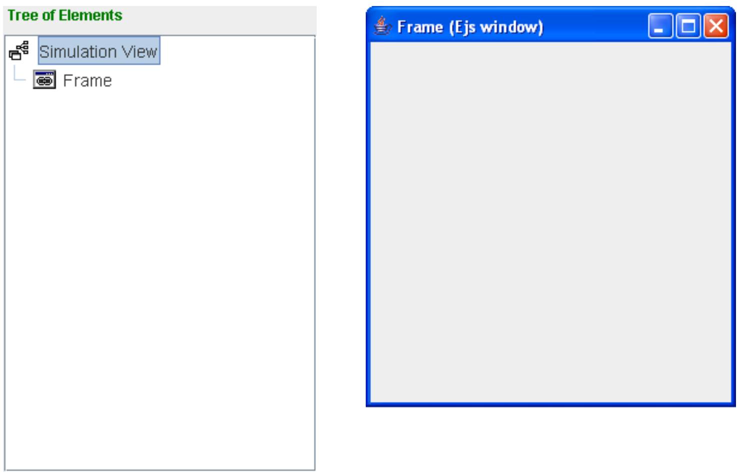
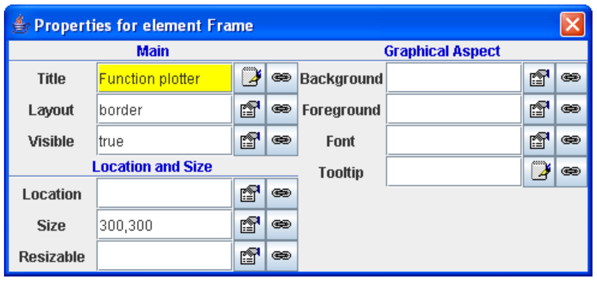


Figure 3.13. Initial tree of elements and the non-edited frame.

For the figures of this chapter, though, we have left the fields we edited with the yellow background, so that you can easily distinguish which fields have been modified.



Main		Graphical Aspect	
Title	Function plotter	Background	
Layout	border	Foreground	
Visible	true	Font	
Location and Size		Tooltip	
Location			
Size	300,300		
Resizable			

Figure 3.14. Panel of properties for the main window.

In this new frame, which has by default a border layout, we will create two children. The one at the center will be a plotting panel and the one in the `Down` position will hold the controls for the parameters of the function.

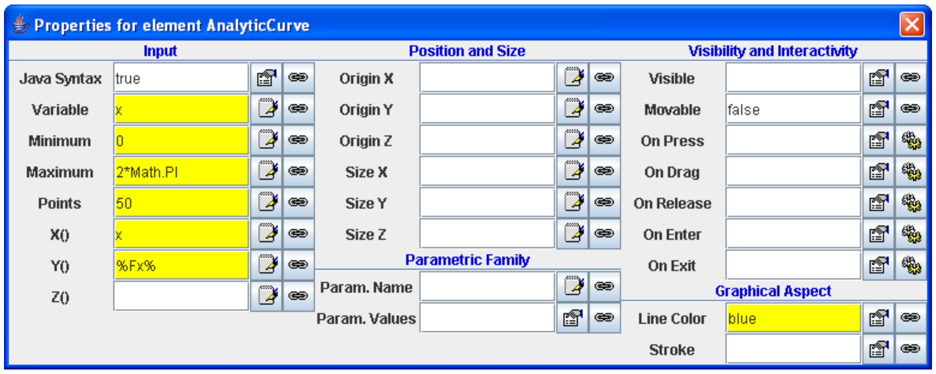
Plotting panel

Select the icon for the type "PlottingPanel", , and click with the magic wand on our frame. Accept the proposed name and place the new panel on its parent's center. A big panel with axes will be created and will occupy the interior of the frame. Edit the properties of the panel to change its "Title" to `Graph of the function`, its "Title X" to `x`, and its "Title Y" to `f(x)`.

Now, from the subpanel of drawable elements, select the tab header labeled as "Bodies". From the icons in the corresponding subpanel, select the one for the type "AnalyticCurve", and create an element of this type as child of the plotting panel we created above. The name suggested by *Ejs* is acceptable.

> The element "AnalyticCurve" creates the graph of a curve in space (that is a set of points `(x,y,z)`) from the analytic formula provided to compute these points. In this sense, it is one of the elements offered by *Ejs* that incorporates more computational power independently of the model. For more information about the element "AnalyticCurve" consult its reference page.

Edit the properties of this new element as shown in Figure 3.15. With this we are asking the element to display a `blue` colored graph made of `50` points with coordinates `(x,%Fx%)`, where these expressions for the X and Y coordinates are interpreted as functions of the "Variable" `x` which varies in the interval from `0` to `2*`π. This finally results in the graph of the function of variable `x`, given by the expression contained in the text variable `Fx`.



Properties for element AnalyticCurve

Input		Position and Size		Visibility and Interactivity	
Java Syntax	true	Origin X		Visible	
Variable	x	Origin Y		Movable	false
Minimum	0	Origin Z		On Press	
Maximum	2*Math.PI	Size X		On Drag	
Points	50	Size Y		On Release	
X()	x	Size Z		On Enter	
Y()	%Fx%	**Parametric Family**		On Exit	
Z()		Param. Name		**Graphical Aspect**	
		Param. Values		Line Color	blue
				Stroke	

Figure 3.15. Panel of properties for the analytic curve.

The tree of elements for our simulation will reflect the changes and will now look as Figure 3.16 shows. You will notice that the plotting panel now displays a horizontal blue line. This is the graph of the function we are plotting. The reason that it is just a horizontal line is that we haven't yet defined the text variable `Fx`.

Control panel

In order to define this variable, as well as other parameters that may help defining the function, we will create a panel that will hold several controls. In the first place, select the "Panel" icon, □, in the panel of containers, and click with the magic wand on `Frame` to create an element of type "Panel" as second child of it. The name

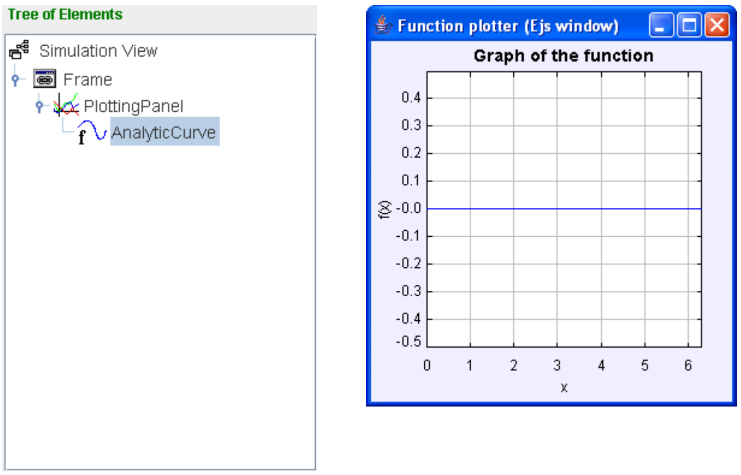


Figure 3.16. Tree of elements (under construction) and panel displaying the graph.

suggested by *Ejs*, `Panel`, is acceptable. Place the panel in the “Down” position of the frame. We won’t need to edit the properties of this element.

Notice that, although the panel appears in the tree of elements, it is not visible in the frame itself. This is because the panel is still empty, and it therefore doesn’t claim any screen space from its parent. As soon as we add children that do claim for space, the situation will change.

The two children that we will add to the panel will be again elements of type “Panel”. Since this icon is probably still selected, create two new elements of this type as children of `Panel` with names `PanelFx` and `PanelParameters`. Place them in the positions “Up” and “Center”, respectively.

Even when the frame still looks the same, the tree of elements should look like in Figure 3.17.

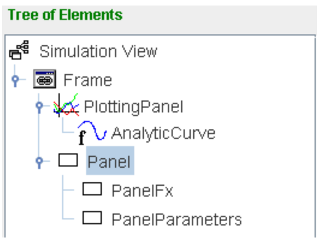
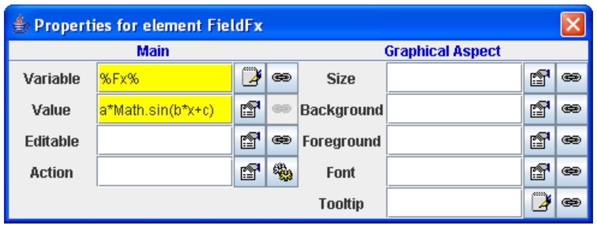


Figure 3.17. Tree of elements under construction.

We will only need to modify the layout property of the element `PanelParameters` so that it takes the form of a grid with 0 rows and 1 column (that is, a column as long as needed). For this type `grid:0,1` in the “Layout” text field of the panel of properties for `PanelParameters`, or use the specialized editor for layouts by clicking the auxiliary edition button, , for this property.

Now, create a label, **A**, on the left side of the panel `PanelFx` (the proposed name will do) and edit its “Text” property typing `f(x)=` in the corresponding field. In the center of this panel, create a text field, , called `FieldFx` and edit its properties as in Figure 3.18. With this we are instructing the text field to associate whatever we write on it with the variable `Fx`. We also give an initial value to this variable using the property called “Value”, typing in it the function we want to visualize, using the correct Java syntax: `a*Math.sin(b*x+c)`.



Properties for element FieldFx

Main		Graphical Aspect	
Variable	%Fx%	Size	
Value	a*Math.sin(b*x+c)	Background	
Editable		Foreground	
Action		Font	
		Tooltip	

Figure 3.18. Properties for `FieldFx`.

Observe that the function we are suggesting (of course, you can use any other one) contains three variables `a`, `b` and `c`, that have not been defined (`x` in the expression refers to the independent variable with respect to which the graph is built). We will need to give non-zero values to these parameters so that the curve is interesting.

We will do this using the `PanelParameters` panel. Choose now the element of type “Slider”, , and create three such sliders in this panel with names `SliderA`, `SliderB` and `SliderC`. Since the layout of the parent places the elements in form of a column, you will not be prompted to choose the position for the new elements. This takes us to the final structure of the tree of elements for our view, which you can see in the left image of Figure 3.19.

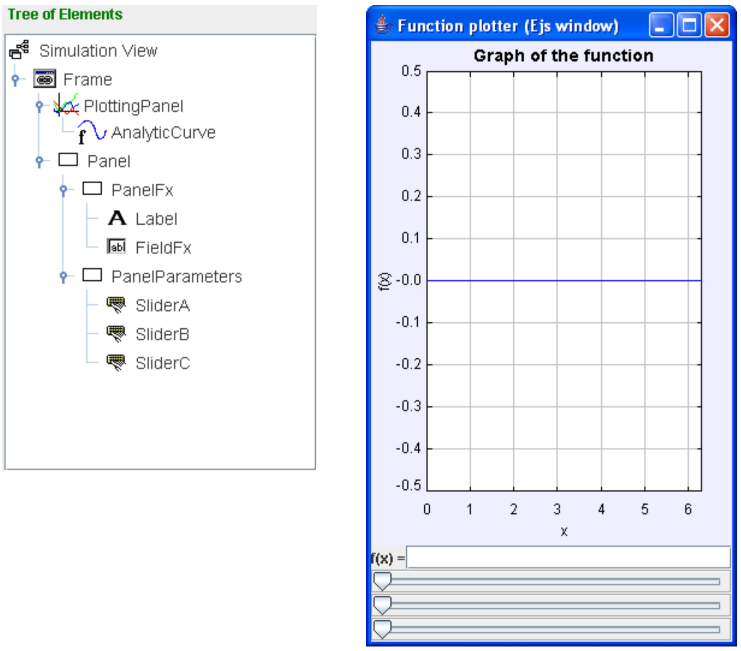
We will still need to customize the sliders, but since the creation of new elements is limiting the available space for the original plot (and the customization we foresee for the sliders will make these even bigger), we will resize the main window. For this, edit again the properties for `Frame` and change its size to `300,500`. The final result should look as in the right-hand side image of Figure 3.19.

To finish the example, edit first the properties of `SliderA` as in Figure 3.20. The most important fact of this customization is that the slider will allow us to modify the variable `a` in a range from `0.0` to `5.0`, giving to `a` an initial value of `1.0`. (The value `a=0.00` for the property “Format” doesn’t assign to `a` any value, it just indicates how the value of `a` should be displayed; in this case, with two decimal figures.)

Finally, edit the properties of `SliderB` exactly as those above but changing `a` by `b`, and those of `SliderC` as shown in Figure 3.21.

Using the plotter

The example is now complete. (Don’t forget to save it to disk!). Now, if you run it, the graph displayed in the upper panel will correspond to the sine function. Play



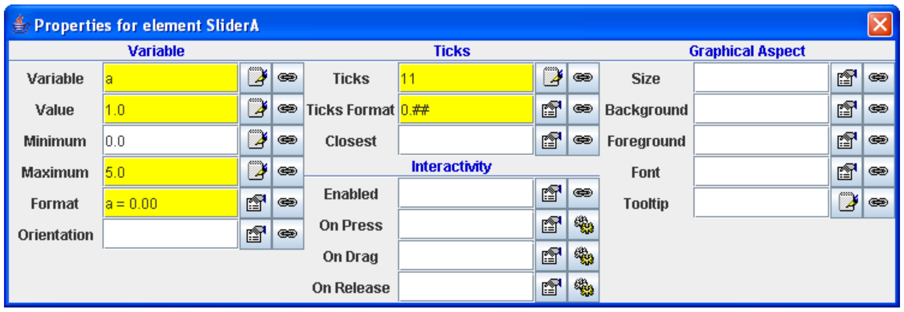
Tree of Elements

- Simulation View
  - Frame
    - PlottingPanel
      - AnalyticCurve
    - Panel
      - PanelFx
        - Label
        - FieldFx
      - PanelParameters
        - SliderA
        - SliderB
        - SliderC

Figure 3.19. Final tree of elements (left) and frame still under construction.

with the sliders for a, b, and c to see the effect of each of the parameters on the graph of the curve. You can also introduce different expressions in the text field for the function to plot (respecting the correct Java syntax) which can or can not use the parameters. See Figure 3.22.

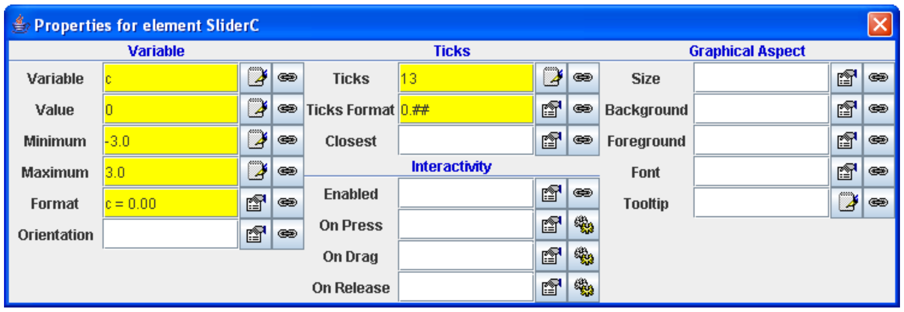
We would like to emphasize that this example shows how the view can have a life on its own, independently of the model. In our example, in fact, we created no model at all, and all the variables have been autonomously created by the view. However, if you now create the variables a, b, and c in the table of variables of the model and modify them in the body of it, the variables of the view will always



Properties for element SliderA

Variable		Ticks		Graphical Aspect	
Variable	a	Ticks	11	Size	
Value	1.0	Ticks Format	0.##	Background	
Minimum	0.0	Closest		Foreground	
Maximum	5.0	**Interactivity**		Font	
Format	a = 0.00	Enabled		Tooltip	
Orientation		On Press			
		On Drag			
		On Release			

Figure 3.20. Properties for `SliderA`.



Properties for element SliderC

Variable		**Ticks**		**Graphical Aspect**	
Variable	c	Ticks	13	Size	
Value	0	Ticks Format	0.##	Background	
Minimum	-3.0	Closest		Foreground	
Maximum	3.0	**Interactivity**		Font	
Format	c = 0.00	Enabled		Tooltip	
Orientation		On Press			
		On Drag			
		On Release			

Figure 3.21. Properties for `SliderC`.

use the corresponding values, thus automatically establishing a connection between them thanks to their common name.

A corollary of this is that we can create simulations in which the view defines and uses variables that don't need to have been declared by the model. However, these variables are usually of auxiliary nature; any really interesting behavior will undoubtedly be based in the definition and modification of variables in the model.

Exercises

The subdirectory **_examples/Manual/View** of your **Simulations** directory contains the complete example of this chapter under the name **FunctionPlotter.xml**.

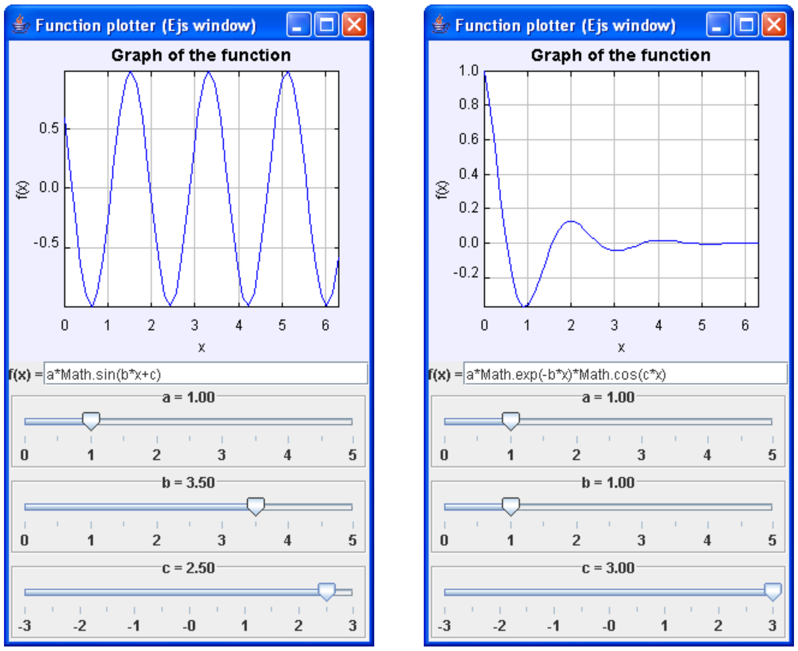
Exercise 3.1. Create a simple model for the example of Section 3.6 that defines the variables `a`, `b`, and `c`, and such that it gives them an interesting use. For instance, one in which the evolution consists in increasing 20 times per second the variable `c` in, say, 0.1 units. The result must be a traveling wave that moves to the left.

Exercise 3.2. If you look again, in Figure 3.15, at the table of properties of the element `AnalyticCurve`, you will observe that you can provide an analytic expression for the three coordinates X, Y, and Z. This means that you can easily create a plotter for parametric curves. That is, for curves in the plane of the form $(x(t), y(t))$ (or of the form $(x(t), y(t), z(t))$ for curves in space).

Create a plotter for planar (or spatial, if you prefer) parametric curves starting from the example in Section 3.6.

Exercise 3.3. If you feel inclined to work in three dimensions, create a plotter for functions of two variables $f(x, y)$ using the element "AnalyticSurface", **f**. (You will need to use "DrawingPanel3D" instead of the two-dimensional "PlottingPanel".)

Exercise 3.4. If you still feel inclined to it, create a plotter for parametric surfaces $(x(u, v), y(u, v), z(u, v))$ in general, and use it to display different surfaces such as a



f(x) = a*Math.sin(b*x+c)
a = 1.00
b = 3.50
c = 2.50

f(x) = a*Math.exp(-b*x)*Math.cos(c*x)
a = 1.00
b = 1.00
c = 3.00

Figure 3.22. Graphs of two functions using our plotter.

sphere, a cylinder, a hyperbolic paraboloid, a Möbius band, etc.

Exercise 3.5. Create a model for the simulations of the two previous exercises that allows you to animate the resulting graphs to simulate waves in two and three dimensions, or dynamic changes in the surfaces.

You will find the solution to some of these exercises in the directory cited above.

CHAPTER 4

Using the simulation

As soon as you create your own simulations, you will most likely be interested in using them in your lectures or sharing them with your colleagues. You may even want to publish them on the Internet! This chapter will teach you how to do this.

4.1 Using your simulations

Simulations created with *Easy Java Simulations* can be run in three different forms. The first form is using *Ejs* itself, in a way similar to what we did in Chapter 1. The second form consists in executing the simulation as an applet, using a Web browser. The third form consists in running the simulation as an independent Java application.

The first option has an important pedagogical advantage: the user can see how the simulation was created, learning from the knowledge that you used when building the simulation. This offers, in our opinion, a great added value. But we must admit that it also has a small inconvenience: the user must have *Ejs* installed in her computer and need to know how to use it, at least in a basic way.

Even when we may agree that *Ejs* is a wonderful tool[1] which, furthermore, is free for distribution, you, most likely, don't want that *all* your users need to install it and

[1]We, proud authors, do think so!⌣̈

learn its use just to be able to run a simulation. Fortunately, simulations created with *Ejs* are, once generated, independent from it. Thus, when this situation appears, we recommend to run the simulation in form of Java applet.

A Java applet is a special type of application that has been designed to be run inside a Web browser. The browser loads an HTML file (HTML stands for *Hyper Text Markup Language*) which indicates the browser that it must run the required applet inside its own window. This HTML file and the corresponding applet can be located on your hard disk or in an Internet location and be served to you through the network by a so-called Web server, a computer that runs this special service.

A second reason for this recommendation is that the HTML pages that *Ejs* creates for the applet can be modified so that to complete the narrative that you included in the introduction for the simulation. This allows you to create a complete set of pedagogical units that can be used for your teaching duties. Finally, it is also possible to include in this narrative controls of a simple script language called JavaScript that integrate the text with the control of the simulation in a very natural way. [2]

The third form of execution of simulations, as independent Java applications, is also possible without installing *Ejs*. The user only needs to have a Java Virtual Machine (such as that provided by the Java Runtime Environment) installed in her computer. Simulations running as applications can be installed on the hard disk, or can also be served through the network by a Web server using Java Web Start technology. We describe this technology further below.

An important reason to use this third form is when you want to run (independently of *Ejs*) a simulation that saves data to the hard disk. As we explained in Subsection 2.7.3, simulations created with *Ejs* can, if the author decided to offer this possibility, read data from the hard disk or from the Web, independently of the form in which they run.

However, to first create this data, it is necessary to be able to write on disk, which, for security reasons included in Web browsers, is only possible when you run the simulation from within *Ejs* or as an independent application. (In this second case, the applications must be installed in your hard disk. Java Web Start includes a security system similar to that of applets.)

Distribution of a simulation within *Ejs*

Distributing a simulation created with *Ejs* for other people to use it with *Ejs* is immediate: you just need to provide your user with the simulation file (the one with

[2] Although it is out of the scope of this manual the complete description of the format of HTML files and of JavaScript, we will provide a basic introduction which is enough to illustrate their use with *Ejs*. You can surely find appropriated books on these topics in your usual technical bookstore.

extension **.xml**) together with any auxiliary files, such as images or data, that the simulation may need.

Hence, for instance, for the simulation of Chapter 1 (which uses no additional data file), you'll only need to provide the file called **Spring.xml**. Your user will need to know how to start *Ejs*, load this file, and work with it, similarly to what you did in that chapter.

The rest of this chapter is devoted to explain how to run the simulations in any of the other two forms, as well as to teach you how to correctly distribute the simulations created with *Ejs* independently from it.

Copyright and disclaimer

This is a good moment to remind you of the copyright restrictions about *Easy Java Simulations* and the simulations created with it. Good news! There are very minor restrictions. Here is a copy of the conditions of use of *Ejs*.

Easy Java Simulations is the exclusive copyright of its author, Francisco Esquembre, who distributes it under a GNU GPL license. Examples of simulations included with *Ejs* are copyright of their authors.

Easy Java Simulations and its JAR library files can be copied and distributed without limit and without previous permission, provided this is done for non-commercial reasons. In any case, the reference to the author that appears in the program must always be preserved.

Authors can distribute any simulation that they create using *Easy Java Simulations*, provided a reference to this fact is included, together with a link to the official Web page for *Easy Java Simulations*, `http://fem.um.es/Ejs`. It is not necessary to include this in all pages with a simulation on it of an educational unit; including a reference for the whole set in a clearly visible place will suffice.

Any publication that results from the use of *Easy Java Simulations* must refer to the official Web server for *Ejs*, `http://fem.um.es/Ejs`.

Finally, a short disclaimer. Although *Ejs* has gone through a long sequence of tests, *Easy Java Simulations* is provided 'as is'. That is, we refuse any responsibility for any problem or damage caused by the use of the software.

4.2 Files generated for a simulation

We need to describe briefly what files are created when we run a simulation with *Ejs*, right before the simulation actually appears on the computer screen. We will illustrate the process using the example of Chapter 1.

Recall that the name of that example was **Spring.xml**. After running the example you will find the following files in your **Simulations** directory:

Spring.java and SpringApplet.java These are the files that contain the Java code for the simulation and its applet. Recall that *Ejs* is, after all, a code generator: it collects all the information that you provide to it in its different panels and generates the necessary Java code.

There is a long way from the information you provide to the final result, but *Ejs* takes care of everything automatically. The Java code contained in these files unveils some of our secrets and you can inspect it if you want. However, only a Java programmer with particular needs would be interested in modifying the code directly. You can therefore, after all, safely instruct *Ejs* to delete automatically these files after using them.

Actually, it is very likely that you don't find these files in your **Simulations** directory, to begin with. This is because *Ejs* is configured by default to delete them after generating the simulation. We mention them here because they are important to understand how *Ejs* works. See Subsection 4.3 to learn how to configure *Ejs* to not to delete them.

spring.jar This is the final file produced by the Java compiler when it processes the previous files. Well..., not quite. Compilation can produce a lot of small files that *Ejs* groups on a single file that it then compresses to facilitate the distribution. This file is, for our example, precisely **spring.jar**.

This file is a (Java) self-executable file. Thus, if your system has the Java Runtime Environment installed, you can, most likely, run the simulation by double-clicking on the JAR file. (Read however, the distribution notes of Section 4.6.)

Spring.html This is the main HTML file generated by *Ejs* in order to run the simulation in form of a Java applet. [3] We say that this is the *main* HTML file because, depending on the configuration options of *Ejs* (see Subsection 4.3) and on the number of pages of introduction that we wrote for the simulation, *Ejs* generates a set of more or less HTML pages that all start with the name **Spring**. We will describe in more detail the contents of this main HTML file in Section 4.4.

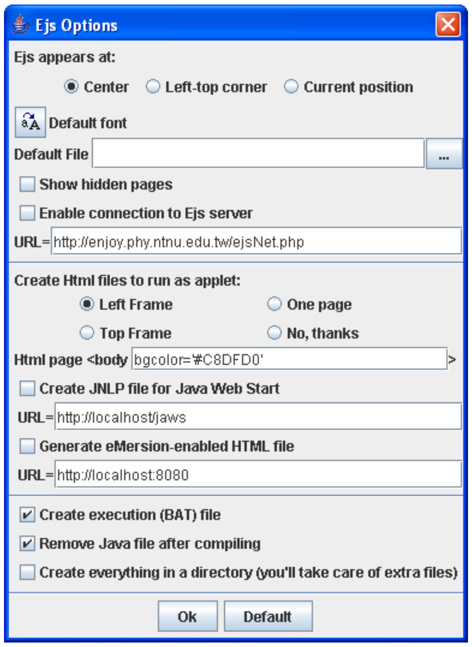
Spring.bat This is, finally, an auxiliary file that can be used to run the simulation as an application, if double-clicking the JAR file fails. It will be discussed in detail in Section 4.5.

[3]It is possible that *Ejs* is configured not to generate HTML files. Although it is not by default. See Subsection 4.3.

You will also find in your working directory the **_library** subdirectory, other directories with examples, and, probably, also some other files which resulted from the previous execution of other simulations. The **_library** subdirectory contains Java libraries that are necessary for the execution of the simulation and they will need to be distributed along with the files for the simulation itself, as we will see in Section 4.6.

4.3 *Ejs* configuration options

The behavior of *Ejs* can be modified a little bit using the configuration panel displayed in Figure 4.1. Because some of the options affect the files that *Ejs* creates along with the simulation, we describe all these options here.



Ejs appears at: [✓ Center] Left-top corner Current position

Default font

Default File

Show hidden pages

Enable connection to Ejs server

URL=http://enjoy.phy.ntnu.edu.tw/ejsNet.php

Create Html files to run as applet: [✓ Left Frame] One page Top Frame No, thanks

Html page <body bgcolor='#C8DFD0' >

Create JNLP file for Java Web Start

URL=http://localhost/jaws

Generate eMersion-enabled HTML file

URL=http://localhost:8080

[✓ Create execution (BAT) file]

[✓ Remove Java file after compiling]

Create everything in a directory (you'll take care of extra files)

Figure 4.1. *Ejs*' configuration options.

We access this panel by clicking on the icon in *Ejs*' taskbar. The options are grouped in blocks and their values are saved at the end of every session. The first block allows us to configure the initial aspect of *Ejs*. The second block helps us determine which files are generated for the distribution of the simulation from a Web server. The final block concerns the creation of other generated files for the simulation.

Options which affect the appearance of *Ejs*

The first option in the first block lets us to choose the location in which *Ejs* appears at the beginning of a session. The options are the center of the screen, the upper-left corner of it, or the current position. This last option allows us to select any location on the screen.

The second option lets us choose the default font for the code editors in *Ejs*.

The third option allows us to select a predefined file as basis for future simulations. This can be useful if, for instance, all your simulations happen to have a similar basic structure for the view. In this case, you can create this structure beforehand, save it to a file, and indicate the name of this file in this configuration field. This way, every time you click on the "New" icon of *Ejs*'s taskbar, *Ejs* will remove the current simulation and will automatically load this file. This feature can be of special interest to facilitate your students the creation of standard views.

A fourth option in the first block tells *Ejs* whether it should show or hide the so-called hidden pages of the model. See Section 2.2 for more details about what this means.

The final option in this first block enables *Ejs* to connect to a special type of network server that can be used to exchange simulation files among users. This is still an experimental development. But, typically, this will enable a new icon in *Ejs*' taskbar that you can click to connect to the server specified in the corresponding "URL" field. We will provide more details about this in *Ejs*' home page, `http://fem.um.es/Ejs`, when it is ready for general use.

Options for files for Web-based distribution of simulations

As mentioned already, *Ejs* creates a set of HTML pages, all starting with the name of the simulation, with the purpose of including in them all the information provided by you in the "Introduction" panel, together with an extra page that embeds the simulation itself in form of a Java applet. It also creates, finally, a master page that organizes the structure of all other pages and serves as entry point for the set.

The first option in this block allows you to choose the appearance of this master HTML page: either using frames with the table of contents on the left, similarly but with the table of contents located at the top, everything in one single page (which we only recommend if the introduction is really small), or even not to create HTML pages at all. This last possibility can help you keep your **Simulations** directory clean if you plan to use your simulations always from within *Ejs*, or run them as applications.

The option labeled "HTML page <body" refers to the possibility of adding a parameter of your choice to the `<body>` tag of all HTML pages generated by *Ejs*.

This can be useful, for instance, to let you choose your favorite background color for the pages, or to include a background image in them.

A third option in this same block lets you choose whether you want *Ejs* to generate a JNLP file for distribution using Java Web Start. In this case, you'll need to provide the URL from which you will be serving the JNLP file. See Section 4.6 for more details.

Finally, there is an option in this block that allows you to create a separate HTML file for use with **eMersion**. **eMersion** (see `http://eMersion.epfl.ch`) is a collaborative tool created at the EPFL in Lausanne, Switzerland. Although this is still an experimental development, *Ejs* generates eMersion-enabled simulations. The use of *Ejs* with eMersion will be described in a separate document, once it is ready for general use.

Options for the creation of other generated files

Finally, we find a block with three options. The first option asks us whether or not we want *Ejs* to generate an execution BAT file for running the simulation from a system prompt. Typically, you will uncheck this option if running under Windows and Mac OSX operating systems, and will leave this checked for Linux (which are usually not configured by default to run JAR files by double-clicking on them).

The second option in this block allows you to instruct *Ejs* to automatically delete the Java files that it creates when generating the simulation, after processing them. This can help you keep your **Simulations** directory clean.

The final option lets you tell *Ejs* to generate all the files for a simulation in a subdirectory of the **Simulations** directory. This option can help you keep your **Simulations** directory organized and clean, but has a small inconvenience. *Ejs* can't guarantee that all the data files that your simulation needs are copied to this subdirectory. For this reason, if you check this option, you'll need to make sure by yourself that all data (specially image) files are present in this subdirectory, copying them by yourself if necessary.

4.4 Running the simulation as an applet

As we said above, one of the possible ways to run a simulation created with *Ejs*, independently of it, is through the corresponding HTML page. When a simulation is successfully generated, *Ejs* creates (except if configured otherwise) a set of HTML pages for it. One of these pages, the one we called master HTML page, will be named exactly as the simulation, if only it will have the extension **.html**.

You can run the simulation by simply loading this master HTML page in your favorite Web browser. We need to make an important remark, though. Both *Ejs* and the simulations it generates use Java components that require version 1.4 or later of Java. (Current release, at the time of this writing, is 1.5.0_04.) For this reason, your Web browser will need to support this version in order to successfully run the simulations.

Unfortunately, even when Java is a well established standard, different commercial interests of the software companies involved, caused that, nowadays, some browsers only support, by default, versions of Java that we could call prehistorical. The good news is that updating your browser to more recent versions is not only easy, but also free.

All you need to do is to download an updated version of the so-called Java *plug-in* and install it. If you followed the installation instructions of Section 1.2, then your browser has most likely already been updated. If, on the contrary, your browser doesn't visualize properly the simulations generated by *Ejs*, please refer to the installation instructions for *Ejs*, which you will find in the Web server for *Ejs*. (If you got *Easy Java Simulations* from a CD ROM, please look there for this information, too.) You can also find the necessary software in the Web server of Sun Microsystems, `http://java.sun.com`. The recommended Java version is 1.5.0_04 or later.

4.4.1 The content of the HTML files

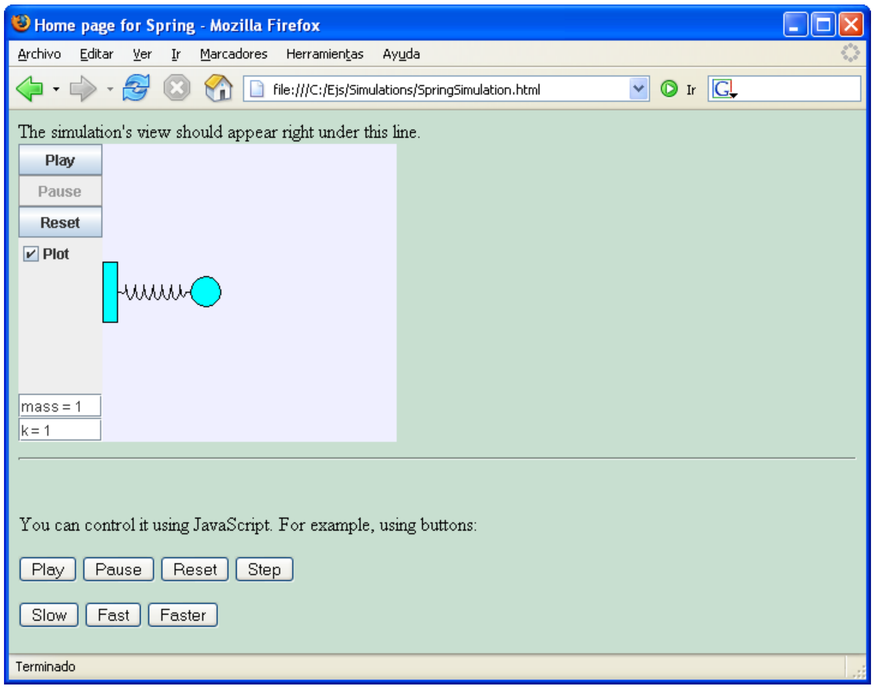
Ejs generates an HTML file for each of the pages of the introduction, which contain basically what you wrote in them. *Ejs* creates also a master page that organizes all other pages by using frames, one of which displays a table of contents. Finally, *Ejs* generates an HTML page that includes the simulation in form of Java applet. The name of this page is that of the simulation followed by the word **Simulation** and by the extension **.html**. Thus, for instance, the file created for the example of Chapter 1 is called **SpringSimulation.html**. We now describe the contents of this page. [4]

The file **SpringSimulation.xml** has three different parts, that we list separately. The result of loading this file on a Web browser is shown in Figure 4.2.

The first part of the file consists of a simple header, necessary in all HTML pages:

```
<html>
  <head>
    <title> Home page for Spring</title>
```

[4]In case you configured *Ejs* to generate a single HTML page, the content of this file will appear inside that page.


Home page for Spring - Mozilla Firefox
Archivo Editar Ver Ir Marcadores Herramientas Ayuda
file:///C:/Ejs/Simulations/SpringSimulation.html
Ir
Play
Pause
Reset
Plot
mass = 1
k = 1
Play Pause Reset Step
Slow Fast Faster
Terminado

The simulation's view should appear right under this line.

You can control it using JavaScript. For example, using buttons:

Figure 4.2. HTML page with the simulation.

```
  </head>
  <body bgcolor='#C8DFD0'>
```

This header declares the file as an HTML page, gives it a title, and opens the section `<body>` of the page, where the real content is. You will recognize in this header the name of the simulation in the `<title>` tag, and the value of the `<body>` tag indicated in *Ejs*' configuration panel.

The second is the most important part of the page, since, after a short introductory message (which you can remove, if you wish):

```
The simulation's view should appear right under this line.<br>
```

we find the `<applet>` tag, used to embed the simulation in the HTML page:

```
<applet code="spring.SpringApplet.class"
        codebase="." archive="_library/ejsBasic.jar,spring.jar"
        name="Spring"  id="Spring"
        width="315" height="248">
</applet>
```

This instruction tells the browser to load the applet called `SpringApplet`, which *Ejs* generated for our simulation. The tag also tells the browser to display the simulation with the size it had in our view. In this case, 315 pixels wide and 248 pixels high.

Please pay attention to the second line of the `<applet>` tag above. The parameter called `archive` lists the files that the applet will need to run correctly. In this case, these are the JAR files generated for the simulation, **spring.jar** and the basic library of *Ejs*, **ejsBasic.jar**. Their location is indicated relatively starting from the directory indicated by the parameter `codebase` which, in this case, is ".", that is, the same directory where the HTML page is.

For this reason, the **_library** directory must always be present in the **Simulations** directory. However, you can easily modify, if you want, any of these parameters, `codebase` or `archive`, in order to place your JAR files in any other location.

Pay attention too, finally, to the third line of the `<applet>` tag. This line provides a name for the simulation inside the HTML page through the use of the parameters `name` and `id`, [5] which we will use in the next paragraph.

4.4.2 Control of the simulation using JavaScript

The third part of the content of the page is made of the following lines:

```
<!--- Finally the JavaScript buttons --->
<br><hr width="100%" size="2"><br>
<p>You can control it using JavaScript. For example, using buttons:</p>
<p>
<input type="BUTTON" value="Play"  onclick="document.Spring._play();";>
<input type="BUTTON" value="Pause" onclick="document.Spring._pause();";>
<input type="BUTTON" value="Reset" onclick="document.Spring._reset();";>
<input type="BUTTON" value="Step"  onclick="document.Spring._step();";>
</p><p>
<input type="BUTTON" value="Slow"  onclick="document.Spring._setFPS(1);";>
<input type="BUTTON" value="Fast"  onclick="document.Spring._setFPS(10);";>
<input type="BUTTON" value="Faster"
                                  onclick="document.Spring._setFPS(1000);";>
</p>
  </body>
</html>
```

in which you will observe that the name of the simulation appears several times, exactly as indicated by the parameters `name` and `id` above.

[5] We need both parameters for compatibility reasons with the two main browsers.

The lines with the `</body>` and `</html>` tags simply close the page. The most interesting lines are those with the `<input>` tag, that show how we can define JavaScript buttons that interact with the simulation.

JavaScript is a simple script language supported by most Web browsers that allows a basic level of programming inside an HTML page. Even when we do not describe JavaScript in detail here, we will show how to use it to control the simulation in an additional way to the use of its user interface.

JavaScript can access the simulations created with *Ejs* to:

- Invoke any of the predefined methods of *Ejs*.
- Invoke any of the custom public methods that we may have defined in the model.
- Set or read the value of any of the variables of the model.

JavaScript control using buttons

The procedure is always similar to the one shown above. We first need to include an entry button using the `<input>` tag:

```
<input type="BUTTON" value="Play"
       onclick="document.Spring._play();";>
```

where the value of the parameter `value` indicates the text that will be displayed by the button in the page (in our case, `Play`), and the value of the parameter `onclick`, the method that must be invoked . In this case, the method is the predefined method `_play()`. The prefix `document.Spring` must be included exactly as shown, since it identifies the object (`Spring`) in this page (`document`) that defines the method. The result is that clicking the button labeled `Play` of Figure 4.2 will play the simulation.

Thus, for instance, if we had a public method called `myMethod()`, defined in the panel of custom methods of *Ejs* for the model of this simulation, we could include a JavaScript button that will invoke it, using the following `<input>` tag (notice the inclusion of the word `_model`):

```
<input type="BUTTON" value="Invoke my method"
       onclick="document.Spring._model.myMethod();";>
```

JavaScript control using hyperlinks

An alternative way of using JavaScript is through the HTML tag for hyperlinks, `<a>`. The same example as above would now read as follows:

```
To invoke my method,
<a href="JavaScript:document.Spring._model.myMethod();">
  click here
</a>
```

Methods with parameters

If the method that you want to invoke accepts parameters (such as `_setDelay(int delay)` or `_readState(String filename)`, for instance) simply include these parameters between the parentheses of the method's invocation. In the particular case that the parameter is a text, you will need to delimit it using simple quotes, as in:

```
<input type="BUTTON" value="Read State"
       onclick="document.Spring._readState('url:data.dat');";>
```

This example requires that we previously create the file **data.dat** (invoking the method `_saveState("data.dat")`) which must be located in the same directory of the hard disk or Web server from which the HTML file for the simulation has been loaded.

Warning: The example may not work with some configurations when reading the simulation from the hard disk, depending on how strict the security policy of your Web browser is. Reading data from a Web server should cause no problems, though.

A particularly interesting method is `_setVariables(String command)`, that can be used to set the value of one or more variables of the simulation. Thus, to set the initial conditions $x = 0.5$ and $vx = 0$ for the spring, we would use the instruction:

```
<input type="BUTTON" value="Initial conditions"
       onclick="document.Spring._setVariables('x=0.5; vx=0;');";>
```

Of course, the model must define the corresponding variables. Notice how the individuals instructions are separated by semicolons.

4.4.3 Passing parameters to the applet

Every applet has a built-in way of reading parameters from the `<applet>` tag. For this, you need to give the parameter a name and a value and include a `<param>` line between the lines which contain the `<applet>` and `</applet>` keyword.

For instance, suppose we want to pass our simulation the parameter called `MyParameter` with the value `10`. The corresponding applet tag for the **Spring** simulation would be:

```
<applet code="spring.SpringApplet.class"
        codebase="." archive="_library/ejsBasic.jar,spring.jar"
        name="Spring"  id="Spring"
        width="315" height="248">
  <param name="MyParameter" value="10">
</applet>
```

Note the inverted commas that surround the parameter's name and value.

To get the value of this parameter in the simulation, you'll need to invoke, in any suitable part of it, the predefined method `String _getParameter(String name)` (see Subsection 2.7.3). It is important to notice that this method returns a String. You should take care of properly extracting the information, if this is a numeric value, from the returned string. Notice also that, if the parameter is not defined, the `_getParameter()` method returns a null string.

For the example above, a correct (and safe) way of processing a parameter would be as follows:

```
double value = 0.0; // default value for the variable
String parameter = _getParameter ("MyParameter");
if (parameter!=null) value = Double.valueOf (parameter);
```

Finally, note that you can define as many parameters and include as many `<param>` lines in the `<applet>` tag as you need.

4.4.4 Writing your own HTML code

Once we have seen the basic content that your HTML needs in order to include the simulation as an applet, and the format of the possible JavaScript commands to control it, you can modify your HTML page in any way you find convenient.

In particular, if you know how to write HTML code or you have an specialized editor, you can enrich your Web pages for the simulation with new narrative or with detailed instructions of use of the simulation.

4.5 Running the simulation as an application

The third of the forms in which you can run a simulation is, as we said in the introduction for this chapter, as an independent Java application. For this, however, your computer must have a Java Virtual Machine installed. If you followed the installation instructions of Chapter 1, then there is one already installed in your computer. If you didn't, please read the installation instructions for *Ejs* (see Section 1.2) or get a Java Virtual Machine from the Web server of Sun Microsystems, `http://java.sun.com`. The recommended version is, again, 1.5.0_04 or later.

The file you need to run the simulation as an application is **Spring.bat**. If we inspect its contents, [6] we find the following lines:

```
"C:\Program files\Java\jdk1.5.0_04\jre\bin\java" -jar itt.jar
```

This single line calls the run-time engine of Java (which in our system is in the directory **C:\Program files\Java\jdk1.5.0_04\jre\bin**) telling it to run the simulation contained in the self-executable JAR file **spring.jar**.

Recall that the file is self-executable, but that it requires the **_library** subdirectory to be present in the same directory as **spring.jar**. This dependence is specified in the so-called *manifest* file inside the **spring.jar** file. Advanced programmers can edit this manifest to change the location of the **_library** directory.

If you execute the file **Spring.bat** in the standard way for your operating system, a window will appear displaying the view of the simulation.

4.5.1 Running the simulation using Launcher

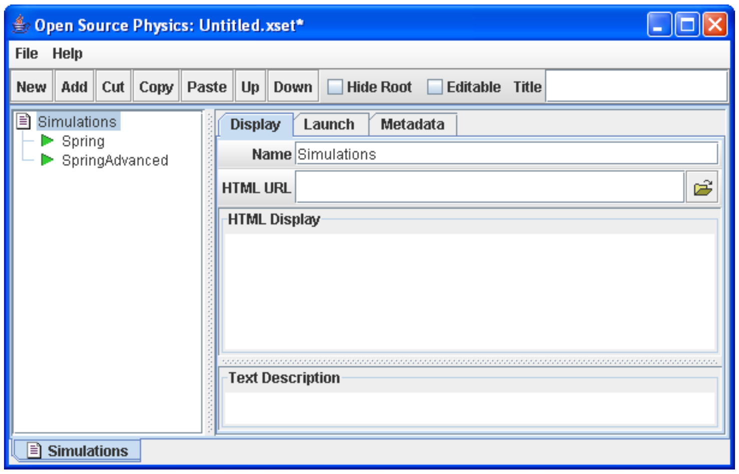
Launcher and **LaunchBuilder** are two tools, created by Doug Brown and included in the Open Source Physics library distributed with *Ejs*, that can be used to organize a set of self-executable JAR files, and to provide an end-user with a single window from where to run them.

We don't describe any of these tools in detail here (interested readers can read the OSP Guide –consult `http://www.opensourcephysics.org`) since, actually, they are very easy to use. But we need to mention that *Easy Java Simulations* includes both tools to help you organize the simulations you create with it. This is specially useful if you want to distribute a number of simulations in a single directory. These tools can help you provide a single, documented, and easy to use, entry point to all of them.

For this, once you have generated the simulation, or simulations, you want, start **LaunchBuilder** using the button provided by *Ejs*' console or running one of the script files **LaunchBuilder.bat** (for Windows) or **LaunchBuilder.sh** (for Mac OS X and Linux). This creates automatically in your **Simulations** directory two files called **_Launcher_.bat** and **_Launcher_.osp** which can be used to organize your simulation JAR files.

[6] We illustrate here only the file which corresponds to Windows operating system. The files for other operating systems are equally simple.

Actually, after creating the files, **LaunchBuilder** appears on the screen to help you customize this organization. (Again, the use of **LaunchBuilder** is rather natural, but you can refer to the OSP Guide for more information.) See Figure 4.3.



Name: Simulations

Figure 4.3. LaunchBuilder interface for the simulations of Chapter 1.

Once the edition is finished, you can run your simulations from **Launcher** by double clicking the **_Launcher_.jar** file that has been now created in the **Simulations** directory. The interface for **Launcher** is displayed in Figure 4.4.

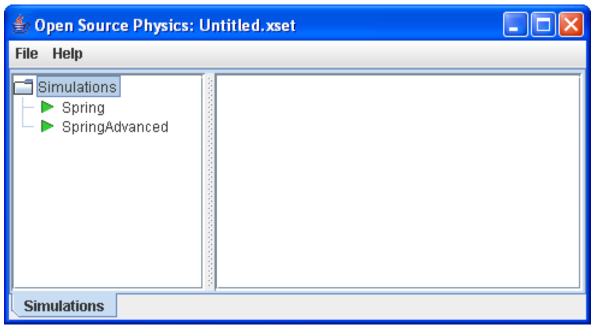


Figure 4.4. The final Launcher interface for the same simulations.

The **_Launcher_.jar** and the **_Launcher_.osp** files can be distributed together with the simulations (see below) to help your end users run the simulations.

4.6 Distribution of simulations

As we have said several times, simulations created with *Ejs* are independent of it, if only they need some libraries that include the graphic elements and other required

Java classes. These libraries are not part of the standard Java distribution, because they have been specially created for *Ejs* to simplify the construction of simulations and to help add specific functionality without much user effort.

Because of this, when you distribute your simulations, you need to remember to include these libraries in the distribution package. This, fortunately, is very easy to do. To distribute any simulation created with *Ejs*, you just need to provide the files generated by *Ejs* for the simulation, as we saw in Section 4.2, together with the **_library** directory (with all its contents). Also, if you designed your simulation to use additional files (such as GIF images, sound, or other data files), you'll need to provide these too.

Simulations created with *Ejs* can be distributed using any of the following ways:

From a Web server You'll need to copy the JAR, HTML, and auxiliary files for the simulation in a directory of your server. Copy also the **_library** directory into the same directory as your simulation on the Web server.

In a CD-ROM This procedure is similar to the previous one. Just copy the JAR, HTML, and auxiliary files, and the **_library** directory to the CD.

As mentioned above, you can also include properly configured copies of the **_Launcher_.jar** and **_Launcher_.osp** files, so that your users can use them to run the simulations as applications.

Using Java Web Start This is a technology created by Sun to help deliver Java applications from a Web server. The programs are downloaded from a server at a single mouse click, and they install automatically and run as independent applications.

Easy Java Simulations is prepared to help you deliver your simulations using this technology. More precisely, *Ejs* can automatically generate a Java Web Start JNLP file for your simulation. For this, in *Ejs*' configuration options (see Subsection 4.3) click on the "Create JNLP file for Java Web Start" check box and type in the file below it the URL of the directory (only the directory!) from which you will be serving this JNLP file. Now, when you generate the simulation, a new file with the name of the simulation, but with the extension **jnlp**, will be created. Copy this file along with the other files generated for the simulation to the directory of the Web server you specified.

Finally, your server will need to report, for any file with the extension **jnlp**, a MIME type of `application/x-java-jnlp-file`. Not all servers are configured to do this by default. The way to do this depends on your browser, but, for instance, on the Apache server you just need to stop the server, edit the **conf/mime.types** file to add a line like the following:

```
application/x-java-jnlp-file JNLP
```

and re-start the server again.

If you distribute more than one simulation on a CD or from the same Web server, you can install a single copy of the **_library** directory, as long as all the execution files for your simulations correctly point to that directory. This can be achieved by editing the `<applet>` tags (for applets) or the manifest files of the JAR files (for applications) in a convenient way. However, we recommend you to take the easy way out and just copy all the simulations in the same directory.

Finally, don't forget to tell your users to install a Java Virtual Machine, or the necessary Java plug-in for the Web browser. The recommended version is 1.5.0_04 or later.

Exercises

Exercise 4.1. If you have access to a Web server, place one of the simulations we created on the previous chapters in it. Check that the simulation can be executed using a Web browser (with the corresponding plug-in).

Exercise 4.2. Modify the HTML for the simulation you published in this Web server, introducing in it some JavaScript controls, using both buttons and hyperlinks.

Exercise 4.3. Create a complete didactic unit on resonances from the improved simulation of the spring that we created in Chapter 1. Distribute the resulting didactic unit on a CD or from a Web server.