Today's program

Today we will produce many simulation runs of another, extremely simple model. The goal is to get trained in the most frequently used steps when using Lsd

1. Run a simulation exercise.
2. Analyse the results.
3. Re-load a new configuration.
4. Change either the number of objects or the initial values for lagged variables and/or parameters.

Students are supposed to work mostly alone, reading their notes and trying to get out of troubles using the online help manual.

Logistic Chaotic Model

Consider the model made of the single equation

$$X_t = m * X_{t-1} * (1 - X_{t-1})$$

. To implement this model follow the usual steps:

1. Create a new model using the model browser in **LMM**.
2. Insert the equation's code for the model.
3. Compile and run the model (menu **Model/Run**).
4. With the resulting **Lsd model program** generate one object and place in it variable X with 1 lag and parameter m.

Logistic Chaotic Model

The model equation can be written as follows

```
EQUATION("X")
/*
Logistic equation
*/
v[0]=VL("X",1);
v[1]=V("m");
v[2]=v[1]*v[0]*(1-v[0]);

RESULT( v[2])
```

Simulating the logistic function

Assuming $X_0 = 0.5$ we obtain different results for different values of m. What happens for $m = 2$?

$$X_t = m * X_{t-1} * (1 - X_{t-1})$$

| X_t	$m = 1$	$m = 2.5$	$m = 2.9$	$m = 3.1$	$m = 3.4$	$m = 3.7$	$m = 3.99$
X_0	0.5	0.5	0.5	0.5	0.5	0.5	0.5
X_1	0.25	0.625	0.725	0.775	0.85	0.925	0.9975
X_2	0.1875	0.585938	0.578188	0.540563	0.4335	0.256687	0.00995006
X_3	0.152344	0.606537	0.707271	0.7699	0.834964	0.705956	0.0393057
X_4	0.129135	0.596625	0.600412	0.549178	0.468516	0.768053	0.150666
X_5	0.112459	0.601659	0.695761	0.767503	0.84663	0.659146	0.510582
X_6	0.099812	0.599164	0.613865	0.553171	0.441482	0.831289	0.997053
X_7	0.0898497	0.600416	0.6874	0.766236	0.838357	0.518916	0.0117231
X_8	0.0817767	0.599791	0.623155	0.555267	0.460749	0.923676	0.0462268
X_9	0.0750893	0.600104	0.681015	0.765531	0.844762	0.260845	0.175918
X_{10}	0.0694509	0.599948	0.629977	0.556429	0.445874	0.713378	0.578435

Logistic Chaotic Model

We can see the results in graphical terms. The following graphs all the series for the first 10 time steps and then four graphs representing couples of series over 100 time steps. While observing each graph set m to one of the values used and replicate the simulation results.
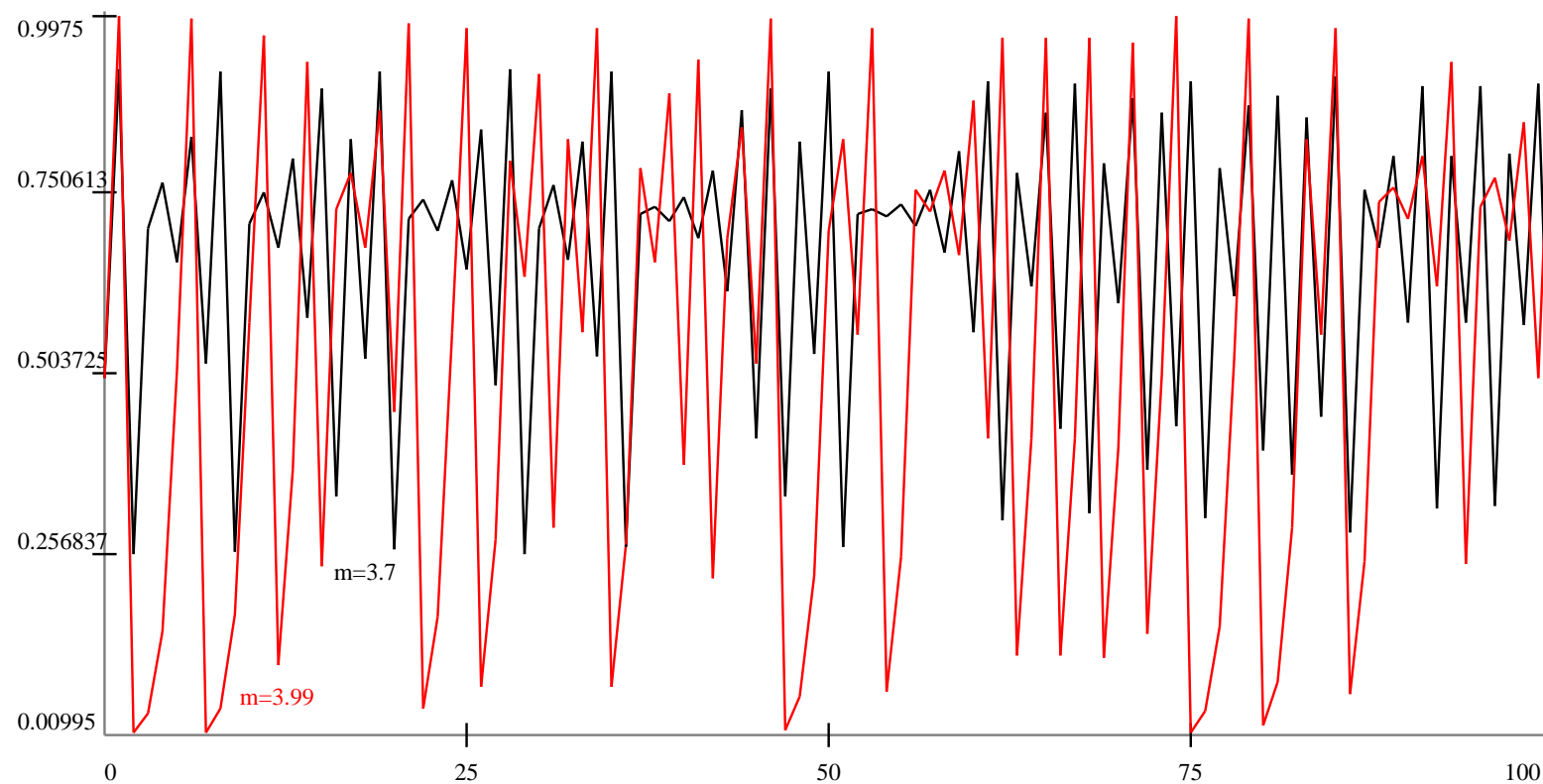
Remind: menu **Run/Sim.Settings** sets the number of steps in the simulation. Menu **Data/Init.Values** sets the initial values for the data in an object. Menu **File/Reload** reloads a fresh configuration at the end of a simulation run.

m=3.7

m=3.99
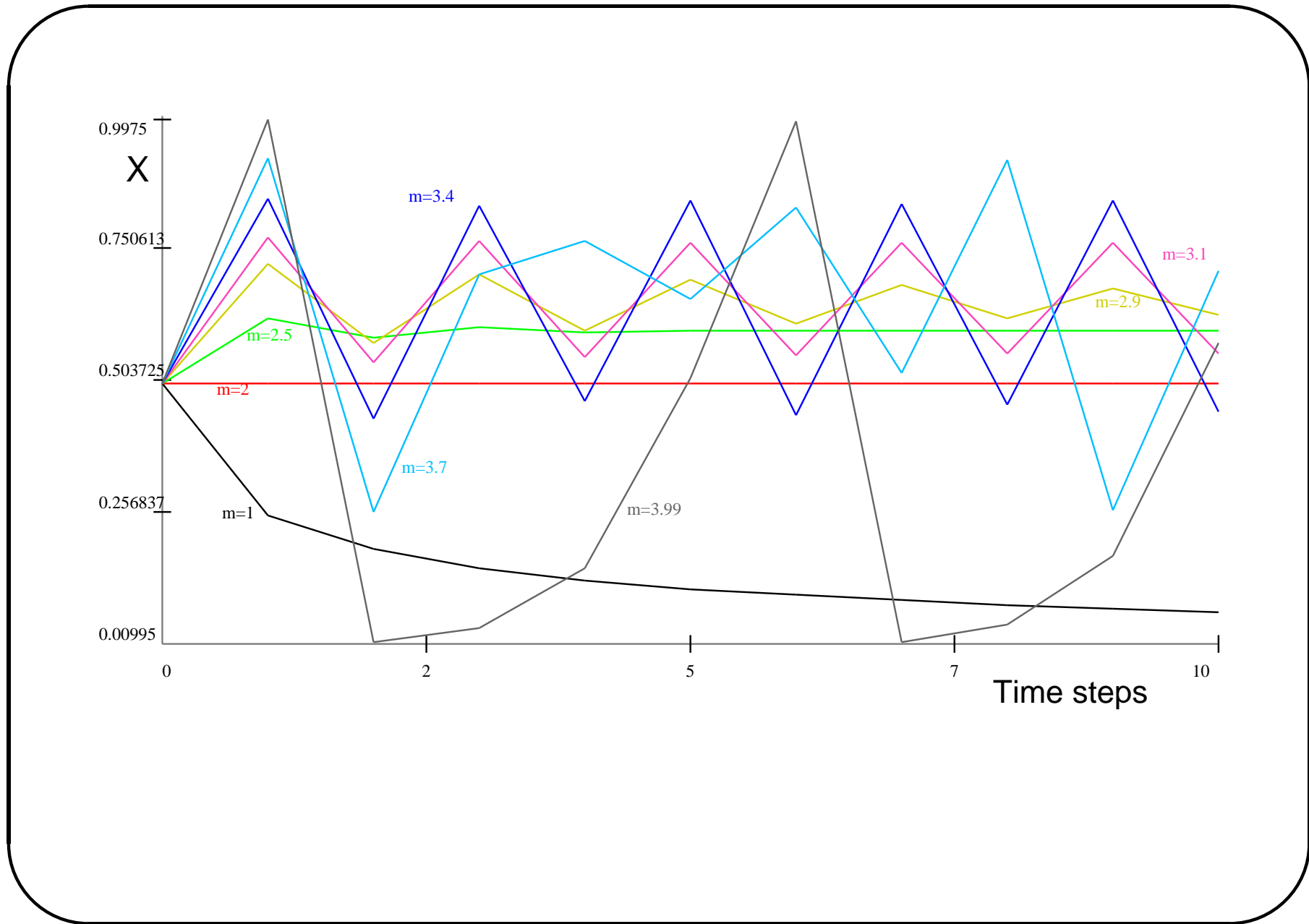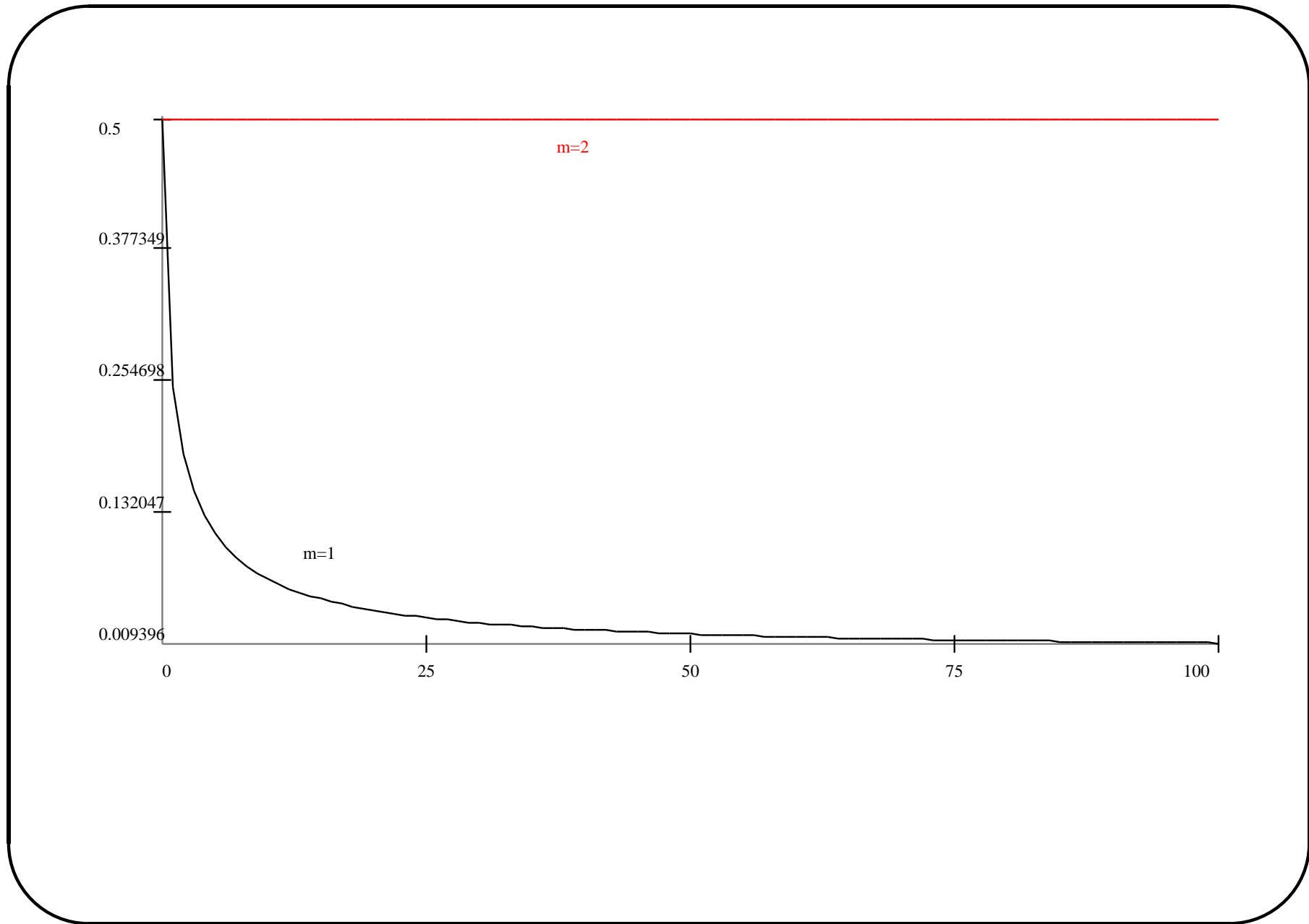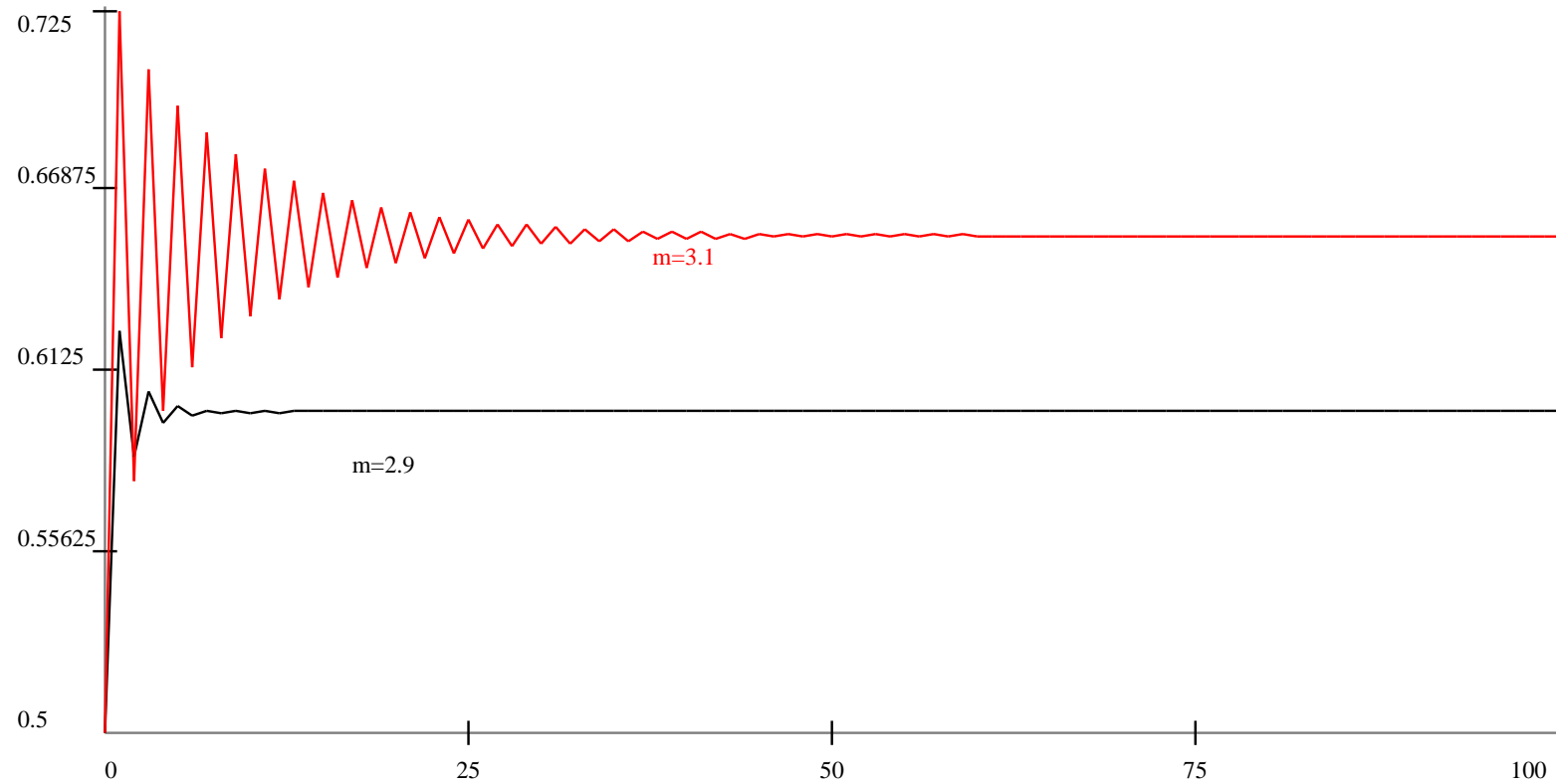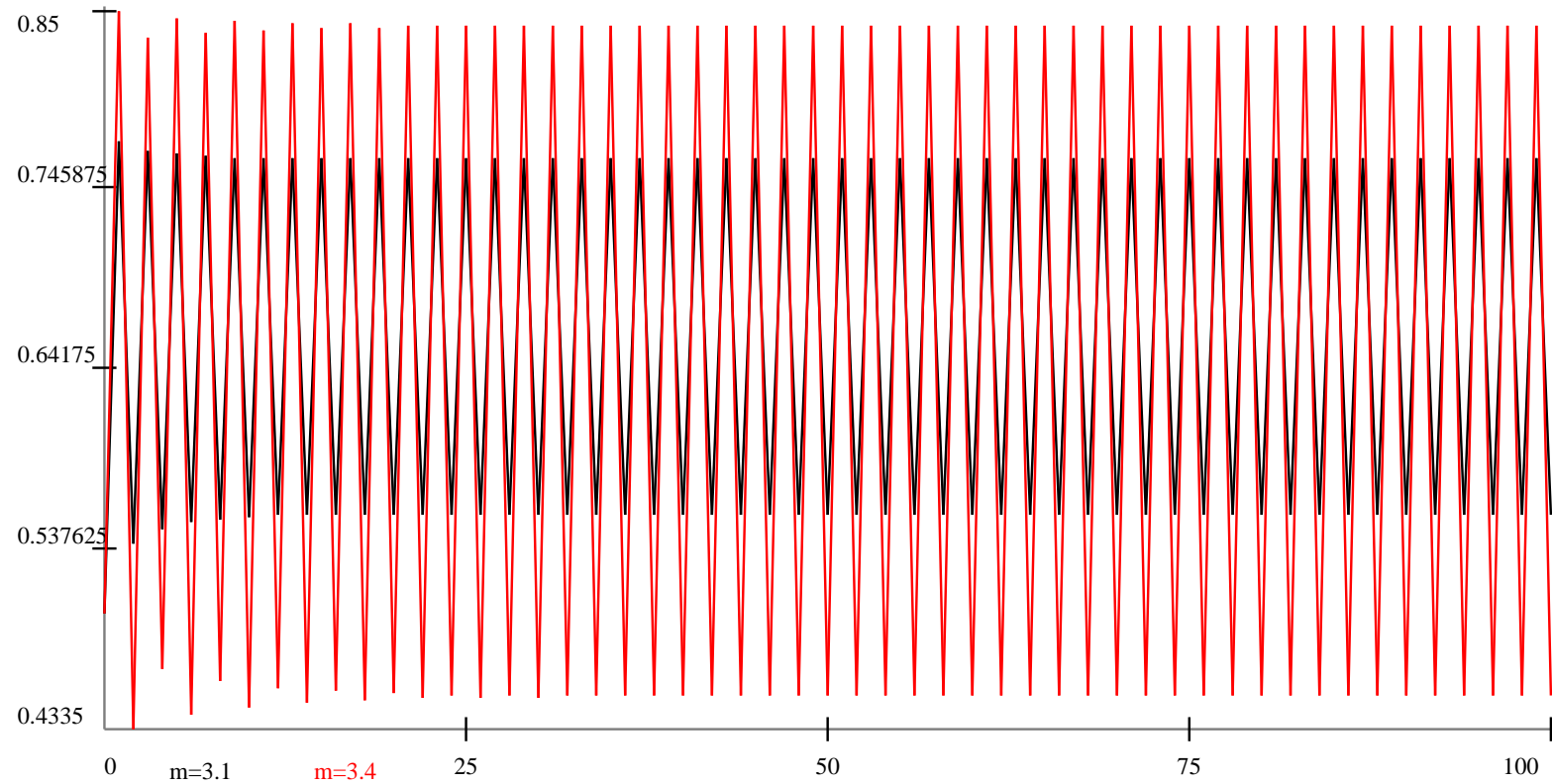
Logistic Chaotic Model

The function provides extremely different results depending on the value of m. To understand how the results depend on m let's make a systematic analysis of the model.

1. Use menu **Data/Set.Obj.Num/All Obj** to generate 1000 copies of the object.
2. Place the Browser to show the object's content.
3. Open the initial values interface with **Data/Init.Values**.
4. Set the values for m with the **Set All** button.
5. Choose to set increasing values starting from 2.8 increasing of 0.0012 for each step.
6. Choose to set all the X with random values from a uniform between 0 and 1.
7. Use menu **Run/Sim.Settings** to make 1000 time steps.

Notice that the initialization window shows only the first 100 values.

Looking inside the model

The Lsd Browser shows the content of the model in terms of classes of objects. The interfaces to set the number of objects or the initial values are specifically designed for that purposes. There is another way to browse a Lsd model which allows a full observation of all copies of objects and of the values of the elements in the model.

Choose menu **Data/Data Browser**. Observe the results and, if necessary, use the menu **Help** to clarify elements of the window.

Running a multiple object simulation

Set both X and m to have their values saved (double-click on their label and check on the option **Save**).

Control that X is not set to be plotted in the Run Time Plot window. If you ran a simulation with this option than you would have the window crowded with 1000 series. To remove the plotting option you can either double-click on the label for X or simply choose menu **Run/Remove Plot Flags**.

Run the simulation and, at the end, open the analysis of results module (menu **Data/Analysis of Results**).

Analyse the results: Cross Section graphs

The analysis window shows 2000 series available (all the m's and X's). If this is not the case, exit the analysis of results module and set on the option to save the missing item. Then re-run the simulation and open the Analysis of Results module.
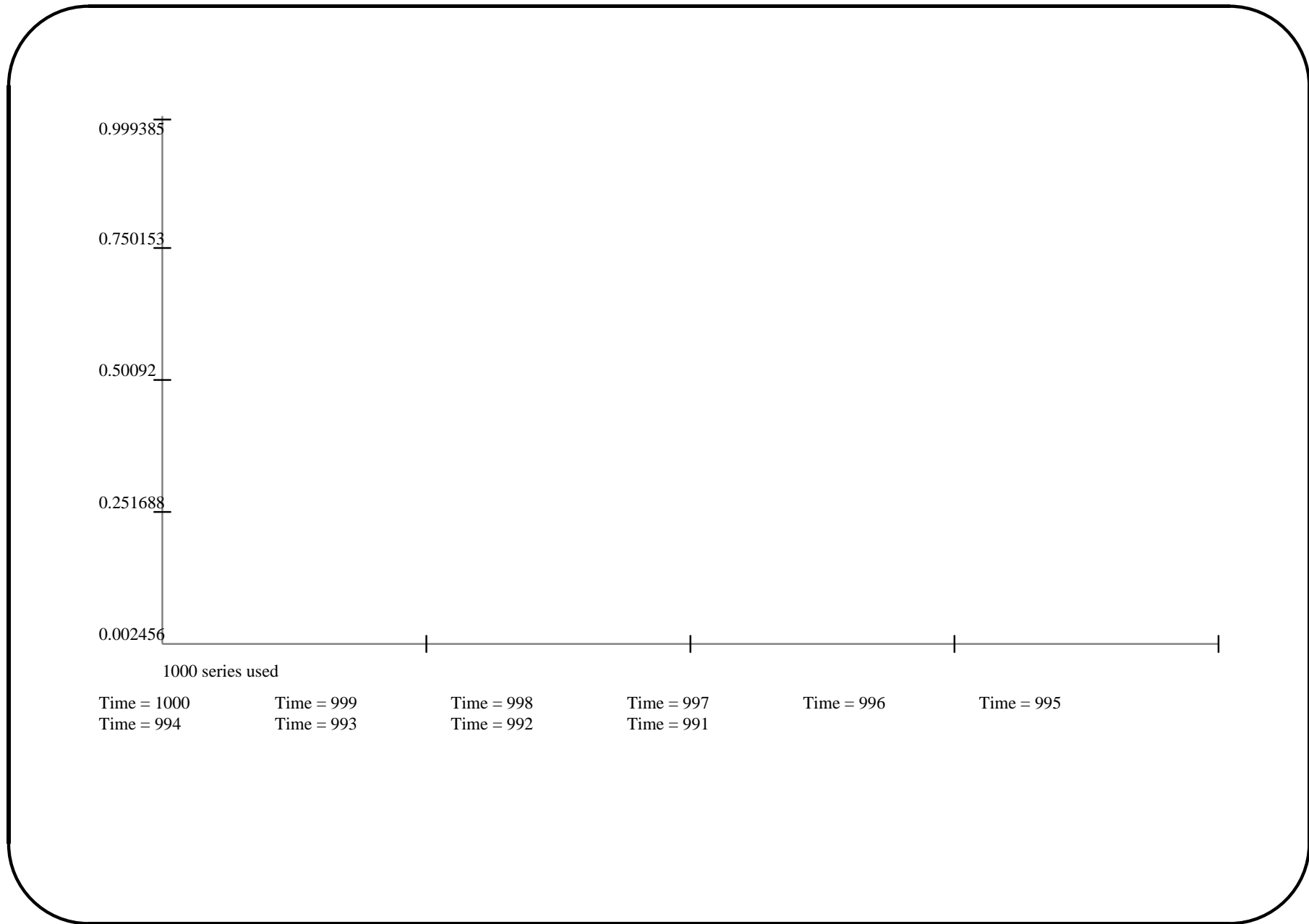
1. Select in the **Series Selected** list all X's. Click with the *right button* of the mouse over one label for the X. The resulting window allows to move in **Series Selected** either all series for X, or a selection determined by a threshold. Don't enter any value for selecting all series and press **Ok**.

2. Choose the plotting options: **Points**, **Cross Section** and **Sequence**.

3. Press **Plot**.

4. In the resulting window type 1000 and press button **Add**. Press **Continue** to generate the graph.

Reading Cross Section graphs

The graphs we have seen so far show the variations of a variable through time, which appeared on the horizontal axis. Cross section graphs, instead, show different variables on the horizontal axis and plot one line (or a sequence of points) for one time step.

In other terms, all the values for the variables at a specified time step make up a series plotted in the order of the variables.

As an exercise, generate a cross section graph with the values of the variables X's for all the times from 991 to 1000. The next window shows the result when the **No colors** option is set on.

0.999385

0.750153

0.50092

0.251688

0.002456

1000 series used

Time = 1000   Time = 999   Time = 998   Time = 997   Time = 996   Time = 995
Time = 994   Time = 993   Time = 992   Time = 991

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Analyse the results: XY graphs

Let's now see the results making an explicit link between the m's and the X's. Click on **Clear** to remove all series from the **Series Selected** list.

1. Select in the **Series Selected** list first all m's and then all X's.
2. Choose the plotting options: **Points**, **Cross Section** and **XY plots**.
3. Press **Plot**.
4. In the resulting window accept the default options. Press **Ok**. Press **Yes** if a warning appears.

Reading scatter, or XY, plots

A scatter plot is generated considering the values at a given time step of the two blocks of variables, by default the first and the second half of the series present in the **Series Selected** list. In our case, the first block consist of all values at time 1000 for all the m's. The second block is composed by the values at the same time of the X series. Points are determine by the couple of values for one series in the first block and one in the second block.

The scatter plot places a point at the horizontal level determined from the first value (in our example the m) and at the vertical level determined by the second value (the X).

Since our m are already organized for increasing values, the resulting graph is identical to the one generated as cross section graph. The differences depend only on the different formats used for the graphical generation of the graphs.

Exercise on scatter plot

Try to select one X series only and set the options **Points**, **Time Series**, and **XY plot**. After pressing **Plot** choose 1, 2, or 3. Can you interpret the resulting graphs? Try different series X, including the last one available. Why is there such difference?