LSD- Laboratory for Simulation Development

Lecture 1 - Linear model

Goal

In order to familiarize with the procedures required to create and use a simulation program in LSD we start with an extremely simple model:

$$X_t = X_{t-1} + m$$

The simplicity of the model will allow to focus on the use of the LSD interfaces.

Content

In this lesson we will perform the following steps:

1. Use LMM to create a new model, call it “Simulation 0”.
2. Write the C++/LSD code for the equation of X and compile the LSD model program.
3. Usethe LSD model program to create:
   1. an object *Obj*;
   2. a variable X in *Obj*;
   3. a parameter m in *Obj*;
4. Set the initial values for the number of copies of *Obj*, the X_0’s, and m’s.
5. Run a simulation exercise and read the results.

LMM - create a new model

The latest version of LSD can be downloaded from `https://github.com/marcov64/lsd`.

To start the system run the `run.bat` file (Windows) or the `lmm` executable (MacOS or Linux, see the readme.txt file).

You will launch LMM, an editor specialized to code LSD models and compile LSD model programs.

At start time LMM offers the opportunity to browse the existing models. Choose this option or, if you already started the system, choose the menu entry **Model/Browse Models**.

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3. Open menu **Edit/New Model**, and choose **New Model**.
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3. Open menu **Edit/New Model**, and choose **New Model**.
4. Assign a model name "Simulation 0", a version number, 0.1, and a directory name, `S0`.
5. Now LMM shows the equation file prepared for the new model.

At any time you can press **Cancel** or the *Esc* key to abort the procedure and start again.

LMM - The equation file

Any equation file must contain the following text:

```
#include "fun_head.h"

MODELBEGIN

MODELEND

void close_sim(void)
{

}
```

The code for a model's equation must always be placed in between the `MODELBEGIN` and `MODELEND` lines.

LMM - The equation file

Out purpose is to code the equation:

$$X_t = X_{t-1} + m$$

.

The minimal expression for this equation in the LSD equation file is:

```
EQUATION("X")
RESULT(VL("X",1)+V("m") )
```

Let's see the meaning of the commands used in the LSD expression of the equation.

LMM - The equation file

In LSD the equations are written as separate blocks of code beginning with `EQUATION("VarName")` and ending with `RESULT(anyValue)`.

These lines correspond to the expression:

$$VarName_t = anyValue$$

Within the heading and closing commands for an equation the modeler can insert any legal C++ code or LSD keyword.

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The command `V("...")` has a few variations. The one we need is `VL("Y",lag)`, returning the value of the variable *Y* computed `lag` periods before the present, that is Y_{t-lag}. Note that `V("Y")=VL("Y",0)`.

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There are many LSD commands available for common computational structure. See the LMM help pages on the Macros for LSD Equations.

LMM - The equation file

The equation's code we wrote earlier was called "minimal" because, though working, is too compact.

Typically, using long variables' labels and with expressions entailing more than a few operators, the expression of the equation within the `RESULT( )` becomes impractical.

It is far clearer and more efficient to write the equation over several lines, breaking the computation in small pieces, and storing intermediate results in temporary variables.

The modeler can use a vector of values, referred to as `v[0]`, `v[1]`, etc., to store intermediate results during the computation of the equation for a variable.

LMM - The equation file

The equation $X_t = X_{t-1} + m$ can be expressed in a clearer and more general format as follows:

```
EQUATION("X")
/*
The new X is equal to its own past value plus `m`
*/
v[0]=VL("X",1); //past value of X, lagged of 1 period
v[1]=V("m"); //current value of m
v[2]=v[0]+v[1];
RESULT(v[2] )
```

LMM - The equation file

The C++ local variables `v[0]`, `v[1]`, `v[2]`, etc. are temporary storing places for intermediate calculations. The values stored there can be used only within one execution of the equation, and cannot be used to transfer values across different equations. These variables are created when an equation begins its computation, and are destroyed immediately after its conclusion.

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Notice also the comments added just below the beginning of the equation. All the text placed in this position is considered by LSD the "official" documentation of the variable, and will be automatically included in the documentation of the model.

LMM - Scripts

The text for the equations can be inserted manually as in any editor. However, LMM is endowed with specific functions to insert automatically the most frequently used commands for LSD equations, speeding up the coding time and reducing the number of typing errors.

These functions are called *scripts*, and when activated insert automatically text in the position of the cursor in the LMM page, asking the modeler for any required for information.

LMM - Scripts

Once activated the script place the text starting at the position of the text cursor in the equation file.

The activation of the scripts can be performed in several ways:

1. using the keyboard combination **`Control-i`**;
2. using the right-button of the mouse;

In both cases you are offered the whole list of available scripts, and then you can choose one using the mouse or pressing a letter indicated in the scripts.

LMM - Scripts

For example, you can insert the lines for `EQUATION("VarLabel") ... RESULT( )` pressing **`Control-i`** to show the available scripts and **`e`** for inserting an equation.

Any script shows a specialized window allowing to fill the information required for the script. Read the text of the entries, and, in case of doubts, accept the proposed default choice.

Any text entered by a script can be modified later and, if necessary, scrapped.

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3. Use **Control-i** and then **v** to store m in the temporary variable `v[1]`. Insert the element label **m**.
4. Type the line `v[2]=v[0]+v[1];` (beware of the concluding semicolon!)
5. Insert in the result value `v[2]` in the `RESULT( )` concluding line.

Done!

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In case of success you will see a new interface appearing on the screen. If this is not the case you probably inserted text that has not been recognized by the compiler as legal code.

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In these case, LMM generates a new window with approximate indications on the type and location of the error. Read the error messages; every line starts with the file name of the equations you are using and a number, indicating the line where the error was acknowledged, meaning that likely it occurred at that line or one immediately above.

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Crucially, **never change** the file name for the equations. LMM associates a specific file to a model. If you edit the equation file and save it with a different name LMM will keep on using the old one for the equations.

LSD Browser

The browser shows the content of an object. An empty model contains only the default object **Root**, so this is the object appearing when the model program starts.

The Browser shows the content of the object separated in two lists: one for the variables and parameters of in the object (**Variables**) and the other for the descending objects (**Descendants**).

LSD Browser

The LSD model programs accept commands stored into menus, whose overall content is the following:

- **File**: Load and save configuration files.
- **Model**: Create a model structure (define variables, parameters, objects); generate documentation.
- **Data**: Define and observe initial values; analyse or save results.
- **Run**: Define simulation settings and run simulations.
- **Help**: Open help pages on LSD interfaces and on the model.

Generate Model Structure

Let's use the LSD Browser to generate the model structure. We need to define one object containing a variable and a parameter.
IMPORTANT: to label model entities use only characters (no spaces or other symbols). Elements' labels are case-sensitive.

1. **Model/Add Descending Obj**: Create an object `Obj`.
2. Click on `Obj` in the list of **Descendants**. The Browser shows the new object.
3. **Model/Add a Variable**: Create an variable `X` with 1 lag.
4. **Model/Add a Parameter**: Create a parameter `m`.
5. **File/Save as**: Save the current configuration in a new file `Sim1`.

Fixing Structural Errors

It is easy to make mistakes in typing the labels of the elements or placing them in the wrong object. To correct any error double-click on the element and select in the resulting window the button **Properties** under name element's label.

There are several options for fixing different types of error. Each option needs to be used independently and confirmed when exiting the properties.

To remove an element altogether assign an empty string to its name.

Generate Initial Data

Any model can start only when the data for its state at time t=1 are assigned. The initial data concern the number of objects, the parameters, and the initial values for the variables expressed with a lag in the equations. In our case: number of copies for the object `Obj`, values of the X at time 0, and parameters m

1. (with the Browser showing `Obj`) **Data/Set num. objects/All objects** (shortcut `control-o`): there is initially only one copy of `Obj`. Click on the number and insert 10. Press Ok and Exit to return to the **Browser**.
2. (with the Browser showing `Obj`) **Data/Init. values** (shortcut `control-i`): the window shows one cell for each X_0 and for each m, indicated by an indicator for the copy of `Obj`. Use **Set All** to generate all X equal to 10 and the m ranging from -5 to 4.

Help yourself

All the windows have pretty intuitive graphical interfaces. Moreover, each window has a button (or menu item) for help. Use these help pages for understanding how to operate the windows. Notice that the help pages are linked to others, related help pages. The whole LSD hyper-manual is organized for the main menu items.

In doubt, always opt for the **default choice** offered by interfaces.

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Move the Browser on `Obj` and double-click on *X*. The system will show the options available for the variable. Select the option **Save for later analysis** and ensure it is checked on. This operation tells the system to store the values for all the copies of *X*'s in memory in order to perform post-simulation analysis.

Simulation Settings

There are other settings relevant for a simulation run that do not concern directly the model content.

Choose menu **Run**/**Sim.Setting**. The window will allow to set several options concerning how to manage simulation runs. Ignore all of them and assign 10 to the number of steps, replacing the default value of 100.

Simulation run

We can now run the simulation. Choose menu **Run**/**Run** and a summary window will appear.

This window reminds the user that the configuration defining the model, initial values, options, etc. is going to be saved in a file before starting the actual simulation. Any file with the same name possibly present will be cancelled and overwritten.

Saving the configuration allows the user to be able to perfectly replicate the last simulation, so that errors or unexpected results can be replicated and investigated. To avoid overwriting a file it is sufficient to change name of the configuration.

Confirm and the simulation will start, finishing shortly after.

Simulation run

After a simulation run the browser will re-appear. Though nothing seems changed as compared to before running the simulation, the LSD model program differs in its internal content: the initial configuration has been replaced by the configuration of the model at the end of the simulation run.

The system forbids to use this configuration to start directly a new simulation (it would overwrite a file meant to contain the initial configuration). Try to choose again **Run**/**Run**, and an error message will appear. Press **Cancel** to return.

Analysis of Results

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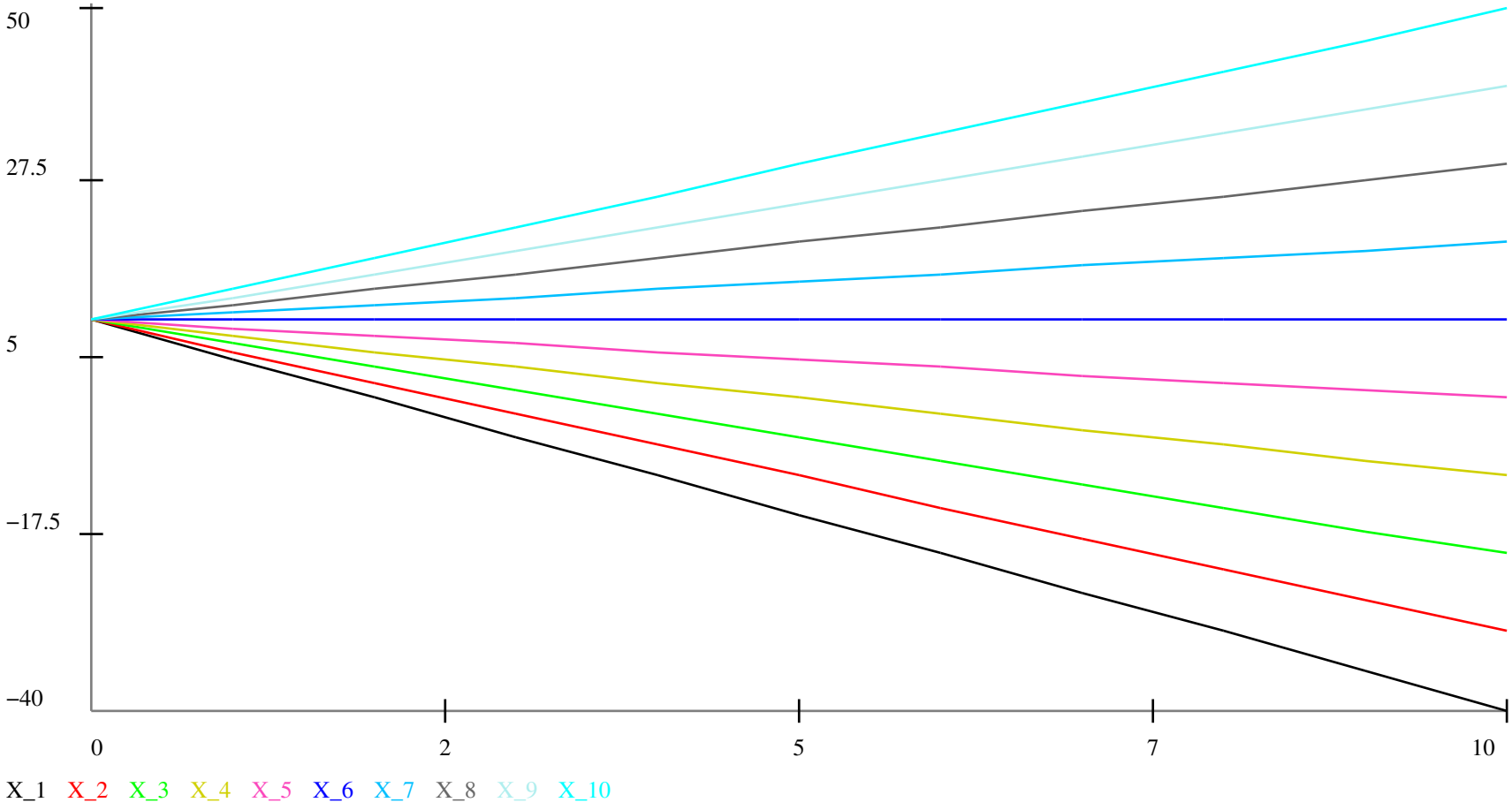
3. Select all series from the list **Series Available** and move them to the list **Series Selected** using the button $>$. Press **Plot**. You are expected to obtain a graph as in the following slide.


50
27.5
5
−17.5
−40
0
2
5
7
10
X_1 X_2 X_3 X_4 X_5 X_6 X_7 X_8 X_9 X_10

Summary

The operations we have performed in this lesson are:

1. Design a model on paper;
2. Write the code implementing the equation;
3. Define the model structure and initialization;
4. Run the simulation;
5. Analyse the results.

Exercise

- Test the *Simulation 0* model with different initializations, number of `Obj` and number of steps. Check that it actually provides the expected results.
- Modify the format of the equation, using for example a power function or any other discrete-time dynamics.