I. Introduction to Stella

A. About Stella

Stella is the name of an educational software product that allows users to visually build a model of a system and simulate how it operates. It is made by ISee Systems (http://www.iseesystems.com) At UCSC, we have purchased a site license for this product which is accessible at some computer labs and online through remote desktop sharing (see later section.)

B. Accessing Stella

There are 3 ways to use Stella. They are listed below in order of preference.

1. From campus computer labs: This is the preferred method for usage in this class. One or more of our labs scheduled for CMPS 80B will have this software installed inside the lab. It sill usually be accessible in MS Windows systems from a path like this:

START -> Class Applications -> Computer Science -> Stella 9.0.1

However ITS could have a slightly different location for it. We will explore this on the first day of the lab. Make sure you don’t miss it!

2. Using “Windows remote desktop sharing” from outside the labs: This method is great if you need access from home, or somewhere else on campus and have a PC laptop or desktop. Warning: you must have broadband access; otherwise, it becomes unacceptably slow and won’t work for our purposes. Also, your particular installation of Windows may not have remote desktop connection or it may not be available for your account. Unfortunately, we cannot provide any help under those circumstances and thus your best bet is to come to the labs during scheduled hours.

Using your PC running Windows XP or later, log into the remote desktop server as follows:

START -> All Programs -> Accessories -> Communications -> Remote Desktop Connection

For “computer” type in exactly: windows.ic.ucsc.edu
Username and password are your normal Unix campus credentials. Same thing you use for your cruzmail access.

Warning: There’s a “timeout” associated with remote desktop. If you don’t interact with the remote desktop for a long time, the connection closes and you will lose your work.
3. Downloading the trial version from the vendor (iseesystems.com)

Isee Systems allows for download of a “30 day trial version.” I’m not sure what limitations this particular version may have so it may not look like the one we use in the labs. For example, last year, they disabled the “save” option and thus the trial version did not allow one to save the project to work on later which is crucial for us.

This option is not recommended unless you have no other choice. The Fall quarter spans more than 30 days. You could download and get into a routine of using this trial version and by near the end of the quarter when you need it most, it may no longer work. (And it may not allow you to install the trial version again.)
C. Using Stella

Once you run Stella 9.0.1, the software, you should see a blank map screen with some button on the top and some tabs on the left hand side. The important features are shown below:

**Tabs Overview:** You’ll start out at the Maps Tab. This allows you to build the model by placing elements and connecting them together. Once you are finished with this, you can switch to the “Model” tab where you can examine and input numbers and equations into your model elements. Once done with that, you “run” the model and see the results.

**Elements Overview:** There are four basic elements that you need to know about. We will cover them below. The interface is an older design and may not be intuitive to all users, so please follow the directions exactly for best experience:

- **Stocks:** Stocks are containers of something, usually something that’s a quantity like money, marbles or water. It is important that you know by what units the quantity that the stock represents is measured. We will be using stocks in every single exercise so it is the most important element. To create a stock:
Click once on the stock element on the top part of the window. You should notice that your mouse cursor changes to a rectangle.

Click somewhere on the model page where you want the stock to be placed.

Click on the name above the stock to change it to a meaningful identifier for your model.

- **Flows**: Flows represent a change of quantity. As the name suggests, they flow something either in, or out of a stock, and sometimes both. Flows have a distinct beginning and end. The beginning is usually the place where some additional quantity begins to flow and the “end” is where it flows into and increases the quantity that already exists there. Bidirectional flows are capable of doing the reverse as well. In order to create a flow:
  - Click once on the flow element symbol on the top of the window.
  - Click and hold at the location in your model where you want the flow to start.
  - Drag your mouse over to where the flow is suppose to end
  - Let go of the mouse button.
  - Click on the name below the spigot symbol in the middle of the flow to rename the element to a meaningful identifier in your model.

For example, if you want to represent an increase to a stock that you already have, click the flow symbol, then click and hold close to the stock, drag your mouse right on top of the stock and then let go. If you want to represent a decrease, (i.e. flowing out of a stock), click on the symbol, then click and hold on top of the stock, drag your mouse away from the stock and then let go.

- **Converters**: Converters can be thought of as variables or additional factors that go into calculations inside flows or other converters. For example, a flow could increase the quantity of oil represented in a stock by 2 Million Barrels per day. Or it could increase by 20 times the number of cars in the United States. Since the second formula involves knowing another factor, namely the “number of cars in the US”, that factor could be represented in a converter called “number of cars in the US.” Making a converter is just like making a stock: first click on the symbol, then click anywhere on the page where you want the converter to appear.

- **Action Connectors**: An action connector transmits information from one element to the other where it can be used as a variable. For example, the Converter, once created is still unknown to a flow that may want to use the converter’s value. In order to make that value available to the flow, we must connect the converter to the flow using an action connector. Making an action connector is just like making a flow. First click on the symbol, then click and hold on the starting element, drag your mouse to the ending element and then let go.

- **Text Box**: Text boxes are extremely useful in order to provide some English language information or description of your model. You can place them anywhere and type in the text. To make on, click once on the text box icon and then click on the page where you would like it to be displayed. Click on the box to change its text.
- **Ghosts**: A ghost is just a convenient way to represent one element in multiple locations on the page. In complex models there may be, for example, way too many flows and action connectors coming in and out of a stock. To make a new connection to this stock, you may choose to “ghost” it somewhere else on the page so that you can make the connection to the ghost representation instead. The ghost can be treated just like the real thing and the quantity in the ghost always reflects exactly the quantity in the original element. To ghost an element:
  
  - Click once on the Ghost Symbol on the top right of the window.
  - Move your curser over the element that you would like to ghost and click on it. Your mouse should change to the shape of the element.
  - Click on the new location where you want to place the ghost. The ghost appears as the same element except with a dotted outline. Normally, you would want to keep the same name on the ghost as on the original.

- **Tables, Graphs, Status Indicators and Numeric Displays**: These elements are located at the top center portion of the window. They are not used in the models directly. They just display information during and after the model is “run.” Each element can be placed somewhere on the page, resized and pinned down. In addition, each element has to be “programmed” so that it knows which information from your model to display or graph.
II. Hands on Problem: My Bank Account

A. Systems concepts

Accumulation, Linear growth and decay

B. Stella concepts

Stocks, Flows, Converters, graphs and tables

C. Scenario Description

You are a college student moving into a new house with your 3 friends. You also have a new part time job of 20 hours per week that pays $9.75 / hour. Your parents are paying for your tuition and books and contributing $500 per month to your bank account for rent. You are responsible for all the bills and the rest. You estimate about $350 a month for food and groceries for yourself. You also spend about $80 a month on transportation.

The house rent is $1800 per month. Your electricity bill is about $90 per month and your cable bill is $45 per month. The rent and the utilities are divided evenly between all residents. There’s no heating in this house!

The other thing you need to do is save money to buy a new laptop computer and speakers which cost about $3500.

D. Building a Model

1. Building Stocks and Flows

To build a model of your finances, we first have to identify a central container concept. In Stella, models are usually built around a container that stores something. This is called a stock. In our case, the stock is your bank account, because that’s where a quantity of money is stored.

So we can make a Stock and name it “My Bank Account.” The initial amount should be zero since your account starts out with nothing. Your Stella model should look like this right now.

My Bank Account

[Diagram of Stock]
Now that we have a stock, we need to construct flows. Flows are things that add to stocks or subtract from stocks. What adds to a bank account? Income, of course! And what makes the size of your bank account smaller? Spending. So we construct two flows, one for income which flows into the bank account, and one for expenses which flows away from the bank account.

2. Building Converters and Connectors

Flows work by adding to or taking away from the stock some amount for every time period. If you typed in “50” into the income flow right now, it means that every time period, 50 gets added to whatever is already in the bank account. Our time period will be months, because most of the figures we have are “per month” figures. So our time base for income and expenses are also months.

How many sources of income do we have per month? The answer is two: one from work, and another from parental contribution. We could of course figure out how much money each of those sources bring in every month, add them up and put them inside the Income flow. But that would be confusing and difficult to change later. Instead, we try not to do any calculations ourselves and let Stella do all the mathematics for us. Also, we will break up the types of income and add them in separately, for clarity and diagnosis purposes.

This is easy. We just take our two separate income sources and make converters for each one. A converter is a just a place where we can store a number or do some calculation. We add a converter and name it “Parents” to denote the amount of money the parents are contributing every month, and we add another converter called “Work income” to denote how much money we bring in from work. Lastly, we have to connect these two converters to our Income flow, so they can be counted as income going into the bank account. We do this by using information arrows to go from each converter into the flows. Our model should look like this:

Now that we have some external information coming into the income flow, Stella wants us to specify how these pieces of information relate. So we can open the income flow while in the “Model” tab and write in a formula that represents our total monthly income.

That formula is very easy. It’s just Total Income = (Parents)+(Work Income).
This means that every month, the system takes whatever number is in the “Parents” and the “Work Income” converters, adds them together and then adds that result to the bank account stock.

Now we have to specify a number in each of these converters. “Parents” is easy because we know exactly how much comes in every month from them: $500. So we can just type in “500” into that converter.

“Work Income” is not so straightforward. We weren’t given the total amount of work income that we have every month. We were just given an hourly wage and a number of hours. This means that monthly income really depends on two other numbers. In Stella, whenever something depends on something else, we should try to represent that relationship in our model. First this makes our model more comprehensive and communicates more information. Second, if we ever want to change one number we know which converter to change.

So we construct two more converters. One called “Hours per week” and the other “Per hour wage.” We connect them to the “Work Income” converter with information arrows. The formula for “Work Income” is (Hours per week)*(Per hour wage), so we can fill that in. The two newer converters are just constant that were given in the problem, namely 20 for “Hours per week” and “9.75” for “Per hour wage.” We will type this information.

We should now have ended up with this model.

We are done with the income side of the model, for now. Using the same techniques we can go ahead and model the expenses side. Keep in mind these hints as you build the model:

- When-ever there is a conceptual dependency, express that with converters and information arrows.
- As a rule, try to have a dedicated converter for each piece of numeric information that you are given in the problem. For example: “number of residents” or “cable bill.”
- If you have two or more factors that contribute to a flow or a converter, break them up into separate structures using more converters and use the convergence point to combine these factors using a formula.
After completing the expenses side, your model should look like this:

As we can see, there are four arrows going into the “Expenses” flow. So the formula for that flow will be this:

\[(\text{My Food Expenses}) + (\text{My Cable Bill}) + (\text{My Electric Bill}) + (\text{My Rent})\]

Note also that many things depend on “number of residents” since the total bills get divided by this number to figure out your particular bill.

We know the initial numbers for rent, food, cable and electricity expenses from the scenario description and we can fill those in. We are now ready to perform the simulation and see some results.

3. Setting Parameters

Before we run the simulation, we should make sure we have correct parameters. From the Stella menu, choose “Run” and then “Run Specs.” Here you get a window with some options you can change. First, we should make sure the time units are correct. As we said before, the main time unit we are concerned with is months. In the middle we can choose that among the other choices given like hours or days.

Over on the left column, Stella allows us to specify the length of simulation. Since our units are in months, this length will also be measured in months. We put 0 to 24 to denote two years of simulation.

Lastly, immediately below the simulation length is a box called “DT.” DT means how many times per time unit do we want to update numbers. Since we have a linear model in this exercise the DT value doesn’t matter. But we should always set it to 1 as default. 1 means that only one set of numbers should be calculated and displayed per month.

Later, we can experiment with fractional DT times. For example, if we want to detect a certain boundary that is less than the time unit, we can do that by reducing the DT number.
4. Graphs and Tables

Graphs and tables is how Stella shows us simulation results. Before we run anything, we should tell Stella how to display its results to us. There are two different types that Stella can provide.

Tables simply display any of the Stella elements for every unit of time. To make a table, you can click on the table symbol at the top part of the Stella window. You must specify which variables you would like to see in the table. Do this by clicking on the table and choosing the variables from the left hand side and moving them to the right hand side window.

In Stella, stocks are usually very important. We typically want to see the values for stocks in both graphs and tables.

Once you have chosen the values you would like to examine, “pin” down the table on a portion of the screen and then run the simulation by going to “Run” menu and clicking on “Run.”

Just like tables, graphs can visually display the numbers that are stored in each of the Stella elements and plot them against time. To make a graph, click on the graph icon on the top portion, choose the elements you would like to graph as with tables, and then hit “Run” again. The following is a display of a graph and a table for our scenario.
Graphs and tables have many options, such as ranges and scales. You should experiment with both of these mechanisms to understand them better.
III. Questions and Exercises

Answer the following questions about the scenario in part II using Stella.

1. How many months will it take until you have $3500 saved up?

2. How much money will you have in your account at the end of the first year and the second year?

3. In the graph, do the income and expenditure lines ever cross each other? If so at what point in time?

4. In the graph, do the bank account and income lines ever cross each other? If so at what point in time?

5. Do the following changes in order and answer this question: How long will it take you to save up $3500 now?
   a) Change your working hours to 15, instead of 20 per week.
   b) Change your hourly income to $10 and answer the same question.
   c) Add an additional “entertainment” expense of $50/month.
   d) Add a birthday gift of $180 on your own birthday every year. Assume we start the problem on January 1st.

6. The bank now offers an interest of 1%. Add this to the model by making two new converters: interest rate and interest income. Connect the interest income to the income flow and treat it just like another income source. What are the inputs necessary to go into the interest income converter? How much does this new income add to your monthly income? How much money do you now have at the end of year 1 and year 2? Is 1% income get you closer to your goal of saving $3500 faster than working 22 hours a week? How many extra hours a week do you have to work without interest, to save the same amount of money that you would with interest?