LABORATORY INSTRUCTION/RECORD PAGES

Laboratory Experiments With

Attractors

Using a Variety of Computer Program

GENSCI 104 - ARTIFICIAL LIFE, CHAOS, AND COMPLEXITY
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Purpose

An attractor is any state toward which a system naturally evolves. Attractors exist around us everywhere, in all forms, and we want you to begin to look for, and see, attractors for what they are when you see them, in any form that you see them. The attractors we examine here are all mathematical ones, but we will explore these qualitatively, not quantitatively (i.e. you are not going to have to understand and explain how the equations work; we will assume the computer is smart enough to calculate them for us.) But at the end we will have a class seminar, and try to generalize the attractor concept out to the world.

Rememder, we identified 3 general types of attractors, listed below. (If you need further review go to the handout: **ATTRACTORS: STRANGE AND OTHERWISE** in the notebook.) In addition to these we will briefly explore in the experiments two other types of attractors, the spiral and the circular.

☞ ***FIXED POINT*** - a steady state system. The attractor is a single point, all trajectories spiral inward toward it, e.g. a pendulum steadily losing energy to friction until there is no motion at all and the pendulum hangs vertically, held fixed by the single point which is the center of gravity.

☞ ***LIMIT CYCLE (OR PERIODIC)*** - a system which repeats itself, exactly, continuously.

☞ ***STRANGE (CHAOTIC)*** - an attractor in which the trajectory of the points circle around a region of phase space, but never exactly repeat their path. That is, they do have a predictable overall form, but the form is made up of unpredictable details. Turbulence is an example with multiple swirling eddies which go round and round the same spot, but that never repeat exactly. They may also may periodically change their direction of rotation.

Notes and Comments

☺ When it comes time to do the formal experiments **follow the instructions below**. They are designed to systematically lead you through a series of observations.

☺ You may consult with your instructor about questions that come up in your experiments.

☺ You may discuss your experiments with other class members, but the results in your ARecord of Experimental Results@ must follow logically from your own observations and specific experimental results.

Both the Instructions for the experiments and the spaces for recording your experimental results are contained here.

X-next and Attractors

Opening the X-next Program

- ❑ We have already explored the X-next equation, and these experiments use the same program. The program is available only in the Geology Department computer lab, Miller 232. All the computers have the program.
- ❑ Turn the computer and monitor on. It will open to a Windows95 screen.
- ❑ When the Windows Program Screen comes open click on the **A-Life** icon and then double click the **X-next** icon.

By now you already have a good feeling for the X-next logistic equation, and what we ask you to do here will not surprise you. What we want you to do, however, is just look at the results of the calculations through new eyes and try to see the output in terms of attractors.

1. Experiment One - X-next Attractors at 100 Iterations

- ❑ Begin with **Iterations** of **100**, and "**r**" of **0.2** . We want you to find the ranges of Ar@ where X-next is in a particular attractor state.

Write down the ranges of **"r"** where each attractor resides.

None: r=____ ➜ r=_____ (essentially an asymptotic attenuation [1])

Point: r=____ ➜ r=_____

Oscillating: r=____ ➜ r=_____

Chaotic: r=____ ➜ r=_____

Extinction: r=____ ➜ r=_____

What do the following attractors look like on the screen. Make a sketch.

POINT: at Ar@ of ___	OSCILLATING: at Ar@ of ___	CHAOTIC: at Ar@ of ___

Are these attractors in time series, or phase space? By What criteria? Can you sketch the differences?

[1] In VIEW OUTPUT for r=.02 this shows up as a descending series of negative exponents, e.g. 3.12078037829356E-05 is 3.120... x 10^{-5}

We did our calculations out to only 100 iterations which, as our earlier experiments with attenuation demonstrated, is not enough to really know the long term fate of an attractor.

Describe the effects of observation time and attenuation on the recognition and identification of attractors. Experiment around if you need to to answer this question.

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The Lorenz Attractor

Programmed by Stephen J. Baedke

Opening the Lorenz Program

- ❏ The program is available only in the Geology Department computer lab, Miller 232. All the computers have the program.
- ❏ Turn the computer and monitor on. It will open to a Windows95 screen.
- ❏ When the Windows Program Screen comes open:
  - ☞ Click on the **A-Life** icon to bring that window up front.
  - ☞ Double click the **Lorenz** icon to bring up the program.

Exploring the Lorenz Program

- ❏ **Lorenz** is a Windows based program.
- ❏ In principle the program is not unlike the X-next equation, but has more variables, and exists in 3-dimensions rather than 2. Observe on the Lorenz screen the following:
  - ☞ Variables a, b, c, d and their default values.
  - ☞ ***Initial*** x0, y0 and z0. These are the starting values on the 3-dimensional x-y-z graph (phase space).
  - ☞ ***Start:*** Every time you click Start the program starts the calculations over again at the initial values.
  - ☞ ***End:*** Stops the calculations but leaves the screen up.
  - ☞ ***View Equation:*** shows the Lorenz equations used here.
  - ☞ ***Wait Interval:*** time between calculations (depends on individual computer speeds).
  - ☞ To exit, click the ⊠ box in the upper right.

The Lorenz attractor was discovered in 1963 by Edward Lorenz who was trying to model the behavior of the atmosphere. It was the first chaotic (strange) attractor discovered and possesses the shape of a butterfly, hence the "butterfly effect."

Lorenz's original work had 3 equations with 3 variables, but this version has 3 equations with 4 variables (a, b, c, d). We do not want to explore the mathematics of this system, but rely on the program to show us the outcomes so we can qualitatively evaluate what is going on.

2. Experiment Two - Observing the Lorenz Attractor

❏ Begin with the default conditions.

☞ ***Try This:*** Just observe the program as it runs. Notice that it starts at one point, circles about a loop for a while, and then circles around the second loop, eventually returning to the first loop, etc..

☞ Observe that the screen periodically refreshes itself, that is, clears the lines of the attractor. The program does not start over, but continues drawing where it left off. This keeps the screen from getting too messy.

☞ Also, click START over and over and notice that the attractor always starts at the same initial point.

Write down the default values. a = _____ b = _____ c = _____ d = _____	In the space below sketch the Lorenz attractor (Note that the Lorenz attractor exists in 3-dimensions, but is drawn on the screen in only 2-dimensions.)
Described what is it about the behavior of this object that makes it a strange attractor.	
Is this attractor in time series, or phase space? By What criteria?	

3. Experiment Three - Varying Variable "a"

❑ In this experiment we are going to systematically change one of the variables and observe what happens.

Variable "a" default is 5.0. Systematically increase "a" by values of 1 (e.g. 6, 7, 8, etc.) until you think nothing more is going to happen.	Name and describe or sketch the attractor which results.
Now systematically ***decrease*** **Variable "a"** by values of 1.0 from its default of 5.0	Name and describe or sketch the attractor which results.

4. Experiment Four - Variables b, c, and d

❑ Now, does increasing or decreasing the other 3 variables produce the same effects?

For each variable below, describe the effects. Choose what ever values you deem best. Feel free to experiment and play around to get a feel for the system.	
Variable "b" Increasing	Decreasing
Variable "c" Increasing	Decreasing

Variable "d" Increasing	Decreasing

5. Experiment Five - Really Getting Pushy.

- ❑ If you did not do it in your earlier experiments we want you to now take some of these variables and push them really hard to see what happens.

Change each variable below as suggested, and describe the effects. Feel free to experiment and play around.
Variable "a" Increase the "a" variable by 10's beginning at 10 until a change occurs. What was the change? Can you describe it in terms of attractors?
Now keep pushing "a" higher and higher until another change occurs. Start off gradually, but increase your increments (i.e. jumps of 50, 100, etc.) as you need to get results. What was the change? Can you describe it in terms of attractors?

Variable "d" Decrease and increase the "d" variable by one decimal place, e.g. .003 to .03, or .003 to .0003 until changes occur. Describe the changes in terms of attractors.

Do you think variables "b" and "c" will behave the same way? Why or why not?

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The Complexity Lab's Julian Attractor

Programmed by William H. Roetzheim [2]

Opening the Complexity Lab's New Attractor Program

- ❑ The program is available only in the Geology Department computer lab, Miller 232. All the computers have the program.
- ❑ When the Windows Program Screen comes open:
  - ☞ Double Click on the **Complexity Lab** icon to bring that window up front.
  - ☞ Click FILE: NEW ATTRACTOR to bring up the program.

Exploring the New Attractor Program

- ❑ Go to ATTRACTOR: SETUP and peruse the screen:
  - ☞ Lower right shows two attractors to choose from, **Julian** and **Lorenz**. We will only use the default Julian attractor here, but you may play with the Lorenz if you want (see Help file).
  - ☞ ***Initial*** x0, y1, and z0. Note these two attractors have the standard 3-dimensional x, y, and z axes.
  - ☞ ***Coefficients:*** There are only 3 variables (coefficients) here, A, B, and C (instead of the four we used with the last program).
  - ☞ ***Speed:*** "0" is the fastest; the higher the number the slower it is; try changing by 100's.
  - ☞ ***Points*** to draw is essentially how long the program will calculate and plot points.. Just leave them at the defaults.

- ❑ Go to HELP: TOPIC SEARCH which will bring up some suggestions for making attractors. There are two things to note here.
  - ① Descriptions of various kinds of attractors. Roetzheim is not using exactly the same types we are using, but they are close enough you can figure them out.
  - ② Suggested values for either the Julian or the Lorenz attractor to illustrate what that attractor looks like when drawn on the phase space.

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[2] This program came with the book Enter the Complexity Lab: Where Chaos Meets Complexity by William H. Roetzheim, Sams Publishing, 1994, 208 pages (with computer disc). The book is now out of print..

6. Experiment Six - The Julian Attractor

- ❑ We have two very specific goals here:
  - ① To learn to recognize a Julian Attractor.
  - ② To see attractors plotted in a different format, and learn to recognize them.

Write down the default values. a = _____ b = _____ c = _____	In the space below sketch the Julian attractor (Note that the Julian attractor exists in 3-dimensions, but is drawn on the screen in only 2-dimensions.)
Go to ATTRACTOR: RUN and described what is it about the behavior of this object that makes it a strange attractor?	

7. Experiment Seven - The Circular vs. Julian Attractors

- ❑ Go To HELP: TOPIC SEARCH and read about the Circular Attractor.
- ❑ Set the **Initial Coordinates** for the Julian equation to, **1, 1, 1**; the **Coefficients** to **0.2, 0.2,** and **2.0** for the coefficients.
- ❑ Go To: ATTRACTOR: RUN and observe the outcome. You may want to do it several times, or set the speed to, say 300, to slow it down.

Write down the values for a circular attractor. x = _____ a = _____ y = _____ b = _____ z = _____ c = _____	Sketch the attractor.

Run the attractor again, but this time focus on the X, Y, and Z boxes on the left. They are plotting out the calculated values for each individual 3-D axis.

Run this as many time as you need to simultaneously observe all three graphs, X, Y, and Z (now there is a trick!), OR slow the processor speed down.

☞ Notice that each axis plots out a wave form. The circle you see to the right is the sum total of all 3 axes.

Your task here is to observe all three axes and describe the relationships among them. How well synchronized are they?

Now, compare the circular attractor with the Julian attractor.

You can set both attractors up on the same screen to observe simultaneously by doing the following:

① *Expand the Complexity Laboratory screen to full size (little box in upper right hand corner.)*

② *Go to FILE: NEW ATTRACTOR and click it to open a second attractor screen. Drag and size this new screen so it does not overlap the first.*

③ *Notice if you click the top bar of the attractor window which is gray/green, it will turn red making it the active window.*

④ *You can control each window separately, and run them more or less simultaneously.*

Now set up the default values for the Julian attractor (**Initial x=0, y=1, z=0**, and **a=0.2, b=0.2, c=5.7**) and compare the circular and Julian attractors. How are they similar and different? Sketch the differences between them.

X - Circular	X - Julian
Y	Y
Z	Z

8. Experiment Eight - The Spiral Attractor (Just for Fun)

- ❏ Go To ATTRACTOR: SETUP and for the Julian attractor set the Initial values at 0, 1, 0 and the Coefficients at 0, 0, 0.

Observe what is happening at the X, Y, and Z graphs as the spiral progresses out. What is happening, and why?

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Galaxy Attractors

Opening the Galaxy Program

❑ We have already used the Galaxy program, so just open it again and proceed with the experiments. Review Exploring Galaxy in the Galaxy experiment if you need reminding how it works.

9. Experiment 9: Galaxy Attractors Run One:

❑ FILE: OPEN = 3.ini. Do INIT and RUN several times until you get a feel for what is happening.

❑ FILE: OPEN = 10.ini. Do INIT and RUN several times until you get a feel for what is happening.

❑ FILE: OPEN = 200.ini. Do INIT and RUN several times until you get a feel for what is happening.

☞ **OBSERVE** that many of these simulation require time to develop fully, so sit back, relax and let them do their thing.

❑ RUN several of the other programs available under FILE: OPEN.

❑ Data page is at the end. Record:
1. Statements describing what you observe is happening for each star field.
2. Kind of attractor each run represents:
3. An explanation of why it is that kind of attractor.

10. Galaxy Attractors Run Ten:

❑ There is a good likelihood that some of your last experimental runs produced complex attractor behavior, switching from one attractor type to another and back. Did you catch that? Go back and find a simulation containing changing attractor behavior.

Which simulation produced the most complex attractor behavior?

List the sequence of attractors which develop over a relatively long run in that simulation.
Now focus in on one attractor transition. How soon can you detect when the system is about to switch attractors? Can you identify the behavior in the system that clues you into the fact the system is changing?
Thinking about the behavior of an attractor transition. Do you think this kind of behavior is more universal than just a star simulation? For example, do you think the behavior you observed in the star simulation as it began to switch attractors can be applied in any way to observations of human behavior? Why or why not?

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Stretching the Imagination About Attractors

10. Thought Experiments About Attractors

OK, we have been looking at a lot of mathematical attractors, and by now you should have a good sense of the different kinds of attractors and their behavior. But from our point of view, this knowledge is useless if you cannot apply it to the real world, at least by analogy.

So, think about the following ideas and see what you can come up with. We will have a class seminar to discuss them. It is ok to collaborate with classmates in this project. And, you might be a lot more creative than we are, but for some of these we just cannot think of an example.

Physical World Examples: For each of the attractors below, come up with as many ***physical world examples*** as you can think of.

Point

Circular

Outward Spiral

Limit Cycle (Periodic)

Strange (Chaotic)

Biological World Examples: Come up with as many ***biological world examples*** as you can think of.

Point

Circular

Outward Spiral

Limit Cycle (Periodic)
Strange (Chaotic)

Human History Examples: For each of the attractors below, come up with as many ***human history examples*** as you can think of. Human history includes any behavior associated with human activity, social, political, economic, etc. Point
Circular
Outward Spiral
Limit Cycle (Periodic)
Strange (Chaotic)

PERSONAL EXAMPLES: For each of the attractors below, come up with as many ***personal examples*** as you can think of. These are examples that apply to your personal life, either your mental worlds (dreams, fantasies, plans, etc), or your behavioral world. Note that ***you will not have to reveal any of these to anyone*** if you do not want to, so go ahead and take the risk of thinking about it. Point
Circular
Outward Spiral
Limit Cycle (Periodic)
Strange (Chaotic)

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(Observe: a system may evolve from one attractor type to another)	
Stars = 2	**Attractor** =
Description of what is happening.	
Stars = 3	**Attractor** =
Description of what is happening.	
Stars = 10	**Attractor** =
Description of what is happening.	
Stars = 200	**Attractor** =
Description of what is happening.	
Stars =	**Attractor** =
Description of what is happening.	
Stars =	**Attractor** =

Description of what is happening.

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