Living Control Systems III Demonstration Instructions

SYSTEM MINIMUM REQUIREMENTS

Program files   Download 7-zip file

Hardware: Personal computer

Speed of 900 MHz or faster recommended
CD-ROM drive Any standard CD-ROM drive
Memory: One Gigabyte recommended
Screen resolution: 800 x 600 or better recommended
Hard drive space: 100 Megabytes of disc space recommended
Operating systems: Tested on Windows XP (Home, Media Edition, and Pro), and Windows Vista (not the minimum versions).
Tested on Windows XP under VMWare Fusion and under Parallels (two environments for running virtual Windows machines) on Apple Macs. The tester suggests the programs might also work under other virtualizers available on the Web, some free. Newer Macs, which use Intel processors, can be booted into Windows with the Leopard operating system or BootCamp (part of Leopard).

CD INSTALLATION

In Chapters 2 through 9, the discussion is supported by one or more interactive computer programs to give you hands-on experience with perceptual control theory principles.

The CD is set up menu style. Load the CD and open it. The double-click LCS3Install.bat. The demonstration programs will be copied to the C drive in a new folder called LCS3Programs, The red ball icon (LCS3Menu) appears on the desktop, When you double-click it, a menu will appear on the screen. Highlight the name of the demo called for in the book, Start the demo by clicking Run Selected Demo.

To facilitate your transition from reading concepts to trying the demonstrations, as you call up each demo to your screen, take a minute to review the control panels and display windows. Then follow the steps (bulleted text) in the book. You can also click the on-tine instructions button, available on most screens, for tips and reminders.

To avoid clutter, many popup windows close only by using the X in the upper-right corner.

NOTATION

CONTROLS   TO ACTIVATE

LABELED BUTTONS single click

Radio Buttons   click the new selection

Sliders click-drag the pointer

Spinners   click the up-down triangles

Min/Max/Close box   click x to close the program

Foreword: The Fact of Control

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This work began in the second sub-basement of the Argonne Cancer Research Hospital at the University of Chicago in 1952, when I was all of 26 years old. That was the year I gave up my interest in dianetics and went back to physics, the same year my friend Kirk Sattley showed me a small book called Cybernetics: Control and communication in the animal and the machine, and unwisely let me borrow it. Kirk died in 2002, but I still have his book. In my new job as a very junior health physicist, I had time to do some experiments with human control systems. One of them was an attempt to use external positive feedback to measure the amount of internal negative feedback in the galvanic skin response to loud sounds. There is no need to inform me that this experiment was rather confused in its premises. So was I. But I did begin to study engineering texts on control theory, and the work started that led, over many years, to this book and four others before it.
Now, with this book, I seem to have done about as much as I can to preserve my version of this thread of thinking and pass it on to those who will make the best use of it. It still seems to me, as it seemed an hour after putting down Norbert Wiener's book 55 years ago, that negative feedback control is the ingredient that has been missing from the life sciences for as long as they have existed, and is the concept that will finally put those sciences on a par with physics and chemistry. I can't begin to guess why it has taken so long, why so many people have explored the phenomena of negative feedback control in living systems without seeing that they were looking at a revolution straining to happen, and why so many more have simply refused to learn anything about it. But that's their problem.
In this book I have only one goal: to establish in the mind of the reader the literal reality of negative feedback control as the basic organizing principle of human behavior. Human beings do not plan actions and then carry them out; they do not respond to stimuli according to the way they have been reinforced. They control. They never produce any behavior except for the purpose of making what

Concepts of Control 1

This book is about control theory and its uses as a way of explaining how human behavior, and perhaps the behavior of all organisms, works. Before getting into the computer demonstrations, we'll spend one chapter on some generalizations that may be helpful, and some claims with which I hope you will eventually agree.

I'll make a deal with you. You can skip Chapter 1 if you will agree that before you raise objections about something said in later chapters, you will go back and read it. It's a bit heavy on mathematical concepts and not strictly necessary for understanding what comes next, but I believe the mental exercise will be at least a little helpful. If you disagree, just skip to Chapter 2 and get started with the demonstrations.

Whatever method of control one proposes, the basic concept of control is the same. To control something is to act to bring it to a specified condition, and then maintain it close to that condition even if unpredictable external forces and changes in environmental properties tend to alter it. Human behavior, as later chapters will suggest through numerous examples, is control behavior. All of it.

Anyone encountering for the first time the brand of control theory used here, PCT (perceptual control theory), might be a little confused if some other kind of control theory has happened to

Human Control Systems

Demonstration: Choose Control 2
We aren't going to spend any more time driving cars or generalizing. Instead we'll focus on capable and precise control systems that each reader carries around—a few among many hundreds, or thousands, that make up the human system. As you go through the rest of this book, you'll encounter updated examples of various PCT experiments and demonstrations that I've worked out since the early 1970s. I built the models to show how control systems work by actually running and behaving like control systems (and, demonstrably> like people). They run as they do because of the way they are organized, not because of labels or theories or technical jargon. The original models have all been rewritten and improved by Bruce Abbott.
The best way to learn about control systems is to experience them in operation, and the best ones to experience in operation are your own. You see your own control systems from a unique point of view unavailable to anyone else; you can see the real point of your actions where others observing you have no idea what you're perceiving. Only you can know (though others, and even a computer, can sometimes guess correctly) what you are really controlling. That is the point of the first demonstration.

A Feel for Control

Demonstration: Live Block 3
Now we have several immediate objectives. The first is for the reader to become better acquainted with the odd properties of PCT'S
basic control-system unit of organization, as we add some details to the model and then experiment with it in simulation. The second objective, addressed in Chapter 4, is to go back 60 years or so and replicate a venerable experiment. In Chapter 5 we shall correct a mistake that was made and prepare the way to broaden our picture of human control systems.
The important thing to accomplish in this chapter is to develop a feel for the way a control system operates, which may ward off some misconceptions that somehow got attached to this subject early in its development. Someone who had eavesdropped on conversations among engineers but obviously had never tried to build a working control system made some very confident claims: an input-output system that produces regular effects in response to stimuli (or to central pattern generators) is simpler than a negative feedback control system; it can behave faster, is more stable, is more precise, and is more likely to have evolved than the "complex" control system. Not one of those claims is correct. Once concepts like that have been proposed by someone famous and have been believed however, it is devilishly hard to get people to unbelieve them, even when given overwhelming evidence that the claims are mistaken.

Tracking
Demonstration: Track Analyze 4

If Chapter 3 succeeded in its aims, you now have a considerably enhanced idea of what a negative feedback control system is and how it works (some readers, of course, already knew). This is only a building-block; a complete theory of behavior would use many of these control systems operating in parallel and at many levels of organization. But even one building-block can be applied to isolated behaviors of many kinds from the simple to the complex, in each case suggesting how some low or high level of control might be organized. The object of this chapter is to see how well the model in Chapter 3 can describe and predict what we observe in a simple tracking task.

SIMULATION AS A SCIENTIFIC METHOD

The strategy, which we saw briefly in Chapter 2, involves constructing a working model and using it to simulate human behavior in a set task. The model, when expressed as a simulation, is the equivalent of a detailed and quantitative prediction of behavior that can be compared with real behavior.

The two main aspects of a model are its architecture and its realization. The architecture is the block diagram in Figure 3-1 in Chapter 3, without any mathematics—just labels for the parts, the connections among parts, and general descriptions of what the parts are and do. A block diagram is really a whole family of models that can behave entirely differently depending on which realization

Nonadaptive Adaptive Control

Demonstration: Nonadaptive 5

Among the many intriguing properties of negative feedback control systems is their apparent ability to adapt to changing environments without altering their characteristics at all. The point of this chapter isn't that a control theory of human beings can ignore learning and adaptation, but that negative feedback control can work across a wide range of conditions without the degree of adaptation that in the past has been assumed necessary. Negative feedback control systems can function without needing changes in their properties to meet every little variation in the environment, the way other kinds of behavioral models need to change—even some models that are called control-system models. You have seen a hint of this in exploring the Live Block Diagram.

We will have our first look here at a multileveled control system, a very simple one with only a single control system at each of two
levels. The lower level controls a perception of velocity by altering the force applied to a movable mass in the environment. The second controls a perception of the position of the mass by mean of varying the reference signal sent to the velocity control system. This arrangement actually approximates the control systems that exist in the vertebrate spinal cord, where phasic stretch receptors

Multidimensional Control

Demonstration: Live Three 6

We turn now from control systems stacked into a hierarchy to control systems all at one level, operating in parallel but controlling in different dimensions of the local world. The basic approach to control in many dimensions that we will take here is elementary, but it is a start toward understanding large organizations made of control systems.

A dimension is, mathematically, simply a way that something can be changed without altering it in any of the other ways it can change (my apologies to mathematicians). An object in space, for example, can move left and right relative to an observer, and up and down, and closer and farther away. Those are the familiar three dimensions of space. But the same object can also turn around any of three axes at right angles to each other, and it can have its shape, its color, its surface texture, its temperature, and its price changed, each way of changing being at first glance independent of the other ways. If we want to control all these aspects of the object, the problem is solved rather simply, it would seem, by assigning one control system to sense and act on the object in each independent dimension.

E. Coli (Random Walk) Reorganization

Demonstrations: E.Coli, Three Systems 7
When I first began working on a control-theoretic model with the late Robert K. Clark in the 1950s, it became clear to me that some gaps had been overlooked in the concept of learning that psychologists accepted. A basic question about living control systems is How do they get that way?—how do they learn to control things like tractors and computers and musical instruments and baseballs that have not been in existence long enough for evolution to have contributed anything helpful. Psychologists liked to study what they called "learning curves" that showed how an animal or a person gradually acquires a skill. The problem was and is that this process looks as if the organism knows what skill it is trying to learn before it learns it, and simply gets better and better at it before actually succeeding enough to be "rewarded" (or to survive and reproduce).
The phenomenon that seemed to define the problem for me was B. F. Skinner's demonstration of "shaping," in which he showed that by administering reinforcers—bits of food perceived through a theoretical filter—to pigeons, he could get them to execute alternating left and right turns while walking, so they followed a figure-eight pattern. In what universe could a pigeon have genetic instructions telling it that walking in a figure eight when hungry

Multiple Control Systems at Multiple Levels
Demonstrations: Arm Control Reorganization,
Coordination, Arm Tracking 8

Now we will extend the model of reorganization beyond three dimensions, to show that it works as well in fourteen dimensions as in three. Then we will add a second layer of control systems to show how coordinations can be handled in this model, and a third to show how the two levels of coordinated control can be used to control a relationship of the arm to an independent object. The subject of reorganization will be left behind as we consider coordination> not because it doesn't apply but because it will take someone a little younger and possibly smarter than I to deal with all the problems involved. Reorganization will apply in the first demonstration that follows.

REORGANIZING IN FOURTEEN DIMENSIONS

Demo 8-1, Arm Control Reorganization, which I will now assume you have started, shows someone's disembodied right arm floating in space, as seen in Figure 8-1.

Demonstrations of Principles
Square-Circle, Crowd (four versions),
Inverted Pendulum 9

In this last chapter of demonstrations, we will look at some aids to understanding that were developed as various points of difficulty arose.

SQUARING THE CIRCLE

Control of perception means control of the state of an existing perception (as was seen in Chapter 2). It doesn't mean making one kind of perception into another kind. But there is another dimension to understanding control of perception: namely, understanding that we control perceptions rather than actions. In Demonstration 9-1 you will be controlling a perceptual variable, tracing a shape by moving a point of light around in two dimensions using the mouse. The mouse movements are your means of controlling the perceptual variable, but the movements themselves are not what is controlled in this task. By the time you have finished with the demonstration, you will know why we speak of controlling perceptions, not actions. Demo 9-1, Square Circle, concerns a perception of a pretty good square.

The Purposive Self-Motivated System 10

I learned to write digital computer programs in the mid 1950s, on an IBM 650 in a back room of the Dearborn Observatory where I had, a few years previously, worked and lived as an undergraduate at Northwestern University. This kind of programming came into being after I had already learned to program an analog computer, the sort of computer (begat by the slide rule out of Napier's Bones) that flourished briefly before the digital revolution. Ever since then, whenever I had the opportunity, I have been tricking digital computers into behaving like analog computers, with the results you have seen in this book.

Why "tricking?" Because it is the analog computer, not the digital computer, that is organized the way living systems are organized. Digital computers with operating systems such as Windows or Unix are viewed and used as "event-driven" systems. They do nothing until some external stimulus, such as a user clicking on a button on the screen, stirs them into action. Then one event leads to another, just as the behaviorists at the turn of the last century and the biologists before them—and many, many scientists after them to this very day—believed organisms to work. When all the events have played themselves out, some data are stored or printed out or sent outward

Epilogue: What Good Is It?

If behavior is governed by control systems at every level from top to bottom, if the fundamental process of life is negative feedback control, it quite possibly follows that all other theories about how people and other organisms work are wrong. I think that is basically why it is taking so long for the life sciences to get around to adopting control theory. Not only must all the wrong ideas be cleared away and all the conclusions drawn from them be canceled, but the people best equipped to accomplish the housecleaning are the very ones who have the most to lose from it. For every wrong idea and every false conclusion, a hero is required who was at one time firmly convinced that the idea was right, whose reputation was built on its rightness, who has earned a living from its rightness, who has taught innocent youth about its rightness. One can understand why it's hard to find such heroes, but I have met a few. The Control Systems Group contains a number of them.

When Queen Victoria asked Faraday "What good is electricity?" he allegedly replied "What good is a baby?" What good is perceptual control theory? I would like to find out. I hope that more heroes volunteer pretty soon.

Again and again I have been backed into a conclusion, and I hope many readers of this book find themselves in the same position. My

Appendix

In this appendix we present some mathematical analysis of the control systems described in this book. We assume familiarity only with basic algebra and linear differential equations. In places we will use Laplace transforms to simplify the solution of linear differential equations in multiple variables. A good reference for the control theory used in this book is [Lei04].

1 THE PROPORTIONAL CONTROLLER

We shall begin with the control system demonstrated in Chapter 3, pictured in Figure 1.