ECOSYSTEM MODELS

Frame-Based, Part 1

Tony Starfield

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So where we are at the moment is we have two modeling techniques that both relate to the top-down approach. The one is data-driven and not mechanism driven, but works well on a computer. The other is mechanism driven but doesn't run on a computer. The obvious thing to do is to try and take the mechanism-driven model and turn it into something that runs on a computer, and this idea leads to something that I call **frame-based modeling**.

And if we go back to this diagram you will probably have noticed that I misspoke previously and used the word frame instead of state. What I want to do now is describe these states as frames. And the concept of frame is something that comes out of computer science and is just a handy way of talking about what we're going to do.

So forget about states now. What we have is a system with three frames, jack pine frame, white pine frame and spruce frame. At any time step, which remember is 10 years, we are in one of these frames. Suppose we are in the spruce frame. We are looking for the simplest possible model we could build in the spruce frame. And remember, when one's building simple models, one wants to have an objective. And the way to have an objective is to say, "What I want to do in the spruce frame model at each time step is answer one of two questions." The one question is, 'Am I still in the spruce frame 10 years later?' And the second question is, 'If I'm not still in the spruce frame, where am I?' And that's the sole purpose of the model at this stage. It's a model at every time step only considers those processes and those factors that determine whether you're still in the frame or out of it.

Now, remember, if we go back to the diagram, there's only one arrow out of the spruce frame. And to recall what the state and transition model said about that arrow, it was, this switch occurs whenever there is a fire. If fires are not controlled, the fire interval is likely to be about 20 years. In other words, all we need to see in our model world for the spruce frame is fire.

So how could we model fire in the spruce frame? Well, we're told that natural fires occur with a frequency of approximately 1 in 20 years, or a probability in 10 years of .5. So we could generate our random number, and if it's less than .5, say, fire. And if it's greater than .5, say,

no fire. Well, if you think about this, this is exactly what we were doing in the matrix model. Because if we go back and look at it, if we were in the spruce frame, we would generate a random number. If it were less than .5, we would say fire, although we didn't know why we were saying it, and we would switch to jack pine. Otherwise, if it were greater than .5, we would stay in spruce.

But there's a subtle but really important difference here, because now we know that that .5 relates to fire. So if we were writing an interactive computer model - if the model came back and said fire, it could ask us the question, 'do you want to put it out?' And if we said, yes. We could control that fire and we would not switch. So now we have put the management action into the model. We could even use more information and have a situation where if we say yes, we know that 9 times out of 10 trying to control a fire in a spruce patch is successful, but 1 time in 10 it isn't. So the computer program could come back at you and say, "We tried to put it out but we didn't. Sorry, you've switched to the jack pine frame." And that simple difference is what makes for a **management oriented model** rather than just a straight data-driven model.

Okay. What happens if we switched to jack pine? If we go back and look at our model, once we're in the jack pine frame, we are now going to switch to a completely different model. Because now what's driving our model is, do we stay in the jack pine frame or do we move out of it? And if you look at this, there are two arrows that move out of the jack pine frame, and what we need to do is read the state and transition model descriptions for each of those arrows.

For arrow 1, it's a rather complicated story. It says... the switch can occur in one of two ways. If there is an interval of 40 years or more between successive fires, which would allow white pine trees to grow to a height at which they will survive fire. Then a fire will destroy almost all jack pine and spruce, but leave a cohort of white pine trees. If fires are strictly controlled for between 80 and 100 years. Then jack pine will die leaving behind an under story that is dominated by white pine, provided the density of deer is low. So if you just think about what was inherent in that statement. One has to be concerned about deer density. One has to be concerned about fire. And one has to be concerned about time since last fire. Because that will give you the age of the white pine in the under story as well as the age of the jack pine.

If one looks at this arrow from jack pine to spruce, it is this switch occurs after 80 to 100 years if fires are strictly controlled and the density of deer is high. So again, we need to look at fire, deer and time since last fire. It's a completely different model.

We're now beginning to see how, what I would call, a frame-based model would work. You might have one of those CD players that can play three or four or five CDs and you can switch from one CD to the other. Well, a frame-based model works in exactly the same way.

Suppose you start in the spruce frame, then you are playing the spruce CD. The spruce CD is all about fire. So you are listening to this fire music, and at each time step you are saying, should we still be listening to this music or should we be switching to the jack pine CD? At a certain point, you will have the rule that triggers that switches you to jack pine. That's equivalent to stopping the spruce CD and starting to play the jack pine CD. And the jack pine CD is a completely different type of music. Now you are interested not only in fire, but you have the deer theme and you have the time since last fire theme.

And now the purpose of that CD or model is to decide whether you stay in jack pine or if you switch whether you go to white pine or back to spruce. So you play that CD until you trigger a switch. If you trigger a switch to white pine, for example, then you are going to start playing the white pine tune. And we haven't talked about the white pine frame, so I'm not quite sure what's in it. But notice we can be a little more sophisticated. Because if you go from jack pine to white pine, it is likely to be after a period of 40 or more years, and that is the age of the white pine stand. So in a sense, you're not just saying switch to the white pine CD - you're saying switch to track 4 or track 5 or track 6 of the white pine CD, because the white pine is already 50 or 60 years old.

Now, notice the difference between this and the bottom-up approach. In each case we had circles, and in each case we developed models for the circles. The difference is that all the circle models were running at the same time in the bottom-up approach. Whereas here we only have one model actually running at a time. The computer decides which model to run and runs it until it decides, or is told, to switch to another model. And the models have a very, very simple, clear first objective. The sole purpose is to decide whether you're staying in that frame or switching.

In other words, you could get a frame-based model up and running on a computer in a day or two. You could test it. You could go back to the real world and say, gee, is this the sort of thing we're looking for? Does this make sense? If it doesn't make sense, after two days' work you can afford to throw it out. What have you lost? Two days' effort. Compare that with bottom up.

Imagine being caught in a situation where you've spent tens of thousands of dollars and many man years developing a model before you see how it all works and then you decide it isn't the model you want.

On the other hand, in the frame-based model, if you decide it's the model you want, you might say, well, what's the next level of detail we need to put in? So now because you are prototyping, you are not making the decision to put everything in because you don't know whether it's going to be important. You've got a strategy for putting in the most important things first and then adding detail until you no longer need more detail. It's kind of like a cook adding a pinch of salt and then another pinch of salt and another pinch of salt to make sure that whatever the cook is cooking tastes good.

Notice, by the way, the difficulty with bottom up is that if you have spent all that time on developing a model and it isn't what you want, as I said previously, it's very difficult to throw it away. So what you tend to say is, “You know, this model is probably not working because there's not enough detail in it.” So you tend to add more detail to it. And you get into a loop where you are in trouble because you've bought a too detailed model. The model is not working, so how do you try to fix it? You try to fix it by adding more detail. It's an unstable strategy. Whereas, by allowing rapid prototyping, the frame-based approach is a stable strategy. Where at any step you can afford to go back, you can afford to redo, or you can decide exactly what you're going to add and test to see what difference it's going to make.

Well, how does this play out on the computer? The next step is going to be to look at the jack pine, white pine, spruce model that we have been talking about as implemented on a computer model.

I'm going to show you this model in a moment, but for the purposes of the demo, I want to go back to the diagram, because we have simplified the model a bit. The jack pine and spruce frames work as before, but what we have done in the white pine frame is assume that we are going to control all fires once we get into white pine and that we are going to harvest the white pine at a particular age. We are going to remove the trees in such a way that the under story remains and, therefore, after a harvest you will automatically switch from white pine to spruce. In other words, we are putting in an oversimplified white pine frame just to see how this might work on the computer.

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