HYBRID MODELS: LAKE ST. LUCIA - PART 3

TONY STARFIELD: So qualitative modeling looks like an interesting, powerful, useful, intuitive tool. What's the problem with it? Suppose you have a variable, and suppose you have a set of conditions, and instead of having that variable go up one state or down one state under those conditions, you want the variable to go up half a state. Or even worse, a quarter of a state. What are you going to do then?

If you think about it, you only have two options. The one option is that you have to have many more states, and that is going to be awfully messy. And the other is that you're going to have to have much smaller timesteps, and that also is going to be messy. Perhaps not as messy as more states, but still messy. So one has the difficulty of wanting to go with a qualitative approach because, intuitively, it converts qualitative knowledge into a model so easily, but one still wants to be able go up fractions of a state.

Well, it turns out one can take a hybrid approach. Suppose we have a variable. Suppose that variable is "x," and suppose at time "t" I write down that "x" subscript "t" is equal to 3.14. What does that mean? You might say, "Oh, well, okay, we're back to numerical modeling. ‘X’ is 3.14.” No. Not as simple as that. What we’re really saying in hybrid modeling is that “x” is a qualitative variable, it is in state 3, that’s the “3” part, but it is .14, 14 percent of the way towards state 4. And now I’m in a position to have the best of both worlds. As far as the rest of my model is concerned, “x” is 3. But with that .14 there, I know that I’m heading toward state 4.

Suppose we have a set of conditions--I don’t care what they are--for the next timestep. And suppose for that set of conditions, we say, “Gee, I think “x” would go up one-fifth of a state.” Well, what we would do then is say that “x_t plus one” is 3.34. In the next timestep, suppose we have a different set of conditions, and suppose that “x” goes up by three-quarters of a state. Well, then 3.34 plus .75 is going to get to “x_t plus two” being 4.09. And now we have changed states. The “x” is in state 4, and only just in state 4.

How could we implement this in practice? I’ve been talking about certain set of conditions. Well, it turns out, we can put this together very neatly using tables. So let’s take another example. Suppose we’re interested in how prairie grass biomass changes as a function of summer rainfall and the buffalo biomass. Well, again, we’re developing a qualitative model, and summer rainfall, we're going to say, is "low, medium, high." And we would define what we mean by that. And suppose the buffalo biomass is low, medium, or high. Or to look at it in another way, in state 1, 2, or 3.

And what we then do is we say that the grass biomass, at time "t plus one" is whatever it was at time "t" plus the appropriate entry from a table. And we create a table and we say, "Gee, well, this is still a qualitative model, how am I going to get at the entries of that table?" And it turns out there is a very easy way to think that through. So we've got grass, we've got rainfall, we've got buffalo. And if I were working with people knowledgeable about the system, trying to put numbers into their table, I would begin by saying to them, "What are the conditions that would lead to maximal growth of grass?" And they'd say, "High rainfall, low buffalo." So good, we're looking at the top right-hand cell of that table. And then I would say to them, "Under those conditions, what do you think would happen to the grass?" And they would say, "It would increase. It would increase one state." And I say, "Good. Well, put in "plus one point zero" in that cell.

So now we have the entry of 1.0 in the top right-hand corner of our table. The next question I would ask the experts is, "What is the worst set of conditions for the grass?” And they would say, “That’s easy. If you have a year of low rainfall and high buffalo biomass, that’s going to be as bad as it can get.” So I would say, “Okay, well what would you expect to happen then?” And they would say, “Well, it would go down at least one state, but it wouldn’t quite go down two states. So it’s going to be a number between one and two.”

And then the line of questioning I would develop would be something along these lines. “Suppose you have low summer rainfall and high buffalo biomass year after year after year, without interruption. What would happen in two years, or three years?” And they’d think about that a bit, and they might say, “Well, after two years, we’d probably go down three states.” And people usually find it fairly easy to think in terms of whole numbers like that. And if you have two years and you go down three states, that means you go down one-and-a-half states each year, and the number we would fill in to the bottom left-hand cell would be “minus one point five.”

And now we’ve kind of got the table pegged at the two ends, the best and the worst. And usually once you’ve done that, it becomes easier to fill in the rest of the table. So I would now go back towards the top right-hand end of the table and I would start saying, “Well, what’s better? To have medium rainfall and low buffalo, or high rainfall and medium buffalo?” And I think you can see, I’m looking just to the left of the 1.0 and just below the 1.0. And they would think about it a bit, and they would say, “From the grass’s point of view, it’s better to have medium rainfall and low buffalo.” In other words, buffalo are having more of an effect on the grass than the rainfall, if one’s looking at going from high to medium rainfall.

And then again, we have this question of, “Okay, well, would the grass increase if you had medium rainfall and low buffalo?” And they would say, “Yeah. It would probably take two years for it to jump to one state.” Until we put in “plus zero point five.” And then we’d switch to high rainfall, medium buffalo biomass, and they would say, “Yeah, it would still increase. But it would probably take three years, now, to go up one state.” So we want to put “plus a third,” which is about point three four. And I think you can see how one can then argue this through.

So, for example, if we had low rainfall and low buffalo, maybe the experts would be unsure as to whether it’s going to increase or decrease, and you could push them a bit and they would say, “Well, it might just--you’d probably lose a little bit of the grass biomass if you kept on having conditions like that of low rainfall and low buffalo." And then you would say, "Well, how many years would it take to drop one state?" and they might say, "It's very slow. Probably ten years before you drop the state." So you put in "minus zero point one." And similarly, if you have a high rainfall and high buffalo, maybe they'd argue it would take five years to drop a state, so you would put in "minus point two." I think you can see how you can fill in the rest of the table that way.

Now once you have that table, you no longer have to think in terms of long runs of conditions because each year, each timestep, you're going to have different values of buffalo and different values for rainfall. But all you do is you would go to the appropriate cell in the table, pull that out, and add it to the current value of your grass biomass. And if the number's negative, your grass biomass is going to go down, and if it's positive, it'll go up, and that is the way you model the grass biomass.

Now, this sounds a bit messy and complicated but, in fact, it's very simple in practice. And it's remarkable, I have found, how quickly people manage to fill numbers into a table like this. And if you think about it, the numbers in that table are the parameters of our model. Also, if you think about it, you could have a series of tables like this. So your whole model is driven by tables like this. They might be different tables for different variables, or you might, in fact, have different tables for the same variable.

Suppose for some reason we decided that management action was to fertilize the grass. We're going to go with drones or airplanes over the whole prairie, dropping fertilizer. Well, then we could produce another table exactly like this table, except the numbers would now be the numbers you would expect to have if you have fertilized the grass. And now you're developing a model where you can put in a management action or leave it out.

Notice, too, you're keeping the qualities of a qualitative model because, although the grass, at any time, might have a value like "three point six," if there's something else in the model that is driven by grass--what could that be? Frogs. Then as far as that part of the model is concerned, all that matters is that the grass is in state 3. You don't have to think through an equation for the grass being in state 3.6. And, in fact, if you look at table A, you realize that we probably did that with the buffalo. Probably somewhere else in the model is a table that tells us how the buffalo varies from one year to the next year. That would represent the population dynamics of the buffalo. And maybe that's going to depend on wolves and hunters. And here, all we see of the buffalo variable is whether it's 1, 2, or 3. We don't care what's after the decimal point. And this is the hybrid approach.

And the advantages of it are that you're maintaining the simplicity of thinking that goes with a qualitative model. You are still dealing with qualitative variables and qualitative information, but you've cut through the difficulty of dealing with fractions of a state. What's good about this? This is a great way to develop rapid prototypes. And as we've seen, the secret of developing a rapid prototype is to get to a working model as quickly as possible. And something like this is quite easy using tables to put on a spreadsheet, and so you can start getting numbers out of your model very, very quickly using an approach like this.

The second thing is that when we look at ecological modeling and when we talk about frames, this type of approach is a really neat way to develop simple models within a frame. And you'll see examples of that in the section on frame-based modeling. So would I go for a pure qualitative approach at this stage? And the answer is, "probably not." Because if you think about it, the hybrid approach already contains the purely qualitative approach. Instead of the rules, if we used a hybrid approach with tables, the only difference between a purely qualitative model and a hybrid approach is that the entries in the table, the parameters in the table, would be whole numbers, which means you're always going up or down one or more states. Or staying the same. And so I find that I can use, and I can get other people to use, hybrid modeling very easily to get a quick first prototype of a model working.

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