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"COGNITIVE PSYCHOLOGY"

"Production Systems"

Executive Producer ..... Michael Philps

Production ..... Roger Penfound

Producer's Assistant ..... Laura Jones

Taking Part

Dr. Clive Holloway (O.U.)

Dr. Richard Young

Invited audience

D303 Opening Generic Titles

TJ. Production Systems

TJ. Presented by Dr. Clive Holloway Open University and
Dr. Richard Young University of Edinburgh

(Effects: audience talking)

DR. CLIVE HOLLOWAY:

Hello. Welcome to our second talk on problem solving which is part of our series of broadcasts on artificial intelligence. Again we're at the University of Edinburgh and I'd like to introduce Richard Young who works in the Artificial Intelligence Department here. Now he's interested in human problem solving and cognitive skills and the way that kind of behaviour might be modelled in a computer program.
Now Richard, what sort of behaviour are you particularly interested in?

DR. RICHARD YOUNG:

Well, I'm especially interested in skills, the kind of things that involve people in really doing things, rather than just sitting still and thinking and of course that includes a large number of everyday practical skills.

DR. CLIVE HOLLOWAY:

O.K., well, in fact, we've already agreed that we're going to look at one simple human activity as a basis for constructing your model, so simple in facts, it's just frying one egg and putting it on a piece of toast. O.K., now before you get going on your model, if I may, what I'd like to do is to have a go at representing the task using a method that's fairly familiar to us and which has served us well in the past and that's a flow chart. O.K.?
Well, flow charts are fairly easy. They consist of series of

operations and tests, actions to be carried out like start the toaster, do the toast and then we would have a check. We would go down to a check situations in which we found out whether the toast had popped, if not we would wait. If it had popped, yes, we'd go to another action. Well, that would take care of the toast thing. Let's see how we'd go from there. We'd get ready to cook the egg so we'd go on to a sort of turning on the heat, put the butter in, then we'd have to wait because we'd have to check that the butter was sizzling before we go any further, but when it was, on we would go to a different part of the flow chart and in this case, up to the top again and add the egg, O.K., then we would wait again and test whether the egg was cooked. If it was, we would remove the egg. Now I think that's a fairly reasonable way to represent a simple task like the one we've got there.

DR. RICHARD YOUNG:

Well, it certainly seems quite reasonable but Clive, why don't you go ahead and try doing it and we'll see what actually happens.

DR. CLIVE HOLLOWAY:

O.K., well, we have a kitchen set here so why not. Now let me see - the place to start I suppose is to put the toast in. O.K., down you go. Right. Now what shall I do next? I'll put the heat on, I suppose. O.K., now I'll put the butter and just wait for that, Now then, that's got to melt before I can do anything else. O.K., that's beginning to melt so I'll get on and do the egg and believe me, it hasn't cracked. O.K., we'll just have to wait a little while for that to set. That's coming on nicely. O.K. That's beautiful. Let's get the egg out, right. Turn that off. Now then. Oops, good. Well, that's more or less it.

DR. RICHARD YOUNG:

O.K., well, that's fine but what actually happened? I mean, / how did Clive actually do it? In particular, did he do it the way that it said on the flow chart? Can anybody see any differences? Can you tell me a difference?

LADY IN AUDIENCE:

The toast didn't pop before he turned on the heat.

DR. RICHARD YOUNG:

Yup, that's absolutely right. Whereas on the flow chart, it says he starts off by worrying about the toast and doing all that and then going on and dealing with the egg, in fact, he started off by putting the toast in, starting the egg and having both parts of the cooking proceeding simultaneously.

DR. CLIVE HOLLOWAY:

O.K., but couldn't we sort of deal with that if I could move the chart round a bit, sort of take account of that different order?

DR. RICHARD YOUNG:

Well, yes, sure, we could change that flow chart so that if models the particular way you did it on this occasion. Well, I can show you how. All I have to do is to move this part to do with the toast down to the end and then of course I have to fill in with those first two slots but the trouble is that the toast could have popped much earlier in the cooking process, at any time, like maybe back here or over here. And of course, so there's no way one flow chart can be right for all those different possiblities. Well, one way of thinking about this kind of problem is to realise that when someone is doing a skilled activity they don't normally go through a fixed sequence of actions in a fixed order. It's quite the opposite, I mean, a large part of

the skill of somebody like Clive cooking egg on toast consists of being able to respond appropriately to the situation, to respond to events in the environment as and when they occur. So of course a much better way, it would be much nicer if we could somehow directly capture this sort of responsiveness of human beings, the way what they do is determined by the momentary circumstances they find themselves in. Now in fact there has been a suggestion for how to do this and it involves using a notation called a production system and this is mainly what we're going to be talking about this evening. Well, let's have a look at a simple production system. We can see the kind of thing it is. As you can see it's simply a collection of rules and each rule has a left-hand side which is a condition and a right-hand side which is an action and all any one of these rules means that when the condition on the left is true when it's satisfied then the subject goes ahead, the person goes ahead and does the action it says on the right. O.K., for example, this first rule, this means that whenever the butter is sizzling, then add the egg into the pan. Or the next rules says when the egg's cooked then remove it, take it out of the pan, put it on the plate, and so on with the rest of the rules. Well, I think maybe the best way to see how the, get a feel for how the whole thing works is, well, Clive, if you don't mind, to do the cooking again, O.K., but this time to have the production system running and I'm going to ask people to play the part of some of the rules. O.K., so let's do that. I'm going to ask people round here if they wouldn't mind volunteering and perhaps you could be that rule, you could be that one, thanks, thank you very much. O.K., so now the idea is that everybody who has a rule keep watching out for when your condition side, when the left-hand is true, when it does, hold the rule up, show it to me and yell out what is says on the right, the action that Clive's supposed to do. O.K., is that clear? O.K. fine, I'll start things moving. I'll ask Clive, would you please mind cooking us another egg on toast. O.K., so that's a request.

Who's got the request?

MAN IN AUDIENCE:

Start toaster.

DR. RICHARD YOUNG:

Fine, so you should start the toaster.

DR. CLIVE HOLLOWAY:

Start toaster. Right.

DR. RICHARD YOUNG:

There he goes, starting the toaster. (O.K.) Thank you very much. You can put that down. Now the toaster's on, but the heat's off. Can you hold that up, please? Fine and what should he do?

LADY IN AUDIENCE:

Turn/heat on.

DR. RICHARD YOUNG:

Could / you turn the heat on, please.

DR. CLIVE HOLLOWAY:

Turn the heat on, like that. (THANK YOU) There we go.

DR. RICHARD YOUNG:

Now the heat's on but the pan's empty. Who's that?

LADY IN AUDIENCE:

Put the butter in.

DR. RICHARD YOUNG:

O.K., so in with the butter , please.

DR. CLIVE HOLLOWAY:

In with the butter.

DR. RICHARD YOUNG:

Now we may have to wait a little bit for it to warm up. How's that doing, Clive?

DR. CLIVE HOLLOWAY:

Well, it's coming on, it's just beginning to sizzle.

DR. RICHARD YOUNG:

O.K., so the butter's sizzling.

LADY IN AUDIENCE:

Add egg.

DR. RICHARD YOUNG:

O.K., add the egg, please.

DR. CLIVE HOLLOWAY:

Add egg. Right. Like that. Now then I might have to wait a little while for this to set.

DR. RICHARD YOUNG:

Ah, the toast has come up. Who's that?

MAN IN AUDIENCE:

Remove toast.

DR. RICHARD YOUNG:

O.K., so out with the toast please. How's the egg doing?

DR. CLIVE HOLLOWAY:

Well, actually, it's done.

DR. RICHARD YOUNG:

O.K., so the egg's ready.

LADY IN AUDIENCE:

Remove egg.

DR. RICHARD YOUNG:

Can you remove the egg, please.

DR. CLIVE HOLLOWAY:

Remove the egg. O.K.

DR. RICHARD YOUNG:

Fine, O.K., thanks very much,Clive. Well, I hope you noticed, and thank you also. I hope you noticed that that time things happened in a rather different order. The toast popped up earlier than it did the first time through. It came up soon after he put the egg in. Whereas the first time we went through, it was only at the very end that the toast came up. Well, the production system still behaved right because each rule is set up so as it fires off when it applies. O.K., well in fact the production system is even more flexible than that. We'll think about the following question. Supposing we'd started off with some butter already in the pan before Clive started cooking. What would the difference have been? Could you hold up your rule a minute please? What would you have done if in fact there had been butter in the pan already?

LADY IN AUDIENCE:

I wouldn't have done anything.

DR. RICHARD YOUNG:

That's right. You wouldn't have, your condition would never have been true, so the right-hand side would never have been needed. Thanks very much. So we can see that these production systems are flexible in a couple of ways, not only can the rules fire off in different orders as is appropriate, but also if there's a rule that never needs to fire, then in fact it would never be called.

DR. CLIVE HOLLOWAY:

Well, that system's beautifully simple and I think it's a lot better than the cumbersome flow chart which would have a lot of difficulty with that situation, so I'll agree that production systems are flexible. But what about a totally unexpected event. Now that rehearsal last week when we were doing the cooking sequence, shall we show them what we're talking about?

RECORDED REHEARSAL SEQUENCE:

STAGE MANAGER:

Thank you.

DR. CLIVE HOLLOWAY:

Now we're going to cook some eggs on toast and we'll start off with the toast in the toaster, turn on, and the next thing is to get the cooker on. (Match striking) Oh, blimey, that's O.K. Now we're going to heat the pan with some butter in it. O.K. That'll do. Next the egg. There we go - beautiful. Now we're just going to have to wait for this to set for one or two seconds, so if you'll just bear with me. That seems to be going - hey! Hold on! What's going on here? What's ..... aii! (Fire extinguisher) Did you do that? Was that something to do with you? (Laughter).

DR. RICHARD YOUNG:

O.K. fine. So what happened there was that Clive dealt appropriately with something he wasn't expecting to have happen. Well, let's think about trying to model that type of behaviour using the two sorts of methods that we're talking about this evening - that's flow charts, on the one hand, and production systems on the other. Well, it's certainly possible to do this kind of thing with flow charts but we have to think very carefully about what would be involved. Let's have a look at this, this is the flow chart that we started upwards, we going to be seeing in a minute. Now it's laid out differently but it's in fact meant to be the same flow chart and we're going to just look at the first couple of rules. The first couple of boxes. There they are. Now there's nothing to stop us inserting a test between them to see whether the toast has burst into flames and if so to do something to rescue it, but the trouble is that accident could have happened anytime during the cooking process, so if that sort of test is to be of any use, then we have to put it everywhere in the flow chart and we'll see that in just a second. You can see that it's there throughout the flow chart. Well, maybe that's not too bad in this particular case but I think you can see that if it were a much more complicated flow chart and there were many more things to check for, then things would become horribly complicated. What's more, there's something worse than that because it's also wrong psychologically Obviously we don't spend all our time checking for the things that might have happened but usually don't, like toast suddenly catching fire or maybe the telephone suddenly starting to ring. What in fact we do is we let the occurrence of those events actually trigger the behaviour of dealing with them. Now that kind of thing is much easier to deal with if we have a production system. Let me show you. All I have to do with the production system is to add one more rule, this time the one that says, well, if the toast bursts into flames, rescue it and then the production system will deal correctly

with that.

DR. CLIVE HOLLOWAY:

O.K., well, I'm pretty convinced by now but, well, I'm still not totally happy because it doesn't model some kind of cognitive skills. What you've done, is you've added a production rule and you've extended the skill, you've increased its range but it's sort of all at one level. Now I can think of some cognitive skills where when your skill improves what happens is your behaviour suddenly changes form. It does something dramatically different. Now can a production system cope with that kind of thing?

DR. RICHARD YOUNG:

Yeah, I agree with you about that difference but production systems do have something to say about that kind of thing as well. I think maybe the best way to think about it is we should look at another skill, a different one, this time totally different to cooking and this is one that's normally given to young children. Let's begin by looking at a film we made a few years ago of a little girl called Penny who's been asked to put a number of blocks in order of size. There she is. (Effects: bricks being put down) Well, I hope that the task is clear. The child's given a heap of wooden blocks of different size, she has to arrange them in a straight line so that they're in order of size. That kind of task is known as the seriation task. It's one of the kind of things that Piaget studied a lot. Typically, what he does is to give that task or something like it to a number of different children of different ages and then he goes ahead and classifies the children as being in one of three stages of development. O.K., well, we'll see in a couple of minutes that we don't necessarily want to agreed completely with this idea of distinct stages but nevertheless, if we go ahead and do what Piaget did and observe the children carefully, then we find, and this is really

important, that different children use different methods for doing the task. O.K., now we've seen the way that Penny did it, let's have a look now at the way a little boy called Simon sets about it. (Effects: bricks being put down) Well, that certainly looked different to Penny, didn't it? Whereas the way Penny did it was by choosing the blocks in the first place in the right order, Simon simply reached out, tookethe first one that came to hand and then rearranged them at the line if it was necessary. O.K. Well, so in addition to those two different methods, there are also some other ones that we haven't looked at. Then in addition to those, of course, there are the younger children who cannot do the task at all. But even they set about doing it in a number of different ways. Let me try and illustrate some of them. The very youngest children don't bother at all about the size of the blocks and they land up with something that looks rather like this, where the blocks are just totally out of order. Perhaps when they get a bit older, they take a small block and a big block and put them together in pairs, so we land up with an arrangement which looks like that, alternate big and small blocks. Another thing they might do is perhaps build two separate series but they're unable to put them together. There's one and there's another. Or another thing they do that's rather similar to that is to build a series out of some of the blocks but then there are maybe one or two left over that they're not able to incorporate into the line. O.K. Well, let's think a little bit more about this kind of result and see if we could use production systems in any way to throw light on how a child might produce that result and how he might progress from there to being able to do the task properly perhaps in the way we saw Simon doing it. If we go over to this board here, you'll see that we have a little production system doing seriation, well for tackling seriation but we'll see in a minute that it doesn't always do it right. The top rule says that if the child needs a block, then he reaches out and takes the one that

comes to hand, the nearest one. When he has a new block, then he goes ahead and adds it to the line. This third rule says that if there's a new configuration, that is, if the shape of the line's changed at all then he examines it, that is, he looks very carefully at the part of the line that's been changed and the bottom rule says that if the result of that examination is that the block seemed to be too big then he rejects it. That is, he puts it back in the pool where it came from. Well, let's have a look now at how that kind of production system behaves when it runs. Well, imagine the child starts off by, well, she's already placed the first block, she needs another one, so the top rule fires, that leads to the action of get nearest, so she reaches out and grabs the block. Now she has a new one, so the second rule down fires and she adds it to the line. That makes a new configuration, so she examines it and this time it's smaller so that's O.K. Now she needs another block, so that's the top rule again. She gets one, she adds it to the line, so that's a new configuration, she examines it but of course it's seen to be too big, so it's the bottom rule that fires and lands up rejecting it, putting it back in the pool. O.K., she needs another block, so she gets one, she puts it in the line, examines it and that's alright. Then again with the smallest block, that gets added to the line as well. Now with this very last block, it gets put in the line, examined, but again it's too big so it gets rejected. And that's as good a job at seriation as this production system is able to do. Now notice that the final shape of the configuration it builds is just the same as what we have over here on the table, namely a partial series, just part of the series with a couple of blocks left over that couldn't be placed and happens because that production system has no way of correcting the line once it's gone wrong. Once this block's been left out from here, then it's a smaller block that gets placed, so when this one's eventually brought up it will be too big and will be rejected. So you can see that unless one's extremely lucky with the

way the blocks happen to be laid out in the first place that one will lang up with that kind of configuration. Now just imagine what happens if I add one more rule to the system. This time it's one that says, if the result of the examination is one of these reversal patterns where it goes up at the end, then switch the two blocks round. O.K., well, let's see how that enlarged production system behaves. Let's suppose this time that the subject has already placed most of the blocks and that there are just two left, two more to place. So just like last time, the smallest one gets added to the line, that makes a new configuration, that's examincd but then it's O.K. Now for the last block. It gets put in the line, it's examined and we have one of these reversal patterns, so it's the bottom rule that fires now and she switches the two block round. Again that makes a new configuration, the middle rule fires, she examines it again and again it's the reversal, so the bottom rule fires, she switches them around, again a new configuration and this time it's all right and notice that that's just the same kind of technique as we saw Simon using. (Effects: bricks being put down)

DR. CLIVE HOLLOWAY:

Gosh. So the idea is that with a production system model, you have a change in skill represented as a gradual growth process and addition of rules and in fact that can sometimes lead to the kind of situation where you just extend a skill and that's the cooking example and sometimes you can have a situation where the addition of just one rule will radically change the behaviour. Now we've only had time to look at two examples - cooking and seriation - would you very briefly like to say why you think this production system analysis has general advantages?

DR. RICHARD YOUNG:

Well, certainly the most important point is the ability of a production

system to capture the flexibility and adaptiveness of human skill. You know, the way that what a person does depends on the situation he finds himself in.

DR. CLIVE HOLLOWAY:

Now are there any disadvantages, very quickly, could you be a cordon bleu chef, could you model that?

DR. RICHARD YOUNG:

No, I mean, just think about the difficulty of the perceptual aspects of it. The experienced taste that he has. I don't think production systems help us with that.

DR. CLIVE HOLLOWAY:

O.K., fair enough. Richard, thank you. Well, we've seen programmes on perception and now we've just finished doing some programmes on problem solving. In the next two broadcasts we're going to have a look at a very important area of research, language comprehension, so I look forward to meeting you all then. Thank you very much indeed, goodbye.

(Effects: audience talking)

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