Debugging a Model Which Has Perceptual and Motor Actions

In this text we are going to implement a model which can perform a simple experiment which requires visual and motor actions. While doing so we will encounter some problems which we will walk through debugging. We will also discuss some of the additional things that one should be careful about with respect to visual tasks in particular and also introduce some additional tools in the ACT-R Environment which may be helpful in debugging and analyzing models.

The Task

The experiment which this model will have to perform involves the following steps:

- A letter is presented on the screen for between 1.5 and 2.5 seconds
- After the letter goes away either the word "next" or the word "previous" is displayed
- When the prompt is displayed the participant must type the letter which was presented followed by the appropriate letter in the alphabet based on the prompt

The perceptual-motor-issues.lisp file in this unit includes the code to implement such an experiment for the model as well as a starting model. To run the task you need to call the simple-task function and you may provide either the string "next" or "previous" as a parameter to pick which prompt to display, or if neither is given a random prompt will be chosen for the trial. The return value from the function will be a list of the prompt and t or nil to indicate if the model made the correct responses. Before running it however we will first discuss the design for the model which we are attempting to write.

The Model Design

For most models, including this one, there are two important pieces to the model's design. The first is how to represent the knowledge necessary for the model to be able to perform the task, and the other is the steps the model will perform to actually do the task. How the knowledge is represented for the model will affect how the model has to perform the task, and knowing what the model needs to do will affect what needs to be encoded in the knowledge representation. In general, these two design issues are intertwined and one will typically need to work on both of them together when starting the planning for the model. Below we will describe those two pieces of the model we have started to write for this task along with some explanation as to why we've made some of the choices we did. As we run the model and encounter problems we may find that our initial design choices are not sufficient to perform the task and thus we will have to adjust our design.

Knowledge representation

Because this model is performing a very simple task, we are not concerned with fitting human performance data, and we are only using the symbolic level of ACT-R's declarative memory we can choose a representation which should make the modeling task easier. If we were concerned about fitting human performance, we would have to consider the consequences of the representation more thoroughly and would likely require something more involved than what we will use here.

This model needs to know about letters of the alphabet and their ordering. We will represent that in chunks in the model's declarative memory. The first choice to make is how we will distinguish letters, and we will use the simple assumption that each letter will be represented as a separate chunk using a chunk-type called letter. Now we have to decide on what slots the letter type needs and what information will be contained in those slots. Since this model will be reading a letter from the screen and typing keys it will be important to have the letter's visual representation included in the chunk as well as a representation which can be used to type the letter. Both the visual and motor representations use a Lisp string to represent a letter. Thus that single representation is all we need to have in the chunk and will store it in a slot called name. The other thing which the model needs to be able to determine is the next and previous letter of the alphabet given a particular letter. There are many ways that one could represent that, but because we are writing a simple symbolic model we will explicitly encode that information in the chunks for a given letter in slots called next and previous. In fact, to make things even easier for the model we will encode the next and previous information using the same perceptual/motor representation as we do for the name of the letter (a Lisp string). Here is what the letter chunk-type and a chunk representation for the letter B look like in the model:

```
(chunk-type letter name next previous)

(b isa letter name "b" next "c" previous "a")
```

A more plausible model would likely represent the next and previous values with a reference to the other chunks instead of directly encoding the perceptual representations. In fact, it might even only encode the next value instead of both next and previous if we believe that most people only encode the alphabet in the forward direction. After we work through this example, as an exercise, you may want to try changing the model's representation to something like that and see if you can then adjust the model's actions appropriately so that it can still do the task.

We also need a way to represent the information needed to perform the task. Because this is a very simple task, we are not going to use a goal chunk to hold state information and will instead rely on the perceptual input and buffer contents to drive the state of the model. We will however create a chunk to maintain the letter which we have read from the screen in the imaginal buffer. Since that letter is the only information we need in that chunk the chunk-type only needs that one slot and we can create a new type called task to use:

```
(chunk-type task letter)
```

Actions to perform

Now we will describe how we want our model to perform the task. As noted above we are not going to use an explicit goal state to drive the model. Instead we will rely on the visual-location buffer stuffing mechanism to have the model know when the screen changes and use the contents of the buffers and states of the modules to determine what to do next. Here is the high-level description of the steps which the model will perform:

- When it detects a letter on the screen attend it and record it in the imaginal buffer
- When it sees next or previous on the screen press the current key and retrieve the appropriate letter chunk from declarative memory
- Once a chunk is retrieved press the appropriate key

There are other ways one could choose to perform this task, and as with the representation issues noted above, after working through the debugging of this model you may want to consider other ways of performing the task and try to model them.

To implement that sequence of actions we have written five productions. This is what each production is intended to do:

find-letter – responds to the appearance of the letter due to buffer stuffing and then requests a visual attention shift to the letter and create a new chunk in the imaginal buffer

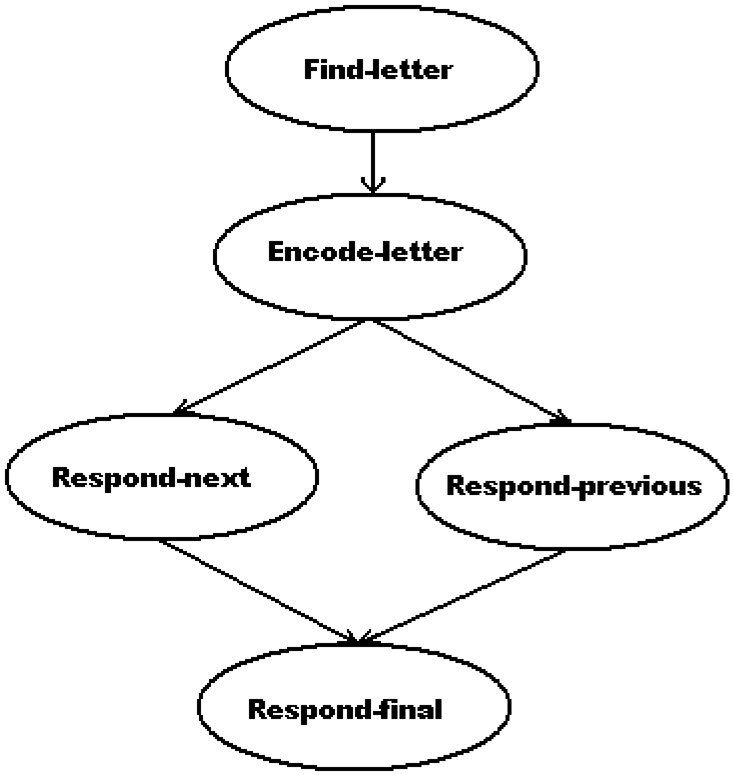
encode-letter – when the chunks resulting from the actions of find-letter are available in the imaginal and visual buffers update the imaginal buffer with the letter that is seen

respond-next – when the model sees the word “next” on the screen press the current letter’s key and make a retrieval request for the letter which occurs after the current one

respond-previous – when the model sees the word “previous” on the screen press the current letter’s key and make a retrieval request for the letter which occurs before the current one

respond-final – when a letter chunk has been retrieved press the corresponding key

This is how we expect them to fire to do the task where the choice of whether it is respond-next or respond-previous depends on the prompt displayed:



If you look over the productions you may see some potential problems in them or with the overall design of the model, but please don't get ahead of the exercise and just leave them alone until we encounter the problems during the testing walkthrough below.

Load and Run the initial Model

There are no warnings when this model is loaded because we have turned off the style warnings so that we can focus on particular issues in the model. There is a section at the end where we show the style warnings which would be displayed if they were enabled and describe how seeing those may have affected how we worked through fixing the model. Since there are no syntax errors or other problems which we must fix before trying to run it we will run the model to see how it performs. To keep the testing consistent we will run it through trials for the "next" item until we have that working and then move on to testing the "previous" trials. Also, for consistency, we have set a seed parameter in the model. That way it will always be seeing the same letter and perform the same way. Once we are satisfied with its performance with the seed fixed we will remove that and test it under more variable conditions.

Here is the trace we get when we run the model:

```
> (simple-task "next")
0.000   VISION        SET-BUFFER-CHUNK VISUAL-LOCATION VISUAL-LOCATION0-0 REQUESTED NIL
0.000   PROCEDURAL    CONFLICT-RESOLUTION
0.050   PROCEDURAL    PRODUCTION-FIRED FIND-LETTER
0.050   PROCEDURAL    CLEAR-BUFFER VISUAL-LOCATION
0.050   PROCEDURAL    CLEAR-BUFFER VISUAL
0.050   PROCEDURAL    CLEAR-BUFFER IMAGINAL
0.050   PROCEDURAL    CONFLICT-RESOLUTION
0.135   VISION        Encoding-complete VISUAL-LOCATION0-0-0 NIL
0.135   VISION        SET-BUFFER-CHUNK VISUAL TEXT0
0.135   PROCEDURAL    CONFLICT-RESOLUTION
0.250   IMAGINAL      SET-BUFFER-CHUNK IMAGINAL CHUNK0
0.250   PROCEDURAL    CONFLICT-RESOLUTION
0.300   PROCEDURAL    PRODUCTION-FIRED ENCODE-LETTER
0.300   PROCEDURAL    CLEAR-BUFFER VISUAL
0.300   PROCEDURAL    CONFLICT-RESOLUTION
2.090   NONE          DISPLAY-PROMPT next
2.090   VISION        SET-BUFFER-CHUNK VISUAL-LOCATION VISUAL-LOCATION1-0 REQUESTED NIL
2.090   PROCEDURAL    CONFLICT-RESOLUTION
2.175   VISION        Encoding-complete VISUAL-LOCATION0-0-0 NIL
2.175   VISION        SET-BUFFER-CHUNK VISUAL TEXT1 REQUESTED NIL
2.175   PROCEDURAL    CONFLICT-RESOLUTION
2.225   PROCEDURAL    PRODUCTION-FIRED FIND-LETTER
2.225   PROCEDURAL    CLEAR-BUFFER VISUAL-LOCATION
2.225   PROCEDURAL    CLEAR-BUFFER VISUAL
2.225   PROCEDURAL    CLEAR-BUFFER IMAGINAL
2.225   PROCEDURAL    CONFLICT-RESOLUTION
2.310   VISION        Encoding-complete VISUAL-LOCATION1-0-0 NIL
2.310   VISION        SET-BUFFER-CHUNK VISUAL TEXT2
2.310   PROCEDURAL    CONFLICT-RESOLUTION
2.425   IMAGINAL      SET-BUFFER-CHUNK IMAGINAL CHUNK1
2.425   PROCEDURAL    CONFLICT-RESOLUTION
2.475   PROCEDURAL    PRODUCTION-FIRED ENCODE-LETTER
2.475   PROCEDURAL    CLEAR-BUFFER VISUAL
2.475   PROCEDURAL    CONFLICT-RESOLUTION
2.475   ------        Stopped because no events left to process
("next" NIL)
```

The model did not respond correctly to the task as indicated by the return value, and looking at the trace we see that the productions did not fire in the sequence we expected. There are a couple of things we could investigate, but we will start by determining where the model first deviated from our plan and address that.

The first issue appears to be at time 2.225 when find-letter fires a second time. Here is the find-letter production:

```
(p find-letter
   =visual-location>
   ?visual>
     state       free
 ==>
   +visual>
     cmd         move-attention
     screen-pos  =visual-location
```

```
   +imaginal>
)
```

Before trying to fix the production we should make sure we understand why it fired again. If we look at the conditions of the production all it requires to fire is that there is a chunk in the visual-location buffer and that the vision module not be busy. Looking at the trace we see that at time 2.090 when the display of the "next" prompt occurs there is a new chunk placed into the visual-location buffer. That happens because every time there is a change to the screen the visual-location buffer will be stuffed with a chunk if it is empty. At time 2.175 we see that the vision module completes the re-encoding of the display and thus at that point the module is free (we could check that by using the stepper and inspecting the buffer status at that time, but for now we will assume that's the case). Those are the only two conditions for the find-letter production and since they are satisfied it can be selected and fired again.

There are a few things we can do to correct that at this point: we could add additional tests to the production so that it only fires when we want it to (the start of the task), we could change it or other productions so that its conditions are not satisfied at time 2.175, or we could consider redesigning the steps that we want the model to perform and rewrite this and other productions. As a first step, we will take the first of those options and adjust this production to only fire when we expect it to. After testing things further we may find that that is not sufficient and other changes to our design and/or the model's productions are necessary, but progressing in small steps is often a good way to start.

Now we will consider what we can add to the production to make it only fire at the start. One option would be to add a goal chunk to the model so that we could explicitly mark a start state, but we would like to avoid doing that if possible because not having a goal chunk was part of our design. Thus, we need to find something else which we can test. One place to look for something like that is in the actions of the production itself – what does it do to change things that can be tested to prevent it from firing again? A good candidate for that would be the imaginal request since that is a change in the model which we expect to only occur once, whereas the visual buffer is going to be used in multiple places and thus is not a change unique to this production. This production is making a request to put a chunk into the imaginal buffer (all requests to the imaginal buffer are to create a chunk, even if there are no slots specified) and prior to that the buffer will be empty. If we test that the imaginal buffer is empty in the conditions of find-letter that might be sufficient to prevent it from firing again later when we don't want it to. We could just make that change and run the model again to see if it'll work, but instead we will first run the model again and use the stepper to see if that change will help at time 2.175 when the production is selected the second time. [Because this is such a small model which runs quickly we don't really need to perform that verification because we could determine it from the trace or really just try it and see what happens, but in the interest of completeness we will do so because in larger or more complicated models that may be a better choice.]

To perform the test we will open the stepper and then run the task again. Since we know what time the production is selected, the conflict-resolution at time 2.175, we can use the run-until button to advance the model to that time and then step forward to the conflict-resolution event. Once we are there we can open a buffer viewer and look at the imaginal buffer. At that time we see that it does indeed have a chunk in it:

```
IMAGINAL: CHUNK0-0
CHUNK0-0
   LETTER  "n"
```

Therefore adding a test that the imaginal buffer is empty to find-letter should help. Here is the new find-letter production with a query for the imaginal buffer being empty added:

```
(p find-letter
   =visual-location>
   ?visual>
     state        free
   ?imaginal>
     buffer       empty
 ==>
   +visual>
     cmd          move-attention
     screen-pos   =visual-location
   +imaginal>
)
```

We need to save that change and then reload the model.

Second version of the model

Here is the trace we get when we run the updated model:

```
> (simple-task "next")
0.000   VISION        SET-BUFFER-CHUNK VISUAL-LOCATION VISUAL-LOCATION0-0 REQUESTED NIL
0.000   PROCEDURAL    CONFLICT-RESOLUTION
0.050   PROCEDURAL    PRODUCTION-FIRED FIND-LETTER
0.050   PROCEDURAL    CLEAR-BUFFER VISUAL-LOCATION
0.050   PROCEDURAL    CLEAR-BUFFER VISUAL
```

```
0.050   PROCEDURAL   CLEAR-BUFFER IMAGINAL
0.050   PROCEDURAL   CONFLICT-RESOLUTION
0.135   VISION       Encoding-complete VISUAL-LOCATION0-0-0 NIL
0.135   VISION       SET-BUFFER-CHUNK VISUAL TEXT0
0.135   PROCEDURAL   CONFLICT-RESOLUTION
0.250   IMAGINAL     SET-BUFFER-CHUNK IMAGINAL CHUNK0
0.250   PROCEDURAL   CONFLICT-RESOLUTION
0.300   PROCEDURAL   PRODUCTION-FIRED ENCODE-LETTER
0.300   PROCEDURAL   CLEAR-BUFFER VISUAL
0.300   PROCEDURAL   CONFLICT-RESOLUTION
2.090   NONE         DISPLAY-PROMPT next
2.090   VISION       SET-BUFFER-CHUNK VISUAL-LOCATION VISUAL-LOCATION1-0 REQUESTED NIL
2.090   PROCEDURAL   CONFLICT-RESOLUTION
2.175   VISION       Encoding-complete VISUAL-LOCATION0-0-0 NIL
2.175   VISION       SET-BUFFER-CHUNK VISUAL TEXT1 REQUESTED NIL
2.175   PROCEDURAL   CONFLICT-RESOLUTION
2.175   ------                 Stopped because no events left to process
("next" NIL)
```

We don't have a second firing of find-letter, but the model still doesn't do the task correctly. We are expecting the respond-next production to fire at this point, but it does not. Since the model is stopped we can immediately use whynot to find out what the issue is. Here is what whynot reports for respond-next:

```
> (whynot respond-next)

Production RESPOND-NEXT does NOT match.
(P RESPOND-NEXT
   =IMAGINAL>
       LETTER =LETTER
   =VISUAL>
       VALUE "next"
   ?MANUAL>
       STATE BUSY
 ==>
   +RETRIEVAL>
       PREVIOUS =LETTER
   +MANUAL>
       CMD PRESS-KEY
       KEY =LETTER
)
It fails because:
The STATE BUSY query of the MANUAL buffer failed.
```

Looking at the reason given and the production it should be fairly obvious that the issue is a mistake in the production. We should be testing that the manual module's state is free instead of busy. If this were a more complicated model that may not be so obvious, and in that situation we would likely want to investigate that further. To do so we would use the "Buffer Status viewer" tool in the Environment or the buffer-status command to show us all of the current status information for the given buffer/module and we may need to do so in conjunction with the stepper to see how it changes as the model progresses. In this case we don't need to do so, but here is what it shows for the manual buffer for the sake of completeness:

```
MANUAL:
  buffer empty          : T
  buffer full           : NIL
  buffer failure        : NIL
  buffer requested      : NIL
  buffer unrequested    : NIL
  state free            : T
  state busy            : NIL
  state error           : NIL
  preparation free      : T
  preparation busy      : NIL
  processor free        : T
  processor busy        : NIL
  execution free        : T
  execution busy        : NIL
  last-command          : NONE
```

There we can see that the state busy query is NIL at this time whereas the state free query is T. We need to change that test from busy to free in the production, save the model, and load it.

Model version 3

Here is the trace we get from running the model now:

```
> (simple-task "next")
0.000   VISION      SET-BUFFER-CHUNK VISUAL-LOCATION VISUAL-LOCATION0-0 REQUESTED NIL
0.000   PROCEDURAL  CONFLICT-RESOLUTION
0.050   PROCEDURAL  PRODUCTION-FIRED FIND-LETTER
0.050   PROCEDURAL  CLEAR-BUFFER VISUAL-LOCATION
0.050   PROCEDURAL  CLEAR-BUFFER VISUAL
0.050   PROCEDURAL  CLEAR-BUFFER IMAGINAL
0.050   PROCEDURAL  CONFLICT-RESOLUTION
0.135   VISION      Encoding-complete VISUAL-LOCATION0-0-0 NIL
0.135   VISION      SET-BUFFER-CHUNK VISUAL TEXT0
0.135   PROCEDURAL  CONFLICT-RESOLUTION
0.250   IMAGINAL    SET-BUFFER-CHUNK IMAGINAL CHUNK0
0.250   PROCEDURAL  CONFLICT-RESOLUTION
0.300   PROCEDURAL  PRODUCTION-FIRED ENCODE-LETTER
0.300   PROCEDURAL  CLEAR-BUFFER VISUAL
0.300   PROCEDURAL  CONFLICT-RESOLUTION
2.090   NONE        DISPLAY-PROMPT next
2.090   VISION      SET-BUFFER-CHUNK VISUAL-LOCATION VISUAL-LOCATION1-0 REQUESTED NIL
2.090   PROCEDURAL  CONFLICT-RESOLUTION
2.175   VISION      Encoding-complete VISUAL-LOCATION0-0-0 NIL
2.175   VISION      SET-BUFFER-CHUNK VISUAL TEXT1 REQUESTED NIL
2.175   PROCEDURAL  CONFLICT-RESOLUTION
2.225   PROCEDURAL  PRODUCTION-FIRED RESPOND-NEXT
2.225   PROCEDURAL  CLEAR-BUFFER IMAGINAL
2.225   PROCEDURAL  CLEAR-BUFFER VISUAL
2.225   PROCEDURAL  CLEAR-BUFFER RETRIEVAL
2.225   PROCEDURAL  CLEAR-BUFFER MANUAL
2.225   MOTOR       PRESS-KEY KEY n
2.225   DECLARATIVE START-RETRIEVAL
2.225   DECLARATIVE RETRIEVED-CHUNK O
2.225   DECLARATIVE SET-BUFFER-CHUNK RETRIEVAL O
2.225   PROCEDURAL  CONFLICT-RESOLUTION
2.275   PROCEDURAL  PRODUCTION-FIRED FIND-LETTER
2.275   PROCEDURAL  CLEAR-BUFFER VISUAL-LOCATION
2.275   PROCEDURAL  CLEAR-BUFFER VISUAL
```

```
2.275   PROCEDURAL  CLEAR-BUFFER IMAGINAL
2.275   PROCEDURAL  CONFLICT-RESOLUTION
2.325   PROCEDURAL  PRODUCTION-FIRED RESPOND-FINAL
2.325   PROCEDURAL  CLEAR-BUFFER RETRIEVAL
2.325   PROCEDURAL  CLEAR-BUFFER MANUAL
2.325   MOTOR       PRESS-KEY KEY o
#|Warning: Module :MOTOR jammed at time 2.325 |#
2.325   PROCEDURAL  CONFLICT-RESOLUTION
2.360   VISION      Encoding-complete VISUAL-LOCATION1-0-0 NIL
2.360   VISION      SET-BUFFER-CHUNK VISUAL TEXT2
2.360   PROCEDURAL  CONFLICT-RESOLUTION
2.475   IMAGINAL    SET-BUFFER-CHUNK IMAGINAL CHUNK1
2.475   PROCEDURAL  CONFLICT-RESOLUTION
2.525   PROCEDURAL  PRODUCTION-FIRED ENCODE-LETTER
2.525   PROCEDURAL  CLEAR-BUFFER VISUAL
2.525   PROCEDURAL  CONFLICT-RESOLUTION
2.625   MOTOR       OUTPUT-KEY #(6 5)
2.625   PROCEDURAL  CONFLICT-RESOLUTION
2.775   PROCEDURAL  CONFLICT-RESOLUTION
2.775   ------      Stopped because no events left to process
("next" NIL)
```

The model still did not complete the task correctly, but it does appear to have fired the productions we expected in order (we will ignore the extra productions fired at the end of the run for now) and attempted to press the correct keys: n and o. However the warning that is printed at time 2.325 seems to be a problem:

```
#|Warning: Module :MOTOR jammed at time 2.325 |#
```

A module gets "jammed" when there are multiple concurrent requests which it is unable to process. That is usually not something which the model should do, thus eliminating the cause of that warning seems like the next step to take. Looking at the trace, the respond-final production is the last one to fire before the warning and since we know that that production is supposed to press a key that makes it the likely candidate for having caused the problem. Before looking at the production itself, we will first look at the state of the motor module at the time that production fires. To do that we will open the stepper, start the task, and then pick production for the run until option, enter respond-final, and then hit the "Run Until" button. The model will then be stopped just before the production fires and we can open the "Buffer Status viewer" to look at the motor module's state as reported by the manual buffer:

```
MANUAL:
  buffer empty          : T
  buffer full           : NIL
  buffer failure        : NIL
  buffer requested      : NIL
  buffer unrequested    : NIL
  state free            : NIL
  state busy            : T
  state error           : NIL
  preparation free      : NIL
```

```
  preparation busy      : T
  processor free        : NIL
  processor busy        : T
  execution free        : T
  execution busy        : NIL
  last-command          : PRESS-KEY
```

There we see that the module is busy at that time and respond-final should not be making a request to the manual buffer because it is not ready. Here is the text of our respond-final production:

```
(p respond-final
   =retrieval>
     isa         letter
     name        =letter
   ==>
   +manual>
     cmd         press-key
     key         =letter
)
```

It does not have a condition to make sure that the motor module is not busy, but because it is making a manual buffer request it should have such a check to avoid the jamming which occurs. Here is an updated version of that production which has a query of the state to avoid the jamming:

```
(p respond-final
   =retrieval>
     isa         letter
     name        =letter
   ?manual>
     state       free
 ==>
   +manual>
     cmd         press-key
     key         =letter
)
```

We need to save that change and again reload the model.

Model version 4

Here is the trace of the model running after that change:

```
> (simple-task "next")
0.000   VISION      SET-BUFFER-CHUNK VISUAL-LOCATION VISUAL-LOCATION0-0 REQUESTED NIL
0.000   PROCEDURAL  CONFLICT-RESOLUTION
0.050   PROCEDURAL  PRODUCTION-FIRED FIND-LETTER
0.050   PROCEDURAL  CLEAR-BUFFER VISUAL-LOCATION
0.050   PROCEDURAL  CLEAR-BUFFER VISUAL
0.050   PROCEDURAL  CLEAR-BUFFER IMAGINAL
0.050   PROCEDURAL  CONFLICT-RESOLUTION
0.135   VISION      Encoding-complete VISUAL-LOCATION0-0-0 NIL
```

```
0.135   VISION      SET-BUFFER-CHUNK VISUAL TEXT0
0.135   PROCEDURAL  CONFLICT-RESOLUTION
0.250   IMAGINAL    SET-BUFFER-CHUNK IMAGINAL CHUNK0
0.250   PROCEDURAL  CONFLICT-RESOLUTION
0.300   PROCEDURAL  PRODUCTION-FIRED ENCODE-LETTER
0.300   PROCEDURAL  CLEAR-BUFFER VISUAL
0.300   PROCEDURAL  CONFLICT-RESOLUTION
2.090   NONE        DISPLAY-PROMPT next
2.090   VISION      SET-BUFFER-CHUNK VISUAL-LOCATION VISUAL-LOCATION1-0 REQUESTED NIL
2.090   PROCEDURAL  CONFLICT-RESOLUTION
2.175   VISION      Encoding-complete VISUAL-LOCATION0-0-0 NIL
2.175   VISION      SET-BUFFER-CHUNK VISUAL TEXT1 REQUESTED NIL
2.175   PROCEDURAL  CONFLICT-RESOLUTION
2.225   PROCEDURAL  PRODUCTION-FIRED RESPOND-NEXT
2.225   PROCEDURAL  CLEAR-BUFFER IMAGINAL
2.225   PROCEDURAL  CLEAR-BUFFER VISUAL
2.225   PROCEDURAL  CLEAR-BUFFER RETRIEVAL
2.225   PROCEDURAL  CLEAR-BUFFER MANUAL
2.225   MOTOR       PRESS-KEY KEY n
2.225   DECLARATIVE START-RETRIEVAL
2.225   DECLARATIVE RETRIEVED-CHUNK O
2.225   DECLARATIVE SET-BUFFER-CHUNK RETRIEVAL O
2.225   PROCEDURAL  CONFLICT-RESOLUTION
2.275   PROCEDURAL  PRODUCTION-FIRED FIND-LETTER
2.275   PROCEDURAL  CLEAR-BUFFER VISUAL-LOCATION
2.275   PROCEDURAL  CLEAR-BUFFER VISUAL
2.275   PROCEDURAL  CLEAR-BUFFER IMAGINAL
2.275   PROCEDURAL  CONFLICT-RESOLUTION
2.360   VISION      Encoding-complete VISUAL-LOCATION1-0-0 NIL
2.360   VISION      SET-BUFFER-CHUNK VISUAL TEXT2
2.360   PROCEDURAL  CONFLICT-RESOLUTION
2.475   IMAGINAL    SET-BUFFER-CHUNK IMAGINAL CHUNK1
2.475   PROCEDURAL  CONFLICT-RESOLUTION
2.525   PROCEDURAL  PRODUCTION-FIRED ENCODE-LETTER
2.525   PROCEDURAL  CLEAR-BUFFER VISUAL
2.525   PROCEDURAL  CONFLICT-RESOLUTION
2.625   MOTOR       OUTPUT-KEY #(6 5)
2.625   PROCEDURAL  CONFLICT-RESOLUTION
2.775   PROCEDURAL  CONFLICT-RESOLUTION
2.825   PROCEDURAL  PRODUCTION-FIRED RESPOND-FINAL
2.825   PROCEDURAL  CLEAR-BUFFER RETRIEVAL
2.825   PROCEDURAL  CLEAR-BUFFER MANUAL
2.825   MOTOR       PRESS-KEY KEY o
2.825   PROCEDURAL  CONFLICT-RESOLUTION
2.975   PROCEDURAL  CONFLICT-RESOLUTION
3.025   PROCEDURAL  CONFLICT-RESOLUTION
3.125   MOTOR       OUTPUT-KEY #(9 3)
3.125   PROCEDURAL  CONFLICT-RESOLUTION
3.275   PROCEDURAL  CONFLICT-RESOLUTION
3.275   ------      Stopped because no events left to process
("next" T)
```

The return value indicates that the model performed the task correctly. However, if we look at the trace thoroughly we see that there are still unexpected firings of the find-letter and encode-letter productions. So, while the model has performed the task correctly, it still isn't running the way we expect it to. We will have to again look into why find-letter is firing unexpectedly.

Here is our current find-letter production which has the additional constraint that the imaginal buffer is empty which we added previously to prevent it from firing when we didn't want it to:

```
(p find-letter
   =visual-location>
   ?visual>
     state       free
   ?imaginal>
     buffer      empty
 ==>
   +visual>
     cmd         move-attention
     screen-pos  =visual-location
   +imaginal>
)
```

So the question is why is it now firing at time 2.275? We could use the stepper to slowly walk the model up to that point and watch what happens with the buffer viewers, which you may find to be a useful exercise for practice, but we can also look at the trace for clues. Looking at the trace shows this event at time 2.225:

```
2.225   PROCEDURAL  CLEAR-BUFFER IMAGINAL
```

which indicates that a production has cleared the imaginal buffer. As we saw the last time we adjusted this production the screen change is resulting in the visual-location buffer being stuffed with a chunk. Since there are no visual requests pending at that time that means that all of the conditions in the production are again satisfied and it can be selected to fire.

The first question raised here is why does the imaginal buffer get cleared at time 2.225? Looking at the trace, the respond-next production is the one which caused that action to occur because it's the production which fired at the same time as the buffer was cleared. Here is the text of that production:

```
(p respond-next
   =imaginal>
     isa         task
     letter      =letter
   =visual>
     isa         visual-object
     value       "next"
   ?manual>
     state       free
 ==>
   +retrieval>
     isa         letter
     previous    =letter
   +manual>
     cmd         press-key
```

```
     key          =letter
)
```

The reason why that causes the imaginal buffer to be cleared is the strict harvesting mechanism – if a production tests a buffer on the LHS and does not modify the chunk in that buffer on the RHS then it will automatically be cleared.

Now we have to decide how we are going to fix this in the model. There are a lot of options available and we should consider the possibilities and their implications instead of just applying the first option that comes to mind.

One possibility would be to abandon our design plan of not using a goal and embed explicit goal states into all of the productions. That would definitely allow us to avoid these unexpected production firings. The downside is that the model then becomes less flexible since it must follow those states. In the task which we are modeling here that would not be a serious problem, but in other tasks flexibility is necessary and for the purpose of this exercise we would like to keep the model flexible as an example.

Another option would be to find another automatic state indicator, like the buffer being empty which we used before, that we could add to find-letter to prevent it from firing now. Given the overall design of our task however (which has very little in the way of state changes) and the fact that we are already testing conditions on both of the buffers for which the find-letter production performs actions (the state that it changes directly) this doesn't seem like a good path to go down. While we may be able to find some other implicit state test that we could perform to block it from matching at time 2.225 that's likely just going to push the problem off to yet another time for which we will have to find another state test to add.

Instead of finding another state marker to test, we could modify other productions which fire so that they don't create the state which is problematic. In particular, if the imaginal buffer were not cleared then the existing conditions in the find-letter production would prevent it from not firing again. Based on the design of our model the imaginal buffer does not need to be cleared and thus this seems like it might be a good option. In other models however clearing of the buffer may be important because it might be necessary for learning (as we'll see in unit 4) or we may need to clear it to put a different chunk in there.

Something else to consider is that perhaps the overall design we've chosen for performing the task itself needs to be modified. We may not have chosen a sequence of actions which the model can perform to adequately complete this task. Often when building models one may want to reevaluate the initial design. Some reasons for that would be because of unexpected situations which are discovered that the design did not address, because one finds that there were assumptions made in the design which weren't apparent before trying to run it, or perhaps because the design leads to a model which is unable to meet the desired performance objectives. While there are almost always small adjustments that can be made to the model to try to get it working "better", if there are lots of adjustments being made it might be a sign that the design itself needs to be evaluated.

In this case, we're going to go with the easy option for now (not clearing the imaginal buffer), but if we have any more problems we will look at our design before adjusting the model further. There are multiple things we could do to keep the chunk in the imaginal buffer for this model since we are not really constrained by other productions which use the buffer or the chunk that's created there. What seems like the easiest option here is to just change the respond-next production so that it keeps the chunk in the buffer instead of allowing strict harvesting to clear it. To do that, we need to perform a modification action on the RHS of respond-next. There isn't a meaningful modification that we need to make, but that's alright because a production is allowed to make what's called an empty modification for exactly this purpose. To do that one just adds an = buffer action on the RHS without specifying any slots and values to modify. Here is what the updated respond-next production looks like:

```
(p respond-next
   =imaginal>
     isa         task
     letter      =letter
   =visual>
     isa         visual-object
     value       "next"
   ?manual>
     state       free
   ==>
   =imaginal>
   +retrieval>
     isa         letter
     previous    =letter
   +manual>
     cmd         press-key
     key         =letter
)
```

We should make a similar change to the respond-previous production while we are modifying the model since we will likely encounter the same issue there.

If we didn't want to make that change or if there were lots of productions or instances where this was an issue in the model we could alternatively turn off the strict harvesting mechanism for the imaginal buffer. That can be done using the :do-not-harvest parameter in the system. In this simple mode that would not cause any issues, but for larger models one would have to consider that carefully because it may affect other productions which also use the buffer and then require the model to explicitly clear that buffer in some places.

Now we will save that change and again reload the model.

Model version 5

This is what the trace looks like now when we run it:

```
> (simple-task "next")
0.000   VISION      SET-BUFFER-CHUNK VISUAL-LOCATION VISUAL-LOCATION0-0 REQUESTED NIL
0.000   PROCEDURAL  CONFLICT-RESOLUTION
0.050   PROCEDURAL  PRODUCTION-FIRED FIND-LETTER
0.050   PROCEDURAL  CLEAR-BUFFER VISUAL-LOCATION
0.050   PROCEDURAL  CLEAR-BUFFER VISUAL
0.050   PROCEDURAL  CLEAR-BUFFER IMAGINAL
0.050   PROCEDURAL  CONFLICT-RESOLUTION
0.135   VISION      Encoding-complete VISUAL-LOCATION0-0-0 NIL
0.135   VISION      SET-BUFFER-CHUNK VISUAL TEXT0
0.135   PROCEDURAL  CONFLICT-RESOLUTION
0.250   IMAGINAL    SET-BUFFER-CHUNK IMAGINAL CHUNK0
0.250   PROCEDURAL  CONFLICT-RESOLUTION
0.300   PROCEDURAL  PRODUCTION-FIRED ENCODE-LETTER
0.300   PROCEDURAL  CLEAR-BUFFER VISUAL
0.300   PROCEDURAL  CONFLICT-RESOLUTION
2.090   NONE        DISPLAY-PROMPT next
2.090   VISION      SET-BUFFER-CHUNK VISUAL-LOCATION VISUAL-LOCATION1-0 REQUESTED NIL
2.090   PROCEDURAL  CONFLICT-RESOLUTION
2.175   VISION      Encoding-complete VISUAL-LOCATION0-0-0 NIL
2.175   VISION      SET-BUFFER-CHUNK VISUAL TEXT1 REQUESTED NIL
2.175   PROCEDURAL  CONFLICT-RESOLUTION
2.225   PROCEDURAL  PRODUCTION-FIRED RESPOND-NEXT
2.225   PROCEDURAL  CLEAR-BUFFER VISUAL
2.225   PROCEDURAL  CLEAR-BUFFER RETRIEVAL
2.225   PROCEDURAL  CLEAR-BUFFER MANUAL
2.225   MOTOR       PRESS-KEY KEY n
2.225   DECLARATIVE START-RETRIEVAL
2.225   DECLARATIVE RETRIEVED-CHUNK O
2.225   DECLARATIVE SET-BUFFER-CHUNK RETRIEVAL O
2.225   PROCEDURAL  CONFLICT-RESOLUTION
2.475   PROCEDURAL  CONFLICT-RESOLUTION
2.525   PROCEDURAL  CONFLICT-RESOLUTION
2.625   MOTOR       OUTPUT-KEY #(6 5)
2.625   PROCEDURAL  CONFLICT-RESOLUTION
```

```
2.775   PROCEDURAL  CONFLICT-RESOLUTION
2.825   PROCEDURAL  PRODUCTION-FIRED RESPOND-FINAL
2.825   PROCEDURAL  CLEAR-BUFFER RETRIEVAL
2.825   PROCEDURAL  CLEAR-BUFFER MANUAL
2.825   MOTOR       PRESS-KEY KEY o
2.825   PROCEDURAL  CONFLICT-RESOLUTION
2.975   PROCEDURAL  CONFLICT-RESOLUTION
3.025   PROCEDURAL  CONFLICT-RESOLUTION
3.125   MOTOR       OUTPUT-KEY #(9 3)
3.125   PROCEDURAL  CONFLICT-RESOLUTION
3.275   PROCEDURAL  CONFLICT-RESOLUTION
3.275   ------      Stopped because no events left to process
("next" T)
```

Here we see that the model has performed the task correctly and that it performed the steps which we expected. Before moving on and trying the “previous” trials however we may want to perform some more tests so that we are confident that it works well for the “next” prompt. In particular, this model has the :seed parameter set to keep things consistent while debugging. We should try removing that from the model and running it a couple of times so that we can see if it is able to perform the task for letters other than “N” and when the prompt is displayed at times other than 2.090. Instead of actually removing that line from the model however it is probably best to just “comment it out” so that we can easily restore it for testing if things go wrong and for when we start testing the “previous” prompt. In Lisp, the semi-colon character is used to create comments and everything on a line after the semi-colon will be ignored. Thus, we should put a semi-colon at the start of the line where the seed is set:

```
;    (sgp :seed (101 1))
```

In addition, we may also want to turn the trace-detail down to low since we expect to just be checking a correctly function model at this point and don’t need all the extra details. After making those changes, save the model and reload it. Running it a few times seems to indicate that it is still able to perform the task correctly and as expected with varying letters and different prompting times. So, now we should test trials with the “previous” prompt.

Testing “previous” trial

Before starting to test the “previous” trials it is probably best to uncomment the :seed parameter setting by removing the semi-colon and set the trace-detail level back to medium. After making those changes, saving and then loading the model here is what we get for the trial with previous:

```
> (simple-task "previous")
0.000   VISION      SET-BUFFER-CHUNK VISUAL-LOCATION VISUAL-LOCATION0-0 REQUESTED NIL
0.000   PROCEDURAL  CONFLICT-RESOLUTION
0.050   PROCEDURAL  PRODUCTION-FIRED FIND-LETTER
0.050   PROCEDURAL  CLEAR-BUFFER VISUAL-LOCATION
0.050   PROCEDURAL  CLEAR-BUFFER VISUAL
0.050   PROCEDURAL  CLEAR-BUFFER IMAGINAL
0.050   PROCEDURAL  CONFLICT-RESOLUTION
0.135   VISION      Encoding-complete VISUAL-LOCATION0-0-0 NIL
0.135   VISION      SET-BUFFER-CHUNK VISUAL TEXT0
0.135   PROCEDURAL  CONFLICT-RESOLUTION
0.250   IMAGINAL    SET-BUFFER-CHUNK IMAGINAL CHUNK0
0.250   PROCEDURAL  CONFLICT-RESOLUTION
0.300   PROCEDURAL  PRODUCTION-FIRED ENCODE-LETTER
0.300   PROCEDURAL  CLEAR-BUFFER VISUAL
0.300   PROCEDURAL  CONFLICT-RESOLUTION
2.090   NONE        DISPLAY-PROMPT previous
2.090   VISION      SET-BUFFER-CHUNK VISUAL-LOCATION VISUAL-LOCATION1-0 REQUESTED NIL
2.090   PROCEDURAL  CONFLICT-RESOLUTION
2.175   VISION      Encoding-complete VISUAL-LOCATION0-0-0 NIL
2.175   VISION      No visual-object found
2.175   PROCEDURAL  CONFLICT-RESOLUTION
2.175   ------      Stopped because no events left to process
("previous" NIL)
```

The model failed to do the task so now we need to investigate why. The next production which we expect to fire is respond-previous and we can request the whynot information about it now since the model has stopped when we expect it to be selected:

```
Production RESPOND-PREVIOUS does NOT match.
(P RESPOND-PREVIOUS
   =IMAGINAL>
       LETTER =LETTER
   =VISUAL>
       VALUE "previous"
       TEXT T
   ?MANUAL>
       STATE FREE
 ==>
   =IMAGINAL>
   +RETRIEVAL>
       NEXT =LETTER
   +MANUAL>
       CMD PRESS-KEY
       KEY =LETTER
)
It fails because:
The VISUAL buffer is empty.
```

It's failing to match because the visual buffer is empty. So, now the question becomes why is the visual buffer empty since it worked for the prompt "next"? Before looking at the model trace we might want to make sure that there isn't a bug in the Lisp code which presented the experiment to the model. To do that we can look at the experiment window which was presented and make sure it has the word previous displayed in it, which it does. Then the next thing to check would be the model's visicon to make sure that it has properly updated with the current information. That can be done using the print-visicon command or with the "Visicon" button in the Environment. Here is what that displays:

```
Loc        Att   Kind           Value             Color          ID
---------  ---   -------------  ----------------  -------------  -------------
(154 156)  NEW   TEXT           "previous"        BLACK          VISUAL-LOCATION1
```

So, indeed the vision module has processed that the word previous is visible on the screen and thus the experiment code appears to be working correctly and the problem must be with the model. Doing a simple check like that before proceeding can be very helpful to make sure you know what is happening before trying to fix a problem in the model which might not even exist.

One more thing that we'll do before trying to change the model is compare what happens in the vision module after the prompt appears on a "next" trial to what happens on a "previous" trial. Here is the trace for the correct "next" trial:

```
2.090   NONE         DISPLAY-PROMPT next
2.090   VISION       SET-BUFFER-CHUNK VISUAL-LOCATION VISUAL-LOCATION1-0 REQUESTED NIL
2.090   PROCEDURAL   CONFLICT-RESOLUTION
2.175   VISION       Encoding-complete VISUAL-LOCATION0-0-0 NIL
2.175   VISION       SET-BUFFER-CHUNK VISUAL TEXT1 REQUESTED NIL
```

and here is the trace from the same segment of the "previous" trial:

```
2.090   NONE         DISPLAY-PROMPT previous
2.090   VISION       SET-BUFFER-CHUNK VISUAL-LOCATION VISUAL-LOCATION1-0 REQUESTED NIL
2.090   PROCEDURAL   CONFLICT-RESOLUTION
2.175   VISION       Encoding-complete VISUAL-LOCATION0-0-0 NIL
2.175   VISION       No visual-object found
```

In the "next" trial we see a chunk placed into the visual buffer, but in the "previous" trial the module reports that there is no visual-object found. The first question to ask would seem to be why is there any visual activity at all, since there isn't a request made by a production? The answer to that is that in addition to stuffing a chunk in the visual-location buffer when there is a change to the visual scene the vision module will automatically re-encode the location where it is currently attending. So, that is what causes the encoding which completes at time 2.175. That hadn't actually been taken into account in our original design, but by chance we got lucky with the "next" prompt. Before deciding what to do about it we should first figure out why it works for "next" and see how that differs from "previous". To investigate that we should look at the visicon for the three different items which get displayed: the letter, “next”, and “previous”. To do that we’ll use the stepper to pause the model at the start of the task to see the letter information and then advance to the time when the screen changes to see what things look like there.

Here are the visicon entries for those items:

```
Loc         Att   Kind            Value             Color           ID
---------   ---   -------------   ----------------  --------------  -------------
(135 156)   NEW   TEXT            "n"               BLACK           VISUAL-LOCATION0

Loc         Att   Kind            Value             Color           ID
---------   ---   -------------   ----------------  --------------  -------------
(140 156)   NEW   TEXT            "next"            BLACK           VISUAL-LOCATION1

Loc         Att   Kind            Value             Color           ID
---------   ---   -------------   ----------------  --------------  -------------
(154 156)   NEW   TEXT            "previous"        BLACK           VISUAL-LOCATION1
```

In addition to what the model sees, we can also look at the commands from the Lisp code which generate those displays. Here is the function call that puts the letter on the display:

```
(add-text-to-exp-window :text letter :x 130 :y 150)
```

and here is the one used to display both prompts:

```
(add-text-to-exp-window :text prompt :x 125 :y 150)
```

Notice how each visicon entry is at a different location and those locations do not exactly match where the text was displayed. That’s because the locations in the visicon are determined by the center of the item (which is meaningful to the model), but the display functions use the upper left corner for creating the display (the default GUI layout mechanism in various Lisps). That still doesn’t directly answer why “next” gets attended but “previous” does not. The missing piece to the puzzle is what it means for the model to re-encode the currently attended location. The re-encoding action which the vision module automatically performs when there is a scene change allows for some movement of items in the visual scene. As long as there is some object “close” to where it is attending that new object will be attended automatically. What it means to be close is controlled by a parameter in the vision module. We won’t discuss the details here, but they can be found in the reference manual. The important thing for our current purposes is to notice that “next” is closer to the letter than “previous” is and thus apparently “next” is close enough to be re-encoded but “previous” is not.

After working through that, now the question becomes what do we do about it? Looking back at the design of our model, we see that we hadn’t actually built in a way for the model to attend to the prompt. That’s a flaw in the design of the model which we should address so that it can correctly perform the task.

Before doing so however, we will consider some other possible fixes for the model. Since it works correctly for “next” we could modify the code that presents the experiment so that it also displays “previous” close enough to the letter that it gets attended automatically. Alternatively, we could adjust the parameter that controls how close something needs to be to be automatically re-attended so that both prompts work. Either of those should be sufficient to have the model complete the task, but are they good things to do? If one believes that that aspect of the task is not relevant to the data being collected then perhaps one could consider those to be reasonable changes, but it does then mean that there is an assumption in the design of the model – it can only perform the task if the prompts are displayed in the “same” location as the letter (where same means within the re-encoding range of the vision module). If one is trying to build a model which can perform the more general task which we have described here (there is no constraint on where the prompts are displayed in the task description) then such a model is not sufficient to do that task. In general, engineering the experiment or support code so that the model performs “better” or just adjusting parameters without a good reason is not a good approach to modeling. The model should be robust enough that it can perform the task regardless of particular details in the code with which it is interacting and it should not be dependent on assumptions which are not true of the task it is supposed to be performing. Similarly, it is generally better to have a model which works well with the default parameters for aspects of the model which are not relevant to the task than it is to have a model which only works well because of specific parameter settings which are changing things that aren’t directly relevant to the current task. Thus, we will not attempt either of those fixes for this model.

Reconsidering the model design

Now we will consider how we need to change the design for the model. Here is the design which we had originally planned:

- When it detects a letter on the screen attend it and then store it in the imaginal buffer
- When it sees next or previous press the current key and retrieve the appropriate letter chunk from declarative memory
- Once a chunk is retrieved press that key

There are many ways to go about changing that design, but since it was almost working we will first consider the simple addition of the step which we seem to be missing. Thus, we will add an additional step to explicitly attend to the prompt when we see the screen change:

- When it detects a letter on the screen attend it and then store it in the imaginal buffer
- When it detects the screen change attend to the location of the new item
- When it sees next or previous press the current key and retrieve the appropriate letter chunk from declarative memory
- Once a chunk is retrieved press that key

That change seems to be sufficient to address the problem we had and does not require changing any of the other assumptions we have in the design. Thus, we should be able to keep the model we have and just add productions as necessary to implement that new step. Other changes to the design would likely require more changes to the model or adjustments of our design assumptions so we will not look at those for now.

Adding the new step

To implement the new step we need another production which should look a lot like the production needed for the first step, except that it will not need to initialize the imaginal buffer. We will call that production find-prompt and here is what it looks like:

```
(p find-prompt
   =visual-location>
   ?visual>
     state       free
   ?imaginal>
     buffer      full
 ==>
   +visual>
     cmd         move-attention
```

```
     screen-pos  =visual-location
)
```

Because buffer stuffing will put a chunk into the visual-location buffer automatically we test that on the LHS – that is how we detect that the prompt has been displayed. Then because we will be making a request to the visual buffer we test that it is free so we do not jam the module, and then we test that the imaginal buffer has a chunk in it. That test is to differentiate it from the find-letter production which tests that the buffer is empty because when the prompt is displayed we will already have a chunk in the imaginal buffer from encoding the letter. The only action this production needs to perform is to attend to the location which was stuffed into the visual-location buffer. Note that we could also have tested for a chunk in the imaginal buffer by simply having an =imaginal> test like we do for the visual-location buffer, but the explicit query is used here for consistency with the find-letter production.

We need to save that change to the model and load it again.

Model version 6

Here is the trace for running the updated model on a trial with "previous":

```
> (simple-task "previous")
0.000   VISION       SET-BUFFER-CHUNK VISUAL-LOCATION VISUAL-LOCATION0-0 REQUESTED NIL
0.000   PROCEDURAL   CONFLICT-RESOLUTION
0.050   PROCEDURAL   PRODUCTION-FIRED FIND-LETTER
0.050   PROCEDURAL   CLEAR-BUFFER VISUAL-LOCATION
0.050   PROCEDURAL   CLEAR-BUFFER VISUAL
0.050   PROCEDURAL   CLEAR-BUFFER IMAGINAL
0.050   PROCEDURAL   CONFLICT-RESOLUTION
0.135   VISION       Encoding-complete VISUAL-LOCATION0-0-0 NIL
0.135   VISION       SET-BUFFER-CHUNK VISUAL TEXT0
0.135   PROCEDURAL   CONFLICT-RESOLUTION
0.250   IMAGINAL     SET-BUFFER-CHUNK IMAGINAL CHUNK0
0.250   PROCEDURAL   CONFLICT-RESOLUTION
0.300   PROCEDURAL   PRODUCTION-FIRED ENCODE-LETTER
0.300   PROCEDURAL   CLEAR-BUFFER VISUAL
0.300   PROCEDURAL   CONFLICT-RESOLUTION
2.090   NONE         DISPLAY-PROMPT previous
2.090   VISION       SET-BUFFER-CHUNK VISUAL-LOCATION VISUAL-LOCATION1-0 REQUESTED NIL
2.090   PROCEDURAL   CONFLICT-RESOLUTION
2.175   VISION       Encoding-complete VISUAL-LOCATION0-0-0 NIL
2.175   VISION       No visual-object found
2.175   PROCEDURAL   CONFLICT-RESOLUTION
2.225   PROCEDURAL   PRODUCTION-FIRED FIND-PROMPT
2.225   PROCEDURAL   CLEAR-BUFFER VISUAL-LOCATION
2.225   PROCEDURAL   CLEAR-BUFFER VISUAL
2.225   PROCEDURAL   CONFLICT-RESOLUTION
2.310   VISION       Encoding-complete VISUAL-LOCATION1-0-0 NIL
2.310   VISION       SET-BUFFER-CHUNK VISUAL TEXT1
2.310   PROCEDURAL   CONFLICT-RESOLUTION
```

```
2.360   PROCEDURAL  PRODUCTION-FIRED RESPOND-PREVIOUS
2.360   PROCEDURAL  CLEAR-BUFFER VISUAL
2.360   PROCEDURAL  CLEAR-BUFFER RETRIEVAL
2.360   PROCEDURAL  CLEAR-BUFFER MANUAL
2.360   MOTOR       PRESS-KEY KEY n
2.360   DECLARATIVE START-RETRIEVAL
2.360   DECLARATIVE RETRIEVED-CHUNK M
2.360   DECLARATIVE SET-BUFFER-CHUNK RETRIEVAL M
2.360   PROCEDURAL  CONFLICT-RESOLUTION
2.610   PROCEDURAL  CONFLICT-RESOLUTION
2.660   PROCEDURAL  CONFLICT-RESOLUTION
2.760   MOTOR       OUTPUT-KEY #(6 5)
2.760   PROCEDURAL  CONFLICT-RESOLUTION
2.910   PROCEDURAL  CONFLICT-RESOLUTION
2.960   PROCEDURAL  PRODUCTION-FIRED RESPOND-FINAL
2.960   PROCEDURAL  CLEAR-BUFFER RETRIEVAL
2.960   PROCEDURAL  CLEAR-BUFFER MANUAL
2.960   MOTOR       PRESS-KEY KEY m
2.960   PROCEDURAL  CONFLICT-RESOLUTION
3.010   PROCEDURAL  CONFLICT-RESOLUTION
3.060   PROCEDURAL  CONFLICT-RESOLUTION
3.160   MOTOR       OUTPUT-KEY #(7 5)
3.160   PROCEDURAL  CONFLICT-RESOLUTION
3.310   PROCEDURAL  CONFLICT-RESOLUTION
3.310   ------      Stopped because no events left to process
("previous" T)
```

The model successfully completed the task for “previous” and performed the steps which we expected it to. Now we should test it on a trial for “next” to make sure that it can still do those trials as well:

```
> (simple-task "next")
0.000   VISION      SET-BUFFER-CHUNK VISUAL-LOCATION VISUAL-LOCATION0-0 REQUESTED NIL
0.000   PROCEDURAL  CONFLICT-RESOLUTION
0.050   PROCEDURAL  PRODUCTION-FIRED FIND-LETTER
0.050   PROCEDURAL  CLEAR-BUFFER VISUAL-LOCATION
0.050   PROCEDURAL  CLEAR-BUFFER VISUAL
0.050   PROCEDURAL  CLEAR-BUFFER IMAGINAL
0.050   PROCEDURAL  CONFLICT-RESOLUTION
0.135   VISION      Encoding-complete VISUAL-LOCATION0-0-0 NIL
0.135   VISION      SET-BUFFER-CHUNK VISUAL TEXT0
0.135   PROCEDURAL  CONFLICT-RESOLUTION
0.250   IMAGINAL    SET-BUFFER-CHUNK IMAGINAL CHUNK0
0.250   PROCEDURAL  CONFLICT-RESOLUTION
0.300   PROCEDURAL  PRODUCTION-FIRED ENCODE-LETTER
0.300   PROCEDURAL  CLEAR-BUFFER VISUAL
0.300   PROCEDURAL  CONFLICT-RESOLUTION
2.090   NONE        DISPLAY-PROMPT next
2.090   VISION      SET-BUFFER-CHUNK VISUAL-LOCATION VISUAL-LOCATION1-0 REQUESTED NIL
2.090   PROCEDURAL  CONFLICT-RESOLUTION
2.175   VISION      Encoding-complete VISUAL-LOCATION0-0-0 NIL
2.175   VISION      SET-BUFFER-CHUNK VISUAL TEXT1 REQUESTED NIL
2.175   PROCEDURAL  CONFLICT-RESOLUTION
2.225   PROCEDURAL  PRODUCTION-FIRED FIND-PROMPT
2.225   PROCEDURAL  CLEAR-BUFFER VISUAL-LOCATION
2.225   PROCEDURAL  CLEAR-BUFFER VISUAL
2.225   PROCEDURAL  CONFLICT-RESOLUTION
2.310   VISION      Encoding-complete VISUAL-LOCATION1-0-0 NIL
```

```
2.310   VISION      SET-BUFFER-CHUNK VISUAL TEXT2
2.310   PROCEDURAL  CONFLICT-RESOLUTION
2.360   PROCEDURAL  PRODUCTION-FIRED RESPOND-NEXT
2.360   PROCEDURAL  CLEAR-BUFFER VISUAL
2.360   PROCEDURAL  CLEAR-BUFFER RETRIEVAL
2.360   PROCEDURAL  CLEAR-BUFFER MANUAL
2.360   MOTOR       PRESS-KEY KEY n
2.360   DECLARATIVE START-RETRIEVAL
2.360   DECLARATIVE RETRIEVED-CHUNK O
2.360   DECLARATIVE SET-BUFFER-CHUNK RETRIEVAL O
2.360   PROCEDURAL  CONFLICT-RESOLUTION
2.610   PROCEDURAL  CONFLICT-RESOLUTION
2.660   PROCEDURAL  CONFLICT-RESOLUTION
2.760   MOTOR       OUTPUT-KEY #(6 5)
2.760   PROCEDURAL  CONFLICT-RESOLUTION
2.910   PROCEDURAL  CONFLICT-RESOLUTION
2.960   PROCEDURAL  PRODUCTION-FIRED RESPOND-FINAL
2.960   PROCEDURAL  CLEAR-BUFFER RETRIEVAL
2.960   PROCEDURAL  CLEAR-BUFFER MANUAL
2.960   MOTOR       PRESS-KEY KEY o
2.960   PROCEDURAL  CONFLICT-RESOLUTION
3.110   PROCEDURAL  CONFLICT-RESOLUTION
3.160   PROCEDURAL  CONFLICT-RESOLUTION
3.260   MOTOR       OUTPUT-KEY #(9 3)
3.260   PROCEDURAL  CONFLICT-RESOLUTION
3.410   PROCEDURAL  CONFLICT-RESOLUTION
3.410   ------      Stopped because no events left to process
("next" T)
```

Here again it did the task correctly and fired the productions which we expected. At this point one might consider the model done, but we should remove the seed parameter setting (or comment it out) and perform some more tests to make sure that the model doesn't have a dependence on that particular parameter setting.

Further tests of the working model

For the trials with "previous" everything still seems to work after running a few trials, but for next occasionally we get a trial where it does not complete the task correctly and looks something like this:

```
> (simple-task "next")
0.000   VISION      SET-BUFFER-CHUNK VISUAL-LOCATION VISUAL-LOCATION0-0 REQUESTED NIL
0.000   PROCEDURAL  CONFLICT-RESOLUTION
0.050   PROCEDURAL  PRODUCTION-FIRED FIND-LETTER
0.050   PROCEDURAL  CLEAR-BUFFER VISUAL-LOCATION
0.050   PROCEDURAL  CLEAR-BUFFER VISUAL
0.050   PROCEDURAL  CLEAR-BUFFER IMAGINAL
0.050   PROCEDURAL  CONFLICT-RESOLUTION
0.135   VISION      Encoding-complete VISUAL-LOCATION0-0-0 NIL
0.135   VISION      SET-BUFFER-CHUNK VISUAL TEXT0
0.135   PROCEDURAL  CONFLICT-RESOLUTION
0.250   IMAGINAL    SET-BUFFER-CHUNK IMAGINAL CHUNK0
0.250   PROCEDURAL  CONFLICT-RESOLUTION
0.300   PROCEDURAL  PRODUCTION-FIRED ENCODE-LETTER
```

```
0.300   PROCEDURAL  CLEAR-BUFFER VISUAL
0.300   PROCEDURAL  CONFLICT-RESOLUTION
2.030   NONE        DISPLAY-PROMPT next
2.030   VISION      SET-BUFFER-CHUNK VISUAL-LOCATION VISUAL-LOCATION1-0 REQUESTED NIL
2.030   PROCEDURAL  CONFLICT-RESOLUTION
2.115   VISION      Encoding-complete VISUAL-LOCATION0-0-0 NIL
2.115   VISION      SET-BUFFER-CHUNK VISUAL TEXT1 REQUESTED NIL
2.115   PROCEDURAL  CONFLICT-RESOLUTION
2.165   PROCEDURAL  PRODUCTION-FIRED RESPOND-NEXT
2.165   PROCEDURAL  CLEAR-BUFFER VISUAL
2.165   PROCEDURAL  CLEAR-BUFFER RETRIEVAL
2.165   PROCEDURAL  CLEAR-BUFFER MANUAL
2.165   MOTOR       PRESS-KEY KEY w
2.165   DECLARATIVE START-RETRIEVAL
2.165   DECLARATIVE RETRIEVED-CHUNK X
2.165   DECLARATIVE SET-BUFFER-CHUNK RETRIEVAL X
2.165   PROCEDURAL  CONFLICT-RESOLUTION
2.215   PROCEDURAL  PRODUCTION-FIRED FIND-PROMPT
2.215   PROCEDURAL  CLEAR-BUFFER VISUAL-LOCATION
2.215   PROCEDURAL  CLEAR-BUFFER VISUAL
2.215   PROCEDURAL  CONFLICT-RESOLUTION
2.300   VISION      Encoding-complete VISUAL-LOCATION1-0-0 NIL
2.300   VISION      SET-BUFFER-CHUNK VISUAL TEXT2
2.300   PROCEDURAL  CONFLICT-RESOLUTION
2.415   PROCEDURAL  CONFLICT-RESOLUTION
2.465   PROCEDURAL  CONFLICT-RESOLUTION
2.565   MOTOR       OUTPUT-KEY #(2 3)
2.565   PROCEDURAL  CONFLICT-RESOLUTION
2.715   PROCEDURAL  CONFLICT-RESOLUTION
2.765   PROCEDURAL  PRODUCTION-FIRED RESPOND-FINAL
2.765   PROCEDURAL  CLEAR-BUFFER RETRIEVAL
2.765   PROCEDURAL  CLEAR-BUFFER MANUAL
2.765   MOTOR       PRESS-KEY KEY x
2.765   PROCEDURAL  CONFLICT-RESOLUTION
2.815   PROCEDURAL  CONFLICT-RESOLUTION
2.865   PROCEDURAL  CONFLICT-RESOLUTION
2.965   MOTOR       OUTPUT-KEY #(2 5)
2.965   PROCEDURAL  CONFLICT-RESOLUTION
3.115   PROCEDURAL  CONFLICT-RESOLUTION
3.165   PROCEDURAL  PRODUCTION-FIRED RESPOND-NEXT
3.165   PROCEDURAL  CLEAR-BUFFER VISUAL
3.165   PROCEDURAL  CLEAR-BUFFER RETRIEVAL
3.165   PROCEDURAL  CLEAR-BUFFER MANUAL
3.165   MOTOR       PRESS-KEY KEY w
3.165   DECLARATIVE START-RETRIEVAL
3.165   DECLARATIVE RETRIEVED-CHUNK X
3.165   DECLARATIVE SET-BUFFER-CHUNK RETRIEVAL X
3.165   PROCEDURAL  CONFLICT-RESOLUTION
3.215   PROCEDURAL  CONFLICT-RESOLUTION
3.265   PROCEDURAL  CONFLICT-RESOLUTION
3.365   MOTOR       OUTPUT-KEY #(2 3)
3.365   PROCEDURAL  CONFLICT-RESOLUTION
3.515   PROCEDURAL  CONFLICT-RESOLUTION
3.565   PROCEDURAL  PRODUCTION-FIRED RESPOND-FINAL
3.565   PROCEDURAL  CLEAR-BUFFER RETRIEVAL
3.565   PROCEDURAL  CLEAR-BUFFER MANUAL
3.565   MOTOR       PRESS-KEY KEY x
3.565   PROCEDURAL  CONFLICT-RESOLUTION
3.615   PROCEDURAL  CONFLICT-RESOLUTION
3.665   PROCEDURAL  CONFLICT-RESOLUTION
3.765   MOTOR       OUTPUT-KEY #(2 5)
3.765   PROCEDURAL  CONFLICT-RESOLUTION
3.915   PROCEDURAL  CONFLICT-RESOLUTION
```

```
3.915   ------      Stopped because no events left to process
("next" NIL)
```

Looking at the trace we see that the respond-next production fired when we expected our find-prompt production to fire, and then find-prompt fired after that which caused respond-next to fire again after respond-final. That caused the model to press each of the keys twice and thus failing the task.

While it may be possible with this simple model to determine why this occurred from the trace and looking at the productions, in other cases one may need to investigate that further with the stepper and the inspection tools. Because it only happens on some of the trials that can become a difficult task since one may have to go through things several times before seeing the problem again. Before discussing ways to fix this model we will cover a couple of things that can be done to help with investigating randomly occurring problems like this.

Techniques for working with randomly occurring problems

The first thing that one can do is have additional information displayed in the trace. That might be enough to help fix things without having to use the stepper and other tools because then one can just run the model until a problem trial occurs and inspect the additional information in the trace. Some modules provide extra trace information which can be turned on to show more details about what they are doing. In this case, we could take advantage of two traces which the procedural module provides. They are called the "conflict set trace" and the "conflict resolution trace" and can be enabled by setting the :cst and :crt parameters respectively in the model. If those parameters are set to t then details about which productions match are shown in the trace for each conflict resolution action. We will not describe those traces further here, but you can try them out with this model to see the type of information they provide.

Another thing that can be done is to use the seed parameter to force the model to repeat a particular sequence of actions. We've seen that used often in the tutorial to provide consistent examples, but the problem is how do you find a seed for a "bad" trial so that you can replay it for further inspection? One approach is to just run the model repeatedly letting it pick its own seed (if the model definition does not specify a seed a new one will be generated each time it is reset) and have it display that initial seed at the start of the task. Then, when you find a trial that doesn't work correctly you can take the seed value that was displayed and set it in the model so that you can repeat that broken trial to inspect it further. The easy way to do that is to just add a call to sgp specifying the :seed parameter as the first command in the model definition like this:

```
(sgp :seed)
```

If a value isn't provided for a parameter to the sgp command it prints out the current value of that parameter along with the default value and some documentation. Thus, if we add that to the top of our current model and turn the trace off so that things run faster we should be able to quickly find a seed value which will allow us to repeat a broken trial for further inspection. For example, here is a sample of what that might look like for the current task (your seed values are likely to differ from those shown below since the starting seed is pseudo-randomly determined if one is not provided):

```
> (simple-task "next")
:SEED (74053450058 261) (default NO-DEFAULT) : Current seed of the random number generator
("next" T)

> (simple-task "next")
:SEED (74053450058 297) (default NO-DEFAULT) : Current seed of the random number generator
("next" T)

> (simple-task "next")
:SEED (74053450058 333) (default NO-DEFAULT) : Current seed of the random number generator
("next" NIL)
```

In this case we found that a seed of (74053450058 333) leads to the model failing the task. Now we can set that seed in the model definition like this:

```
(sgp :seed (74053450058 333))
```

and the model will always perform that same bad trial which we can then investigate further.

Using the seed parameter like that can be very convenient, not only for debugging but for demonstration purposes to find a situation that one wants to repeat (as is done for the tutorial models). However, there is one requirement of the model and experiment code to be able to use it that way. It will only work if all of the randomness in both the model and the experiment depends on the ACT-R provided randomness functions. If the task or model uses some other source of random numbers (for instance the Lisp random function) then setting the ACT-R seed parameter will not guarantee that the same sequence of actions will occur and one will also have to control that other random source as well to guarantee a repeatable trial. All of the tasks in the tutorial satisfy the constraint of only using the ACT-R randomness functions.

The broken "next" trial

Now that we have a way to recreate a non-working trial we can investigate it further. The first thing we want to do is turn the trace back on and run it to look at what happens. Here is the trace we get:

```
> (simple-task "next")
0.000   VISION      SET-BUFFER-CHUNK VISUAL-LOCATION VISUAL-LOCATION0-0 REQUESTED NIL
0.000   PROCEDURAL  CONFLICT-RESOLUTION
0.050   PROCEDURAL  PRODUCTION-FIRED FIND-LETTER
0.050   PROCEDURAL  CLEAR-BUFFER VISUAL-LOCATION
0.050   PROCEDURAL  CLEAR-BUFFER VISUAL
0.050   PROCEDURAL  CLEAR-BUFFER IMAGINAL
0.050   PROCEDURAL  CONFLICT-RESOLUTION
0.135   VISION      Encoding-complete VISUAL-LOCATION0-0-0 NIL
0.135   VISION      SET-BUFFER-CHUNK VISUAL TEXT0
0.135   PROCEDURAL  CONFLICT-RESOLUTION
0.250   IMAGINAL    SET-BUFFER-CHUNK IMAGINAL CHUNK0
0.250   PROCEDURAL  CONFLICT-RESOLUTION
0.300   PROCEDURAL  PRODUCTION-FIRED ENCODE-LETTER
0.300   PROCEDURAL  CLEAR-BUFFER VISUAL
0.300   PROCEDURAL  CONFLICT-RESOLUTION
2.151   NONE        DISPLAY-PROMPT next
2.151   VISION      SET-BUFFER-CHUNK VISUAL-LOCATION VISUAL-LOCATION1-0 REQUESTED NIL
2.151   PROCEDURAL  CONFLICT-RESOLUTION
2.236   VISION      Encoding-complete VISUAL-LOCATION0-0-0 NIL
2.236   VISION      SET-BUFFER-CHUNK VISUAL TEXT1 REQUESTED NIL
2.236   PROCEDURAL  CONFLICT-RESOLUTION
2.286   PROCEDURAL  PRODUCTION-FIRED RESPOND-NEXT
2.286   PROCEDURAL  CLEAR-BUFFER VISUAL
2.286   PROCEDURAL  CLEAR-BUFFER RETRIEVAL
2.286   PROCEDURAL  CLEAR-BUFFER MANUAL
2.286   MOTOR       PRESS-KEY KEY m
2.286   DECLARATIVE START-RETRIEVAL
2.286   DECLARATIVE RETRIEVED-CHUNK N
2.286   DECLARATIVE SET-BUFFER-CHUNK RETRIEVAL N
2.286   PROCEDURAL  CONFLICT-RESOLUTION
2.336   PROCEDURAL  PRODUCTION-FIRED FIND-PROMPT
2.336   PROCEDURAL  CLEAR-BUFFER VISUAL-LOCATION
2.336   PROCEDURAL  CLEAR-BUFFER VISUAL
2.336   PROCEDURAL  CONFLICT-RESOLUTION
2.421   VISION      Encoding-complete VISUAL-LOCATION1-0-0 NIL
2.421   VISION      SET-BUFFER-CHUNK VISUAL TEXT2
2.421   PROCEDURAL  CONFLICT-RESOLUTION
2.536   PROCEDURAL  CONFLICT-RESOLUTION
2.586   PROCEDURAL  CONFLICT-RESOLUTION
2.686   MOTOR       OUTPUT-KEY #(7 5)
2.686   PROCEDURAL  CONFLICT-RESOLUTION
2.836   PROCEDURAL  CONFLICT-RESOLUTION
2.886   PROCEDURAL  PRODUCTION-FIRED RESPOND-FINAL
2.886   PROCEDURAL  CLEAR-BUFFER RETRIEVAL
2.886   PROCEDURAL  CLEAR-BUFFER MANUAL
2.886   MOTOR       PRESS-KEY KEY n
```

```
2.886   PROCEDURAL  CONFLICT-RESOLUTION
2.936   PROCEDURAL  CONFLICT-RESOLUTION
2.986   PROCEDURAL  CONFLICT-RESOLUTION
3.086   MOTOR       OUTPUT-KEY #(6 5)
3.086   PROCEDURAL  CONFLICT-RESOLUTION
3.236   PROCEDURAL  CONFLICT-RESOLUTION
3.286   PROCEDURAL  PRODUCTION-FIRED RESPOND-NEXT
3.286   PROCEDURAL  CLEAR-BUFFER VISUAL
3.286   PROCEDURAL  CLEAR-BUFFER RETRIEVAL
3.286   PROCEDURAL  CLEAR-BUFFER MANUAL
3.286   MOTOR       PRESS-KEY KEY m
3.286   DECLARATIVE START-RETRIEVAL
3.286   DECLARATIVE RETRIEVED-CHUNK N
3.286   DECLARATIVE SET-BUFFER-CHUNK RETRIEVAL N
3.286   PROCEDURAL  CONFLICT-RESOLUTION
3.336   PROCEDURAL  CONFLICT-RESOLUTION
3.386   PROCEDURAL  CONFLICT-RESOLUTION
3.486   MOTOR       OUTPUT-KEY #(7 5)
3.486   PROCEDURAL  CONFLICT-RESOLUTION
3.636   PROCEDURAL  CONFLICT-RESOLUTION
3.686   PROCEDURAL  PRODUCTION-FIRED RESPOND-FINAL
3.686   PROCEDURAL  CLEAR-BUFFER RETRIEVAL
3.686   PROCEDURAL  CLEAR-BUFFER MANUAL
3.686   MOTOR       PRESS-KEY KEY n
3.686   PROCEDURAL  CONFLICT-RESOLUTION
3.736   PROCEDURAL  CONFLICT-RESOLUTION
3.786   PROCEDURAL  CONFLICT-RESOLUTION
3.886   MOTOR       OUTPUT-KEY #(6 5)
3.886   PROCEDURAL  CONFLICT-RESOLUTION
4.036   PROCEDURAL  CONFLICT-RESOLUTION
4.036   ------      Stopped because no events left to process
("next" NIL)
```

The first problem in the trace shows up at time 2.286 when respond-next fires and we expect find-prompt to fire. However, stepping to that point will be too late because the real issue we want to investigate is during the conflict resolution action which results in respond-next being selected – we want to see why find-prompt isn't selected at that time. To see the production selection event in the trace (and thus be able to step to it) we will have to set the trace-detail parameter to high. If we make that change, save and then load the model we can now step to the point where the problem occurs, which is time 2.236, when the conflict resolution action selects respond-next instead of find-prompt.

Stepping to that production selection event we see that in fact both respond-next and find-prompt match at that point in time. So, now the question is why is one chosen over the other? The answer to that has to do with how the procedural module selects among productions when more than one matches. The first determination is by utility values; the production with the higher utility value will be the one chosen. In this case both productions have the same utility which is the default of 0 since we have not changed them. When productions have the same utility how the procedural module decides is determined by the setting of the :er (enable randomness) parameter. If the parameter is set to nil (which is the default value) then the module will use an unspecified but deterministic mechanism to choose one of the two productions. That will result in a specific model always having the same production chosen when that same tie situation occurs, but it does not guarantee that same choice will be made for any other model or even for that same model if it is changed in any way. While that is deterministic and can be useful when starting to work on a model it is not generally a good thing to rely on for a robust model. Instead the recommendation is to set the :er parameter to t which means that whenever there is a tie for the top utility value the model will randomly pick which production to fire (of course as was discussed above even the random processes of the model can be made deterministic by setting the seed parameter). In this model the :er parameter is set to t, thus that is why sometimes it works and sometimes it does not.

Options for how to fix the problem

Now that we know what's wrong with the model we need to make sure that find-prompt always fires instead of respond-next in that situation. There are a few options available, including yet another redesign of our task. We will look at some of the options available before making a choice or determining whether or not to amend the design again.

The first thing we could do is turn off the :er parameter and see which one it favors. If find-prompt is the winner then that would solve the problem. However, that's not really a good choice since it would only work because of an arbitrary mechanism in the procedural module which we cannot control and if we make any other changes to the model it may stop working.

As was done in the sperling model for the unit 3 example we could set explicit utilities on the productions involved. That way we could guarantee that find-prompt was always chosen over respond-next. This would be better than the previous option since we would be in control of how the choice was made. In this situation that seems like a reasonable solution, but when we get to later units and are working with models that are able to learn utilities we will find that setting fixed initial values to control the operation of the model may not work as well.

We could try to find some state that differs at that time which would allow us to add additional conditions to one or both of those productions to prevent them from both matching at that point.

Both productions already have tests using the imaginal and visual buffers, so those are not likely to provide any differentiation. However, read-prompt requires a chunk in the visual-location buffer and respond-next does not. So, we could make that explicit by adding a test that the visual-location buffer was empty to respond-next and that should prevent them from both matching at the same time. If we choose to do that we would also want to make that same change to respond-previous to be consistent.

The next alternative is to adjust the earlier productions in the model so that it has a different state than it does now at that critical time when the screen changes so that both productions no longer match. Here there seem to be a variety of options available. One would be to add a goal buffer chunk with an explicit state which could be tested, but we've been trying to avoid that as part of the design for the model. Instead of using the goal buffer, since we already have a chunk in the imaginal buffer, we could add some explicit state marker to that chunk or perhaps set the contents of that chunk's existing slot in such a way as to implicitly indicate the state. That however seems to still go against the design we have for the model and also goes against the distinction between the goal and imaginal buffers in ACT-R i.e. that goal should be used for state information and imaginal for problem representation. Another option would be to change the state by changing the actions which the model performs. In particular, we can stop the automatic re-encoding from happening by having the model stop attending to the location of the letter once it has encoded it. That would prevent respond-next and respond-previous from being able to match until after find-prompt fires because there wouldn't be a chunk in the visual buffer. In fact if we had done that earlier it may have avoided some of the other problems we encountered.

Now we have three options which seem reasonable: set explicit utilities for the productions, add an additional condition to the respond productions, or have the model stop attending the letter. So, how do we decide which one to use? The important thing to consider in making that decision is why are we creating the model? If we had data for this task that we were trying to fit then that might help us to make the decision based on how the model's response times might differ among the options. Something else to consider would be cognitive plausibility – are we trying to create a model which we think performs the task like a person? If so, then we would want to consider which of the options seems to best correspond to what we think a person does while performing the task. If one has other objectives for building the model, then comparing the options with respect to those objectives would be the thing to do. Essentially, there is not a single “right” model for a task. What is important is that the model one builds satisfies the purposes for which it was written, and that usually involves understanding the details about how the model works and being able to justify the choices made.

Since the objective of this model is demonstrating debugging and modeling techniques related to perceptual and motor module issues, any of those options seems like a justifiable choice. The last one of the three however seems like it would be the best since it uses another perceptual action which may provide additional areas to investigate.

Adding the new action

To make the model stop attending we need to make an explicit request to the vision module indicating that with the “cmd clear” request. In this task the model does not need to keep attending the letter after it has harvested the information from the visual buffer and that happens in the encode-letter production. Thus, that is where we want to make the request to stop attending. In addition to making the request we should also add a test to the LHS of the production to make sure the module is free to avoid the possibility of jamming when it gets that request. Here is the updated production with those changes:

```
(p encode-letter
   =imaginal>
     isa         task
     letter      nil
   =visual>
     isa         visual-object
     value       =letter
   ?visual>
     state       free
 ==>
   +visual>
     cmd         clear
   =imaginal>
     letter      =letter
)
```

With that change and the trace-detail set back to medium here is the trace we get when running it with the seed we had set for the incorrect trial:

```
> (simple-task "next")
0.000   VISION      SET-BUFFER-CHUNK VISUAL-LOCATION VISUAL-LOCATION0-0 REQUESTED NIL
0.000   PROCEDURAL  CONFLICT-RESOLUTION
0.050   PROCEDURAL  PRODUCTION-FIRED FIND-LETTER
0.050   PROCEDURAL  CLEAR-BUFFER VISUAL-LOCATION
```

```
0.050   PROCEDURAL  CLEAR-BUFFER VISUAL
0.050   PROCEDURAL  CLEAR-BUFFER IMAGINAL
0.050   PROCEDURAL  CONFLICT-RESOLUTION
0.135   VISION      Encoding-complete VISUAL-LOCATION0-0-0 NIL
0.135   VISION      SET-BUFFER-CHUNK VISUAL TEXT0
0.135   PROCEDURAL  CONFLICT-RESOLUTION
0.250   IMAGINAL    SET-BUFFER-CHUNK IMAGINAL CHUNK0
0.250   PROCEDURAL  CONFLICT-RESOLUTION
0.300   PROCEDURAL  PRODUCTION-FIRED ENCODE-LETTER
0.300   PROCEDURAL  CLEAR-BUFFER VISUAL
0.300   VISION      CLEAR
0.300   PROCEDURAL  CONFLICT-RESOLUTION
0.350   PROCEDURAL  CONFLICT-RESOLUTION
2.151   NONE        DISPLAY-PROMPT next
2.151   VISION      SET-BUFFER-CHUNK VISUAL-LOCATION VISUAL-LOCATION1-0 REQUESTED NIL
2.151   PROCEDURAL  CONFLICT-RESOLUTION
2.201   PROCEDURAL  PRODUCTION-FIRED FIND-PROMPT
2.201   PROCEDURAL  CLEAR-BUFFER VISUAL-LOCATION
2.201   PROCEDURAL  CLEAR-BUFFER VISUAL
2.201   PROCEDURAL  CONFLICT-RESOLUTION
2.286   VISION      Encoding-complete VISUAL-LOCATION1-0-0 NIL
2.286   VISION      SET-BUFFER-CHUNK VISUAL TEXT1
2.286   PROCEDURAL  CONFLICT-RESOLUTION
2.336   PROCEDURAL  PRODUCTION-FIRED RESPOND-NEXT
2.336   PROCEDURAL  CLEAR-BUFFER VISUAL
2.336   PROCEDURAL  CLEAR-BUFFER RETRIEVAL
2.336   PROCEDURAL  CLEAR-BUFFER MANUAL
2.336   MOTOR       PRESS-KEY KEY m
2.336   DECLARATIVE START-RETRIEVAL
2.336   DECLARATIVE RETRIEVED-CHUNK N
2.336   DECLARATIVE SET-BUFFER-CHUNK RETRIEVAL N
2.336   PROCEDURAL  CONFLICT-RESOLUTION
2.586   PROCEDURAL  CONFLICT-RESOLUTION
2.636   PROCEDURAL  CONFLICT-RESOLUTION
2.736   MOTOR       OUTPUT-KEY #(7 5)
2.736   PROCEDURAL  CONFLICT-RESOLUTION
2.886   PROCEDURAL  CONFLICT-RESOLUTION
2.936   PROCEDURAL  PRODUCTION-FIRED RESPOND-FINAL
2.936   PROCEDURAL  CLEAR-BUFFER RETRIEVAL
2.936   PROCEDURAL  CLEAR-BUFFER MANUAL
2.936   MOTOR       PRESS-KEY KEY n
2.936   PROCEDURAL  CONFLICT-RESOLUTION
2.986   PROCEDURAL  CONFLICT-RESOLUTION
3.036   PROCEDURAL  CONFLICT-RESOLUTION
3.136   MOTOR       OUTPUT-KEY #(6 5)
3.136   PROCEDURAL  CONFLICT-RESOLUTION
3.286   PROCEDURAL  CONFLICT-RESOLUTION
3.286   ------      Stopped because no events left to process
("next" T)
```

The model successfully completed the task. So, now it looks like the model is working correctly, but we should remove the seed parameter setting and run a few more tests to make sure. Running some additional tests seems to show that the model is now able to perform the task as expected. Given some of the issues that we encountered however, there is some additional testing that might be worthwhile to perform. Because we had issues with where the letter and prompts were displayed it might be a good idea to change the code which presents those items to make sure that the model can perform the task regardless of where the items are on the screen. We will not work through those tests here, but you should try that out on your own to see what happens. In addition to that you may also want to consider implementing some of the proposed, but not chosen, fixes that were described as we encountered some of the problems to see how those solutions differ in performance, if at all, from the options that were chosen. Finally, you might also want to consider alternative designs for performing the task and for the initial letter representations.

Additional Environment Tools

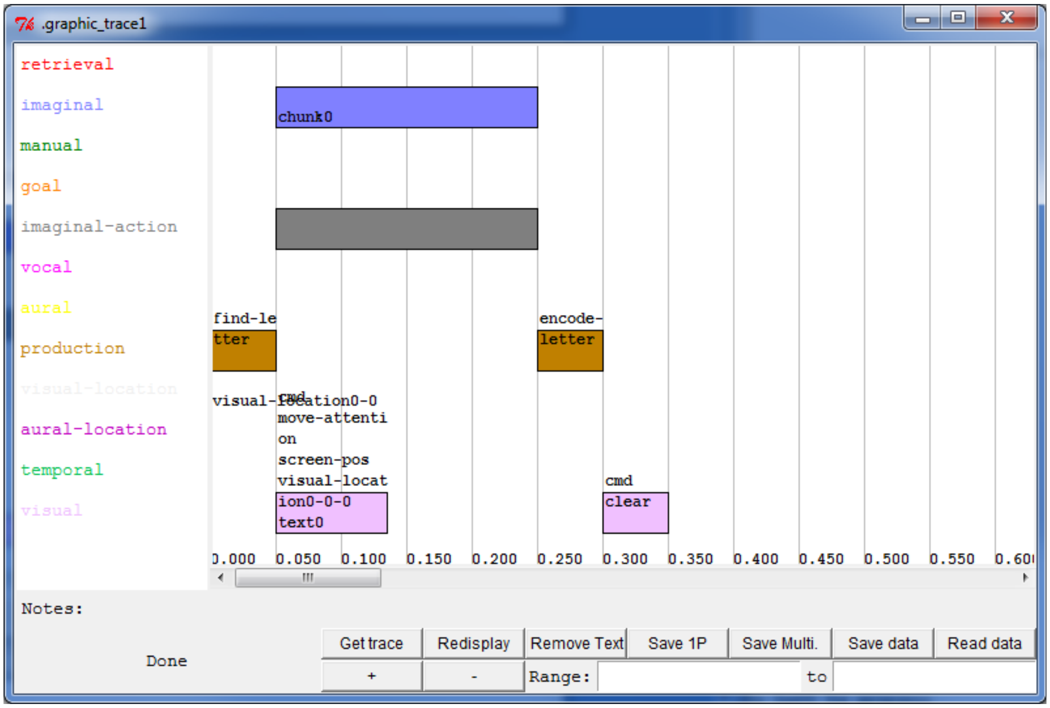
To debug this model we have relied on reading the trace, inspecting the buffer contents and status, and using the stepper. Those are important skills to learn because they will be useful for almost all ACT-R modeling tasks. However, there are some other tools available in the Environment which we could also have used while working with this model. The tools in the "Tracing" and "History" sections of the Control Panel can often be useful when working with larger models or models which run for longer periods of time. We will briefly describe some of those tools here and provide some suggestions for how they may be useful. For more details on using those tools you should consult the Environment's manual which is included in the docs directory of the ACT-R 6 distribution.

General Usage

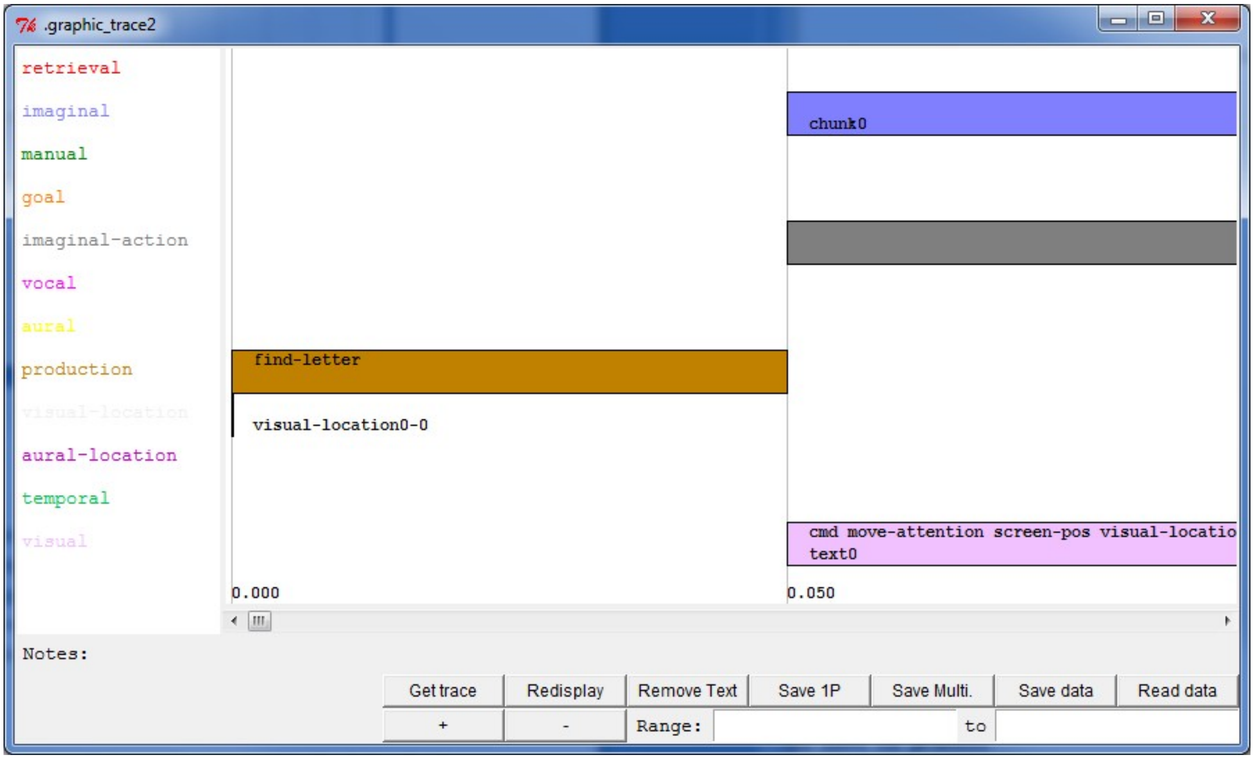
The tools in the "History" and "Tracing" sections of the control panel must be enabled before they will work. There are two ways to enable a particular tool. Either it can be opened before running the model as is done with the Stepper or one can set the appropriate parameters in the model to enable it. Enabling one of these tools makes the system record some additional details as it runs which can then be displayed after the model has stopped. Unlike the Stepper, these tools will not update automatically and one will have to request the information be displayed by pressing a button in the tool.

Graphic Traces

Instead of reading through the text based trace one can instead use a graphic representation of the model's activities. The "Horiz. Buffer Trace" and "Vert. Buffer Trace" buttons open viewers which will show the activities the model performed for each buffer in the model. The only difference between the two is which way the display is oriented – horizontally or vertically. To get the trace you need to hit the “Get trace” button in the window after the model has run. Here is what that will look like using the horizontal tool after running the final version of the model:



On the left we see the names of all the buffers (plus a line for production) and along the bottom we see the time. For each buffer there are boxes displayed which correspond to the actions which occurred related to that buffer with text in the box to indicate what happened. At this scale not all of the text fits into the boxes so we can zoom in with the “+” button to expand the boxes or hit the “Remove Text” button to clear that up. If we zoom in a couple of times we see this:

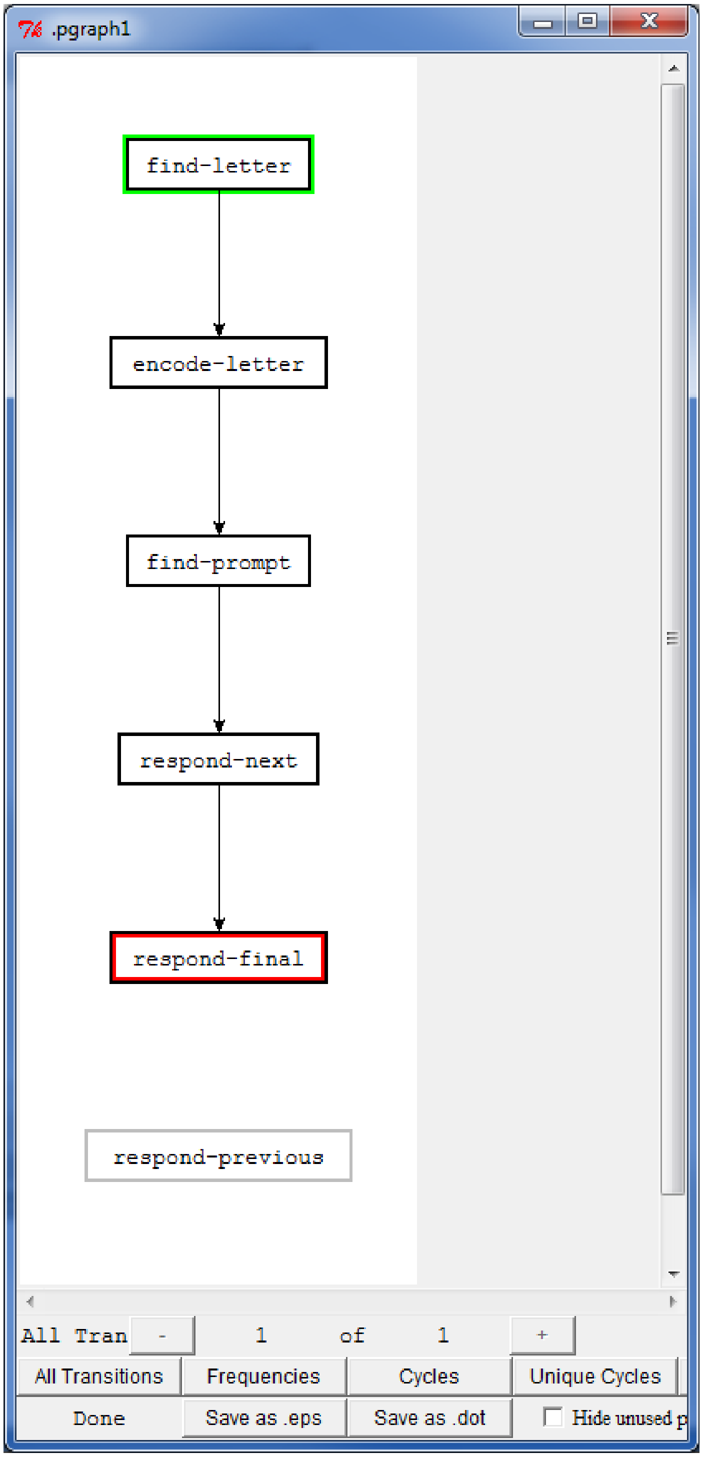


The boxes in the production row show the names of the productions which fired, and for the other buffers they display the request which was made at the top of the box and the name of the resulting chunk (if there was one) along the bottom.

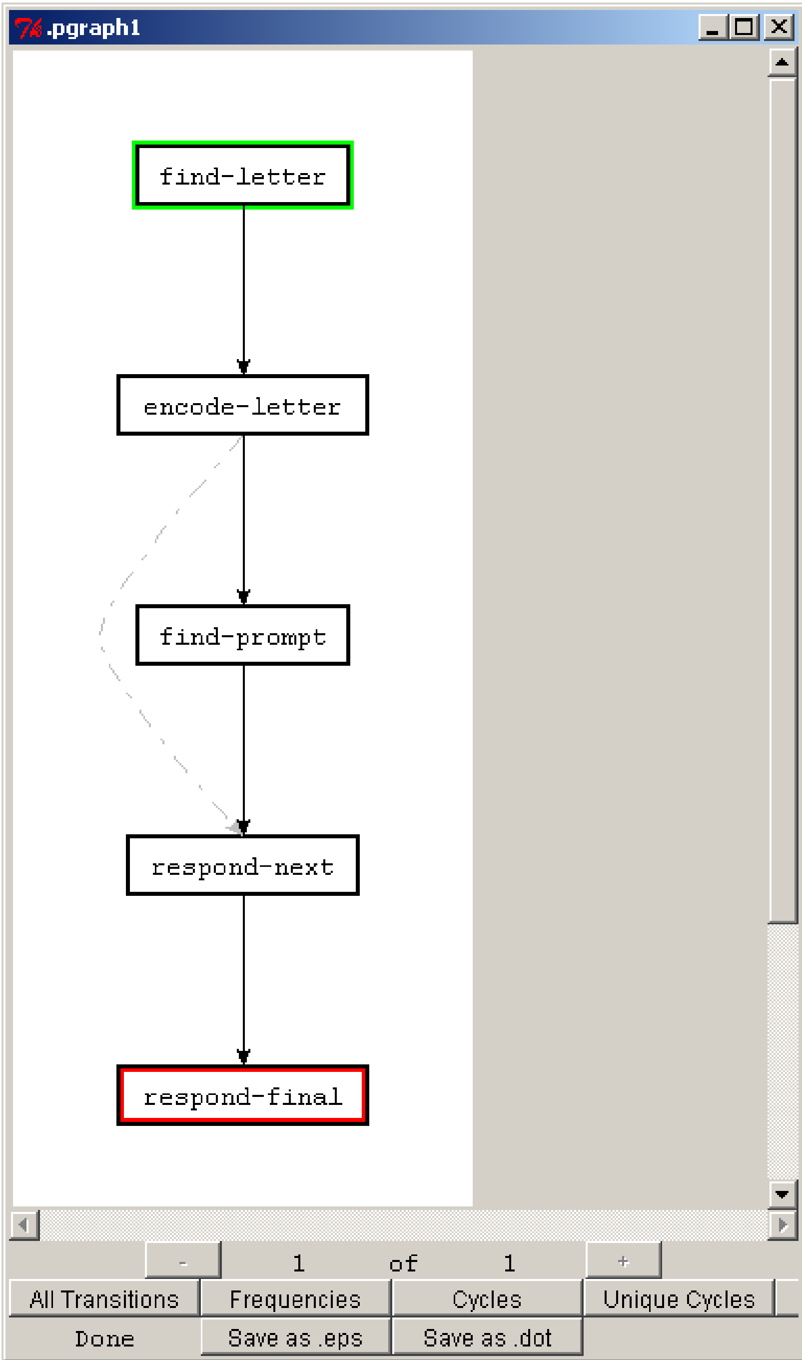
For this task, since the model was relatively small there may not have been much benefit to using the graphic trace over the text trace for debugging purposes. For larger models however it may be easier to find problems using the graphic trace because things like dependencies may be easier to see with the graphic representation. For example, it may be easier to see why encode-letter isn't selected until time .250 in the graph than in the text trace because the dependence on the completion of the imaginal buffer's action is more obvious.

Production Graph

The "Production Graph" tool can be used to show a graph of the production transitions which occur in the model. Here is what that looks like for the final version of the model using the "All Transitions" display (after resizing the window somewhat):



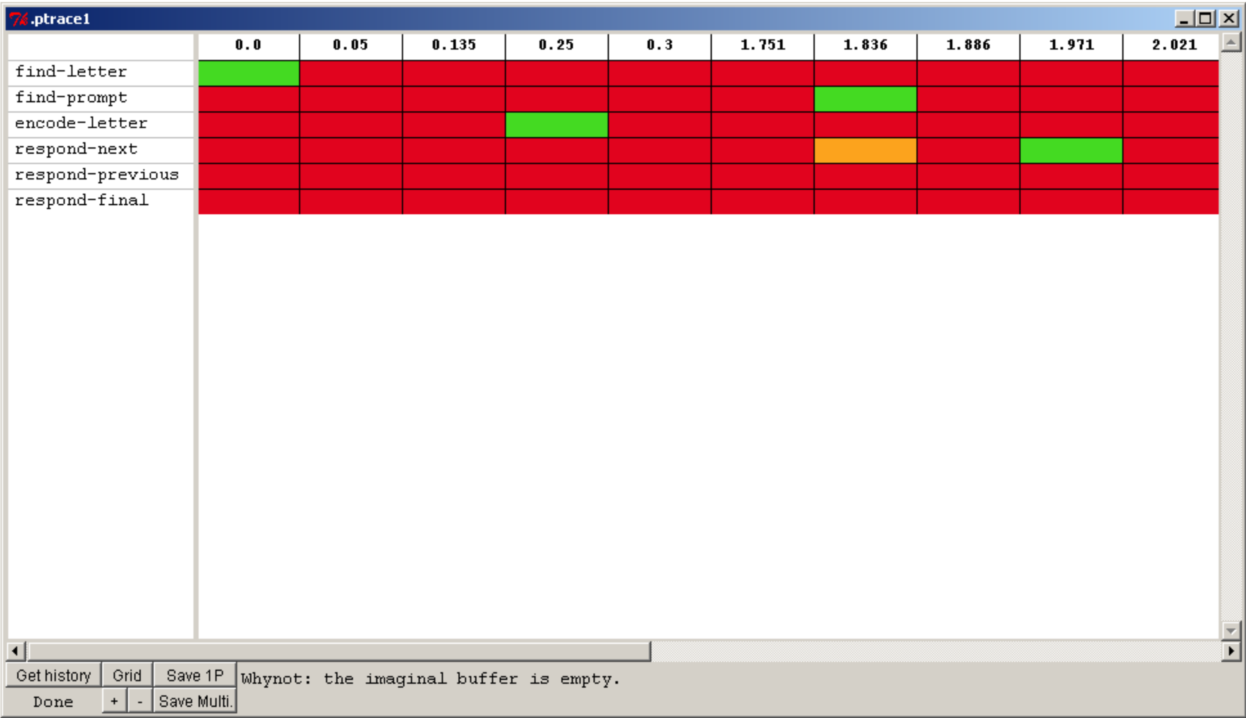
It shows the sequence of productions which occurred in the model from start (green) to end (red) along with productions which were not used in gray boxes. This provides an easy way to compare the model's production firings to what we would expect. It can also help with detecting problems along the way because it also shows productions which match but are not selected which would require turning on additional traces to see in the text trace. In particular here is a view of the graph for our model version 6 on a trial where it performed correctly:



The dotted line shows us that the respond-next production could have fired after encode-letter but didn't. That would have let us know that there was a problem without having to run additional tests to find a trial where the model actually responded incorrectly.

Production History

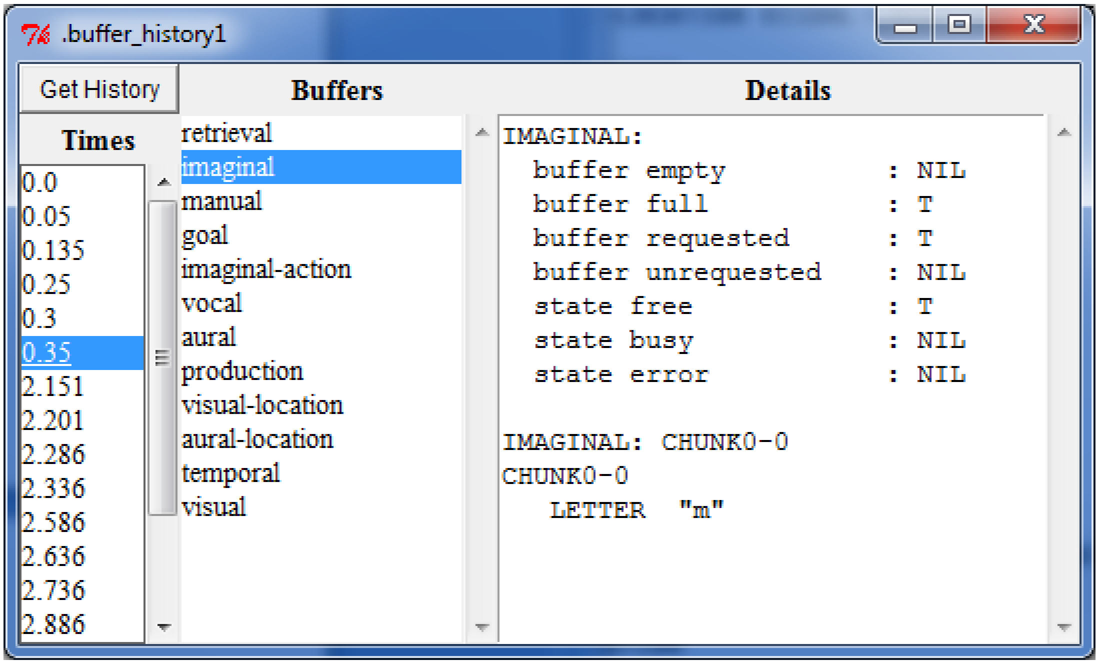
The "Production History" tool is similar to the "Production Graph" except that it shows the production selection and firing information in a chart where each column corresponds to a conflict resolution action. Here is the same model run as shown in the graph above:



The green boxes are the selected productions, red means it did not match, and orange means that it matched but was not selected. In addition to that, the tool will also display the whynot information for the unselected productions at the bottom when the mouse cursor is placed over the red boxes to show why that production was not selected during that specific conflict resolution event. In longer running models having all the whynot information recorded for inspection afterwards can be much easier than stepping through the model to particular times and then requesting the whynot information.

Buffer History

The "Buffer History" tool records all of the changes which occur to the buffers during a run. Here is the display for a run of the final model in this task:



In the column on the left are all the times at which some buffer change occurred in the model. The middle column shows the names of all the buffers. Picking a time and a buffer will then cause the window on the right to display both the buffer status information as well as the chunk which was in that buffer at that time. Like the "Production History" tool this can be helpful for larger models because the information is available for all the model's actions without having to use the stepper to see them individually. In addition to that, since one can have multiple "Buffer History" windows open, it is easy to compare the contents and states of a buffer at different times during the run.

Original Style Warnings

One last thing to look at is what we would have seen if we had left the style warnings enabled with the starting model. That would have resulted in seeing these two warnings:

```
#|Warning: Production FIND-LETTER makes a request to buffer IMAGINAL without a query
in the conditions. |#
#|Warning: Production RESPOND-FINAL makes a request to buffer MANUAL without a query
in the conditions. |#
```

Both of those warnings indicate problems which we fixed while working through the model. Had we seen them in advance we likely would have immediately added state free queries to the productions indicated because that is the obvious thing to do when warned about making a request without querying the module. That would have avoided the motor module jamming issue we encountered, but would not actually have changed the problem with find-letter firing again because the imaginal module was also free at the time of that second firing. Thus if we had left the warnings on (which is strongly recommended) it would have saved us some time debugging the model, but just fixing the warnings would not have been enough to make the model run correctly right from the start.