TDT4137 (Cognitive Architectures) Assignment Sheet 2

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Acknowledgements

While working on this assignment, some topics were discussed in a group. The group members are Piri Babayev, Danilas Miscenko (me) and Aleksander Simmersholm. Because of the discussion that has taken place, some similarities between answers may arrise, but all of the assignment tasks were completed individually, as the point of the discussions is to get a better understanding of the subject and not copy each others work.

1 Building blocks of Cognitive Architectures

Symbolic vs. sub-symbolic representations

General questions

Task 1.1: Why do we separate methods in symbolic methods and sub-symbolic methods? Explain the difference. Why is it customary to use the term 'sub-symbolic' and not 'non-symbolic'?

We separate the symbolic and sub-symbolic methods because they are fundamentally different. Symbolic methods use symbols to represent data which they can then manipulate using some production rules. These types of methods are non-probabilistic, as the production rules are not up for interpretation. Sub-symbolic methods do not use symbols, instead representing data by either numeric real values or patterns of activation units across distributed networks that refference some real values. They then manipulate the data through some probabilistic means.

It's not possible to say whether or not one method is better than the other, because they all have their strengths and weaknesses. Therefore, the one that should be used for some specific task is highly dependent on the task itself.

It's customary to use the term 'sub-symbolic' because non-symbolic methods can refer to methods that are not classified as sub-symbolic.

Task 1.2: What is the main difference between cognitivistic and emergent approaches?

Emergent approaches assume that the mind, body and (interpretation and its effect on) the environment all play a role in the agents cognitive process, while cognitivistic approaches assume that only the mind and its interpretation of the environment is a factor in the cognition process. In other words, the body is necessary for an emergent system to be able to observe and interact with the world, and learn from these interactions.

The answer from Task 1.1 can also be used as an explanation, since emergent approaches use sub-symbolic methods while cognitivistic approaches use symbolic methods.

Task 1.3: If a system shows intelligent behavior through emergent approaches, what does this mean?

It means that the system autonomously developed some sort of behaviour that we as humans would consider intelligent. The systems intelligence is also measured in its autonomous characteristics. This can be how well and

effective it learns new behaviors and it's ability to realize when it needs to better itself, i.e. Reinforcement Learning.

Hybrid architectures

Task 1.4: What are some key benefits of creating hybrid architectures? Why do people create this type of architecture?

The main goal of creating a hybrid architecture is to reap the benefits of both symbolic and sub-symbolic architectures, but without getting any of the disadvantages of either architecture. One benefit of such an architecture is that the symbolic representation that is used by the system is constructed by the system itself as it interacts with and explores the world it's in.

"Interaction becomes an organizing mechanism that establishes a learned association between perception and action." [1]

Task 1.5: When combining symbolic and sub-symbolic systems to create a hybrid architecture, what is included from each?

The Vernon book has an excellent explanation of this [1]:

Typically, hybrid systems exploit symbolic knowledge to represent the agent's world and logical rule-based systems to reason with this knowledge to pursue tasks and achieve goals. At the same time, they typically use emergent models of perception and action to explore the world and construct this knowledge.

Perception and sensing

Task 1.6: Why is cognitive architecture research very often centered around vision?

This is due to some factors. The first one I'd like to bring up is that it's quite easy to come up with an experiment involving vision. Because of this ease, a lot of experiments have been conducted which means that a lot of results have been produced. This amount of results, or data, is the second factor. These two factors have a compound effect on each other, as the data from the first factor allows for more complex experiments to be ran, which again produces more data which lead to new discoveries in the field.

Another big influence for a surge of popularity of the vision field were the findings of David Marr, which were published in the book "Vision" after his death.

Task 1.7: Explain the three stages of vision as proposed by David Marr.

Early stage: In the early stage of vision, the data stream of the actual scene is being taken in by the system from the visual sensor (camera or something of the like). Parallel processing is used to extract simple elements like color, motion, luminance, etc.

Intermediate stage: In the intermediate stage, the elements from the early stage get grouped together into regions.

Late stage:) In the late stage, the system recognises objects in the scene and assigns meaning to them.

Task 1.8: What applications is audition used for in cognitive architectures?

The meaning of audition is sound, so one application of it in cognitive architectures is training the system to understand human speech. This can then be used to either control the system using voice commands, or some other applications of it. Another example of an application of audition is the KISMET robot from MIT, which did not understand speech, but could instead infer determine approval, prohibition or soothing based on how things were said to it. The last application that I want to mention is to use sound for orientation, either by echolocation or by just moving towards the source of the loudest sound.

Attention

Task 1.9: Explain the three classes of information reduction mechanisms and how they relate to each other

The grouping suggested by Tsotsos are:

1. Selection: Choosing one element to focus on out of many potential targets. This includes selecting;
    - Gaze and viewport - for example, an embodied system automatically selects a viewport because of the point the camera is directed at.
    - World model - as in objects or events to focus on.
    - Selecting region/events of interest/time/objects/features.
2. Restriction: Limiting the amount of potential elements by using the information of the task at hand;
    - Priming - basically telling the system what it should focus on beforehand.

- Limiting by the objects, events, space and knowledge.

3. Suppression: ignoring some elements from the information flow;
    - Feature or spatial inhibition - Ignoring information around the object that's being focused on.
    - Ignore information that is unimportant for the task.
    - Negative priming - telling the system what it should ignore beforehand.
    - Location/object inhibition of return - biasing the system against getting back to the region of the previous point of attention.

Task 1.10: Explain the difference between data-driven and task-driven attention. Use at least one example.

Data-driven attention is a bottom-up approach, while task-driven attention is a top-down approach. This means that the data-driven approach looks at the whole picture and finds the regions that might be interesting, sort of working it's way from no information to some information (or from the bottom and up), while the task-driven approach looks at the regions selected by the data-driven approach and determines which of the regions is the one we're looking for, sort of going from some information down to the specific piece of information that is needed for the task (or from the top and downwards).

Action selection

Task 1.11: What are the two major approaches to action selection, and how does this relate to symbolic vs. non-symbolic architectures?

The two major approaches to action selection are planning and dynamic selection. Planning chooses a set of actions that are meant to reach some goal. This method is more prevalent in symbolic architectures, as both are fit for a logical system.

The dynamic selection approach is when an action is chosen based on the current information. No sequence of actions are deduced, but rather the actions get chosen and executed in real time. This approach is well suited for adaptation, as the approach can choose the best possible action in any situation. This approach is most prevalent in sub-symbolic architectures because it's probabilistic by nature (each action is usually evaluated by the probability of that action taking the agent closer to its goal).

Memory

Task 1.12: Explain the multi-store concept of memory.

The multistore concept entails using both long term and short term memory together. Long term memory is where the system stores all of its knowledge, as in, past experiences, information on objects and so on. Short term memory is where the system stores current percepts, the current state of the world, as well as information on the current task. Short term memory, as the name implies isn't stored for very long, while long term memory might never be erased if there is sufficient space to store the information.

Task 1.13: It is common to distinguish between short-term and long-term memory. From which research discipline does this separation come from?

It is common to distinguish the two terms because they both serve different purposes. The separation comes from the Cognitive Psychology field.

Task 1.14: optional Can you imagine a disadvantage with this approach?

In "A Review of 40 Years in Cognitive Architecture Research Core Cognitive Abilities And Practical Applications" it is mentioned that "*its [the multi-store memory model] utility for engineering is questioned by some because it does not provide a functional description of various memory mechanisms*" [2].

This may be interpreted as the fact that this method of storage may not be the best way to store information. We as humans have evolved this type of memory, but that doesn't mean that it is the most efficient or otherwise best method for storing memory.

Task 1.15: Mention some key differences in how knowledge is represented in symbolic vs. non-symbolic architectures.

Syb-symbolic architectures are better suited to represent implicit knowledge, as implicit knowledge is captured by sub-symbolic structures such as neural networks. Symbolic architectures are better suited for explicit knowledge, as the explicit knowledge is represented by symbolic means.

2 Soar

Task 1.16: Explain the following phases: Input phase, Operator selection, and Operator application.

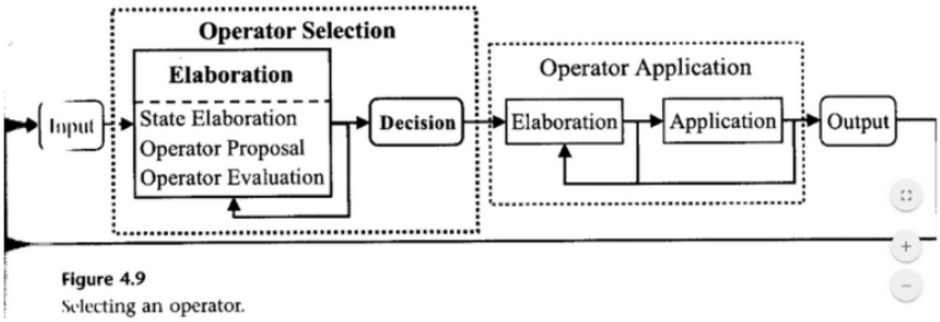

Figure 4.9
Selecting an operator.

The figure above describes the decision cycle of a SOAR system. There are five stages that are grouped into three phases.

1. **Input phase:** In this phase, the system takes input data (the percepts) and puts it into the working memory.

2. **Operator selection:** In this phase, the system elaborates the percept data in the working memory, that is to say, it matches it against rules the system has stored in its long term memory and tries to find the next course of action. This elaboration step is executed multiple times, as there might be more than one applicable action in any current situation. When all of the possible courses of action have been elaborated, the one to be taken is decided upon in the decision stage. The system has some decision procedures that influence the choice of the best course of action to take.

3. **Operator application:** Once a decision is made, it can still go through the elaboration stage if it's deemed necessary. After that, the course of action is taken (or applied), and an output is produced. After that the system can move on to the next step.

Bibliography

[1] D. Vernon, *Artificial Cognitive Systems.* MIT Press, 2014.

[2] I. KOTSERUBA and J. K. TSOTSOS, "A review of 40 years in cognitive architecture research core cognitive abilities and practical applications," *arXiv preprint arXiv:1610.08602*, 2016.