Robert Johns
CS7637: Knowledge-Based AI
Midterm Exam
February 22, 2018

1. Consider the given sentences.

   a. *Represent the sentences using frames.*

I am electing to represent background knowledge from the context of the story in addition to the information in the sentences themselves. An underlying assumption of the frames below is that the constructor of the frame has read the story up to and including the sentence being modeled.

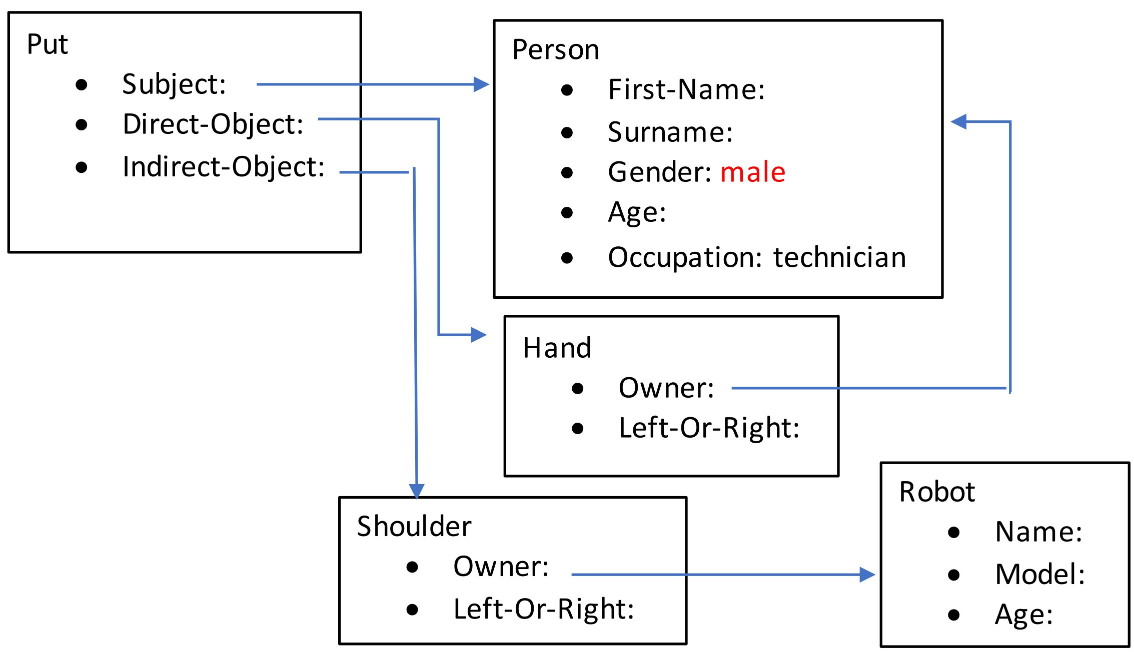

Figure 1: Complex frame structure for "I put my hand on its shoulder". Default values are in red

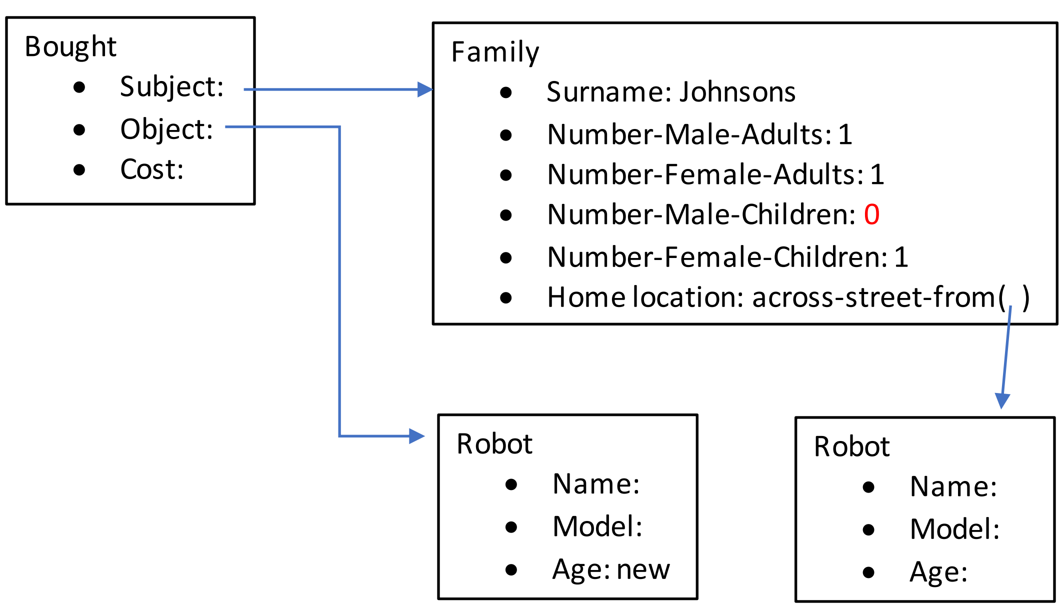

Figure 2: Complex frame structure for "The Johnsons across the street bought a new robot". Default values are in red

We can imagine these two structures, representing individual sentences, fitting into a larger structure representing the entire story. Each sentence will get its own frame, which can be given an order representing the story as a whole. An advantage of this structure is modularity: when different sentences or events refer to the robot in the story, we can have those events' frames point to a single frame representing the robot, rather than creating a new frame each time the robot is mentioned. This technique has the added advantage of allowing the agent to add information dynamically about an object to its frame each time a new piece of information is learned in the story.

A key aspect of frames is that of *default values* arising from *stereotypes* of the different objects mentioned, overridden only once the story gives contradictory information (Goel, Joyner & Thaker, 2016, p. 86). Default values in the frames are written in red for emphasis. For example, it is not stated whether the family has a male child, so it is assumed that they do not until the story gives information to the contrary.

b. Represent the sentences using propositional logic.

As neither of these two sentences are conditionals, they would form part of the knowledge base, rather than rules of inference, for a propositional logic system representing the story or the diagnostic process of the protagonist. In that sense, both of these sentences can be treated as predicates, functions that map arguments about an object either to true or false (Goel, Joyner & Thaker, 2016, p. 151); the arguments will be the subjects of the sentences (as the subject of the first sentence is the protagonist him/herself, the argument is "self").

- "I put my hand on its shoulder.": PutHandOnShoulder(self)
- "The Johnsons across the street bought a new robot.": BoughtNewRobot(neighbor)

These two predicates could be used as part of the protagonist's diagnostic process. The protagonist could use functions like the first one to catalogue different actions he has taken to fix the robot, and functions like the second one to catalogue and analyze information (e.g. the robot's physical condition or behavior). Once these predicates have been catalogued, they can be joined by rules of inference (conditionals) to create a map of the protagonist's full diagnostic process.

c. Discuss the advantages and disadvantages of using frames over propositional logic, and vice-versa.

Frames are a beneficial mainly for the detail they provide. Employing frames to describe the semantic meaning of sentences within a story can capture nearly every important detail. Also, frames can be straightforward to implement in a programming language: each frame could be represented as its own object, with instance variables representing the slots and fillers. In addition, the default values that frames employ closely mirror human stereotyping; a typical human (stereotyping again) would likely assume that the speaker of "I put my hand on its shoulder" is male until shown otherwise, due to the protagonist's occupation. However, frames come with a corresponding disadvantage: due to the amount of detail that can be captured, expressing a large story in a frame structure can get memory-intensive and cumbersome very quickly.

The advantages and disadvantages of propositional logic are orthogonal to those of frames. In propositional logic, details of sentences are dropped as the sentence is transformed into an atomic unit of truth. For example, while our frame for the sentence "I put my hand on its shoulder" requires half of a page, our representation of the same sentence using propositional logic employs a mere five words squished into one. The flipside of this representational economy is that all details are lost, and semantic meaning is abandoned, a serious disadvantage when designing an agent to represent and analyze a written story.

2. Consider the diagnosis process the protagonist performs on the robot in the story.

    a. *Illustrate the process as a production system.*

A production system is a set of rules that map percepts (inputs) to actions (outputs) (Goel, Joyner & Thaker, 2016, p. 68). The protagonist of this story is a technician who repairs robots. The percepts would be the results of different examinations of a robot, for example:

- Condition of the robot's exterior
- Condition of the robot's interior
- Robot's reaction to the command "respond to my voice"
- Robot's verbal explanation of what its problem is
- Robot's response to a heartfelt explanation of the irrationality of human love

With these percepts being the inputs, we must now note the actions the technician can take as a response to these percepts. These include:

- Examining the exterior of the robot
- Opening the robot's panel to examine the interior of the robot
- Commanding the robot to respond
- Asking the robot if it is functioning correctly
- Asking the robot what its problem is

Finally, we must note the rules that map the percepts to the actions. These will be situationally dependent on the state of the diagnosis process- for example, when the technician asks the robot "are you functioning correctly?", he could simply be looking for proper voice recognition, or a demonstration of full semantic understanding; each of these states would have different resulting actions. Examples of rules include:

- If the robot is in good physical condition, command it to respond
- If the robot responds, ask it if it is functioning properly
- If the robot indicates that it is functioning properly, ask it what its problem is
- If the robot indicates that it doesn't understand why its owners would still want it despite the availability of newer models, explain the irrationality of human love to the robot

These are fourteen examples of percepts, actions and rules that would, in any kind of expert system, be a tiny fraction of a much larger set. For objects as complex as sentient robots, the possible situations number in the hundreds, if not thousands, and each of those would require a unique set of percepts, actions and rules.

    b. *Illustrate the process as a case-based reasoning method.*

Case-based reasoning (CBR) is a natural model for a mechanical repair process. Robots and their issues will be similar, though not identical, and a good mechanic will learn from each robot and adapt solutions to fit new cases. In a CBR system modeling robot repair, the cases will be the previously encountered malfunctioning robots. To make retrieval efficient and manageable, these cases can be divided up into groups based on where in the line of functionality the robot is failing (corroded wires, depression, etc.). An outline of a CBR agent's diagnostic process follows:

1. Search through the solution database to find the closest-matching problem to the current problem and attempt that solution.
2. While the current solution doesn't work, modify the solution and try again.
    a. To make these modifications, the mechanic could employ a second database containing descriptions of the robot's working systems to know what to try next in the fixing process; that way, the mechanic could "zoom in" on the what's malfunctioning and identify potential fixes quickly.
3. If the found solution requires a method different enough from any in the database, store it in the database.

c. *Discuss the advantages and disadvantages of using a production system (rule-based reasoning) over case-based reasoning, and vice-versa.*

A Production system is unambiguous and fast, but cannot learn without an additional chunking system. Once the system is programmed, it's simple and efficient for a production system to go about the diagnostic process; all it need do is follow the rules given in each particular state, and at each step the agent will receive a simple and unambiguous set of instructions. The main disadvantage of a simple production system here is that a production system could encounter a situation where it receives two incompatible instructions, or a novel situation that would require some kind of reasoning outside of the production system.

On the flipside, A CBR system is designed to learn in the way a simple production system can't; a CBR system is more dynamic and flexible than a production system. However, such a system would operate much slower as, when it encounters a situation without an exact-matching case, the agent would need to go through an instruction-modification process that could become extensive as the agent searches for an acceptable set of instructions.

d. *Suppose the production system was missing one of its rules in the long-term. Show why, when and how this rule may be learned from the case base.*

If our production system were missing a rule (which is more than likely as the number of possible situations is innumerable and we are unlikely to be able to account for all of them), the agent would, eventually, encounter a percept or state for which it has no rule. This would bring our robot to an impasse, and we would need to employ *chunking* (searching through memory to turn knowledge of previous events into a new production rule) to break the impasse (Goel, Joyner & Thaker, 2016, p. 78). Chunking can be looked at as a specific instance of case-based reasoning: the agent will need to search through its memory of cases and potentially modify an existing rule to fit a novel situation. The case-based reasoning process outlined in (b) is designed specifically for this purpose, and could be implemented alongside the production system given in (a).

3. <u>It's unclear if we are discussing a human or robotic protagonist. Does this matter?</u>

All four methods detailed in the answers above are designed as models of human cognition that have also been implemented in computer programs; as such, these methods could be used to model a human or a robot with similar efficacy. While some are closer models of human cognition than others, the design of a KBAI agent is meant to mimic a human agent, so while the values of variables and the details of functions would need to change, ultimately there will be little substantive difference between modeling a human versus a robotic agent using these methods.

In the context of the story, all that really matters is that the protagonist is a technician capable of comprehending speech and expressing itself. If this were *Blade Runner* the distinction would be much more important. In terms of modeling the protagonist's decision-making and learning process, there are also few differences of importance. While a robotic protagonist would certainly have its process more explicitly stated, case-based reasoning and production systems function as good models of human cognition: experts learn by case-based reasoning, and all people who do a job every day develop routines much like production systems.

Note that, each of the methods discussed above are individually insufficient and incomplete. An ideal model or design would have all of these methods working together: using frames to efficiently capture all relevant information, and a production system to, using predicates defined in a propositional logic system, move through states to find a suggested solution to the problem. If no exact historical solution exists, the agent would employ a case-based reasoning process to find a new action to attempt. Neither the human mind nor the efficient robot employs one system in isolation; multiple systems work together to solve problems, hence both the magic and the difficulty.

Works Cited

Goel, Ashok; Joyner, David; Thaker, Bhavin (2016). *KBAI Ebook: Knowledge-Based Artificial Intelligence*. Publisher, city and state not given.