Natural Language, Artificial Language, and Reasoning

Scott Martin

July 27, 2010

Reasoning

- We engage in the cognitive process of **reasoning** to arrive at beliefs or conclusions about the way things are or could be.
- Ideally, our patterns of reasoning are **truth preserving**: any conclusions reached from a given set of true beliefs or factual observations should also be true.
- Studying our reasoning patterns means examining natural language (NL):
  - Our beliefs and reasoning patterns themselves are not directly observable.
  - Correspondingly, we invent the abstract notion of a proposition as the object of belief, then relate propositions to NL utterances.
  - By talking about NL utterances and the proposition(s) they denote, we can indirectly talk about belief and reasoning.
- This is part of a more general pattern in science of relating what is observable with what is not (directly) observable.

Two Types of Reasoning

Inductive reasoning draws conclusions about new observations based on a series of previous observations. Maybe the most famous example is due to Hume:

Premise The sun has risen in the east every morning up until now.

Conclusion The sun will rise in the east tomorrow morning.

- This type of reasoning is frequently used both in daily life and in scientific exploration.
- One problem is that the truth of the conclusion can never quite be guaranteed based on the premise(s):
  - Flipping a coin that lands on tails any number of times does not guarantee the next flip will be tails.
  - Observing only black dogs throughout the course of a lifetime does not mean that all dogs are black.

- Reasoning by induction thus yields conclusions that are probable to a greater or lesser degree, but can never be certain (even based on true premises) because it is impossible to exhaust all observations.
- In science, reasonable inductive conclusions stand until new observations are found that contradict, or falsify, them.

Deductive reasoning starts with a set of beliefs that are assumed to be true (a.k.a. **assumptions**, **givens**, or **primitives**) and derives new true beliefs based on them.

- So reasoning by deduction preserves truth: starting from truth, we arrive at new truth.
- Example:

  Premise If a person is a cowboy, that person chews tobacco.

  Premise Dusty is a cowboy.

  Conclusion Dusty chews tobacco.

  Note that if the premises are true, the conclusion must necessarily be true too.
- We will use deductive reasoning to model the kind of reasoning that involves propositions corresponding to NL utterances.

Relating Propositions and Utterances

We say that a proposition has a **truth value** because it can either be true or false. But mapping NL utterances to propositions is fraught with difficulty:

- Not all utterances denote propositions, only **declaratives**:

  Declaratives in English are sequences of words that can be inserted into the blank in *It's true that* __ to produce a grammatical word sequence. Consider the grammatical sentence

  (1) Guy Noir is a private eye.

  - (1) is a declarative sentence because *It's true that Guy Noir is a private eye* is grammatical.
  - In terms of meaning, (1) expresses a proposition because it has a truth value.
  - Note that *Guy Noir is not a private eye* has the opposite truth value of (1), whichever it is.

  Interrogatives (a.k.a. questions) do not pass the declarative test:

  (2) a. * It's true that does Lefty like rhubarb pie.
  b. * It's true that whether Lefty likes rhubarb pie.
  c. * It's true that what does Lefty like.

  None of the sentences in (2) are grammatical, so none of them denote a proposition. Also, neither of

  (3) What does Lefty like?

(4) Does Lefty like rhubarb pie?

have a truth value.

Imperatives (or commands) are not declaratives.

(5) a. Do your homework.
b. * It's true that do your homework.

The sentence in (5b) is not syntactically well formed, while (5a) is grammatical but does not express a proposition (has no truth value).

Invitations are not declaratives either, for similar reasons as for imperatives:

(6) a. Let's start eating more ketchup.
b. * It's true that let's start eating more ketchup.

Here again, (6a) does not have a truth value, and (6b) is ungrammatical.

- NL utterances are often **ambiguous** (express more than one distinct proposition):

  (7) Clint Bunsen saw Pastor Ingqvist with binoculars.

  The sentence in (7) clearly denotes a proposition because it passes the declarative test. But it could be paraphrased by either

  1. *Clint Bunsen used binoculars to see Pastor Ingqvist*, or
  2. *Clint Bunsen saw Pastor Ingqvist, who had binoculars.*

  Notice that (7) could be paraphrased either way, but not both ways simultaneously, in a given context.

- Certain words in NL utterances cause them to be **vague** (to rely on the context they occur in for their interpretation). Pronouns and other **deictic** words are good examples of this phenomenon:

  (8) He is eating Powdermilk Biscuits now.

  To know the truth value of the proposition expressed by (8), we need to know who *he* and what time *now* refer to, and to do this we need access to the context in which (8) is uttered.

Natural and Artificial Languages

Natural languages differ from artificial ones in that natural languages occur naturally while artificial ones are created. They are similar in that

- Both have a syntax (form) and semantics (meaning or interpretation) that are distinct from one another.
- Both have a notion of syntactic well formedness (or grammaticality).

- Both build larger units of meaning from smaller ones compositionally.

In terms of analyzing NL meanings, an artificial language is beneficial in certain ways. In the case of artificial languages,

- We can restrict the notion of syntactic well formedness as much as we want.
- We can dictate that sentence meanings are not vague or ambiguous.
- We can make as many (or as few) simplifying assumptions as we want, depending on what NL meanings we are trying to analyze.

An Example Artificial Language

As an example, we will invent an artificial language that might be used to talk about various card games. At the most basic level, our artificial language needs to be able to say, syntactically, what counts as a card is and what counts as a hand.

Definition (Syntax of Card Language)**.** Cards and hands are described in the following rules:

1. A name is one of 2, 3, 4, 5, 6, 7, 8, 9, 10, J, Q, K, A.
2. A suit is one of ♣, ♢, ♡, ♠.
3. A card is a suit followed by a name.
4. A (single) card is also a hand.
5. If $\mathcal{H}$ is a hand and c is a card, then $\mathcal{H}, c$ is also a hand.
6. Nothing else is either a card or a hand.

Some things to notice about the syntax of card language:

- By the definition, ♡4, ♠A, and ♣10 are all examples of syntactically well formed cards (but are obviously not the only ones).
- The following are not well-formed hands by the definition: ♠, ♡K2, ♣♡8, ♢♢, #$@#()%.
- The rules governing what counts as a hand are **recursive**: they allow a hand to be made up of an artitrary number of cards because another card can always be added to any hand. For example, the single cards already mentioned all count as hands, as do the following combinations:

  ♠A,♠A,♣10
♡4,♠A,♣10,♠A,♡4
♣10,♡4,♣10,♡4,♡4,♡4
♠A,♠A,♠A,♠A

  et cetera. In fact, *any* combination of any (non-zero, positive) number of of well-formed cards counts as a hand. So the card language defined here captures an infinite number of hands.
- We have not yet said anything about how cards or hands are to be *interpreted*, only what counts as a card and as a hand (and what does not). That is, we have given a syntax, but we would still need a different semantics stating (among other things) how many cards can be in a hand, which hands beat which other hands, etc. for each individual card game.

Homework

Exercise 1. Which of the following is a declarative sentence of English?

1. Does Bertha like rhubarb pie or Powdermilk Biscuits?
2. Lake Wobegon is a town in Minnesota.
3. Please remember to go by Skogelin's 5 and dime for coasters.
4. When is the lutefisk shipment arriving from Norway?
5. Myrtle wondered when the Leeches game was.
6. Clint and Clarence are having lunch at the Chatterbox Cafe.

Exercise 2. For each of the following ambiguous sentences, write down two distinct propositions expressed:

1. The man from the cities fooled someone at Ralph's Grocery with a mask.
2. Lake Wobegon needs more friendly pastors.
3. Two pickups were reported stolen by Bunsen Motors.

Exercise 3. Give truth values for each of the following sentences, if possible. If you are unable to do so, say why not.

1. It is raining in Lake Wobegon now.
2. There's no High Street in Columbus, Ohio.
3. Massachusetts is in New England.
4. Where does this class meet?
5. Does Clint have one fish shack, or two?
6. Let's go down to Curl Up and Dye for a shampoo and a cut.

Exercise 4. Using the syntax given in the definition on page 4, give three examples of a well-formed card and three examples of a well-formed hand (other than, of course, the ones we already discussed).

Exercise 5. What would be involved in giving a semantics for the card language in the definition on page 4 that would tell which cards were better than which other cards and which hands were better than which other hands? Your answer should take into account that hand well-formedness is recursively defined. (Excessive detail is not required in your answer).