COSC343: Artificial Intelligence

Lecture 20: Introduction to Natural Language

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Course Overview: recap

We're onto the last section of the course: natural language.

Part I: Autonomous agents	Introduction Robots	2 lectures
Part II: Learning agents	Probability theory Classification/regression Neural networks Kernel methods Optimisation, GAs Unsupervised learning	14 lectures
Part III: Searching agents	Uninformed search Informed search Adversarial search	3 lectures
Part IV: Natural language		5 lectures
Coda	The ethics of AI	1 lecture

Agents and communication

The notion of agents is a central focus for this AI course.

- Stimulus-response agents
- Agents that plan and search
- Agents that reason

Agents can also communicate.

- Communicating with another agent consists (at its most basic level) of changing the other agent's internal state.
- How might one agent communicate with another?

Benefits of communication

Why would an agent *want* to communicate with another agent?

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Life is not a zero-sum game, and there are advantages in agents collaborating with one another.

- These advantages are eventually evolutionary.
- Populations of agents frequently develop methods of communicating with one another.

Human language as action

Sometimes, a human agent can achieve a goal either by physical action or by communication.

- E.g.

Communication is such a central part of our life that there are many situations where communication *is* the goal.

- Examples of communicative goals?

Communicative acts

A communicative goal is just like an ordinary goal, in many respects.

- The agent has a repertoire of actions.
- The agent has a representation of the world, which specifies what the consequences are for each of these actions.
- Some actions in an agent's repertoire are utterances.
- Some of these utterances are specified to achieve certain communicative goals.

Communicating propositions

Let's concentrate on utterances which communicate propositions.

- We'll use predicate logic to represent propositions.

Lightning primer on predicate logic

An atomic proposition is a predicate, with a number of arguments.

- E.g. $outside(Mammoth01, Cave01)$.
  (Arguments with capital letters are object constants.)

You can combine atomic propositions with the logical connectives.

- $\wedge$ (and), $\vee$ (or), $\neg$ (not), $\Rightarrow$ (implies).
- E.g. $outside(Mammoth01, Cave01) \wedge big(Mammoth01)$.

You can also create quantified propositions, using symbols $\forall$ and $\exists$.

- E.g. $\forall x[mammoth(x) \Rightarrow big(x)]$.
  E.g. $\exists x[outside(x, Cave01)]$.
  (Arguments with small letters are variables.)

Communicating propositions

Say we want to communicate proposition P, expressed in predicate logic, to agent X.

We need a system of *conventions*, that map utterances to propositions.

- Utterance U_1 means proposition $outside(Mammoth, Cave)\ldots$
- Utterance U_n means proposition $big(Mammoth)\ldots$

What would be a sensible system?

Communicative conventions

We could just use a lookup table mapping whole utterances onto whole propositions.

Proposition	Utterance
$in(Crocodile01, Swamp01)$	‘Ungawa’
$belong(Bone01, Me)$	‘Uvavu’
$love(Me, You)$	‘Iranu’
...	...

What’s wrong with this system?

Is it like human language?

A compositional language

The problem:

- There’s an infinite number of possible propositions. (That’s something you can easily show in predicate logic.)

The solution: we can specify a lookup table mapping the atomic components of a predicate calculus language onto atomic linguistic objects.

Pred. calculus symbol	Atomic linguistic object
$in/2$	‘ug’
$Crocodile01$	‘ga’
$Swamp01$	‘na’
$Me\ldots$	‘ja’...

‘Atomic linguistic objects’ are *words*, basically.

Putting words together into sentences

To convey a whole proposition, we need to join several words together. This is basically what a *sentence* is.

- Q: what word sequence would convey $in(Crocodile01, Swamp01)$?

We also need rules for how the *order* of words in a complex utterance relates to the *structure* of the proposition being expressed.

pred. calc. expression	word sequence
$P(T1, T2)$	word_for(T1), word_for(P), word_for(T2)
$in(Crocodile01, Swamp01)$	‘ga-ug-na’

What other propositions can we express using this system?

Human language

Human language works this way, basically.

- Propositions are syntactically complex things, built out of atomic elements. (E.g. predicates, object constants, variables.)
- Natural language utterances (sentences) are also syntactically complex.
- The atomic components of sentences (words) 'contribute' atomic elements of a proposition.
- The *syntactic structure* of a sentence provides information about how these atomic elements combine to form a proposition.
- Using this scheme, we can convey an infinite number of propositions with a finite number of words.

This is why we can understand sentences we've never heard before.

Human language

Sentences in a natural language are syntactic objects, just like expressions in predicate logic.

- We can speak about well-formed and ill-formed sentences, just as we can for logical expressions.
- The meaning of a sentence is determined by its form, just like the meaning of a logical expression.

However:

- We *know* the syntax of predicate logic, because we invented it.
- The syntax of a natural language is something we have to *discover*.

Building a syntactic theory

We have decided that words combine together to produce the meaning of a sentence. Now we need to work out *how* they do this.

Since there are an infinite number of possible sentences, we will clearly need to invoke *general principles* in our explanation. I'll introduce two kinds of general principle:

- Principles which group words into *general categories*.
- Principles which define *hierarchical structure* in sentences.

Any language also encodes a lot of *specific* knowledge:

- Knowledge of individual word meanings
- Knowledge of *idioms*: word combinations that occur particularly frequently.

Summary

- Language is ultimately just a kind of action: we make utterances because they help us achieve goals.
- A simple language could be implemented as a look-up table for a fixed set of meanings.
- But human language is not like that. The meaning of a natural language sentence is *constructed* out of the meanings of its component parts (words), plus its syntactic structure.
- To know a language is to have a lot of *specific* knowledge (about words and their meanings, and about idioms), and to know some *general rules* (about word classes, and about hierarchical structures in sentences).

Readings

For this lecture (and next lecture): AIMA Section 23.1.