University of Malta
BSc(IT) HonsYear III

CSA305: Natural Language Processing

Lecture 3

Module 3

- SHRDLU
- Architecture of NLP Systems

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SHRDLU (T. Winograd 1971)

Basic Principles

1. A computer cannot deal reasonably with language unless it can understand the subject it is discussing.

2. In modeling language understanding, *all aspects of language* must be integrated.

3. Humans do not understand isolated sentences. Sentences always occur *in a context* which includes
   - Physical situation.
   - Discourse context.
   - Shared social knowledge.
   - Shared world knowledge.

Serious Problems

- Linguistic versus world knowledge. World knowledge is intractable in the general case.
- It is difficult or impossible to isolate one aspect of language use (syntax, mophology, semantics, pragmatics) from another: e.g.

  He gave the house plants to charity vs.
  He gave the boy plants to water

  Assigning the correct syntactic structure depends on complex interactions between syntax and semantics.
- How can these problems be addressed?

Key Idea #1

- Strictly limit the subject area in order to address general issues of how language is used in a framework of physical objects, events, and continuing discourse.

- Winograd's strategy was to pick a *microworld* to talk about. A microworld in Winograd's sense is essentially a finite collection of entities and relations, together with rules allowing them to be manipulated.

Winograd's Microworld

The subject chosen was the "blocks world" of a toy robot. In the course of a dialogue:

- Manipulate objects (of different sizes, shapes and colours) in blocks world
- Answer questions about current configuration of blocks
- Discuss events that have taken place during the interaction
- Limited discussion of its own reasoning
- Accept new facts that it is told

World Model

The program makes use of a detailed world model, describing both the current state of the blocks world and procedures for changing that state.

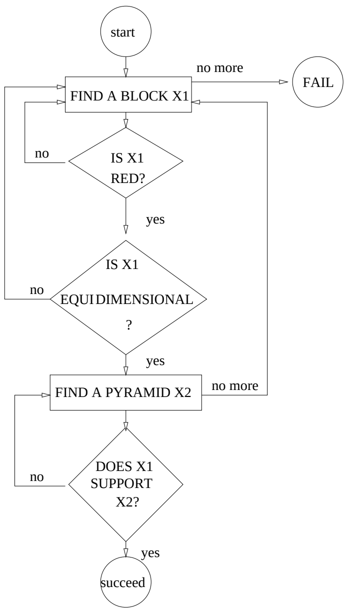
```
(IS B1 BLOCK)
(IS B2 PYRAMID)
(AT B1 (LOCATION 100 100 0))
(SUPPORT B1 B2)
(CLEARTOP B2)
(MANIPULABLE B1)
(CONTAIN BOX1 B4)
(COLOR-OF B1 RED)
(SHAPE-OF B2 POINTED)
(IS BLUE COLOUR)
(CAUSE EVENT27 EVENT29)
```

- Objects
- Relations
  - Type Information
  - Spatial and Physical Information
  - Temporal/Causal Information

Key Idea #2: Procedural Semantics

Meaning of a phrase is a procedure

"A Red Cube That Supports a Pyramid"



A Red Cube That Supports a Pyramid

```
(GOAL (Is ?X1 BLOCK))
(GOAL (COLOR-OF ?X1 RED))
(GOAL (EQUIDIMENSIONAL ?X1))
(GOAL (IS ?X2 PYRAMID))
(GOAL (SUPPORT ?X1 ?X2))
```

The same procedure expressed in the programming language MICROPLANNER

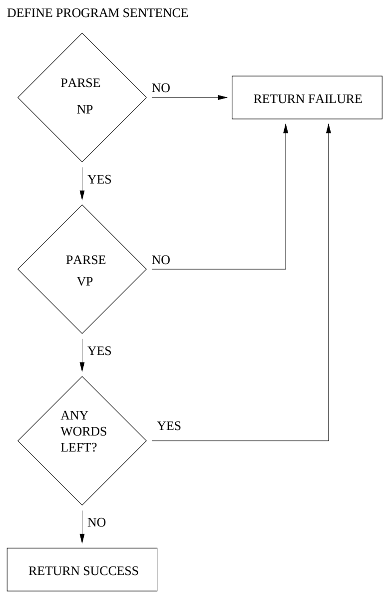
This language was specially developed for describing plans based on finding goals.

Expressions in the language constitute an executable meaning representation for sentences of English.

Issue: what is easy/difficult to express in this way?

Key Idea #3: Encode English Grammar

The program includes a large-scale procedurally expressed grammar of English.



Main Components

- Syntactic Parser - works with a large-scale grammar of English
- Collection of semantic routines that embody the kind of knowledge needed to interpret English words and phrases
- World Model
- Cognitive/deductive system for exploring the consequences of facts, making plans to carry out commands, finding the answers to questions.
- Simple set of programs for generating appropriate English responses.

SHRDLU - Example Interaction

Pick up a red block

OK.

Grasp the pyramid

I DON'T UNDERSTAND WHICH PYRAMID YOU MEAN.

(There are 3 pyramids in the scene.)

Find a block which is taller than the one you are holding and put it in the box

(System has to figure out what is meant by "one" and "it", as well as do deduction to figure out which block it is holding)

BY "IT" I ASSUME YOU MEAN THE BLOCK WHICH IS TALLER THAN THE ONE I AM HOLDING.

What does the box contain?

The blue pyramid and the blue block.

What is the pyramid supported by?

(Now the system understands the phrase "the pyramid").

The box.

How many blocks are not in the box?

(negatives must be handled properly)

Four of them.

.SHRDLU Example Interaction

Is at least one of them narrower than the one which I told you to pick up?

(the phases "at least one of them" must be analysed to refer back to the previous question. Complex quantifier expressions must be handled)

YES, THE RED CUBE.

Is it supported?

YES, BY THE TABLE.

(heuristics about what people expect to hear in addition to yes or no)

The blue pyramid is mine.

I own all blocks which are not red, but I don't own anything which supports a pyramid.

I UNDERSTAND

(The result of understanding these sentences is is the creation of new procedures for deducing whether I own something.

Do I own anything in the box?

YES. TWO THINGS: THE BLUE BOX AND THE BLUE PYRAMID

(Extra information supplied. Form of a list)

SHRDLU Example Interaction

Had you touched any pyramid before you put the little green one on the little cube?

YES, THE GREEN ONE

(The system deduces from its memory what event is being referred to, and can relate other events to it in time. The analysis includes complex tenses of verb groups).

When did you pick it up?

WHILE I WAS STACKING UP THE RED CUBE, A LARGE RED BLOCK AND A LARGE GREEN CUBE.

(A time is described by naming the main goal that was being worked on)

Why?

TO GET RID OF IT.

(By keeping track of selected parts of the subgoal tree, the system has some understanding of its own motives.)

Why did you do that?

TO CLEAN OFF THE RED CUBE.

Why did you clear off that cube

TO PUT IT ON A LARGE GREEN CUBE

Why did you do that?

BECAUSE YOU ASKED ME TO

Dictionary Information

We have seen how meanings will be represented. To construct such interpretations we must interpret individual words with respect to the syntactic structures in which they occur.

Here is an example of the system's dictionary entry for the word "cube".

```
(CUBE
  ((NOUN   (OBJECT
             ((MANIPULABLE RECTANGULAR)
              ((IS ? BLOCK)
               (EQUIDIMENSIONAL ?)))))))
```

- The entry specifies both syntactic and semantic information.
- A cube is an object that is rectangular and manipulable, and can be recognised by the fact that it is a block and equidimensional.

The word "contain"

```
(CONTAIN
  ((VERB
      ((TRANSITIVE
          (RELATION
A--->      (((CONTAINER)) ((PHYSICAL-OBJECT))
            (CONTAIN #1 #2))
B--->       (((CONSTRUCT)) ((PHYSICAL-OBJECT))
            (PART-OF #2 #1))))))))
```

This entry provides two meanings for the word "contain". These are distinguished by considering the "types" of the two things in the containment relationship (cf. A and B)

- If applied to a container and a physical object, (e.g. "the box contains 3 pyramids") the container contains the objects).
- If applied to a construct and an object, (e.g. "the stack contains 3 objects"), the sense is that the object is a part of the construct.

Remarks on Dictionary Entries

The possibility of associating arbitrary programs with dictionary entries makes it easy to incorporate complex procedures into the interpretation process.

For example, the word "the" is associated with a procedure that checks the current context for a unique object that fits a certain description. If more than one such object is found, a special message is generated.

Key Idea #4: Interleaving Syntactic and Semantic Processing

- Program does not operate by first parsing a sentence, then doing semantic analysis, then using deduction to produce a response. These activities go on *concurrently*.
- As soon as a piece of syntactic structure takes shape, a semantic program is called to see if it makes sense. This in turn might involve deductive reasoning. Example:

  Put the blue pyramid on the block in the box

  Put [the blue pyramid on the block] in the box

  Put the blue pyramid [on the block in the box]

Limitations

- Limited range of declarative utterance types.
- Brittle: model is overdependent upon syntax.
- Closed world assumption of semantics.
- Impoverished level of world knowledge compared to a human.
- Program cannot produce sentences of a syntactic complexity that matches input.

Other Remarks

Yorick Wilks has argued that SHRDLU'S power does not come from linguistic analysis but from the use of problem-solving methods in a simple, logical, and closed domain ("table-top" world), thus eliminating the need to face some of the more difficult language issues.

It seems doubtful that if SHRDLU were extended to a larger domain, it would be able to deal with these problems. Further, the level at which SHRDLU seeks to simulate the intermixing of knowledge sources typical of human rea soning is embedded in its processes rather than made explicit in its control structure, where it would be most powerful.

Lastly, its problem solving is still highly oriented toward predicate calculus and limited in its use of inferential and heuristic data.

Organisation of NLP Systems