Linguistic Faculties & Cognitive Architecture

A Tentative Research Plan
ARAKAWA, Naoya 2013-02

Personal Background

- Interested in Brain Modeling (undergraduate)
- Rule-based Machine Translation (the 80's)
- Philosophy of Language
  The Naturalization of Reference
- NLP research in the 90's
  including dialogue systems
- Ontology-based NLP+some statistics
- Now taking the criticism on symbolism by Cognitive Linguistics seriously...

Background of the Plan
— Issues in Cognitive Science

- Symbolic vs. Connectionist Debates
  - Languages have recursive/generative structure.
  - How can neural networks cope with generativity?
- *A* Frame Problem
  - How can a cognitive system find relevant-enough information in real-time task-solving situations?
- The Problem with Classical Categories
  - The categories we use aren't clear-cut, but fuzzy, prototypical, ...
    Pointed out in Cognitive Linguistics (ref. Lakoff)

Background of the Plan
— Issues of Integration

- The Binding Problem
  - How can (inherently parallel/distributed processing) brains integrate various modes of information (including images and symbols)?
- The Evolutionary Perspective
  - Did linguistic faculties evolve from other cognitive faculties for surviving in the world?
- Occam's Razor
  - The simpler, the better.

The (tentative) Research Goal

To integrate linguistic faculties
   in a more general cognitive architecture.

thereby coping with the above-mentioned issues:
- symbolic-connectionist debate
- The frame problem
- The problem of classical categories
- The binding problem for linguistic faculties
- Linking linguistic faculties to other faculties...

Linguistic Faculties

- Understanding
  Parsing linguistic expressions to associate with conceptual representations (/ with actions).

- Generation
  Generating linguistic expressions from conceptual & intentional representations.

- Learning
  Learning the faculties of understanding & generating linguistic expressions.

Cognitive Architecture

A **cognitive architecture** is a blueprint for
  intelligent agents. It proposes (artificial) computational
  processes that act like certain cognitive systems, most
  often, like a person, or acts intelligent under some
  definition. [*Wikipedia*]

  Examples of (rather symbolic) cognitive architectures: SOAR, ACT-R, ...

Prioritized aspects in Cognitive Architecture
  in my research:

- ***Associtaion***
- ***Working Memory***

Association

Association is a function of our mind
  (psychological function).

Association is naturally implemented in neural
  network models.

Association with a neural network model can
  cope with:

- *the* Frame Problem stated earlier as it could find
  most relevant information
- the Issue of Non-Classical Categories as it can
  represent prototypical categories, etc.

Working Memory

Working memory is the system that actively holds multiple pieces of transitory information in the mind, where they can be manipulated. This involves execution of verbal and nonverbal tasks—such as reasoning and comprehension... [*Wikipedia*]

- Language understanding and generation requires inferences and planning ⇒ requiring WM.

- There seems no received theory of WM for the over-all language faculties yet.

- An association-based model would be desirable for natural explanation with neural models.

Things to do

- Surveying WM modelsref. *Models of Worki* *Memory*, Miyake & Shah, eds.

- Designing associational
  - WM (including planning faculties)
  - conceptual representation
  - language understanding mechanism
  - language generation mechanism

Language Acquisition

In this project, the model is to learn
- language understanding
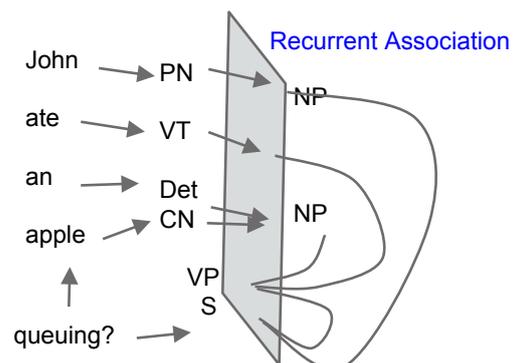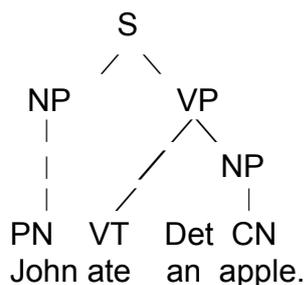- language generation

Out of scope:
- phonology
- morphology
- concept forming
- etc.

Conceptual structure & morphemes (words) are given.

Parsing ← Language Understanding

- Constructing phrase structure for utterances
- Phrase structure -- recursive
- *Associative model* if possible
- *Rules should be learned* without teaching.

```
              S
            / \
         NP     VP
         |     / \
         |    /   NP
         |   /   / |
        PN  VT Det CN
       John ate an apple.
```

Recurrent Association

```
John  →  PN
                    NP
ate   →  VT

an    →  Det
apple →  CN        NP

                   VP
                    S
queuing? →
```

Semantic Analysis
← Language Understanding

- Associating phrase structure to semantic representation in WM via *learning*.

- Semantics would be represented in an associative network.

Conventional semantic analysis
- Semantic Reps.: frame-like feature structure,
- Analysis by given transformation rules, ...

doesn't explain language acquisition.

Conceptual Representation —
of *Situations*, in particular...

- The representation of situations is a basic building block in semantics/linguistic cognitive theories such as:
  - Situation Theory
  - (Segmented) Discourse Representation Theory
  - Mental Spaces

- Involves the representations of time & space

- Related to episodic memory

- Corresponds to syntactic *clauses*

Language Generation

- Input
  - Intention (Questioning, Asserting, etc.)
  - Semantic representation
- Constraints
  - Cooperative Maxims (ref. P. Grice)
- *Planning* of speech acts
- Associating the input to phrase structure

Summary

The project aims to
- explain language faculties with an associative WM model.

Thereby aiming at solving
- some frame problem
- the problem of classical categories
- puzzles of neurally implementing language faculties, including
  - (indefinite) recursive structure
  - some binding problems