Elements of Representation

The Problem

- Two parts:
  - What needs to be represented?
  - How exactly do we represent it?
- We saw that FOPC
  - Gives us some nice tools
  - Has adequacy limitations that quickly become apparent for NL.
  - Mapping sentences/utterances to logic representations isn't at all straightforward.

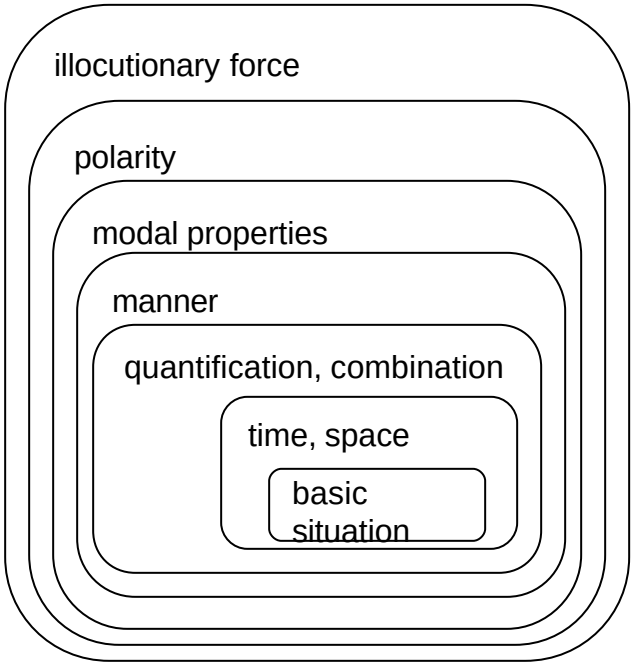
Factoring out Meaning Components

- What kinds of underlying meaning components might there be?
- Linguistically, can look for simpler and more complex language forms:

  "Jan broke the window."

  "Shouldn't Jan have quickly broken the window with a hammer yesterday?"
- The intuition is that there are more or less simple core "situations", from which we build up more complicated ones.

Core and Elaborations, Crudely



Picture is Really Quite Messy

- Semantic components can get conveyed by a variety of different linguistic objects.
- They can get clumped together in different ways, depending heavily on the language.
- E.g., situation type is typically conveyed by a verb (conflated with some temporal information, etc.), it may equally well come as a noun (e.g., “the debate, “the construction”)
  - incidentally, without the temporal information.

Lots of Cross-linguistic Messiness

- English (and, supposedly, all of Indo-European except Romance) and Chinese often incorporate manner and cause into the verb
  - "shout", "whisper" incorporate manner ("vocalize loudly/softly"; "crawl", "drive", "swim" describe manners of motion)
  - "flatten" is "cause to be flat"; "kill" is "cause to die"
- Romance tends to incorporate direction
  - which we see in English, "ascend", "enter", "leave", mostly from the French…
- Some languages (notably Atsugewi and Navajo) incorporate object information into verb
  - which you also see in English with verbs like "spit" (and "drink", as in "For my New Year's resolution, I quit drinking."?)

Kinds of Meanings

- Philosophers have distinguished between “sentence meaning” and “speaker meaning”.
- *Sentence meaning* is supposed to be:
  - assigned to sentences independent of context, speaker, etc. (There may be multiple potential assignments, in which case the sentence is ambiguous.)
  - compositional (in terms of the lexicon and the grammar)
  - determined by (or equal to) truth conditions
  - equivalent to “literal meaning”
- *Speaker meaning* is supposed to be:
  - what a speaker means by using the sentence
  - subject to various kinds of non-literal interpretation, e.g., metaphor, idioms, speech acts, literary devices, sarcasm, etc.
  - equivalent to the sentence meaning when there is no reason to depart from it.

Examples of Speaker Meaning Departing from Sentence Meaning

- "It's cold in here."
  - In the right context, might be a request that the listener turn on the heat, close a window, etc.
- "Jan kicked the bucket."
  - Intended (non-literal) interpretation may be about dying.
- "That was a brilliant idea."
  - When uttered sarcastically, used to mean opposite of its sentence meaning.
- "No man is an island."
  - Use is no doubt metaphorical (and hence, is a counter-example to assuming non-literal interpretations attempted only when there is some semantic conflict.)
- "I'm out of here."
  - Recent form in which the meaning is false in the present to indicate it coming true in the immediate future.

Components of How Utterances are *Used*

- Austin (an "ordinary language" vs. "ideal language" philosopher) made the following distinctions:
  - *Propositional content*
  - *Illocutionary force*
    - These are the "universal and inevitable consequences of an utterance".
    - E.g., question, assertion, command, request, promise
  - *Perlocutionary force*
    - non-universal effect of the utterance
    - E.g., convince, persuade, insult, inform

Where Do These Fit In?

- “Propositional content” is all but the last oval,
- which is the “illocutionary” force.
- It’s not that we want to ignore perlocutionary force.
- It’s just that this be completely inferential, without a linguistic “anchor”.

Sentence/Speaker is Probably Fatally Flawed

- A decent account of a language's grammar and lexical should let us find for a sentence
  - conventional, but non-compositional interpretations (e.g., idioms)
  - conventional, but metaphoric interpretations
  - its illocationary force
    - (was it a question, a command, etc.?)

Sentence/Speaker Flaws

- On the other hand, just the grammar+lexicon may produce something that is too abstract to serve as a meaning.
  - Consider “The cat is on the mat.”
    - » which means “lying”, but this may require an inference from lexical entry for “on”.
  - Noun-noun compounds
    - » “grass seed” vs. “bird seed”, “coast road”
  - Adjectival modification
    - » “red pen”

An Alternative: Primal Versus Actual Content

- Primal/Linguistic Content
  - What you can derive from the lexicon and grammar, both broadly construed
  - To include
    - non-productive forms (e.g., idioms)
    - conventionalized metaphor
    - illocutionary force
  - But with might not be by itself a candidate for the meaning of the utterance.

Primal Versus Actual Content

- The content part of speaker meaning
  - So doesn't include result of indirect speech act inference
  - Is non-compositional, requiring extra-linguistic knowledge and inference to determine that "red pen" means "pen writing red", etc.
- The actual content assigned by the *sensible speaker/hearer* is *ordinary content*.
- It's really ordinary content that is of primary interest to us.

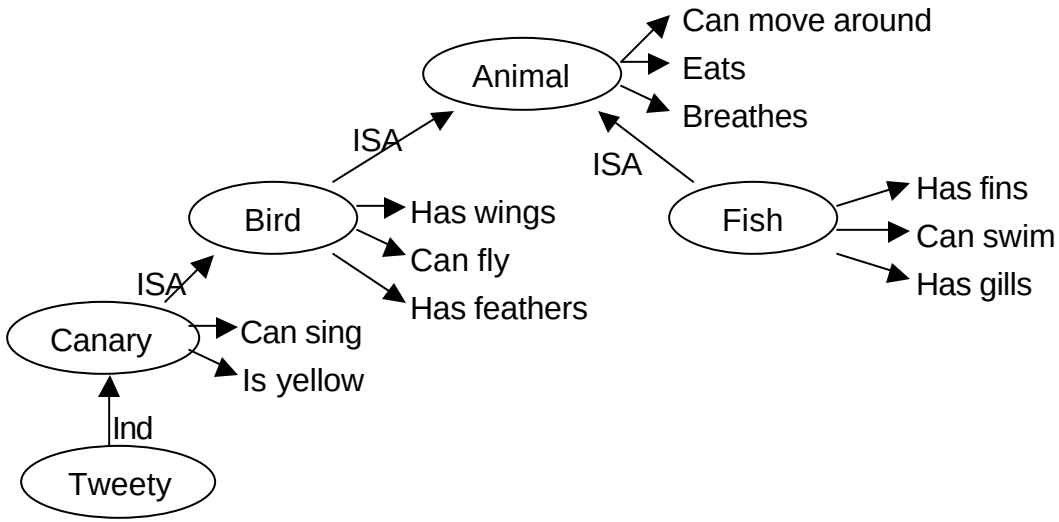
Representing Core Situations

- Situations have *participants*.
  - For example, our "breaking" situation involves Jan, a window, and a hammer.
- Participants, as well as the situations to which they belong, are generally *individuals* of some *category*.
  - These are sometimes also called *tokens* and *types*, respectively.
  - "Jan" might be an individual "Person", "a window", an individual "Window", etc.
- Situations involve participants of particular categories in specific ways. E.g., breaking involves something that got broken, which has to be a physical object.
- Participants, and, perhaps a bit less obviously, situations, generally fall into a *hierarchy* of *supertypes* and *subtypes*.
  - E.g., categories for "Person", "Man", "Women", "Physical-object"; "Man" would be a subtype of "Person", etc.

Some History

- In the late '60s, Quillian proposed a *semantic memory* in which
  - nodes represent concepts
  - links represent relations between concepts.

Early Semantic Memory Example

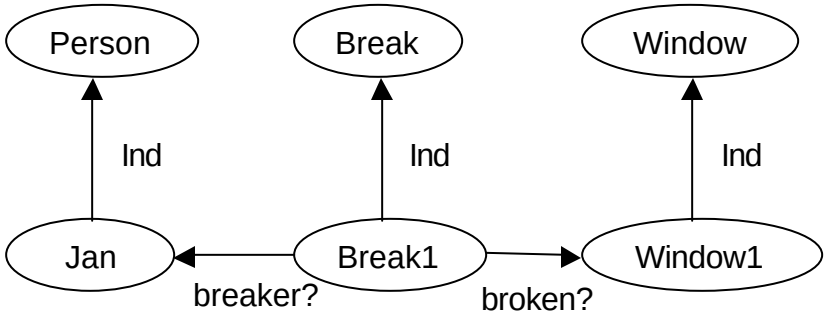


- Introduced *hierarchies* and *inheritance*.
- Motivated by computation economy (store "Can fly" once, with bird, inherit)
- Psychological reality? Did it take longer for humans to answer "Do canaries have wings?" than "Do birds have wings?"
  - Initial results suggestive, complicated by "penguins".

Early Semantic Memory (con't)

- No clear idea what "properties should be or how to represent them.
- However, while "situations" seemed more complicated, they had more or less statable sets of participants.
- Led to the extension of concepts having "roles".

Example: Adding Roles



- This elaboration is called a *semantic network*.
- A *network* is a set of nodes connected with directed arcs.
- In semantics networks,
  - node correspond to word senses
  - arcs designate semantic relationships between a verb and its surrounding nominal concepts

Enter Frames

- In 1974, Minsky published a very influential paper, “A Framework for Representing Knowledge”.
- Minsky argued:
  - There is a need to organize knowledge into *larger chunks*, as opposed to lots of separate PC formulas, say.
    - » E.g., our knowledge of rooms, birthday parties, comprise lots of coherent information.
  - Many researchers had arrived at similar conclusions in their respective fields,
    - » in particular Schank, Abelson and Norman. But actually, the idea is much older, going back to at least Barlett's notion of *schema*, and (arguably, to Kant.)
  - There was a super-general way to think about this notion of larger chunks of knowledge, namely, *frames*.

A Frame Is

- A data structure for representing a stereotyped situation,
  - E.g., being in a certain kind of room, or attending a child's birthday party.
- A network of *nodes* and *relations*.
  - Top-levels of the frame are fixed (representing what is invariantly true),
  - lower levels have *terminals* (i.e., slots) filled in specific instances of the frame.
  - Slots might be restricted to be filled by a certain type of object, e.g., a person or an event, or to having a certain relation to another slot.
  - Slots get to specify *defaults*.
- Frames where arranged in collections called *frame systems*.
  - Different frames in a system share the same terminals, so the frames in effect constitute different points of view of the same object.

Using Frames

- Minsky claimed that lots of intelligent tasks involve
  - finding a frame suitable for a given situation (perhaps taking into account one's goals)
  - and *matching* it to the situation.
- Minsky intended frames as an antidote to logic-oriented approaches, emphasizing:
  - Selecting relevant knowledge, i.e., the importance of knowledge about how knowledge is used
  - The importance of making assumptions over proving conditions
  - The non-monotonicity of real reasoning
  - The inappropriateness of logical properties like consistency and completeness

Impact

- Minsky's work on frames had several important impacts:
  - It unified what many researchers were already doing.
  - It gave rise to frame languages, notably:
    - KRL (Bobrow and Winograd)
    - FRL (Goldstein and Roberts)

What Frames Actually Meant for Representation

- *Objects*, corresponding to concepts/situation categories
- *Slots* bearing restrictions associated with objects
- *Hierarchies* and *inheritance*
- *Defaults*
- *Procedural attachment*
- Perhaps some ontological distinctions
- Syntactic sugar

Example of Concepts in a Generic Frame Language (actually, KRL)

(Travel a type of Event with
(traveler (a Person))
(destination (a Location))
(origin (a Location) Default (a Home))
(mode (a Vehicle)))

(Visit a type of Social-interaction with
(visitor (a Person))
(visitee (a Person)))

Now We Can Define An Individual

(Event137
an individual Travel with
(traveler Jan)
(destination SanFrancisco)
(mode Plane)
an individual Visit with
(visitor Jan)
(visitee Lynn))

Alternatively,

```
(an individual Travel with
    (traveler Jan)
        (destination SanFrancisco)
        (mode Plane)
 an individual Visit with
    (visitor Jan)
    (visitee Lynn))
```

- with token symbols generating internally.

Using Procedural Attachment

- If we know home of individual traveler, we might want to have it automatically inserted in the origin slot of an individual travel event.
- We could do so by
  - attaching a procedure to “origin” slot,
  - Which, whenever instance of event is created, checks to see if home is known, and, if so, inserts it in “origin” slot of new event.

Frames for Persons, etc.

- Would have similar objects for “Person”, “City”, and “Jan”, “Lynn” and “SanFrancisco”.
- For example:

(Person a type of Thing with
    (name (a Person-name))
    (address (an Address))
    (age (a Number (Btw 0 120)))) ; or maybe, an Age?

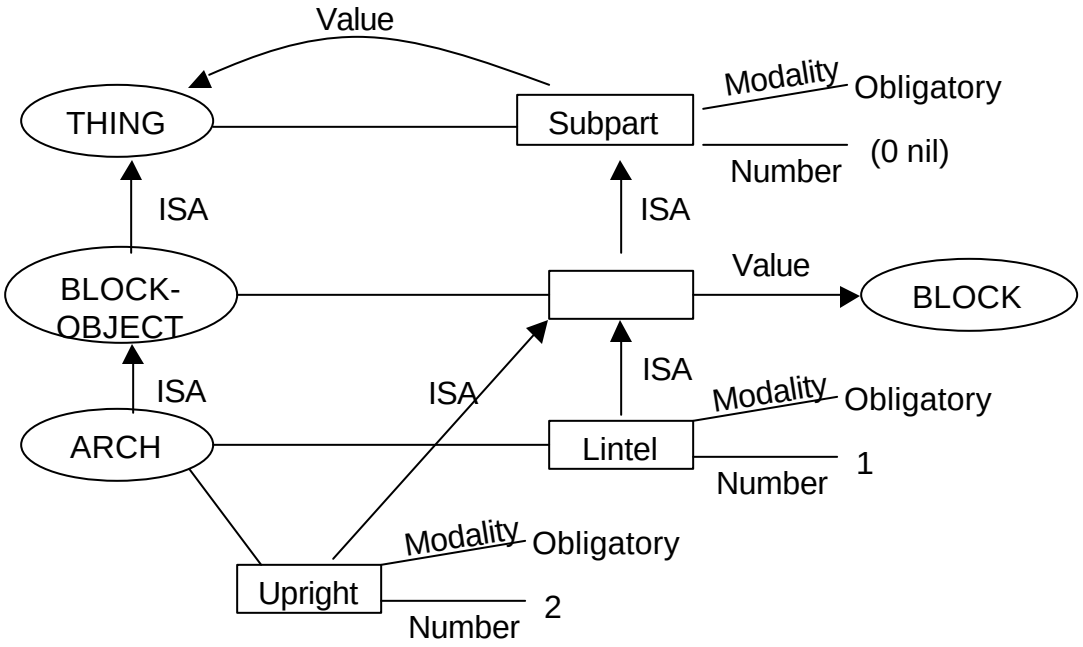
(an individual Person with
    (name (an individual Name with (firstname “Jan”))))

Although exactly what to include as slots is not clear…

Frames and Semantic Networks

- Frame systems had frames and roles
  - and defaults, procedural attachment, constraints on role fillers
- Semantic networks had concepts and relations.
- Semantic networks incorporated the new features, mostly by *reifying* roles.
  - Make roles object, say lots of things about them.
- Exemplified by languages like KL-ONE (Brachman et al.)

Example: The Concept of an Arch in KL-ONE



- Ovals represent concepts, boxes represent roles.
- Lines from roles provide information about roles:
  - **Value** states that concept playing role for an individual of concept bearing role is restricted to be of a certain type.
  - **Modality** specifies whether role is optional or required.
  - **Number** states number of such roles that can appear in individuals of concept.

Inheritance Revisited

- The insight here is that inheritance requires a *set* of links including
  - links between roles
  - rather than just a link between concepts,

  to establish the relation of one object in a hierarchy to another.
- This set of links is referred to as a *cable*.
- A similar cable with **Individuate** links would link an individual concept and its component roles to the concept it individuates.
- This idea is referred to as *structured inheritance*.

Limitations

- Some kinds of relational information between roles could be accommodated in this spirit.
  - For example, it is possible to link two roles to show that their fillers must be the same.
- On the other hand, some relational information is not so easily represented.
  - For example, we have not represented the crucial relational fact that, in a arch, the uprights support the lintel.
  - To do so in general may require an escape into predicate calculus.

More Problems

- Questions:
  - What does it mean to be a slot in a frame?
  - What can be a slot in a frame?
  - How do we express certain concepts?

What Does It Mean to Be a Slot in a Frame?

- You don't even get to express what relational concepts like "Age-of" "Address-of" mean, other than by how they appear in frames and how they are "used by the system".

What Can Be a Role Where?

- While determining the roles for situation concepts (i.e. “participants”) in was more or less clear, the roles for objects, etc., were much less clear, and perhaps, hopelessly ill-defined.
- The intuition is that a concept “has” a slot. But what is the nature of this intuition?
- If we allow “Name” in “Person”,
  - We should allow “Mother” and “Father” also.
  - But then, what about “Uncle”, or “Mother's-maiden-name” or “Favorite-Robert-De-Niro-Movie”?
- I.e., “has” represents very different relations, and is context dependent.
- Frame aficionados would often say that the presence of any particular slot is an efficiency consideration.
- But this is just an admission of guilt.
  - Frames aren't a knowledge representation, then, but just a convenient indexing (and data entry) scheme.

Hard to Express Important Concepts This Way

- E.g., “Age” is usually a slot, and therefore gets defined procedurally.
- But “Age” is a perfectly good concept.
- Indeed, it is easier to define than “Person” (but not just is a frame/semantic network notation).