Semantics

- What is Semantics?
  - "the scientific study of the relations between signs or symbols an what they denote or mean". (Woods).
  - The correspondence btw linguistic expressions & the things they denote or mean.

Two views (Linguist vs Philosopher)

Linguist is concerned with the translation of natural lang. Into formal representations of their meanings.

Philosopher is interested in the meanings of such formal representation (determining when an expression is "true" or "false").

Semantics

- Procedural Semantics

Specification of truth conditions can be made by means of procedures/functions as well. A function that assigns truth values to propositions in a particular world. ("Procedural Semantics").

- Misconceptions about Semantics
  - Extending the coverage of the term to relation between linguistic form & meaning, and also to all of the retrieval & inference capabilities of the system. (for lack of terminology. So we can use sth like: "semantic inference" instead of extending the meaning of the term).

Semantics

- Misconceptions about Semantics
  - At the other extreme there are those who say that there is no difference in principle between syntax & semantics

How do we figure out what part of the system is semantics?

Semantics of programming languages

- Programming languages lack many of the features of the natural languages. They are not sufficient for modeling the semantics of natural language.

- The advantage of programming language theorists over philosophers & linguists:
  - Their semantic representation is based on procedures that the machine is to carry out, so "they stand on firmer ground"! The procedure is itself abstract which only gets instantiated whenever it is carried out, otherwise, all you have when it is not running is some representation of it.

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- Other competitors: predicate calculus, Lakoff-type deep structures, etc…
- What are the criteria / requirements for this representation?
  - We need a precise, formal, unambiguous representation of any particular interpretation humans place on a sentence.
  - Adequacy
  - An algorithm/procedure for translating the original sentence into this representation
  - Algorithms which can make use of this representation in inferences and deductions.

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Concepts:

- Intensions & Extension

  Example: the word "red"

  Intension: the notion of redness. An abstract entity characterizing what it means for sth to be red.

  Extension: The set of all red things.
- Attributes & Values

  Example: Height 6 feet, Age 25

  JOHN

HEIGHT	6 feet
AGE	25

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Challenges:

"John's height is greater than 6 feet?"

JOHN

HEIGHT(GREATERTHAN 6 FEET)

So the node can now be a predicate which must be true of the value.

"John's height is greater than Sue's."

Have John & Sue connected via the HEIGHT link to intensional nodes representing "Sue's height" & "John's height", then we can establish a relation GREATER between the two intensional nodes.

Woods suggest using the concept of EGOs, which tell what a given node stands for.

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- Links & Predicates

  "John likes Sue."

  JOHN

  LIKES SUE

  (here the link stands for a relation between the nodes & not an attribute).

  We need a unifying interpretation for the two types of links.

  One possible solution is Church's lambda notation:

  (LAMBDA (X Y) (EQUAL (HEIGHT X) Y)).

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Other challenges:

- Relations with more than two arguments

  how to show sth like: (LAMBDA (X Y Z) (Y is btw X & Z))?

  One inadequate way would be:

  Y

  LOCATION (BETWEEN X Z)

  Semantics of the notation are unknown. Here we need to define what the LOCATION link means!

  Finding a natural binary decomposition for sentences involving more than 2 arguments is not guaranteed.

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Solution: Case Representation

case: "is the name of a particular role that a noun phrase or other participant takes in the state or activity expressed by the verb of a sentence."

example: "John sold Sue a book"

John (*agent)* , Sue (*recipient*), Book (*patient/object*)

Here the fact is no longer asserted by a link but by a node.

SELL

AGT	JOHN
RECIP	MARY
PAT	BOOK

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A better way to represent the same sentence is:

S1234

VERB	SELL
AGT	JOHN
RECIP	MARY
PAT	BOOK

S1234 is a unique internal handle on the node representing this instance of selling. SELL becomes an internal handle on the concept of selling.

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- Assertional & Structural links

assertional: Their presence represents an assertion btw the nodes they connect. They are not part of the EGO of a node.

Functional/structural: They constitute the definition of what a node means.

(example see AGT/VERB/RECIP links for node S1234).

- Problems in Knowledge Representation
  - Representation of restrictive relative clauses
  - Representation of quantified information

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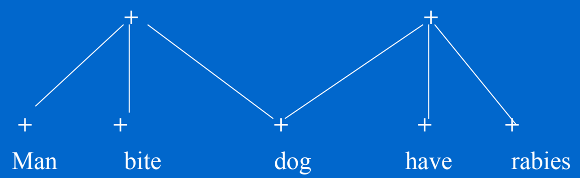
- Relative cluases
  - One technique for dealing with relative cluases is to take the main & the relative cluases and just represent them as two separate propositions, which is inadequate.

  Example: “The dog that had rabies bit the man.”



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- Relative cluases
  - The transient-process

  The relative clause has a temporary rule (used to understand for example which dog we are talking about) but it is not a new fact to be added to our system and it goes away once it serves its purpose.

  Arguments against the transient point of view:

  - It doesn’t take care of all occurrences of relative clauses. When you read the sentence out of context & don’t know about the dog! What should the process do then?

    This can be solved by using EGO.

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  - 2nd argument: Let’s say we go with the transient model, we still need sth equivalent to use for the search process. The model doesn’t eliminate the need for this representation.
  - 3rd argument: The transient-process doesn’t solve the problem at all! It just pushes the problem onto someone else’s plate.

  So a bigger question here is how exactly do we represent complex sentences?

- Definite & Indefinite Entities

When you infer a node like “**the** dog that bit the man”, this node has a certain definiteness to it and we can later on refer to it and add additional information about it. “the” represents a certain dog & not a class of dogs.

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Now consider: “Was the man bitten by **a** dog that had rabies?” We have a description of an indefinite dog. We are not asserting that such a dog exists we are questioning its existence.

Allow the construction of this new node type (intensional nodes) which doesn’t necessarily represent a real existing object.

Example: “I want a vacation.” You don’t assert the existence of the object desired, but you must have some representation for it!

- Consequences of Intensional Nodes

How to tell the 2 types of nodes apart? How do you know which type of node to create given a sentence? How to perform inference?

Ex: “every boy loves his dog” (a variable definite object)

Ex: “every boy needs a dog” (a variable indefinite object)

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- Quantified expressions

"3 lookouts saw 2 boats" (ambiguous)

3 possible interpretations are:

1) 1 group of 3 lookouts participated in the act of seeing 1 group of 2 boats.
2) Each of the 3 lookouts saw 2 boats (between 2 to 6 actually!)
3) Each of the 2 boats was seen by 3 men.

One thing we don't want to do:

Creating 3 nodes for the men & asserting about each of them that they saw 2 boats! Although it could be logically sound, it is not a good representation! (imagine representing "250 million ppl live in US"!)

Impossible to represent universally quantified expressions over sets with an unknown cardinality.

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- Quantified expressions

1) (∀X/integer) (∃Y/integer) (GREATER X Y)
2) (∃Y/integer) (∀X/integer) (GREATER X Y)

One possible representation (quantifiers as higher operators):

treat the quantifier as predicates which "take as arguments a variable name, a specification of the range of quantification, a possible restriction on the range and the proposition to be quantified.

1) (FOR EVERY X / INTEGER: T ;
   (FOR SOME Y / INTEGER: T ; (GREATER X Y)))
2) (FOR SOME Y / INTEGER: T;
   (FOR EVERY X / INTEGER: T ; (GREATER X Y)))

*T is a proposition restricting the range. Whatever is after "**;**" is the proposition being quantified.*

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S1200

TYPE	QUANT
QUANT_TYPE	EVERY
VARIABLE	X
CLASS	INTEGER
RESTRICTION	T
PROP	S1201

S1201

TYPE	QUANT
QUANT_TYPE	SOME
VARIABLE	Y
RESTRICTION	T
PROP	S1202

S1202

TYPE	PROPOSITION
VERB	GREATER
ARG1	X
ARG2	Y

(Technique used by Shapiro 1971).

The cost we pay here is in the directness of associative paths!

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- Quantified expressions

Other representations are:

- Skolem function method (also used in resolution thm. Proving)

The quantified expression you begin with should not have negative operators in its quantifier prefix.

Exchange: ("not every" for "some not" & "not some" for "every not")

Replace (∃) variables with unique function names whose arguments are the (∀) variables, in whose scopes the existensially quantified variable lies. Then delete the (∃ quantifiers) and also the (∀ quantifiers).

Example: $(\forall x)(\exists y)(\forall z)(\exists w)\ P(x,y,z,w) \equiv P(x, f(x), z, g(x,z))$

The good thing about this representation is that the implicit functions above can be used to represent things we refer to in natural language dialogs.

Example: "Is there someone here from Virgina? If so I have a prize for him"

him refers to the value of such a function.

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- Quantified expressions
- Lambda abstraction method (a notational variant of the higher-operator quantifier)

"every integer is greater than some integer"

(FORALL INTEGER (LAMBDA (X)
    (FORSOME INTEGER (LAMBDA (Y)
    (GREATER X Y)))))

For each value of X you get a different predicate to be applied to the Ys.

The representation of the above in semantic network will be the following:

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S1200

TYPE	PROPOSITION
VERB	FORALL
CLASS	INTEGER
PRED	P1201

S1201

TYPE	PREDICATE
ARGUMENTS	(X)
BODY	S1202

S1202

TYPE	PROPOSITION
VERB	FORSOME
CLASS	INTEGER
PRED	P1203

P1203

TYPE	PREDICATE
ARGUMENTS	(Y)
BODY	S1204

S1204

TYPE	PROPOSITION
VERB	GREATER
ARG1	X
ARG2	Y

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- Conclusion

There are still other problems to be solved such as the representation of "mass terms, adverbial modification, probabilistic information, degrees of certainty, and time.