On Eliciting Requirements For Agent Semantics From Linguistics Concepts

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Semantics is a limiting issue for agent transactions.

- We use agreed protocols for the exchange of data. On each side of the exchange, data are held within a model of a domain.

- **BUT,**
  Agents lack agreement on *the methods for semantic exchange.*

- **BECAUSE**
  Semantic exchange is not defined
An Analogy for a Goal ...

Agent-to-Agent ESPERANTO

Agent-to-Human ESPERANTO
We are Seeking
An Engineering Solution

We Will Build It.
An Engineering Solution is Formed From …

- Precise definitions
  - Including: Words, sentences, ontologies, meaning, semantics, knowledge, ...
- Underlying principles
  - Equality, replacement,
- Embodiment
  - Key data structures
  - Needed algorithms
- The Criteria for Success and A Means to Establish Proof of Success
Perspective

- Agent Semantic Transactions is **Not a solved problem**
- As a first step towards reaching a solution, a clear **statement of requirements** is needed.
- Because natural language is our primary source of semantic exchange, **linguistics offers a source of those requirements**
- Within linguistics, semantic exchange may be partitioned into two levels
  - Low-level; referents, structures, sentences
  - High-level; dialogues, Q&A, roles/identities, speech acts, ...
- High level semantics depends on low level semantics
Other Sources of Requirements

- Sign Language
- Mathematics
- Logic
- Maps
- Signs / Semiotics
- Chemistry
- Music
- Body Language
To instigate discussion, included in the presentation are:

- Some issues in semantic transactions
- Some draft requirements
- Some claims and some local definitions

- Slides marked with reflect my personal perspective
Some cautions for using linguistics as a source of requirements

- Only a small part of linguistics, (semantics and grammar) offers support
  - Phonology, History, Semiotics, ... provide little additional information
- There are substantial disagreements among linguists on many topics
  - “The Linguistic Wars”
- Much of the work is speculative and has little experimental validation

However, linguistics references supply excellent sets of posed problems, insights, and examples
Coarse Outline

- Why Agents Need Semantics
- Requirements
- A Perspective on Semantics

Low Level Semantics
- Referents and Words
- Lexical Structures
- Sentences
- Organization of Sentences
- Control of Organizations

High Level Semantics
- Questions & Answers
- Identities and Roles
- Pragmatics
- Context
- Dialogues

Making Sense with Others

Making Sense
Semantics

An account of how abstracted representations are linked to their real world counterparts.

-- After Patrick Hayes, 1974
How We Inform Each Other

Semantic Exchange

Performative
- Visual
  - Pantomime
- Audible
  - “Hum a few bars”

Representational
- Graphical
  - Barber Poles, Portraits
- Symbolic
  - Letters, to Words, to Dialogues
Linguistic Viewpoints on Meaning

- Usage of words (Wittgenstein)
- Referents
- Field (related terms) (Muller)
- Affect (Osgood)
- Prototype / Ideal / Category (Lakoff)
- Semantic nets (e.g., Schank)

- Entailments (Logic)
- Translation
- Process / Action (meaning exists in terms of process)
Semantics is not knowledge

- Knowledge (what-we-know) is captured in terms of semantics and held as instances in memory.

- Better representation and expressivity in semantics enable better recording of knowledge.

- Domain models mimic memory, the recorded form of knowledge
  - Lexical
  - Indexical
  - Episodic
Knowledge in Domain Models (Memory Structures)

- Indexical Model
  - Classification
  - Categories
  - Entities
  - Relations
  - Attributes
  - Values
  - Instructions
- Indexical Instances
  - Facts
  - Descriptions
  - Statements
  - Processes
- Context
- Conditionals

- "Catalog"
- "Books"

- "Movies"

Scenes
Sequences
Episodic Instances

"Catalog"
"Books"
Two fundamental Low-Level Semantics Requirements

- Representation
  - Can we say what we mean?

- Expressivity
  - How well can we say what we mean?
Low-Level Semantics IS about representation and about expressivity BUT it is not about “TRUTH.”

Knowledge may be ...

- Wrong
- Redundant
- Conflicting
- Missing
- Degraded
- Duplicated
- Changing
  - Changed again
- Validated (or NOT)
- Referenced (or NOT)

In 786 AD, it was “true” that the world was flat.

BEFORE we can assess “TRUTH” of the matter, we need to express it.
The Goal is Not to Reason

- True/false are not of interest...
- The goal is to represent so that some external process may reason.

If you want modal logic, we must provide modal verbs;
If you want temporal logic, we must provide tense and aspect.
If you want subtraction, we must provide numbers.
Meaning Links
Referents with Actions

- Process (Actions)
  - Protocols
  - Framework – Contracts
- Upper
  - Dialogue
  - Context
  - Pragmatics
  - Questions & Answers
- Lower
  - Sentences
  - Static Structures
  - Words
  - Referents
Semantic Sense vs. Meaning

- George: “Please give me the hammer.”
- Gracie: “There is ice in the cooler.”

Makes sense but is not meaningful to the process

Colorless green ideas sleep furiously.
-- Noam Chomsky

Makes no sense
Low Level Semantics Makes Sense

Low-level Semantics is about making sense by placing the right words into sentence structures.

Low-level Semantics
- Is Not about Reasoning
- Is Not about Truth
- Is Not about Knowledge
- Is Not about Meaning
Meaning is based on connections:

I. From real-world referents to their lexemes

II. Through difference relationships of lexemes with other lexemes

III. By the coupling of lexemes into sentences

IV. To affect processes

What the Words Identify

The Right Words

Making Sense

Providing Meaning
High-level Semantics Enables Exchange

- Question and Answers
- Context
- Pragmatics
  - Roles & Identities
  - Deixis
  - Implicature
  - Speech Acts
- Dialogue
The Interactions in Linguistic Semantic Exchange are Complex

Words

Variations

Sentences

Questions

Answers

Referents

Lexical Structures

Ontological Structures

Episodic Structures

Pragmatics

Process “A”

Dialogue

Process “B”
A Difficult Problem

Think of the first time someone considered how to represent integers and real numbers within a fixed word size...

This is much more complicated.
Part 1 Low-Level Semantics

Making Sense
Exchange is enabled and constrained by the common models.

- **My model** of the world
- **Common Model of Some of the World**
- **Your model** of the world
There are many common models

- My model of the world
- Common Model of Some of the World
- Common Model of Some of the World
- Common Model of Some of the World
- Your model of the world
Three ways to acquire knowledge

- Sensors
- A model of the world
- Analysis
- Exchange
- Another model of the world
When we answer a question, we use the “what we know” which is held in the domain model to chose the lexemes needed. Then we apply a grammar (“how we say it”) to populate the sentences that comprise the answer.

A Personal Model “What I Know” Expressed as sentences and held episodically and indexically

Inside the Symbolic Model
Exchanges between models are made with sentences
Draft Requirements

Agents will need to map:
- Lexical Structures
- Ontological Structures
- Episodic Structures

Two possible methods:
- A direct mapping or
- An indirect mapping to a shared structure
Linguistics as a source of requirements

Natural Language has been our medium of exchange for a very, very long time
Natural Language is a basis of requirements for symbolic semantic exchange.

There are many ways to “say” the same thing ...
Coarse definitions

- A Language consists of a set of words and the set of possible sentences they can create
  - It may also include sounds, gestures

- A Sentence –
  - An output of a grammar
  - What we can say / write

- Lexeme – a element used in a sentence
  - Usually a word or combination (e.g. blue-green ocean)
  - A morpheme – an element of a word
    - Unpleasant
What the Words Mean -- Lexemes and Lexical Structures
Referents:
From Reality to Representation

Word: Tree

Character / Alphabet - Sanskrit

Graphical Composite-Symbols - Chinese

Sound Partitions / Hieroglyphics

Ordered Graphical Symbols
American Sign Language

Symbols for Semantic Sounds

Graphical Symbols
Barber Pole, Trademarks,

Semantic Sounds

Mediation

Sensor
Referents –
The real world side of the abstractions

- Referents are:
  - Processes
    - Growing
    - “verb”
  - Results of Processes
    - A Tree
    - “noun”
  - Descriptions that apply to multiple processes and results
    - Slowly (applies to many processes)
    - “Adverb”
    - Green (applies to many results)
    - “Adjective”
Referential Semantics

Every lexeme must be traceable to some real world reference(s).

Blue:

the color of the clear sky in the day viewed from the earth
Agent Issue #1: What Color is Blue?

Different languages and different cultures do not map lexemes to the same referents. How do we know what standard is being used?
From Lexeme to Referent; A One-to-Many Map
The Scope of a Lexeme

- To have meaning, every lexeme must be traceable to some real world reference(s).

- These referents differ in scope among:
  - Languages,
  - Cultures, and
  - Individuals.
Language Scope

- Different Languages express “common concepts” with differing precision and referents

- Physics:
  - Color requires three dimensions in physics (e.g. Hue, Saturation, Intensity)

- Language
  - In English, blue is a single color;
    - In Russian it is two.
  - In Welsh, blue is “glas”
    - But it is also the color of growing things
  - Black, white, and grey have no hue;
    - are they colors?
Cultural Scope

- **Culture**: Lexemes are defined in terms of cultural standards.

- E.g., What makes someone “good” is often determined by a comparison to ideal actions in a process context.
  - ‘A good person’ will tell the truth in every circumstance.
Blue:

- the color of the clear sky
- in the day
- viewed from the earth

*What if you are color blind?*
Unicorns

- What if there is no referent?
  - A camel is imagined beast in Antarctica

- We can construct new elements within lexical classifications by combining attributes without regard to "reality" or other constraints.
  - "A unicorn is the same as a horse except there is also long horn on its forehead ..."
  - We need these capabilities to express conjecture – ('what if ...")
Agent Issue #2: Hogs v. Pigs

You are selling hogs.
I am buying pigs.

How do we know if my definition of a pig is sufficiently the same as your definition of a hog for the purpose of this transaction?

Would a steer be an acceptable replacement?
Natural Language can be ambiguous

- Because of Syntax
  - Pronouns
    - John and Sam were dueling
    - He shot him.
  - Modifier Order
    - The man was dancing with a wooden leg.

- Because of Overloading
  - Words
  - Functions

Ambiguity is unintentional;
Generality is purposeful
Hot! - An overloaded word

- Spicy
- Warm
- Color
- Attractive
- Stolen
- Doing very well

Polysemy: Same word; different meaning
Draft Requirements -- Referent

- No ambiguity!
  - No pronouns
  - No polysemy
  - No homonyms
  - No overloading of cases
The Scope of a Lexeme

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  - Languages,
  - Cultures, and
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Language Scope

Different Languages express “common concepts” with differing precision and partitions in their referents

Physics:
- Color requires three dimensions in physics (e.g. Hue, Saturation, Intensity)

But in Natural Language ...
- In English, blue is a single color;
  - In Russian it is two (“sinij” and “goluboj”).
- In Welsh, blue is “glas”
  - But glas is also the color of growing things
- In Hanunoo, there are only four colors
- Black, white, and grey have no hue;
  - Are they colors?

See David Crystal
Cultural Scope

- **Culture**: Lexemes are defined in terms of cultural standards.

- E.g., What makes someone “good” is often determined by a comparison to ideal actions in a process context.
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Individual Scope

Blue:
the color of the clear sky
in the day
viewed from the earth

What if you are color blind?
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Would a steer be an acceptable replacement?

Does it matter if it is dead or alive?
Natural Language can be ambiguous

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- Stolen
- Doing very well

Polysemy: Same word; different meaning
Plurals –

- Plural forms are a change in morphology to indicate More Than One

- More than one?
  - In English, the plural refers to more than one
  - In other languages, it can refer to more than two, or more than three ...

- Polysemy Plurals – the plural changes the definition
  - Singular:
    - “Provision” – part of an agreement
  - Plural
    - “Provisions” – supplies

See David Crystal
Closed vs. Open Word Classes

- **Open Class**
  - We make up new words
    - Nouns, Verbs, Adjectives, Adverbs, ...

- **Closed Class**
  - We use only the words already available:
    - Conjunctions
    - Demonstratives
    - Quantifiers
    - Prepositions
Draft Requirements – For Lexeme Referents

- No ambiguity!
  - No pronouns
  - No polysemy
  - No homonyms
  - No overloading of cases
Lexical Structures

The relationships of words to their referents and with one another
Overlapping Lexical Structures

- Dictionaries
  - OED – Oxford English dictionary

- Word Nets
  - Roget’s Thesaurus
  - May or may not be included in a dictionary
Dictionaries

More than a difference
The Lexicographer's Task

After George Miller

Definition

Wrench
Agreement of words is the basis for communication

What do you mean by tree?

Katie’s Tree Definition
- Has Height
- Has Color
- Is Near Water

Jan’s Tree Definition
- Has Height
- Has 1st Color
- Provide fire
- Has 2nd Color

The AGREED Definitions of Jan and Katie

Dictionary
Types of Definitions

- **Constructive**
  - Provides the information needed to construct an instance

- **Differential**
  - Assumes meaning of at least one related term is already understood
    - “Canine” may be defined by reference to: “dog”, “wolf”, and “fox”
  - Provides the information needed to confirm / distinguish an instance
A Constructive Use Of A Differential Definition

- Dictionary definition of “Erode”
  - “To eat out, to eat away”
- A little girl wrote:
  
  "Our family erodes a lot."

    -- George Miller
What Constitutes a Definition?

- ... Some Criteria
  - A function based on attributes and their values
- ... or A Prototype
  - An “average” of attributes
- ... or Exemplars
  - A list of examples
- ... or A Standard
  - An agreed referent
    - E.g. the standard meter in Paris
There is more than one Dictionary.

Agent Dictionaries will need to include Decision Functions.
A Word ... is pointer to a Description with an embedded Decision

When we talk about trees, we refer to:

- A description
  - Tall, green, plant, ...

- Plus ... the criteria to determine if an individual instance matches the description
  - A tree is larger than a shrub
When is a cup a bowl?

- The criteria gives a different output as there is a change in the values of attributes (height, width).

After George Miller
Different Criteria Prove Different Structures

- Cladists vs. Pheneticists -- Different Criteria for Biological Taxonomy
  - Pheneticists:
    - Similarity in form, function, and biological role
    - "If it walks like a duck and it talks like a duck ..."
  - Cladists:
    - Shared, derived evolutionary characteristics

"... I regret to report that there is surely no such thing as a fish."
– Steven J. Gould
(What, If Anything is a Zebra? 1983)
Draft Requirements - Definitions

- We must establish the Scope of the Lexemes
  - The Referents subtended by a Lexeme
  - Its Affectivity: time; location; conditions ...

- There must be One True Source of Definition
  - A single Location
    - A definition
      - External reference (human reference)
      - Internal
    - Datatype (image, sound, ...)
  - A decision function
    - Tells what matches or does not match

- A responsible party must maintain the definition.
Word Nets

“You shall know a word by the company it keeps.”
-- J. R. Firth
Suppose there was only one word ...

- We construct new words to portray differences.
Differences Provide Meaning

1) Distinctions in word definitions
2) Differences in How Words Relate to One Another

We use lexical structures to identify and to organize the differences among lexemes.

A rich set of definitions and relations allow us to find “just the right word.”
Lexemes are related in Lexical Structures

- The lexical structure describes how words are semantically differ from one another.
  - Words can be semantically associated by ...
    - Synonymy
    - Antonymy
    - Meronymy
    - Hyponymy
    - Incompatibility
    - Compatibility

These associations are not relationships; they are the types of relationships
Synonymy

- Synonyms “mean the same” (almost)

- Lexical classifications can be very different from real-world classifications
  - Worms are regarded as insects (in Japanese)

- Synonyms depend on **conditions**!
  - “Dutch” may be a synonym for “South Africa”
Antonymy

- Antonyms
  - One term excludes the others
    - Think: “radio buttons”
  - Gradable: an ordinal scale
    - High/Low allows Very high, ... very low
  - Complements - binary values only
    - On/ Off

- Antonymous groups
  - Mutually exclusive values
  - Selection list: Rose, Iris
  - Selection list: North, South, East, West
    - AND North is opposite to South ...

- Cyclical
  - Sunday, Monday, ... Saturday

- Hierarchies
  - Ranks in the Military
Hyponymy

- Hyponym – a term whose meaning is included in another term
  - Dog is a hyponym of animal
  - Animal is a hypernym of dog

- Hyponyms are more restrictive than their hypernym
  - In a data model, they have additional attributes or limited values of attributes

- The restrictions may not imply alternative values
  - Lamb is a young sheep
  - There is no single word for “not young sheep”

In data models, they occur in relationships called
- “IS-A” or “A KIND OF”
Hypo/Hypernyms -- “IS A”

"A fox is a canine."

Many to one

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<th>Parts</th>
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<td>ZZZ</td>
<td>Cats</td>
</tr>
<tr>
<td>SSS</td>
<td>Horses</td>
</tr>
</tbody>
</table>
Lexical Blocking -- a side effect of hyponymy

To convey precision in our descriptions, we choose words that are neither too general nor too specific.

- There is a cow in my office.
- There is an animal in my office. (Too general: Conveys insufficient information)
- There is a Holstein in my office. (Too specific: Conveys useless information)

To convey meaning, the appropriate term “blocks” the others.

- Blocking may be partial
  - Is a thumb a finger?

- The boundary may be vague
  - Is a hill a kind of mountain?
The Manner of ... Troponyms

- Hyponyms for verbs
  - E.g., Stagger is a troponym of walk
Part / Whole -- Meronymy

- Think: “Bill of Materials”

- Whole/part relationships are different than hyponyms
  - A leg is part of a chair but not a kind of a chair.
  - Chair is NOT a hypernym of leg.

- In data models these relationships are called “HAS-A”
Part / Whole -- “HAS A”

“The green Mercedes has a wheel and has a handle ....”
Types of Meronymy

- Component/Object (branch/tree)
- Member/Collection (tree/forest)
- Portion/Mass (slice/cake)
- Feature/Activity (paying/shopping)
- Place/Area (Idaho, USA)
- Phase/Process (Child/Person)
Constraints:
Semantic Incompatibility

- Incompatible – a term whose sense is excluded by another
  - A flower that is a wind

- Sometimes the semantics are unclear
  - Should “black, white, and gray” be allowed as colors?
Semantic Compatibility

- Words that may ‘go together’
  - Mother
    - Birth, Foster, ...
  - Black
    - But not green
Lexical Claims

- There will be alternate lexical structures
- Remember that different sources will produce different structures
  - Lexical $\neq$ Lexical
  - Lexical $\neq$ Physical
  - Physical $\neq$ Physical
- These differences occur not only across languages but also within languages
Summary (so far)

- Linguistics is a source of semantic requirements
- Low level semantics is the basis for "making sense."
- "Making sense" is the first requirement of Agent Semantics
- Making Sense depends on:
  - Mapping words with their referents
  - Combining those words into sentences
- Better Sense depends on:
  - Choosing the right words based on lexical relation

Representation
Expressivity
Next -- Part 2. Sentences

A sentence is a semantic unit that is built by combining words with one another.

Of interest is how the words may be combined.