Human and Machine Understanding of Natural Language (NL) Character Strings

Presented by Peter Tripodes

The Problem

To impose structures on NL character strings which make it possible to:

- Account for different ways that humans might understand them.
- Account for how different ways of understanding them induce different patterns of deductive connections among them.
- Infer ways of understanding from the patterns of deductive connections which they induce.

For This Purpose

Structures of NL character strings need to be:

- Conceptually Natural (to account for how humans understand them)
- Flexible (to account for different ways that humans understand them)
- Usable as a Deductive Base (to account for how different ways of understanding them induce different patterns of deductive connections among them, and from which those ways of understanding them can be inferred)

Conceptually Normal Structures of NL Character Strings Are Structures that:

- Preserve the order of their constituent characters.
- Reflect as directly and simply as possible how those characters enter into meaning-bearing combinations.

pgtripodes@cs.com - PeterGTripodes.com

The question is...

- Are conceptually normal structures of NL character strings compatible with their being usable as a deductive base.?

Historically, Two Types of Structures

- <u>Logic based structures</u>: Usable for machine deduction, but not conceptually normal.
- <u>Linguistic based structures</u>: Conceptually normal, but not usable for machine deduction.

Readings

- We propose structures of NL character strings called “readings,” which are defined along the lines of logic based structures, but which are conceptually normal and flexible as well as usable as a deductive base.

Readings, Intuitively Considered

- Intuitively, a reading of an NL character string is a way of understanding it as an organization of meaning bearing parts together with an assignment of meanings to those parts.

pgtripodes@cs.com - PeterGTripodes.com

Readings, Formalized

- A reading of an NL character string c is formalized as a pair consisting of:
  - A syntactic structure of c (SYN(c)) +
  - A semantic structure of c (SEM(c)) where:
    - SYN(c) = A formal representation of the meaning bearing parts of c and of their mode of organization.
    - SEM(c) = The set of all assignments SEM(c/f) of set theoretic meanings to the meaning bearing parts of SYN(c) imposed by interpretations f.

Our proposed notion of reading...

- Differs from usual logic based structures for NL, with respect to both SYN(c) and SEM(c).
- I will be talking here primarily about SYN(c).

pgtripodes@cs.com - PeterGTripodes.com

Expressions of SYN(c)

- An expression of SYN (c) is a tree structure whose leaves are representational morphemes and whose (single) root is either unlabelled or labeled R (with or without superscripts) or labeled T (with or without paired subscripts)

Types of Expressions of Syn(c)

- An unlabeled expression of SYN(c) is called a modifier of SYN (c)
- An expression of SYN (c) labeled with R or R^n is called a relation expression of SYN(c). If labeled R^n, it is called an n-place relation expression of SYN(c).
- An expression of SYN (c) labeled with T or ${}_{l}T_{k}$ is called a thing expression of SYN(c).

pgtripodes@cs.com - PeterGTripodes.com

Some Aspects of the Grammar of SYN(c)

- SYN(c) has no variable.
- The grammar of SYN(c) is an "open" grammar, which means that for any given occurrence of a given character string c, SYN(c) can be an n-place relation expression r^n, a thing expression a, or a modifier expression.
- Rationale of using an open grammar: This type of grammar is needed to account for differences in different users' understanding of given natural language character strings.

Interpretations of Expressions of SYN(c)

- An interpretation f on SYN(c) is a function which assigns denotations to expressions in SYN(c) as follows:
  - f assigns to every n-place relation expression r^n in syn(c) a set f[r^n] of n-tuples of elements of the universe of discourse;
  - f assigns to every thing expression a in syn(c) a set f[a] of subsets of the universe of discourse;
  - f assigns to every modifier expression m in syn(c) a function f[m] which assigns tuples and sets of subsets of elements of the universe of discourse to tuples and sets of subsets of the universe of discourse.

Sentential Readings, Intuitively Considered

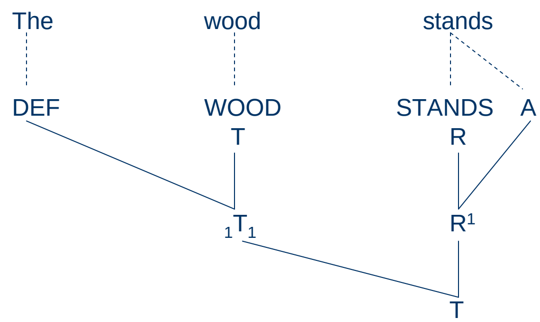
- Intuitively, a sentential reading of an NL character string c is a way of understanding c "as a sentence." That is, as a linguistic entity capable of being judged as true or false.

Sentential Readings, Formally Considered

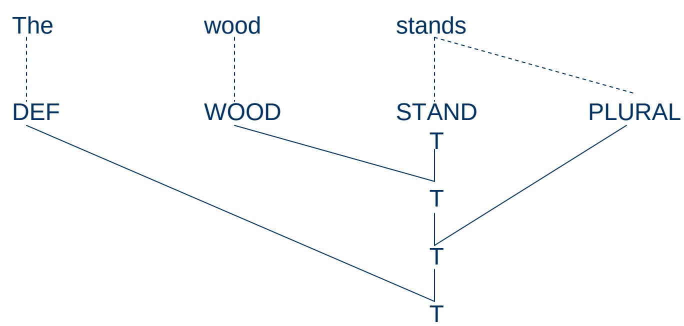
- A sentential reading of an NL character string c is a reading of c whose syntactic structure SYN(c) has the form:
  - $r^n (a_1, ..., a_n)$, where:
  - r^n is an n-place relation expression composed of a base relation $(r^n)^B$ with or without modifiers, together with an ordered set of case markers indicating the semantic roles to be played by each of the n thing expressions occupying the n places of r^n.
  - $a_1, ..., a_n$ are n thing-expressions which are to occupy the n places of r^n, each with or without modifiers, each with an indication of its scope relative to the other n-1 thing expressions occupying the n places of r^n, and its place relative to ordered set of case markers in r^n.

pgtripodes@cs.com - PeterGTripodes.com

Example: A Sentential Syntactic Structure



Example: A Non-sentential Syntactic Structure



pgtripodes@cs.com - PeterGTripodes.com

Regarding Conceptually Natural Readings

- Syn(c) represents the meaning-bearing parts of c and their mode of organization in a manner which parallels the occurrence order and organization of those parts in c.
- Sem(c/f) represents the meanings of those meaning bearing parts assigned to them by the interpretation f; those meanings are sets built out of elements of an underlying domain of discourse, and parallels the mode of organization of those parts.

Sentential Reading Assignments (SRAs)

- A Sentential Reading Assignment (SRA) on a Set C of NL Character Strings

  =

- An assignment of a sentential syntactic structure SYN(c) to each character string c in C.

pgtripodes@cs.com - PeterGTripodes.com

Sets SRA(C) and SRA(C^) of Syntactic Structures

- Let SRA(C) be a sentential reading assignment on a set C of character strings, and let SRA(C^) be a sentential reading assignment on an auxiliary set C^ of character strings.

- SRA(C^) functions as a set of Assumptions for SRA(C).

Induced Patterns of Deductive Connections

- Definition: A Pattern of Deductive Connections induced on C by an SRA(C U C^) is a relation R between subsets C' of SRA(C) and elements SYN(c) of SRA(C) such that:

- R holds between C' and SYN(c) if and only if SYN(c) is true under every interpretation f under which every character string in C'U SRA(C^) is true.

pgtripodes@cs.com - PeterGTripodes.com

Proof Theoretic Version

- The Pattern R could have been defined proof theoretically as well as semantically, as follows:
- "... R holds between C' and SYN(c) if and only if there is a proof of SYN(c) from C' and the set of assumptions SRA(C^).

Normality of Patterns of Deductive Connections

- A pattern of deductive connections on C relative to C^ is *normal* or *non-normal* according as (or to the degree that) that pattern is consistent or inconsistent with language users' deductive intuitions regarding C relative to C^ in typical contexts-of-use.

pgtripodes@cs.com - PeterGTripodes.com

Deductive Normality of SRAs

- An SRA on a set C of character strings relative to an assumptive set C^ is said to be *deductively normal* or *deductively non-normal* according as (or to the degree that) the pattern of deductive connections which that SRA induces on C relative to C^ is normal or non-normal.

Example of a Deductively Normal SRA

- **Let C = {All men are mortal, Socrates is a featherless biped, Socrates is mortal}.**
- **Let C^ = {All featherless bipeds are men}.**
- **Let R be a pattern on C** which included only the deductive implication of “Socrates is mortal” from the set consisting of “All men are mortal” and “Socrates is a featherless biped,” relative to the assumption, “All featherless bipeds are mortal.”
- **R would be considered deductively normal** inasmuch as it would probably be consistent with language users’ deductive intuitions relative to that assumption in typical contexts-of-use.
- **And so would any SRA which induced the pattern R on C relative to C^.**

Example of A Deductively Normal SRA

- Let C = {All men are mortal, Socrates is a featherless biped, Socrates is mortal}
- Let C^ = {All featherless bipeds are men}
- Let R = {<SRA({All men are mortal), Socrates is a featherless biped)>} relative to SRA(CU C^)

Variability in SRAs Used

- Variability in SRAs on a set C of character strings relative to the assumptive set C^ and relative to a context-of-use can derive from various sources:
  - Variability in the syntactic representations used
  - Variability in the semantic representations used
  - Variability in the assumptive set C^
  - Variability in the context-of-use

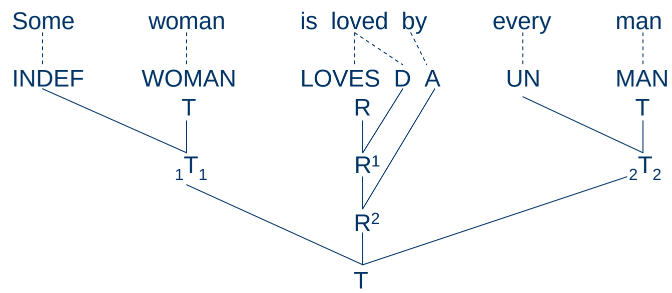
A Further Example

- Let C consist of the following character strings:
  1. John is a man.
  2. Some woman is loved by every man.
  3. Some woman loves every man.
  4. Some woman loves John.
  5. John loves some woman.

A Further Example (cont'd)

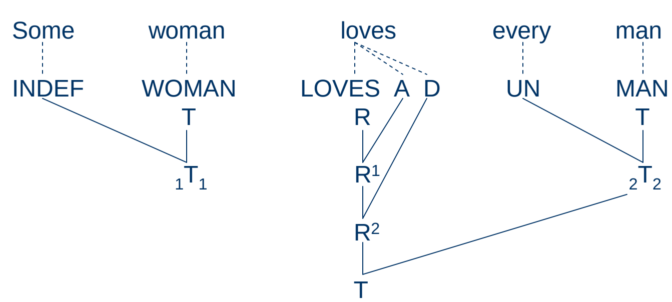
- A *deductively normal pattern (A)* of deductive connections on C relative to an empty assumptive set C^ would include the following deductive connections: (1) and (3) together deductively imply (4), and (1) and (2) together imply (5).
- Pattern (A) would be induced by an SRA-1 which included the following syntactic representations SYN-1(2) and SYN-1(3) of character strings (2) and (3) respectively.

SYN-1(2)



[i.e., Some woman is such that she is loved by every man.]

SYN-1(3)

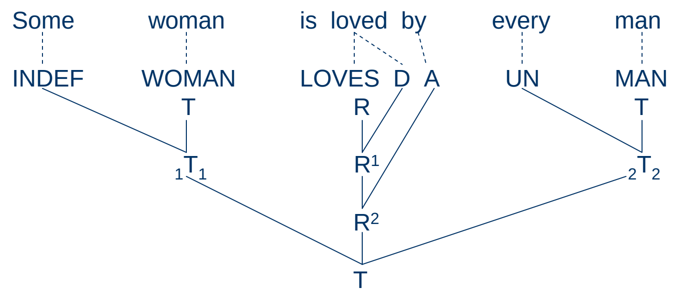


[i.e., Some woman is such that she loves every man.]

Deductively Non-normal Pattern (B)

- A *deductively non-normal pattern (B)* of deductive connections on C relative to an empty assumptive set C^ would be one which included the deductive connection that (2) and (3) deductively imply each other, so that (1) and (2) together now deductively imply each of (4) and (5).
- Pattern (B) would be induced by an SRA-2 which included the following syntactic representations SYN-2(2) and SYN-2(3) of character strings (2) and (3) respectively.

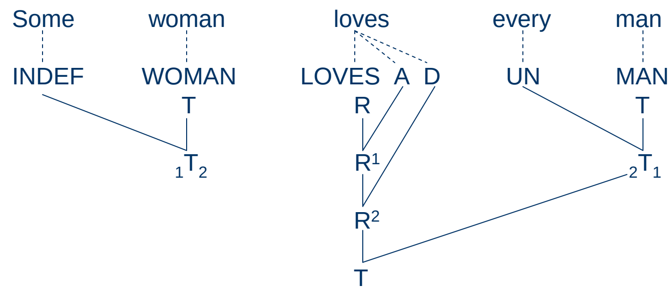
SYN-2(2)



[i.e., Some woman is such that she loves every man.]

pgtripodes@cs.com - PeterGTripodes.com

SYN-2(3)



[i.e., Some woman is such that she is loved by every man.]