Natural Language Processing vs. Logic.
Is logic useful in the computational interpretation of language?

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Communication through language
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Communication through language

thought

emotion

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Communication through language

thought

emotion

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language

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Communication through language
Logic and NL

• Logic: the expression of rigour
• Challenge of logical formalisms in NL: code any language expression in logical form
• Usefulness: clear out ambiguities

• Skeptics: to what extend can a message be encoded in logic?
The logic of language communication

...two horses...

– the emitter is a man, lives in England in 1926, a worker of the field
– the receiver is this man’s master

⇒

– both emitter and receiver have a common knowledge on the word horse
– the emitter knows that the receiver has the same meaning as himself on horse
– the emitter intends to make the receiver build the representation:

\[ S = \{ x \mid \text{horse}(x) \} \land \text{card}(S) = 2, \]  
where:

\[ \text{card}(S): \text{the cardinal of the set } S, \]

\[ \text{horse}(x): \text{a qualifying function asserting that } x \text{ belongs to a class of objects sharing the semantic property that is currently denominated in English by the word } \text{horse}, \text{ and that the pragmatic context in which the expression is uttered clearly separates the different meanings that this English word may encode.} \]

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When is logic of help...
Chunks level: Generative Lexicon and Qualia Structures


- meaning of words decomposed on 4 coordinates:
  - *Formal* (F): encoding taxonomic information about the lexical item (the *is-a* relation);
  - *Constitutive* (C): encoding information on the parts and constitution of an object (*part-of* or *made-of* relation);
  - *Telic* (T): encoding information on purpose and function (the *used-for* or *functions-as* relation);
  - *Agentive* (A): encoding information about the origin of the object (the *created-by* relation)
Qualia Structures

• Represent meaning of compositions of words
  – *large car* (F = vehicle),
  – *broken car* (C = motor),
  – *speedy car* (T = drive),
  – *Italian car* (A = made in Italy)
What skeptics grump?

- How to master the enormous range of possible combinations?
- Has *likes* the same meaning?
  
  – *He likes my sister.* vs. *He likes vanilla ice cream.*
Discourse level: meaning of sequences of sentences

*Maria dropped the egg from her hand.*
*She cleaned the floor.*
To link sentences we make inferences.

Maria dropped the egg from her hand.
To link sentences we make inferences

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To link sentences we make inferences

Maria dropped the egg from her hand.

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To link sentences we make inferences

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She cleaned the floor.

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To link sentences we make inferences

Maria dropped the egg from her hand.
drops(AG: Maria, OB: egg) => falls(REC: egg) => touches(AG: egg, OB: X)
   Qualia.Formal(egg) = container;
   Qualia.Constitutive(egg) = {eggshell(fragile), liquid}
=> breaks(REC: eggshell) => leaks(REC: liquid, ON: X) =>
   perceives(AG: Maria, OB: dirty(X))

She cleaned the floor.
=> cleans(AG: Maria, OB: floor) =>
   perceives(AG: Maria, OB: dirty(floor))
To link sentences we make inferences.

Maria dropped the egg from her hand.

She cleaned the floor.

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To link sentences we make inferences

Maria dropped the egg from her hand.
She turned the light on.
Discourse level: variability in language

Meaning

Variability

Language

Ambiguity

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Discourse level: variability in language

• Reduce the distance between form and meaning are: Information Retrieval (IE), Textual Entailment (TE) and Question Answering (QA)
Textual Entailment

• Text $t$ entails hypothesis $h$ ($t \implies h$) if humans reading $t$ will infer that $h$ is most likely true

A true entailment

• $t$: *...a shootout at the Guadalajara airport in May, 1993, that killed Cardinal Juan Jesus Posadas Ocampo and six others.*

• $h$: *Cardinal Juan Jesus Posadas Ocampo died in 1993.*
Textual Entailment

...and of a false one

- $t$: Regan attended a ceremony in Washington to commemorate the landings in Normandy.
- $h$: Washington is located in Normandy.
How is entailment checked?

• $t$:

  *Philanthropic Golding Inc. came into existence in January 2004. One year after its foundation the company declared bankruptcy.*

• $h$:

  *Philanthropic Golding Inc. bankrupted in January 2005.*
How is entailment checked?

• Launch a pipeline of processes, at the end of which the sentences of both $t$ and $h$ are expressed in a symbolic form that allows close comparison.
How is entailment checked?

*Philanthropic Golding Inc. came into existence in January 2004.*

- **Step1**: tokenisation (not shown), part-of-speech tagging (not shown), chunking noun phrases and clashing multi-word expressions.

  &lt;NP id=”n1”&gt;Philanthropic Golding Inc.&lt;/NP&gt;
  &lt;MWE id=”m1”&gt;came into existence&lt;/MWE&gt;
How is entailment checked?

• **Step 2**: recognition of entity mentions, of time expressions and resolution of anaphora.

  `<COREF-LIST id="ent1" TYPE = "ENTITY" REF-LIST="n1" />`
  
  *Philanthropic Golding Inc.* is a named entity

  `<TIMEX3 tid="t1" type="DATE" value="2004-01">January 2004</TIMEX3>`

  *January 2004 is a temporal expression*
How is entailment checked?

• Step 3: functional dependency parsing; here we show a Universal Dependency (UD) coding

[Diagram showing dependency parsing with labels: Philanthropic Golding Inc. nsubj, came into existence mll, in, January 2004 tll, nmod:time, case]
How is entailment checked?

• **Step 4:** time analysis, in which EVENT and TLINK elements, formalizing the events and their temporal relations, are generated.

  `<EVENT eid="ev1" VB="m1" AG="ent1"/>

  The coming into existence of Philanthropic Golding Inc. is an event

  `<TLINK eventId="ev1" relatedToTime="t1"
  relType="BEGINS"/>

  The moment of this event is the one coded by the temporal expression

  January 2004`
How is entailment checked?

• **Step 5**: equivalent structures (transformations) and computation of transitive closures of temporal relations: equivalence of the expressions: *X comes into existence* and *UNKNOWN founds X*  
  
  \[<\text{EVENT} \text{eid}="\text{ev2}" \text{VB}="\text{found}" \text{AG}="\text{UNKNOWN}" \text{OB}="\text{ent1}"/>\]

  The *coming into existence* of *Philanthropic Golding Inc.* can equally be expressed by a founding event in which *PGI* has the object role.

  \[<\text{TLINK} \text{eventID}="\text{ev2}" \text{relatedToTime}="\text{t1}" \text{relType}="\text{BEGINS}"/>\]

  The moment of this event is the one coded by the temporal expression *January 2004*. 

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How is entailment checked?

_One year after its foundation the company declared bankruptcy._

• **Step 1: NP-chunking**
  
  ```xml
  <NP id="n3"><NP id="n2">its</NP>foundation</NP>
  <NP id="n4">the company</NP>
  <NP id="n5">bankruptcy</NP>
  ```
How is entailment checked?

• **Step 2:** NER, Timex and AR

  <TIMEX3 tid="t2" type="DURATION" value="P1Y">one year</TIMEX3>

  *one year* is a temporal expression

  <COREF-LIST id="ent1" TYPE="ENTITY" REF-LIST="n1 n2 n4" />  
  *its* and *the company* are coreferential with *Philanthropic Golding Inc.*

  <COREF-LIST id="eve1" TYPE="EVENT" REF-LIST="ev1 ev2 n3" />  
  *its foundation* is recognised as an event coreferential with the founding of  
  *Philanthropic Golding Inc.*

  <COREF-LIST id="eve2" TYPE="EVENT" REF-LIST="n5" />  
  *bankruptcy* is recognised as an event
How is entailment checked?

- **Step 3**: UD
How is entailment checked?

• **Step 4**: EVENT and TLINK elements

```xml
<EVENT eid="e3" POS="VERB" CLASS="REPORTING"
AG="ent1" OB="eve2">declared</EVENT>

<EVENT eid="e4" POS="NOUN" CLASS="OCCURRENCE"
AG="ent1">bankruptcy</EVENT>

Both acts of *declaring bankruptcy* and of *bankruptcy* itself involving *Philanthropic Golding Inc.* are recognised as events.

<TLINK eventID="e3" relatedToTime="t2" relType="AFTER"/>

<SLINK eventID="e3" subordinatedEvent="e4"
relType="FACTIVE"/>

The declaring bankruptcy event takes place one year after the foundation event.

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How is entailment checked?

• **Step 5**: the Time Closure tool

  <TIMEX3 tid="t4" type="DATE" value="2005-01-xx"/>
  <TLINK eventID="e4" relatedToTime="t4"
  relType="DURING"/>

  The declaring bankruptcy event takes in January 2005.
How is entailment checked?

*Philanthropic Golding Inc. bankrupted in January 2005.*

- A similar processing chain produces:

  `<EVENT eid="e5" POS="VERB" AG="ent1">bankrupted</EVENT>`

  An event of bankruptcy in which is involved *Philanthropic Golding Inc.*

  `<TIMEX3 tid="t5" type="DATE" value="2005-01-xx">January 2005</TIMEX3>`

  `<TLINK eventID="e5" relatedToTime="t5" relType="DURING"/>`

  The moment of this event is January 2005.
Other formalisms

• Natural Logic: Tree structured Recursive Neural Networks can learn to identify logical relationships such as entailment and contradiction...
And when logic is of no use?...
Double negation

- **Double Negation languages** (among which standard varieties of Germanic and Scandinavian):
  - two negative elements cancel each other out resulting in a positive reading:

  > Paul didn’t see nobody. = Paul saw somebody.
  > “There is an individual x, such that Paul saw x.”


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Double negation

• **Negative Concord languages** (among which Romanian and Italian):
  – multiple occurrences of negation are interpreted as one semantic negation:

  *Paul n-a văzut pe nimeni.* = *Paul didn’t see anybody.*
  “It is not the case that there is an individual x, such that Paul saw x.”
Linear position ambivalence

• Associations noun+adjective vs. adjective+noun have different meanings

*femeia singură* => *the woman alone*

* singura femeie => *the only woman*

Linear position ambivalence

10 years ago

today

vechea lui mașină

mașina lui (cea) veche

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Linear position ambivalence...

• ... does not apply to any adjective: certain modifiers make sense only when situated in the pre-position with respect to the modified noun

$biet$ ($poor$, $pitiful$) is not accepted unless it precedes the noun: $biet$ $om$ ($poor$ $man$), but not: $om$ $biet$

Linear position

• The intersection-based composition contradicted:
  – if $X$ (adj) and $Y$ (noun), then $X \cap Y$ (or $Y \cap X$):
    • set of objects $Y$ that have the property $X$
    • intersection between the set of objects having the property $X$ and the set of objects $Y$

$\Rightarrow$ *poor men*: intersection between the set of things which are poor and the set of men

$\Rightarrow$ *still, bieții oameni*: subset of the set of men which are in a pitiful/miserable state
Contexts and the mist of pragmatics

• Textual context: sense fixed by the context
• Disambiguation computed statistically...

Google Translate

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Textual context and word senses

• Logic lacks power
  How would a logical solution work?
  And if one exists, what would be the cost of the supportive lexical-semantic resources to generalise it?
The wood language

• Words induce different reactions in humans: here humorous (contrary to the intention)

“Să luptăm pentru propăşirea neamului şi aducerea României pe cele mai înalte culmi de civilizaţie multilateral dezvoltată.”

(approx. Let’s fight to thrive our stirps and bring Romania on the highest peaks of multilaterally developed civilization.)

The wood language

“The wood language

“Pus astfel în lumină, ancorat în sinergia faptelor, recursul la universalitate nu eludează meandrele concretului.”

(approx. Thus put in light, anchored in the synergy of facts, the appeal to universality does not circumvent the meanders of the concrete.)

attributed to Ion Iliescu

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Style in literature

• Humans perceive co-occurrence of words as producing very suggestive images

“constelația ochilor mei” (the constellation of my eyes)
“atingi cu auzul” (approx. your hearing touches)
“nisipuri de fiară” (beast sands)

Nichita Stănescu, Autoportret în timp de veghe (Auto portrait during watch time)
Style in literature

• Seizing emotions incurred by sentences like the following in logical expressions?

"It’s enough for me to be sure that you and I exist at this moment."

Gabriel Garcia Marquez: *One Hundred Years of Solitude*
Style in literature

• Formalise in logical terms a metonymic sense of an expression?

“lipindu-se de răcoarea tocului ușii” (approx. sticking to the chill of the door frame)

Gabriel Garcia Marquez: One Hundred Years of Solitude

A touched object is replaced with a sensation that the agent borrows from that object.

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Style in literature

• Look for logical equivalent of metaphorical language:

“Te mângâi cu degetele muiate în amintiri.” (I caress you with my fingers dipped in memories)
Style in literature

• Confronted with the extraordinary diversity of suggestions that words can convey, logic seems to me faint, forceless, impuissant.

• How could such poetical expressions be encoded in logical constructions?
And the solution is?

- Logic proves successful in representing many language aspects.
- There should be a limit where the ambition to express natural language in logical form has to stop because it reaches an insurmountable limit.
And the solution is?

- 4 categories of thinkers on the relationship between language and logic
  - the logic purists: everything can be expressed in logical (symbolic) forms
  - the statistical-neural purists: everything can be expressed by statistics/neural formalisms
  - the skepticals: language can never be interpreted totally, neither by symbolic nor statistical means
  - the moderates, dirty workers: only a combination between the two paradigms can help, and this only to a certain limit

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Instead of conclusions

• Their lack of confidence in logic as a universal machinery for processing language comes from observations of the inability of logic to support exhaustively the processing infrastructures of language.

• They don’t believe that each sentence, or each sequence of sentences, should be transformed into a theorem that necessitates a proof.
Instead of conclusions

• Reasoning, that part of language use that necessitates volitional connections in order to decipher information, to find explicit links, without which understanding would be impossible – yes.

• Primary processes that enable the use of language to express emotions, therefore that allow cognition based on language – no.
Thank you!