Formal and distributional semantics model different notions of meaning

Matthijs Westera & Gemma Boleda
Universitat Pompeu Fabra

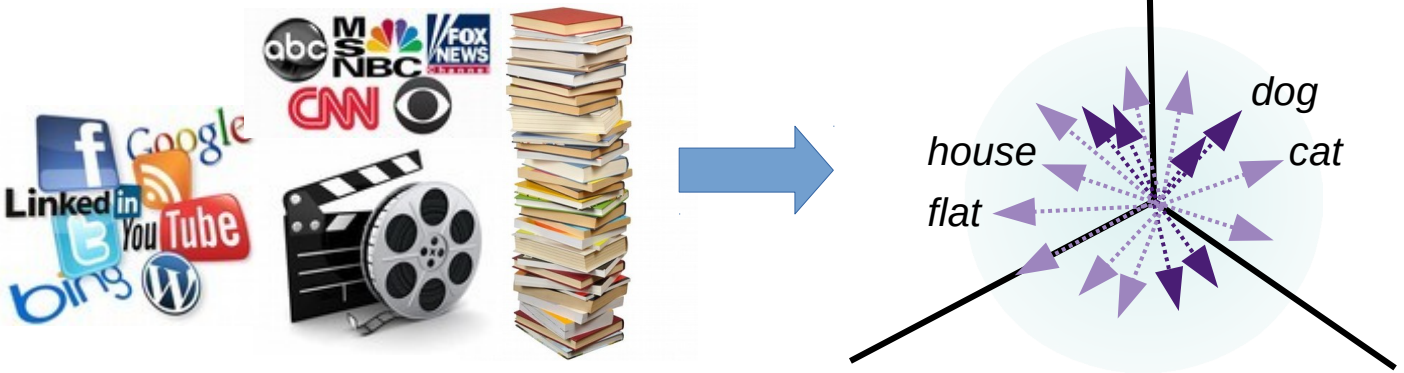
Our starting point

- Speakers somehow use linguistic expressions to convey their communicative intentions (**speaker meaning**).
- How? Part of the standard answer: linguistic expressions (as *types*) have meanings in their own right.
- This auxiliary notion of **expression meaning** should:
  1) provide an **adequate starting point** for explaining how a speaker in a context uses the expression;
  2) be **derivative** of the expression's (past) usage in the relevant linguistic community.

Distributional semantics

(e.g., Harris 1954; Firth 1957; Turney and Pantel 2010, ...)

- Expressions are assigned numerical, high-D vectors,
- Obtained through abstraction over distributions in a dataset.



- Two views (e.g., Lenci '08):
  - **'Weak':** What DS models *correlates* in certain ways with expression meaning.
  - **'Strong':** What DS models *is* expression meaning.

Could DS model expression meaning?

- Recall:

> This auxiliary notion of **expression meaning** should:
>
> 1) provide an **adequate starting point** for explaining how a speaker in a context uses the expression;
>
> 2) be **derivative** of the expression's (past) usage in the relevant linguistic community.

- DS immediately satisfies (2).
- But it doesn't seem *sufficient* for (1): (e.g., Boleda & Herbelot '16)
  - it cannot *really* do truth conditions,
  - entailment (e.g., Beltagy et al. 2013)
  - reference,
  - compositionality (cf. Baroni & Zamparelli 2010 a.o.)…

basically what *formal* semantics is good at…

Formal vs. distributional semantics

The red cat sees a mouse.

DS:

FS: ιx[(x) ∧ (x)] ∃y ((y) ∧ (x,y))

Apparent complementary strengths (e.g., Boleda & Herbelot ‘16):

- Distributional semantics: ‘conceptual’ aspects
- Formal semantics: ‘logical’ aspects

Which suggests a possible integration (e.g., Beltagy et al. ‘13, Erk ‘13, McNally ‘16)…

Our proposal

- FS and DS are *not* complementary models of the same notion of meaning.
- Plausibly, FS has inadvertently modeled *speaker meaning*.
  - And truth, reference, compositionality, etc. may belong with speaker meaning, not expression meaning.
- This takes a burden off DS, enabling the ‘strong’ view.

Proposal:

Distributional semantics: expression meaning

Formal semantics: speaker meaning

FS as a model of speaker meaning?!

Several reasons for assuming this:

- Centrality of ‘semantic intuitions’ as evidence:
  - These are about *stereotypical speaker meaning* (e.g., Strawson ‘50, Grice ‘75, Schwarz ‘96, Bach ‘02, increasingly in X-prag).
- Natural language is notoriously vague (Wittgenstein ‘53); *single* uses are more amenable to formal modeling.
  - E.g., failure of sense enumeration (Erk ‘10); vagueness of lexical/logical distinction (Abrusan et al. ‘18).
- Confusion about the semantics/pragmatics divide (Bach ‘97):
  - e.g., ‘sentence meaning is necessarily part of speaker meaning’.

A closer look at DS

And after that:

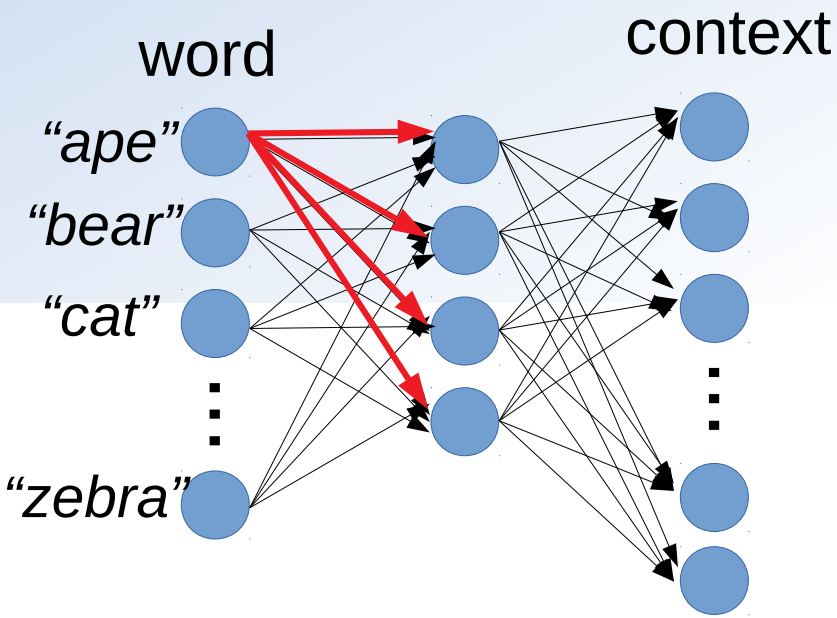
- Integrating FS and DS.

A closer look at DS

Two main types of DS (for comparison see Baroni et al. ‘14):

- **Count-based:**
  - create a huge table of word-occurrence-per-context
  - obtain abstraction by dimensionality reduction.
- **Prediction-based:**
  - train a neural network to predict the use of each word;
  - it will learn abstract representations of words.

Prediction-based DS



- Two main possible tasks:
  - Given a word, predict its context (e.g., Collobert & Weston ‘08).
  - Given a context, predict a word (e.g., Mikolov, Yih, & Zweig ‘13).
- Contexts could be:
  - Sentences; neighboring words; syntax trees.
  - Image + caption (+ referents); movies + subtitles.
  - …
- Extremely successful in NLP (“word embeddings”).

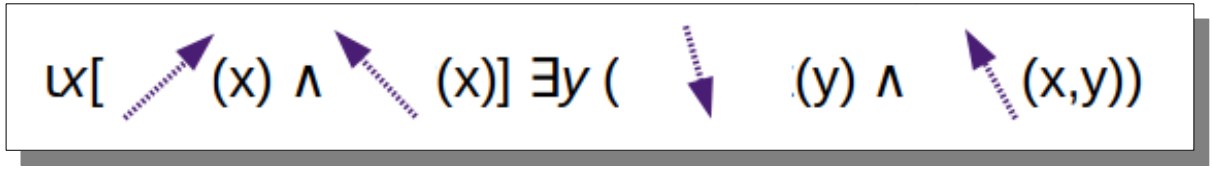
as those made by mice and other small animals. They can see in near
e being solitary hunters, are a social species, and cat communication in
nes and types of cat-specific body language.[8]

egistered pedigree pets, a hobby known as cat fancy. Failure to control
large numbers of feral cats worldwide, requiring population control.[10]
nction of many bird species. Cats have been known to extirpate a bird sp
to be primarily responsible for the extinction of 87 species of birds,[12]
eintroduction.[13]

mesticated there,[14] but there may have been instances of domesticat
domestic cats descended from the Near Eastern wildcat and diverged ar
ugh this line of partially domesticated cats leaves no trace in the domes
by farmers in the Near East around 9,000 years ago.[20][21]

after freshwater fish.[22] In a 2010 study, they were ranked the third-mo

- Recall:



But this isn't quite right:

- The DS vector for "cat" wouldn't model **the concept CAT**;
- But **the concept *of the word* "cat"**. (Uncontroversial.)

With this interpretation, the 'strong' view on DS is:

The meaning of an expression is its concept.

Let’s assess: the ‘strong’ view of DS

This auxiliary notion of **expression meaning** should:

1) provide an **adequate starting point** for explaining how a speaker in a context uses the expression;
2) be **derivative** of the expression’s (past) usage in the relevant linguistic community.

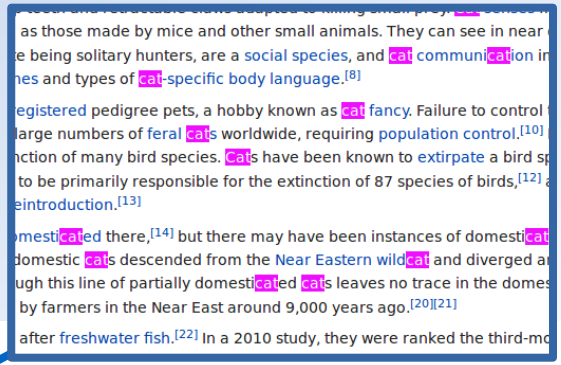
DS as a model of expression meaning (‘strong’ view):

- **Adequate starting point?**
  - Possibly, provided truth, reference etc. belong with speaker meaning.
  - Plausibly: where else to start if not the expression’s concept?
  - ***YES!*** according to NLP.
- **Derivative of use?**
  - Yes, through general-purpose abstraction/learning.

The final part:

towards Integrating DS and FS

The resulting picture



The red cat sees a mouse.

DS:

(expression meaning)

(speaker meaning)

FS: ιx[RED(x) ∧ CAT(x)] ∃*y* (MOUSE(y) ∧ SEE(x,y))

Two questions (of many)**:**

- How to get from to CAT?
- Where is compositionality?

How to get from ↘ to CAT?

A Gricean pragmatic perspective (Grice, ‘67):

- **Quality, Relevance, Quantity:**

  speaker meaning ↔ speaker’s goals and beliefs.

- **Manner:** speaker meaning ↔ expression meaning:

An attempt at Manner (cf. Relevance theory, Recanati ‘04):

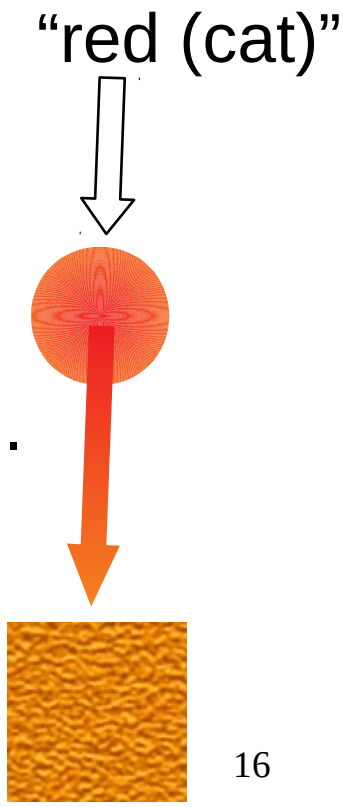
- “Activate the word concepts; then, from each, keep ‘associating’ to the first concepts whose composition results in the content of a possibly cooperative speech act.”

Where does composition happen?

- The foregoing attempt at Manner:
  - ...when the right concepts have been found.
    (cf. Borge ‘09: speaker meaning)

- But the boundary may not be so clear:
  - Red cats are actually *orange*.
  - When does this *modulation* take place?

(e.g. Erk & Padó ‘08, Aina ‘18, for DS approaches).



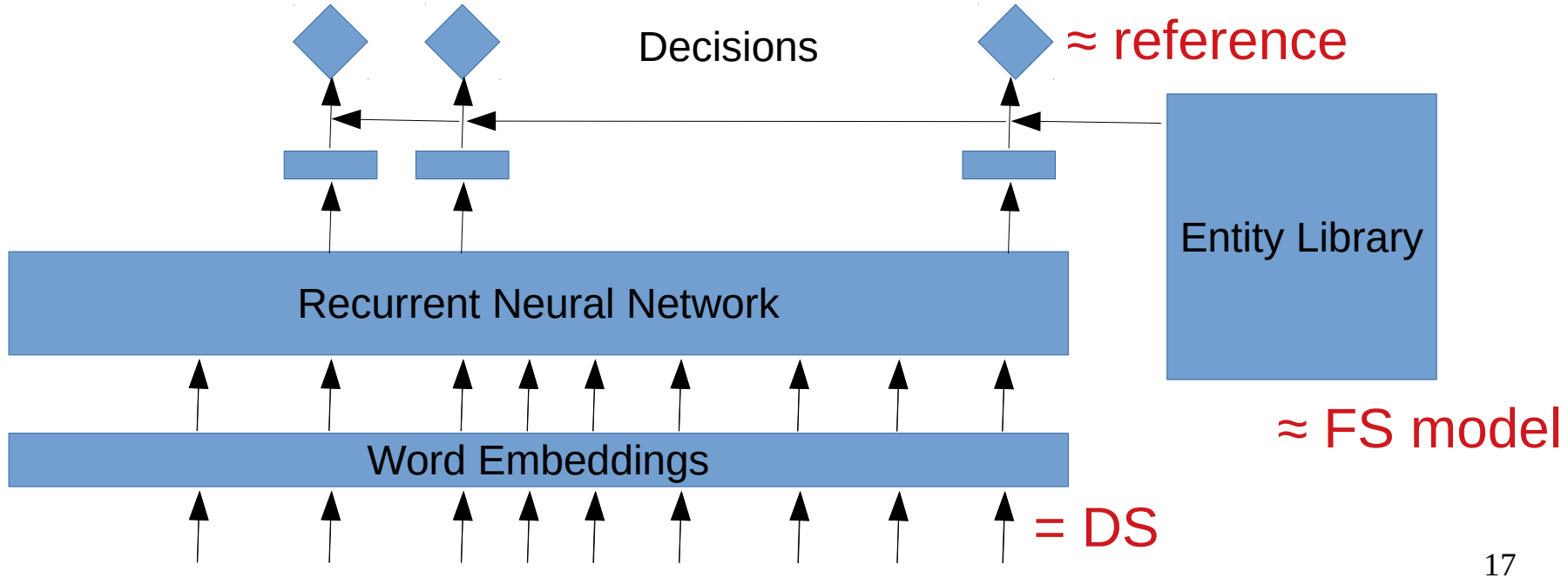
Not just a theory

(Example from Aina e

- Reference resol
- Model (simplifie

Two questions (again)**:**

- How to get from to CAT?
- Where is compositionality?



Conclusion

Proposal:

Distributional semantics: expression meaning
Formal semantics: speaker meaning

Gives a new outlook on their integration:

- *Not* ‘complementary’ models of a single notion;
- but two **very different explanatory roles** in a theory.
- Linked by ‘association and composition in context’ (Griceans: *Manner*; NLPers: *deep neural networks*).

We think this integration is vital to the field.

Acknowledgments

This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement No 715154). This paper reflects the authors' view only, and the EU is not responsible for any use that may be made of the information it contains.