The Moment of Meaning

The Moment of Meaning

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figure eight

Joint work with:

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- Lasha Abzianidze
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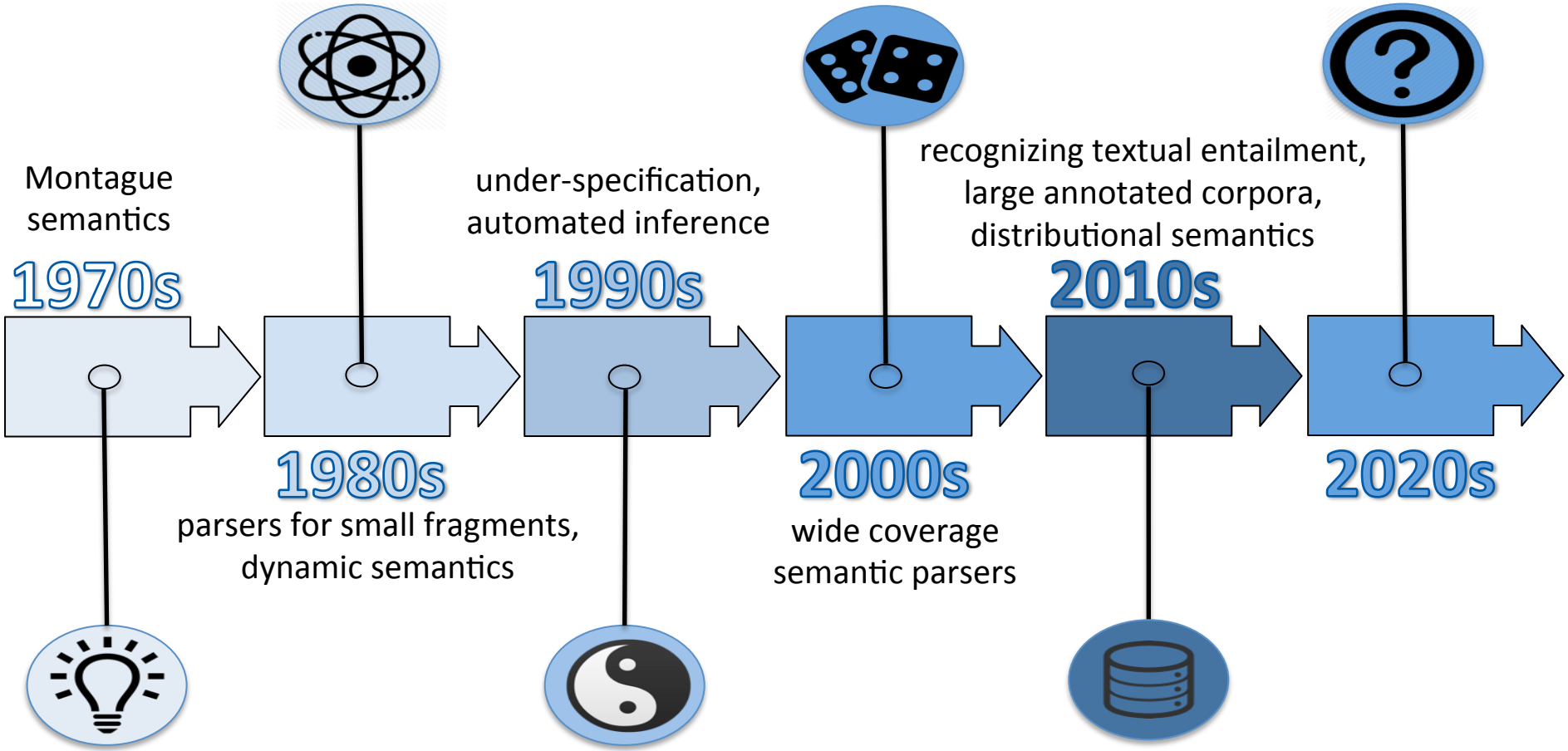
- Mostafa Abdou
- Noortje Venhuizen
- Pierre Ludmann
- Rik van Noord
- Talita Antonio
- Valerio Basile


Montague semantics
1970s
1980s
parsers for small fragments, dynamic semantics
under-specification, automated inference
1990s
2000s
wide coverage semantic parsers
recognizing textual entailment, large annotated corpora, distributional semantics
2010s
2020s

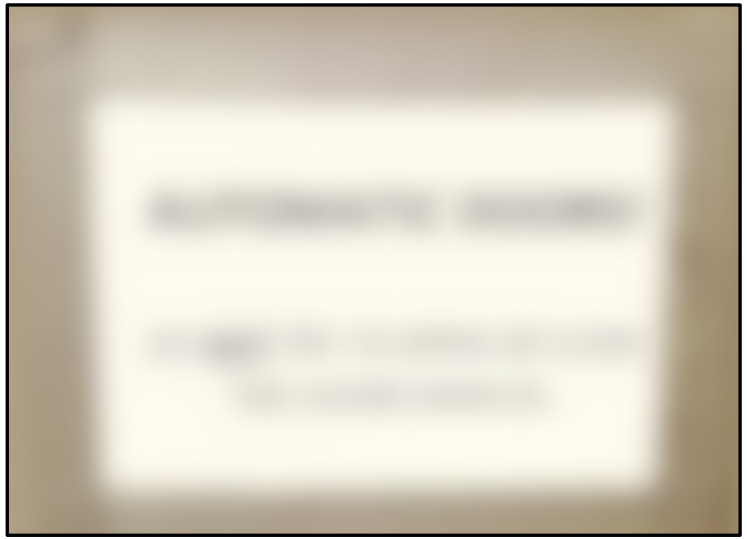
Why Semantics?

① Future Language Technology requires semantic interpretation – “explainable NLP”

② Improve MT – contradiction checking

③ Semantics is fun because it is super-interdisciplinary

Lost in Translation



Machine Translation

Engels | Nederlands | Frans | Taal herkennen

I saw two birds with a cat.

28/5000

Nederlands | Engels | Frans | Vertaal

Ik zag twee vliegen in een kat.

2017: bad

English | Spanish | French | Detect language

I saw two birds with a cat.

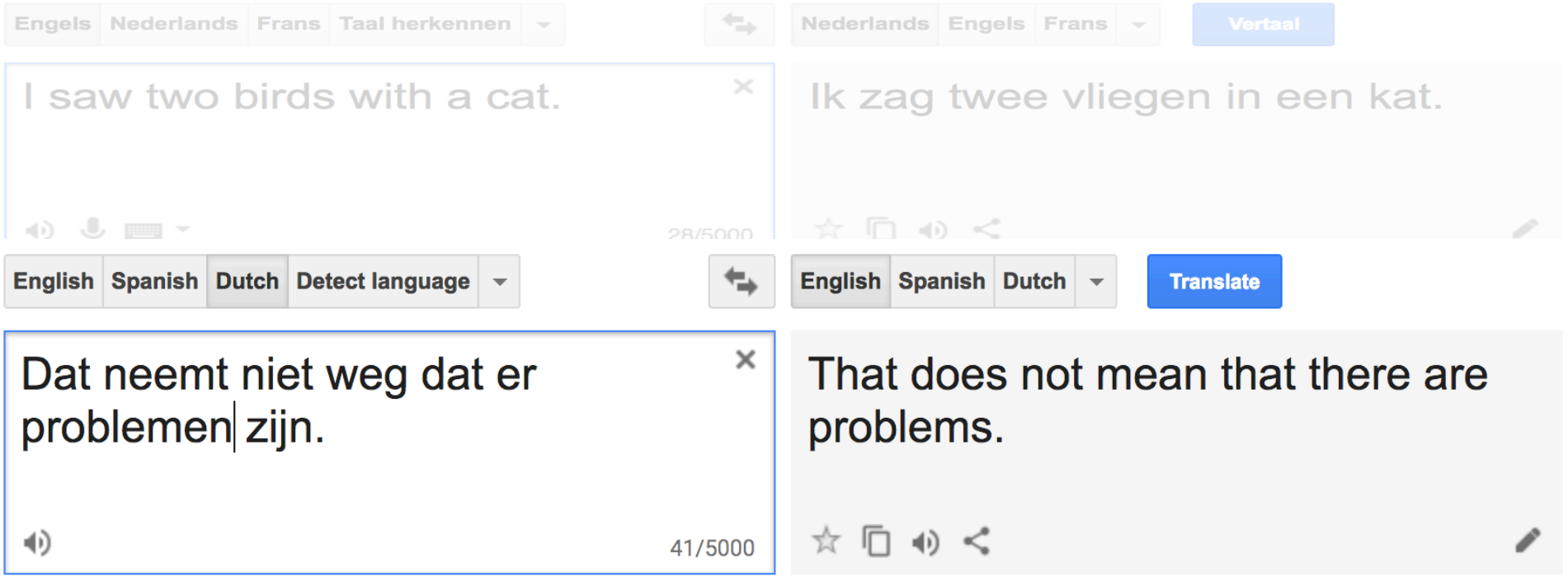
27/5000

English | Spanish | Dutch | Translate

Ik zag twee vogels met een kat.

2018: good

Machine Translation



	Explication
English:	The “Magpies”, Newcastle United Football Club, have ...
German:	Die “Elstern”, **wie der** Newcastle United Football Club **auch genannt wird**, brachten ...
	Hyperonym – Hyponym
English:	... have produced some of Britain’s finest **players**.
German:	... brachten einige der besten **Fußballspieler** Großbritanniens hervor.
	Co-Hyponym
English:	... the chance to **taste a pint** of beer and have a chat with the locals
German:	... die Gelegenheit **ein Glas** Bier zu **trinken** und mit den Einheimischen zu plaudern.
	Simile
English	... passing through the ranks of the Ostyak (...) **like a scythe through standing grain**.
German	... herüberwanderten und Otjaken (...) **buchstäblich niedermähten**.
	Anaphoric Expression
English:	Construction of the first floor (...) began on August 9, 1173. **This first floor** is ...
German:	Der Bau der ersten Etage (...) begann am 9. August 1173. **Diese Etage** ist ...
	Numerical Expression (Langeveld 1986)
English:	That man is **not above** forty. *(e.g.* ≤ 40*)*
Dutch:	Die man is **nog geen** veertig. *(e.g.* < 40*)*

Meaning Banking

Motivation

- Integrate Lexical and Formal Sem.
- Gold-standard meanings
- Multi-lingual
- Resource for parsing/translation

Discourse Representation Theory (Kamp 1981)

Parallel MEANING BANK

Method

- Machine-produced, human-corrected
- Language-neutral annotation
- Use parallel corpora
- English first, annotation projection

Results

- Four languages
- WordNet/VerbNet/DRT
- Bronze/Silver/Gold data
- Easily available: pmb.let.rug.nl

qtleap QA@CLEF-2004 TED

PASCAL2 Pattern Analysis, Statistical Modelling and Computational Learning

OPUS

TATOEBA BETA project

This school was founded in 1650.

Diese Schule wurde 1650 gegründet.

x1 e1 t1	x1 e1 t1
school.n.01(x1)	school.n.01(x1)
time.n.08(t1)	time.n.08(t1)
YearOfCentury(t1, 1650)	YearOfCentury(t1, 1650)
t1 < now	t1 < now
found.v.01(e1)	found.v.01(e1)
Time(e1, t1)	Time(e1, t1)
Theme(e1, x1)	Theme(e1, x1)

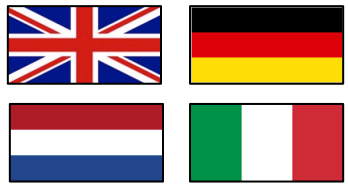
Language-Neutral Linguistic Analysis

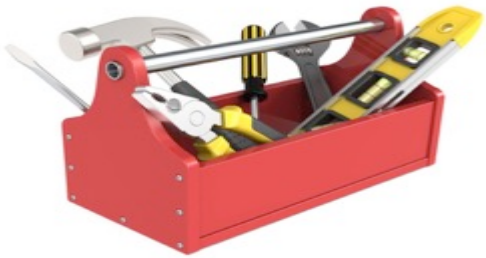
Segmentation: 1 tagset, 1 tokeniser (Elephant)

Parsing: 1 tagset, 1 parser (easyCCG)

Semantic Tagging: 1 tagset, 1 tagger

Boxing: 1 boxer





Combinatory Categorial Grammar (Steedman 2000)

CCG

$$\frac{X/Y \quad Y}{X} >$$

$$\frac{Y \quad X\backslash Y}{X} <$$

$$\frac{X/Y \quad Y/Z}{X/Z} >B$$

$$\frac{Y\backslash Z \quad X\backslash Y}{X\backslash Z} <B$$

$$\frac{X/Y \quad Y\backslash Z}{X\backslash Z} >Bx$$

$$\frac{Y/Z \quad X\backslash Y}{X/Z} <Bx$$

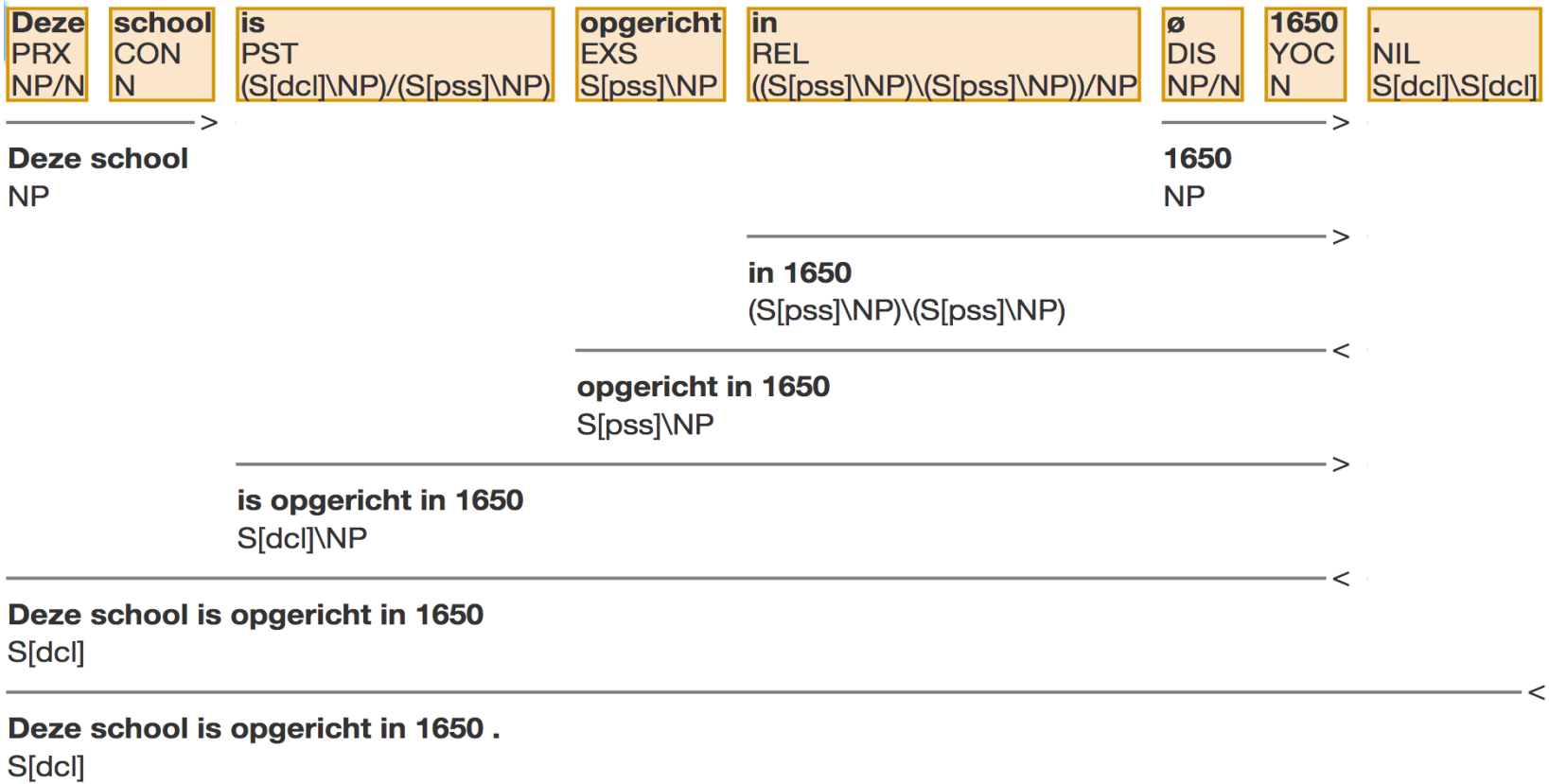
$$\frac{X}{Y/(Y\backslash X)} >T$$

$$\frac{(X/Y)/Z \quad Y/Z}{X/Z} >S$$

$$\frac{Y/Z \quad (X\backslash Y)/Z}{X/Z} <Sx$$

$$\frac{X}{X\backslash(Y/X)} <T$$

Syntactic Analysis -- CCG



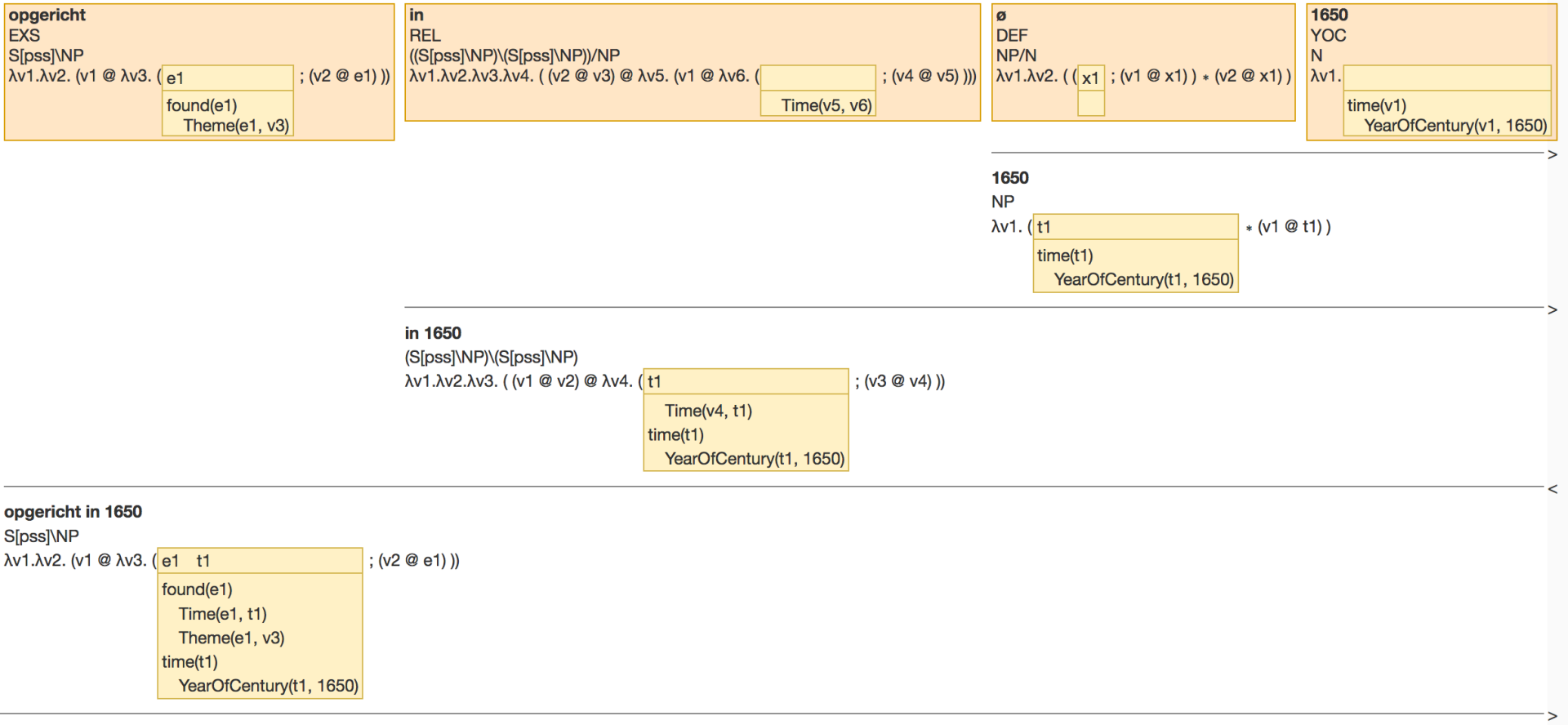
Semantic Tagging

- 72 sem-tags divided into 13 classes
- Designed in a data-driven fashion
- POS-tagging not informative enough
- Includes named entity recognition
- Semantically motivated
- Language-neutral

Abdou et al.: *What can we learn from Semantic Tagging?* EMNLP 2018.

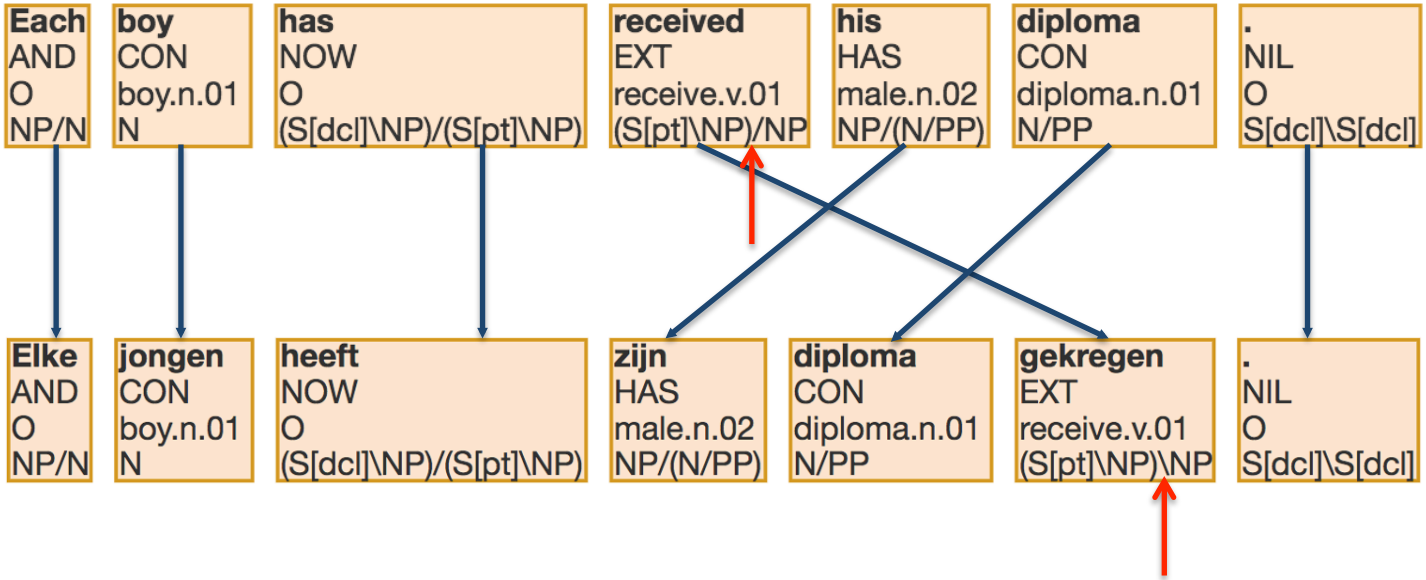
Bjerva, Plank & Bos: *Semantic Tagging with Deep Residual Networks*. COLING 2016.

Compositional Semantics (λ-DRT)



Projection with a Twist: EN → NL (PMB 19/0830)

Word alignment (Giza ++)



Evang & Bos: *Cross-lingual Learning of an Open-domain Semantic Parser*. COLING 2016.

Copy, Merge & Split

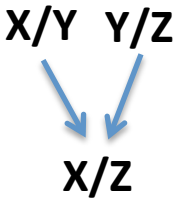
Copy:
transfer of
category from
source to target

PMB 01/0935

N/N: **default** N: **value**

>

N: **standaardbedrag**



Merge:
two source categories
merge into one target
category (composition)

PMB 32/2284

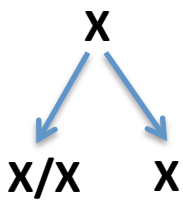
NP: **you** (S\NP)/NP: **have**

>T

S/(S\NP): **you**

>B

S/NP: **hai**



Split:
one source category
into two target categories
(de-composition)

$S_{[adj]}$\NP: **impossible**

>

(S/NP)/(S\NP): **niet** $S_{[adj]}$\NP: **mogelijk**

Projection challenges – an example

PMB: 10/0864

 : My eyes hurt.

 : Meine Augen schmerzen.

 : **Ik** heb pijn aan mijn ogen.

 : Mi fanno male **gli** occhi.

Learning from translations

PMB: 59/1946

I **do** like ice cream.

Ich mag **wirklich** Eiscreme.

PMB: 68/2811

I **do** believe it's called a leek.

Io credo **davvero** che si chiama porro.

Boxing Day

DRS – Discourse Representation Structure

x1 x2 x3
08293641(x1) 15160774(x2) ARG23(x2,1650) <(x2,now) 02431950(x3) ARG6(x3,x2) ARG3(x3,x2)

x1 e1 t1
school.n.01(x1) time.n.08(t1) YearOfCentury(t1,1650) t1 < now establish.v.01(e1) Time(e1,t1) Theme(e1,x1)

x1 e1 t1

school.n.01(x1)
time.n.08(t1)
    YearOfCentury(t1,1650)
    t1 < now
establish.v.01(e1)
    Time(e1,t1)
    Theme(e1,x1)

AMR

```
(e1 / establish-01
      :ARG1 (x1 / school)
      :time (t1 / date-entity
                  :year 1650))
```

DRS

e1 x1 t1
establish.v.01(e1) Theme(e1,x1) Time(e1,t1) school.n.01(x1) time.n.08(t1) YearOfCentury(t1,1650) t1 < now

AMR

```
[e1 | establish-01
    :ARG1 [x1 | school]
    :time [t1 | date-entity
                :year 1650]]
```

DRS

e1 x1 t1
establish.v.01(e1) Theme(e1,x1) Time(e1,t1) school.n.01(x1) time.n.08(t1) YearOfCentury(t1,1650) t1 < now

AMS

```
[e1 | establish-01(e1)
     :ARG1 [x1 | school(x1)]
     :time [t1 | date-entity(t1)
                 :year 1650]]
```

DRS

e1 x1 t1
establish.v.01(e1) Theme(e1,x1) Time(e1,t1) school.n.01(x1) time.n.08(t1) YearOfCentury(t1,1650) t1 < now

ARS

[e1 | establish-01(e1)
ARG1(e1,x1) [x1 | school(x1)]
time(e1,t1) [t1 | date-entity(t1)
year(t1,1650)]]

DRS

e1 x1 t1
establish.v.01(e1) Theme(e1,x1) Time(e1,t1) school.n.01(x1) time.n.08(t1) YearOfCentury(t1,1650) t1 < now

DRS

[e1 x1 t1 |
establish-01(e1)
ARG1(e1,x1)
time(e1,t1)
school(x1)
date-entity(t1)
year(t1,1650)]

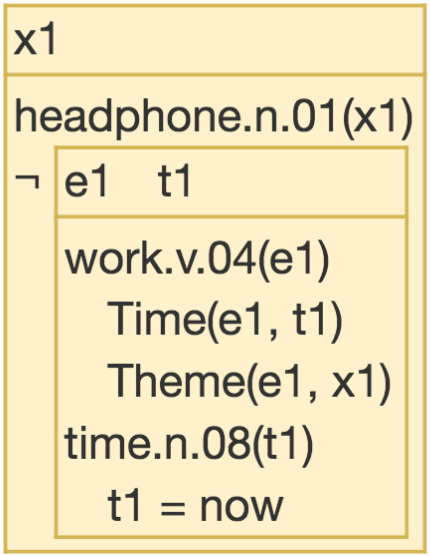
DRS

e1 x1 t1
establish.v.01(e1) Theme(e1,x1) Time(e1,t1) school.n.01(x1) time.n.08(t1) YearOfCentury(t1,1650) t1 < now

DRS: recursive structures

96/2544 These headphones don’t work.

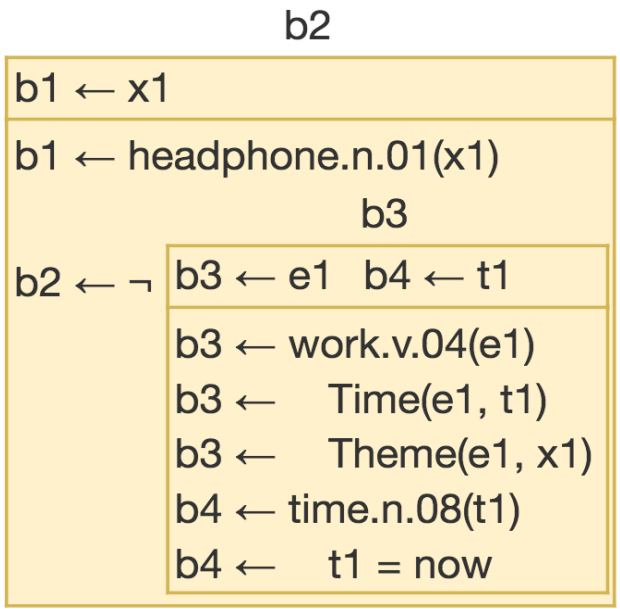
Show: ☐ pointers ☑ senses



DRS: context-sensitive

96/2544 These headphones don't work.

Show: ☑ pointers ☑ senses



Venhuizen et al.: *Discourse Semantics with Information Structure*. Journal of Semantics 2018.

Most likely interpretation

41/2289: Tom is stuck in his sleeping bag.

sleeping_bag.n.01(x)

in his sleeping~bag

PP

λv1.

x1 x2
Location(v1, x2) male.n.02(x1) sleeping_bag.n.01(x2) User(x2, x1)

1. MWE nouns
2. MWE particle verbs
3. Named entities
4. Person gender
5. Literal names
6. Word senses WN
7. Thematic roles VN
8. Comparison op
9. Agent/Role nouns
10. Quantification
11. Definite descriptions
12. Pronouns
13. Possessives
14. Discourse relations
15. Numbers
16. Dates
17. Clock times
18. Decades
19. Scores
20. Negation
21. Never/always
22. Disjunction
23. Conditionals
24. Past tense
25. Present tense
26. Future tense
27. Container nouns
28. Arithmetic
29. Modals <>
30. Modals []
31. Spatial relations
32. Co-reference
33. Control
34. Coordination
35. Deictic pronouns
36. Reflexive pronouns
37. Measures
38. Noun compounds
39. GPE Adjectives
40. Weather verbs
41. Questions
42. Imperatives

Parallel MEANING BANK

List of Phenomena (PMB)

Drowning by Numbers

Evaluating Meaning Representations

Semantic Evaluation

- Check for logical equivalence
- Use standard theorem provers for first-order logic (Blackburn & Bos 2005
- Discrete Score:
  0 (no proof)
  1 (proof)

Syntactic Evaluation

- Check matching tuples
- Implementations:
  - Allen et al. 2008
  - Smatch (Cai & Knight 2013)
  - Counter (van Noord et al. 2018)
- Continuous Score:
  0.00 (no matches)
  0.XX (some but not all)
  1.00 (perfect match)

DRS: clause notation

96/2544 These headphones don't work.

```
b1 REF x1                  % These [0...5]
b1 headphone "n.01" x1     % headphones [6...16]
b3 Time e1 t1              % do [17...19]
b4 REF t1                  % do [17...19]
b4 EQU t1 "now"            % do [17...19]
b4 time "n.08" t1          % do [17...19]
b2 NOT b3                  % n't [19...22]
b3 REF e1                  % work [23...27]
b3 Theme e1 x1             % work [23...27]
b3 work "v.04" e1          % work [23...27]
                           % . [27...28]
```

PMB: 96/3505

Tom was moaning in pain.

Tom kreunde van de pijn.

```
8 out of 9 clauses match

F-score  : 0.8889

Matching clauses:

b1 Name x1 "tom"   % Tom [0...3]      | b1 Name x1 "tom"   % Tom [0...3]
b1 male "n.02" x1  % Tom [0...3]      | b1 male "n.02" x1  % Tom [0...3]
b0 Time e1 t1      % kreunde [4...11] | b0 Time e1 t1      % was [4...7]
b4 TPR t1 "now"    % kreunde [4...11] | b3 TPR t1 "now"    % was [4...7]
b4 time "n.08" t1  % kreunde [4...11] | b3 time "n.08" t1  % was [4...7]
b0 Agent e1 x1     % kreunde [4...11] | b0 Agent e1 x1     % moaning [8...15]
b0 moan "v.01" e1  % kreunde [4...11] | b0 moan "v.01" e1  % moaning [8...15]
b0 Theme e1 x2     % van [12...15]    | b0 Theme e1 x2     % in [16...18]

Non-matching clauses:

b3 pain "n.01" x2  % pijn [19...23] | b0 pain "n.01" x2  % pain [19...23]

Concepts normalized to synset ID:

moan.v.01 -> groan.v.01
time.n.08 -> fourth_dimension.n.01
```

The Match

Classic Boxer

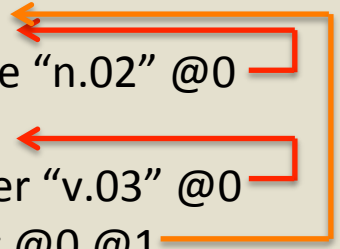
- ✓ Tokenisation (Elephant)
- ✓ Syntactic parsing (EasyCCG)
- ✓ Semantic tagging
- ✓ Thematic role labelling
- ✓ Word sense disambiguation
- ✓ Pronoun resolution
- ✓ Presupposition projection
- ✓ Lambda calculus
- ✓ Coach: Johan Bos

Neural Boxer

- ✓ No tokenisation
- ✓ OpenNMT
- ✓ 2 bi-LSTM layers
- ✓ 300 nodes
- ✓ Naïve dropout: 0.2
- ✓ General attention
- ✓ Beam size 10 during decoding
- ✓ Coach: Rik van Noord

Variables as nameless dummies (de Bruyn 1972)

	Original	*Using de Bruyn indexing*
Input:	"She showers every morning"	"She showers every morning"
Output:	b3 REF x1 b3 female "n.02" x1 b4 REF e1 b4 shower "v.03" e1 b4 Agent e1 x1 b4 Time e1 x2 b2 REF x2 b2 morning "n.01" x2 b0 IMP b2 b4	$0 REF $0 female "n.02" @0 $1 REF $1 shower "v.03" @0 $1 Agent @0 @1 $1 Time @0 @-1 $2 REF $2 morning "n.01" @0 $3 IMP $2 $1



Neural Boxer, character-based

Input: S,h,e,+,s,h,o,w,e,r,s,+,e,v,e,r,y,+,m,o,r,n,i,n,g,.

Output:
$0,+,REF,|||, $0,+,f,e,m,a,l,e,+,"n.02”,+,@0,|||,
$1,+,REF,|||, $1,+,s,h,o,w,e,r,+,"v.03”,+,@0,|||,
$1,+,Agent,+,@1,+,@0,|||, $1,+,Time,+,@-1,+,@0,|||,
$2,+,REF,|||,$2,+,m,o,r,n,i,n,g,+,"n.01”,+,@0,|||,
$3,+,IMP,+,$2,+,$1,|||

DRS parser	F-score
Spar	40
Classic Boxer	74
Neural Boxer	
Neural Boxer + silver data	

Van Noord, Abzianidze, Toral, Bos: *Exploring Neural Methods for Parsing Discourse Representation Structures*. TACL 2018 (to appear soon).

DRS parser	F-score
Spar	40
Classic Boxer	74
Neural Boxer	78
Neural Boxer + silver data	

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DRS parser	F-score
Spar	40
Classic Boxer	74
Neural Boxer	78
Neural Boxer + silver data	84

Van Noord, Abzianidze, Toral, Bos: *Exploring Neural Methods for Parsing Discourse Representation Structures*. TACL 2018 (to appear soon).

The Silence of the Lambdas

seq2seq, no spaces (only 5% decrease in F-score)

S,h,e,s,h,o,w,e,r,s,e,v,e,r,y,m,o,r,n,i,n,g,.

$0,+,REF,|||,
$0,+,f,e,m,a,l,e,+,"n.02”,+,@0,|||,
$1,+,REF,|||,
$1,+,s,h,o,w,e,r,+,"v.03" + @0 |||,
$1,+,Agent,+,@1,+,@0,|||,
$1,+,Time,+,@-1,+,@0,|||,
$2,+,REF,|||,
$2,+,m,o,r,n,i,n,g,+,"n.01”,+,@0,|||,
$3,+,IMP,+,$2,+,$1,|||

Is NB learning recursive structures?

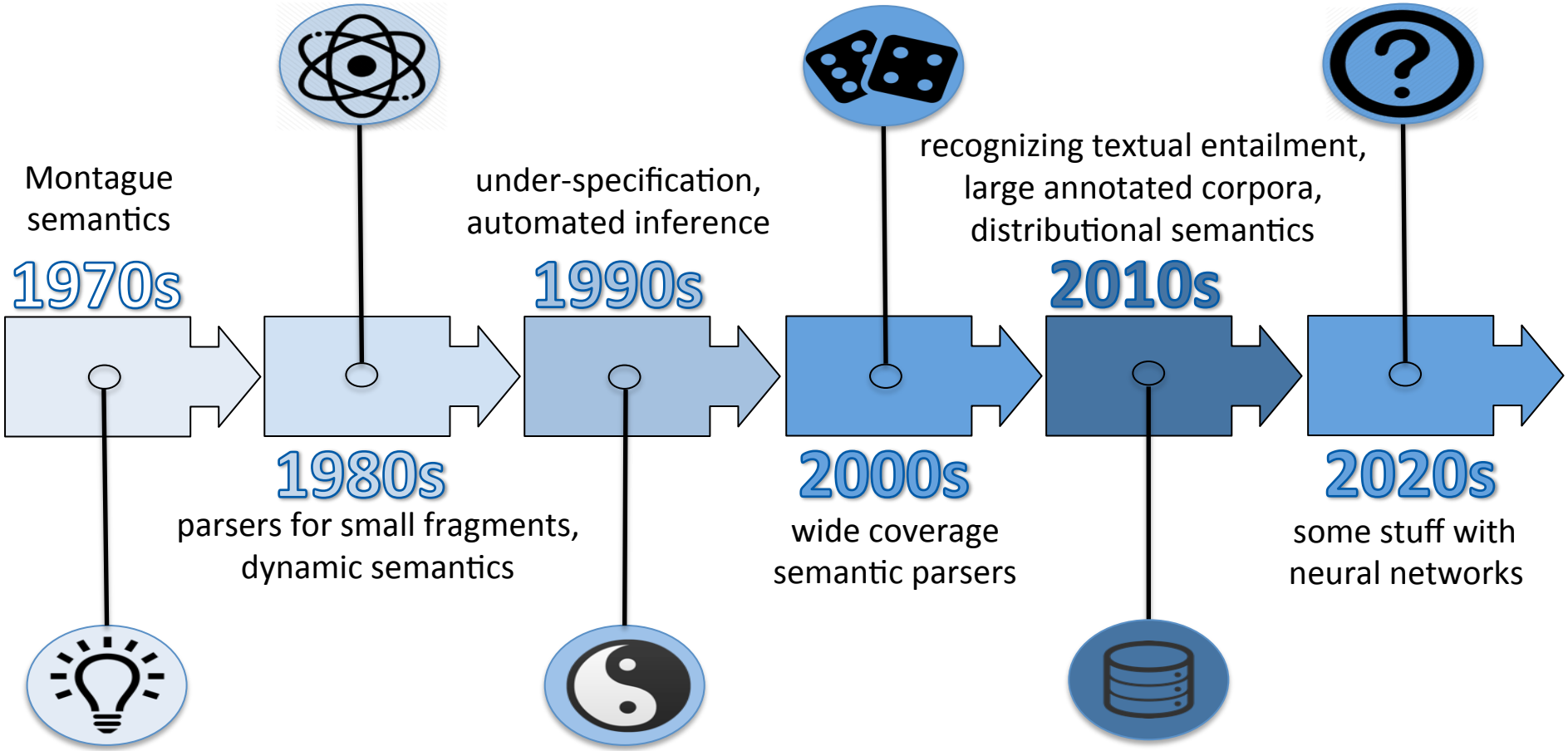
Tom's cellphone rang and he answered it.

B4:[x1][male(x1),Name(x1,tom)]
B5:[x2][cellphone(x2),User(x2,x1)]
B2:[x3][ring(x3),Theme(x3,x2)]
B5:[x5][answer(x5),Agent(x5,x2),Patient(x5,x6)]
B7:[x6][entity(x6)]
B2:CONTINUATION B3 B4

Back to the Future

Results – the Moment of Meaning

- Meaning Banking
  - integrating lexical with formal semantics
  - Language-neutral semantic annotation
  - Multi-lingual (projection saves annotation time!)
- Meaning Interpretation
  - Semantic tagging
  - Neural semantic parsing outperforms traditional parsing
  - Still lots of stuff to explore


Montague semantics
1970s
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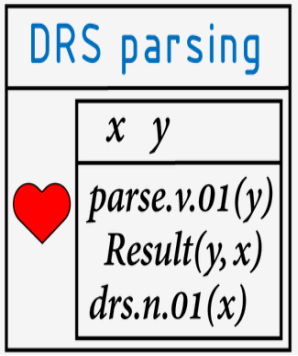
parsers for small fragments, dynamic semantics
under-specification, automated inference
1990s
2000s
wide coverage semantic parsers
recognizing textual entailment, large annotated corpora, distributional semantics
2010s
2020s
some stuff with neural networks

Future

- Computational Semantics
  - We need other resources for inference (Poliak et al. 2018)
  - Explainable NLP (not just labels)
  - We need to think more “multilingual”
- Add meaning to MT
  - Verify translations with semantic parsing
  - MTL with semantic tagging as aux task?
  - Outperform BLEU

Shared Task on DRS parsing

IWCS, Gothenburg, 23-27 May 2019



DRS parsing in a nutshell

English raw text

He played the piano and she sang.

System input

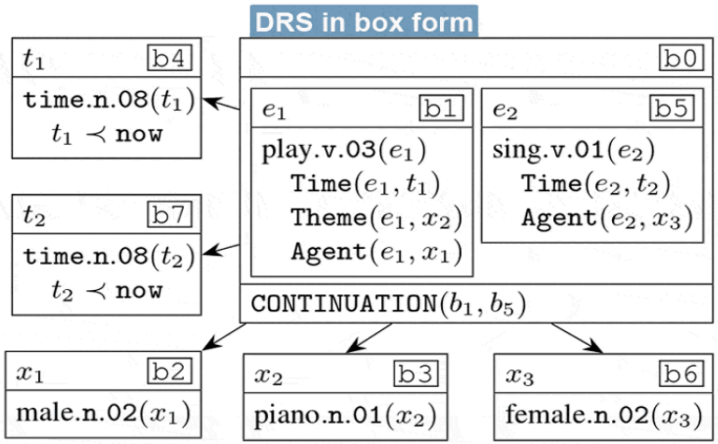
DRS PARSING

System output

DRS in clausal form

```
b0 DRS b1                    b0 DRS b5
b2 REF x1                    b6 REF x3
b2 male "n.02" x1            b6 female "n.02" x3
b1 REF e1                    b5 REF e2
b1 play "v.03" e1            b5 sing "v.01" e2
b1 Agent e1 x1               b5 Agent e2 x3
b1 Theme e1 x2               b5 Time e2 t2
b3 REF x2                    b7 REF t2
b3 piano "n.01" x2           b7 TPR t2 "now"
b4 REF t1                    b7 time "n.08" t2
b4 time "n.08" t1            b0 CONTINUATION b1 b5
b4 TPR t1 "now"              b1 Time e1 t1
```

DRS in box form



EQUIVALENCE

The End

pmb.let.rug.nl

competitions.codalab.org/competitions/20220

References

1. Abdou, Ravishankar, Kulmizev, Abzianidze, Bos (2018): *What Can We Learn From Semantic Tagging?* EMNLP
2. Allen, Swift, de Beaumont (2008): *Deep Semantic Analysis of Text*. STEP
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