

The Parallel Meaning Bank

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figure
eight

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The Parallel Meaning Bank:
from text to interlingual meaning representations

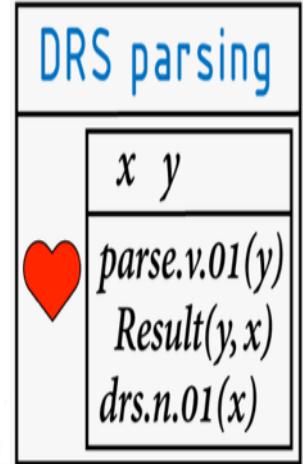
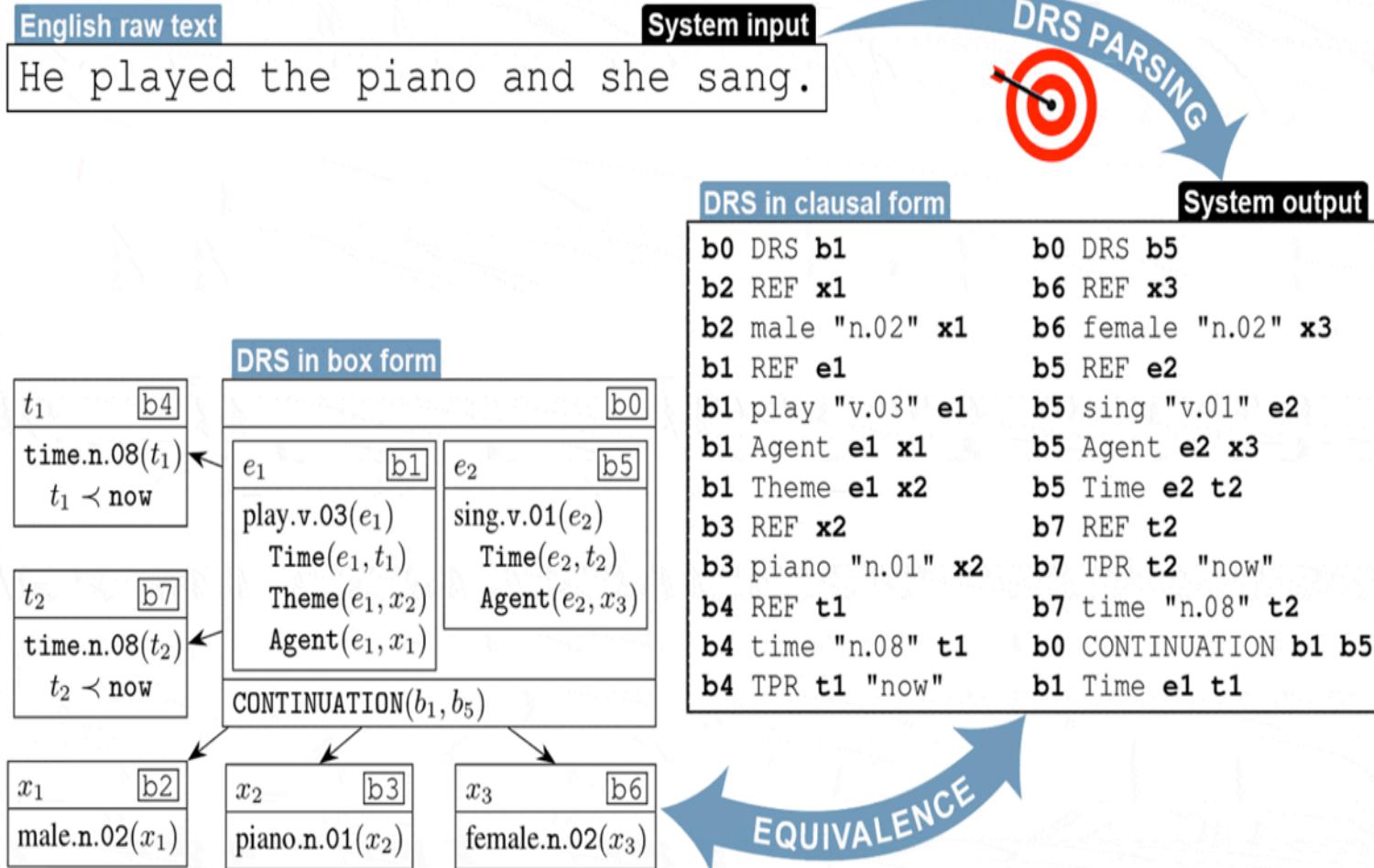
Why Computational Semantics?

- ① Semantics is fun because it is super-interdisciplinary!
- ② Future Language Technology needs semantic interpretation – “explainable NLP”
- ③ Improve applications requiring inference
QA, DS, MT



Semantic Parsing (“Boxing”)

DRS parsing in a nutshell



Motivation

- ◆ Integrate Lexical and Formal Sem.
- ◆ Gold-standard meanings
- ◆ Multi-lingual (not just English)
- ◆ Resource for parsing/translation

Method

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



Results

- ◆ Four languages
- ◆ WordNet/VerbNet/DRT
- ◆ Silver: 130K DRSs; Gold: 12K DRSs
- ◆ Easily available: pmb.let.rug.nl

qt leap

QA@CLEF-2004

TED



PASCAL2
Pattern Analysis, Statistical Modelling and
Computational learning

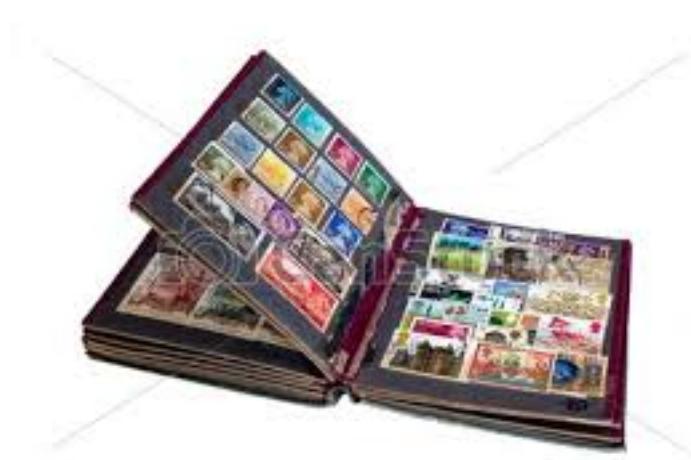
CORPUS

TATOeba
BETA
project



DRS example

Damon showed me
his stamp album.

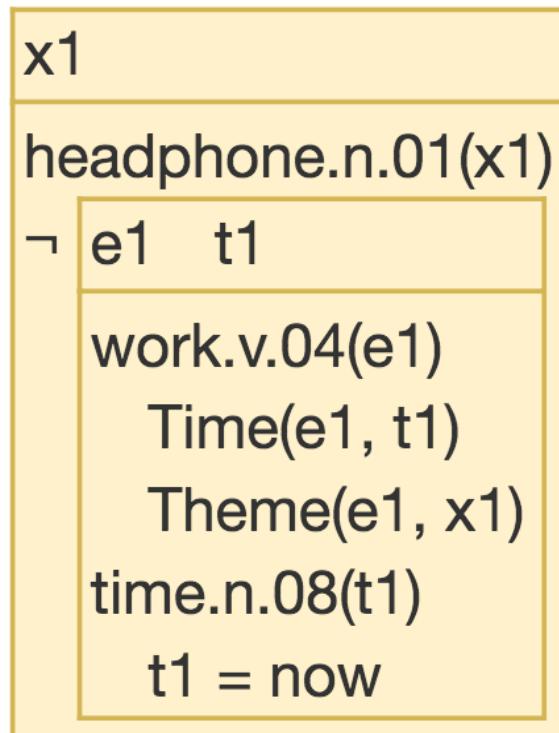


x1	x2	e1	t1
male.n.02(x1)			
Name(x1, damon)			
time.n.08(t1)			
t1 < now			
show.v.04(e1)			
Time(e1, t1)			
Recipient(e1, speaker)			
Theme(e1, x2)			
Agent(e1, x1)			
stamp_album.n.01(x2)			
Owner(x2, x1)			

DRS: recursive structures

96/2544 These headphones don't work.

Show: pointers senses





This school was founded in 1650.

Queste scuola è stata fondata nel 1650.

x1 e1 t1

t1 tθ tχ

school.n.01(x1)

(tχ)t0.n.looold

time.n.08(t1)

(tʃ)80.n.emit

YearOfCentury(t1, 1650) (06@t , tʃ)χnushtCen@Year

t1 < now

won > tʃ

found.v.01(e1)

(tθ)t0.v.bnudot

Time(e1, t1)

(tʃ , tθ)emitiT

Theme(e1, x1)

(tχ , tθ)ememT

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

Language-Neutral Linguistic Analysis

Segmentation: 1 tagset, 1 tokeniser (Elephant)

Parsing: 1 tagset, 1 parser (easyCCG)

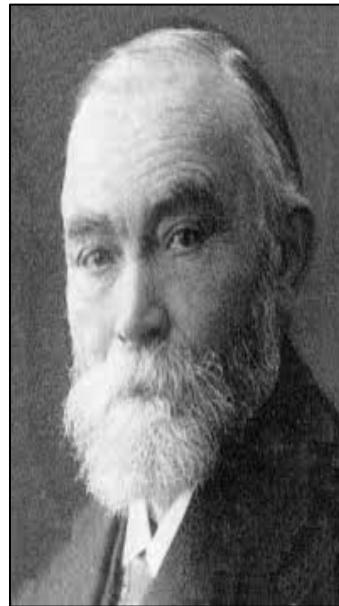
Semantic Tagging: 1 tagset, 1 tagger

Boxing: 1 boxer



Compositionality

- ① as a principle?
- ② as a religion?
- ③ as a method!

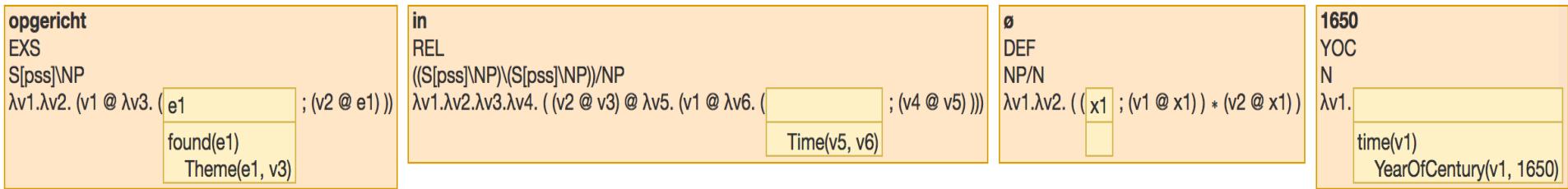


Frege



Carnap

Compositional Semantics (λ -DRT)



>

1650 NP $\lambda v1. (t1 * (v1 @ t1))$
time(t1) YearOfCentury(t1, 1650)

>

in 1650 (S[pss]\NP)\(S[pss]\NP) $\lambda v1.\lambda v2.\lambda v3. ((v1 @ v2) @ \lambda v4. (t1 ; (v3 @ v4)))$
Time(v4, t1) time(t1) YearOfCentury(t1, 1650)

<

opgericht in 1650

S[pss]\NP $\lambda v1.\lambda v2.(v1 @ \lambda v3. (e1 t1 ; (v2 @ e1)))$
found(e1) Time(e1, t1) Theme(e1, v3) time(t1) YearOfCentury(t1, 1650)

>

The Atoms of Meaning

Compound Names



Expression	Meaning
San Diego	location.n.01(x) & Name(x,"San~Diego")
Royal Bank of Scotland	organisation.n.01(x) & Name(x,"Royal~Bank~of~Scotland")
Michael Jackson	male.n.02(x) Name(x,"Michael~Jackson")



→ MWE, no further analysis

Noun-Noun Compounds

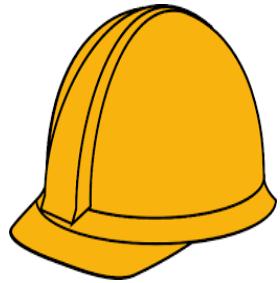


Expression	Meaning
police officer	police_officer.n.01(x)
police car	police_car.n.01(x)
police official	official.n.01(x) & PartOf(x,y) & police.n.01(y)
Polizeibeamter	???



→ MWE if in WordNet...

Adjective-Noun Compounds



Expression	Meaning
hard hat	hard_hat.n.02(x)
hard shoulder	hard_shoulder.n.01(x)
old woman	old_woman.n.01(x) ???



→ MWE if in WordNet...

Inflected Adjectives

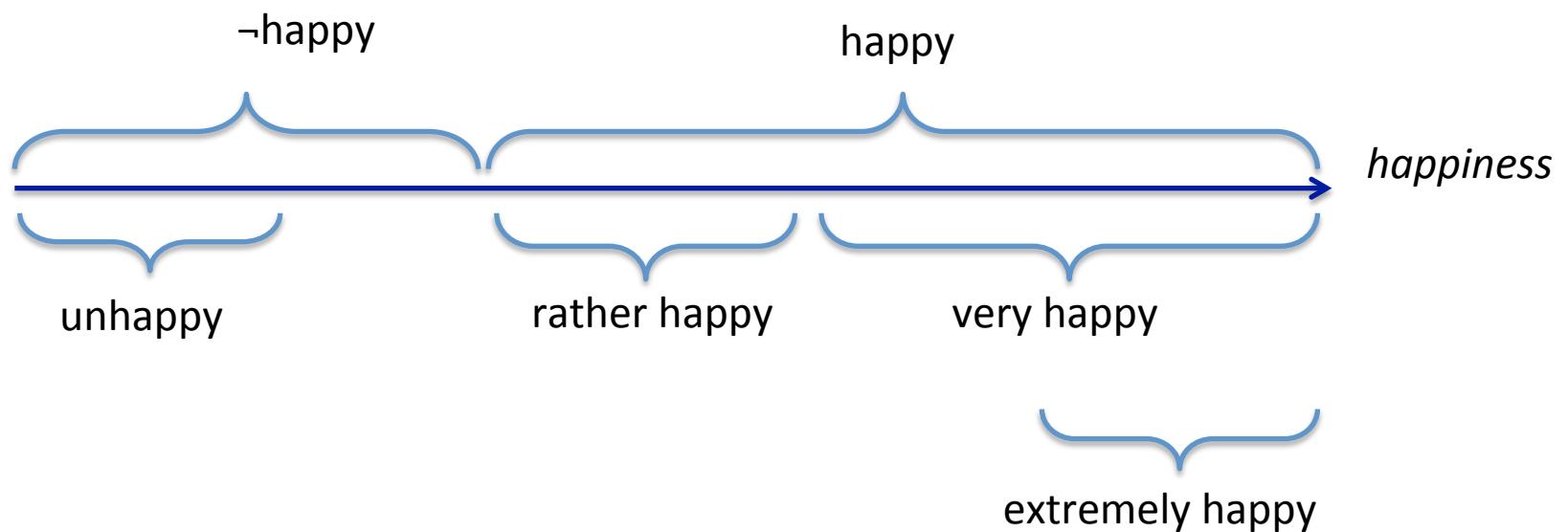


Expression	Meaning
impolite	$\neg \text{polite.a.01}(x)$
unhappy	$\neg \text{happy.a.01}(x)$?
important	$\neg \text{portant.01}(x)$????



→ unclear what to do here...

Semantics of Gradable Adjectives



Compound Adjectives



Expression	Meaning
a 10-year-old boy	boy.n.01(x) & measure.n.01(z) & Unit(z,year) & Quantity(z,10) & old.a.01(y) & Theme(y,x) & Value(y,z)
a data-driven approach	...
a New York-based company	...



→ need to decompose here ...

Drowning by Numbers



Expression	Meaning
forty five	$40 + 5$
two hundred	2×100
367	$3 \times 10^2 + 6 \times 10^1 + 7 \times 10^0$



→ Don't try to be clever: MWE

What's the time?



Expression	Meaning
2pm	14:00
half past eight	08:30
five to ten	09:55



→ Don't try to be clever: MWE

Particle and Phrasal Verbs



Expression	Meaning
We picked up the hitchhiker	pick_up.v.03
We picked it up	pick_up.v.01



- Dummy semantics for particle
- “pick” gets right wordnet sense

Negative Concord

- Non ho visto nessuno.
not have seen nobody.
(I haven't seen anybody.)

Modal Concord

- Ik kan onmogelijk komen.

I can impossibly come.

(I cannot come)

Noun Idioms

Expression	Literal Meaning	Figurative Meaning
bread and butter	group.n.01(x) & Part(x,y) & Part(x,z) bread.n.01(y) & butter.n.01(z)	bread_and_butter. n.01(x)
cup of tea	tea.n.01(x) & cup.n.01(y) & Content(y,x)	cup_of_tea.n.01(x)



→ rescued by WordNet

Compositional (Decomposable) Idioms

Idiom	Literal Meaning	Figurative Meaning
spill the beans	spill.v.01(e) & Theme(e,x) &	spill.v.05(e) & Theme(e,x) & secret.n.01(x)

Verb

- S: (v) **spill the beans**, let the cat out of the bag, talk, tattle, blab, peach, babble, sing, babble out, blab out (divulge confidential information or secrets) "Be careful--his secretary talks"

Non-Compositional Idioms

Idiom	Literal Meaning	Figurative Meaning
kick the bucket	kick.v.03(e) & Patient(e,x) & bucket.n.01(x)	die.v.01(e)

Verb

- S: (v) die, decease, perish, go, exit, pass away, expire, pass, **kick the bucket**, cash in one's chips, buy the farm, conk, give-up the ghost, drop dead, pop off, choke, croak, snuff it (pass from physical life and lose all bodily attributes and functions necessary to sustain life) "She died from cancer"; "The children perished in the fire"; "The patient went peacefully"; "The old guy kicked the bucket at the age of 102"

Syntactic Analysis -- CCG

Questa	scuola	è	stata	fondato	nel	1650	.
NP/N	N	(S[dcl]\NP)/(S[pt]\NP)	(S[pt]\NP)/(S[pss]\NP)	S[pss]\NP	((S[pss]\NP)\(S[pss]\NP))/N	N	S[dcl]\S[dcl]

Questo scuola
NP

nel 1650
(S[pss]\NP)\(S[pss]\NP)

fondato nel 1650
S[pss]\NP

stata fondato nel 1650
S[pt]\NP

è stata fondata nel 1650
S[dcl]\NP

Questo scuola è stata fondata nel 1650
S[dcl]

Questo scuola è stata fondata nel 1650 .
S[dcl]

Combinatory Categorial Grammar

- CCG is a lexicalised theory of grammar
 - Many different lexical categories
 - Few grammar rules (based on combinatory logic)
 - Covers complex cases of coordination and long-distance dependencies
- Not just theory, also used in practice
 - OpenCCG (Baldridge, White)
 - CCGbank (Hockenmaier)
 - C&C supertagger and parser (Clark, Curran)

Basic Categories

S	sentence
NP	noun phrase
N	noun
PP	prepositional phrase

Note: The category S comes with a feature to distinguish between various sentence mood and verb phrase forms.

Examples: S_{dcl} (declarative sentence)

$S_{\text{ng}} \setminus NP$ (present participle)

Functor Categories

The direction of the slash determines where the argument appears: forward slash (/): on its right; backward slash (\): on its left

NP/N	determiner
N/N	adjective
$S_{\text{dcl}} \setminus \text{NP}$	verb phrase (declarative mood)
$(S_{\text{pt}} \setminus \text{NP}) / \text{NP}$	transitive verb (present participle)
$(S_x \setminus \text{NP}) \setminus (S_x \setminus \text{NP})$	adverb
$(N \setminus N) / \text{NP}$	preposition (modifying noun)

Example Lexicon

Word	Category
boy	: N
everything	: NP
the	: NP/N
eats	: $S_{\text{dcl}} \setminus \text{NP}$
eats	: $(S_{\text{dcl}} \setminus \text{NP}) / \text{NP}$
quickly	: $(S_x \setminus \text{NP}) \setminus (S_x \setminus \text{NP})$

Application

Forward >
Backward <

Composition

(Generalised) Forward >B
(Generalised) Backward <B

Crossed Composition

(Generalised) Forward >Bx
(Generalised) Backward <Bx

Type Raising

Forward >T
Backward <T

Substitution

Forward >S
Backward <S

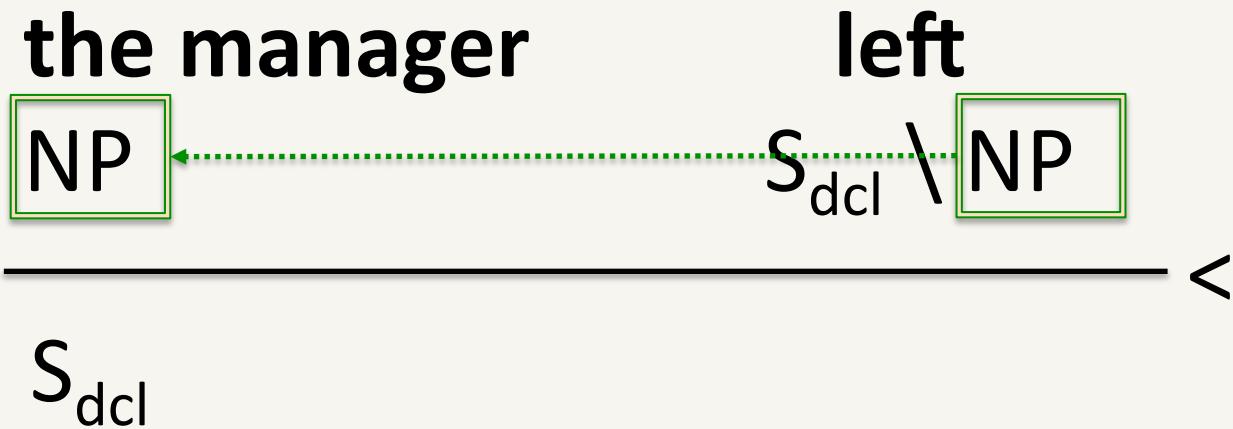
Crossed Substitution

Forward >Sx
Backward <Sx

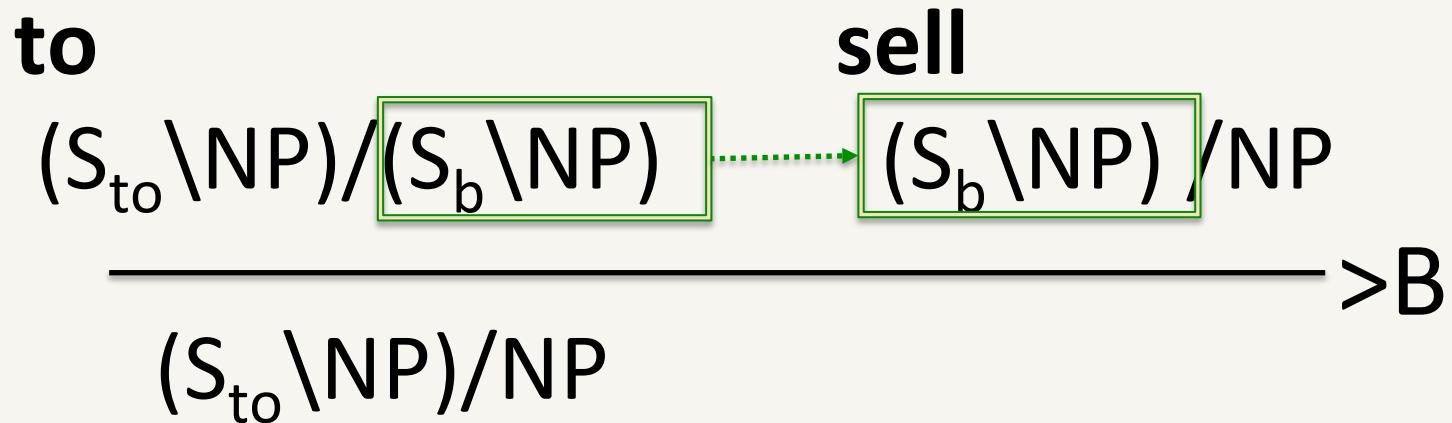
Combinatory Rules of CCG



Forward Application (>)



Backward Application (<)



Forward Composition (>B)

to

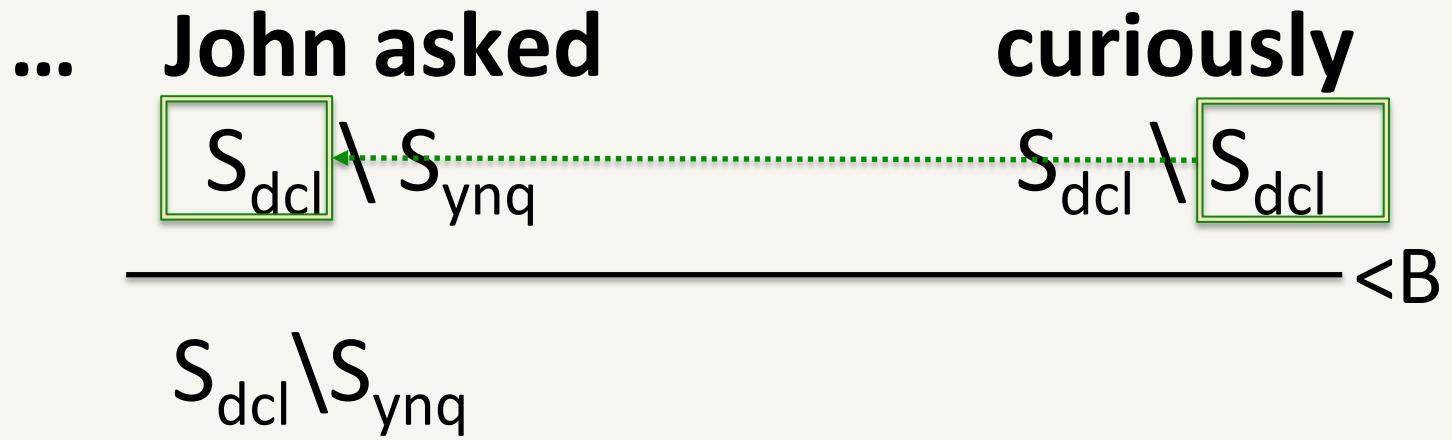
$(S_{\text{to}} \setminus \text{NP}) / (S_b \setminus \text{NP})$

sell

$(S_b \setminus \text{NP}) / \text{NP}$

$(S_{\text{to}} \setminus \text{NP}) / \text{NP}$

Forward Composition (>B)



Backward Composition ($<\text{B}$)

... John asked

$S_{\text{dcl}} \setminus S_{\text{ynq}}$

curiously

$S_{\text{dcl}} \setminus S_{\text{dcl}}$

$S_{\text{dcl}} \setminus S_{\text{ynq}}$

<B

Backward Composition (<B)

did

$(S_{\text{dcl}} \setminus \text{NP}) / (S_b \setminus \text{NP})$

not

$(S_{\text{dcl}} \setminus \text{NP}) \setminus (S_{\text{dcl}} \setminus \text{NP})$

$(S_{\text{dcl}} \setminus \text{NP}) / (S_b \setminus \text{NP})$

$\text{$

Backward Crossed Composition (<Bx)

did

$(S_{\text{dcl}} \setminus \text{NP}) / (S_b \setminus \text{NP})$

not

$(S_{\text{dcl}} \setminus \text{NP}) \setminus (S_{\text{dcl}} \setminus \text{NP})$

$(S_{\text{dcl}} \setminus \text{NP}) / (S_b \setminus \text{NP})$

$\text{$

Backward Crossed Composition ($\text{)$

 X/Y Y

$$\xrightarrow{\hspace{1cm}} \\ X$$

 Y $X\backslash Y$

$$\xleftarrow{\hspace{1cm}} \\ X$$

 X/Y Y/Z

$$\xrightarrow{\hspace{1cm}} >B \\ X/Z$$

 $Y\backslash Z$ $X\backslash Y$

$$\xleftarrow{\hspace{1cm}} <B \\ X\backslash Z$$

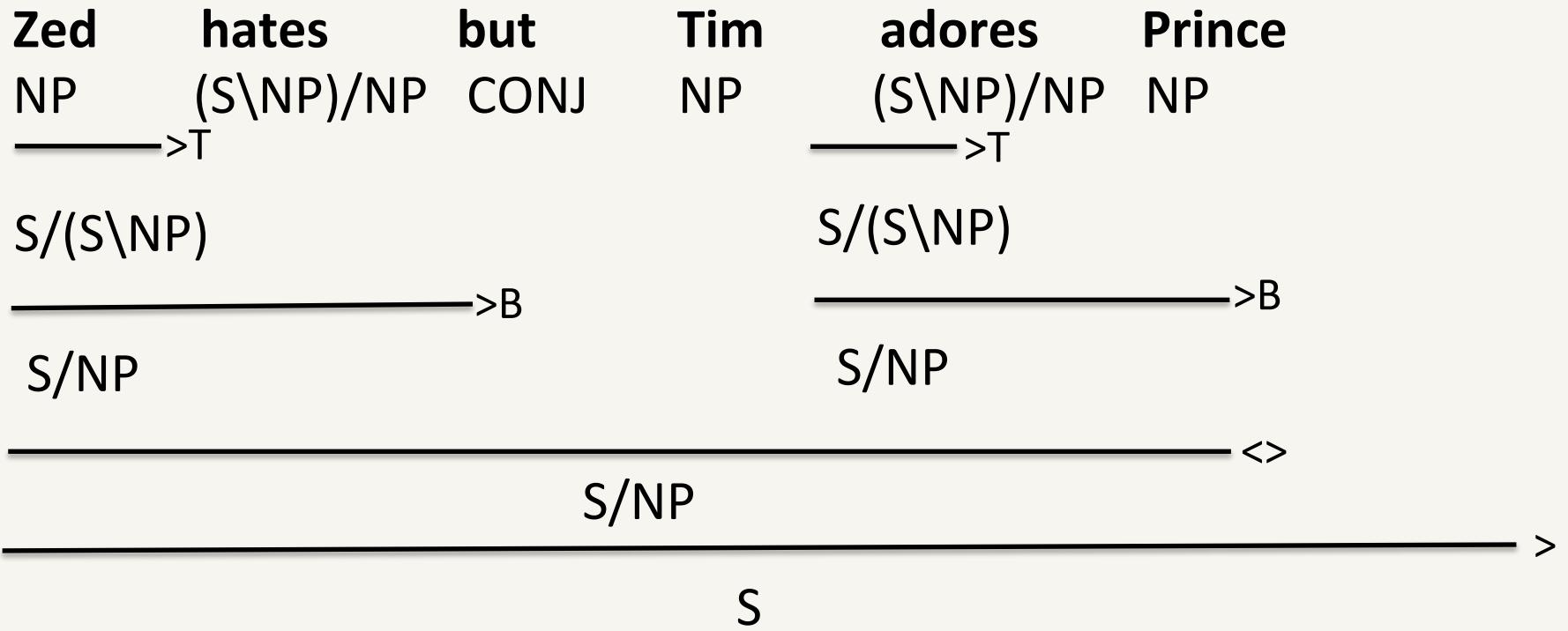
 X/Y $Y\backslash Z$

$$\xrightarrow{\hspace{1cm}} >Bx \\ X\backslash Z$$

 Y/Z $X\backslash Y$

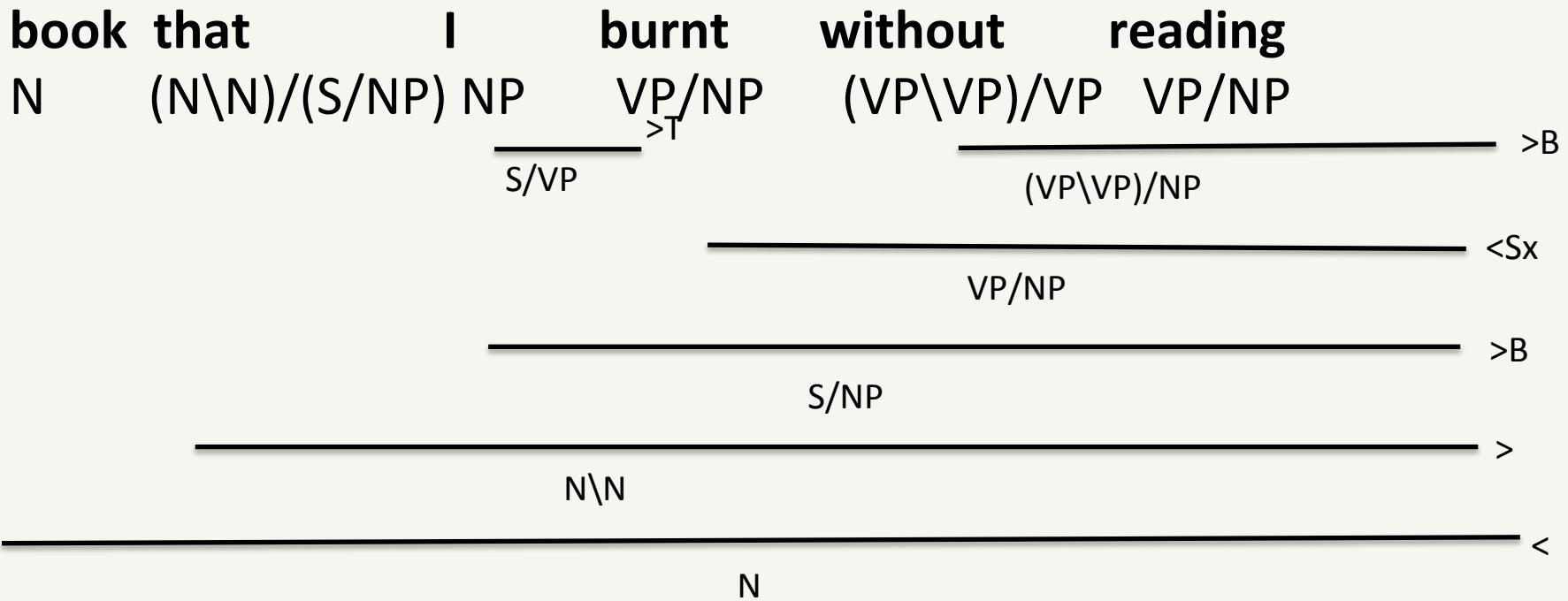
$$\xleftarrow{\hspace{1cm}} <Bx \\ X/Z$$

CCG rule schemata (1)



Type Raising (>T) and Coordination (↔)

Substitution (S), “parasitic gap”



Which paper did the professor read ... without understanding ... ?





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

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

$$\frac{X \quad \text{CONJ} \quad X}{X} <>$$

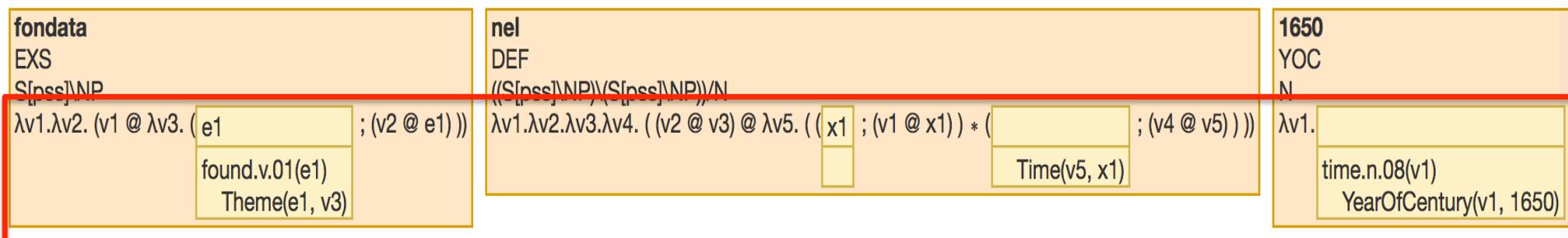
$$\frac{(X/Y)/Z \quad Y/Z}{X/Z} > S$$

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



CCG rule schemata (2)

Compositional Semantics (λ -DRT)



nel 1650
 $(S[pss]\NP)\backslash(S[pss]\NP)$
 $\lambda v1.\lambda v2.\lambda v3. ((v1 @ v2) @ \lambda v4. (t1 ; (v3 @ v4)))$
Time(v4, t1)
time.n.08(t1)
YearOfCentury(t1, 1650)

fondata nel 1650
S[pss]\NP
 $\lambda v1.\lambda v2. (v1 @ \lambda v3. (e1 t1 ; (v2 @ e1)))$
found.v.01(e1)
Time(e1, t1)
Theme(e1, v3)
time.n.08(t1)
YearOfCentury(t1, 1650)

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.



Semantic Tagging

Questa	scuola	è	stata	fondata	nel	1650	.
PRX	CON	NOW	PFT	EXS	DEF	YOC	NIL
NP/N	N	(S[dcl]\NP)/(S[pt]\NP)	(S[pt]\NP)/(S[pss]\NP)	S[pss]\NP	((S[pss]\NP)\(S[pss]\NP))/N	N	S[dcl]\S[dcl]

Questa scuola

NP

nel 1650

(S[pss]\NP)\(S[pss]\NP)

fondata nel 1650

S[pss]\NP

stata fondata nel 1650

S[pt]\NP

è stata fondata nel 1650

S[dcl]\NP

Questa scuola è stata fondata nel 1650

S[dcl]

Questa scuola è stata fondata nel 1650 .

S[dcl]

Word senses?

Gold:

I can't understand this table.

Neural Boxer: *I can't understand this table.*

	A	B	C	D
1	Date	Apples	Oranges	Total Fruit
2	6/1/2012	125	75	200
3	6/2/2012	118	84	202
4	6/3/2012	164	72	236
5	6/4/2012	114	65	179
6	6/5/2012	98	96	194
7	6/6/2012	172	82	254



b1 POS b2

b3 NOT b1

b2 REF x1

b2 Experiencer x1 "speaker"

b2 Stimulus x1 x2

b2 understand "v.01" x1

b4 REF x2

b4 table "n.02" x2



Practical Session

pmb.let.rug.nl