LANGUAGE AND INFERENCE

Day 1: Types of Inference
Day 2: Designing Meaning Representations
Day 3: Building Meaning Representations
Day 4: Projection and Presupposition
Day 5: Inference in the Real World

university of groningen

johan.bos@rug.nl

Discourse Representation Theory

- DRT is a formal semantic theory of text
- Predicts difference in acceptability of pronouns
- It employs box-like representations (DRS)

(blocked) anaphoric readings

“A politician spoke. He lied.”

=> anaphoric reading

“Every politician spoke. *He lied.”

=> no anaphoric reading

“It isn’t the case that no politician spoke. *He lied.”

=> no anaphoric reading

Indefinite noun phrases

"A politician spoke. He lied."

- Scope of "A politician" extends beyond clause
- Indefinite NP appears to be existential quantifier
- Or is it referential?

Indefinites in donkey sentences

Every farmer who owns a donkey beats it.

- Scope of “a donkey” extends beyond clause
- Indefinite NP appears to be universal quantifier
- It definitely isn’t referential!

Donkey sentences exist (google search)

Every nation that has a nuke, uses it.
(ToolMangler1)

Every system that receives a packet will inspect it.
(Eric A. Hall)

Seriously, almost every person who bought a mac bought it because they are "cool"
(xxBURTONxx)

Empirical observations

1. Singular NPs (“a” and “every”) have different anaphoric possibilities
2. Logically equivalent sentences have different anaphoric possibilities
3. Scope of an indefinite NP extends beyond clause boundaries
4. An indefinite noun phrase is sometimes interpreted as an existential, sometimes as a universal quantifier

Discourse Referents

- DRT analyses indefinite noun phrases as neither quantificational nor referential -- instead, they introduce variables
- These variables are called **discourse referents**
- Discourse referents are part of DRSs (Discourse Representation Structures)

Discourse Representation Structure

- DRS is a semantic representation of a text
- It serves as both <u>content</u> and <u>context</u>

  - **Content**:
    semantic interpretation of sentences already processed

  - **Context**:
    helps interpretation of anaphoric expressions in subsequent processing

DRS examples

- Discourse Representation Structures (DRS)
  - Are represented as (nested) boxes
  - Structure of the box plays role in pronoun resolution

A spokesman lied.
He …

x e y
spokesman(x)
lie(e)
agent(e,x)
y=x

Every spokesman lied.
**He …*

y
x
spokesman(x)
⇒
e
lie(e)
agent(e,x)
y=?

DRS examples

- Butch stole a chopper.
- It belonged to Zed.

- Butch stole no chopper.
- ?? It belonged to Zed.

- Butch stole a bike or a car.
- ?? The car belonged to Zed.

- Butch stole a chopper.
- It belonged to Zed.

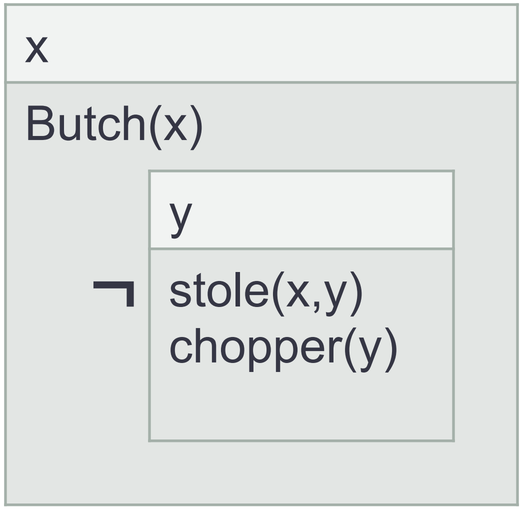
x y
Butch(x) stole(x,y) chopper(y)

- ✓ Butch stole a chopper.
- ○ It belonged to Zed.

x y u v
Butch(x) stole(x,y) chopper(y) u=y belonged-to(u,v) Zed(v)

- ✓ Butch stole a chopper.
- ✓ It belonged to Zed.

- Butch stole no chopper.
- ?? It belonged to Zed.

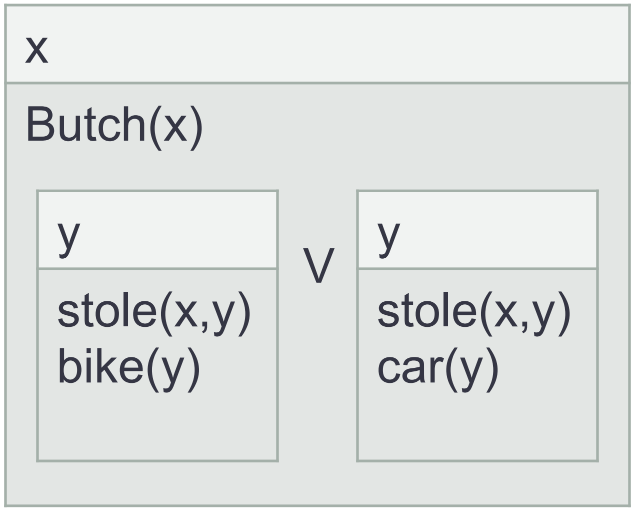


- ✓ Butch stole no chopper.
- ○ ?? It belonged to Zed.

x u v
Butch(x) ¬ [y | stole(x,y), chopper(y)] u=?? belonged-to(u,v) Zed(v)

- Butch stole no chopper.
- ?? It belonged to Zed.

- Butch stole either a bike or a car.
- ?? The car belonged to Zed.



- ✓ Butch stole either a bike or a car.
- ○ ?? The car belonged to Zed.

x u v

Butch(x)

y		y
stole(x,y) bike(y)	V	stole(x,y) car(y)

car(u)
u=??
belonged-to(u,v)
v=x

- ✓ Butch stole either a bike or a car.
- ✓ ?? The car belonged to Zed.

Syntax of DRS

<DRS> ::=

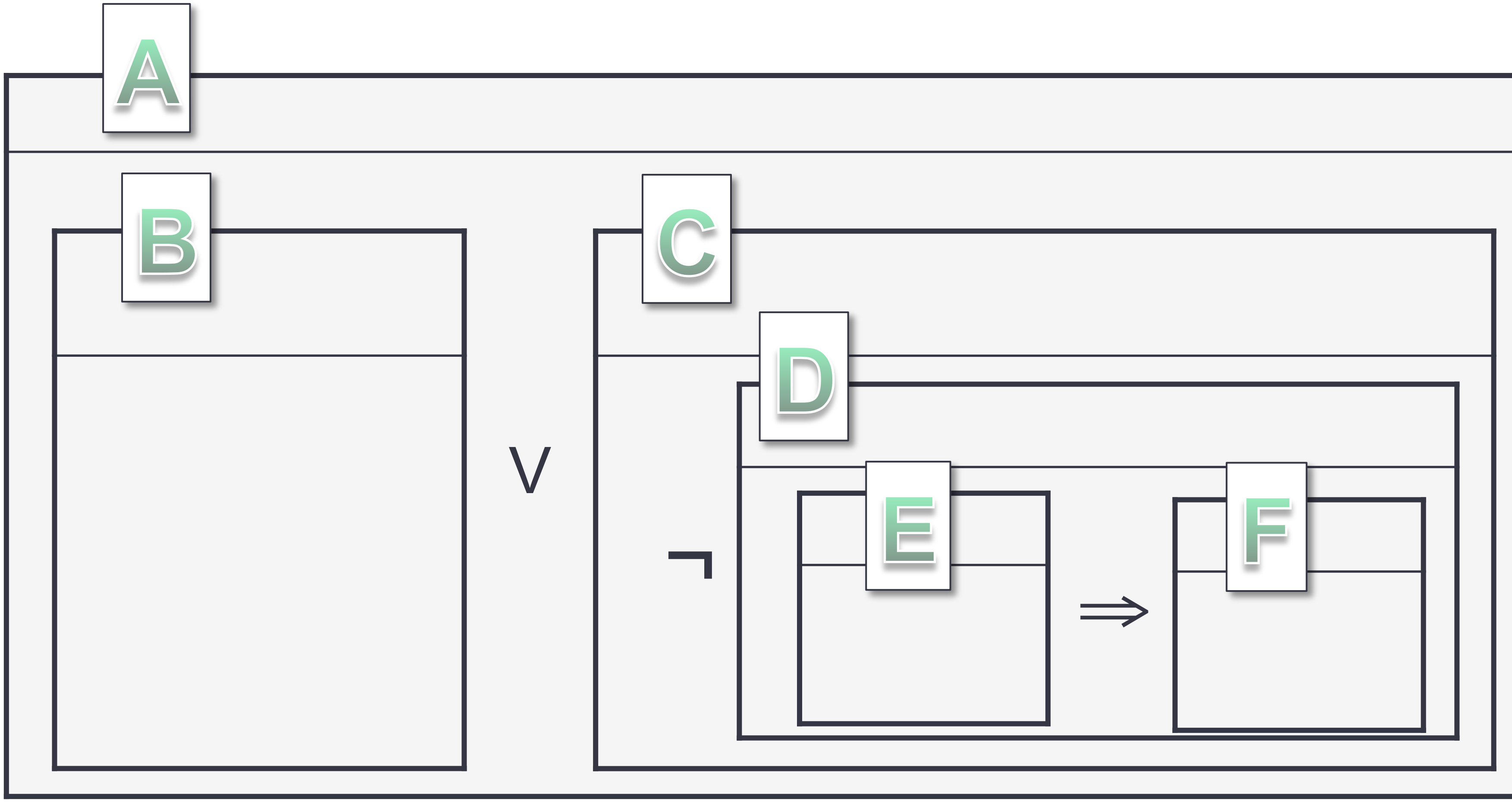
<VAR>*
<CON>*

<CON> ::= <BASIC> | <COMPLEX>

<BASIC> ::= <SYM$_1$>(<VAR>) | <SYM$_2$>(<VAR>,<VAR>) |
<VAR> = <VAR>

<COMPLEX> ::= ¬<DRS> | □<DRS> | ◇<DRS> |
<DRS> V <DRS> | <DRS> => <DRS> |
<VAR> : <DRS>

DRS subordination



A subordinates B
A subordinates C
C subordinates D

D subordinates E
E subordinates F
A subordinates D

A subordinates E
A subordinates F
C subordinates E

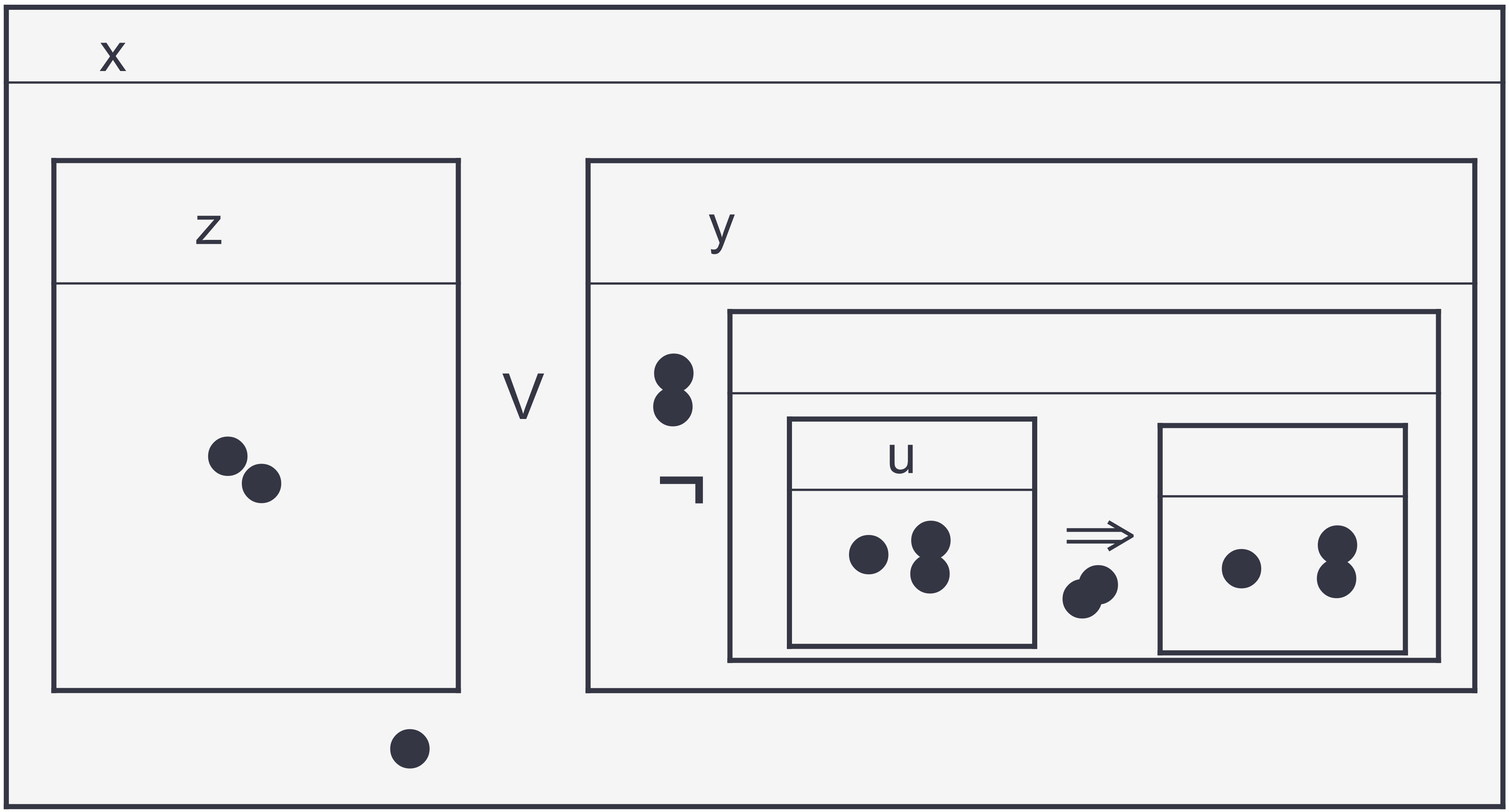
C subordinates F
D subordinates F

DRS accessibility

A discourse referent x in K_1 is accessible from a DRS K_2 iff one of the two conditions holds:

- K_1 subordinates K_2
- $K_1 = K_2$

DRS accessibility



Event Semantics

no events	*Davidsonian*	*Hobbsian*	*neo-Davidsonian*
x y u v	x y e u v e’	x y z e u v w e’	x y e u v e’
Butch(x)	Butch(x)	Butch(x)	Butch(x)
chopper(y)	chopper(y)	chopper(y)	chopper(y)
stole(x,y)	stole(e,x,y)	stole(e,x,y,z)	stole(e)
u=y	u=y	u=y	agent(e,x)
garage(v)	garage(v)	garage(v)	theme(e,y)
parked-in(u,v)	parked(e’,u)	parked(e’,u,v,w)	u=y
	in(e’,v)	in(e’,v)	garage(v)
			parked(e’)
			theme(e’,u)
			location(e’,v)

- Butch stole a chopper.
- It was parked in a garage.

Hybrid conditions

Butch believes that he killed Zed.

x e k z
Butch(x) Zed(z) believe(e) experiencer(e,x) theme(e,k)
k: <table><tr><td>e y</td></tr><tr><td>y=x kill(e) agent(e,y) patient(e,z)</td></tr></table>

Implementing inference for DRT

- It is hard to build an efficient theorem prover for DRT from scratch
- There are many good theorem provers for FOL available
- There is a translation from DRS to FOL

Translating from DRS to FOL

- The “standard” translation from DRS to FOL
- Extension dealing with modal and hybrid DRS-conditions

Translating DRS to FOL

$$\left(\begin{array}{|l|}\hline \mathrm{x}_1, \ldots, \mathrm{x}_n \\ \hline \gamma_1 \\ \cdot \\ \cdot \\ \cdot \\ \gamma_m \\ \hline\end{array}\right)^{fo} = \exists \mathrm{x}_1 \cdots \exists \mathrm{x}_n ((\gamma_1)^{fo} \wedge \cdots \wedge (\gamma_m)^{fo})$$

Translating DRS to FOL

$$
\begin{array}{rcl}
(R(\mathrm{x}_1,\ldots,\mathrm{x}_n))^{fo} & = & R(\mathrm{x}_1,\ldots,\mathrm{x}_n) \\
(\tau_1 = \tau_2)^{fo} & = & \tau_1 = \tau_2 \\
(\neg B)^{fo} & = & \neg(B)^{fo} \\
(B_1 \vee B_2)^{fo} & = & (B_1)^{fo} \vee (B_2)^{fo}
\end{array}
$$

$$
\left(\begin{array}{|l|}\hline \mathrm{x}_1,\ldots,\mathrm{x}_n \\ \hline \gamma_1 \\ . \\ . \\ . \\ \gamma_m \\ \hline \end{array} \Rightarrow B\right)^{fo} = \forall \mathrm{x}_1 \cdots \forall \mathrm{x}_n(((\gamma_1)^{fo} \wedge \cdots \wedge (\gamma_m)^{fo}) \rightarrow (B)^{fo})
$$

Modal operators

$$(\mathrm{v},\Box \mathrm{B})^t = \forall \mathrm{w}(\mathrm{R}(\mathrm{v},\mathrm{w}) \rightarrow (\mathrm{w},\mathrm{B})^t)$$

$$(\mathrm{v},\Diamond \mathrm{B})^t = \exists \mathrm{w}(\mathrm{R}(\mathrm{v},\mathrm{w}) \wedge (\mathrm{w},\mathrm{B})^t)$$

$$(\mathrm{v},\mathrm{x}{:}\mathrm{B})^t = (\mathrm{R}(\mathrm{v},\mathrm{x}) \wedge (\mathrm{x},\mathrm{B})^t)$$

Translate this DRS into FOL