A (Hybrid) Logical Approach to Frame Semantics

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(joint work with Laura Kallmeyer[2] and Rainer Osswald[2])

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Outline

1. Frame Semantics
   - The Frame Hypothesis
   - Frames and Logic
2. Hybrid Logic
   - Reminder on Modal Logic
   - Hybrid Logic
3. Compositional Frame Semantics
   - Quantification
   - Frame Decomposition

Frame Semantics

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- *A frame is a data-structure representing a stereotyped situation* (Minsky 1974, p.1)
- *I thought of each case frame as characterizing a small abstract 'scene' or 'situation', so that to understand the semantic structure of the verb it was necessary to understand the properties of such schematized scenes* (Fillmore 1982, p.115)
- *I propose that frames provide the fundamental representation of knowledge in human cognition* (Barsalou 1992)

The Frame Hypothesis (Löbner 2014)

- H1 The human cognitive system operates with a single general format of representations
- H2 If the human cognitive system operates with one general format of representations, this format is essentially Barsalou's frames

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- Verb meaning frames go beyond "case frames". For instance
  - Aspectual characteristics of the situation
  - Structured relations between semantic arguments

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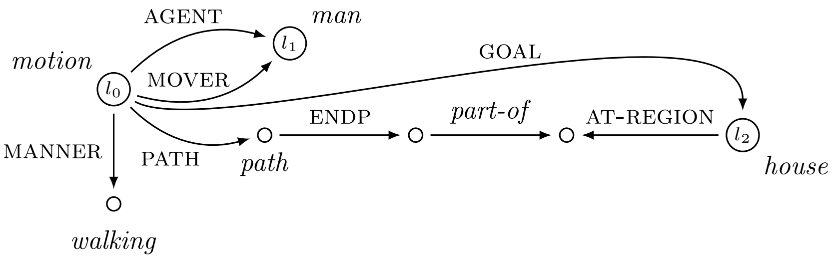
- Verb meaning frames go beyond "case frames". For instance
  - Aspectual characteristics of the situation
  - Structured relations between semantic arguments
- Decompositional approach to meaning (Osswald and Van Valin 2014)

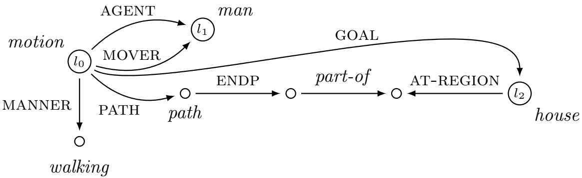
Frame Example

The man walked into the house



Formal Representation of Frames

Frames as base-labelled feature structures with types and relations (Kallmeyer and Osswald 2013)



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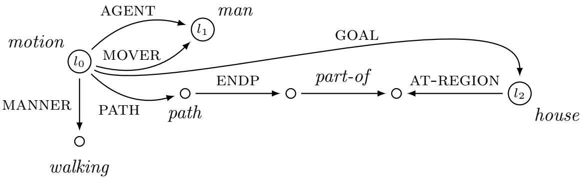

$$\begin{bmatrix} \textit{motion} & \\ \text{AGENT} & \boxed{1}\begin{bmatrix}\textit{man}\end{bmatrix} \\ \text{MOVER} & \boxed{1} \\ \text{GOAL} & \boxed{2}\begin{bmatrix}\textit{house} \\ \text{AT-REGION}\ \boxed{w}\end{bmatrix} \\ \text{PATH} & \begin{bmatrix}\textit{path} \\ \text{ENDP}\ \boxed{v}\end{bmatrix} \\ \text{MANNER} & \begin{bmatrix}\textit{walking}\end{bmatrix} \end{bmatrix}$$

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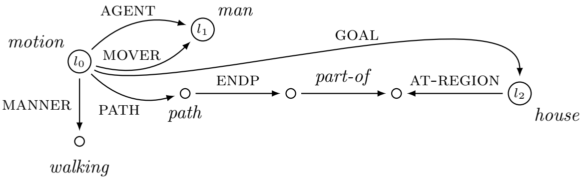

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Labelled attribute-value description (LAVD) language

$\boxed{0} : \textit{motion} \;\wedge$
$\boxed{0} \cdot \text{AGENT} \triangleq \boxed{1} \;\wedge$
$\boxed{0} \cdot \text{AGENT} \doteq \boxed{0} \cdot \text{MOVER} \;\wedge$
$\boxed{0} \cdot \text{GOAL} \triangleq \boxed{2} \;\wedge$
$\boxed{0} \cdot \text{PATH} : \textit{path} \wedge$
$\boxed{0} \cdot \text{MANNER} : \textit{walking} \;\wedge \boxed{1} : \textit{man}$
$\boxed{2} : \textit{house} \;\wedge$
$\langle \boxed{0} \cdot \text{PATH} \cdot \text{ENDP}, \boxed{2} \cdot \text{AT-REGION} \rangle : \textit{part-of}$

Base-Labelled Feature Structures and LAVD Language

Properties:

- A frame is represented as a base-labelled feature structure
- It is specified using the LAVD language
- It is the most general base-labelled feature structures that satisfy the given LAVD formula (minimal first-order model)
- Suitable to frame decomposition and composition
- Variable free
- *We take the semantic structures associated with the syntactic structures as genuine semantic representations, not as some kind of yet to be interpreted logical expressions* (Kallmeyer and Osswald 2013)

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However:

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- Referential entities are treated as definites (reflected by the naming of nodes)
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Proposal

- Frames are considered as relational models → modal logic
- Feature structures specification require the hybrid logic language extension
- Use hybrid logic binders to quantify

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Satisfaction Relation

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Let $\mathcal{M}$ be a model, $w \in M$
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\mathcal{M}, & w \models \langle R \rangle \phi & \text{iff there is a } w' \in M \text{ such that } R^{\mathcal{M}}(w, w') \text{ and } \mathcal{M}, \quad w' \models \phi
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An assignment g is a mapping $g : \mathrm{Svar} \longrightarrow M$.

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An assignment g is a mapping $g : \mathrm{Svar} \longrightarrow M$.
g^x_m is an assignment that differs from g at most on x and such that $g^x_m(x) = m$.

Hybrid Logic (Blackburn 1993; Areces and ten Cate 2007)

Models

Definition (Model)

A *model* $\mathcal{M}$ is a triple $\langle M, (R^{\mathcal{M}})_{R \in \mathrm{Rel}}, V \rangle$ such that:

- M is a non-empty set,
- each $R^{\mathcal{M}}$ is a binary relation on M,
- $V : \mathrm{Prop} \cup \mathrm{Nom} \longrightarrow \wp(M)$ is a valuation such that if $i \in \mathrm{Nom}$ then $V(i)$ is a singleton.

An assignment g is a mapping $g : \mathrm{Svar} \longrightarrow M$.
g_m^x is an assignment that differs from g at most on x and such that $g_m^x(x) = m$.
For $s \in \mathrm{Stat}$, we also define $[s]^{\mathcal{M},g}$ to be the only m such that $V(s) = \{m\}$ if $s \in \mathrm{Nom}$ and $[s]^{\mathcal{M},g} = g(s)$ if $s \in \mathrm{Svar}$.

Modal Logic (Blackburn 1993; Areces and ten Cate 2007)

Satisfaction Relation

Definition (Satisfaction relation)

Let $\mathcal{M}$ be a model, $w \in M$
The *satisfaction relation* $\models$ is defined as follows:

$$
\begin{array}{lll}
\mathcal{M}, & w \models \top & \\
\mathcal{M}, & w \models p & \text{iff } w \in V(p) \text{ for } p \in \text{Prop} \\
\mathcal{M}, & w \models \neg\phi & \text{iff } \mathcal{M}, \quad w \not\models \phi \\
\mathcal{M}, & w \models \phi_1 \wedge \phi_2 & \text{iff } \mathcal{M}, \quad w \models \phi_1 \text{ and } \mathcal{M}, \quad w \models \phi_2 \\
\mathcal{M}, & w \models \langle R \rangle \phi & \text{iff there is a } w' \in M \text{ such that } R^{\mathcal{M}}(w, w') \text{ and } \mathcal{M}, \quad w' \models \phi
\end{array}
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Hybrid Logic (Blackburn 1993; Areces and ten Cate 2007)

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\mathcal{M}, g, w \models s & \text{iff } w = [s]^{\mathcal{M},g} \text{ for } s \in \text{Stat}
\end{array}
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Hybrid Logic (Blackburn 1993; Areces and ten Cate 2007)

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\mathcal{M}, g, w \models s & \text{iff } w = [s]^{\mathcal{M},g} \text{ for } s \in \text{Stat} \\
\mathcal{M}, g, w \models @_s\phi & \text{iff } \mathcal{M}, g, [s]^{\mathcal{M},g} \models \phi \text{ for } s \in \text{Stat}
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\mathcal{M}, g, w \models \downarrow x.\phi & \text{iff } \mathcal{M}, g^x_w, w \models \phi
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\mathcal{M}, g, w \models \langle R \rangle\phi & \text{iff there is a } w' \in M \text{ such that } R^{\mathcal{M}}(w, w') \text{ and } \mathcal{M}, g, w' \models \phi \\
\mathcal{M}, g, w \models s & \text{iff } w = [s]^{\mathcal{M},g} \text{ for } s \in \text{Stat} \\
\mathcal{M}, g, w \models @_s\phi & \text{iff } \mathcal{M}, g, [s]^{\mathcal{M},g} \models \phi \text{ for } s \in \text{Stat} \\
\mathcal{M}, g, w \models \downarrow x.\phi & \text{iff } \mathcal{M}, g^x_w, w \models \phi \\
\mathcal{M}, g, w \models \exists\phi & \text{iff there is a } w' \in M \text{ such that } \mathcal{M}, g, w' \models \phi
\end{array}
$$

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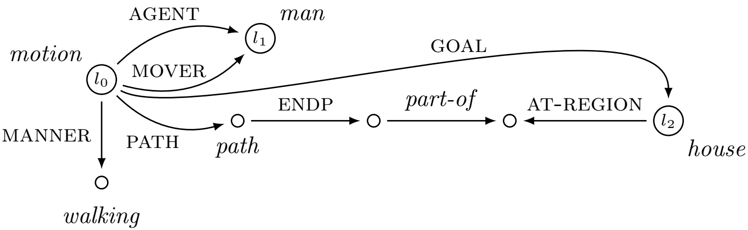
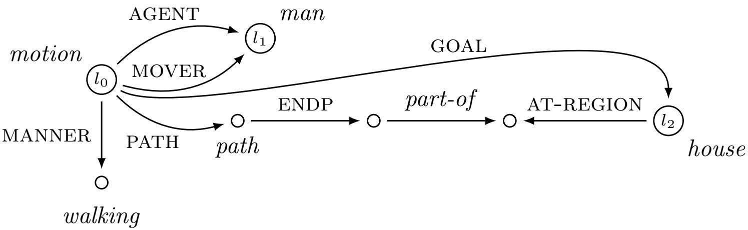
\mathcal{M}, g, w \models @_s\phi & \text{iff } \mathcal{M}, g, [s]^{\mathcal{M},g} \models \phi \text{ for } s \in \text{Stat} \\
\mathcal{M}, g, w \models \downarrow x.\phi & \text{iff } \mathcal{M}, g_w^x, w \models \phi \\
\mathcal{M}, g, w \models \mathbf{\exists}\phi & \text{iff there is a } w' \in M \text{ such that } \mathcal{M}, g, w' \models \phi \\
\mathcal{M}, g, w \models \exists x.\phi & \text{iff there is a } w' \in M \text{ such that } \mathcal{M}, g_{w'}^x, w \models \phi
\end{array}
$$

Example

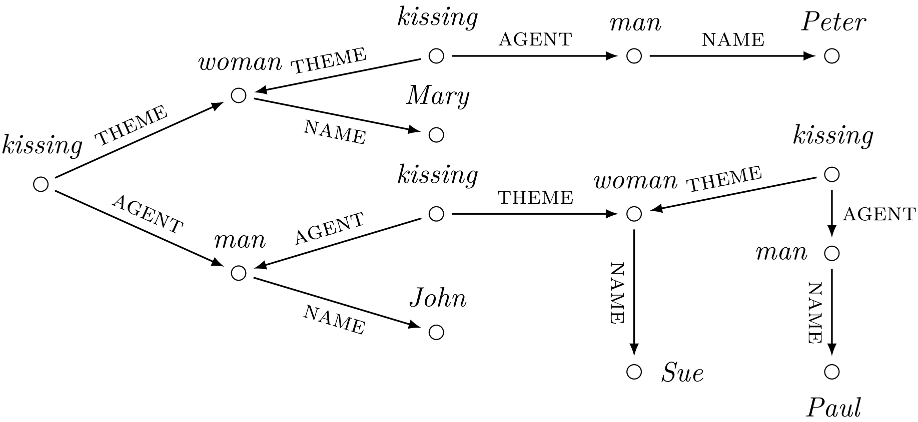

AGENT
man
l_1
motion
MOVER
GOAL
l_0
ENDP
part-of
AT-REGION
l_2
MANNER
PATH
path
house
walking

Example

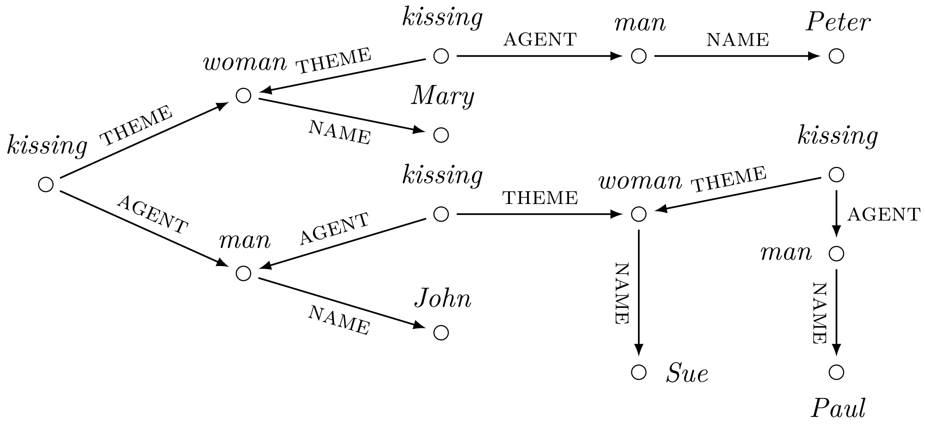


$$l_0 \wedge \textit{motion} \wedge \langle \text{AGENT} \rangle (l_1 \wedge \textit{man}) \wedge \langle \text{MOVER} \rangle l_1 \wedge \langle \text{GOAL} \rangle (l_2 \wedge \textit{house}) \wedge \langle \text{MANNER} \rangle \textit{walking} \wedge (\exists v\ w. \langle \text{PATH} \rangle (\textit{path} \wedge \langle \text{ENDP} \rangle v) \wedge @_{l_2}(\langle \text{AT-REGION} \rangle w) \wedge @_v(\langle \textit{part-of} \rangle w))$$

Quantification

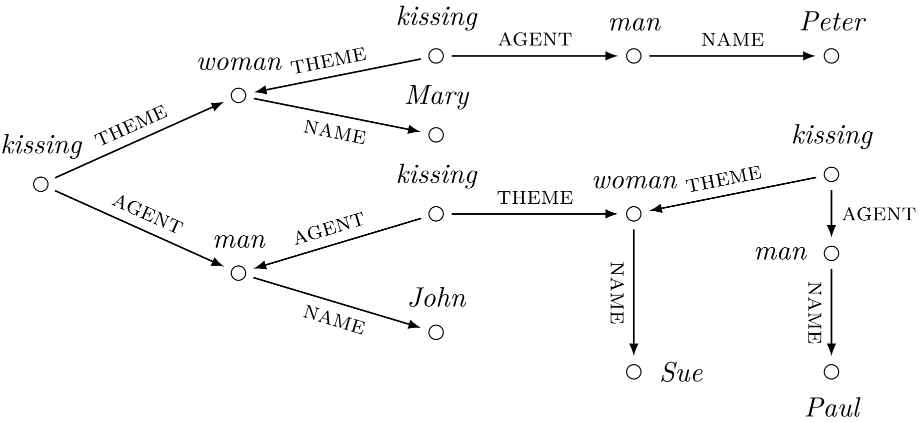


Quantification



(1) *a. John kisses Mary*

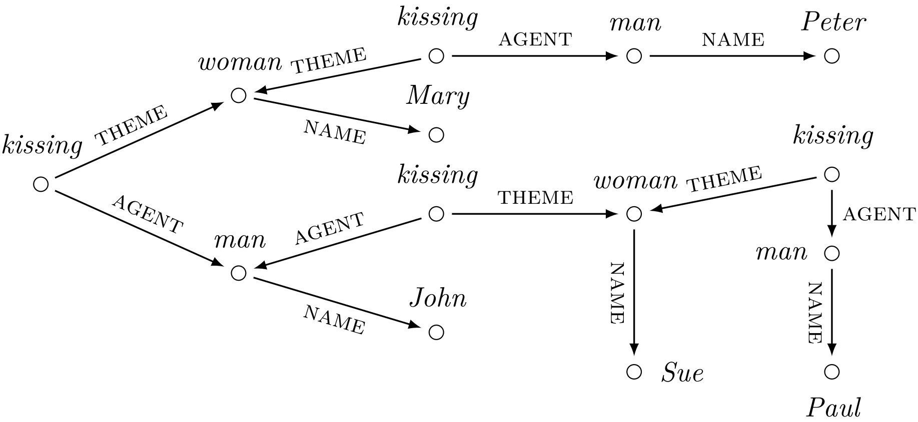
Quantification



(1) *a. John kisses Mary*

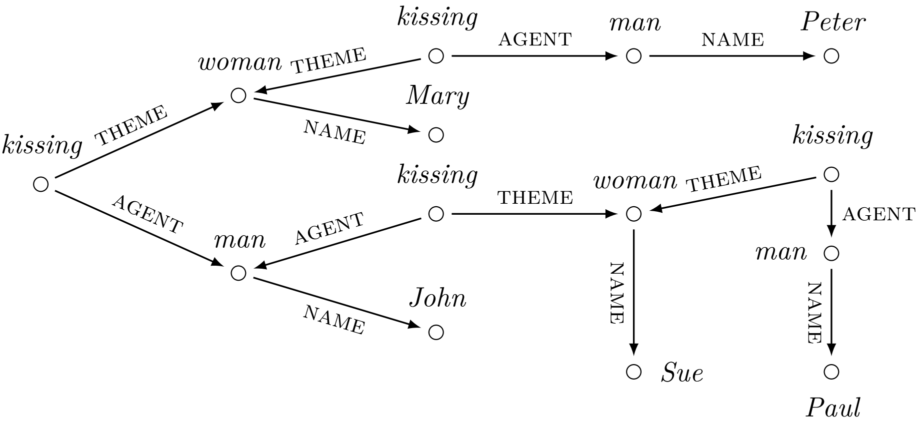
b. $\exists(\textit{kissing} \wedge \langle\text{AGENT}\rangle(\langle\text{NAME}\rangle\textit{John}) \wedge \langle\text{THEME}\rangle(\langle\text{NAME}\rangle\textit{Mary}))$

Quantification



(2) *a. Every man kisses Mary*

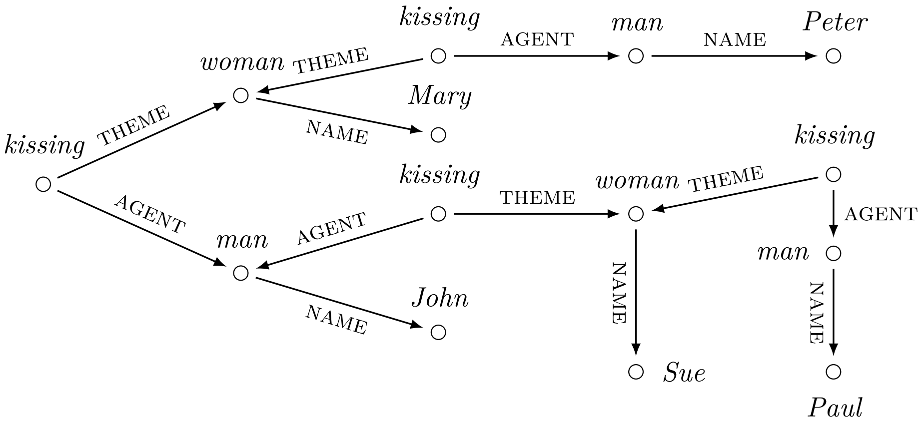
Quantification



(2) a. *Every man kisses Mary*

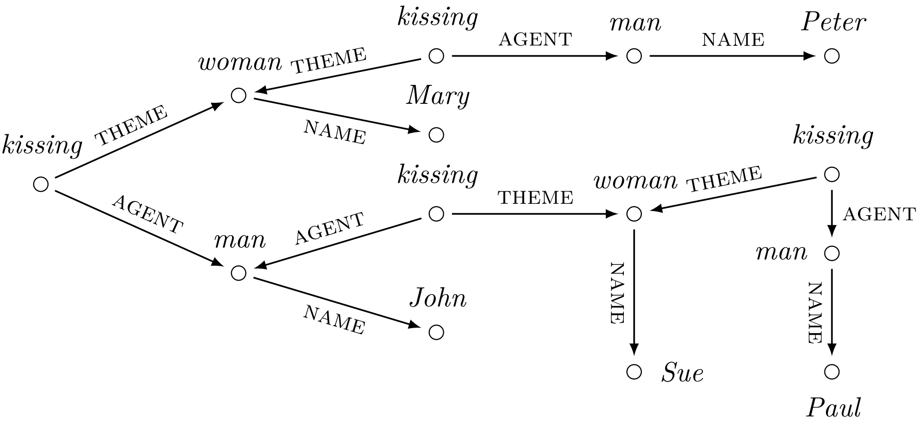
b. $\forall(\downarrow i.man \Rightarrow \exists(kissing \wedge \langle \text{AGENT} \rangle i \wedge \langle \text{THEME} \rangle (\langle \text{NAME} \rangle Mary)))$

Quantification



(3) *a. Every man kisses some woman*

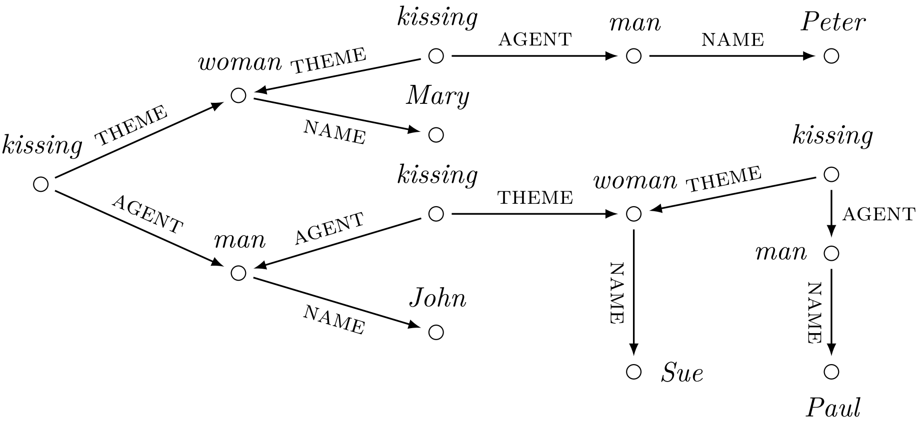
Quantification



(3) a. *Every man kisses some woman*

b. $\forall(\downarrow i.man \Rightarrow \exists(\downarrow i'.woman \wedge \exists(kissing \wedge \langle \text{AGENT} \rangle i \wedge \langle \text{THEME} \rangle i')))$

Quantification

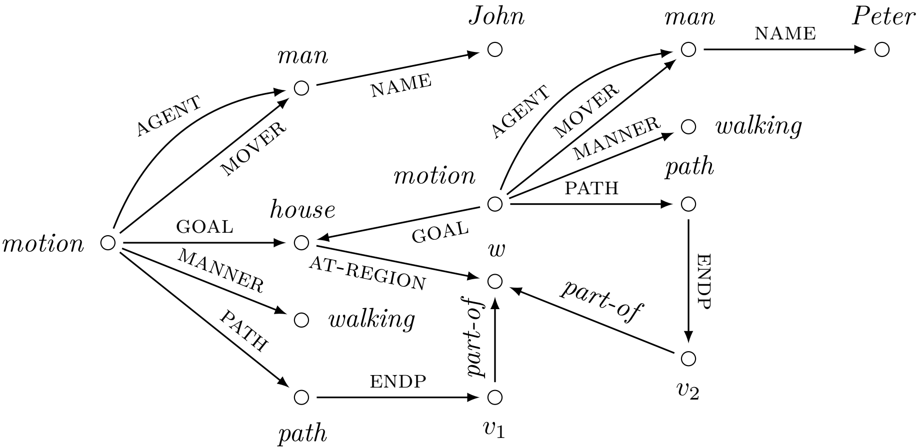


(3) *a. Every man kisses some woman*

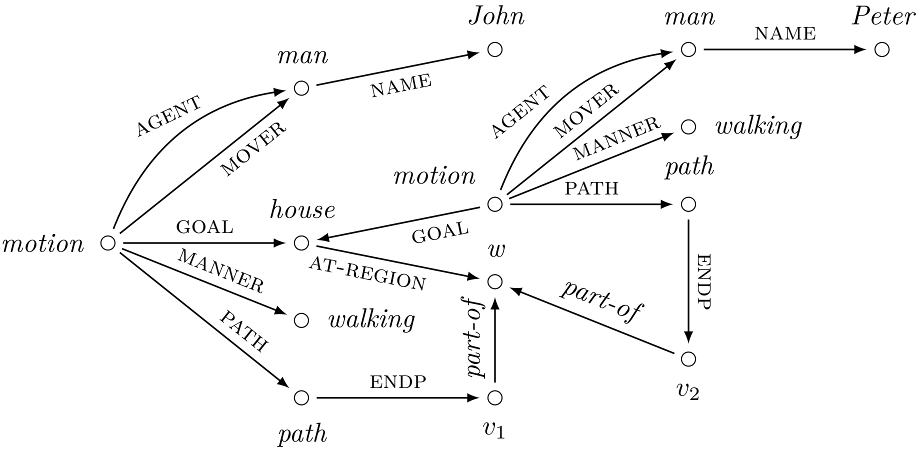
b. $\forall(\downarrow i.man \Rightarrow \exists(\downarrow i'.woman \wedge \exists(kissing \wedge \langle \text{AGENT} \rangle i \wedge \langle \text{THEME} \rangle i')))$

c. $\exists(\downarrow i.woman \wedge \forall(\downarrow i'.man \Rightarrow \exists(kissing \wedge \langle \text{AGENT} \rangle i' \wedge \langle \text{THEME} \rangle i)))$

Example

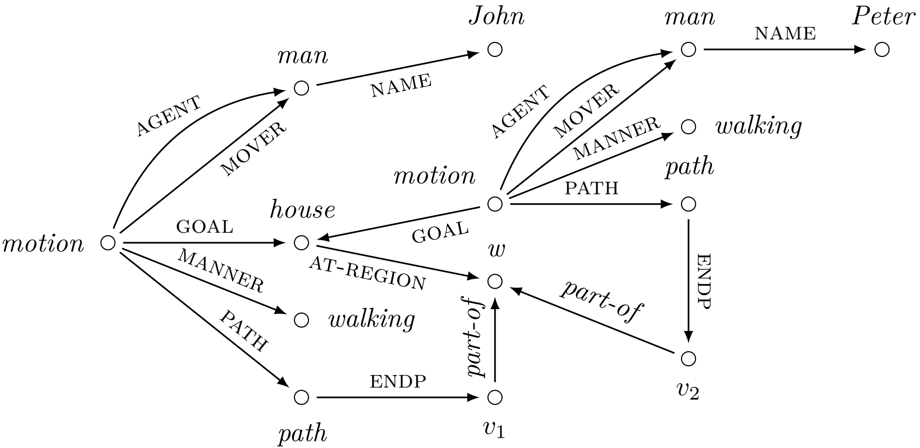

John
man
Peter
NAME
man
NAME
AGENT
MOVER
AGENT
MOVER
MANNER
walking
motion
path
PATH
house
GOAL
GOAL
motion
w
MANNER
AT-REGION
ENDP
walking
part-of
part-of
PATH
ENDP
v1
v2
path

Example



(4) *a. Every man walked to some house*

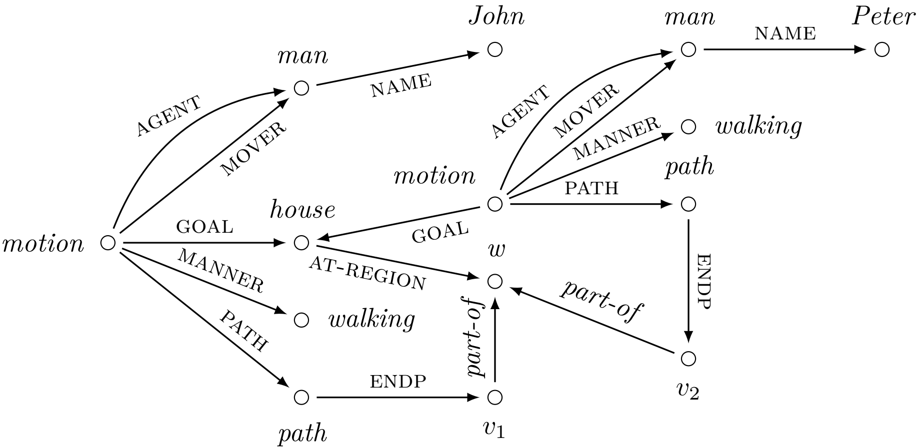
Example



(4) *a. Every man walked to some house*

b. $\boldsymbol{\forall}(\downarrow i.man \Rightarrow (\boldsymbol{\exists}(\downarrow i'.house \wedge (\exists a\ g.\boldsymbol{\exists}(motion \wedge \langle \text{AGENT} \rangle a \wedge \langle \text{MOVER} \rangle a \wedge$
$\langle \text{GOAL} \rangle g \wedge \langle \text{PATH} \rangle path \wedge \langle \text{MANNER} \rangle walking \wedge @_a i \wedge (\exists r\ v\ w.event \wedge$
$\langle \text{PATH} \rangle (path \wedge \langle \text{ENDP} \rangle v) \wedge @_r(\langle \text{AT-REGION} \rangle w) \wedge @_v(\langle part\text{-}of \rangle w) \wedge @_r(g \wedge i'))))))$

Example



(4) *a. Every man walked to some house*

b. $\boldsymbol{\exists}(\downarrow i'.house \wedge (\boldsymbol{\forall}(\downarrow i.man \Rightarrow (\exists a\ g.\boldsymbol{\exists}(motion \wedge \langle \text{AGENT}\rangle a \wedge \langle \text{MOVER}\rangle a \wedge$
$\langle \text{GOAL}\rangle g \wedge \langle \text{PATH}\rangle path \wedge \langle \text{MANNER}\rangle walking \wedge @_a i \wedge (\exists r\ v\ w.event \wedge$
$\langle \text{PATH}\rangle(path \wedge \langle \text{ENDP}\rangle v) \wedge @_r(\langle \text{AT-REGION}\rangle w) \wedge @_v(\langle part\text{-}of\rangle w) \wedge @_r(g \wedge i')))))$

Compositional Frame Semantics

Semantic types and constants

- Types: e, s, t

Compositional Frame Semantics

Semantic types and constants

- Types: e, s, t
- Constants:

$$event, kissing, motion, John, \ldots \qquad : t$$

Compositional Frame Semantics

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$$event, kissing, motion, John, \ldots \quad : t \qquad \# \quad : s \rightarrow t$$

Compositional Frame Semantics

Semantic types and constants

- Types: e, s, t
- Constants:

$$\begin{array}{ll} \mathit{event}, \mathit{kissing}, \mathit{motion}, \mathit{John}, \ldots & : t \qquad \# \quad : s \rightarrow t \\ \langle \text{AGENT} \rangle, \langle \text{THEME} \rangle, \langle \text{MOVER} \rangle, \langle \mathit{part\text{-}of} \rangle, \ldots & : t \rightarrow t \end{array}$$

Compositional Frame Semantics

Semantic types and constants

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- Constants:

$$
\begin{array}{llll}
\mathit{event}, \mathit{kissing}, \mathit{motion}, \mathit{John}, \ldots & : t & \# & : s \rightarrow t \\
\langle \text{AGENT} \rangle, \langle \text{THEME} \rangle, \langle \text{MOVER} \rangle, \langle \mathit{part\text{-}of} \rangle, \ldots & : t \rightarrow t & @ & : s \rightarrow t \rightarrow t
\end{array}
$$

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- Constants:

$$
\begin{array}{llll}
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\langle \text{AGENT} \rangle, \langle \text{THEME} \rangle, \langle \text{MOVER} \rangle, \langle \mathit{part\text{-}of} \rangle, \ldots & : t \rightarrow t & @ & : s \rightarrow t \rightarrow t \\
\wedge, \Rightarrow \quad : t \rightarrow t \rightarrow t & & &
\end{array}
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- Constants:

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$$\wedge, \Rightarrow \quad : t \rightarrow t \rightarrow t \qquad \mathbf{\exists}, \mathbf{\forall} \quad : t \rightarrow t$$

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$$\begin{array}{llll} \textit{event}, \textit{kissing}, \textit{motion}, \textit{John}, \ldots & : t & \# & : s \to t \\ \langle\text{AGENT}\rangle, \langle\text{THEME}\rangle, \langle\text{MOVER}\rangle, \langle \textit{part-of} \rangle, \ldots & : t \to t & @ & : s \to t \to t \\ \wedge, \Rightarrow \quad : t \to t \to t \qquad \mathbf{\exists}, \mathbf{\forall} & : t \to t & \downarrow, \exists & : (s \to t) \to t \end{array}$$

Compositional Frame Semantics

Semantic types and constants

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- Constants:

$$
\begin{array}{llll}
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\langle \text{AGENT} \rangle, \langle \text{THEME} \rangle, \langle \text{MOVER} \rangle, \langle \textit{part-of} \rangle, \ldots & : t \to t & @ & : s \to t \to t \\
\wedge, \Rightarrow \quad : t \to t \to t \qquad \mathbf{E}, \mathbf{A} & : t \to t & \downarrow, \exists & : (s \to t) \to t
\end{array}
$$

Lexical Semantics

$$
\begin{array}{lcl}
[\![\text{John}]\!] & = & \textit{John} \\
[\![\text{Mary}]\!] & = & \textit{Mary} \\
[\![\text{man}]\!] & = & \textit{man} \\
[\![\text{woman}]\!] & = & \textit{woman}
\end{array}
$$

Compositional Frame Semantics

Semantic types and constants

- Types: e, s, t
- Constants:

$$\begin{array}{lllll} \mathit{event}, \mathit{kissing}, \mathit{motion}, \mathit{John}, \ldots & : t & & \# & : s \to t \\ \langle\text{AGENT}\rangle, \langle\text{THEME}\rangle, \langle\text{MOVER}\rangle, \langle \mathit{part\text{-}of} \rangle, \ldots & : t \to t & & @ & : s \to t \to t \\ \wedge, \Rightarrow \quad : t \to t \to t \qquad \mathbf{\exists}, \mathbf{\forall} & : t \to t & & \downarrow, \exists & : (s \to t) \to t \end{array}$$

Lexical Semantics

$$\begin{array}{lll lll} [\![\text{John}]\!] & = & \mathit{John} & [\![\text{some}]\!] & = & \lambda P\ Q.\mathbf{\exists}(\downarrow i.P \wedge (Q\ (\#\, i))) \\ [\![\text{Mary}]\!] & = & \mathit{Mary} & [\![\text{every}]\!] & = & \lambda P\ Q.\mathbf{\forall}(\downarrow i.P \Rightarrow (Q\ (\#\, i))) \\ [\![\text{man}]\!] & = & \mathit{man} & & & \\ [\![\text{woman}]\!] & = & \mathit{woman} & & & \end{array}$$

Compositional Frame Semantics

Semantic types and constants

- Types: e, s, t
- Constants:

$$
\begin{array}{lll}
\mathit{event}, \mathit{kissing}, \mathit{motion}, \mathit{John}, \ldots & : t & \# \quad : s \rightarrow t \\
\langle \text{AGENT} \rangle, \langle \text{THEME} \rangle, \langle \text{MOVER} \rangle, \langle \mathit{part\text{-}of} \rangle, \ldots & : t \rightarrow t & @ \quad : s \rightarrow t \rightarrow t \\
\wedge, \Rightarrow \quad : t \rightarrow t \rightarrow t \qquad \mathbf{\exists}, \mathbf{\forall} & : t \rightarrow t & \downarrow, \exists \quad : (s \rightarrow t) \rightarrow t
\end{array}
$$

Lexical Semantics

$$
\begin{array}{lcllcl}
[\![\text{John}]\!] & = & \mathit{John} & [\![\text{some}]\!] & = & \lambda P\ Q.\mathbf{\exists}(\downarrow i.P \wedge (Q\ (\#\, i))) \\
[\![\text{Mary}]\!] & = & \mathit{Mary} & [\![\text{every}]\!] & = & \lambda P\ Q.\mathbf{\forall}(\downarrow i.P \Rightarrow (Q\ (\#\, i))) \\
[\![\text{man}]\!] & = & \mathit{man} & [\![\text{kisses}]\!] & = & \lambda o\ s.\mathbf{\exists}(\mathit{kissing} \wedge \langle \text{AGENT} \rangle s \wedge \langle \text{THEME} \rangle o) \\
[\![\text{woman}]\!] & = & \mathit{woman} & & &
\end{array}
$$

Compositional Frame Semantics

Semantic types and constants

- Types: e, s, t
- Constants:

$$
\begin{array}{llll}
\mathit{event}, \mathit{kissing}, \mathit{motion}, \mathit{John}, \ldots & : t & \# & : s \to t \\
\langle \text{AGENT} \rangle, \langle \text{THEME} \rangle, \langle \text{MOVER} \rangle, \langle \mathit{part\text{-}of} \rangle, \ldots & : t \to t & @ & : s \to t \to t \\
\wedge, \Rightarrow \quad : t \to t \to t \qquad \mathbf{\exists}, \mathbf{\forall} & : t \to t & \downarrow, \exists & : (s \to t) \to t
\end{array}
$$

Lexical Semantics

$$
\begin{array}{lcl lcl}
[\![\text{John}]\!] & = & \mathit{John} & [\![\text{some}]\!] & = & \lambda P\ Q.\mathbf{\exists}(\downarrow i.P \wedge (Q\ (\#\, i))) \\
[\![\text{Mary}]\!] & = & \mathit{Mary} & [\![\text{every}]\!] & = & \lambda P\ Q.\mathbf{\forall}(\downarrow i.P \Rightarrow (Q\ (\#\, i))) \\
[\![\text{man}]\!] & = & \mathit{man} & [\![\text{kisses}]\!] & = & \lambda o\ s.\mathbf{\exists}(\mathit{kissing} \wedge \langle \text{AGENT} \rangle s \wedge \langle \text{THEME} \rangle o) \\
[\![\text{woman}]\!] & = & \mathit{woman} & & &
\end{array}
$$

$$
[\![\text{kisses}]\!]\ [\![\text{Mary}]\!]\ [\![\text{John}]\!] = \mathbf{\exists}(\mathit{kissing} \wedge \langle \text{AGENT} \rangle(\langle \text{NAME} \rangle \mathit{John}) \wedge \langle \text{THEME} \rangle(\langle \text{NAME} \rangle \mathit{Mary}))
$$

Compositional Frame Semantics

Semantic types and constants

- Types: e, s, t
- Constants:

$$\begin{array}{llll} \mathit{event}, \mathit{kissing}, \mathit{motion}, \mathit{John}, \ldots & : t & \# & : s \to t \\ \langle \text{AGENT} \rangle, \langle \text{THEME} \rangle, \langle \text{MOVER} \rangle, \langle \mathit{part\text{-}of} \rangle, \ldots & : t \to t & @ & : s \to t \to t \\ \wedge, \Rightarrow \quad : t \to t \to t \qquad \mathbf{\exists}, \mathbf{\forall} & : t \to t & \downarrow, \exists & : (s \to t) \to t \end{array}$$

Lexical Semantics

$$\begin{array}{lll} [\![\text{John}]\!] = \mathit{John} & [\![\text{some}]\!] & = \lambda P\ Q.\mathbf{\exists}(\downarrow i.P \wedge (Q\ (\#\, i))) \\ [\![\text{Mary}]\!] = \mathit{Mary} & [\![\text{every}]\!] & = \lambda P\ Q.\mathbf{\forall}(\downarrow i.P \Rightarrow (Q\ (\#\, i))) \\ [\![\text{man}]\!] = \mathit{man} & [\![\text{kisses}]\!] & = \lambda o\ s.\mathbf{\exists}(\mathit{kissing} \wedge \langle \text{AGENT} \rangle s \wedge \langle \text{THEME} \rangle o) \\ [\![\text{woman}]\!] = \mathit{woman} & & \end{array}$$

$$([\![\text{every}]\!]\ [\![\text{man}]\!])\ (\lambda x.[\![\text{kisses}]\!]\ [\![\text{Mary}]\!]\ x) =$$

$$\mathbf{\forall}(\downarrow i.\mathit{man} \Rightarrow \mathbf{\exists}(\mathit{kissing} \wedge \langle \text{AGENT} \rangle i\ \wedge \langle \text{THEME} \rangle(\langle \text{NAME} \rangle \mathit{Mary})))$$

Compositional Frame Semantics

Semantic types and constants

- Types: e, s, t
- Constants:

$$\begin{array}{llllll} \mathit{event}, \mathit{kissing}, \mathit{motion}, \mathit{John}, \ldots & : t & \# & : s \to t \\ \langle \text{AGENT} \rangle, \langle \text{THEME} \rangle, \langle \text{MOVER} \rangle, \langle \mathit{part\text{-}of} \rangle, \ldots & : t \to t & @ & : s \to t \to t \\ \wedge, \Rightarrow \quad : t \to t \to t \qquad \mathbf{\exists}, \mathbf{\forall} & : t \to t & \downarrow, \exists & : (s \to t) \to t \end{array}$$

Lexical Semantics

$$\begin{array}{lll lll} [\![\text{John}]\!] & = & \mathit{John} & [\![\text{some}]\!] & = & \lambda P\, Q.\mathbf{\exists}(\downarrow i.P \wedge (Q\ (\#\, i))) \\ [\![\text{Mary}]\!] & = & \mathit{Mary} & [\![\text{every}]\!] & = & \lambda P\, Q.\mathbf{\forall}(\downarrow i.P \Rightarrow (Q\ (\#\, i))) \\ [\![\text{man}]\!] & = & \mathit{man} & [\![\text{kisses}]\!] & = & \lambda o\ s.\mathbf{\exists}(\mathit{kissing} \wedge \langle \text{AGENT} \rangle s \wedge \langle \text{THEME} \rangle o) \\ [\![\text{woman}]\!] & = & \mathit{woman} & & & \end{array}$$

$$([\![\text{every}]\!]\ [\![\text{man}]\!])\ (\lambda x.([\![\text{some}]\!]\ [\![\text{woman}]\!])\ (\lambda y.[\![\text{kisses}]\!]\ y\ x)) =$$
$$\mathbf{\forall}(\downarrow i.\mathit{man} \Rightarrow \mathbf{\exists}(\downarrow i'.\mathit{woman} \wedge \mathbf{\exists}(\mathit{kissing} \wedge \langle \text{AGENT} \rangle i \wedge \langle \text{THEME} \rangle i')))$$

Compositional Frame Semantics

Semantic types and constants

- Types: e, s, t
- Constants:

$$\begin{array}{llllll} \textit{event}, \textit{kissing}, \textit{motion}, \textit{John}, \ldots & : t & \# & : s \to t \\ \langle \text{AGENT} \rangle, \langle \text{THEME} \rangle, \langle \text{MOVER} \rangle, \langle \textit{part-of} \rangle, \ldots & : t \to t & @ & : s \to t \to t \\ \wedge, \Rightarrow \quad : t \to t \to t \qquad \mathbf{\exists}, \mathbf{\forall} & : t \to t & \downarrow, \exists & : (s \to t) \to t \end{array}$$

Lexical Semantics

$$\begin{array}{lcl lcl} [\![\text{John}]\!] & = & \textit{John} & [\![\text{some}]\!] & = & \lambda P\ Q.\mathbf{\exists}(\downarrow i.P \wedge (Q\ (\#\, i))) \\ [\![\text{Mary}]\!] & = & \textit{Mary} & [\![\text{every}]\!] & = & \lambda P\ Q.\mathbf{\forall}(\downarrow i.P \Rightarrow (Q\ (\#\, i))) \\ [\![\text{man}]\!] & = & \textit{man} & [\![\text{kisses}]\!] & = & \lambda o\ s.\mathbf{\exists}(\textit{kissing} \wedge \langle \text{AGENT} \rangle s \wedge \langle \text{THEME} \rangle o) \\ [\![\text{woman}]\!] & = & \textit{woman} & & & \end{array}$$

$$([\![\text{some}]\!]\ [\![\text{woman}]\!])\ (\lambda y.([\![\text{every}]\!]\ [\![\text{man}]\!])\ (\lambda x.[\![\text{kisses}]\!]\ y\ x)) =$$
$$\mathbf{\exists}(\downarrow i.\textit{woman} \wedge \mathbf{\forall}(\downarrow i'.\textit{man} \Rightarrow \mathbf{\exists}(\textit{kissing} \wedge \langle \text{AGENT} \rangle i' \wedge \langle \text{THEME} \rangle i)))$$

Compositional Frame Semantics (cont'd)

Lexical Semantics

Compositional Frame Semantics (cont'd)

Lexical Semantics

$$\text{walked} \quad = \lambda pp\ s.\exists a\ g.\mathbf{\exists}(\mathit{motion} \wedge \langle \text{AGENT} \rangle (\#\, a) \wedge \langle \text{MOVER} \rangle (\#\, a) \wedge \langle \text{GOAL} \rangle (\#\, g) \wedge \langle \text{PATH} \rangle \mathit{path} \wedge \langle \text{MANNER} \rangle \mathit{walking} \wedge @_a s \wedge (pp\ (\#\, g)))$$

Compositional Frame Semantics (cont'd)

Lexical Semantics

$$\text{walked} = \lambda pp\ s.\exists a\ g.\mathbf{E}(motion \wedge \langle \text{AGENT}\rangle(\#\, a) \wedge \langle \text{MOVER}\rangle(\#\, a) \wedge \langle \text{GOAL}\rangle(\#\, g) \wedge \langle \text{PATH}\rangle path \wedge \langle \text{MANNER}\rangle walking \wedge @_a s \wedge (pp\ (\#\, g)))$$

$$\text{to} = \lambda n\ g.\exists r\ v\ w.event \wedge \langle \text{PATH}\rangle(path \wedge \langle \text{ENDP}\rangle(\#\, v)) \wedge @_r\langle \text{AT-REGION}\rangle(\#\, w) \wedge @_v\langle part\text{-}of\rangle(\#\, w) \wedge @_r(g \wedge n)$$

Compositional Frame Semantics (cont'd)

Lexical Semantics

$$\begin{aligned}\text{walked} &= \lambda pp\ s.\exists a\ g.\mathbf{\exists}(motion \wedge \langle \text{AGENT}\rangle(\#\, a) \wedge \langle \text{MOVER}\rangle(\#\, a)\\ &\quad \wedge\langle \text{GOAL}\rangle(\#\, g) \wedge \langle \text{PATH}\rangle path \wedge \langle \text{MANNER}\rangle walking \wedge @_a s \wedge (pp\ (\#\, g)))\\ \text{to} &= \lambda n\ g.\exists r\ v\ w.event \wedge \langle \text{PATH}\rangle(path \wedge \langle \text{ENDP}\rangle(\#\, v)) \wedge\\ &\quad @_r\langle \text{AT-REGION}\rangle(\#\, w) \wedge @_v\langle part\text{-}of\rangle(\#\, w) \wedge @_r(g \wedge n)\end{aligned}$$

$$\begin{aligned}&[\![(\text{every man})\ (\lambda x.(\text{some house})(\lambda y.\text{walked}\ (\text{to}\ y)\ x))]\!]\\ &\quad = \mathbf{\forall}(\downarrow i.man \Rightarrow (\mathbf{\exists}(\downarrow i'.house \wedge (\exists a\ g.\mathbf{\exists}(motion \wedge \langle \text{AGENT}\rangle a \wedge \langle \text{MOVER}\rangle a \wedge\\ &\quad \langle \text{GOAL}\rangle g \wedge \langle \text{PATH}\rangle path \wedge \langle \text{MANNER}\rangle walking \wedge @_a i \wedge (\exists r\ v\ w.event \wedge\\ &\quad \langle \text{PATH}\rangle(path \wedge \langle \text{ENDP}\rangle v) \wedge @_r(\langle \text{AT-REGION}\rangle w) \wedge\\ &\quad @_v(\langle part\text{-}of\rangle w) \wedge @_r(g \wedge i')))))))\end{aligned}$$

Compositional Frame Semantics (cont'd)

Lexical Semantics

$$\text{walked} = \lambda pp\ s.\exists a\ g.\mathbf{\exists}(motion \wedge \langle \text{AGENT}\rangle(\#\, a) \wedge \langle \text{MOVER}\rangle(\#\, a) \wedge \langle \text{GOAL}\rangle(\#\, g) \wedge \langle \text{PATH}\rangle path \wedge \langle \text{MANNER}\rangle walking \wedge @_a s \wedge (pp\ (\#\, g)))$$

$$\text{to} = \lambda n\ g.\exists r\ v\ w.event \wedge \langle \text{PATH}\rangle(path \wedge \langle \text{ENDP}\rangle(\#\, v)) \wedge @_r\langle \text{AT-REGION}\rangle(\#\, w) \wedge @_v\langle part\text{-}of\rangle(\#\, w) \wedge @_r(g \wedge n)$$

$$[\![(\text{some house})(\lambda y.(\text{every man})\ (\lambda x.\text{walked}\ (\text{to}\ y)\ x))]\!]$$
$$= \mathbf{\exists}(\downarrow i'.house \wedge (\mathbf{\forall}(\downarrow i.man \Rightarrow (\exists a\ g.\mathbf{\exists}(motion \wedge \langle \text{AGENT}\rangle a \wedge \langle \text{MOVER}\rangle a \wedge \langle \text{GOAL}\rangle g \wedge \langle \text{PATH}\rangle path \wedge \langle \text{MANNER}\rangle walking \wedge @_a i \wedge (\exists r\ v\ w.event \wedge \langle \text{PATH}\rangle(path \wedge \langle \text{ENDP}\rangle v) \wedge @_r(\langle \text{AT-REGION}\rangle w) \wedge @_v(\langle part\text{-}of\rangle w) \wedge @_r(g \wedge i')))))))$$

Frame Decomposition and FrameNet (Osswald and Van Valin 2014)

Definitions of FN 1.5 frames of *drying*

- **Being_dry**: An [Item] is in a state of dryness (*dehydrated*, *desiccated*, *dry*, . . .)

Frame Decomposition and FrameNet (Osswald and Van Valin 2014)

Definitions of FN 1.5 frames of *drying*

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$$\begin{bmatrix} \text{Dry\_state} \\ \textsc{patient}\ \boxed{2} \end{bmatrix}$$

Frame Decomposition and FrameNet (Osswald and Van Valin 2014)

Definitions of FN 1.5 frames of *drying*

- **Being_dry**: An [Item] is in a state of dryness (*dehydrated, desiccated, dry, . . .*)
- **Becoming_dry**: An [Entity] loses moisture with the outcome of being in a dry state (*dehydrate, dry up, dry, . . .*)

$$\begin{bmatrix} \text{Dry\_state} \\ \textsc{patient}\ \boxed{2} \end{bmatrix}$$

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$$\begin{bmatrix}\text{Dry\_state}\\ \textsc{patient}\ \boxed{2}\end{bmatrix} \longleftarrow \begin{bmatrix}\text{Inchoation}\\ \textsc{result}\ \begin{bmatrix}\text{Dry\_state}\\ \textsc{patient}\ \boxed{2}\end{bmatrix}\end{bmatrix}$$

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- **Cause_to_be_dry**: an [Agent] causes a [Dryee] (. . .) to become dry (*anhydrate, dehumidify, dehydrate, . . .*)

$$\begin{bmatrix}\text{Dry\_state} \\ \textsc{patient}\ \boxed{2}\end{bmatrix} \longleftarrow \begin{bmatrix}\text{Inchoation} \\ \textsc{result} \begin{bmatrix}\text{Dry\_state} \\ \textsc{patient}\ \boxed{2}\end{bmatrix}\end{bmatrix}$$

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$$\begin{bmatrix}\textsf{Dry\_state} & \\ \textsc{patient} & \boxed{2}\end{bmatrix} \longleftarrow \begin{bmatrix}\textsf{Inchoation} & \\ \textsc{result} & \begin{bmatrix}\textsf{Dry\_state} & \\ \textsc{patient} & \boxed{2}\end{bmatrix}\end{bmatrix} \longleftarrow \begin{bmatrix}\textsf{Causation} & \\ \textsc{cause} & \begin{bmatrix}\textsf{Activity} & \\ \textsc{effector} & \boxed{1}\end{bmatrix} \\ \textsc{effect} & \begin{bmatrix}\textsf{Inchoation} & \\ \textsc{result} & \begin{bmatrix}\textsf{Dry\_state} & \\ \textsc{patient} & \boxed{2}\end{bmatrix}\end{bmatrix}\end{bmatrix}$$

Conclusion

- Frame as a data-structure representing a situation
- The semantic structure associated to a syntactic structure is a hybrid logical formula that need to be further interpreted
- Quantification does not belong to the frame language (contrary to Baldridge and Kruijff 2002 or Kallmeyer and Richter 2014)
- Inference
- Link between dependency structures and logical representation (AMR, ECL—I. A. Mel'čuk, Clas, and Polguère 1995; I. Mel'čuk and Polguère 2018—, etc.)
- Not variable free. . . But discourse referents are now made available!

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