Quantifiers in Frame Semantics

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Introduction

- Frames are a representation format of conceptual and lexical knowledge.
- They are commonly presented as semantic graphs with labelled nodes and edges where nodes correspond to entities (individuals, events, …) and edges to (functional or non-functional) relations between these entities.

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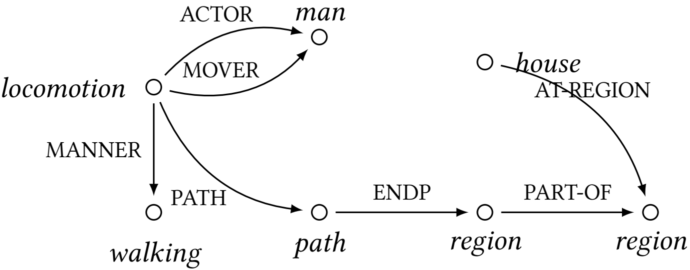

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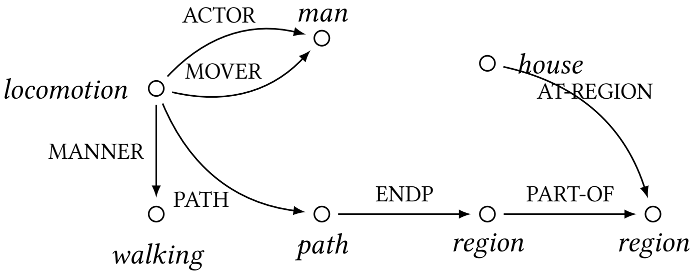

Frames can be formalized as extended typed feature structures.

Question: How can we integrate quantification and negation into frames?

Introduction

Goal: A grammar architecture with

1. lexical meaning specifications in Frame Semantics; and
2. a truth-conditional sentential semantics with (generalized) quantifiers
3. an integration of standard approaches (hole semantics, normal dominance constraints) to scope underspecification

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Two approaches:

1. Integrating quantifiers into frames with a charcaterization of their scopal properties Kallmeyer & Richter (2014).
2. Moving from frames to descriptions of frames in a logic that allows to quantify over frame elements (recent joint work with Timm Lichte, Rainer Osswald, Sylvain Pogodalla and Christian Wurm).

LTAG and Frame Semantics

A *Lexicalized Tree Adjoining Grammar* (LTAG, Joshi & Schabes (1997); Abeillé & Rambow (2000)): Finite set of *elementary trees*.

Larger trees are derived via the tree composition operations *substitution* (replacing a leaf with a new tree) and *adjunction* (replacing an internal node with a new tree).

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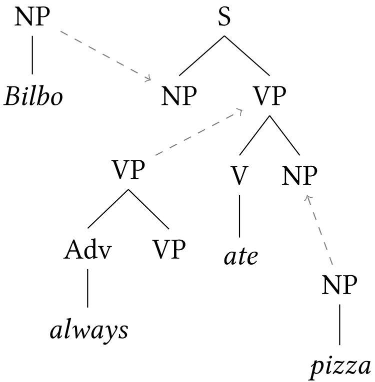

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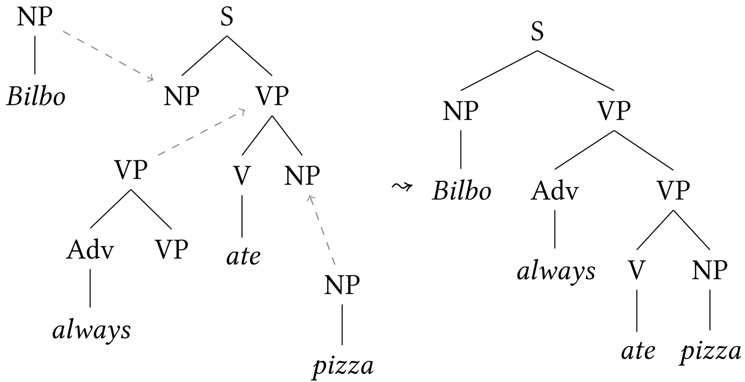

LTAG and Frame Semantics

Syntax semantics interface Kallmeyer & Osswald (2013):

- Link a semantic representation to an entire elementary tree;
- model composition by unifications triggered by substitution and adjunction.
- Semantic representations: frames, expressed as typed feature structures

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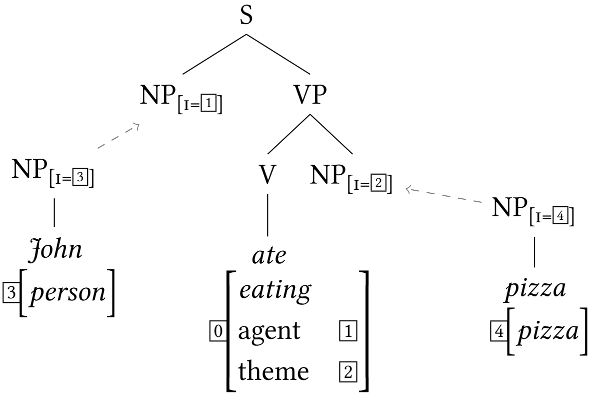

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Quantificational NPs

Ingredients:

- Quantifier frame types *every*, *most*, *two*, etc. capture the relation between the two arguments of binary quantifiers.

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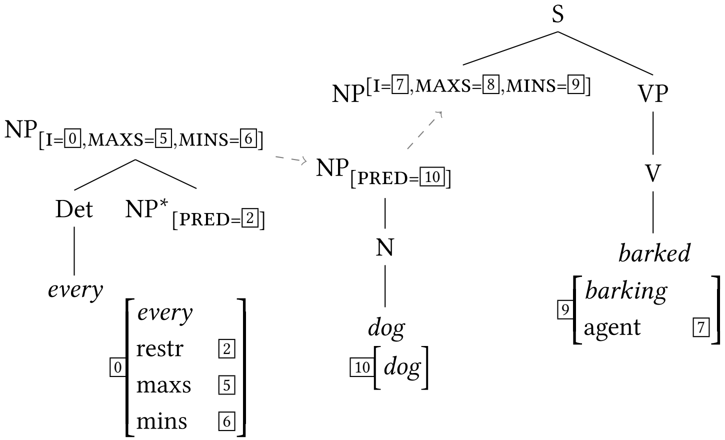
- Note: no scope, no interpretation, separate type system

Quantificational NPs



Quantificational NPs

$$\boxed{9}\begin{bmatrix} \textit{barking} & \\ \text{agent} & \boxed{0} \end{bmatrix} \sqcup \boxed{0}\begin{bmatrix} \textit{every} & \\ \text{restr} & \boxed{2} \\ \text{maxs} & \boxed{5} \\ \text{mins} & \boxed{9} \end{bmatrix} \sqcup \boxed{2}\begin{bmatrix} \textit{dog} \end{bmatrix} =$$

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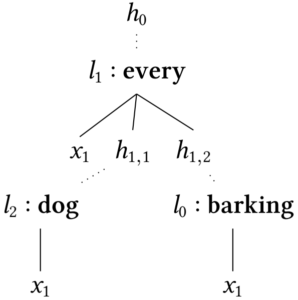
Underspecified Representations of Truth conditions

Underspecified predicate-logical formula for the *barking* frame (dominance constraints in the style of Althaus et al. (2003); Koller et al. (1998)):



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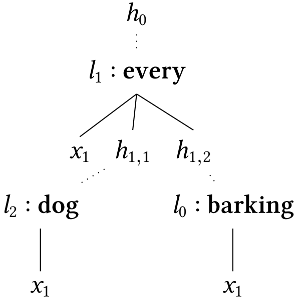

l_0 : **barking**(x_1)
l_1 : **every**$(x_1, h_{1,1}, h_{1,2})$
l_2 : **dog**(x_1)
$h_0 \triangleleft^* l_1, h_{1,1} \triangleleft^* l_2, h_{1,2} \triangleleft^* l_0$

Disambiguation:
$h_0 \rightarrow l_1, h_{1,1} \rightarrow l_2, h_{1,2} \rightarrow l_0$

Underspecified Representations of Truth conditions

Task: read off underspecified predicate-logical formulas from frames:

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- $$\boxed{i}\begin{bmatrix} \textit{pred} & \\ \langle\text{arg1}\rangle & \boxed{j} \\ \langle\text{arg2}\rangle & \boxed{k} \\ \ldots & \end{bmatrix} \quad \rightsquigarrow \quad l_i : \textbf{pred}(x_j, x_k, \ldots)$$

  with *pred* a subtype of *eventuality*

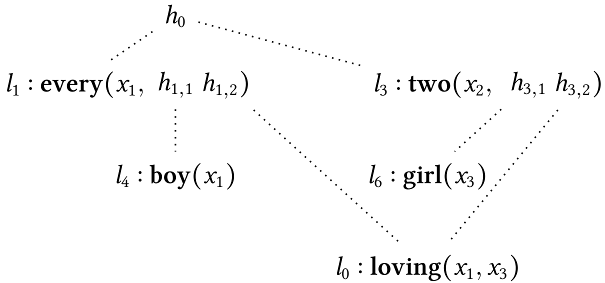
- $$\boxed{i}\begin{bmatrix} \textit{quant} & \\ \text{restr} & \boxed{j}\begin{bmatrix}\textit{pred}\end{bmatrix} \\ \text{maxs} & \boxed{k} \\ \text{mins} & \boxed{l} \end{bmatrix} \quad \rightsquigarrow \quad \begin{array}{l} l_i : \textbf{quant}(x_i, h_{i,1}, h_{i,2}), \\ l_j : \textbf{pred}(x_i), \\ h_k \lhd^* l_i, h_{i,1} \lhd^* l_j, h_{i,2} \lhd^* l_l \end{array}$$

  with *quant* a subtype of *generalized-quantifier* and *pred* a subtype of *entity*

Underspecified Representations of Truth conditions

Result: underspecified dominance constraints for scope ambiguitites

(1) Every boy loves two girls.



Disambiguations:

1. $h_0 \rightarrow l_1, h_{1,1} \rightarrow l_4, h_{1,2} \rightarrow l_3, h_{3,1} \rightarrow l_6, h_{3,2} \rightarrow l_0$
2. $h_0 \rightarrow l_3, h_{1,1} \rightarrow l_4, h_{1,2} \rightarrow l_0, h_{3,1} \rightarrow l_6, h_{3,2} \rightarrow l_1$

Adverbs and scope ambiguities

Case study:
Interaction of operator scope (adverb *again*) with rich structure of semantic frames

(2) Bilbo opened the door again. (ex. from Beck (2005))

Three readings:

a. Bilbo opened the door, and that had happened before. (repetitive reading)
b. Bilbo opened the door, and the door had been opened before.
c. Bilbo opened the door, and the door had been open before. (restitutive reading)

Adverbs and scope ambiguities

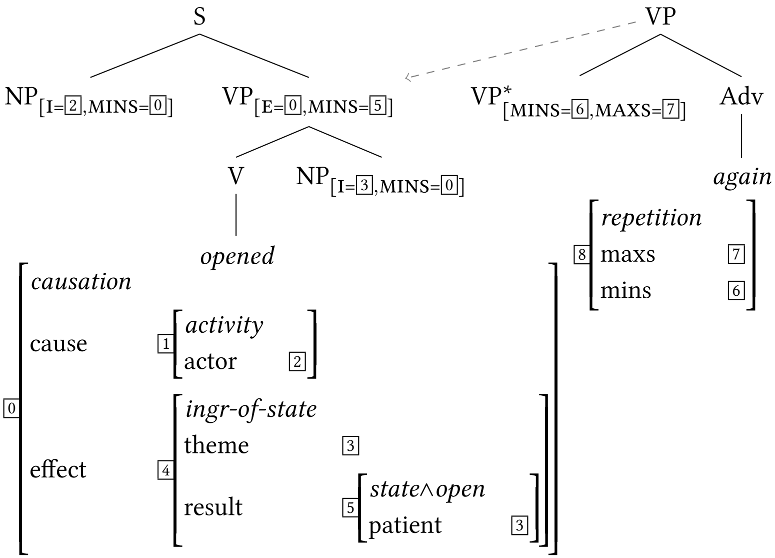
Semantics of *open* (Dowty (1979); Van Valin & LaPolla (1997); Van Valin (2005)):

(3) $[\mathbf{do}(x, \varnothing)]\ \text{CAUSE}\ [\text{INGR}\ \mathbf{open}(y)]$

Corresponding frame, following Kallmeyer & Osswald (2013); Osswald & Van Valin (2014):

$$\begin{bmatrix} \textit{causation} & \\ \text{cause} & \begin{bmatrix} \textit{activity} & \\ \text{actor} & \boxed{1} \end{bmatrix} \\ \text{effect} & \begin{bmatrix} \textit{ingr-of-state} & \\ \text{theme} & \boxed{2} \\ \text{result} & \begin{bmatrix} \textit{state} \wedge \textit{open} & \\ \text{patient} & \boxed{2} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

Adverbs and scope ambiguities



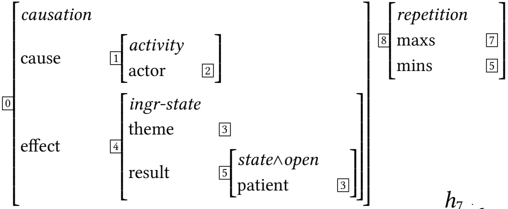
Adverbs and scope ambiguities

Frame:

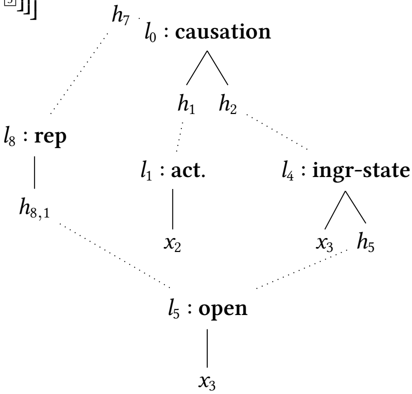
$$\boxed{0}\begin{bmatrix} \textit{causation} & \\ \text{cause} & \boxed{1}\begin{bmatrix} \textit{activity} & \\ \text{actor} & \boxed{2} \end{bmatrix} \\ \text{effect} & \boxed{4}\begin{bmatrix} \textit{ingr-state} & \\ \text{theme} & \boxed{3} \\ \text{result} & \boxed{5}\begin{bmatrix} \textit{state}\wedge\textit{open} & \\ \text{patient} & \boxed{3} \end{bmatrix} \end{bmatrix} \end{bmatrix} \boxed{8}\begin{bmatrix} \textit{repetition} & \\ \text{maxs} & \boxed{7} \\ \text{mins} & \boxed{5} \end{bmatrix}$$

Adverbs and scope ambiguities

Frame:



Dominance constraints:



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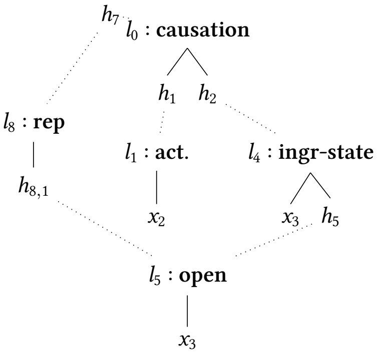

Disambiguations (minimal models of the dominance constraints):

1. **repetition**(**causation**(**activity**(x_2), **ingr-state**(x_3, **open**(x_3))))
2. **causation**(**activity**(x_2), **repetition**(**ingr-state**(x_3, **open**(x_3))))
3. **causation**(**activity**(x_2), **ingr-state**(x_3, **repetition**(**open**(x_3))))

Outline

Hybrid logic for frames

Rel is a set of relational symbols, Prop a set of propositional variables, Nom a set of nominals, and Svar a set of state variables (Stat = Nom ∪ Svar).

The language of formulas is:

$$\text{Forms} ::= \top \mid p \mid s \mid \neg\phi \mid \phi_1 \wedge \phi_2 \mid \langle R\rangle\phi \mid \exists\phi \mid @_s\phi \mid \downarrow x.\phi$$

where $p \in$ Prop, $s \in$ Stat, $R \in$ Rel and $\phi, \phi_1, \phi_2 \in$ Forms (Areces & ten Cate (2007)).

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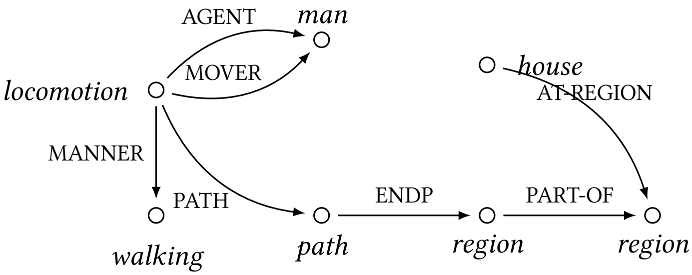
where $p \in$ Prop, $s \in$ Stat, $R \in$ Rel and $\phi, \phi_1, \phi_2 \in$ Forms (Areces & ten Cate (2007)).

The truth of a formula is given with respect to a specific node w of a model M and some assignment g mapping Stat to the nodes in M.

- $\exists\phi$ is true in w if there exists a w' in M that makes ϕ true.
- $@_s\phi$ is true in w if ϕ is true in the node assigned to s, $g(s)$.
- $\downarrow x.\phi$ is true in w if ϕ is true in w under the assignment g^x_w.

Hybrid logic for frames



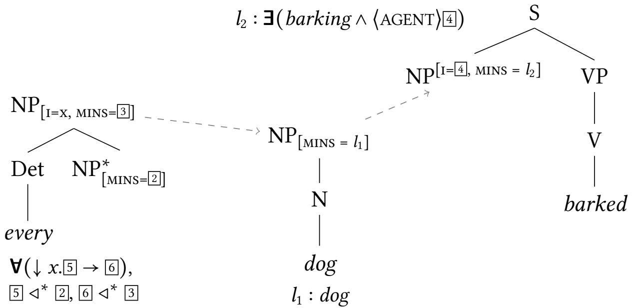
- ⟨AGENT⟩*man* is for instance true at the *locomotion* node.
- $\exists$*house* is true in any node.
- $\langle \textsc{part-of} \rangle \downarrow x.(\mathit{region} \wedge \exists(\mathit{house} \wedge \langle \textsc{at-region} \rangle x))$ is true at the endpoint node of the path.

LTAG and hybrid logic

Idea:

- Pair each elementary tree with a set of underspecified HL formulas, which can contain holes and which can be labeled.
- Composition is then triggered by the syntactic unifications arising from substitution and adjunction.

LTAG and hybrid logic



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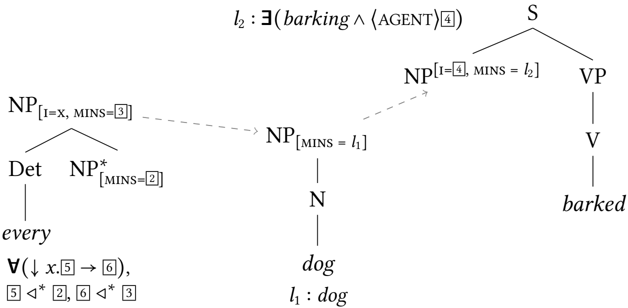


$\forall(\downarrow x.\boxed{5} \rightarrow \boxed{6})$,
$l_1 : dog$, $l_2 : \exists(barking \wedge \langle \text{AGENT} \rangle x)$,
$\boxed{5} \triangleleft^* l_1$, $\boxed{6} \triangleleft^* l_2$

Atelicity and telicity and *for*-adverbials

(4) Bilbo swam for one hour

(5) Bilbo knocked at the door for ten minutes

- In (4), the verb denotes an activity and is thus immediately compatible with the *for*-adverbial.
- In (5), the verb denotes a punctual event, and, hence, calls for additional adjustments in order to be compatible with *for*-adverbials.

⇒ (5) is interpreted as describing a sequence or iteration of knockings.

Atelicity and telicity and *for*-adverbials

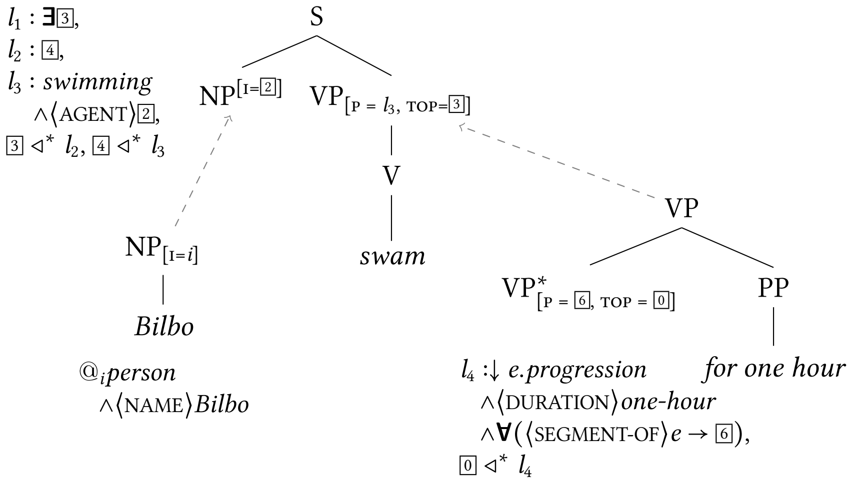
Semantics of *for*-adverbials following Champollion (2013):

(6) $\lambda P \lambda I[AT(P, I) \wedge hours(I) = 1 \wedge \forall \mathcal{J}[\mathcal{J} \in R_I^{short(I)} \rightarrow AT(P, \mathcal{J})]]$

In other words, a *for*- adverbial can only apply to an event P if we can fix a partition of the entire time interval such that in each of the smaller intervals, P holds as well.

- *swim* can be directly used as P.
- In the case of *knock*, one has to apply an iteration operator first (**knock*), and the result can then become the argument of (6).

Atelic events



Atelic events

This yields the underspecified representation:

(7) $@_i person \wedge \langle \textsc{name} \rangle Bilbo,$
$l_1 : \exists \boxed{3}\,, l_2 : \boxed{4}\,,$
$l_4 : \downarrow e.progression \wedge \langle \textsc{duration} \rangle one\text{-}hour \wedge \forall(\langle \textsc{segment-of} \rangle e \rightarrow l_3),$
$l_3 : swimming \wedge \langle \textsc{agent} \rangle i,$
$\boxed{3} \lhd^* l_4, \boxed{3} \lhd^* l_2, \boxed{4} \lhd^* l_3$

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$\boxed{3} \lhd^* l_4, \boxed{3} \lhd^* l_2, \boxed{4} \lhd^* l_3$

After disambiguation, one obtains:

(8) $@_i person \wedge \langle \text{NAME} \rangle Bilbo$
$\wedge \exists \downarrow e.(progression \wedge \langle \text{DURATION} \rangle one\text{-}hour \wedge$
$\forall(\langle \text{SEGMENT-OF} \rangle e \rightarrow swimming \wedge \langle \text{AGENT} \rangle i))$

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Additional constraint lifting P to the entire event:

(9) $\forall(\downarrow e.progression \rightarrow \langle \textsc{segment-of} \rangle e)$

Punctual events

Accounting for (5):
We adopt a more general type *nq-event* which is a supertype of *progression* and *iteration* and which is intended to capture *non-quantized* event types in the sense of Krifka (1998).

(10) $\forall(\textit{nq-event} \leftrightarrow \textit{iteration} \vee \textit{progression})$
$\forall(\textit{iteration} \rightarrow \neg\textit{progression})$

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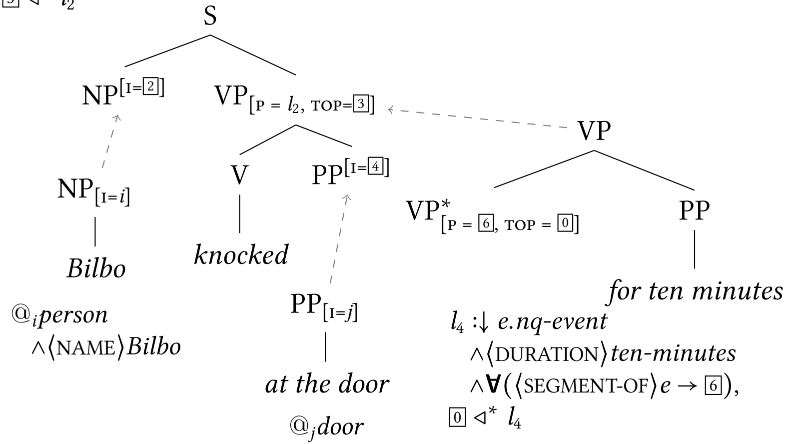
Additional constraints on iterations and progressions concerning the possible types of their segments:

(11) $\forall(\langle\textsc{segment-of}\rangle\textit{iteration} \rightarrow \textit{bounded})$
$\forall(\textit{punctual} \rightarrow \textit{bounded})$
$\forall(\langle\textsc{segment-of}\rangle\textit{progression} \rightarrow \neg\textit{bounded})$

Punctual events

$l_1 : \exists \boxed{3}$,
$l_2 : knocking \wedge \langle \text{AGENT} \rangle \boxed{2} \wedge \langle \text{PATIENT} \rangle \boxed{4}$,
$\boxed{3} \lhd^* l_2$



Punctual events

Result:

(12) $\exists \boxed{3}$,
$l_2 : \mathit{knocking} \wedge \langle \textsc{agent} \rangle i \wedge \langle \textsc{patient} \rangle j$,
$l_4 :\downarrow e.\mathit{nq\text{-}event} \wedge \langle \textsc{duration} \rangle \mathit{ten\text{-}minutes} \wedge \forall(\langle \textsc{segment-of} \rangle e \rightarrow l_2)$,
$@_i(\mathit{person} \wedge \langle \textsc{name} \rangle \mathit{Bilbo})$,
$@_j \mathit{door}$,
$\boxed{3} \lhd^* \ l_2, \boxed{3} \lhd^* \ l_4$

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$@_j door,$
$\boxed{3} \lhd^* l_2, \boxed{3} \lhd^* l_4$

After disambiguation:

(13) $\exists(\downarrow e.nq\text{-}event \wedge \langle \textsc{duration} \rangle ten\text{-}minutes$
$\wedge \forall(\langle \textsc{segment-of} \rangle e \rightarrow knocking \wedge \langle \textsc{agent} \rangle i \wedge \langle \textsc{patient} \rangle j))$
$\wedge @_i(person \wedge \langle \textsc{name} \rangle Bilbo) \wedge @_j door$

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After disambiguation:

(13) $\exists(\downarrow e.\mathit{nq\text{-}event} \wedge \langle \textsc{duration} \rangle \mathit{ten\text{-}minutes}$
$\wedge \forall(\langle \textsc{segment\text{-}of} \rangle e \to \mathit{knocking} \wedge \langle \textsc{agent} \rangle i \wedge \langle \textsc{patient} \rangle j))$
$\wedge @_i(\mathit{person} \wedge \langle \textsc{name} \rangle \mathit{Bilbo}) \wedge @_j \mathit{door}$

With our constraints, e in (13) is necessarily of type *iteration*.

Outline

Conclusion

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- adds quantifier frames to Frame Semantics
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- adds quantifier frames to Frame Semantics
- defines translation from frames to underspecified semantic representations
- grammar architecture: LTAG comprising Frame Semantics with fine-grained lexical decompositions of situations as frames
- supports a well-defined logical semantics with quantificational and intensional operators

Conclusion

Approach 2 (Kallmeyer, Lichte, Osswald, Pogodalla, Wurm)

- takes frames to be our representations of the world
- uses a hybrid logic in order to talk about frames

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- takes frames to be our representations of the world
- uses a hybrid logic in order to talk about frames
- the hybrid logic allows quantification over subevents
- the constraints one can formulate concerning frame types allow to account for the behaviour of *for*-adverbials
- underspecification of types and of immediate dominance in the formula allow in particular an analysis without an explicite iteration operator
- consequently, in (5) the events that *for* quantifies over are single knockings while the entire event is an iteration

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(14) every student in the room talked

Question: how do we picture the situation described in (14)?

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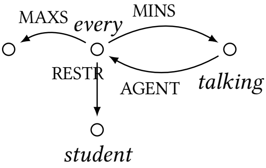
Approach 1: 

Conclusion

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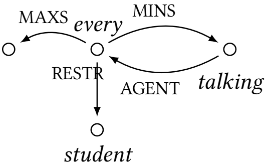
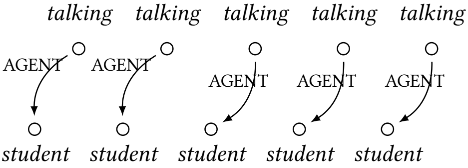
Approach 1: 

Approach 2: 

Conclusion

Question: What is the status of the frames?

Approach 1: Truth conditions are read off the frame, i.e., the frame is constructed first. The frame is supposed to be a conceptual representation that leaves the exact truth conditions underspecified.

Approach 2: The frame is the model. First, truth conditions (HL formulas) are constructed that are then evaluated on the frame. The HL formula is underspecified; it specifies a class of possible frames as its models.

Abeillé, Anne & Owen Rambow. 2000. Tree Adjoining Grammar: An Overview. In Anne Abeillé & Owen Rambow (eds.), *Tree adjoining grammars: Formalisms, linguistic analysis and processing*, 1–68. CSLI.

Althaus, Ernst, Denys Duchier, Alexander Koller, Kurt Mehlhorn, Joachim Niehren & Sven Thiel. 2003. An efficient graph algorithm for dominance constraints. *Journal of Algorithms* 48(1). 194–219.

Areces, Carlos & Balder ten Cate. 2007. Hybrid logics. In Patrick Blackburn, Johan Van Benthem & Frank Wolter (eds.), *Handbook of modal logic*, vol. 3 Studies in Logic and Practical Reasoning, chap. 14, 821–868. Elsevier. doi:10.1016/S1570-2464(07)80017-6.

Beck, Sigrid. 2005. There and back again: A semantic analysis. *Journal of Semantics* 22. 3–51.

Champollion, Lucas. 2013. The scope and processing of *for*-adverbials: A reply to Deo and Piñango. In *Proceedings of salt*, 432–452.

Dowty, David R. 1979. *Word meaning and montague grammar*. D. Reidel Publishing Company.

Joshi, Aravind K. & Yves Schabes. 1997. Tree-Adjoning Grammars. In G. Rozenberg & A. Salomaa (eds.), *Handbook of formal languages*, 69–123. Berlin: Springer.

Kallmeyer, Laura & Rainer Osswald. 2013. Syntax-driven semantic frame composition in Lexicalized Tree Adjoining Grammars. *Journal of Language Modelling* 1(2). 267–330.

Kallmeyer, Laura & Frank Richter. 2014. Quantifiers in frame semantics. In Glyn Morrill, Reinhard Muskens, Rainer Osswald & Frank Richter (eds.), *Formal grammar*, vol. 8612 Lecture Notes in Computer Science, 69–85. Springer Berlin Heidelberg. doi:10.1007/978-3-662-44121-3_5. `http://dx.doi.org/10.1007/978-3-662-44121-3_5`.

Koller, Alexander, Joachim Niehren & Ralf Treinen. 1998. Dominance Constraints: Algorithms and Complexity. In *Proceedings of the third international conference on logical aspects of computational linguistics (lacl)*, Grenoble, France.

Krifka, Manfred. 1998. The origins of telicity. In Susan Rothstein (ed.), *Events and grammar*, 197–235. Dordrecht: Kluwer.

Osswald, Rainer & Robert D. Van Valin. 2014. FrameNet, frame structure, and the syntax-semantics interface. In Thomas Gamerschlag, Doris Gerland, Rainer Osswald & Wiebke Petersen (eds.), *Frames and concept types* (Studies in Linguistics and Philosophy 94), 125–156. Springer.

Van Valin, Robert D., Jr. 2005. *Exploring the syntax-semantics interface*. Cambridge University Press.

Van Valin, Robert D., Jr. & Randy LaPolla. 1997. *Syntax: Structure, meaning and function*. Cambridge University Press.