Database Semantics and Temporal Inferences

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ROLAND HAUSSER
Computational Linguistics
Universität Erlangen Nürnberg
Germany

CLUE

Overview

1. A cognitive approach to NL communication
2. Semantics and pragmatics
3. A computational approach to NL communication
4. Concatenated propositions: a cognitive approach
5. Concatenated propositions: a computational approach
6. The motor algorithm: left-associative grammar
7. The structure of a Slim machine
8. States of cognition
9. Technical details of a semantic interpretation
10. Pragmatic interpretation
11. The source of coherence in language production
12. Example of a subcontext
13. Autonomous navigation as the basis of conceptualization
14. Different temporal prepositions depending on the navigation

1. A cognitive approach to NL communication

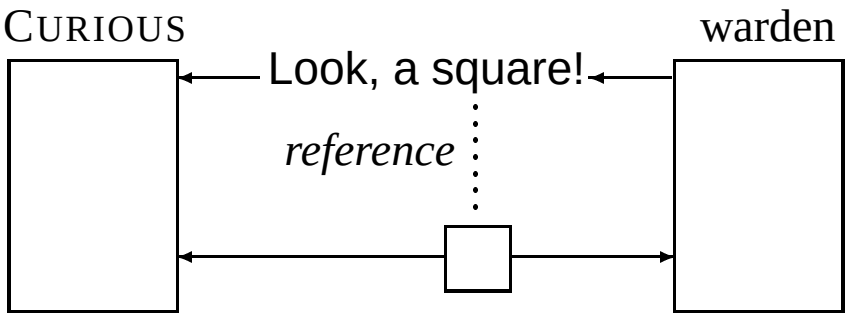
1.1 Different theories of language and their goals

- Behaviorism: maintaining methodological standards.
- Nativism: describing the innate knowledge of the speaker-hearer (PS-grammar).
- Model theory: representing scientific truth (C-grammar).
- SLIM theory: modeling the natural communication mechanism on the computer (LA-grammar).

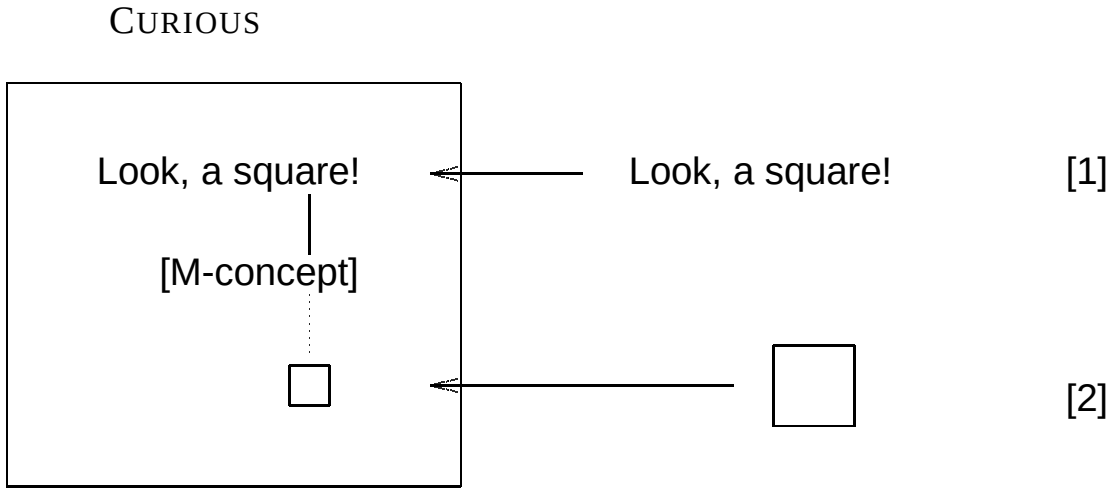
1.2 Principles of the SLIM theory of language

1. ***S****urface compositional* (methodological principle)
   Syntactic-semantic composition assembles only concrete word forms, excluding the use of zero-elements, identity mappings, or transformations.
2. ***L****inear* (empirical principle)
   Interpretation and production of utterances is based on a strictly time-linear derivation order.
3. ***I****nternal* (ontological principle)
   Interpretation and production of utterances is analyzed as cognitive procedures located inside the speaker-hearer.
4. ***M****atching* (functional principle)
   Referring with language to past, current, or future objects and events is modeled in terms of pattern matching between language meaning and context.

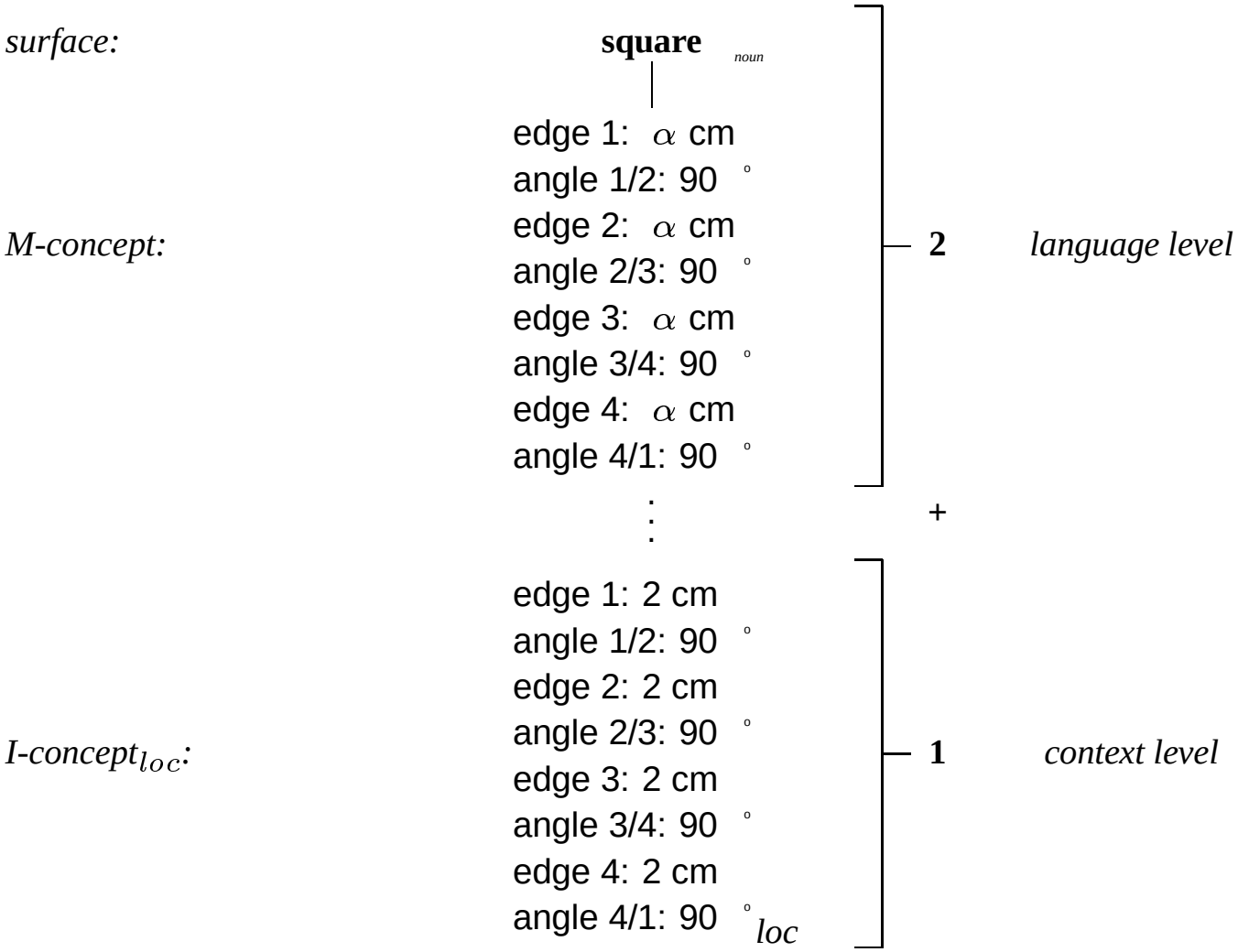
1.3 An external view of reference



1.4 Internal and external aspects of reference

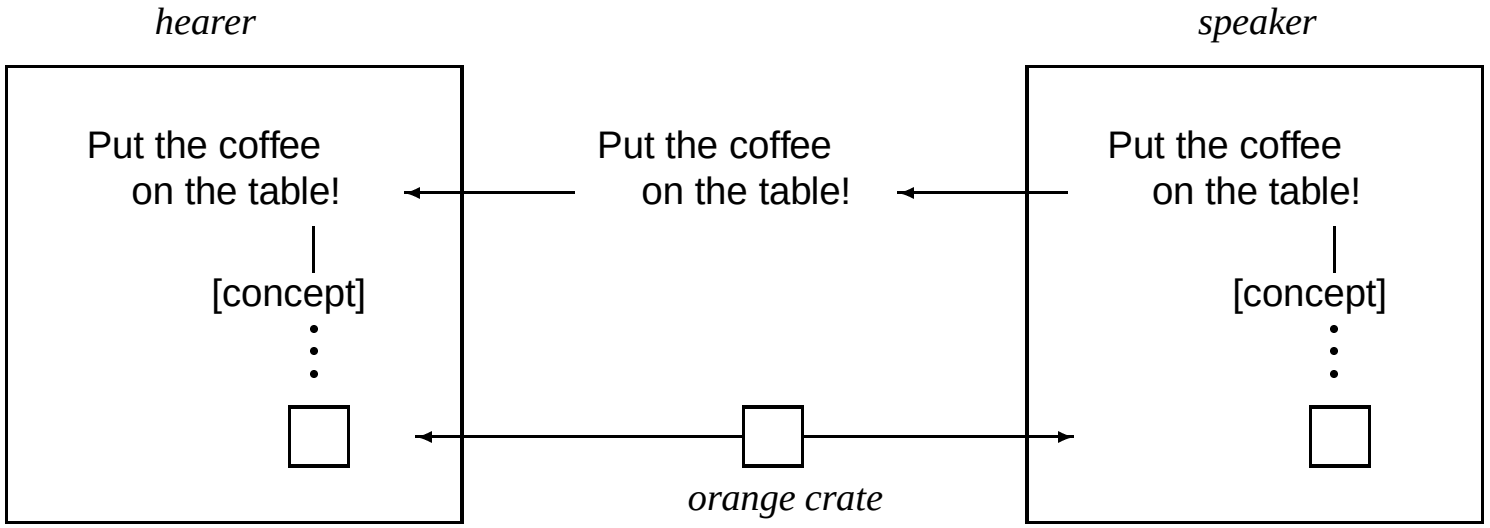


1.5 Cognitive 2+1 level analysis of reference



2. Semantics and pragmatics

2.1 Nonliteral use of the word table: Principle of best match



2.2 Two notions of meaning

- meaning$_1$ = property of signs, also called literal meaning
- meaning$_2$ = property of utterances, also called speaker meaning

2.3 First principle of pragmatics (PoP-1)

The speaker's utterance meaning$_2$ is the use of the sign's literal meaning$_1$ relative to an internal context.

2.4 Central question of linguistic pragmatics

How does the speaker code the selection and delimitation of the used subcontext into the sign and how can these be correctly inferred by the hearer?

2.5 Postcard example

New York, December 1, 1998

Dear Heather,
Your dog is doing fine. The weather is very cold. In the morning he played in the snow. Then he ate a bone. Right now I am sitting in the kitchen. Fido is here, too. The fuzzball hissed at him again. We miss you.

Love,
Spencer

2.6 Parameters of origin of signs (STAR-point)

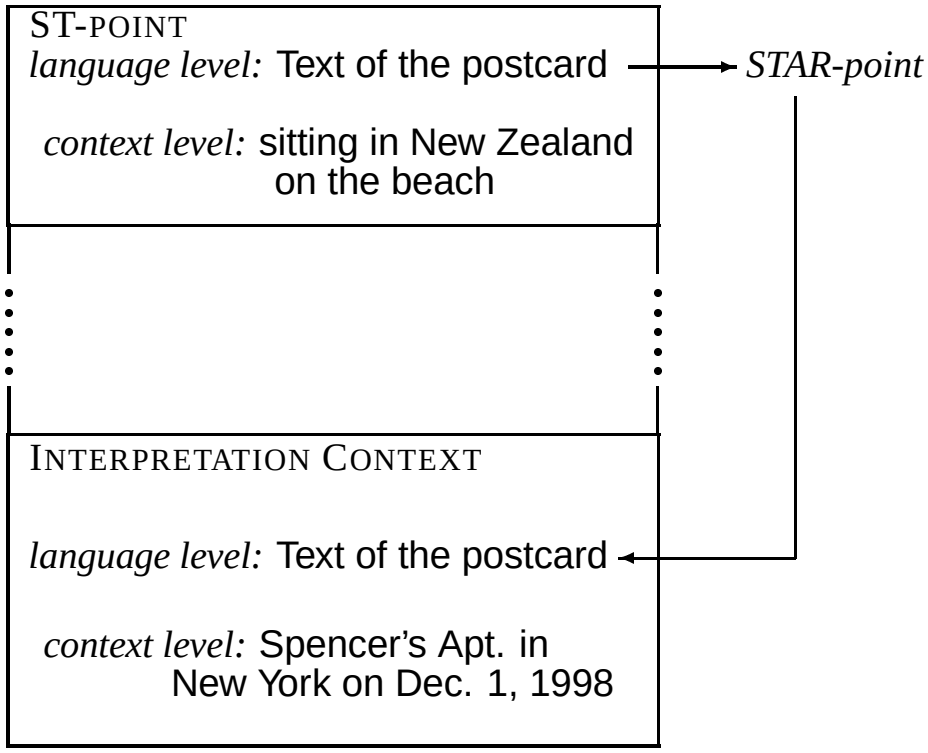
1. S = the **S**patial place of origin
2. T = the **T**emporal moment of origin
3. A = the **A**uthor
4. R = the intended **R**ecipient.

2.7 Second principle of pragmatics (PoP-2)

The STAR-point of the sign determines its primary positioning in the database by specifying the *entry context* of interpretation.

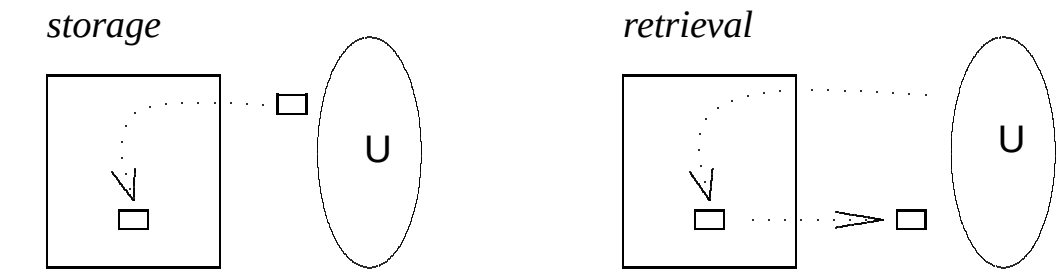
2.8 Primary positioning in terms of the STAR-point

Heather's cognitive representation:

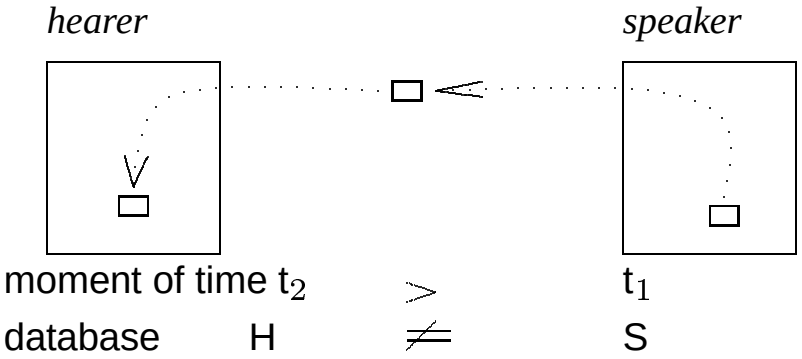


3. A computational approach to NL communication

3.1 Interaction with a conventional database



3.2 Interaction between speaker and hearer



3.3 DB interaction and NL communication

- ENTITIES INVOLVED

  Database interaction: takes place between two different entities, the user and the database.

  NL communication: takes place between two similar and equal cognitive agents, the speaker and the hearer.

- ORIGIN OF CONTROL

  Database interaction: operations of input and output are controlled by the user.

  NL communication: there is no user. Instead, the cognitive agents control each other by alternating in the speaker- and the hearer-mode (*turn taking*).

- METHOD OF CONTROL

  Database interaction: user controls the operations of the database with a programming language the commands of which are executed as electronic procedures.

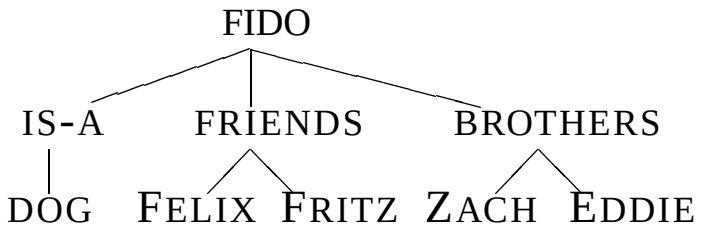
  NL communication: speaker controls language production as an autonomous agent, coding the parameters of the utterance situation into the output expressions. The hearer's interpretation is controlled by the incoming language expression.

- TEMPORAL ORDER

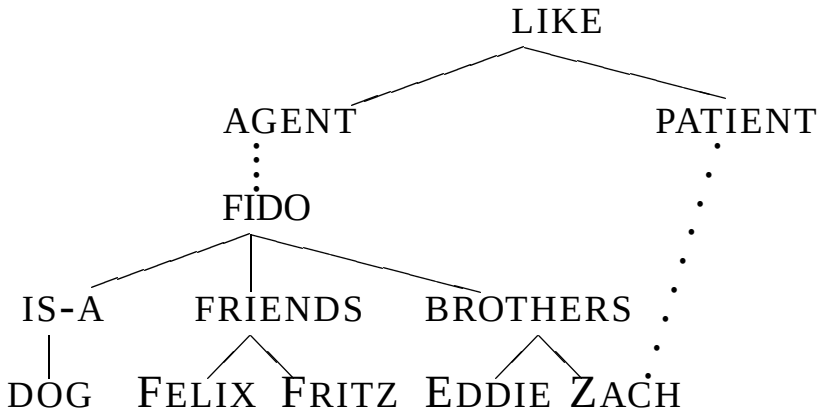
  Database interaction: output (database as 'speaker') occurs necessarily *after* the input (database as 'hearer').

  NL communication: production (output procedure of the speaker) occurs necessarily *before* interpretation (input procedure of the hearer).

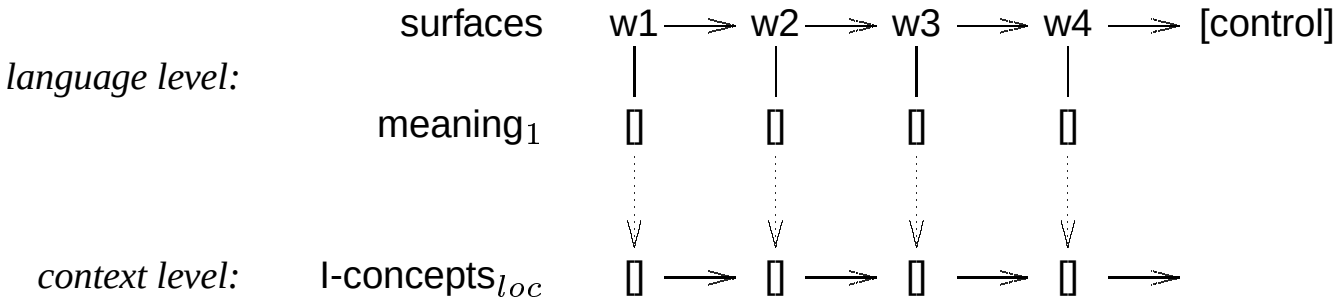
3.4 Sketch of a simple subcontext



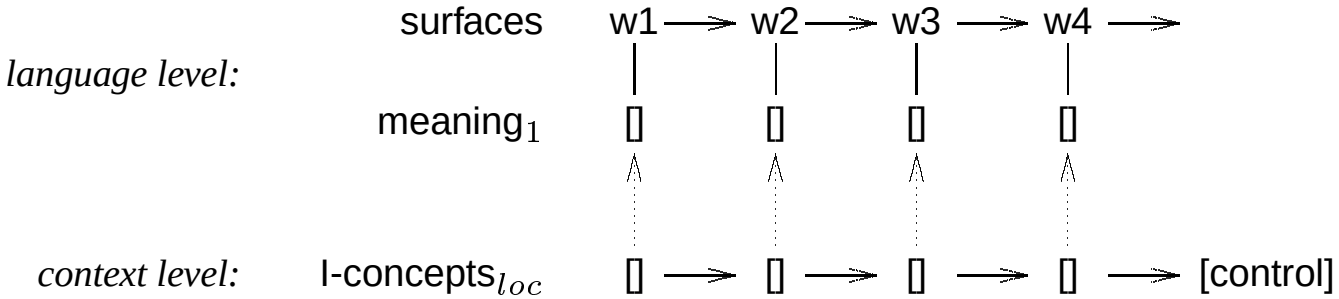
3.5 Adding the content of *Fido likes Zach* to 3.4



3.6 Schema of language interpretation (analysis)



3.7 Schema of language production (generation)

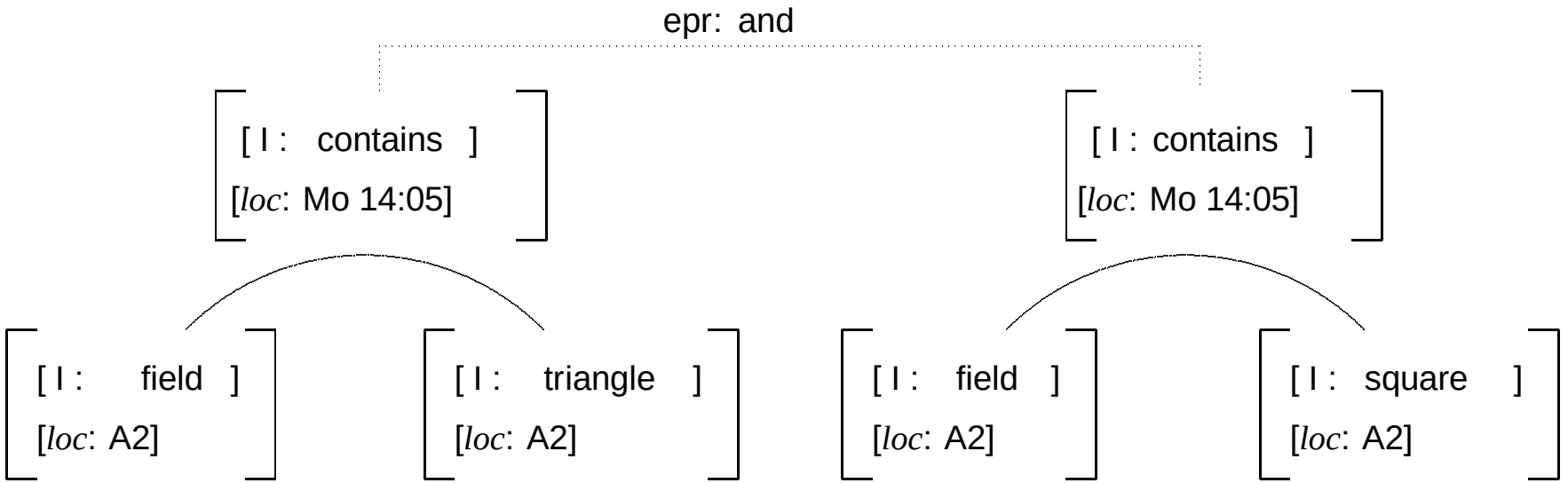


4. Concatenated propositions: a cognitive approach

4.1 The three elements of basic propositions

	logic	*world*	*language*
1.	functor	relation	verb
2.	argument	object	noun
3.	modifier	property	adjective-adverbial

4.2 An example of two contextual propositions



5. Concatenated propositions: a computational approach

5.1 Propositions 4.2 as a word bank

TYPES	SIMPLIFIED PROPLETS	
[M-concept: contain role: functor]	[I-concept$_{loc}$: x2 argument 1:field argument 2:triangle prn: 23 epr: 23 and 24]	[I-concept$_{loc}$: x5 argument 1:field argument 2:square prn: 24 epr: 23 and 24]
[M-concept: field role: argument]	[I-concept$_{loc}$: x1 functor: contain prn: 23 id: 7]	[I-concept$_{loc}$: x4 functor: contain prn: 24 id:7]
[M-concept: square role: argument]	[I-concept$_{loc}$: x6 functor: contain prn: 24 id: 9]	
[M-concept: triangle role: argument]	[I-concept$_{loc}$: x3 functor: contain prn: 23 id: 8]	

5.2 Types of continuations

intrapropositional:
from argument to functor, functor to argument, from modifier to modified and vice versa

extrapropositional:
epr from verb to verb, id from noun to noun

5.3 Types of databases

classic: record based
non-classic: based on the principle of slot and filler

5.4 Types of classic databases

Relational database, hierarchical database, network database

5.5 Example of a network database

owner records	*member records*			
Comp.Sci.	Riedle	Schmidt	Stoll	...
Mathematics	Müller	Barth	Jacobs	...
Physics	Weber	Meier	Miele	...

5.6 Relations between proplet features

type ↔ token
token ↔ prn
prn ↔ epr
token ↔ id
functor ↔ argument
modifier ↔ modified

5.7 Propositional presentation of subcontext 3.5

1. Fido is a dog.
2. Fido has friends.
3. The friends are Zach and Eddie.
4. Fido has brothers.
5. The brothers are Felix and Fritz.

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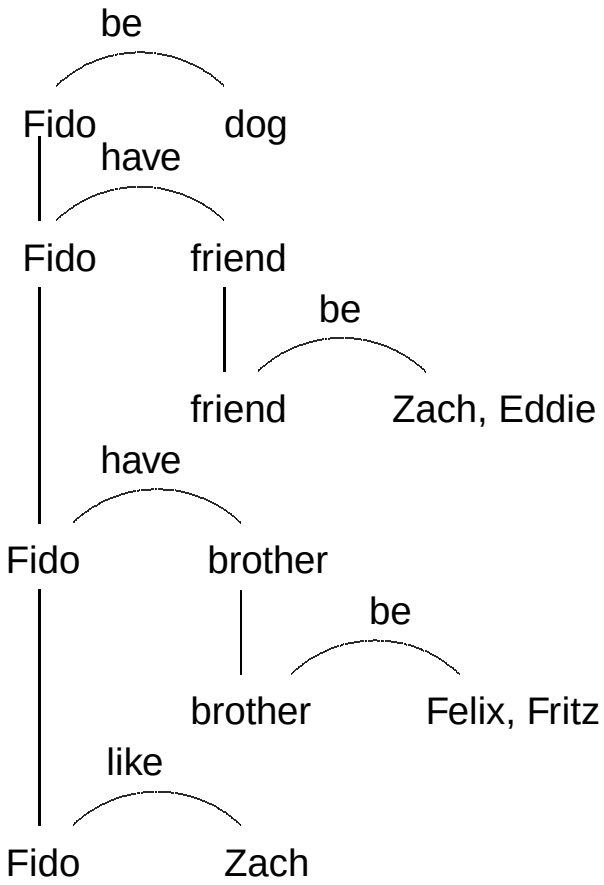
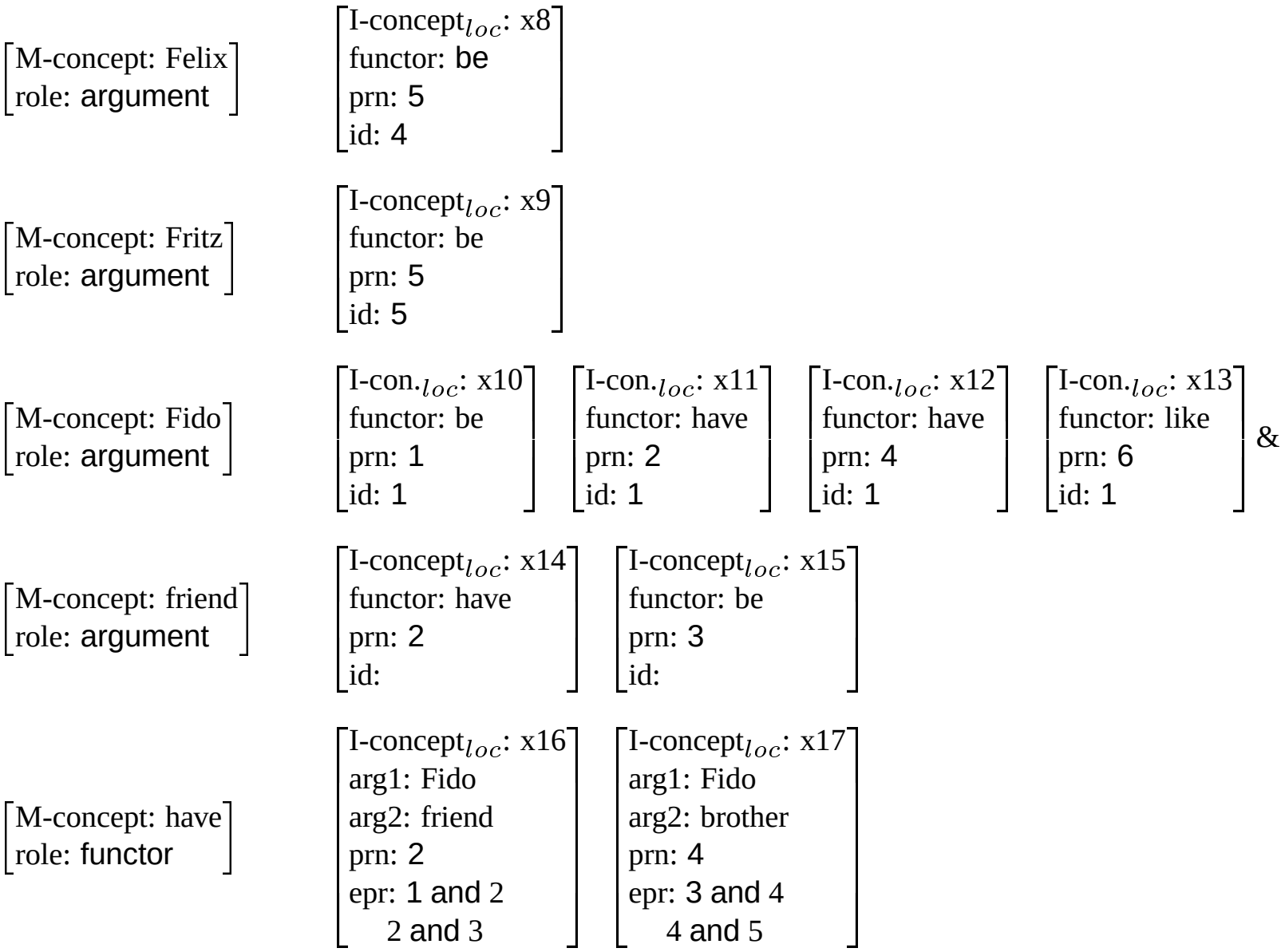
6. Fido likes Zach.

5.8 Graphical presentation of the propositions in 5.7



5.9 Subcontext 5.8 as a word bank

TYPES	PROPLETS		
[M-concept: be role: functor]	[I-concept$_{loc}$: x1 arg1: Fido arg2: dog prn: 1 epr: 1 and 2]	[I-concept$_{loc}$: x2 arg1: friend arg2: Zach, Eddie prn: 3 epr: 2 and 3 3 and 4]	[I-concept$_{loc}$: x3 arg1: brother arg2: Felix, Fritz prn: 5 epr: 4 and 5 5 and 6]
[M-concept: brother role: argument]	[I-concept$_{loc}$: x4 functor: have prn: 4 id:]	[I-concept$_{loc}$: x5 functor: be prn: 5 id:]	
[M-concept: dog role: argument]	[I-concept$_{loc}$: x6 functor: be prn: 4 id:]		
[M-concept: Eddie role: argument]	[I-concept$_{loc}$: x7 functor: be prn: 3 id: 3]		



$$\begin{bmatrix}\text{M-concept: like}\\ \text{role: functor}\end{bmatrix} \quad \begin{bmatrix}\text{I-concept}_{loc}\text{: x18}\\ \text{arg1: Fido}\\ \text{arg2: Zach}\\ \text{prn: 6}\\ \text{epr: 5 and 6}\end{bmatrix} \;\&$$

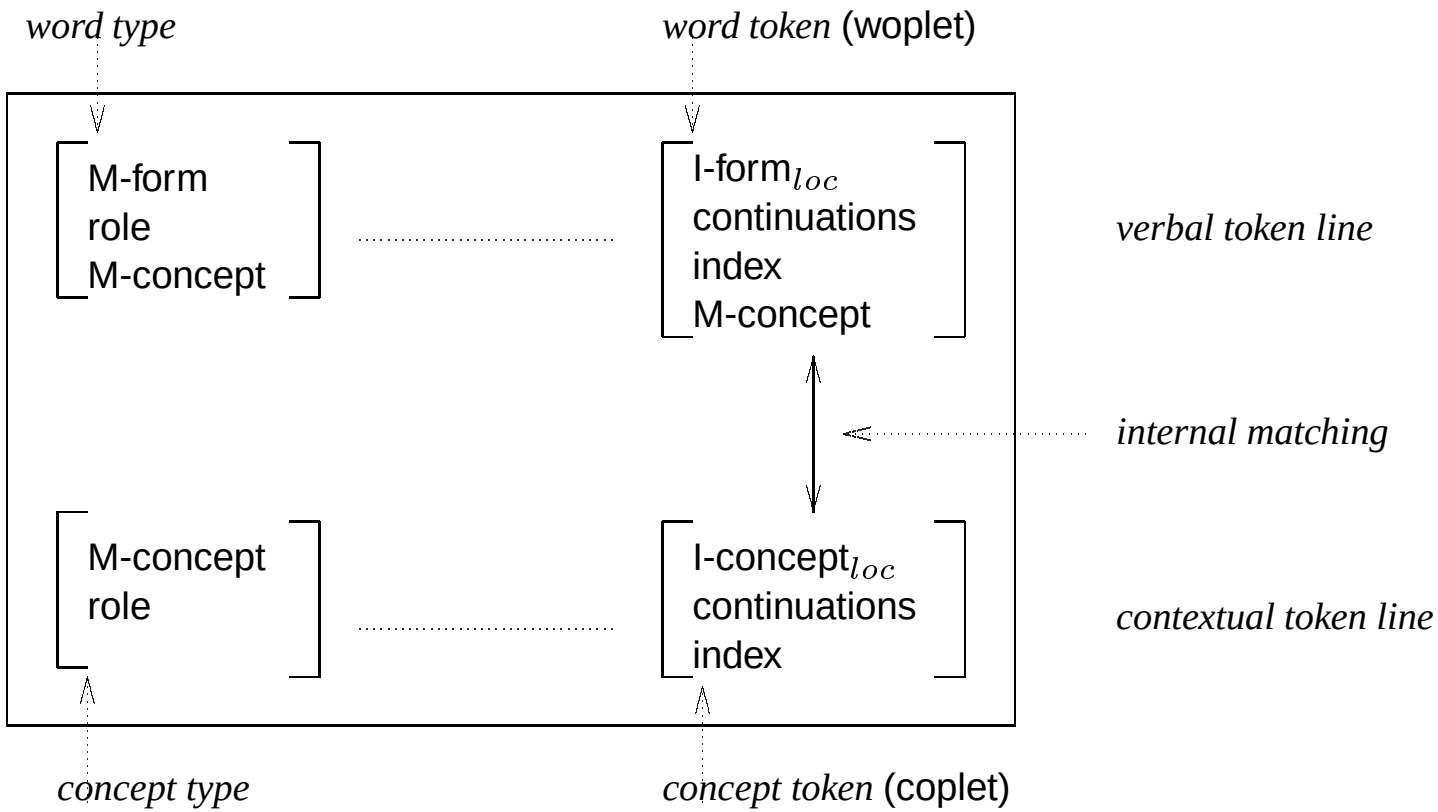
$$\begin{bmatrix}\text{M-concept: Zach}\\ \text{role: argument}\end{bmatrix} \quad \begin{bmatrix}\text{I-concept}_{loc}\text{: x19}\\ \text{functor: be}\\ \text{prn: 3}\\ \text{id: 2}\end{bmatrix} \quad \begin{bmatrix}\text{I-concept}_{loc}\text{: x20}\\ \text{functor: like}\\ \text{prn: 6}\\ \text{id: 2}\end{bmatrix} \;\&$$

5.10 Semantic representation of proposition 6

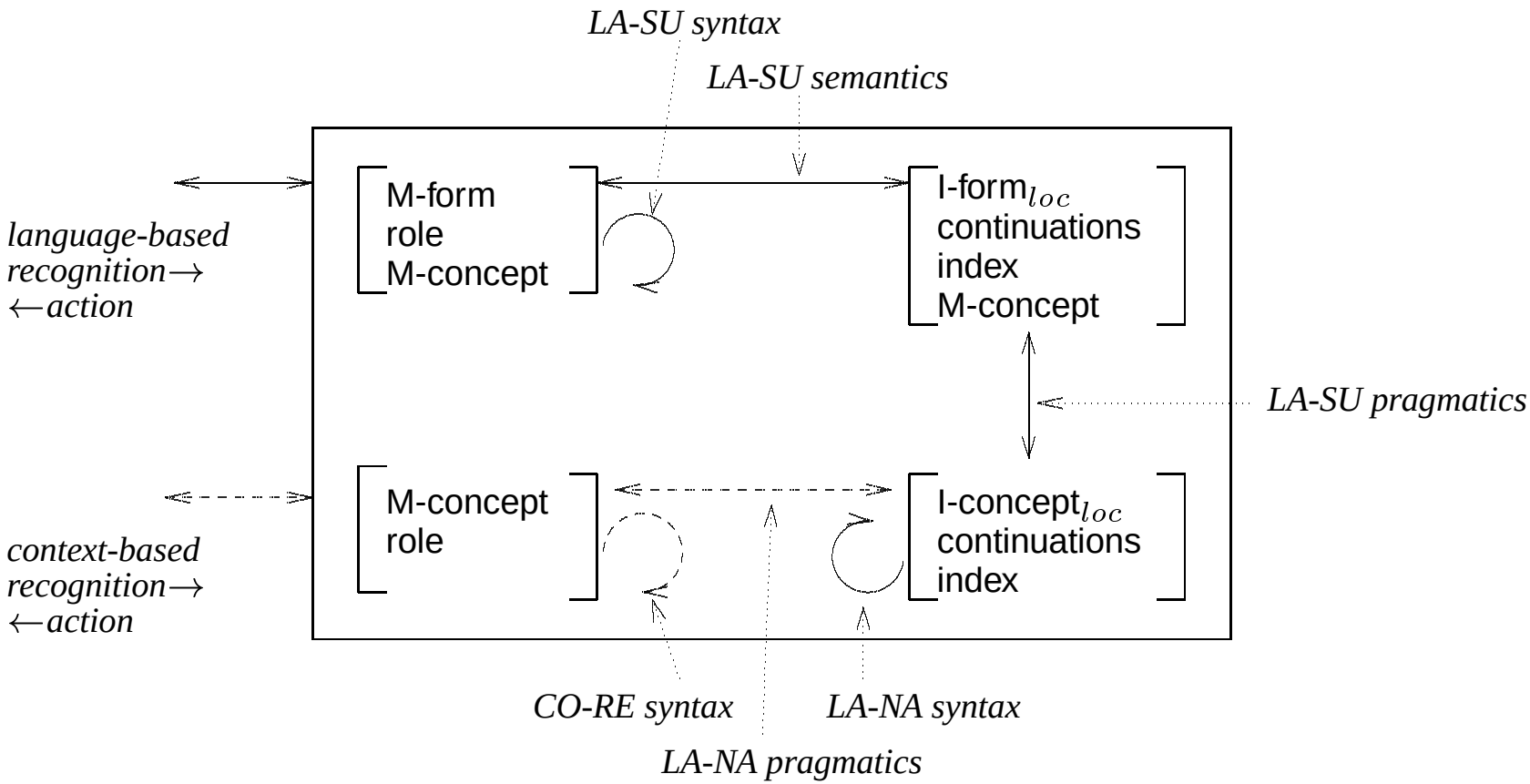
TYPES	PROPLETS
[M-concept: Fido role: argument]	[I-concept$_{loc}$: x13 functor: like prn: 6 id: ?]
[M-concept: like role: functor]	[I-concept$_{loc}$: x18 arg1: Fido arg2: Zach prn: 6 epr: ?]
[M-concept: Zach role: argument]	[I-concept$_{loc}$: x20 functor: like prn: 6 id: ?]

6. The structure of the SLIM machine

6.1 Static structures of the SLIM machine



6.2 External connections and motor algorithms of the SLIM machine



7. The motor algorithm: left-associative grammar

7.1 The principle of possible continuations

Beginning with the first word of the sentence, the grammar describes the possible continuations for each sentence start by specifying the rules which may perform the next grammatical composition (i.e., add the next word).

7.2 Schema of left-associative rule in LA-grammar

r_i: cat_1 $cat_2 \Rightarrow$ cat_3 rp_i

7.3 Schema of a canceling rule in C-grammar

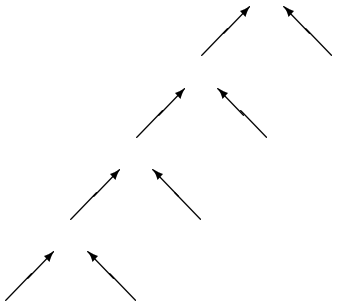
$\alpha_{(Y|X)} \circ \beta_{(Y)} \Rightarrow \alpha\beta_{(X)}$

7.4 Schema of a rewrite rule in PS-grammar

$A \rightarrow B\ C$

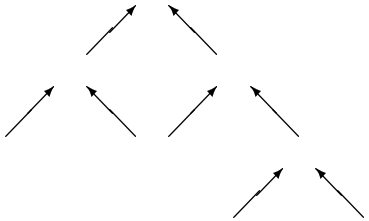
7.5 Three conceptual derivation orders

LA-grammar



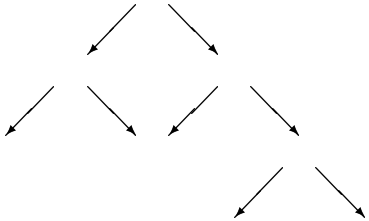
bot.-up left-associative

C-grammar



bottom-up amalgamating

PS-grammar

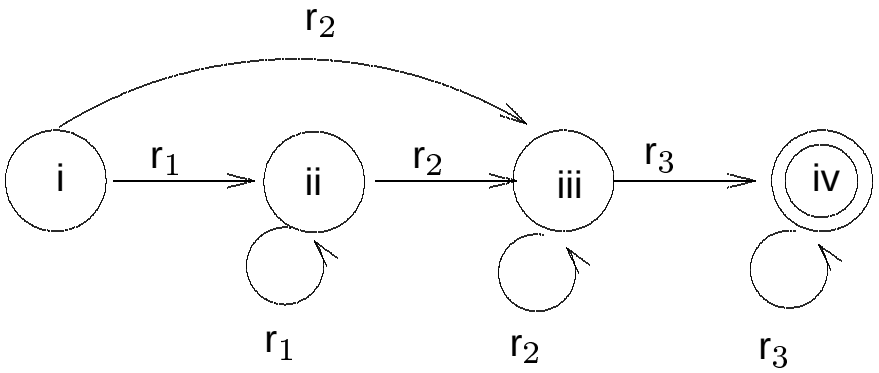


top-down expanding

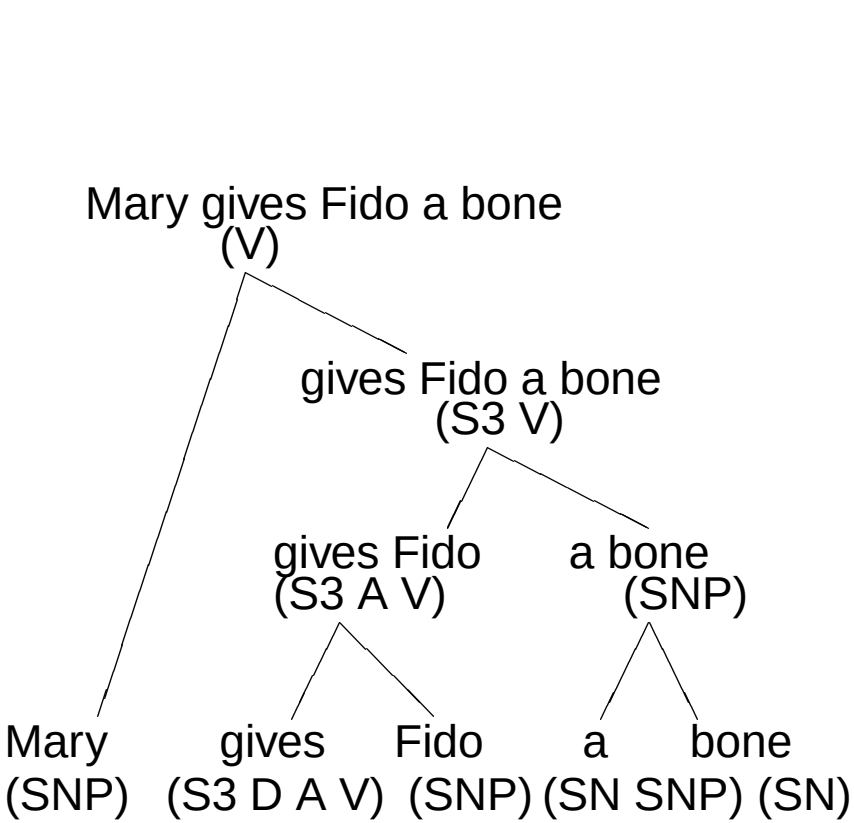
7.6 LA-grammar for $a^k b^k c^k$

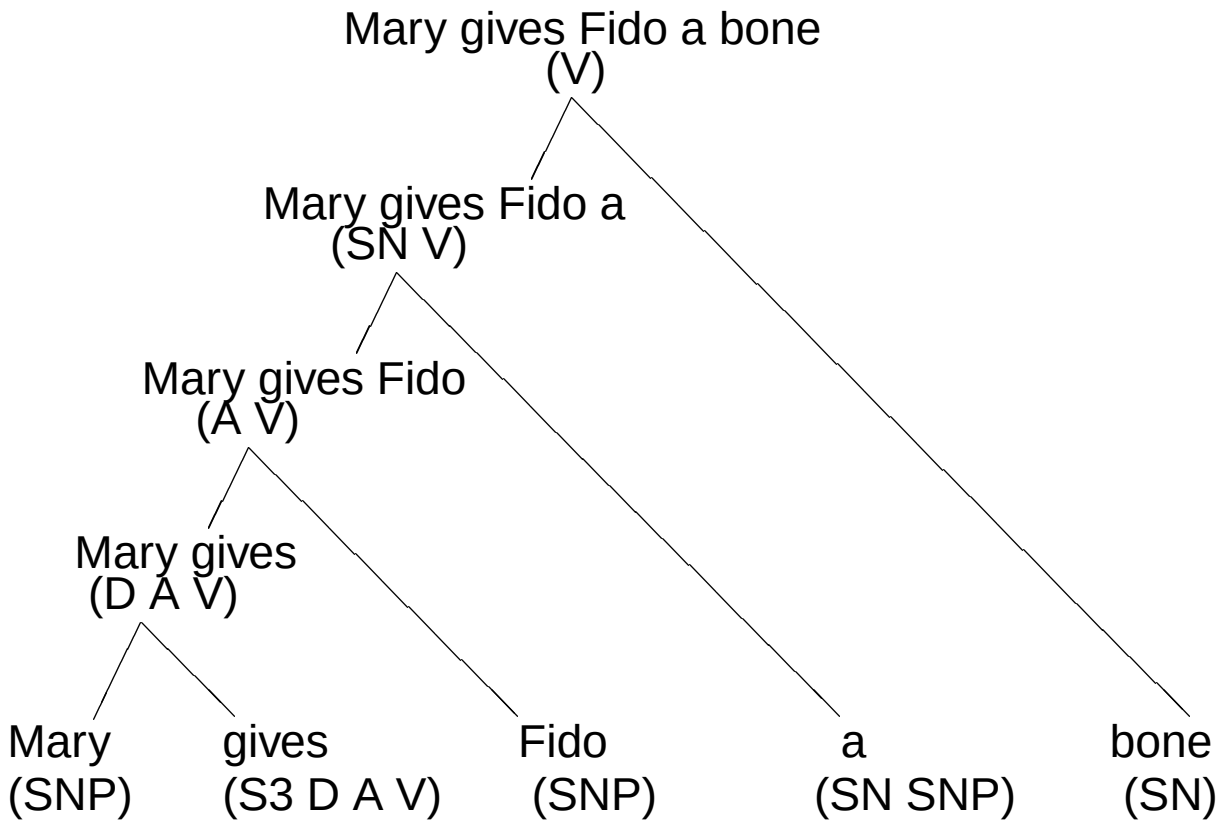
LX $=_{def}$ {[a (a)], [b (b)], [c (c)]}
$ST_S =_{def}$ {[(a) {r_1, r_2}]}
r_1: (X) (a) $\Rightarrow$ (aX) {r_1, r_2}
r_2: (aX) (b) $\Rightarrow$ (Xb) {r_2, r_3}
r_3: (bX) (c) $\Rightarrow$ (X) {r_3}
$ST_F =_{def}$ {[ε rp_3]}.

7.7 The finite state backbone of the LA-grammar for $a^k b^k c^k$



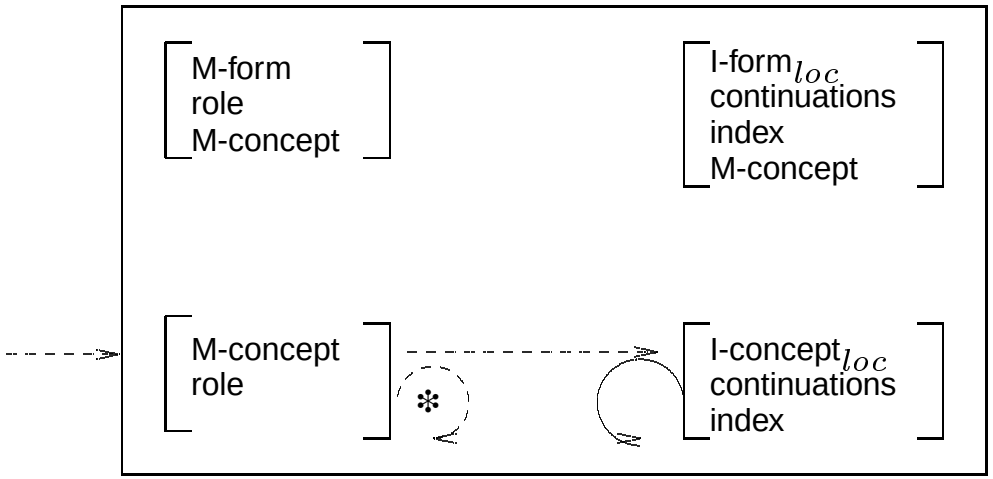
7.8 Comparing constituent structure and time-linear analysis



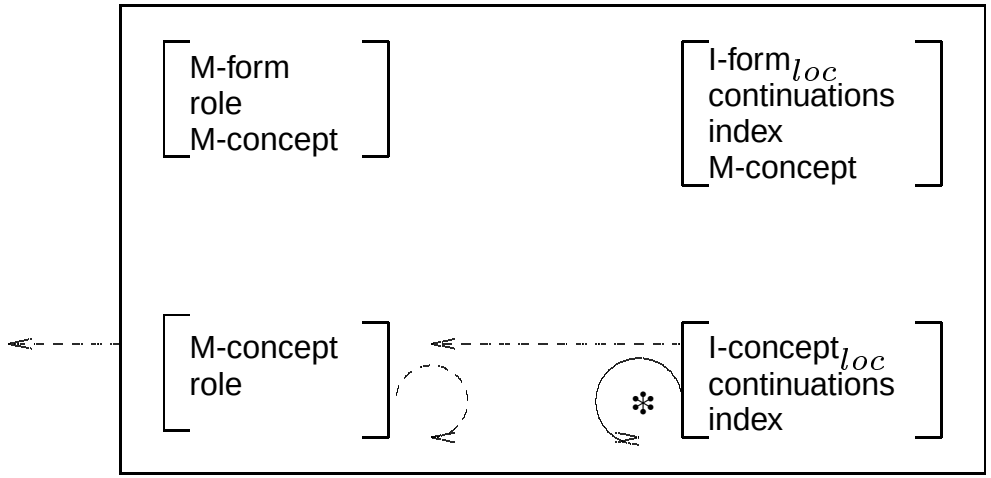


8. States of cognition

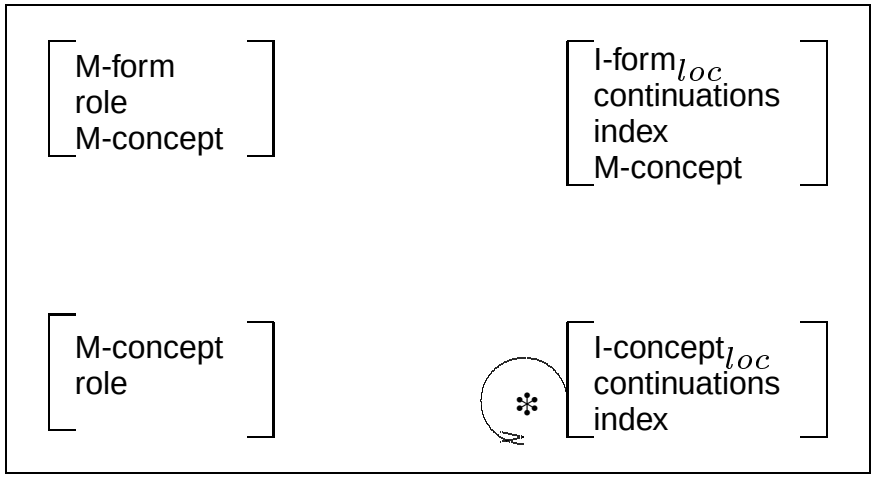
8.1 SLIM 1: Recognition (contextual)



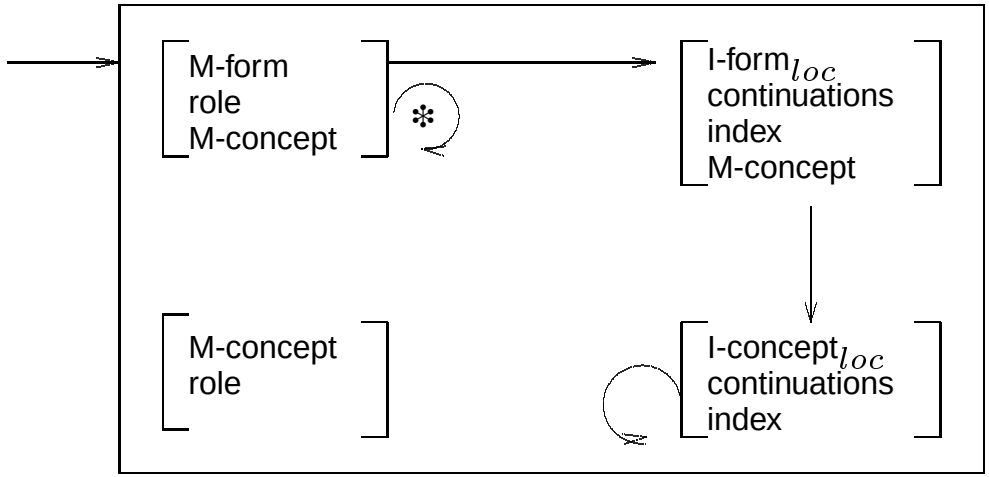
8.2 SLIM 2: Action (contextual)



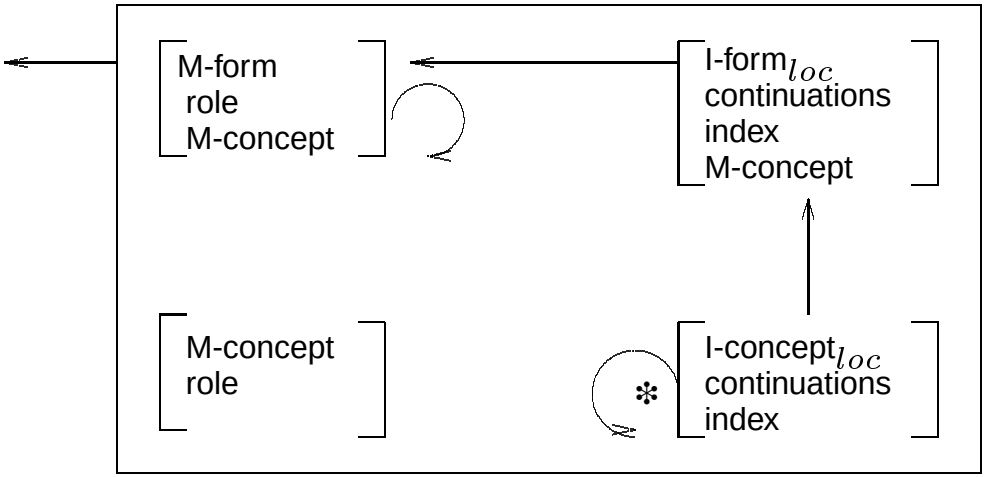
8.3 SLIM 3: **Inference** (contextual)



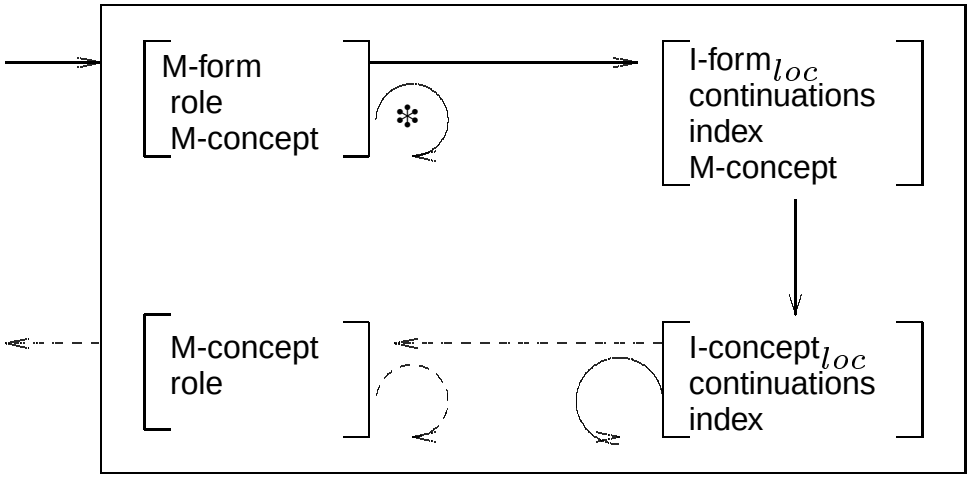
8.4 SLIM 4: **Interpretation of language** (mediated reference)



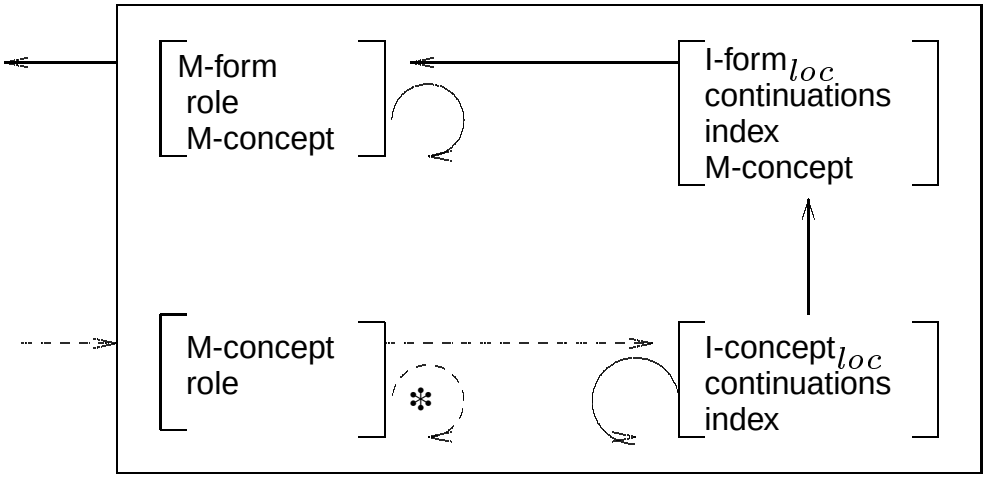
8.5 SLIM 5: **Production of language** (mediated reference)



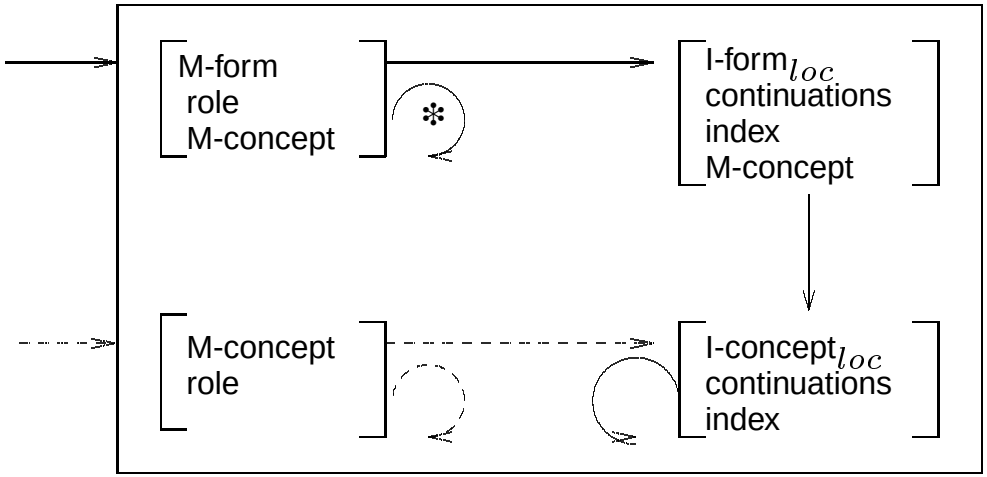
8.6 SLIM 6: **Language-controlled action** (immediate reference)



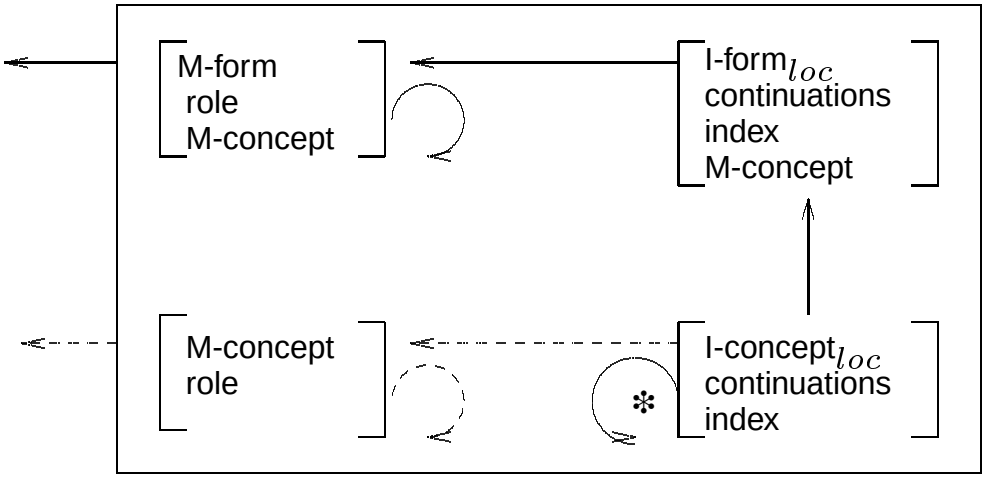
8.7 SLIM 7: Commented recognition (immediate reference)



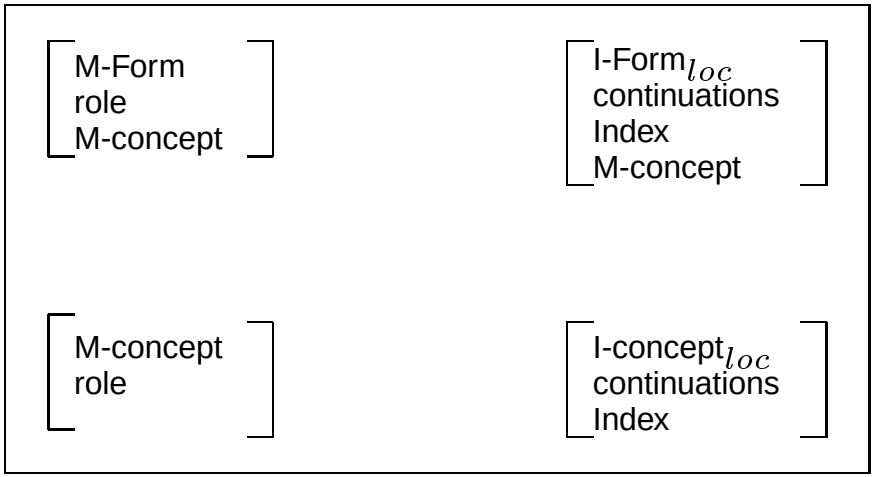
8.8 SLIM 8: Language-controlled recognition (immediate reference)



8.9 SLIM 9: Commented action (immediate reference)



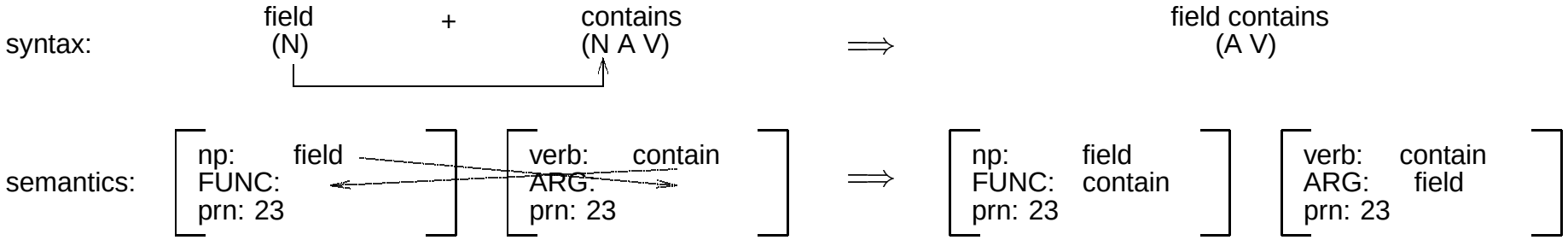
8.10 SLIM 10: Cognitive stillstand



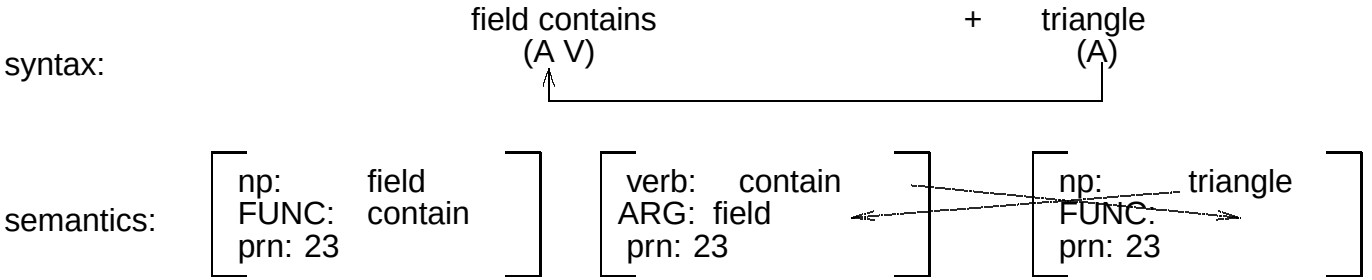
9. Technical details of a semantic interpretation

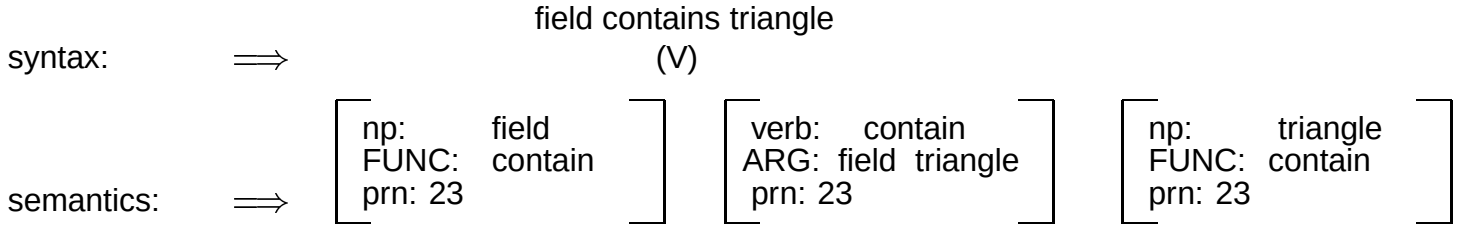
9.1 SYNTACTICO-SEMANTIC ANALYSIS OF field contains triangle

combination step 1:



combination step 2:





9.2 The man gave Mary a flower because he loves her.

9.3 Applying DET+N to *the + man*

syn: $\langle n' \; x \rangle$ $\langle n \rangle$ $\Longrightarrow$ $\langle x \rangle$

sem: nw.M $\xrightarrow{\boxed{r}}$ ss.① copy$_{ss}$

$$\left[\begin{array}{l}\text{sur: the}\\ \text{syn: } \langle SN' \; SNP \rangle\\ \text{sem: } \left[\begin{array}{l}\text{P: } \langle \text{sg def} \rangle\\ \text{C: } \left[\begin{array}{l}\text{MOD:}\\ \text{VERB:}\end{array}\right]\\ \text{I: } \left[\begin{array}{l}\text{prn: } \langle 1 \rangle\\ \text{id: } +1\end{array}\right]\\ \text{M: } ①\end{array}\right]\end{array}\right]_1 + \left[\begin{array}{l}\text{sur: man}\\ \text{syn: } \langle SN \rangle\\ \text{sem: } \left[\begin{array}{l}\text{P:}\\ \text{C: } \left[\begin{array}{l}\text{MOD:}\\ \text{VERB:}\end{array}\right]\\ \text{I: } \left[\begin{array}{l}\text{prn: } =\\ \text{id: } =\end{array}\right]\\ \text{M: } \textit{man}\end{array}\right]\end{array}\right]_2 \Longrightarrow \left[\begin{array}{l}\text{sur: the man}\\ \text{syn: } \star \langle SNP \rangle\\ \text{sem: } \left[\begin{array}{l}\text{P: } \langle \text{sg def} \rangle\\ \text{C: } \left[\begin{array}{l}\text{MOD:}\\ \text{VERB:}\end{array}\right]\\ \text{I: } \left[\begin{array}{l}\text{prn: } \langle 1 \rangle\\ \text{id: } \star 1\end{array}\right]\\ \text{M: } \star \textit{man}\end{array}\right]\end{array}\right]_1$$

9.4 SLIM semantic representation of example 9.2

the man

$$\begin{bmatrix} \text{sur:} \\ \text{syn: } \langle \text{SNP} \rangle \\ \text{sem: } \begin{bmatrix} \text{P: } \langle \text{sg def} \rangle \\ \text{C: } \begin{bmatrix} \text{MOD:} \\ \text{VERB: give} \end{bmatrix} \\ \text{I: } \begin{bmatrix} \text{prn: } \langle 1 \rangle \\ \text{id: } 1 \end{bmatrix} \\ \text{M: } \textit{man} \end{bmatrix} \end{bmatrix}_1$$

gave

$$\begin{bmatrix} \text{sur:} \\ \text{syn: } \langle \text{V} \rangle \\ \text{sem: } \begin{bmatrix} \text{P: } \langle \text{past tense} \rangle \\ \text{C: } \begin{bmatrix} \text{MOD:} \\ \text{NP: } \langle \text{man, Mary, flower} \rangle \end{bmatrix} \\ \text{I: } \begin{bmatrix} \text{prn: } \langle 1 \rangle \\ \text{epr: } 1 \textit{ bec } 2 \end{bmatrix} \\ \text{M: } \textit{give} \end{bmatrix} \end{bmatrix}_3$$

Mary

$$\begin{bmatrix} \text{sur:} \\ \text{syn: } \langle \text{SNP} \rangle \\ \text{sem: } \begin{bmatrix} \text{P: } \langle \text{sg name} \rangle \\ \text{C: } \begin{bmatrix} \text{MOD:} \\ \text{VERB: give} \end{bmatrix} \\ \text{I: } \begin{bmatrix} \text{prn: } \langle 1 \rangle \\ \text{id: } 2 \end{bmatrix} \\ \text{M: } \textit{Mary} \end{bmatrix} \end{bmatrix}_4$$

a flower

$$\begin{bmatrix} \text{sur:} \\ \text{syn: } \langle \text{SNP} \rangle \\ \text{sem: } \begin{bmatrix} \text{P: } \langle \text{sg indef} \rangle \\ \text{C: } \begin{bmatrix} \text{MOD:} \\ \text{VERB: give} \end{bmatrix} \\ \text{I: } \begin{bmatrix} \text{prn: } \langle 1 \rangle \\ \text{id: } 3 \end{bmatrix} \\ \text{M: } \textit{flower} \end{bmatrix} \end{bmatrix}_5$$

because loves

$$\begin{bmatrix} \text{sur:} \\ \text{syn: } \langle \text{V} \rangle \\ \text{sem:} \begin{bmatrix} \text{P: } \langle \text{3sg, present tense} \rangle \\ \text{C: } \begin{bmatrix} \text{MOD:} \\ \text{NP: pro-1, pro-2} \end{bmatrix} \\ \text{I: } \begin{bmatrix} \text{prn: } \langle 2-,1 \rangle \\ \text{epr: 1 } \textit{bec} \text{ 2} \end{bmatrix} \\ \text{M: } \textit{love} \end{bmatrix} \end{bmatrix}_7$$

he

$$\begin{bmatrix} \text{sur:} \\ \text{syn: } \langle \text{SNP} \rangle \\ \text{sem:} \begin{bmatrix} \text{P: } \langle \text{nom sg} \rangle \\ \text{C: } \begin{bmatrix} \text{MOD:} \\ \text{VERB: love} \end{bmatrix} \\ \text{I: } \begin{bmatrix} \text{prn: } \langle 2\text{-, } 1 \rangle \\ \text{id: 1} \end{bmatrix} \\ \text{M: } \textit{pro-1} \end{bmatrix} \end{bmatrix}_8$$

her

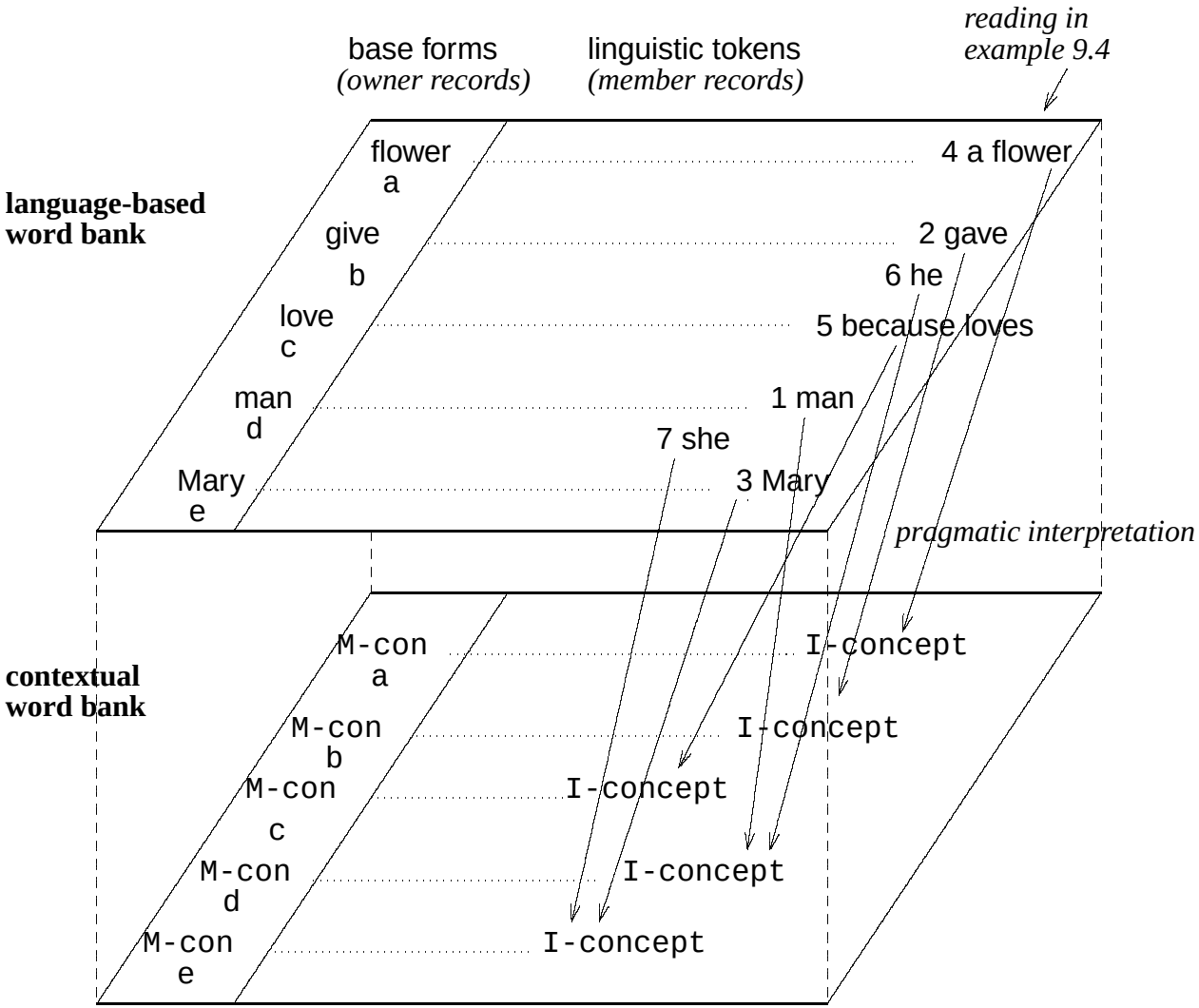
$$\begin{bmatrix} \text{sur:} \\ \text{syn: } \langle \text{SNP} \rangle \\ \text{sem:} \begin{bmatrix} \text{P: } \langle \text{obl sg} \rangle \\ \text{C: } \begin{bmatrix} \text{MOD:} \\ \text{VERB: love} \end{bmatrix} \\ \text{I: } \begin{bmatrix} \text{prn: } \langle 2\text{-,}1 \rangle \\ \text{id: 2} \end{bmatrix} \\ \text{M: } \textit{pro-2} \end{bmatrix} \end{bmatrix}_9$$

9.5 Components of literal meaning (meaning$_1$)

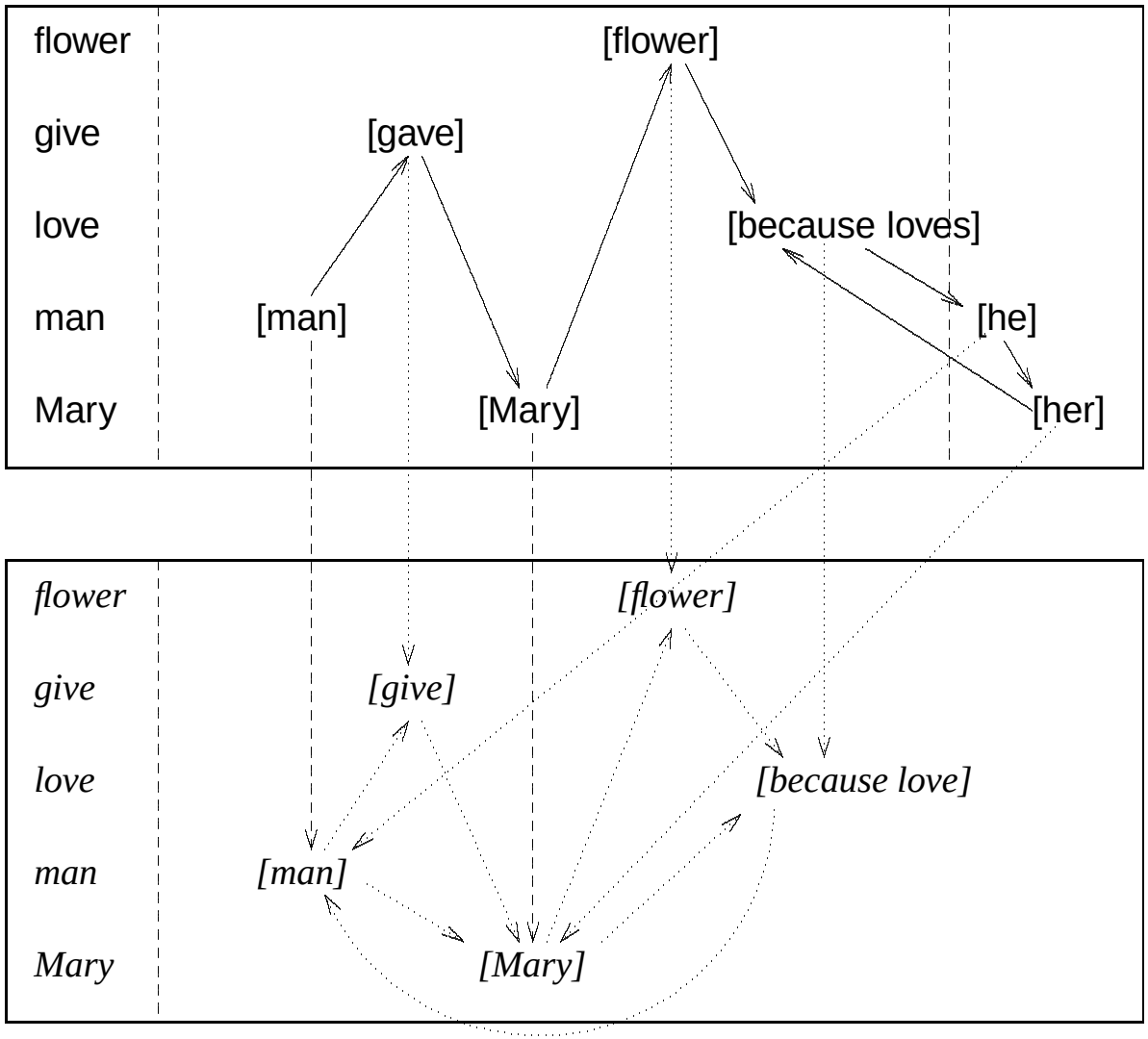
- Compositional semantics (sentence semantics)
  1. Decomposition of input into elementary propositions.
  2. Functor-argument structure within an elementary proposition.
  3. Extrapropositional relations among elementary propositions.
- Lexical semantics (word semantics)
  1. Properties and M-concepts of woplets.
  2. Extrapropositional relations between word types by means of *absolute propositions*.

10. Pragmatic interpretation

10.1 Embedding 9.4 into the contextual word bank



10.2 Time-linear interpretation of language controlling a navigation through the context



11. The source of coherence in language production

11.1 Immediate vs. mediated subcontexts

In immediate subcontexts, the coherence of the content follows directly from the coherence of the external world which they reflect, i.e., the temporal and spatial sequence of events, the part-whole relations of objects, etc. In contrast, mediated subcontexts have the special property that the elements familiar from direct recognition may be reordered and reconnected by the author at will.

11.2 Comparing coherence and inchorence, Example I

The representation of a swimmer standing at the pool side, diving into the water, and disappearing with a splash is coherent. In contrast, a representation in which a pair of feet appears in the foaming water and a swimmer flies feet first into the air landing on the pool side, would be incoherent – unless it is specified in addition that the representation happens to be, e.g., a backward running movie.

11.3 Comparing coherence and inchorence, Example II

A representation of people talking with each other would be coherent. In contrast, a similar representation of a deer conversing with a skunk in English would be incoherent – unless it is specified in addition that the representation happens to be fictional.

12. Example of a subcontext

12.1 Mediated subcontexts reflecting the coherence of the external world

world → speaker context → language → hearer context → world

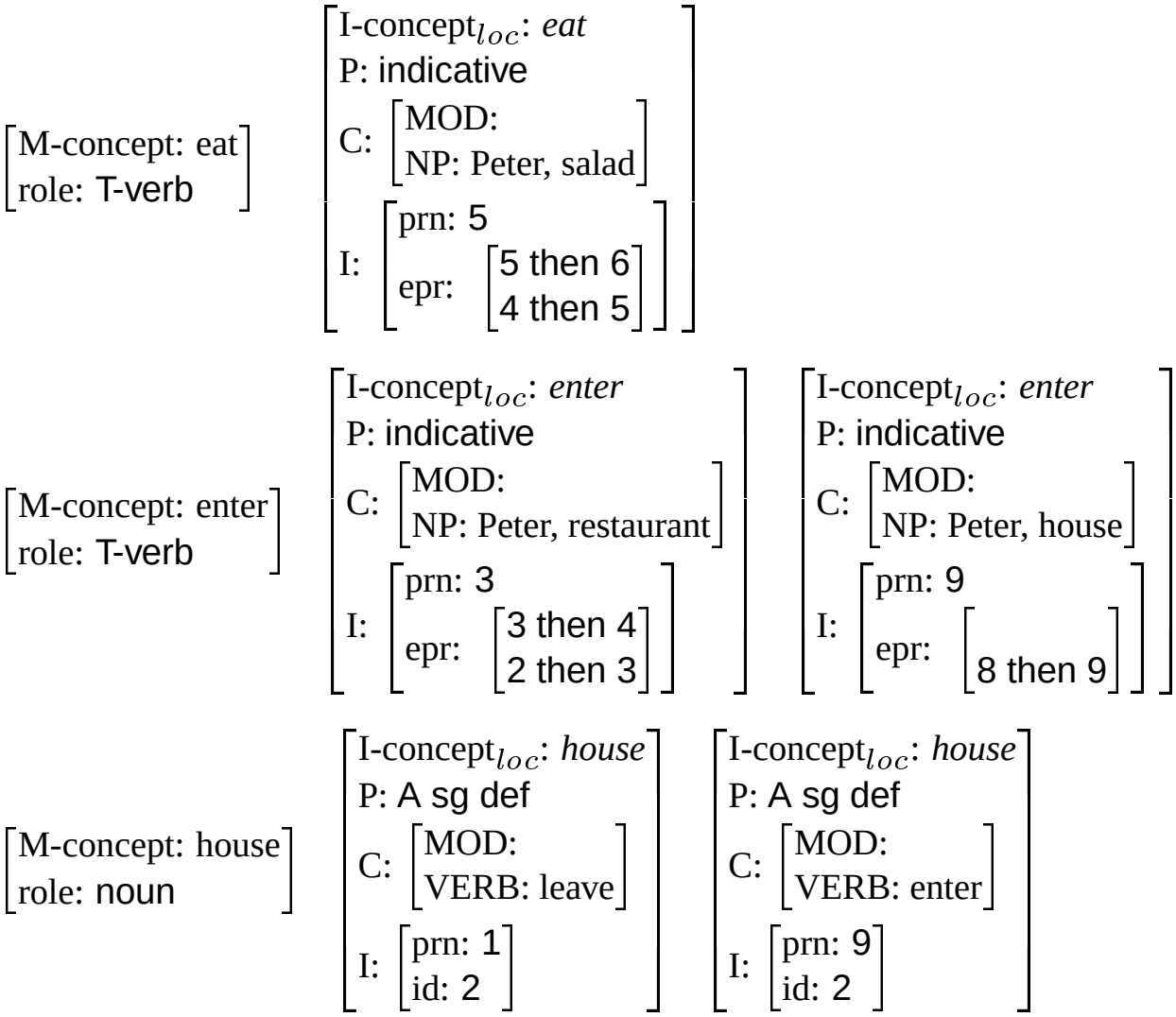
12.2 A sequence of propositions forming a subcontext

1. Peter leaves the house. 2. Peter crosses the street. 3. Peter enters a restaurant. 4. Peter orders a salad. 5. Peter eats the salad. 6. Peter pays the salad. 7. Peter leaves the restaurant. 8. Peter crosses the street. 9. Peter enters the house.

12.3 Representing 12.2 as a word bank

CONCEPT TYPES: COPLETS:

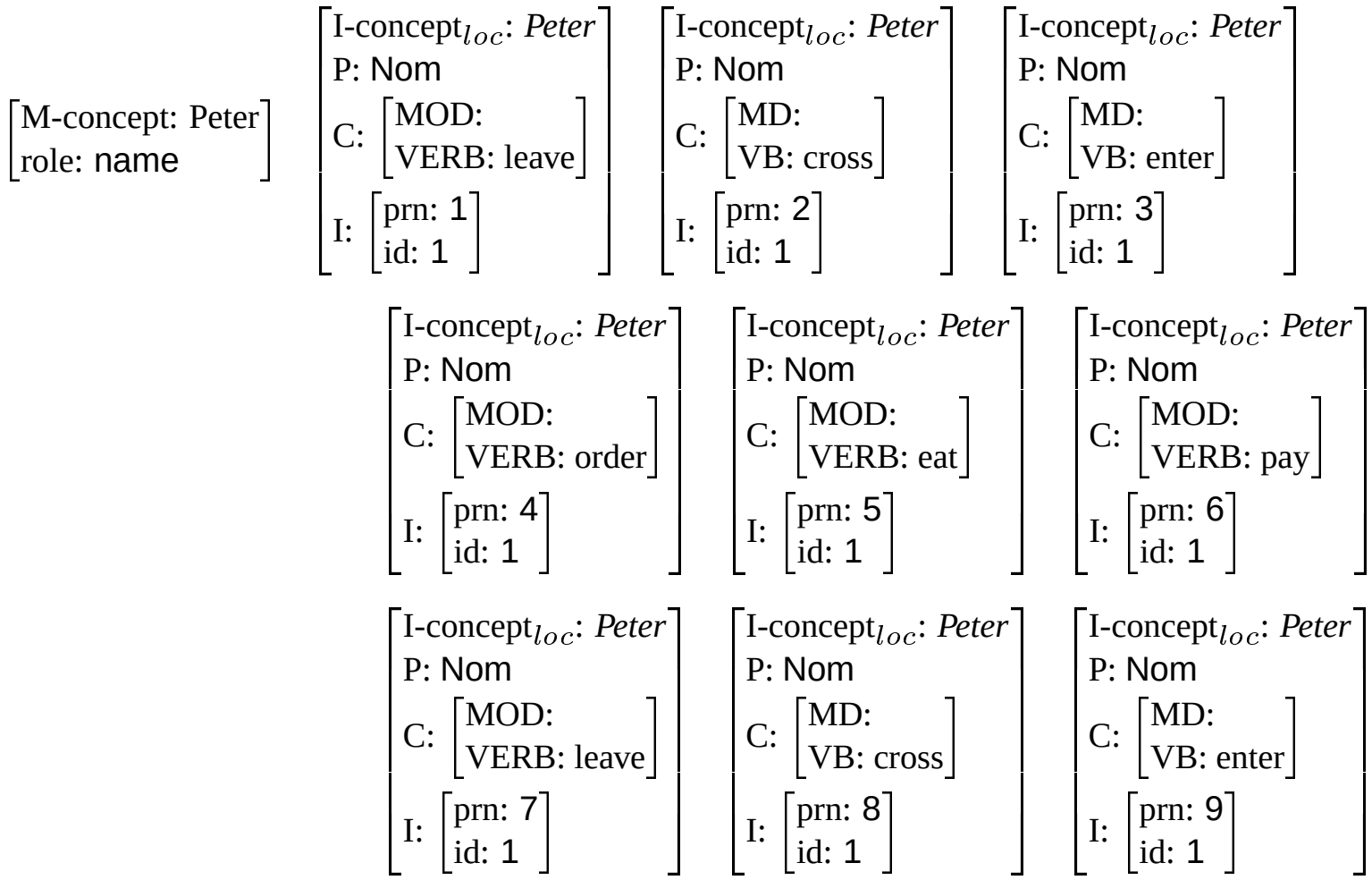
$$\begin{bmatrix}\text{M-concept: cross}\\ \text{role: T-verb}\end{bmatrix} \quad \begin{bmatrix}\text{I-concept}_{loc}\text{: } \textit{cross}\\ \text{P: indicative}\\ \text{C: } \begin{bmatrix}\text{MOD:}\\ \text{NP: Peter, street}\end{bmatrix}\\ \text{I: } \begin{bmatrix}\text{prn: 2}\\ \text{epr: } \begin{bmatrix}\text{2 then 3}\\ \text{1 then 2}\end{bmatrix}\end{bmatrix}\end{bmatrix} \quad \begin{bmatrix}\text{I-concept}_{loc}\text{: } \textit{cross}\\ \text{P: indicative}\\ \text{C: } \begin{bmatrix}\text{MOD:}\\ \text{NP: Peter, street}\end{bmatrix}\\ \text{I: } \begin{bmatrix}\text{prn: 8}\\ \text{epr: } \begin{bmatrix}\text{8 then 9}\\ \text{7 then 8}\end{bmatrix}\end{bmatrix}\end{bmatrix}$$

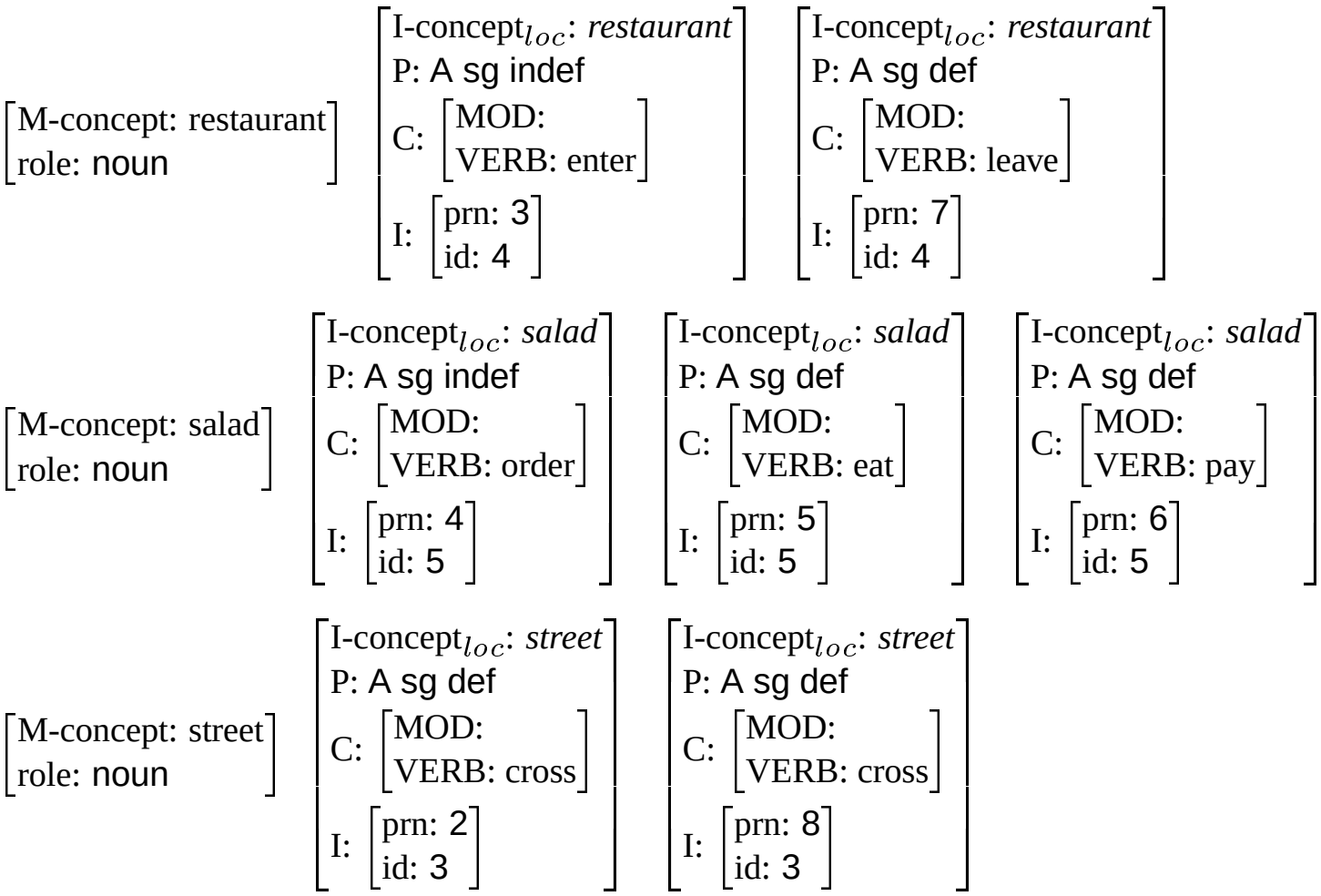


$$\begin{bmatrix}\text{M-concept: leave}\\ \text{role: T-verb}\end{bmatrix}\quad\begin{bmatrix}\text{I-concept}_{loc}\text{: } \textit{leave}\\ \text{P: indicative}\\ \text{C: }\begin{bmatrix}\text{MOD:}\\ \text{NP: Peter, house}\end{bmatrix}\\ \text{I: }\begin{bmatrix}\text{prn: 1}\\ \text{epr: }\begin{bmatrix}\text{1 then 2}\end{bmatrix}\end{bmatrix}\end{bmatrix}\quad\begin{bmatrix}\text{I-concept}_{loc}\text{: } \textit{leave}\\ \text{P: indicative}\\ \text{C: }\begin{bmatrix}\text{MOD:}\\ \text{NP: Peter, restaurant}\end{bmatrix}\\ \text{I: }\begin{bmatrix}\text{prn: 7}\\ \text{epr: }\begin{bmatrix}\text{7 then 8}\\ \text{6 then 7}\end{bmatrix}\end{bmatrix}\end{bmatrix}$$

$$\begin{bmatrix}\text{M-concept: order}\\ \text{role: T-verb}\end{bmatrix}\quad\begin{bmatrix}\text{I-concept}_{loc}\text{: } \textit{order}\\ \text{P: indicative}\\ \text{C: }\begin{bmatrix}\text{MOD:}\\ \text{NP: Peter, salad}\end{bmatrix}\\ \text{I: }\begin{bmatrix}\text{prn: 4}\\ \text{epr: }\begin{bmatrix}\text{4 then 5}\\ \text{3 then 4}\end{bmatrix}\end{bmatrix}\end{bmatrix}$$

$$\begin{bmatrix}\text{M-concept: pay}\\ \text{role: T-verb}\end{bmatrix}\quad\begin{bmatrix}\text{I-concept}_{loc}\text{: } \textit{pay}\\ \text{P: indicative}\\ \text{C: }\begin{bmatrix}\text{MOD:}\\ \text{NP: Peter, salad}\end{bmatrix}\\ \text{I: }\begin{bmatrix}\text{prn: 6}\\ \text{epr: }\begin{bmatrix}\text{6 then 7}\\ \text{5 then 6}\end{bmatrix}\end{bmatrix}\end{bmatrix}$$





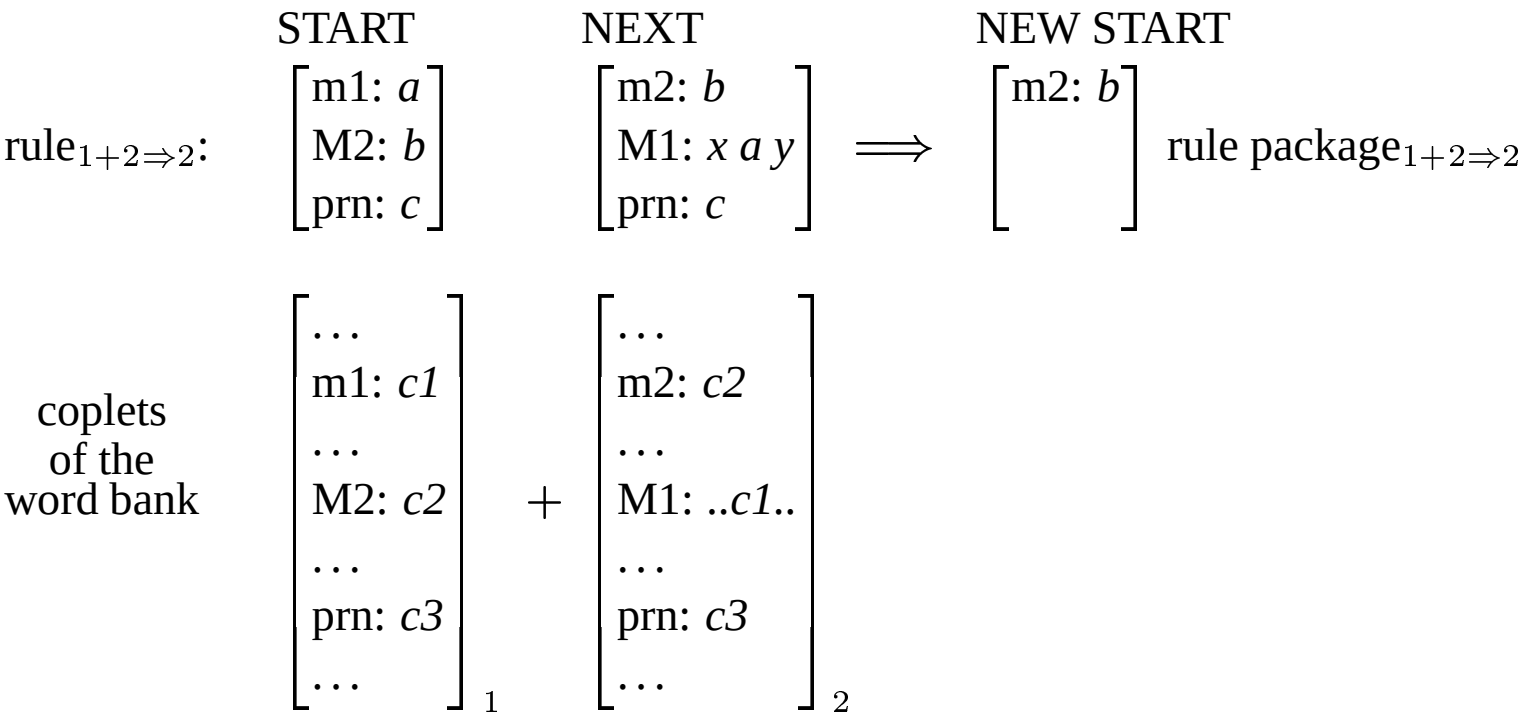
13. Autonomous navigation as the basis of conceptualization

13.1 Step 1 of a LA-NA rule application

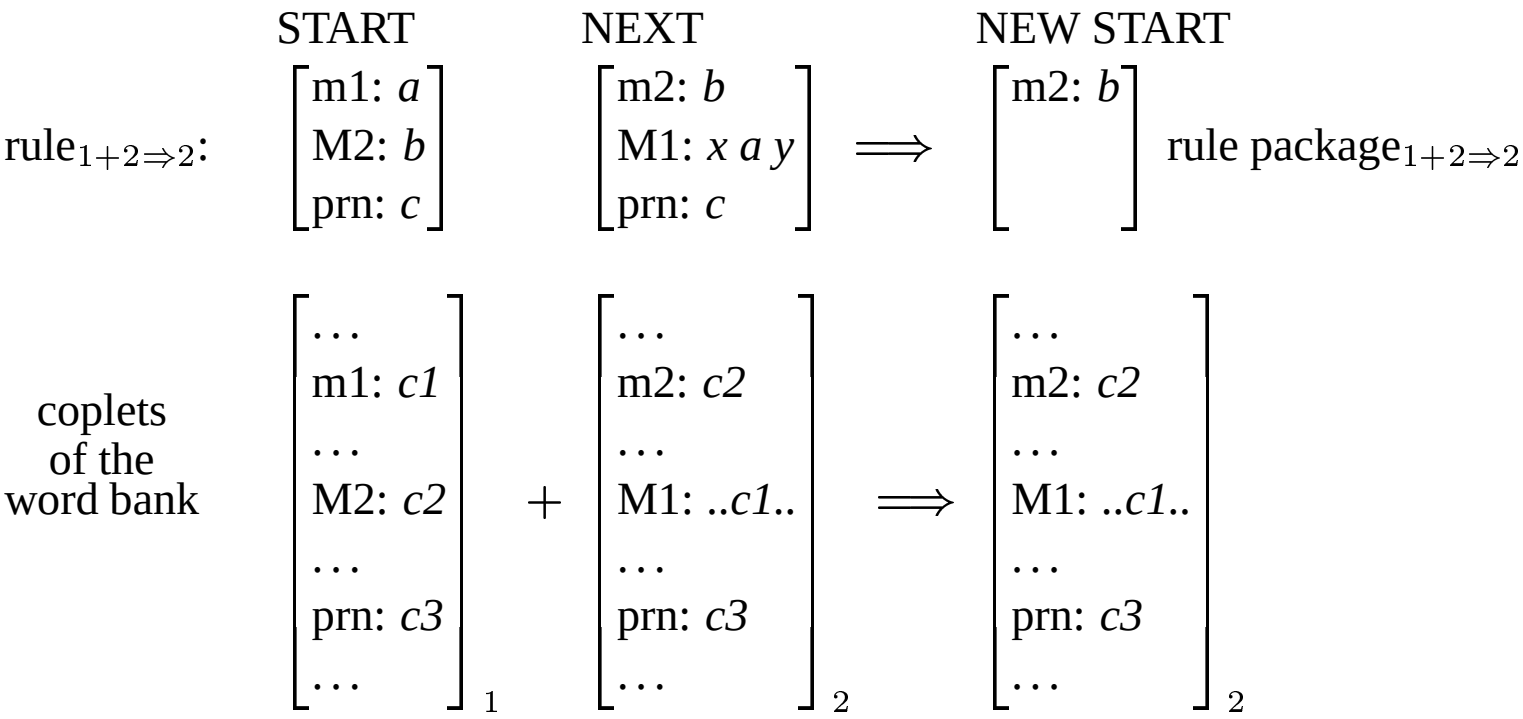
$$\text{rule}_{1+2\Rightarrow 2}: \quad \underset{\text{START}}{\begin{bmatrix} \text{m1: } a \\ \text{M2: } b \\ \text{prn: } c \end{bmatrix}} \quad \underset{\text{NEXT}}{\begin{bmatrix} \text{m2: } b \\ \text{M1: } x\ a\ y \\ \text{prn: } c \end{bmatrix}} \quad \Longrightarrow \quad \underset{\text{NEW START}}{\begin{bmatrix} \text{m2: } b \\ \\ \\ \end{bmatrix}} \quad \text{rule package}_{1+2\Rightarrow 2}$$

$$\text{coplets of the word bank} \quad \begin{bmatrix} \ldots \\ \text{m1: } c1 \\ \ldots \\ \text{M2: } c2 \\ \ldots \\ \text{prn: } c3 \\ \ldots \end{bmatrix}_1$$

13.2 Step 2 of an LA-NA rule application



13.3 Step 3 of a LA-NA rule application



13.4 Tracking principles of LA-navigation

1. *Completeness*
   Within an elementary proposition those coplets are preferred which have not yet been traversed during the current navigation.
2. *Uniqueness*
   If several START or NEXT coplets are available, no more than one of each are selected whereby the choice may be at random or – if activated – based on a specific navigation pattern.
3. *Recency*
   In extrapropositional navigations, propositions which have been least recently traversed are preferred.
4. *Frequency*
   When entering a new subcontext, the navigation prefers paths most frequently traversed in previous navigations.

13.5 Definition of universal LA-NA syntax

ST_S: {([M-np: a] {1 V+NP1, 2 V+NP2})}

V+NP1: $\begin{bmatrix}\text{M-verb: } a\\ \text{NP: } x\ b\ y\\ \text{prn: } m\end{bmatrix}\ \begin{bmatrix}\text{M-np: } b\\ \text{VERB: } a\\ \text{prn: } m\end{bmatrix} \Longrightarrow \begin{bmatrix}\text{M-verb: } a\\ \\ \end{bmatrix}$ {3 V+NP1, 4 V+NP2, 5 V+epr}

V+NP2: $\begin{bmatrix}\text{M-verb: } a\\ \text{NP: } x\ b\ y\\ \text{prn: } m\end{bmatrix}\ \begin{bmatrix}\text{M-np: } b\\ \text{VERB: } a\\ \text{prn: } m\end{bmatrix} \Longrightarrow \begin{bmatrix}\text{M-np: } b\\ \\ \end{bmatrix}$ {6 NP+id}

V+epr: $\begin{bmatrix}\text{M-verb: } a\\ \text{NP: } x\\ \text{prn: } m\\ \text{epr: } m\ C\ n\end{bmatrix}\ \begin{bmatrix}\text{M-verb: } b\\ \text{NP: } y\\ \text{prn: } n\\ \text{epr: } m\ C\ n\end{bmatrix} \Longrightarrow \begin{bmatrix}\text{M-verb: } b\\ \\ \end{bmatrix}$ {7 V+NP1, 8 V+NP2}

NP+id: $\begin{bmatrix}\text{M-np: } a\\ \text{VERB: } b\\ \text{prn: } k\\ \text{id: } m\end{bmatrix}\ \begin{bmatrix}\text{M-np: } a\\ \text{VERB: } c\\ \text{prn: } l\\ \text{id: } m\end{bmatrix} \Longrightarrow \begin{bmatrix}\text{M-verb: } c\\ \text{NP: } x\ a\ y\\ \text{prn: } l\\ \end{bmatrix}$ {9 V+NP1 10 V+NP2}

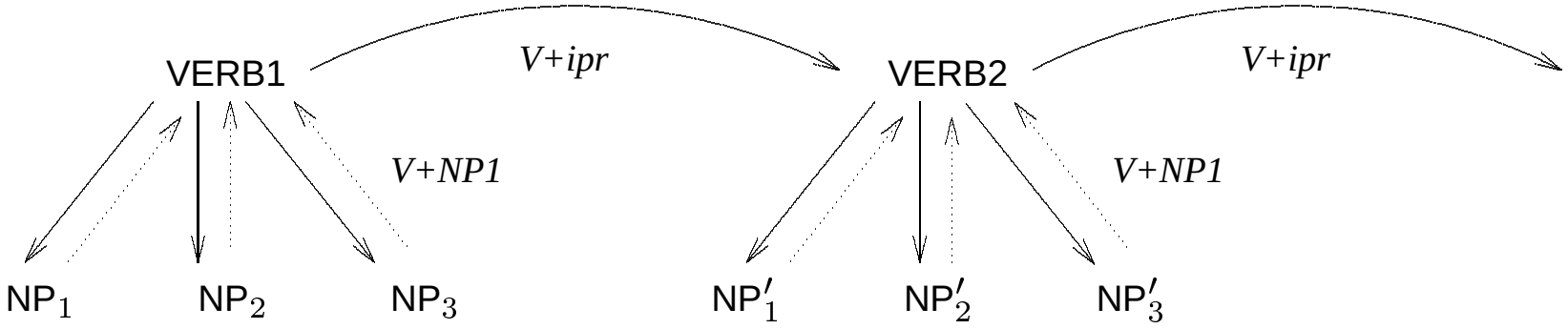
ST_F: { ([M-verb: x] rp $_{\text{V+NP1}}$)}

13.6 First Application of V+NP1 in the word bank 12.3

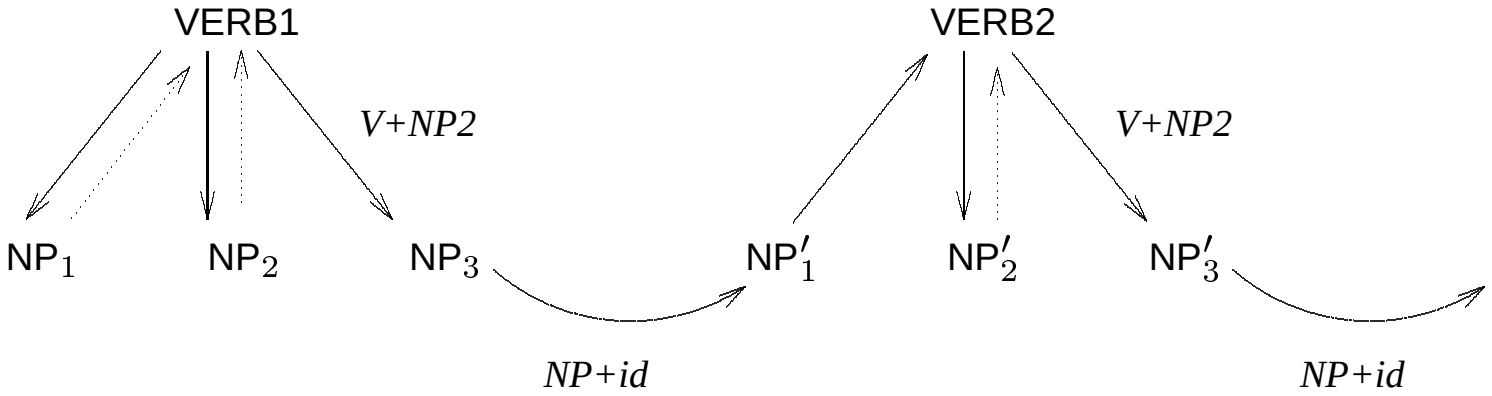
$$\text{V+NP1:}\ \begin{bmatrix}\text{M-verb: } a\\ \text{NP: } x\ b\ y\\ \text{prn: } c\end{bmatrix}\quad\begin{bmatrix}\text{M-np: } b\\ \text{VERB: } a\\ \text{prn: } c\end{bmatrix}\Longrightarrow\quad\begin{bmatrix}\text{M-verb: } a\\ \\ \end{bmatrix}\ \{3\ \text{V+NP1, 4 V+NP2, 5 V+epr}\}$$

$$\begin{bmatrix}\text{I-concept}_{loc}\text{: } eat\\ \text{P: indicative}\\ \text{C: }\begin{bmatrix}\text{MOD:}\\ \text{NP: Peter, salad}\end{bmatrix}\\ \text{I: }\begin{bmatrix}\text{prn: 5}\\ \text{epr: }\begin{bmatrix}\text{5 then 6}\\ \text{4 then 5}\end{bmatrix}\end{bmatrix}\end{bmatrix}\quad\begin{bmatrix}\text{I-concept}_{loc}\text{: } salad\\ \text{P: A sg def}\\ \text{C: }\begin{bmatrix}\text{MOD:}\\ \text{VERB: eat}\end{bmatrix}\\ \text{I: }\begin{bmatrix}\text{prn: 5}\\ \text{id: 2}\end{bmatrix}\end{bmatrix}\quad\begin{bmatrix}\text{I-concept}_{loc}\text{: } eat\\ \text{P: indicative}\\ \text{C: }\begin{bmatrix}\text{MOD:}\\ \text{NP: Peter,salad}\end{bmatrix}\\ \text{I: }\begin{bmatrix}\text{prn: 5}\\ \text{epr: }\begin{bmatrix}\text{5 then 6}\\ \text{4 then 5}\end{bmatrix}\end{bmatrix}\end{bmatrix}$$

13.7 Extrapropositional epr-navigation



13.8 Extrapropositional id-navigation



14. Different temporal prepositions depending on direction of navigation

14.1 epr-coordination

Peter leaves the house. Then he crosses the street.
Peter crosses the street. Before that he leaves the house.

14.2 epr-subordination (adverbial clauses)

Before Peter crosses the street, he leaves the house.
Peter, before he crosses the street, leaves the house.
Peter leaves, before he crosses the street, the house.
Peter leaves the house, before he crosses the street.
After Peter leaves the house, he crosses the street.
Peter, after he leaves the house, crosses the street.
Peter crosses, after he leaves the house, the street.
Peter crosses the street, after he leaves the house.

14.3 id-coordination

Peter orders a salad. The salad is eaten by Peter.

14.4 id-subordination (relative clause)

Peter orders a salad which he eats.

14.5 Different realizations of conjunctions

	temporal	causal	modal
coordinating forward:	P1. Then P2.	P1. Therefore P2.	P1. Thus P2.
coordinating backward:	P2. Earlier P1.		
subordinating forward:	p1, before P2, p1.	p1, for which reason P2, p1.	p1, as P2, p1
subordinating backward:	p2, after P1, p2.	p2, because P1, p2.	

14.6 Adverbial embedding navigation

Peter crossed, after he left the house, the street.

▼*cross*	*Peter*	V+epr			*street*
prn:2	prn:2	*leave*	*Peter house* ▲		prn: 2
(2 then 3)	id: 1	prn: 1	prn:1	prn:1	id: 3
(1 then 2)		(1 then 2)	id:1	id:2	

14.7 Universality and language specificity in a SLIM machine