A Frame-Based Model of Inherent Polysemy, Copredication and Argument Coercion

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Abstract

The paper presents a frame-based model of inherently polysemous nouns (such as 'book', which denotes both a physical object and an informational content) in which the meaning facets are directly accessible via attributes and which also takes into account the semantic relations between the facets. Predication over meaning facets (as in 'memorize the book') is then modeled as targeting the value of the corresponding facet attribute while coercion (as in 'finish the book') is modeled via specific patterns that enrich the predication. We use a compositional framework whose basic components are lexicalized syntactic trees paired with semantic frames and in which frame unification is triggered by tree composition. The approach is applied to a variety of combinations of predications over meaning facets and coercions.

1 Introduction

The lexical representation of inherently polysemous nouns and the variable evocation of their meaning facets by the predications in which they occur continue to be topics of ongoing research. Two questions are of particular interest in this context: (i) What are the mechanisms that underlie *copredication constructions* in which two or more predicates that aim at different meaning facets are applied to the same nominal argument? (ii) How does facet selection for inherently polysemous nouns differ from cases of *argument coercion* in which an apparent mismatch between the semantic type of an argument expression and the requirements of the predicate is resolved by an extended mode of composition that draws on additional pieces of lexical or contextual information?

Examples of inherent polysemy classes are given by nouns such as 'book' and 'letter', which have a physical facet and an information facet, and by nouns such as 'documentation' and 'classification', which have a process and a result facet. The sentence in (1a) illustrates a verb-verb copredication construction in which 'memorize' addresses the information facet of the letter while 'burn' targets its physical facet.

(1) a. Before leaving Rome he had *memorized* and *burned* a nine-page *letter* from Moscow.[1]
   b. [...] and she *ripped* the *offending letter* to shreds.[2]
   c. Although Kafur *burned* the *poem* without having read it, [...][3]

In verb-adjective copredication constructions like (1b), it is the argument-taking verb and the modifying adjective that address different facets of the noun. The example in (1c), by contrast, would count as a case of coercion if we assume that poems do not inherently come with physical facets.

The examples in (2), retrieved via Sketch Engine's interface to the ACL Anthology Reference Corpus (Bird et al., 2008), show an analogous pattern with respect to the evocation of process and result facets. In (2a), 'conducted' addresses the process facets of the classifications while 'evaluated' (most probably) refers to their result facets. Likewise, the modifying adjective 'correct' targets the result facet in (2b).

(2) a. [...] all *classifications* are *conducted* and *evaluated* on the basis of individual instances.[4]
   b. [...] while still *performing correct classification*.[5]
   c. The model generates *automatic summaries* of topics [...][6]

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[1] Forsyth, 1996: *Icon*. (Google Books)

[2] Marshall, 2013: *Margaret Fuller - A New American Life*. (Google books)

[3] Larkin, 2012: *Al-Mutanabbi*. (Google Books)

[4] Feng & Hirst, 2012: *Text-level discourse parsing with rich linguistic features*.

[5] Goldstein & Uzuner, 2010. *Does negation really matter?*

[6] Ramage et al., 2009: *Labeled LDA: A supervised topic model for credit attribution in multi-labeled corpora*.

The example in (2c), on the other hand, would count again as a coercion since the noun 'summary' (in contrast to 'summarization') does not lexically provide reference to a process or event. For instance, 'summary' does not combine well with verbs like 'perform' nor does it go together with 'process' in noun compounds (*'summary process' vs. 'summarization process').

A more systematic approach to distinguishing coercion from polysemy would draw on empirical data from corpus studies and psycholinguistic experiments. As to the former type of approach, Jezek and Vieu (2014) argue that inherent polysemy can be distinguished from coercion by looking at the variability of the co-occuring predicates in copredication constructions, where high variability is taken as an indicator of polysemy. From a psycholinguistic point of view, the hypothesis is that complement coercion comes with higher processing costs (Traxler et al., 2002) than just selecting a lexically provided facet of a polysemous noun. (See Murphy (2021) for a more recent overview of the relevant experiments.) The primary goal of the present paper is not so much to provide a strong empirical basis for the distinction in question but to introduce a formal cognitive model that allows us to represent the postulated semantic differences in a sufficiently fine-grained way.

A good part of the more recent formal modeling approaches for inherent polysemy and coercion rely on some sort of advanced type-theoretical framework such as Type Composition Logic (Asher, 2011), Type Theory with Records (Cooper, 2011), Montagovian Generative Lexical Theory (Mery and Retoré, 2015), Unifying Theory of dependent Types (Chatzikyriakidis and Luo, 2015), and Dependent Type Semantics (Kinoshita et al., 2017, 2018). Most if not all of them were at least partly driven by the aim to overcome what was seen as formal limitations of Pustejovsky (1995)'s original proposal. Notably Asher (2011, p. 87) regards the typed feature structure formalism used by Pustejovsky and feature structure unification as inadequate for modeling copredication and coercion.

In this paper, we present a *frame-semantic* model of inherent polysemy and argument coercion. A central assumption of frame semantics is that *attributes* (*features*) play a crucial role for the structured representation of meaning (Barsalou, 1992; Löbner, 2014). Our approach builds on the framework of Kallmeyer and Osswald (2013), where

(i) frames are defined as *generalized typed feature structures*, (ii) semantic frames are linked with syntactic trees, and (iii) frame unification is guided by syntactic tree operations; cf. Section 2 for details.

Babonnaud et al. (2016) describe a first application of this framework to the analysis of polysemy and coercion. They pursue an "eliminative" strategy with respect to complex types and objects in that they avoid positing special "dot objects" that jointly represent the different meaning facets of an inherently polysemous noun. Their idea is that a frame-based representation of the facets and the semantic relations between them is sufficient for explaining the flexible behavior of polysemous nouns. For instance, they do not introduce a "dot type" *physical-object • information* (*phys-obj • info*, for short) for characterizing the class of polysemous nouns comprising 'book', 'letter', etc. Instead, these nouns are lexically classified as denoting entities of type *info(rmation)-carrier*, which is introduced as a subtype of *phys-obj* together with the constraint that its instances have an attribute CONT(ENT) whose value is of type *info*. More succinctly, in the formal frame description language used in the present paper: *info-carrier* $\Rightarrow$ *phys-obj* $\land$ CONT : *info*.

Babonnaud et al.'s eliminative strategy has the following two issues: (i) It is usually necessary to decide on a "primary" facet of which the other facet is value of an attribute. (ii) In order to access the "non-primary" facet of a polysemous noun, the predicate has to anticipate the underlying attribute structure. To give an illustration, consider the two predications 'memorized the letter' and 'burned the letter'. If 'letter' has the type *info-carrier* then the NP 'the letter' is compatible with the selectional restrictions of the PATIENT argument of the verb 'burned', which requires an argument of type *phys-obj*. Figure 1 sketches how argument substitution would lead to the integration of the NP argument frame into the verb frame in this case. (The specific choice of the syntactic category labels will be explained in Section 2.)

Combining 'the letter' with 'memorized' by NP substitution, on the other hand, calls for more flexible selectional restrictions on the direct object of the verb: the object NP can have the type *info* or the type *info-carrier*. This is shown in Figure 2 where 'memorized' comes with a disjunctive specification: either the direct object is of type *info* and can directly provide the THEME or the THEME is the value of the direct object's CONT attribute. How-
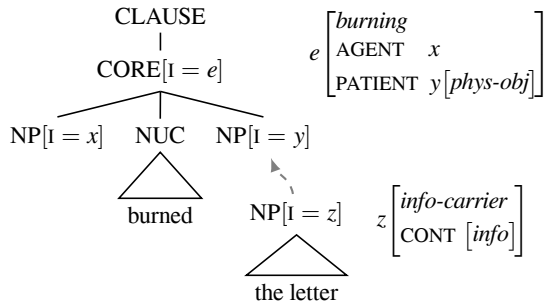
CLAUSE
|
CORE$[I = e]$

$e \begin{bmatrix} burning \\ \text{AGENT} \quad x \\ \text{PATIENT} \quad y[phys\text{-}obj] \end{bmatrix}$

NP$[I = x]$ NUC   NP$[I = y]$

burned

NP$[I = z]$ $z \begin{bmatrix} info\text{-}carrier \\ \text{CONT} \ [info] \end{bmatrix}$

the letter

Figure 1: Syntactic and semantic composition for 'burned the letter' (preliminary version)

CLAUSE
|
CORE$[I = e]$

$y \boxed{1}[info] \ \lor$

$y \begin{bmatrix} info\text{-}carrier \\ \text{CONT} \ \boxed{1}[info] \end{bmatrix}$

NP$[I = x]$ NUC   NP$[I = y]$

memorized

$e \begin{bmatrix} memorizing \\ \text{AGENT} \quad x \\ \text{THEME} \quad \boxed{1} \end{bmatrix}$
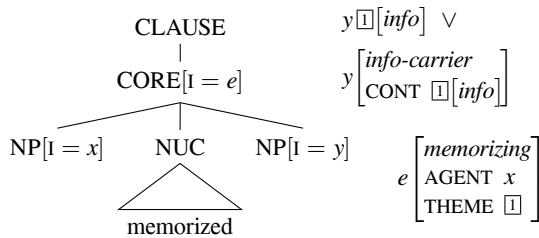
Figure 2: Lexicalized construction for 'memorized' along the lines of Babonnaud et al. (2016)

ever, since having different meaning facets is a lexical property of the polysemous noun, access to them should be provided by the noun entry as well.

A related issue is that Babonnaud et al. (2016) employ the same kind of disjunctive encoding for modeling coercion. However, there should be a distinction between coercion mechanisms (linked to the predicate) and accessing different meaning facets (provided by the noun). An example where the difference matters is the selection of the object of 'perform'. Assuming that in 'perform an annotation', the frame of 'perform' picks the creation event of the 'annotation' frame, and assuming that such an event is also present in the frame of 'summary', it is not clear why the latter cannot be targeted by 'perform'. The crucial difference is that in "perform an annotation" a meaning facet is targeted ('annotation' is a *process • result* dot type noun), while "perform a summary" requires a coercion. The unavailability of 'perform a summary' might therefore be due to the absence of an event facet for 'summary' and, furthermore, the unavailability of an adequate coercion pattern for 'perform'.

The goal of the present paper is to show how a non-eliminative strategy for modeling polysemous nouns by means of frames can overcome the described issues. To this end, dot types are added as proper members of the type hierarchy. They are not related to their component types by inher-
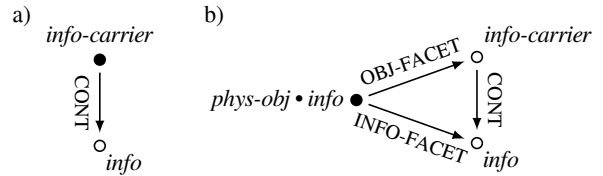
a) *info-carrier*   b)   *info-carrier*

$phys\text{-}obj • info$ ●

Figure 3: Eliminative (a) and non-eliminative (b) frame representations for inherently polysemous nouns like 'letter' and 'book'

itance but rather by functional relations, i.e., by attributes. For example, instances of type *phys-obj • info* have two attributes OBJ(ECT)-FACET and INFO(RMATION)-FACET whose values are of type *info-carrier* and *info*, respectively. The two facets are related by the CONT attribute as before:

(3) $phys\text{-}obj • info \Rightarrow$ OBJ-FACET : *info-carrier* $\land$
     INFO-FACET : *info* $\land$
     OBJ-FACET $\cdot$ CONT $\doteq$ INFO-FACET

Figure 3 depicts the two frame representations for the eliminative and the non-eliminative strategy side by side. Argument coercion, on the other hand, does not involve facet selection but is analyzed via additional patterns that can be used to augment the semantics of a predicate.

2   Background: Syntax-driven frame composition

The formalization of frame semantics used in the present paper is a slightly modified version of the one proposed by Kallmeyer and Osswald (2013). Frames are understood as *generalized feature structures*. Instead of requiring a distinguished root node from which every other node is accessible via a finite attribute sequence, the generalized version allows for multiple labeled nodes under the condition that each node is accessible from at least one of the labeled nodes. Correspondingly, frame unification does not require the identification of designated root nodes but relies on the identification of nodes with the same label. Frames can be defined as *minimal models* of conjunctive attribute-value formulas. The underlying logic is described in Appendix A.

Kallmeyer and Osswald (2013) combine frame semantics with Tree Adjoining Grammars (TAG). The basic components of this approach are *elementary constructions*, which are pairs of elementary syntactic trees and semantic frames where (some of) the constituent nodes of the tree are linked to nodes of the frame. The link is encoded by an I(NDEX)

Constraints for dot types and their meaning facets:

$phys\text{-}obj \bullet info \Rightarrow \text{OBJ-FACET} : info\text{-}carrier \land \text{INFO-FACET} : info \land \text{OBJ-FACET} \cdot \text{CONT} \doteq \text{INFO-FACET}$

$process \bullet result \Rightarrow \text{EVENT-FACET} : process \land \text{EVENT-FACET} \cdot \text{RESULT} \cdot \text{CREATION} \doteq \text{EVENT-FACET}$

$process \bullet result \land \text{EVENT-FACET} \cdot \text{RESULT} \cdot \text{OBJ-FACET} \Rightarrow \text{EVENT-FACET} \cdot \text{RESULT} \cdot \text{OBJ-FACET} \doteq \text{OBJ-FACET}$

$process \bullet result \land \text{EVENT-FACET} \cdot \text{RESULT} \cdot \text{INFO-FACET} \Rightarrow \text{EVENT-FACET} \cdot \text{RESULT} \cdot \text{INFO-FACET} \doteq \text{INFO-FACET}$

Constraints for single types and their meaning facets:

$phys\text{-}obj \Rightarrow \text{OBJ-FACET} \doteq \text{SELF} \qquad event \Rightarrow \text{EVENT-FACET} \doteq \text{SELF} \qquad info \Rightarrow \text{INFO-FACET} \doteq \text{SELF}$

Subtype constraints:

$info\text{-}carrier \Rrightarrow phys\text{-}obj \qquad\qquad sheet \Rrightarrow phys\text{-}obj \qquad\qquad\qquad poem \Rrightarrow info$

$book \Rrightarrow phys\text{-}obj \bullet info \qquad\quad letter \Rrightarrow phys\text{-}obj \bullet info \qquad\quad summary \Rrightarrow phys\text{-}obj \bullet info$

$annotation \Rrightarrow process \bullet result \quad classification \Rrightarrow process \bullet result \quad process \Rrightarrow event$

Specification of attributes depending on types:

$annotation \Rrightarrow \text{EVENT-FACET} \cdot \text{RESULT} : phys\text{-}obj \bullet info \qquad classification \Rrightarrow \text{EVENT-FACET} \cdot \text{RESULT} : phys\text{-}obj \bullet info$

Type incompatibilites:

$phys\text{-}obj \land info \Rightarrow \bot \qquad phys\text{-}obj \land event \Rightarrow \bot \qquad event \land info \Rightarrow \bot$

Type-attribute incompatibilites:

$phys\text{-}obj \land \text{INFO-FACET} : \top \Rightarrow \bot \qquad event \land \text{INFO-FACET} : \top \Rightarrow \bot \qquad info \land \text{EVENT-FACET} : \top \Rightarrow \bot$

$phys\text{-}obj \land \text{EVENT-FACET} : \top \Rightarrow \bot \qquad event \land \text{OBJ-FACET} : \top \Rightarrow \bot \qquad info \land \text{OBJ-FACET} : \top \Rightarrow \bot$

Figure 4: Selected universal AV constraints

feature at the constituent nodes. Tree composition then gives rise to the identification of index values and, thereby, to specific constraints on how the associated semantic frames are unified. For example, the composition of the two constructions in Figure 1 leads to the identification of y and z, i.e. $y \doteq z$.

The syntactic side of the approach is not restricted to TAG but generalizes to other tree rewriting formalisms. In this paper, we use the formalism of Tree Wrapping Grammars (TWG) together with grammatical concepts of Role and Reference Grammar (RRG; Van Valin 2005), for which TWG has been developed (Kallmeyer et al., 2013).

RRG provides an elaborate theory of clause linkage, which comes in handy for the analysis of co-predication constructions, among others. Instead of an X-bar scheme, RRG assumes a layered structure consisting of *nucleus*, *core* and *clause*. The nucleus contains the main predicate, the core contains the nucleus and the (non-extracted) syntactic arguments, and the clause includes the core and extracted arguments. Each layer can have a *periphery* of adjuncts. Grammatical *operators*, that is, closed-class elements encoding tense, modality, aspect, etc., attach to different layers depending on their scope.

Concerning complex constructions, RRG draws not only a distinction between coordination and subordination but assumes in addition *cosubordination* constructions, which are dependent but non-embedded structures of the general form

$[[\quad]_X [\quad]_X]_X$. In such constructions, operators that apply to category X are usually realized only once but have scope over both X-daughters.

The tree composition operations of TWG are *(simple) substitution* (replacing a non-terminal leaf by a tree, as in Figure 1), *sister adjunction* (adding a tree as a subtree of a non-leaf, see the adjunction of 'and' in Figure 9) and *wrapping substitution* (splitting the new tree at a dominance-edge, filling a substitution node with the lower part and adding the upper part to the root of the target tree, cf. Figure 9).

3 Predications over meaning facets

In this section, we develop an analysis of predications that target existing meaning facets (either of dot type nouns or of single type nouns).

Universal constraints. As already mentioned, we introduce attributes for meaning facets and specific types for dot types. Meaning facets occur systematically for certain types, and they are therefore introduced by universal attribute-value constraints of the form $\varphi \Rightarrow \psi$. (Cf. the appendix for the formal background). Some of the relevant constraints for dot types *phys-obj • info* and *process • result* are given in Figure 4. They specify available meaning facets together with the specific relations that hold between the different facets: For *phys-obj • info*, the CONT value of the OBJ-FACET is the INFO-FACET, while for *process • result*, the CREATION value of the OBJ-FACET is the EVENT-FACET and the RESULT of the EVENT-FACET is the OBJ-FACET. For sin-
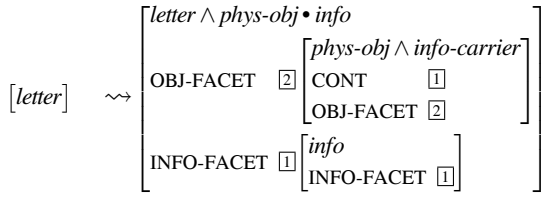
$$\left[letter\right] \rightsquigarrow \begin{bmatrix} letter \wedge phys\text{-}obj \bullet info \\ \text{OBJ-FACET} \quad \boxed{2} \begin{bmatrix} phys\text{-}obj \wedge info\text{-}carrier \\ \text{CONT} \qquad \boxed{1} \\ \text{OBJ-FACET} \ \boxed{2} \end{bmatrix} \\ \text{INFO-FACET} \ \boxed{1} \begin{bmatrix} info \\ \text{INFO-FACET} \ \boxed{1} \end{bmatrix} \end{bmatrix}$$

Figure 5: Application of universal constraints to the lexical entry of *letter*

CLAUSE
|
$\text{CORE}[\text{I} = e]$

$\text{NP}[\text{I} = x]$ NUC $\text{NP}[\text{I} = y]$

burned

$x\begin{bmatrix} \text{OBJ-FACET} \ \boxed{1}[entity] \end{bmatrix}$

$y\begin{bmatrix} \text{OBJ-FACET} \ \boxed{2}[phys\text{-}obj] \end{bmatrix}$

$e\begin{bmatrix} burning \\ \text{AGENT} \quad \boxed{1} \\ \text{PATIENT} \quad \boxed{2} \end{bmatrix}$

$z\begin{bmatrix} letter \\ \text{OBJ-FACET} \begin{bmatrix} info\text{-}carrier \\ \text{CONT} \ \boxed{3} \end{bmatrix} \\ \text{INFO-FACET} \ \boxed{3}[info] \end{bmatrix}$

$\text{NP}[\text{I} = z]$
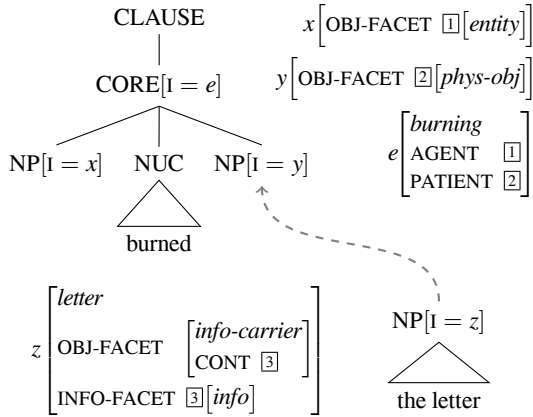
the letter

Figure 6: Revised syntactic and semantic composition for 'burned the letter' (cf. Figure 1)

Figure 7: Resulting frame for 'burned the letter'

$\text{CORE}_N^*[\text{I} = x]$
|
AP_{PERI}

correct/
automatic

frame of 'correct':
$x\begin{bmatrix} \text{INFO-FACET} \begin{bmatrix} \text{QUALITY} \ [correct] \end{bmatrix} \end{bmatrix}$

frame of 'automatic':
$x\begin{bmatrix} \text{EVENT-FACET} \begin{bmatrix} \text{MANNER} \ [auto] \end{bmatrix} \end{bmatrix}$
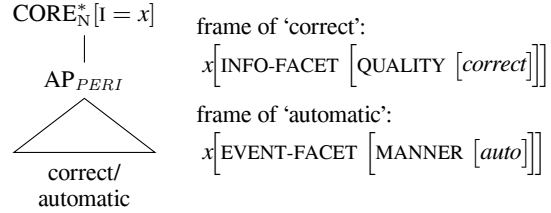
Figure 8: Tree frame pairs for 'correct' and 'automatic'

gle types, the frame node is its own corresponding meaning facet (with SELF denoting the identity function properly restricted). The third group of constraints specifies subtype relations, for instance every entity of type *book* is also of type *phys-obj • info*, and the last two groups detail incompatibilities between types (e.g., nothing can be of types *event* and *phys-obj* at the same time) and between types and attributes (e.g., nothing can be of type *phys-obj* while having an EVENT-FACET). Figure 5 shows the application of these constraints to the lexical frame of 'letter'.

Single verbal predications. (4) lists cases of verbs predicating over single meaning facets of their object nouns (the latter being single or dot type nouns).

(4)   a. Kim burned the sheet/letter.
     b. Kim memorized the poem/letter.
     c. Kim performed the dance/annotation.
     d. Kim evaluated the essay/annotation.

The elementary constructions for the verbs describe the event and its participants and determine which facet of the respective arguments fills which semantic role; see the entry for 'burned' in Figure 6. In combination with the I features on the nodes, the frame encodes that the OBJ-FACET of the di-

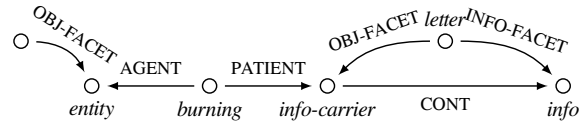rect object is the PATIENT of the *burning* event. The derivation in Figure 6 leads to the frame in Figure 7. The constructions for 'memorized', 'performed' and 'evaluated' look similar, except that the THEME expressed by the direct object is provided by different facets. Due to the frame constraints for meaning facets in single type nouns, the analysis works there as well (as in 'burned the sheet').

Adjectival predications. A second type of predication we consider in this paper are adjectival predications as in (5) where two adjectives modify a noun while targeting different facets of it.

(5)   a. Where manual fine-grained annotation is unavailable, [...][7]
     b. the correct automatic annotation

The elementary constructions for 'correct' and 'automatic' in (5b) are given in Figure 8. The trees are added by sister adjunction to the CORE_N node of an NP tree. The CORE_N is the immediate daughter of NP, and both constituent nodes carry the same I feature. This way, the frame of the adjective unifies with the noun frame.

Multi-verb copredication. We now consider constructions of the form 'NP V_1 and V_2 NP', as in (6).

(6)   a. Kim memorized and burned the letter.
     b. Kim performed and evaluated the annotation.

The two verbs in (6a) and (6b) share their arguments while targeting different facets of the object NP and assigning different semantic roles. They

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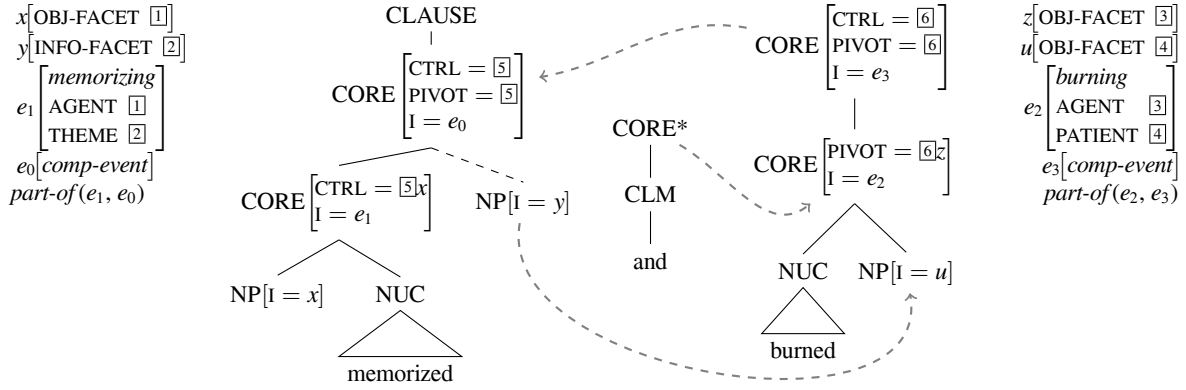[7] Abney and Bird, 2010. *The Human Language Project: Building a Universal Corpus of the World's Languages.*

x[OBJ-FACET ①]
y[INFO-FACET ②]
e_1[memorizing, AGENT ①, THEME ②]
e_0[comp-event]
part-of(e_1, e_0)

CLAUSE
CORE [CTRL = ⑤, PIVOT = ⑤, I = e_0]
CORE [CTRL = ⑤x, I = e_1]   NP[I = y]
NP[I = x]   NUC
memorized

CORE [CTRL = ⑥, PIVOT = ⑥, I = e_3]
CORE*
CLM
and
CORE [PIVOT = ⑥z, I = e_2]
NUC   NP[I = u]
burned

z[OBJ-FACET ③]
u[OBJ-FACET ④]
e_2[burning, AGENT ③, PATIENT ④]
e_3[comp-event]
part-of(e_2, e_3)

Figure 9: Derivation for 'memorized and burned'

constitute a complex event with a certain temporal structure, but they are still distinguishable within the complex event. We therefore analyze their syntactic structure as constituting a complex CORE consisting of two single COREs, i.e., a CORE co-subordination construction in RRG terms; see the tree in Figure 10. We capture the information about the shared subject by means of the features CONTROLLER (CTRL; for the CORE that provides the subject) and PIVOT (for the CORE that needs to retrieve an argument). The shared object NP, however, is present in the trees of both verbs, and the two NP nodes are merged via wrapping substitution (see Figure 9). The first CORE contains a dominance edge that leaves room between the upper CORE node and the shared object NP for inserting the second CORE while merging the object NP nodes.

We introduce a frame type *comp(lex)-event* for events that have several component events that all stand in a *part-of* relation to it. This relation between the complex event and its parts is specified in the corresponding unanchored elementary tree frame pairs, i.e., in the construction.

Figure 9 gives the tree-frame pairs for the two verbs. Each contributes an event that is part of a joint complex event. The first tree contributes the subject or, in more general RRG notions, the privileged syntactic argument (PSA). This is shared between all component events and, to this end, it is made available at the higher CORE node via a CTRL attribute. The second argument of the two trees is a shared NP node, where the sharing is realized via wrapping. Both the PSA and second NP argument can fill different semantic roles for the two events, and, furthermore, different facets of them can fill these roles. As a result of the adjunction, the frames
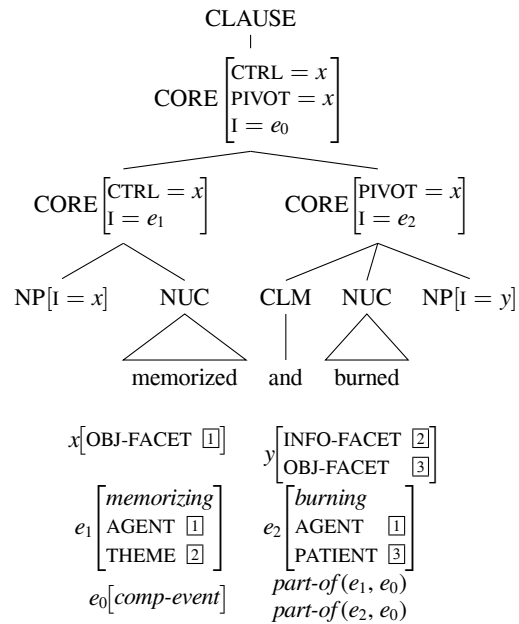
CLAUSE
CORE [CTRL = x, PIVOT = x, I = e_0]
CORE [CTRL = x, I = e_1]   CORE [PIVOT = x, I = e_2]
NP[I = x]   NUC   CLM   NUC   NP[I = y]
memorized   and   burned

x[OBJ-FACET ①]
y[INFO-FACET ②, OBJ-FACET ③]
e_1[memorizing, AGENT ①, THEME ②]
e_2[burning, AGENT ①, PATIENT ③]
e_0[comp-event]
part-of(e_1, e_0)
part-of(e_2, e_0)
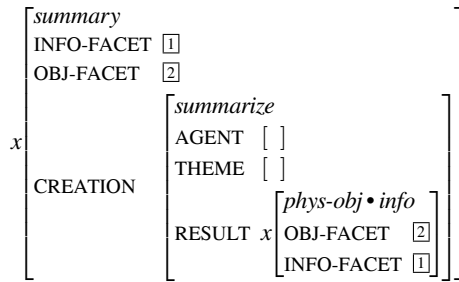
Figure 10: Result of the derivation in Figure 9

e_0 and e_3 unify, which yields a frame (Figure 10) that expresses that we have a complex event consisting of two part events, *memorizing* and *burning*, and that the subject filler provides the respective agents via its object facet, while the object NP filler provide the THEME of *memorizing* via its INFO-FACET and the PATIENT of *burning* via its OBJ-FACET.

For (6b), the analysis is similar, except for targeting different facets of the object NP.

4 Coercion

We now extend our analysis to cases of coercion as in (1c) ('burn the poem') and (2c) ('automatic summary'). The examples in (7) show that for the same predicate, depending on the context, different additional frame fragments are coerced, even for the same object nouns.

Frame for 'summary':

$$x \begin{bmatrix} summary \\ \text{INFO-FACET} \; \boxed{1} \\ \text{OBJ-FACET} \; \boxed{2} \\ \\ \text{CREATION} \begin{bmatrix} summarize \\ \text{AGENT} \; [\;] \\ \text{THEME} \; [\;] \\ \text{RESULT} \; x \begin{bmatrix} phys\text{-}obj \bullet info \\ \text{OBJ-FACET} \quad \boxed{2} \\ \text{INFO-FACET} \quad \boxed{1} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

Revised frame for 'automatic' (tree as in Figure 8):

$$y \Big[\text{EVENT-FACET} \; \big[\text{MANNER} \; [auto] \big] \Big] \; \vee$$
$$y \Big[\text{CREATION} \; \big[\text{MANNER} \; [auto] \big] \Big]$$
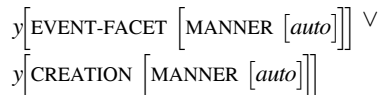
Figure 11: Frames for 'automatic summary'

(7) a. […] Mr. Darcy had much better *finish his letter*.[8]
    b. […] once we start to translate words in a zone, we have to *finish all its words* before moving outside again.[9]

Let us start by discussing 'automatic summary'. If the modified noun has an event facet, we can apply 'automatic' directly. Otherwise, we have to coerce an event. This could simply be done by adding an attribute EVENT-FACET on the fly via unification. But this would predict that we target always the same event, which is not the case. The event facet (if existent) is unique, but not the coerced events. For example, let us assume that Kim has to grade a number of manually and automatically produced summaries. In this situation, 'finished' in sentence (8) may refer to the process of grading the summary while 'automatic' refers to creating it.

(8) Kim just *finished* a bad *automatic summary*.

In 'automatic summary', the noun does not have an event facet, while the adjective adds a manner specification to a process, in this case to the creation of the summary, which is part of the frame of 'summary' (see Figure 11).[10] This type of coercion, namely targeting the creation event, is common among manner adjectives, so we assume that there is a coercion pattern for this, that can be applied to manner modifications in general. Coercion

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CLAUSE
|
CORE[I = e]

NP[I = x]   NUC[I = e]   NP[I = y]

finished

$$e \begin{bmatrix} finishing \\ \text{AGENT} \; x \\ \text{THEME} \; \boxed{2}[event] \end{bmatrix} \wedge$$

$$\left(y \begin{bmatrix} \text{EVENT-FACET} \; \boxed{2} \begin{bmatrix} activity \\ \text{AGENT} \; x \end{bmatrix} \end{bmatrix} \vee \boxed{2} \begin{bmatrix} activity \\ \text{AGENT} \; x \\ \text{UG} \quad y \end{bmatrix} \right)$$
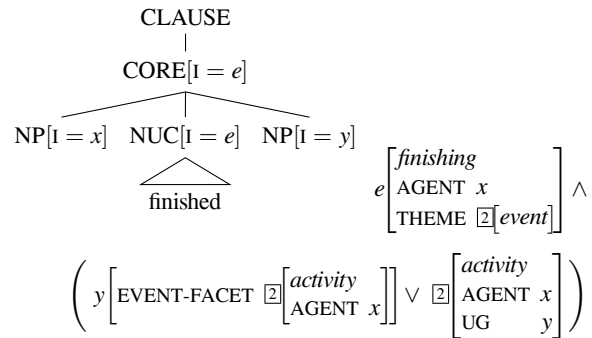
Figure 12: Tree-frame pair for 'finished'

patterns are defined as separate classes in the metagrammar (a factorized description of elementary tree frame pairs) and then combined in a disjunction with the basic pattern. Since coercion patterns are metagrammar classes, they can be (re)used in different constructions. Figure 11 shows the resulting disjunction of frames for 'automatic'. The first frame is used when combining with a noun that has an event facet, while the second is used when combining with a noun that has a CREATION attribute. (Note that, technically, this disjunction is part of the metagrammar and will therefore already be compiled out when computing the elementary constructions.) The composition of 'automatic summary' ($x \doteq y$ in Figure 11) necessarily chooses the coercion option, since a *summary* cannot have an event facet. Coercion can easily be combined with predications over existing meaning facets, as in 'evaluate the automatic summary' since the meaning facets of the noun are not changed by the coercion patterns.

As we have seen, 'automatic' in 'automatic summary' follows an existing path in the noun frame in order to retrieve its argument. This is different for 'finish' in (7). When triggering a coercion, 'finish' creates a new *event* frame (the coerced event) which embeds the denotation of the noun as a participant, more concretely as an undergoer. This is expressed in the frame in Figure 12 where the disjunction contains the basic pattern (the THEME $\boxed{2}$ is the existing EVENT-FACET) and a coercion pattern ($\boxed{2}$ is a newly created event). An aspect that is missing here is that the coerced event tends to be of a type that corresponds to the telic qualia of the noun (e.g., *writing* in (7a); cf. Pustejovsky 1995). One could model this within frames by including frame types as proper frame objects. We leave this for future research.

With this analysis, we can apply more than one coercion leading to different coerced frame elements of the same type, as in (8). And we can

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also apply coercion to dot type nouns, creating new frame nodes in addition to the available facets, even when one of the facets matches the type requirements. For example, if we replace 'summary' in (8) by 'annotation' then 'automatic' refers to the event facet of 'annotation'. In this case, the basic pattern as well as the coercion pattern are possible.

5 Conclusion

In this paper, we proposed a frame-based analysis of dot objects, predications over their meaning facets, and, in contrast to this, coercion. A crucial aspect of our analysis is that the meaning facets are modeled as attributes in the lexical frames of dot type nouns, while coercion involves the application of coercion patterns that are defined in the metagrammar. Their application is constrained by lexical properties, but the meaning components added by coercion are not part of the lexical entries and are in particular not meaning facets. This accounts for the high flexibility of coercion, i.e., the possible variability of the coerced meaning components.

Acknowledgments

Appendix: Attribute-value logic of frames

The appendix describes the attribute-value (AV) logic that underlies the frame approach of this article; see also Kallmeyer and Osswald (2013), who in turn build on Hegner (1994). The logic makes use of two kinds of expressions: *AV formulas* and *AV descriptions*.

AV descriptions are evaluated at frame nodes, formulas on whole frames. AV expressions are defined over a vocabulary $\langle \mathsf{Attr}, \mathsf{Typ}, \mathsf{Rel}, \mathsf{Nnam}, \mathsf{Nvar} \rangle$ consisting of a finite set Attr of *attribute symbols*, a finite set Typ of *type symbols*, a finite set $\mathsf{Rel} = \cup_n \mathsf{Rel}_n$ of *relation symbols* (where Rel_n are *n*-ary relation symbols), a finite set Nnam of *node names* (or *nominals*), and a countably infinite set Nvar of *node variables*. The members of $\mathsf{Nlab} = \mathsf{Nnam} \cup \mathsf{Nvar}$ are referred
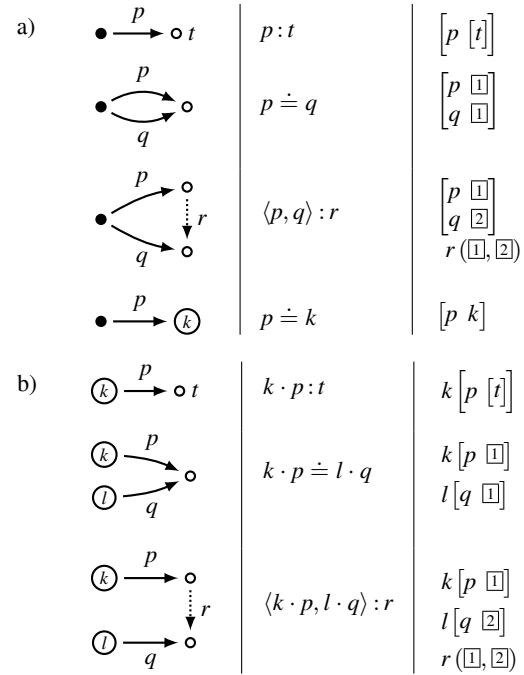

Figure 13: The middle column shows primitive AV descriptions (a) and formulas (b), their notation as AV matrices (right columns), and the structures they denote (left columns)

to as *node labels*. The *primitive AV descriptions* consist of the following expressions:

$$(9) \quad t \mid p:t \mid p \doteq q \mid \langle p_1, \ldots, p_n \rangle : r \mid p \doteq k$$

with $t \in \mathsf{Typ}$, $r \in \mathsf{Rel}$, $p, q, p_i \in \mathsf{Attr}^*$, and $k \in \mathsf{Nlab}$. The intended meaning of these expressions is depicted in Figure 13a, which also shows the equivalent matrix style notations. The filled circles indicate the nodes at which the expressions are evaluated. Node labels are depicted inside nodes, type symbols are depicted at the outside of nodes.

The set of *primitive AV formulas* is defined as follows:

$$(10) \quad k \cdot p : t \mid k \cdot p \doteq l \cdot q \mid \langle k_1 \cdot p_1, \ldots, k_n \cdot p_n \rangle : r$$

with $t \in \mathsf{Typ}$, $r \in \mathsf{Rel}$, $p, q, p_i \in \mathsf{Attr}^*$, and $k, l, k_i \in \mathsf{Nlab}$. AV formulas state that there are certain labeled nodes that have certain properties. The intended meaning of AV formulas is sketched in Figure 13b.

Formally, the satisfaction of AV expressions is defined relative to a *structure* $\langle V, \mathcal{I}, g \rangle$ over the given vocabulary consisting of a set V, the *universe* of "nodes", an *interpretation function* $\mathcal{I}$ defined on $\mathsf{Attr} \cup \mathsf{Typ} \cup \mathsf{Rel} \cup \mathsf{Nnam}$, and a partial *variable assignment* function g from Nvar to V. The func-

tion $\mathcal{I}$ takes members of Attr to partial functions on V, members of Typ to subsets of V, members of Rel_n to n-ary relations on V, and members of Nnam to members of V. Let $\mathcal{I}_g$ be the partial function from Nlab to V that takes k to $\mathcal{I}(k)$ if $k \in$ Nnam and to $g(k)$ if $k \in \text{dom}(g)$. The members of the image of $\mathcal{I}_g$ are called *labeled nodes*. The interpretation of attributes extends naturally to an interpretation of attribute paths such that $\mathcal{I}(p \cdot f) = \mathcal{I}(f) \circ \mathcal{I}(p)$ for $f \in$ Attr and $p \in \text{Attr}^+$. Due to lack of space, we spell out the fairly canonical definitions of satisfaction only for a few cases. For example, primitive descriptions of the form $p : t$ are satisfied at a node v of a structure $\langle V, \mathcal{I}, g \rangle$, in symbols, $\langle V, \mathcal{I}, g \rangle, v \vDash p : t$, iff $v \in \text{dom}(\mathcal{I}(p))$ and $\mathcal{I}(p)(v) \in \mathcal{I}(t)$. By comparison, primitive formulas of the form $k \cdot p \doteq l \cdot q$ are satisfied by a structure $\langle V, \mathcal{I}, g \rangle$ iff $\{k, l\} \subseteq \text{dom}(\mathcal{I}_g)$, $\mathcal{I}_g(k) \in \text{dom}(\mathcal{I}(p))$, $\mathcal{I}_g(l) \in \text{dom}(\mathcal{I}(q))$, and $\mathcal{I}(p)(\mathcal{I}_g(k)) = \mathcal{I}(q)(\mathcal{I}_g(l))$. The AV descriptions and formulas include $\top$ and $\bot$ and are closed under all Boolean operators. The satisfaction relation $\vDash$ can be extended correspondingly in the usual way.

A *frame* is a structure $\langle V, \mathcal{I}, g \rangle$ in which every node is accessible from a labeled node by finitely many applications of attribute functions; that is, for every node v there is a node label k and a finite attribute sequence p such that $v = \mathcal{I}(p)(\mathcal{I}_g(k))$.

Given two frames $F = \langle V, \mathcal{I}, g \rangle$ and $F' = \langle V', \mathcal{I}', g' \rangle$ over $\langle \text{Attr}, \text{Typ}, \text{Rel}, \text{Nnam}, \text{Nvar} \rangle$, F *subsumes* F', or F' *is more informative than* F, in symbols, $F \sqsubseteq F'$, if there is a function h from V to V' that preserves the labeling and the typing in the frame F as well as its attribute structure and the relations between its nodes. For instance, preservation of the attribute structure of F by h means that $h(v) \in \text{dom}(\mathcal{I}'(f))$ and $\mathcal{I}'(f)(h(v)) = h(\mathcal{I}(f)(v))$ for $f \in$ Attr and $v \in \text{dom}(\mathcal{I}(f))$. It is easy to see that if such a function h exists, it is uniquely determined by these conditions. The *unification* $F \sqcup F'$ of two frames F and F' is their least upper bound with respect to subsumption, if existent.

A frame F is a *model* of an AV formula α iff F satisfies α. It is not difficult to see that every finite conjunction of primitive AV formulas has a unique frame model (up to isomorphism) that is *minimal* with respect subsumption. Vice versa, every frame is the minimal model of a finite conjunction of primitive AV formulas.

Frame representations of a certain domain are usually subject to a number of *(universal) AV con-straints* that express implicational relations between types and attributes: Types may be (i) subtypes of other types, (ii) imply the presence of certain attributes (and vice versa), etc. Universal constraints have the general form $\forall \varphi$, with φ a Boolean AV description. A frame (or structure) satisfies $\forall \varphi$ if each of its nodes satisfies φ. If φ is a Horn description, $\forall \varphi$ is called a *Horn constraint*. Instead of $\forall(\varphi \rightarrow \psi)$, we write $\varphi \Rightarrow \psi$. Given a frame F and a finite set of Horn constraints (which do not generate infinite structures),[11] there is a unique frame F' subsumed by F that satisfies all the constraints.

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[11]See Kallmeyer and Osswald (2013, p. 323) for more information about this restriction.

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