A FORMAL REPRESENTATION OF CONCEPT COMPOSITION

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***Abstract**: This paper centers on argument saturation in relational-noun compounds. We argue that these compounds can be analyzed in terms of conceptual types, as introduced by [Löbner 1985, to appear]. He distinguishes between sortal, individual, functional, and proper relational concepts. To describe argument saturation in compounding, we use frames in the sense of [Barsalou 1992] since frames give a decompositional account of concepts and in particular reflect the conceptual types in their structure. Subsequently, we investigate relational-noun compounds in German as derived from their conceptual types. That is, we analyze in how far the conceptual types of the compound constituents determine the concept type of the compound as a whole. For possessive constructions, [Löbner, to appear] argues that a construction with a functional head inherits the type of the modifier. We demonstrate that for constructions with a relational head the case is less straightforward: the construction inherits the relational dimension of the modifier and the non-uniqueness from the head noun. However, we show that the combinations for compounds can follow complex compositional rules.*

***Keywords**: word formation, frames, compounds, lexical semantics*

***ACM Classification Keywords**: A.0 General Literature - Conference proceedings Languages, Theory*

1 Compounding in German

In German, compounding is a very frequent and productive type of word formation. On the linguistic surface, it consists in juxtaposing two or more lexemes, called the compound constituents. German compounds are right-headed; i.e. the last constituent determines the grammatical category of the compound. Morphological classifications of compounds are approached from a paradigmatic as well as from a syntagmatic perspective: the paradigmatic perspective is concerned with the grammatical categories of the constituents, while the syntagmatic perspective deals with the number of constituents being combined. Hypothetically, in German nearly all grammatical categories occur in compounding and there is no limit in combining constituents (as to formation rules in compounding see [Neef 2009]). In practice, however, the most frequent German compounds are binary noun-noun combinations, as shown in the empirical work of [Ortner et al. 1991]. In the following, we refer to the first constituent as the modifier and to the second constituent as the head of the compound.

From the perspective of cognitive semantics, the meaning of compounds is based on an implicitly given relationship between the concepts that are activated by the constituents. Noun-noun compounds seem to be the

most flexible type in that they present a broader range of relationships than other types of compounds [cf. Ortner et al.]. With respect to the interpretation of compounds, [Olsen 1986] distinguishes between occasional and opaque compounds: the meaning of occasional compounds can be deduced from the compound constituents whereas the meaning of opaque compounds is non-transparent. Note that opaqueness and occasionality are not disjunctive categories but rather opponent features of a continuum. Apart from absolute opaque compounds, whose meanings must be stored in the lexicon, the interpretation of occasional compounds is a special type of concept combination in that the compound's meaning results from creating a relationship between the concepts of its constituents; e.g. *Holztisch*, lit: 'wood table', can be interpreted as "table made of wood", where the relative clause paraphrases the relationship between the concepts *Holz* 'wood' and *Tisch* 'table'. Although compounds are potentially ambiguous in most cases [cf. Heringer 1984], [Kanngießer 1987] argues that the realm of possible relationships is restrained by the concepts of the compound constituents. Accordingly, the interpretation of compounds has to be considered as a matter of patterns rather than rules. This view is confirmed by the empirical work of [Maguire et al. 2010] for English who state that the semantic properties of the modifier and the head noun statistically correlate to the interpretation patterns they are preferably used in.

The semantics of compounding can be investigated on a descriptive and a computational level. The descriptive level focuses on documenting the relationships underlying the meanings of compounds while on the computational level, the mechanisms of deducing these relationships from the compound constituents are analyzed and explained. For German, the descriptive aspects of nominal compounding are well documented by [Ortner et al. 1991] who described more than 30 relationships in noun-noun compounds. [Fleischer & Barz 1995] point to similar relationships, but provide additional subtypes of each category. Furthermore, there have also been attempts to develop more abstract categorizations, e.g. the categorization in determinative, copulative, and possessive compounds that can be found in most traditional word-formation grammars. As it is, most of these categorizations are inconsistent [cf. Scalise & Bisetto 2009].

The computational level has been and still is widely debated in linguistics. Early approaches arise in Generative Grammar, but they have mainly been rejected in contemporary linguistic work because of their problematic basic assumptions [cf. ten Hacken 2009]. With respect to recent approaches, [Wisniewski 1997] differentiates between two explanatory accounts, the *thematic-relation view* and the *schema approach*. Both accounts assume that interpreting a (new) compound consists in creating a relationship between the concepts of the compound constituents, but they differ in explaining the way these relationships are created. According to the thematic-relation view, the interpretation is guided by a set of abstract thematic relations that have been deduced from already existing compounds; e.g. the thematic relation underlying the compound *Holztisch* in the above-mentioned interpretation would be "Y is made of X". These thematic relations offer open variables that the concepts of the constituents can instantiate, depending on whether they fulfill selectional restrictions required by the particular thematic relations. Thus, interpreting a compound consists in selecting the appropriate thematic relation. Although the number of assumed thematic relations varies between the different proponents (see [Coolen et al. 1991], [Gleitman & Gleitman 1970], [Levi 1978], [Gagne 2001]), it seems widely accepted that the

mentioned set is restricted. In contrast, the schema approach does not assume a fixed set of thematic relations. Instead, the interpretation of compounds is explained as a matching process of schemata understood as mental representations that are activated by the compound constituents. The proponents of the schema approach either draw on existing theories of mental representation or embed their explanation in an own theory. [Cohen & Murphy 1984] as well as [Wisniewski 1997], for instance, use schemata in the sense of [Minsky 1979], while [Lieber 2009] postulates so-called skeletons as concept-representation format to capture the semantics of compounding.

[Wisniewski, 1997] argues that the schema approach is cognitively more plausible than the thematic-relation view: in several experiments he demonstrates that subjects are able to create new interpretations of compounds spontaneously and that some of these interpretations cannot be captured by current thematic-relation sets postulated by proponents of the thematic-relation view. However, the schema approach lacks explanatory value since the different approaches are either too restricted in their range of application or they use vague notations: [Lieber 2009] is merely able to explain synthetic or copulative compounds. On the other hand, [Cohen & Murphy 1984] and [Wisniewski 1997] only propose possibilities of capturing compounds, but they do not offer a way to implement them within a consistent framework.

In this paper we will explain compounding as operations on frames as they have been introduced by [Barsalou 1992] and modeled as directed graphs by [Petersen 2007]. In contrast to the above-mentioned approaches of [Cohen & Murphy 1984] and [Wisniewski 1997], the frame model relies on a consistent formal basis and is flexible enough to capture a broader range of interpretation patterns than [Lieber, 2009] does. We will demonstrate its explanatory power by applying it to a class of compounds we refer to as relational-noun compounds (e.g. *Parteivorsitzender* lit: 'party chairman', *Whiskeyliebhaber* lit: 'Whiskey fancier"). They correspond to what [Fanselow 1981] calls "relationale Rektionskomposita": Fanselow coins the term in contrast to "Rektionskomposita" (english: synthetic compounds), where the modifier saturates an argument of the deverbal head. In opposition to synthetic compounds, nominal relational compounds are not formed with deverbal nouns but with non-derived relational nouns as heads. Thus, relational-noun compounds are understood as noun-noun compounds, where the head noun is a relational noun whose argument is saturated by the modifier noun.

2 Conceptual noun types

Relational nouns have long been distinguished from sortal nouns. The distinction is generally taken as a distinction between one-place predicates and two- (or more-) place predicates (cf. [Asudeh 2005], [Behaghel 1923], [Partee 1983/1997]). [Vikner & Jensen 2002] argue that relational nouns also exhibit a certain kind of semantic relation inherently determined in their primary interpretation. In contrast, sortal nouns do not exhibit an inherent relation. Their interpretations in possessive constructions depend on the linguistic specification, or on the context of utterance. [Löbner 1985, to appear] amends the distinction between sortal nouns [–R] and relational nouns [+R] (and their concepts, respectively) by introducing a uniqueness property [±U]. As a consequence, four basic noun concepts are distinguished: functional nouns ('FN'; *roof, chancellor, end, wife, trunk*) share the

properties [+R] and [+U]. Functional nouns are construed in a way that there is only one possible referent once the possessor argument is saturated. For example, a house has only one roof and a roof is always the roof of a house. Proper relational nouns ('RN', which Löbner refers to as 'relational nouns') such as *chapter, piece, advisor, user,* or *member* are [+R] but in contrast to functional nouns [–U]; hence, the number of their potential referents is not restricted (an association may have many members, a book generally has several chapters). Individual nouns ('IN'; *Kreml, pope, bible*) are [–R], [+U] and construed as referring uniquely to one entity (without further contextual disambiguation, we may refer to the bible, to the Kreml). Sortal nouns ('SN'; *tree, cake*) are [–R], [–U]. Support for the conceptual noun type distinction is provided by typological (cf. [Gerland & Horn 2010], [Löbner, to appear]) and empirical investigations [cf. Horn & Kimm, to appear].

[Löbner, to appear] claims that the lexical referential properties of nouns influence the way they are used grammatically. In accordance with their referential properties, functional and relational nouns are predisposed for possessive use. Due to their inherent uniqueness, individual and functional nouns have a predisposition for definite use. Consider the examples in (1) for relational and in (2) for functional nouns:

1. a. *A member of the Academy of Science has died.*

   b. *He only read one chapter of the book.*

2. a. *The end of the movie was very sad.*

   b. *The chancellor of Germany is Angela Merkel.*

In use, however, all nouns can be shifted to a different type. Sortal nouns for example are also frequently used in definite NPs when referring to unique entities (*the book, the tree*). In other cases, the possessor argument of a relational or functional noun may be omitted when the possessor can be retrieved from the context of the utterance. For the purposes of this paper, however, only the semantic properties of the conceptual noun types are focused; shifts are consequently not considered here. The question addressed here is how the conceptual types combine in compounds (as we will see in section 4) and how this composition can be formally modelled.

3 The representation of nominal concepts as frames

As a representation of conceptual knowledge, frames as introduced in [Petersen 2007] are based on [Barsalou 1992] and [Carpenter 1992]. Frames give a decompositional account of concepts. In this, they are in the tradition of Carpenter's feature structures. Those are labeled directed graphs which have a root. As argued by Petersen, not all concepts are adequately analyzed by a rooted graph. Thus, frames are more general than classical feature structures. Formally, a frame is represented by a connected directed graph with one central node (marked by a double border). The nodes of the frame are labeled with types which are given by a type signature, and the arcs of the frame are labeled with attributes. On the latter, we have the constraint that attributes are functional; i.e. there cannot be two arcs labeled with the same attribute going out from one node. Note that this does not exclude incoming arcs at the central node; hence, frames are more general than feature structures. Concept frames

feature a marker for open arguments. On the frame graph, we indicate an open argument by a rectangular node. Apart from that, referential uniqueness is marked by a definiteness marker, pictured by an incoming arrow without a source node. The type signature includes a hierarchy of types; that is, it is based on a partially ordered set which is a join semilattice. In addition, the type hierarchy conveys information about the possible attributes for nodes; i.e. it gives types and values that can be in the range and the domain of an attribute.

Conceptual types are reflected in the concept's frame representation. Relationality is indicated by an argument node that is not the central node. Uniqueness is indicated by a path from a definite node to the central node (that path can have length zero). Definite nodes are those that have a marker for unique reference. Therefore, they have a definiteness marker or they are non-central argument nodes. The arguments count as definite in this context since once they are filled, they are definite. Thus, frames representing sortal nouns have one argument node which is the central node [-R], and no path from a definite node to the central node [-U].

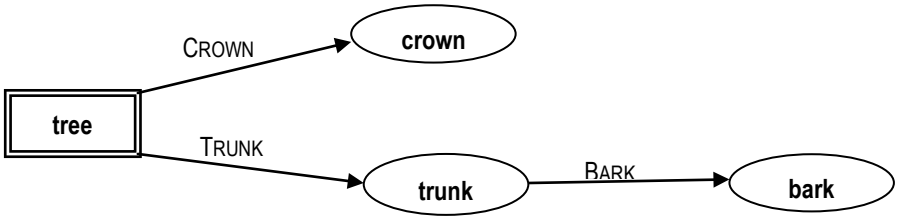

Figure 1. **Frame of the SC *tree***

For example, see Figure 1. Here, we have a frame for the sortal concept *tree*. The central node is the only argument node and in this particular case it is the root node of the graph; thus there is no incoming arc at the central node, in particular not from a definite node. In Figure 2, we have such a determining arc [+U]. *Kremlin* is not relational [-R]. Thus, the frame represents an individual concept.

Figure 2. **Frame for the IC *Kremlin***

Relational concepts are those that have an argument node that is not the central node. As an example for a proper relational concept, regard the frame for *brother* in Figure 3. A brother is analyzed as something that is

male and shares a mother with someone else. As a brother is always the brother of someone, this someone else is an argument for brother [+R]. Note that there is no directed path from the argument node to the central node [-U].

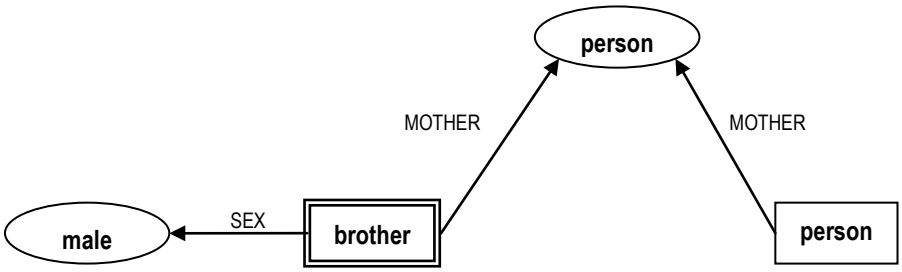

Figure 3. frame for the RC *brother*

Functional concepts have both, an argument apart from the central node [+R] and a path from a definite node to the central node [-U]. The example in Figure 4 shows the frame for the concept *mother*. A mother is something that is female and has something it is mother of. As soon as the argument is filled, the mother's identity is determined. Thus, the concept's referent depends functionally on the value of the argument node.

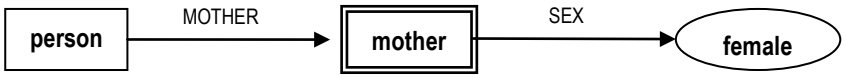

Figure 4. **Frame of the FC *mother***

4 Frame analysis of nominal relational compounds

[Petersen & Osswald 2009] demonstrate that argument saturation in general can be captured in terms of frames by inserting the possessor frame into the open argument of the frame whose argument is satisfied. In the following, we analyze the argument saturation in relational-noun compounds with RNs and FNs as heads. As we distinguish four conceptual types, in each case the argument of the relational or functional head can be saturated in four different ways. Thus we analyze eight combinatorial types of nominal relational compounds. Argument saturation of FN and RN in possessive constructions has already been investigated by [Löbner, to appear]. His findings are summarized in Table 1. In the following, we argue that argument saturation in compounding reflects a

similar but not identical pattern: most of the combinatorial types behave correspondingly to argument saturation in possessive construction, except for combinations of SN and FN.

Table 1: Type composition for head plus possessor combinations [cf. Löbner, to appear: 35]

possessor		**head**		**head with possessor**	
SN	*car*	RN	*door*	SN	*door of a car*
RN	*sister*	RN	*aunt*	RN	*sister of an aunt*
IN	*pope*	RN	*brother*	SN	*brother of the pope*
FN	*mother*	RN	*uncle*	RN	*uncle of a mother*
SN	*boy*	FN	*father*	SN	*father of a boy*
RN	*aunt*	FN	*mother*	RN	*mother of an aunt*
IN	*Croatia*	FN	*capital*	IN	*capital of Croatia*
FN	*mother*	FN	*father*	FN	*father of a mother*

Figure 5 shows the frame of the **SN-RN compound** *Kuchenstück* (lit: *Kuchen* 'cake' *Stück* 'piece'). Since a cake is a special kind of an object, the frames can be unified: the *cake* frame saturates the open argument in the *piece* frame so that the possessor node transforms into a round node. Since there is no further open argument the result of the unification is an SN.

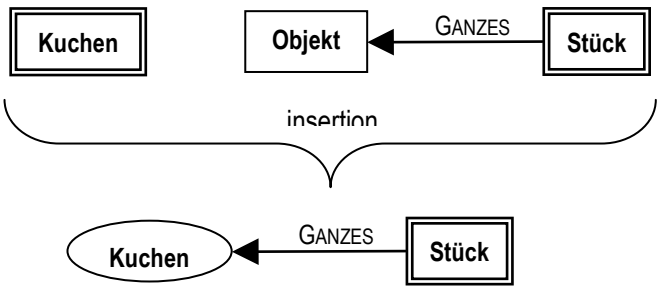

Figure 5. **Kuchen** '**cake**',**Objekt** '**object**', **Ganzes** '**whole**', **Stück** '**piece**'

Kapitel 'chapter'): the open argument in the *chapter* frame is saturated by the *bible* frame.

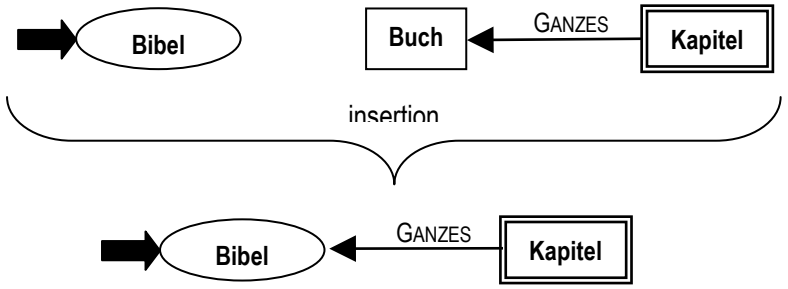

Figure 6. **Bibel** '**bible**', **Buch** '**book**', **Ganzes** '**whole**', **Kapitel** '**chapter**'

The determination of both compounds confirms the validity of our frame-based analysis: Both compounds can be used indefinitely:

3. Ein Kuchenstück ist schon angebissen. "A piece of cake is already been bitten off."

4. Wir mussten ein ganzes Bibelkapitel lesen. "We had to read a whole chapter of the holy bible."

RN-RN and **FN-RN compounds** seem to behave in a similar way: in both cases the result is a RN. Figure 7 shows the frame of the compound *Mitgliederberater* (*Mitglied* 'member' *Berater* 'adviser'), and Figure 8 the frame of the compound *Vorstandsmitglied* (*Vorstand* 'management' *Mitglied* 'member'). The relationality of these compounds results from the fact that the *institution* nodes in both cases are linked to the bridging frame by outgoing and therefore non-determining arcs. Furthermore, the relationality is reflected in the possibility to use the compounds possessively, but indefinitely:

5. ein Mitgliederberater des Tennisclubs "an adviser of members of the tennis club"

6. ein Vorstandsmitglied der Deutschen Bank "a board member of the German Bank"

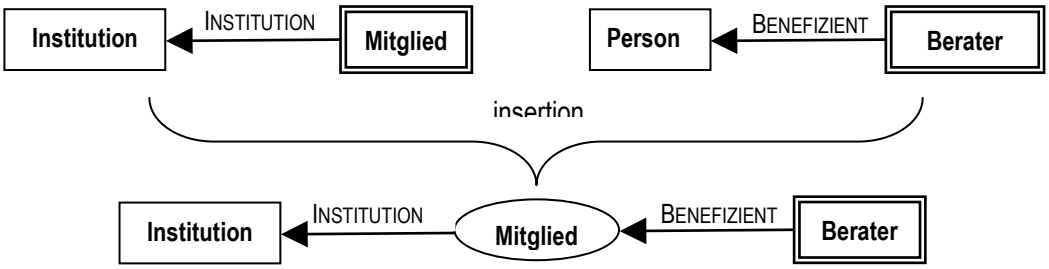

Figure 7. **Institution** '**institution**', **Mitglied** '**member**', **Benefizient** '**beneficient**', **Person** '**person**', **Berater** '**adviser**'

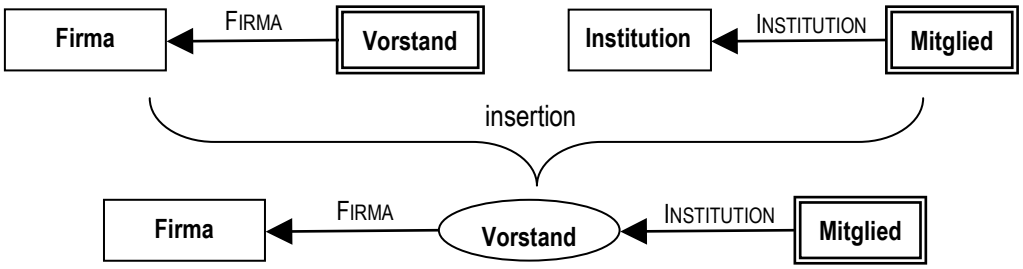

Figure 8. **Firma** '**company**', **Vorstand** '**management**', **Institution** '**institution**', **Mitglied** '**member**'

IN-FN compounds result in INs. Figure 9 demonstrates the unification underlying the compound *Kremldach* (lit: *Kreml* '*Kremlin'* Dach 'roof'). In contrast to IN-RN compounds, the functional head inherits the uniqueness of the IN since the arc labeled ROOF is a determining one, and thus it is uniquely determined to which roof the compound refers.

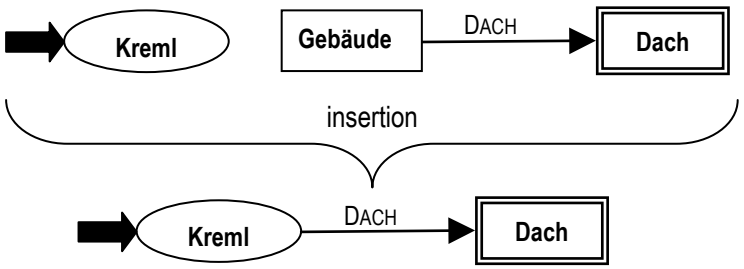

Figure 9. **Kreml** '**Kremlin**', **Gebäude** '**building**', **Dach** '**roof**'

RN-FN compounds are relational but not functional. Figure 10 shows the frame of the compound *Benutzername* (lit: *Benutzer* 'user' *Name* 'name'), since the *name* frame inherits the relationality of the *Benutzer* frame in which the INSTITUTION attribute is unspecified.

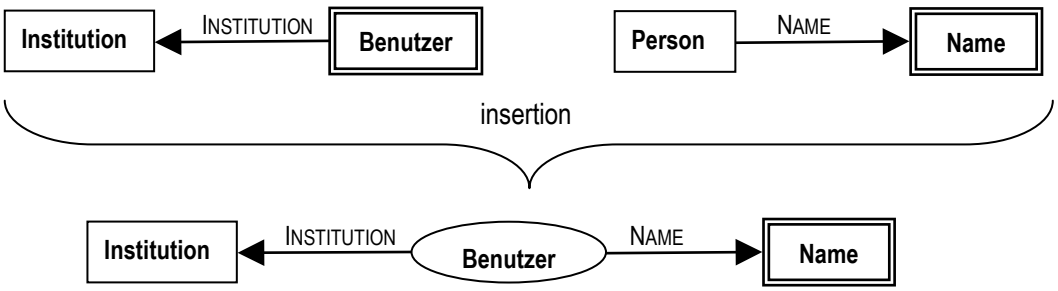

Figure 10. **Institution** '**institution**', **Benutzer** '**user**', **Person** '**person**', **Name** '**name**'

FN-FN compounds are functional. Figure 11 shows the frame structure of the compound *Kanzlergattin* (lit: *Kanzler* 'chancellor' *Gattin* 'wife') in which both constituents are functional. The result is a FN, as it can be deduced from the frame resulting from the unification of the frames of the compound constituents. The attribute CHANCELLOR and the attribute WIFE are series-connected determining arcs; thus, the instantiation of the *nation* node determines the value of the chancellor node that, in turn, determines the value of the *wife* node. In other words: the compound has one open argument and thus it is a functional noun.

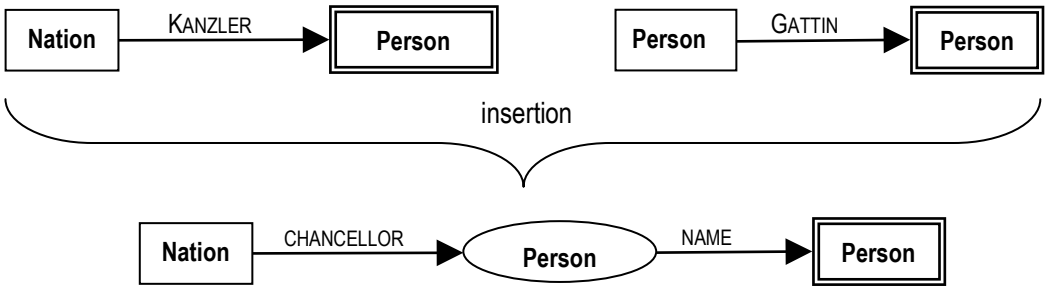

Figure 11. **Nation** '**nation**', **Kanzler** '**chancellor**', **Person** '**person**', **Gattin** '**wife**'

As mentioned above, the analysis of **SN-FN compounds** is not as unambiguous as that of possessive constructions. Instead, compounds of this type can be a SN as well as a FN. In the compound *Filmende* (lit: *Film* 'movie' *Ende* 'end'), the SN *Film* seems to saturate the possessor of the functional head *Ende*. However, the possessor can still be saturated on the linguistic surface (see 7), and the indefinite use of the compound is most heavily marked (see 8). Thus, the modifier does not saturate the argument, but rather constrains the possessor specification: the argument can merely be saturated by concepts that are sub-concepts of the modifier. For this reason, sentence 9 is inconsistent. On the other hand, the compound Baumstamm (Baum 'tree' Stamm 'trunk')

can be used indefinitely (see 10) which is an indication that the compound is a SN. Thus, SN-FN compounds require two frame representations: In Figure 12, the argument is still open, while it is saturated in Figure 13.

7. Das Filmende von "Vom Winde verweht" ist traurig. "The movie end of Gone with the Wind" is sorrowful."
8. ??ein Filmende ist manchmal traurig. ??"A movie end is sometimes sorrowful."
9. §§das Filmende des Buches §§"the movie end of the book"
10. Dort drüben liegt ein Baumstamm. "A trunk of a tree is lying over there"

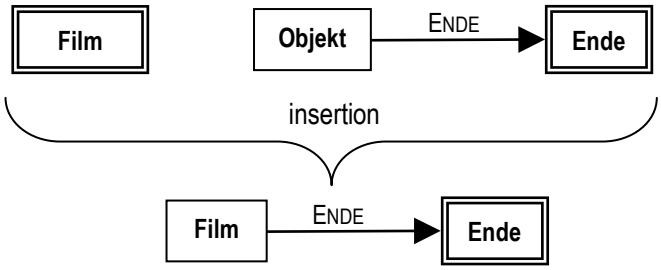

Figure 12. **Film** '**movie**', **Objekt** '**object**', **Ende** '**end**'

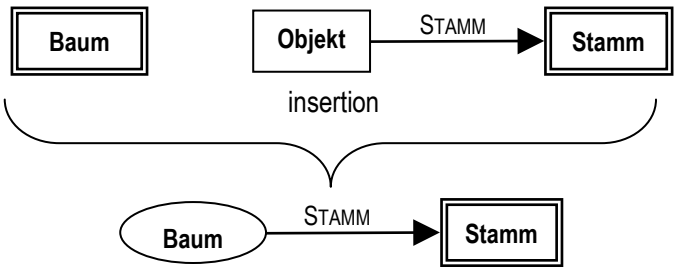

Figure 13. **Baum 'tree', Objekt 'object', Stamm 'trunk'**

5 Conclusion

We presented a formal model of concept composition in compounding with respect to conceptual types in the sense of [Löbner 1985, to appear] to analyze relational-noun compounds. It has been shown how the modifier determines the conceptual type of the whole compound in most cases (see Table 2). The exception is the resulting type of SN-FN compounds that can either be functional or sortal. Thus, SN-FN compounds that are still

functional are no relational-noun compounds in the narrow sense because the argument is not saturated by the modifier. Instead the modifier merely constrains the range of possible concepts which can function as arguments.

Table 2. Combinatorics of conceptual types in compounding

Type of the modifier	Type of the head noun	Resulting type
SN	RN	SN
RN	RN	RN
IN	RN	SN
FN	RN	RN
SN	FN	SN
RN	FN	RN
IN	FN	IN
FN	FN	FN or SN

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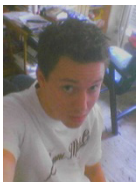

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