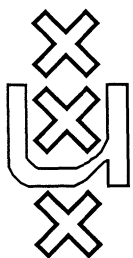


Institute for Language, Logic and Information

**FRAME REPRESENTATIONS
AND
DISCOURSE REPRESENTATIONS**

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Frames are known from linguistics, for example from Fillmore's representations of verbs with their "deep" cases, or from Helbig and Schenkel's representations of verbs with their "valencies" in the *Wörterbuch zur Valenz und Distribution deutscher Verben* and subsequent volumes on adjectives and nouns, following the tradition of dependency grammar that started with Tenière's *Éléments de Syntaxe Structurale* (1959/69), or from Dik's *Functional Grammar* (1978), or from Bresnan's *Lexical Functional Grammar*, but also from logical grammar, where not only verbs but also nouns and adjectives have been represented as relations with abstracted variables that serve as slots in which variables or constants of the appropriate types can be filled in order to build up a sentence. The slots, or valencies, are characterized as to which kinds of grammatical items can be associated there in the formation of complex expressions.

Likewise, frames are known from Artificial Intelligence, at least since Minsky's famous programmatic article *A Framework for Representing Knowledge* (1975). There are frames in many degrees of complexity and for different purposes, as there are Templates, MOP's, Scripts, Superscripts, Plans, Plots, and others that were introduced in the writings by Schank and others (cf. Schank and Abelson 1977 and Lehnert and Ringle 1982). Generally speaking, frames are representations of concepts and connections between concepts. Hereby, relations between concepts are either represented in so-called "semantic nets" by labeled lines or arcs between concept-names, where the labels express the kind of relationship that holds between the concepts, or the relationships are represented for each concept separately by its slots into which names of other concepts or entity-representations of a certain kind can be filled. By means of the slots, concept-representations can be linked to each other. A frame is a semantic net with at least one slot, and in the simplest case at least the name of one concept with one or more slots, by which it can be connected to other frames in order to form a more complex frame.

These representations of conceptual structures are of quite different formats, due to special assumptions of the different authors, and often ad hoc with respect to fairly special purposes they were designed for. In their present formats they are unusable for a logical-linguistic theory of text-interpretation, because they are not formulated in such a way that they fit into a general theory of truth and inference. Such a theory has to comprise a general theory of correct inference, i.e. it has to take into account that understanding a text means to be able to draw the right conclusions from it and to be able to answer questions about the text correctly.

This task has also been the objective in Artificial Intelligence, for example in the school of Roger Schank, but the proposed solutions to the problems involved in this task are merely of a syntactic nature and they

are domain-specific, without any semantically based notion of correct inference, and further use several ad hoc specified relations between concepts or things they are characterizations of. They also suffer from the shortcomings of Schank's "conceptual dependency theory", due to the use of a small set of basic concepts and relations, which never are sufficient to represent a concept adequately and which are combined in rather ad hoc ways to form a concept or a complex of concepts, like a script (cf. Rich 1983). Nevertheless there have been treated lots of interesting questions in this branch of Artificial Intelligence, with useful points of view and frame material, which can be formulated in a more consistent manner, based on a theory of discourse representation. Therewith, a frame representation is a syntactic representation which is of the same kind as the ones used as sentence- and text representations. Then frames and subframes can be linked with text representations by logical operations such as instantiation and implication. Frames do not need to be integrated into the discourse representations of sentences and texts, rather they can be used as conditions (restrictions) on semantic interpretation of these texts, especially by being restrictions on the set of truthful embeddings of discourse representations into a domain of discourse or (partial) world. Using the same kind of syntax for discourse representations and for lexical frames secures a unified semantic theory for lexicon and syntax, which is necessary in a compositional built-up of sentences from lexical items.

In the next paragraphs frame representations will be formulated such that they fit with syntactic representations of texts which have a semantics that comprises an explication of the notion of entailment. These are Kamp's (1981/84) Discourse Representation Structures (DRS) or Heim's (1982 and 1983) representations in files with their file change semantics. Zeevat (unpubl. paper, 1984) has suggested a compositional generation of DRSs, with a compositional semantics following the syntactic composition. Although I shall finally formulate a DRS-syntax that follows more the lines of Zeevat, I shall sometimes use Kamp's original box-format (or, in order to save space, a later version of it which we find for example in Roberts 1987) for the purpose of enhancing visual lucidity. Generally, I shall make use of a linear format of DRSs. The interpretation of DRSs will be arranged following Groenendijk and Stokhof's (1987) semantics for a dynamic predicate logic, which has the binding properties of Discourse Representation Theory (DRT), but has the advantage of being formulated compositionally as a kind of Montague-Grammar.

A basic discourse representation (DRS) is a pair $a = \langle a_0, a_1 \rangle$, where the first member is a set of atomic formulas and the second a set of discourse referents which occur in the formulas of the first. A discourse representation structure (DRS) then is recursively defined as a triple of the form $a = \langle a_0, a_1, a_2 \rangle$, where the third member is a set of pairs $\langle b, c \rangle$ of

DRSs. In the box notation a_0 and a_1 are written into one box, with the discourse referents a_1 on top, and the pairs $\langle b, c \rangle$ are presented as a splitting between two boxes (Kamp 1981/4), or by two boxes connected by an arrow (Roberts 1987). Zeevat (1984 ms) defined the following operations on DRSs and gave a semantics for them: For two DRSs a and b

$$\text{MERGE}(a, b) = \langle a_0 \cup b_0, a_1 \cup b_1, \{a_2, b_2\} \rangle,$$

$$\text{SUB}(a, b) = \langle \emptyset, \emptyset, a, b \rangle, \text{ and}$$

$$\text{NEG}(a) = \langle \emptyset, \emptyset, \langle a, \perp \rangle \rangle.$$

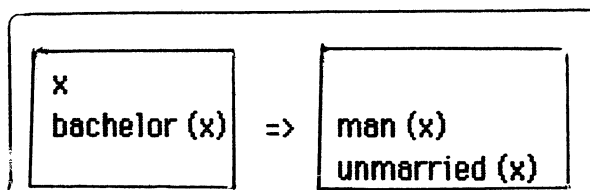
Later I shall use conjunction '&', subjunction '=>' and negation '-' instead and describe their semantics in terms of Groenendijk and Stokhof's dynamic interpretation by relations between assignments: The interpretation of a formula ϕ (including DRSs and conditions) is a set of pairs of assignments $\{\langle g, h \rangle\}$ where h makes ϕ true on the basis of g . Hereby g is an assignment that has made true the preceding text. A formula is true on the basis of the preceding text if there is such an assignment h .

Among the atomic formulas I shall use temporal order relations between situations, events, and scenes, like ' $r < s$ ', as has been done by Kamp and Rohrer (1983) and Hinrichs (1986). Additionally I shall use the inclusion relation ' $r \supset s$ ' which says that a situation (scene, event, process, state, action, activity) r includes the situation s . (The inclusion has been introduced as a basic relationship between space-time regions, and building on this notion and the notion of realization of properties on space-time regions the inclusion has been defined for situations in Bartsch 1983, 1986. Note, that this notion of situation is not the one of Barwise's Situation Semantics, which, in my terminology, parallels the notion of (possible) fact or proposition. I define the proposition a sentence expresses relative to certain contextual factors as a function from possible worlds onto the set of situations in each respective world such that these situations make the sentence true.)

2. Lexical Frames and Scripts

Frames are just like DRSs, except that they are not yet to be interpreted with respect to certain referents in a domain; they are not applied, so to speak, but rather concepts that can be applied to express some information about members of a domain.

Let us consider a traditional example, the meaning postulate for *bachelor*. In DR-theory it will appear as: If someone is a bachelor, he is a man and he is unmarried. That is, all variable assignments make true:



The **concept** 'bachelor' is represented by ' x bachelor (x)', having as its denotation all variable assignments that make 'bachelor (x)' true, or with other words, 'bachelor (x)' is a condition that is satisfied by all these denotations. The representation of this word in the lexicon, called the **Lexical Representation (LR)**, will be the pair consisting of concept representation and meaning postulate, **(CR, MP)**:

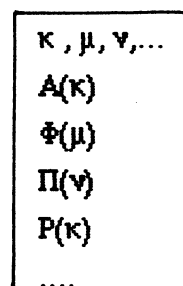
(CR: x bachelor (x), MP: x bachelor (x) \Rightarrow man (x); unmarried (x)).

The MP is just a general DRS. The CR is an abstraction from a basic DRS. Since I shall use Greek letters as addresses for formulas and discourse referents in schemas and formats, a **general format of a lexical representation** for a concept expressing word A is:

LR := (CR: x A(x), MP: x A(x) \Rightarrow [μ, ν, \dots] $\Phi(\mu); \Pi(\nu); \dots; P(\kappa); \dots$)

A representation of a possible instantiation of a LR (i.e. an instantiation type of LR) I shall call a **lexical frame, LF**. A **script** or **scene** associated with the LR is a LF which represents any situation which makes the antecedence and the consequence of the MP true. It has the form:

$[\kappa, \mu, \nu, \dots] A(\kappa); \Phi(\mu); \Pi(\nu); P(\kappa) \dots$, or as a box:



(In fact, the consequence of the MP does not need to be so simple as in this general format; it can be any DRS-form, and accordingly a script or scene can be any such form.)

The lexical frame represents an imagined case of application, a kind of typical scene, as has been the intention with, for example, Schank's scripts. The use of addresses instead of discourse referents indicates that this script is not tied down to a domain as a real discourse would be, rather it is a type of a discourse. We fill in the addresses by constants or variables (discourse referents) in order to generate a special script in order to make a frame or script part of a discourse. Doing this we go back to the proper logical format, which is the LR that consists of CR and MP. The scripts and frames therefore will, for most purposes, be used in the

MP-form. Frames play a role in the explanation of the occurrence of definite noun phrases in texts without an antecedent in the text. With respect to a certain text an instantiation can be constructed by filling the argument places with the appropriate discourse referents from the text-DRS, as far as they are available from there, the others are filled by new discourse referents and can afterwards serve as antecedents for pronouns in the text.

I shall make a distinction between analytic frames (AFs) and scenic frames (SFs). An AF is, for example, the definition of the concept "Restaurant" or "Restaurant visit" by providing a genus proximum and a differentia specifica, in this case "a location at which food is served on the basis of a kind of service contract", where the restaurant visit is a realization of this kind of service contract. On the other hand, an SF is the typical representation of, for example, a restaurant visit as a sequence of scenes, like in Schanks famous Restaurant Script (cf. Rich 1983: 236, although I shall not employ his Conceptual Dependency Structures with their primitives like M-Trans (mental transfer), P-Trans (physical transfer), etc.). Schank's later proposal (1983) to construct a Superscript from Memory Organization Packages (MOPs), instead of using a fixed script, results in a mixed AF/SF-form. The SFs and the mixed forms are useful representations of the conceptual structures of events, and situations and sequences of these generally. AFs serve to represent the conceptual structure of types of things and actions without their temporal build up. AFs express the position of a concept within a conceptual net, especially a taxonomy.

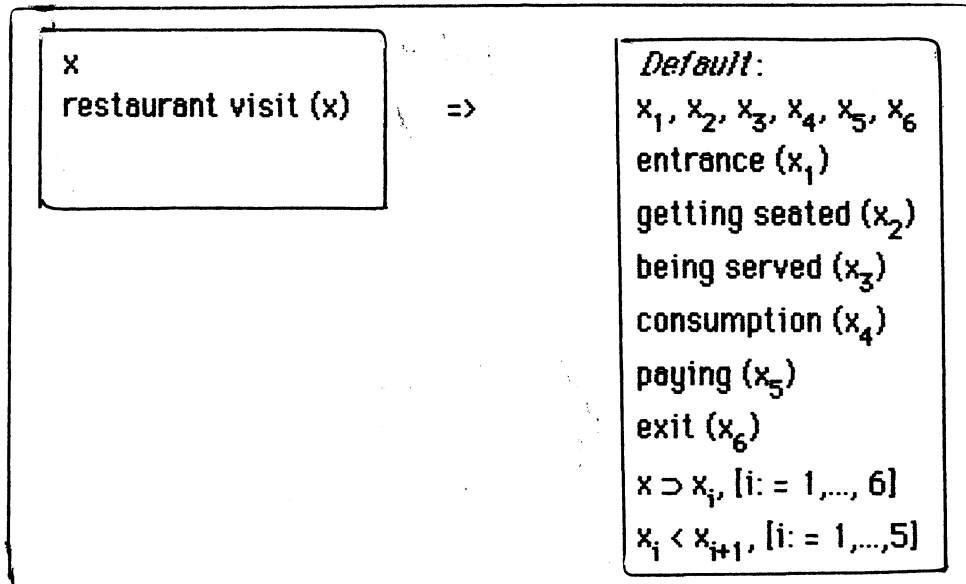
A third type of frame are the local frames (LFs) which represent the build up of a type of thing in space, its parts and the relationships between the parts, like, for example, the shape and build up of a house. There are also mixed forms between AFs, LFs, and SFs. These are scenes in which local and temporal relations between things and between events are relevant.

Individuals are also representable by SFs: for different types of individuals there are standard life histories. These are sequences of scenes or situation types, ordered in space and time. These frames are an abstraction from the fact that an individual is its history, a path through space and time on which at certain places and a certain times properties and action concepts are realized. According to this view, an individual is a local-temporal continuant, i.e. a continuous connection of realizations of properties (including relationships). The inclusion relation is used to express that the realization of a certain property, i.e. a certain event or situations from a certain perspective, is part of the life history of an individual. On this view also the idea is based that for certain formal purposes an individual at a certain time is representable as a set of

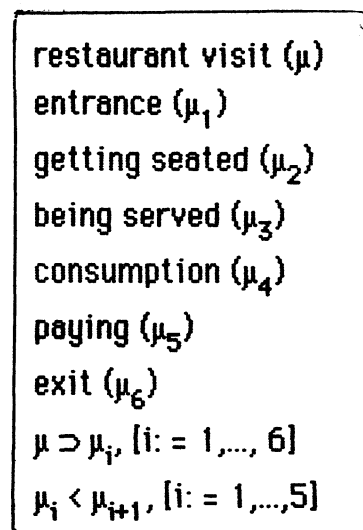
properties.

By way of illustration I shall give an SF-MP and a mixed AF/SF-MP of the example 'Restaurant visit'. For the scenic frame I chose the perspective of the customer. Under this perspective the frame generates a text or discourse of the type "Narrative".

SF-MP (*type*: Restaurant visit without self-service, *perspective*: from the customer):



The corresponding script (scenic frame) is the conjunction between antecedence and consequence of the above subjunction. This means that it is a positive instantiation of the MP, i.e. one in which the antecedent is true, i.e. in which the concept 'Restaurant visit' applies.

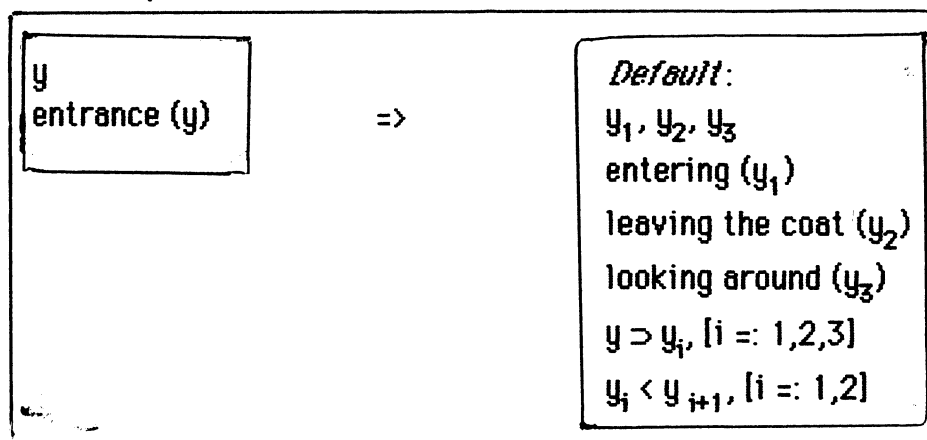


The SF here is a simple sequence of scenes, each can be partitioned into smaller scenes. Thus the scene "Entrance" can be built up from smaller scenes, as there are "Entering the restaurant", "Leaving the coat", "Looking around", or "Being served" can be built up from "Getting the menu",

"ordering drinks and food", "Getting drinks and food". All this information is *default information*. This means that it is entailed only as long as no contrary evidence is provided in the discourse with which this frame is linked by the occurrence of an instance of the antecedence in a discourse representation. We can look at *default* as an epistemical operator: we assume the information under this operator as long as no information to the contrary is available. (Attempts to provide a formal calculus and a semantics for this operator have been made in studies of non-monotonous logics, for example in data semantics by Veltman (unpublished); they are beyond the scope of this paper.)

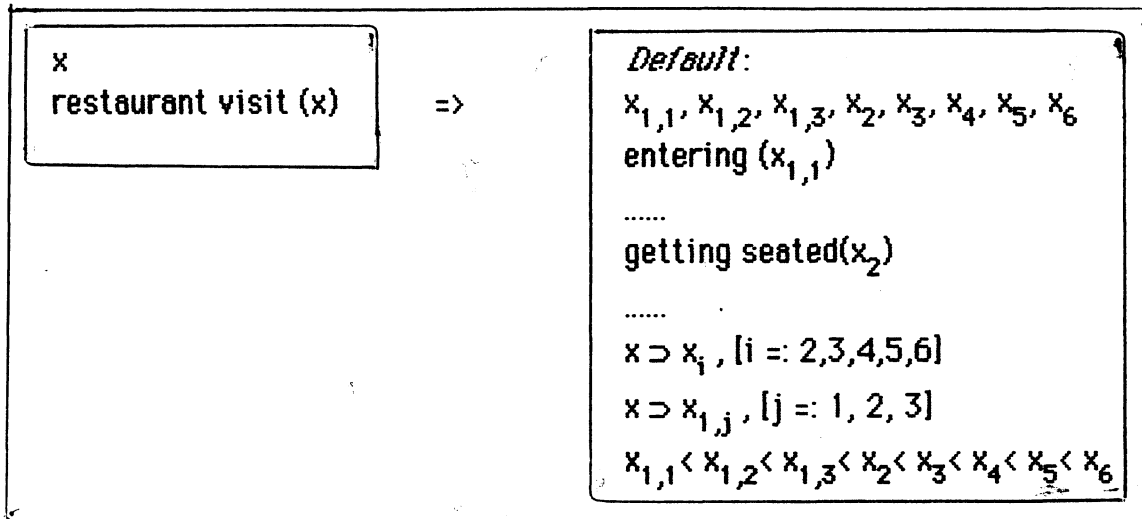
The details of the frame "Entrance", for example, are provided by the following SF-MP:

SF-MP (*Type* : Entrance into a restaurant, *Perspective* : from the customer):



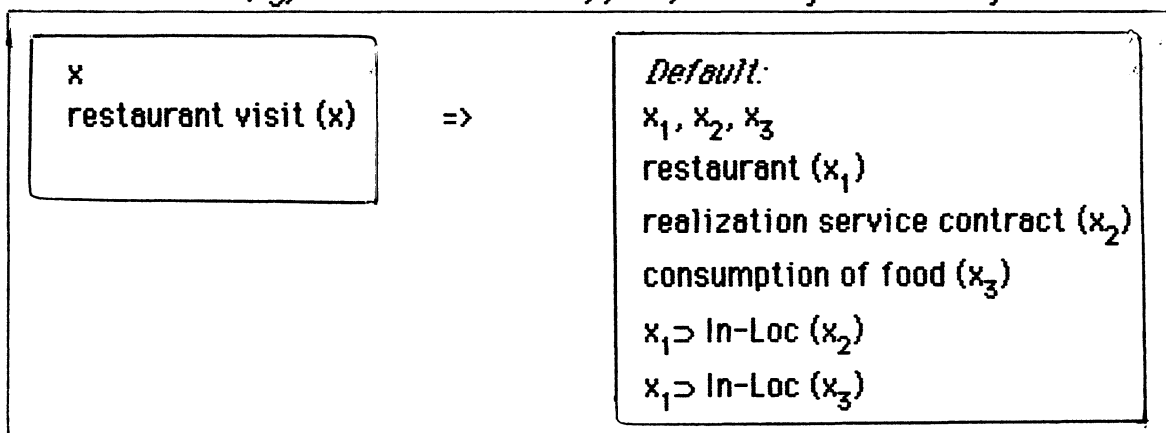
According to the transitivity of the conditional ' \Rightarrow ', ' $p \Rightarrow q \ \& \ q \Rightarrow s \Rightarrow p \Rightarrow q \ \& \ s$ ', the consequence of the sub-frame of "Entrance", i.e. the Entrance-script, can be used as a condition on the reference marker x_1 . Technically this is done in a uniform fashion by substituting x_1 for y , and thus $x_{1,i}$ for y_i . The whole operation of expanding an atomic formula into a sub-frame is a MERGE-operation between the matrix MP, here SF-MP(Restaurant visit) and the detail frame, here SF-MP(Entrance). **MERGE (SF-MP(Restaurant visit), SF-MP(Entrance into a restaurant)) = SF'-MP(Restaurant visit)**. SF' is an expansion of SF.

SF-MP (*Type: Restaurant visit, Perspective: from the customer*):



Besides scenic frames there are analytic frames which are built up from typical realizations of conceptual frames at locations. In this way, Schank's Superscript of a restaurant visit is built up from smaller units, Memory Organization Packages (MOPs, cf. Schank 1983). In this example the central general frame is a MOP of the type "Contract". In our terminology this is an AF. According to it, a restaurant visit is a service and buying contract with certain results and certain initial conditions. From this perspective the analytic frame is built up in another way than a scenic frame, namely roughly as follows: realization of a service contract, *initial conditions*: the place of realization of the contract is a restaurant, the participants are the customers and the employees of the restaurant, *results*: the purpose of eating is satisfied. Thus we have generally:

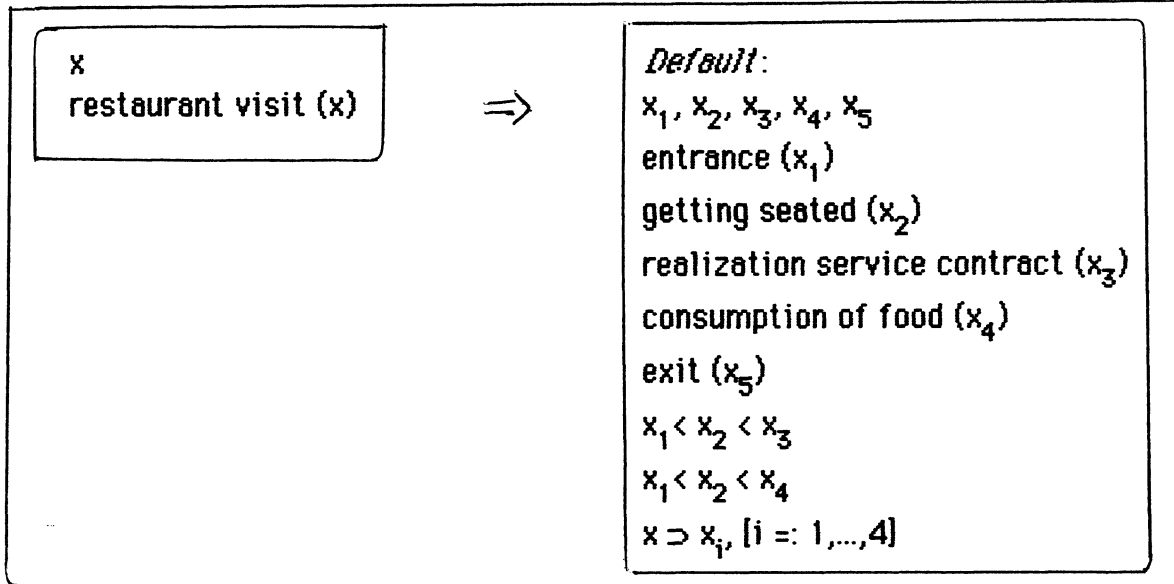
AF/LF-MP (*type: restaurant visit, perspective: juridical-objective*):



The expansion of this frame can happen, like above, by MERGE-operations with detail frames, for example by an AF(contract realization), i.e. the typical acts of settlement of the contract and execution of the contract, or the by the AF(Restaurant), or an AF or SF for "Consumption of food". If

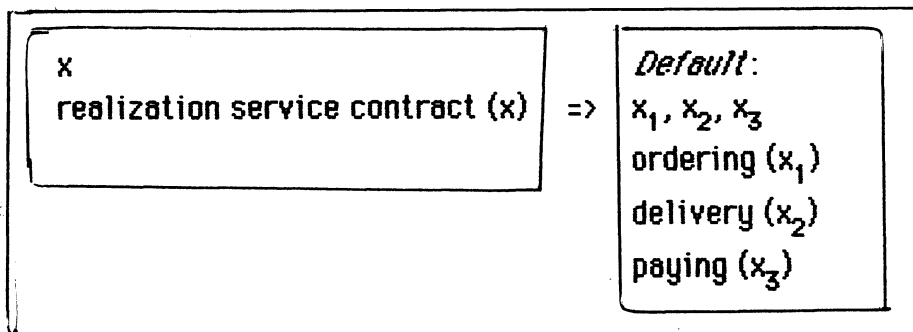
we merge an AF-matrix frame with an SF, we get a mixed AF/SF, which is partly analytic and partly scenic. In our example this would look like the following meaning postulate.

AF/SF-MP (*type*: restaurant visit, *perspectives*: from the customer, and objective-juridical):



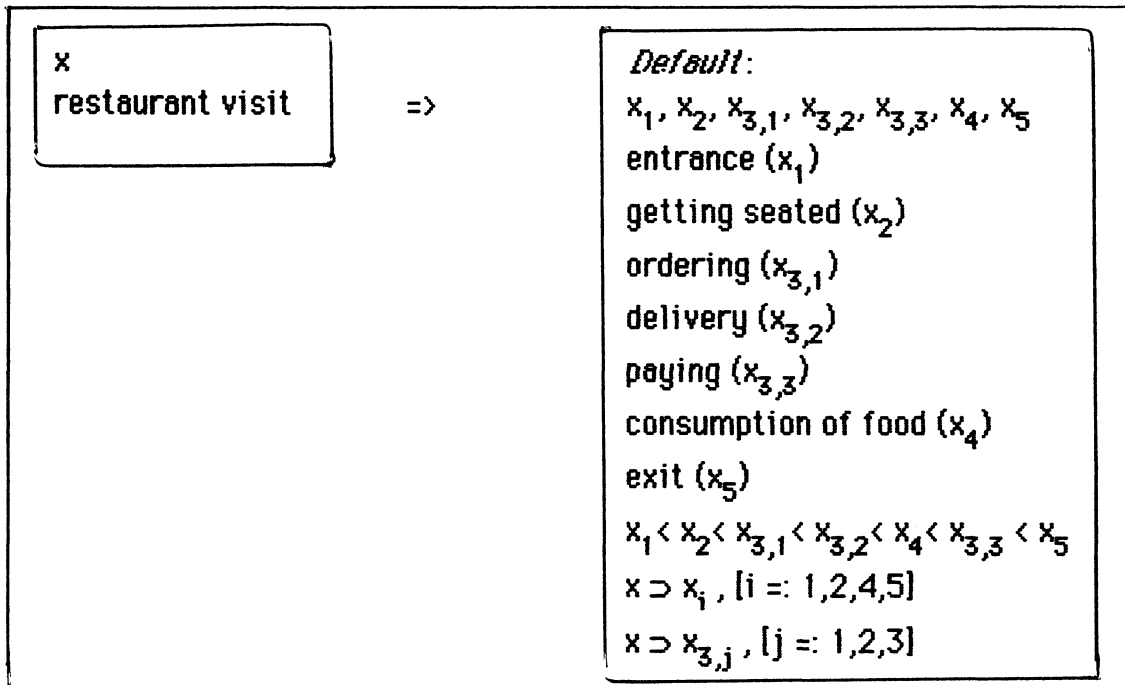
A temporal order between "Realization of the service contract" and "Consumption of food" requires that the realization of the service contract is split up further. After such an expansion, the consumption of food can be located temporally between "Serving the food" and "Paying the bill" in a non-selfservice restaurant. The detail frame is:

AF/SF-MP (*type* : Realization service contract, *perspective*: objective):



If we merge this detail frame with the above matrix frame and apply associativity of ' \Rightarrow ', we receive the following expanded frame.

AF/SF-MP (*type*: restaurant visit, *perspective*: objective):



It is obvious that there is hardly any limit in constructing all kinds of frames, even for this much treated example of a restaurant visit. One step would be to integrate the relevant local frames into the AF/SF- or SF-matrix frames, besides expanding by further analytic frames and scenic frames. How far the process of getting into details should proceed can only be judged by criteria of relevance that are included in the global and local thematic set up of the discourse involved. The construction of such frames may be useful for certain purposes, for example for generating stories, whereby many of the typical aspects need not be made explicit, but serve the overall organization of the story by placing the interesting details, or the deviations from the typical details into their right place and making possible an evaluation of the value of the story as news, i.e. new information.

For the purpose of interpretation of texts, and especially stories, we can construct expanded frames, like Schank's Superscripts, which are just conjunctions of MPs: We put a frame-MP as matrix frame in conjunction with detail frame-MPs and make use of the transitivity of the conditional. By instantiating the expanded MP on the basis of the text under consideration (i.e. identifying variables from the MP with those from the DRS) and by forming the conjunction between the antecedence and the consequence of the MP we receive the script we might need for interpretation of the text and for further inferences.

2. Verb frames, nominal frames, and discourse representations

The topic of the next paragraphs is the integration of concept representations from the lexicon into syntactic forms in building up discourse representations in a compositional way. The basic idea is to associate with each constituent of a sentence a DRS or a concept representation (CRS), whereby I shall call rudimentary forms of DRS/CRS, such as $\langle a_0, a_1 \rangle$ with either $a_0 = \emptyset$ or $a_1 = \emptyset$, also DRS/CRS. I also call all conditions DRSs. The DRS/CRS that is associated with a constituent of syntactic category X is called an X -DRS/CRS. Depending on grammatical relationships in the sentence, expressed by position within the sentence, adpositions (postpositions or prepositions) and cases, the constituent-associated DRSs are linked together by operations MERGE, SUB ('&' and '=>') on the one hand, and functional application (APPL) on the other. In such an application a concept representation is applied to a discourse referent, i.e. is made a condition on such a referent. The above operations or combinations of these take place according to grammatical information (syntactic as well as morphological). I call a DRS/CRS associated with a verb, a noun, etc. a verb-DRS/CRS, a noun-DRS/CRS, etc.

Generally, CRSs become DRSs when applied to the appropriate number of discourse referents. This happens at two occasions, first, when a noun (simple or complex) is combined with a quantifier (like: *a*, *the*, *every*, etc.), and second, when a verb is combined with a temporal determiner (a tense marker). A proper name is either represented by a constant c , or gets an associated DRS of the form $\langle \{\mu=c\}, \{\mu\} \rangle$, which is introduced in front of and in conjunction with a text-DRS.

Since I want to use a syntax with case markings, I use German in all the examples. In order to make it easy to recognize the correspondence between words of the natural language and expressions in DRSs, I also use German expressions in the DRSs. German nouns are lexically marked by grammatical gender which is the major lexical/morphological information for coreference between noun phrases and pronouns. For English we would have prepositions and the position of a noun phrases within the sentence as indicators of the syntactic relations that correspond with cases in German and in any other language with case marking systems or with a regular use of postpositions or prepositions instead.

The DRS-syntax treated in this paper will be a "flat" syntax to begin with, which consists of operations over constituent DRSs. It has some shortcomings from the point of view of compositionality, which will be remedied in part three by a version of syntax and semantics that builds on the first, but employs functional application and higher order variables.

1. The form of the verb

Let us consider a simple verb, e.g. *singen*, 'to sing', in German. It can occur in sentences as 1-place, 2-place, or 3-place verb, as in the following sentences: *Fritz singt*. 'Fred sings', *Fritz singt das Lied*. 'Fred sings the song', and *Fritz singt mir das Lied*. 'Fred sings the song for me'.

The question is whether this verb shall be represented with three different frames in the lexicon, namely with the frames:

*singen*₁: κ sing-⟨f⟩, *singen*₂: κ sing-⟨f⟩ ν, *singen*₃: κ sing-⟨f⟩ μ ν.

Here, ⟨f⟩ is the sign for the finite form, the first address is the one for the Nominative, the last one for the Accusative, and the middle one for the Dative term. (I use the notion '(nominal) term', T or NT, for quantified noun phrases and proper names.) If there is no misunderstanding possible I also use the notion 'noun phrase' for these, but generally linguists count among noun phrases also non-quantified noun phrases, which in Montague Grammar are 'common nouns', a notion that comprises basic as well as complex nouns, like phrases consisting of an adjective and a head noun, a prepositional phrase and a head noun, or a relative clause and a head noun.) It is more convenient to associate with the cases certain places in a standard order, namely as usual: Nominative: 1. place, Accusative: 2. place, Dative: 3. place, and possibly others. Then we have the frames: sing-⟨f⟩ (κ), sing-⟨f⟩ (κ,ν), sing-⟨f⟩ (κ, ν, μ). The concepts that correspond with these frames are:

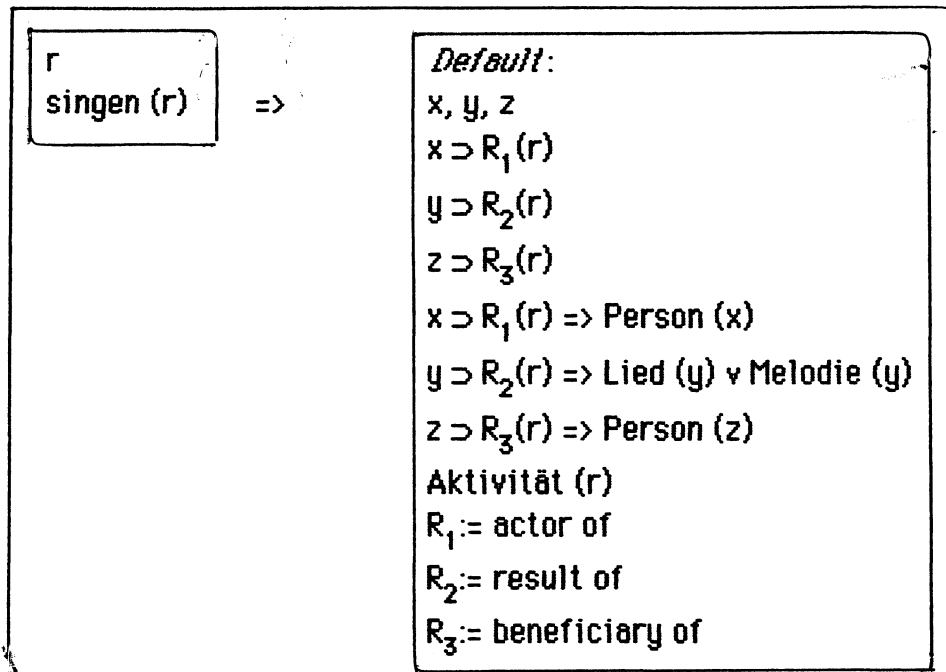
[κ] sing-⟨f⟩ (κ), [κ, ν] sing-⟨f⟩ (κ,ν), [κ, ν, μ] sing-⟨f⟩ (κ, ν, μ)

A problem with these kinds of verb frames is that they don't have a reference marker which could be used to represent pronouns that refer to the action, state, or process itself and not to one of its participants. Using the verb frames above, the text *Fritz singt ein Lied. Es ist schön*. 'Fred is singing a song. It is beautiful' can be interpreted such that the pronoun *es* refers to the song, but it cannot be interpreted as referring to the singing itself, as it must if the text is continued by *aber ich kann dieses Lied nicht leiden*, 'but I can't stand this song'. Also in texts with nominalizations, adverbials, and aspects one has to be able to refer to processes, states, events, actions, activities (short: situations). Constants and variables referring to events have been employed since Reichenbach (1947), and they have been integrated into the verb frames by Davidson (1967/82). Davidson's frames have an additional place for a variable referring to the events described by the verb. A different method had been used in Bartsch 1972/1976 in the analysis of adverbials, and further in Bartsch 1983/1986 in the analysis of nominalizations and aspect. There the participant places and the event place are treated differently by separating the participant places from the verb and using case relations

instead which link the participant terms to the verb. Then it is not necessary to represent a verb like *singen* three times, namely as a 1-, 2-, and 3-place verb (or with the additional event place as a 2-, 3-, and 4-place verb). Rather a single representation as an event concept is sufficient, namely $[r]$ **singen** (r). This untensed verb is not in a finite, but in an infinite form and thus a noun which characterizes the activity of singing.

(It is important to distinguish events, actions, activities, states, processes, individuals (i.e. situations in a broad sense) from facts which are true propositions with respect to a world, i.e. functions which map at least one situation contained in this world onto the value 1.)

Case relations can be treated in the default part, i.e. in the MP-part of the lexical representation of the verb. The MP-part of the lexical representation of *singen* is:



The MP of the lexical representation of a word will not be integrated into the DRS-syntax. It is always available in the lexicon, and it will be held in a buffer when the word is called up in text interpretation, such that its frame is available whenever necessary, for example to find an anaphoric referent for a pronoun, or to make an inference in order to answer a question about the text, and to provide the case relationship which will be selected by the case-marking of an NP that is applied to the verb. The whole MP of a word can be understood as a condition on the verifying assignments that make up the interpretation of the DRS which is the representation of the text in which the word appears.

Instead of three frames for the verb *singen* we now have only one. The cases are in the default part of the lexical representation. This means they do not need to be filled in a sentence, and we even can imagine a singing

without any participants, and a singing that is not even an activity, like some singing among the telephone wires, or just some singing in the air. The verb can be used in a sentence without an indirect or direct object, and even without a subject. Subject- and object terms, i.e. participant NTs can be linked to the verb by means of case markings. For this kind of syntax I shall formulate the rules in the third part of this article, together with the generation of the appropriate DRSs. Before doing this I shall make a short excursion into a valency syntax, taking up the tradition of Dependency Grammar of Tesnière (1959/69) and his followers, and presenting some arguments against one version of it.

2. Dependency (valency) grammar

In dependency grammar the verb is the head of a clause, and all the constituent nominal terms and adverbial phrases are specifications or modifications of the verb. Within noun phrases the noun is the head, which can be modified by adnominal phrases and can be specified by determiners. Likewise the verb can be modified by adverbials and can be specified by its complements and by tense marking. In this view on grammar the question arises whether one will use a complete verb frame, i.e. for German *singen*: the three-place verb frame (or the four-place verb frame with three participant variables and one event variable) and bind those variables by existential quantification that have not been bound by nominal terms occurring within the sentence. In Discourse Representation Theory (DRT) this would amount to either bind the open places by new discourse referents (which amounts to existential quantification), or by previously introduced discourse referents as if the open place was filled by a hidden pronoun. The first alternative is in many cases inadequate, as for example in the following text:

Auf dem Fest gab es eine Menge Kuchen. Diesmal aß auch Jan.

On the party there was a lot of cake. This time also John ate.'

If we use the frame 'aß(x,y)' with $x = \text{Jan}$, and y as a new discourse referent (this is the equivalent of existential quantification), the above text would also be true for a variable assignment that assigns to y some fish or some apple, or whatever, if Jan ate that. But this is not meant by the text. The second alternative, i.e. using a hidden pronoun, and thus a discourse referent already introduced, would provide for the correct result. But it adds to the complexity of the relationship between natural language syntax and DRSs. It is a good strategy to resist assuming hidden grammatical entities as long as other solutions are possible without too much costs. - After having introduced the semantic interpretation in the last part of this paper the interpretation of this example will be handled without

assuming a hidden pronoun as part of the syntax of the second sentence of the above text. In order to avoid hidden pronouns and with this old or newly introduced discourse referents at places where there are no corresponding noun phrases or pronouns in the text, a dependency grammar can chose the following strategy.

Depending on the number and kinds of verb complements (i.e. noun phrases or infinitive constructions as sentence constituents) in a sentence, the right verb frame is chosen from the lexicon. If furtheron in the text a definite noun phrase occurs that refers to a participant of the verb that had not been mentioned as such in the text, a new discourse referent can be introduced for the definite noun phrase and be equated with a participant variable in the MP-frame in the buffer. If in a text we use 1-place *singen*, the concept frame (CF) of the verb together with the R_1 -relation of the MP-frame is used as a lexical frame in the sentence. The R_2 and the R_3 relations only appear in the buffer and their participant variables can serve as antecedent variables in case a definite noun phrase is used that has no antecedent nominal term in the text. If the two-place verb with R_1 and R_2 is used in the text the R_3 relation remains in the buffer for further use, while the other two case relations are copied into the verbframe in the text. The MP in the lexical representation (in the buffer) is instantiated by the discourse referents that occur in the text-DRS, be it in the appropriate case relationships within the syntax, or separately as in the above example about the cake, where the R_2 -case relationship is not coded in the text. Let us now consider the following text:

Hans singt. Das Lied ist mir bekannt.

'John is singing. I know the song.'

Here, the definite noun phrase does not corefer with a discourse referent previously introduced into the DRS of the text. We will introduce a new discourse referent for the noun phrase *das Lied* and equate it with the participant variable of the R_2 relation in the buffer. In this way text connectedness is achieved via the lexical frame in the buffer which provides for additional conditions on the discourse referents of the text-DRSs. The same can, of course, happen with respect to the participant of the R_1 -relation, the agent of the activity expressed by the verb:

Ein Lied wurde gesungen. Der Chor geriet durcheinander.

'A song was being sung. The choir got into a mass.'

Here, the verb frame selected from the lexical representation to be used in the texts contains, next to the CF, also the R_2 relationship. The R_1 relationship appears merely in the buffer. The definite noun phrase in the second sentence has a new discourse referent in its representation, and this is equated with the R_1 -participant of the MP-frame in the buffer.

In the buffer we hold with respect to each lexical item of the text the common knowledge that is provided by the lexicon. This, of course, is in accordance with Heim's (1982, ch. 3) restriction on accommodating missing prior antecedents for definite noun phrases, namely that new file cards introduced in this way must be cross-indexed with existing file cards. This cross-indexing can happen via the lexical information. Heim also pointed out that this is not so for pronouns. Therefore, in the text *Hans singt. Es ist schön* 'Hans is singing, It is beautiful' the pronoun *es* may not be interpreted as referring to the song; it can merely refer to the singing itself.

The relationship can even be more indirect than in the previous examples, where the connection could be made within one lexical frame.

Es erklingt ein Lied. Der Sänger ist heiser.

lit. 'A song asounds. The singer is hoarse.'

In this case the verb, *erklingen*, is a one-place verb without an agent-participant. Its R_1 participant is a sound, which in the text is said to be a song. In the scenic lexical frame of *song* we find the default information that the producer of the sound is a singer. Thus we need two lexical frames to establish the connection of cross-referring, the frame for *erklingen* and the frame for *Lied*. The scenic frame of the MP part of the lexical representation of *Lied* is approximately the following:

MP-SF(Lied): $[x,r]$ Lied(x); Erklingen(r); $x \supset R_1(r) \Rightarrow$

Default: $[y][s]$ Singen(s); Sänger(y); $y \supset R_1(s)$; $x \supset R_2(s)$; verursacht(s,r).

On the basis of the same lexical frame the text could also have been:

Ein Lied erklingt. Das Singen ist schön.

The new discourse referent introduced with the definite term *das Singen*, will be equated with the variable *s* in the scenic frame for *Lied*, after *x* and *r* have been equated with (or replaced by) the respective discourse referents from the DRS of the first sentence of the text, by way of instantiating the meaning postulate by the DRS of the present discourse. With this step the whole default-information, namely the scenic frame of *Lied*, is applied for the present instance. This means that it is a condition on the associated discourse referent of *ein Lied*. In order to treat all occurrences of definite noun phrases alike, we always introduce a new discourse referent with the addition of an equation of this variable with one that has been introduced previously into the text or the buffer (via lexical information), or is found in some background knowledge that is called up into the buffer by certain lexical items. The last would be the case, if for example the phrase *the moon* is used in a text. The lexical item *moon* with its frame is called into the buffer. In the frame of *moon* we find the default-information: $[x]$ moon(x) \Rightarrow *default:* associated with (x, Earth).

I shall now give a provisional procedure for a bottom up construction of

sentences by means of associated DRS/CRSs. If we start the analysis or production of a sentence with a verb frame containing all the places needed for the verb complements of that sentence we have to use a rule schema that will represent the rules that take care of the operation that links a nominal term according to its case marking with the right place of the verb. The rule schema is:

$$\begin{array}{c} \text{MERGE} \\ \{ \underline{\mu_{\kappa-i}} \} \{ \quad \} + \text{APPL}_i (\text{DRS}(\text{NT}), \underline{\mu_i} \text{FR}(V_{\kappa})). \\ \text{SUB} \end{array}$$

This means that first the operation APPL_i has to be performed, i.e. the participant variable μ_i in the R_i -relation (i.e. the i -th place or valence of the verb) has to be replaced by the head-variable of the DRS associated with the NT while the corresponding underlined variable $\underline{\mu_i}$ is erased (this is λ -application), which amounts to application of the verb concept (CRS) in this place to the head-variable of the NT-DRS. In the other places the verb CRS/DRS is a DRS, here a condition. Then the operation MERGE or the operation SUB has to be applied, depending on the kind of NT. Quantifiers of the existential type require MERGE and quantifiers of the universal type require SUB. The rules which instantiate this schema are in this respect context dependent.

Generally, the case frames ' $\kappa \supset R_i(\tau)$ ' are conditions on participants and events; κ is the participant address, and τ is the event address. The index i refers to the different cases. These R_i are syntactic relations; what they amount to in terms of "deep cases" like Agent, Patient, Beneficiary and the like, is different for different verbs or subclasses of verbs and has to be spelled out in the lexicon. This can be done in general rules for subclasses of verbs or separately in the MPs of the lexical representations. The set of underlined variables in front of the above schema is empty if the application is performed with respect to a concept with only one λ -bound (here: underlined, i.e. not yet filled) variable.

The NTs will be applied to the verb according to the linear order in the sentence or clause: what is closest to the verb in the sub-ordinate clause order will be applied to the verb first. This means that the scope of an NT is narrower if it is closer to the verb. According to this procedure, the sentence *Ein Mann singt jedem Mädchen ein Lied* 'A man sings for every girl a song' will be analyzed, according to the subordinate clause phrase order, as *[Ein Mann][jedem Mädchen[ein Lied[singt]]]* while the sentence *Jedem Mädchen singt ein Mann ein Lied* will be treated as *[Jedem Mädchen,*

[ein Mann[ein Lied[singt]]]. It is obvious that the corresponding scope differences will be represented in the resulting DRSs.

In order to accommodate Tense we define temporal frames, which are part of a simple DRS in which a discourse referent for an event is introduced and the time of speech is represented by a constant, and a condition specifies the relationship between the event and the time of speech or other possible discourse referents for preceding events. The general schema of tense application is:

$$[\{\mu_k\}_{k=1,2,3}] \text{MERGE} + \text{APPL}_e (\text{DR}(\text{TENSE}), [\sigma] \text{FR}(\text{VP}))$$

The VP can be the basic verb or a verb together with adverbial modifiers and NT- or infinitive complements. The index e means that the λ -abstracted event variable σ is instantiated by the head variable of the tense DRS, i.e. by the discourse referent for the event that is fixed in temporal relationship with the point of speech or another event. The application of an event-concept to a tense-DRS means that with this the concept is instantiated or realized in space and time. The set of λ -abstracted variables may be empty, as is the case when all places of the verb have been bound by NTs or, generally, if its valency is zero.

The fact that the temporal specification can be done at different places, i.e. directly to the verb, or to the verb with the first NT-specification, or to the verb with the first and second NT specification, or even after all NT-specifications have been done, means that TENSE can have a variety of scope possibilities. Depending on the kinds of noun phrases involved in the interpretations, different scopes for TENSE can amount to the same or to a different result in interpretation. The occurrence of universally quantified NTs generally makes a difference.

For the sentence *Ein Mann singt jedem Mädchen ein Lied*, with narrow TENSE scope we get, according to the sentence structure *[Ein Mann][jedem Mädchen[ein Lied[PRES[sing-]]]* and the rule schemata above:

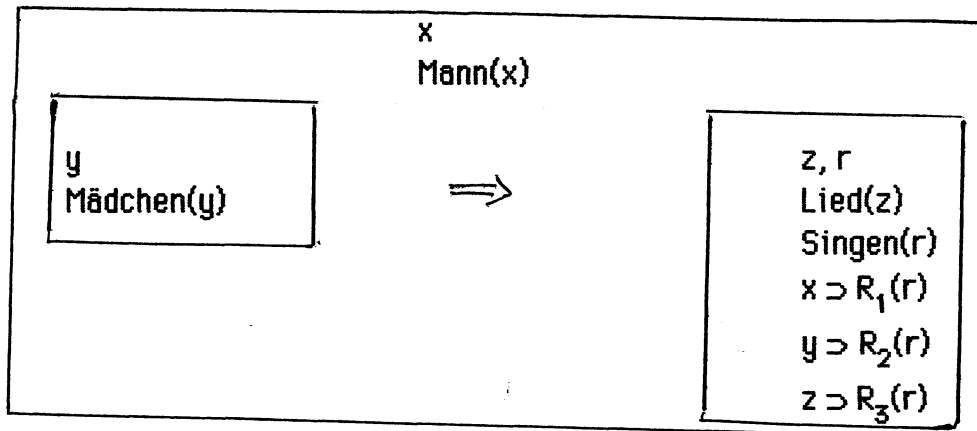
$\text{MERGE} + \text{APPL}_1(\text{DR}(\text{ein-Mann}), [\{\mu_1\}] \text{SUB} + \text{APPL}_3(\text{DR}(\text{jed-Mädchen}), [\{\mu_k\}_{k=3}] \text{MERGE} + \text{APPL}_2(\text{DR}(\text{ein-Lied}), [\{\mu_k\}_{k=2}] \text{MERGE} + \text{APPL}_e(\text{DR}(\text{PRES}), \text{FR}(\text{Singen}_\sigma))))$. Hereby is $\text{FR}(\text{Singen}_\sigma) = \text{Singen}(x_e) \ \& \ x_1 \supset R_1(x_e) \ \& \ x_2 \supset R_2(x_e) \ \& \ x_3 \supset R_3(x_e)$. $\text{DR}(\text{PRES})$ is, either understood as the 'neutral tense': $[r]$, i.e. no temporal condition is provided, or as real present tense: $[r] \ r \supset t_0$, i.e. the event comprises the time of speech. The nominal terms have the following associated DRSs, respectively: $[x] \text{Mann}(x)$, $[y] \text{Mädchen}(x)$, and $[z] \text{Lied}(z)$.

The resulting DRS with 'neutral time' is:

$$[x] \text{Mann}(x) \ \& \ ([y] \text{Mädchen}(y) \Rightarrow [z,r] \text{Lied}(z) \ \& \ \text{Singen}(r) \ \& \ x \supset R_1(r) \ \&$$

$$y \supset R_2(r) \ \& \ z \supset R_3(r)$$

Or in box form:



In this kind of dependency syntax we could as well use the Davidsonian form of verb-frame, in which the cases are not attached to the verb by case relationships, namely the frame 'Singen(x_1, x_2, x_3, x_e)', and have in the lexicon additionally the frames with two, with one and with zero participant variables. But this would not be very elegant; we rather build up a verb representation following the syntactic and morphological information in the sentence. (At the end of section 3 a fairly simple procedure of a compositional translation of dependency syntax into DRS-syntax will be given.)

Splitting up the verb into the verb itself, which is a noun represented by the capitalized infinitive form, and the case relationships as conditions for the specification of the verb by complementary nominal terms, makes it possible to do with one single lexical representation, and it makes possible another kind of syntax which does not need to make use of the above rule schema for linking together representations of NTs and verbs in a sentence, but rather can work with just one simple rule that does not need to refer to place numbers of the verb. This is achieved by constructing the verb with just one participant place at a time. The formula expressing the case relationship, according to the case marking of the NT which is to be connected with the verb, is selected from the verb-MP in the buffer, its participant variable is equated with the head variable of the NT, and this formula is linked to the basic verb-DRS/CRS as an extra condition. The case relationships serve as links between verbs and complementary nominal terms. This means that the case relationships are added whenever they are needed, but they are not part of the verb to begin with. They appear in the default-information of the lexical representation, which is present in the lexicon and copied into a buffer whenever a lexical item is used in a syntactic structure. This kind of syntax I call link-syntax because of the linking function of the case relationships.

3. The link syntax

The above arguments in favour of a syntax that does not use full-blown verb frames when constructing a sentence, but rather builds them up step by step whenever it is indicated to do so by a case- or prepositional noun phrase that has to be linked to the verb, are further supported by linguistic evidence of the following kind:

Verbs can be used in a sentence without objects or subjects:

a. Verbs occur in sentences without some or all of its objects:

Hans nimmt schon. 'Hans accepts'

Hans nimmt gern, aber gibt selten. 'Hans gladly accepts, but seldom gives'

Ich höre gut. Ich höre schon. 'I hear alright'

compared with sentences with some or all objects:

Hans nimmt von Marie, ohne selbst je zu geben. 'Hans takes from Marie without himself ever giving'

Hans nimmt Geld von Marie. 'Hans takes money from Marie'

Hans nimmt Geld. 'Hans takes money'

b. Verbs occur in sentences without subject:

Am Morgen aufstehen, waschen, frühstücken; dann geht es zur Schule. 'In the morning getting up, washing, having breakfast; lit.: and then it goes to school'

Es regnet. Es gibt Milch. Es singt und klingt. 'It is raining. lit.: It gives milk (milk is available). lit.: It is singing and sounding.'

Nein, nicht legen, sondern stellen. lit.: 'No, not lay, rather put upright'

Wenn schon nehmen, dann auch bezahlen. lit.: 'When take then also pay'

c. The unpersonal passive:

Bohnen werden in Butter gekocht. 'Beans are cooked in butter'

Es wird bis zwei Uhr getanzt. lit.: 'It will be danced until two o'clock'

d. Infinitives as nouns:

Ein Auto Fahren macht Spaß. 'Driving a car is fun'

Essen, Trinken, Schlafen sind gesund. 'Eating, drinking, sleeping are healthy'

The principle of a link-syntax is that the verb enters into a sentence without valencies. The cases and adpositions (i.e. pre- or postpositions) are interpreted as relationships that serve to link together nominal terms (noun phrases) and verbs. Hereby the case-relationship or the adposition has two valencies, one of which takes the term and the other takes the simple or complex verb. This happens by equating the head discourse

referent of the noun phrase with the participant variable of the case relationship and the head discourse referent of the verb phrase with the event variable of the case relationship.

3.1. Case relationships

The case markings express the syntactic case relations. Their semantic properties depend on the semantic content of the verb and are therefore part of the default information of the lexical representation of the verb in the lexicon. See the above example for *singen*: There we find that R_1 of *singen* is the actor relationship. This permits that in special cases also a machine or an electric wire can be said to be singing, without assuming this item to be an actor. The R_2 -relationship with respect to *singen* will be the result relationship, i.e. the realization of a song or melody is the result of singing.

The case frames and some prepositional frames appear in the MP of the lexical representations of verbs. Depending on the kind of verb, additional noun phrases can be linked to the verb by pre- or postpositions. This is generally the case for temporal and local specifications. For simplification I shall omit the part which says which is the address for participants and which the one for the event. In the formula ' $\mu \supset R_i(\kappa)$ ' that expresses the case relationship, the μ always is the participant address and the κ the address for events (comprising actions, activities, states, processes). The general format of the case-frames, as they appear in the MPs of verbs, is:

Ki: 1 = Nominativ, 2 = Accusative, 3 = Dative, for $i = 1, 2, 3$

FR(Ki):

$\mu \supset R_i(\kappa)$
event(κ)
participant(μ)

 short:

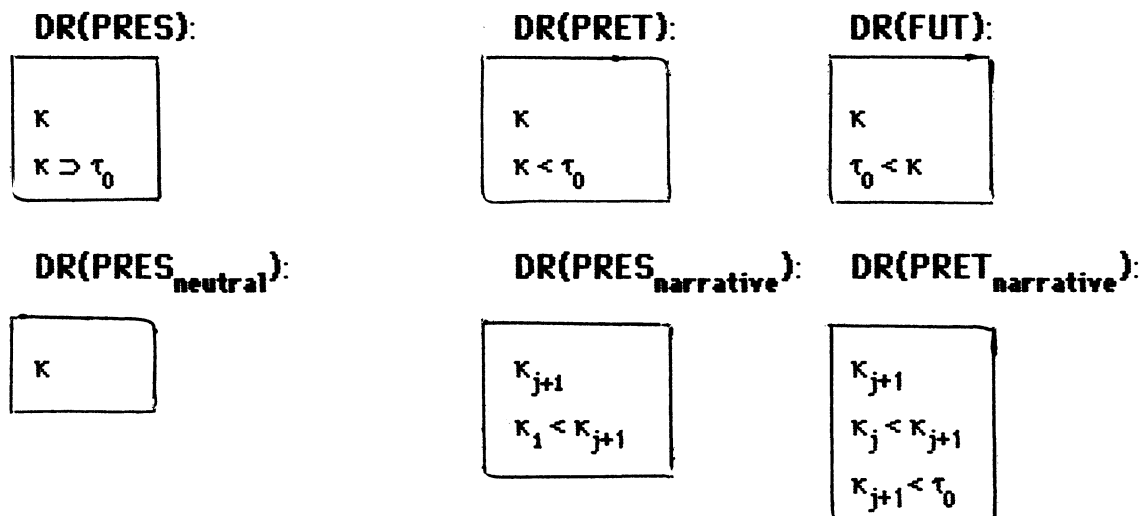
$\mu \supset R_i(\kappa)$

The formula expressing the case-relationship says (in the semantics of conceptualized space-time regions of Bartsch 1983 and 1986) that the event (or action, activity, process, state) κ under the perspective expressed by the case relationship with respect to this particular event (as conceptualized by the verb) is part of the life history of the individual μ . This means that this individual is a participant of the action or event. The individual is represented by its life history which is a path in space and time that consists of continuous connected realizations of properties. Abstracting from this kind of semantic model we can also simply use the

standard relational form: $R_i(\mu, \kappa)$.

3.2. Tenses

The frames for tenses are, like the ones for determiners, DRSs and not CRSs. This means that they establish reference to the domain of interpretation by means of discourse referents. Hereby, t_0 is a constant for the time of speech, which is treated like a proper name, i.e. it is fixed at the beginning of a text and refers to a specific entity in the model of the text. In accordance with recent work on tense in DRT (Kamp and Rohrer 1983, Hinrichs 1986, Partee 1984), I also assume a narrative tense by which a verb frame will be linked to a discourse referent of a preceding event. This is expressed in German by the so-called *erzählendes Präsens* 'narrative present tense', which can be used for present events in a live report (e.g. in reporting sports events) as well as for events that happen in the past and are narratively connected. Likewise there is a narrative preteritum which can only be used for reporting past events in a narrative. Furthermore, I assume a neutral tense, which does not express more than just that there is (or has been, or will be) an event; this is done by just introducing a discourse referent without a condition. We can express this also by the DRS ' $\{x\} T(x)$ ', in which we use the tautological condition. This neutral tense corresponds to the indefinite determiner, i.e. to existential quantification over individuals, or the introduction of a discourse referent. The event is not specified with respect to the time of speech or any other time, though a context might imply a span of time within which the event has to be located. The general formats are:



In principle, the TENSE-DRSs can be linked to any verb-CRS, whether the verb is complex or not. For the time being we assume that the simple verb

or a verb with adverbial modification gets tensed before it takes its NT-complements. Tensing of a verb means that the verb-concept in its event-address is applied to a domain by means of a discourse referent, which is established in the event address. The general format of verb-tensing is:

MERGE+APPL_e (DRS(TENSE), CRS(V))

This means that the verb-CRS in its event address is applied to the head variable of the Tense-DRS and then the MERGE-operation is performed. The index *e* is not really necessary since, because of the restriction just mentioned, there is no other abstracted variable than the event-variable. We first consider the simplest case of tense application, i.e. applying TENSE to the bare verb or the adverbially modified verb, and thus to the verb-CRS. (The other scope possibilities will be discussed later.)

If we use second order variables *P* for properties (i.e. the meanings of CRSs), we can employ the method of functional application: a tense DRS then has the form ' $[P][\mu] \Phi_\mu \& P(\mu)$ ' for some tense Φ , with Φ_μ as the condition on the tense discourse referent, i.e. the respective tense frame in the tense DRSs listed above. With this we assume as the categorial form of a tensed verb $\beta_{VT} : (\Phi_{TENSE}(\beta_V)_{VT})$, which translates into:

$$([P][\mu](\Phi_\mu \& P(\mu)))(\sigma) \beta(\sigma) = [\mu] \Phi_\mu \& \beta(\mu).$$

3.3. Case relationships as part of the nominal term

A possibility of analysis is to let the case relationship be part of the representation of the NT,*i*. This can be done syncategorematically:

$$jed- \alpha, i : [P][\mu][x] \alpha(x) \Rightarrow R_i(x, \mu) \& P(\mu)$$

$$ein- \alpha, i : [P][\mu][x] \alpha(x) \& R_i(x, \mu) \& P(\mu)$$

$$\alpha, i : [P][\mu][x] \alpha=x \& R_i(x, \mu) \& P(\mu), \text{ for } \alpha \text{ as a proper name.}$$

The lexical frame for the respective verb has to specify which cases are appropriate for the complements of the verb. *P* is a variable for the verb-CRS. This means that the verb is untensed. For tensed verbs we cannot use these NT,*i*-schemas, but have to use another schematic formulation. To formulate the connection between NTs and cases categorically we would need a variable *Q* for relations such as the CRSs of the cases which are of the form $[v, \kappa] R_i(v, \kappa)$. An NT-representation would then, for example, be:

$$[Q][P][\mu][x] \alpha(x) \Rightarrow Q(x, \mu) \& P(\mu), \text{ for } jed- \alpha, \text{ and}$$

$$[S][Q][P][\mu][x] S(x) \Rightarrow Q(x, \mu) \& P(\mu), \text{ for the quantifier } jed-. \text{ Hereby}$$

S is a variable for the noun-CRS.

According to this procedure of using case markings, the sentence *Eine Frau liebt jeden Mann*, which is of the categorial form (*Ein-Frau*_{NT,1}(*jed-Mann*_{NT,2}(*lieben*_v)), is a concept that will be bound to a situation by TENSE, which introduces an event that is characterized by this concept. In order to make a sentence out the complex verb whose representation is a CRS, tense is applied, which means that it has broadest scope in the example considered. According to the NT,i-rules above we get as a concept:

$[v][y]$ Frau (y) & R₁(y,v) & ([x] Mann(x) => R₂(x,v) & lieben(v)).

Using neutral tense, the representation of which is of the schematic form '[P][r] P(r)', we get as the final result:

$[r][y]$ Frau(y) & R₁(y,r) & ([x] Mann(x) => R₂(x,r) & lieben(r)).

According to this DRS there is a situation or constellation in which a woman loves every man, but no separate situation for every man as we would get from an analysis with smallest scope for tense. The procedure of keeping the case relations with the terms only provides for these interpretations in which tense has broadest scope. Likewise the sentence

Ein Mann löst einem Jungen jede Rechenaufgabe

'a man solves for a boy every math problem'

has broadest scope for tense in this method of construction. This would mean that there is a situation in which a man solves every math problem for the boy. In order to achieve the readings with smaller or smallest scope for tense, we need the construction methods in which the case relationship is made part of the verb.

3.4. Case relationships as parts of the verb

The other possibility of analysis is to take case relationships to be part of the verb. Here, we have to ways, namely to connect them with tensed verbs or with untensed ones.

3.4.1. Cases linked to tensed verbs

Let us, by way of example, first look at the linking procedure for building up DRSs from verbs and terms with case markings.

Ein Mann gibt einem Jungen jeden Apfel

'A man gives a boy every apple'

The German form of the subordinate clause is:

(weil) ein Mann einem Jungen jeden Apfel gibt

and in categorial form:

[ein Mann]_{T(1)}, [ein Junge]_{T(3)}, [jeden Apfel]_{T(2)}, [gibt]_{v(4)}]]]]

In a more explicit form with respect to case- and tense-information:
[ein- Mann, K1 [ein- Junge, K3 [jed- Apfel, K2 [geben, PRES]]]].

The first step is to form the DRS of the tensed (finite) verb from the verb-CR and the PRES-DRS, in accordance with the above rule schema.

MERGE+APPL ($[r] r \supset t_0, [s] \text{Geben}(s)$) = $[r] r \supset t_0 \ \& \ \text{Geben}(r)$.

Further, the lexical representation of *geben* has been copied from the lexicon into the buffer. Then the DRS associated with the NP *jed- Apfel* has to be formed, which is ' $[x] \text{Apfel}(x)$ ' which requires SUB for linking with the verb.

The next step is to link *jeden Apfel* with the tensed verb. This happens by means of the K2-information, which selects the R_2 -formula in the MP of the verb, and instantiates it in its participant address with the head variable of the DRS(*jed- Apfel*). Doing this we get as the DRS associated to the K2(NP, V):

DRS(K2): $[x] \text{Geben}(x) \Rightarrow R_2(x, x)$. This condition, actually, is too strong; we have to treat it as part of the preceding condition, which means that the R_2 -relation has also to be subordinated under $[x] \text{Apfel}(x)$, as:

$[\mu] \text{Apfel}(\mu) \ \& \ [x] (\text{Geben}(x) \Rightarrow R_2(\mu, x))$.

This K2-DRS is MERGED with the tensed verb-DRS. If we write \Rightarrow for SUB and $\&$ for MERGE we get as the

DRS(*jeden Apfel gibt*):

$[x] \text{Apfel}(x) \Rightarrow [r] r \supset t_0 \ \& \ \text{Geben}(r) \ \& \ ([x] \text{Apfel}(x) \ \& \ [r] \text{Geben}(r) \Rightarrow R_2(x, r))$.

This can be shortened according to the logical truth ' $(p \Rightarrow q) \ \& \ (p \Rightarrow s) \Leftrightarrow (p \Rightarrow q \ \& \ s)$ ' and ' $p \ \& \ (p \Rightarrow q) \Leftrightarrow p \ \& \ q$ ' into:

$[x] \text{Apfel}(x) \Rightarrow [r] r \supset t_0 \ \& \ \text{Geben}(r) \ \& \ R_2(x, r)$.

The associated DRS of *ein- Junge* is ' $[y] \text{Junge}(y)$ ' which requires MERGE for linking with the DRS of the (complex) verb. The K3-information from the MP in the buffer is, with respect to this NP and the verb, the DRS(K3): $[\mu] \text{Apfel}(\mu) \ \& \ [v] \text{Geben}(v) \ \& \ R_2(\mu, v) \Rightarrow R_3(y, v)$. This information is put in conjunction with the DRS of the (complex) verb derived in the previous step. By instantiation and the logical truth ' $(p \Rightarrow q) \ \& \ (q \Rightarrow s) \Leftrightarrow (p \Rightarrow q \ \& \ s)$ ' we get as the

DRS(*einem Jungen jeden Apfel gibt*):

$[y] \text{Junge}(y) \ \& \ ([x] \text{Apfel}(x) \Rightarrow [r] r \supset t_0 \ \& \ \text{Geben}(r) \ \& \ R_2(x, r) \ \& \ R_3(y, r))$

The associated DRS of *ein- Mann* is ' $[z] \text{Mann}(z)$ ' which requires MERGE for linking with the DRS of the (complex) verb. The K1-information from the MP in the buffer, with respect to the verb and this NP, is the DRS(K1):

$[x] \text{Apfel}(x) \ \& \ [r] \text{Geben}(r) \ \& \ R_2(x, r) \ \& \ R_3(y, r) \Rightarrow R_1(z, r)$.

This condition is put in conjunction with the DRS of the (complex) verb

derived in the previous step and we get as the

DRS(*ein Mann einem Jungen jeden Apfel gibt*):

[z] Mann(z) & [y] Junge(y) & ([x] Apfel(x) => [r] r ⊃ t₀ & Geben(r) & R₂(x,r) & R₃(y,r) & R₁(z,r)).

The general schema of linking nominal terms to tensed verbs by case relationships is, for any verb α' with α as its head and accordingly with '[...] ... [σ] α(σ) ...' as its associated DRS, and any term β with case marking Ki:

Schema for NT-VT-linking:

$$\text{DRS}((\beta, K_i)(\alpha'_{VT})_{VT}): [\mu] \beta(\mu) \left\{ \begin{array}{l} \& \\ \Rightarrow \end{array} \right\} [\dots] \dots [\sigma] \alpha(\sigma) \& R_i(\mu, \sigma) \dots$$

For each specific α the case relation R_i is specified according to the semantic relationship listed in the lexical frame of the verb, for example R₁= ACTOR OF, R₂= TRANSFERRED OBJECT OF, R₃= BENEFICIARY OF for the verb *geben* 'give', or R₂= RESULT OF for the three place verb *singen* 'sing'. These lexical specifications are conditions on the interpretation of the DRS.

With second order variables for properties we can use functional application according to the categorial form of terms like is done in Montague Grammar: a term translates into a CRS of the form '[P][μ] β_μ # P(μ)' with # as '&' in the case of existential quantifiers (including proper names), and '=>' in the case of universal quantifiers. The case marking Ki at the term makes the representation of the (complex) verb phrase α', which is of the form '[p]... α(p)...' to be '[σ] ... [p] ... α(p) & R_i(σ,p) ...', where α is the head verb of the verb phrase α'. This is the representation of K_i(α'). With this we can say that the categorial form (β_{T, Ki}(α'_V)_V) is reanalyzed as (β_T(K_i(α'_V)_{V, i})_V), and functional application is used according to this form.

3.4.2. Verb complements, verb modifiers and untensed verbs

Up to now we have linked the NTs to the tensed verb. We can also link NPs and untensed verbs together and tense whatever (complex) verb. If we provide for this, TENSE can have different scopes with respect to the NTs involved. The general schema for linking NTs in cases to verbs, whether tensed or not, is the following:

Schema for NT-V-linking:

$$\text{DRS}((\beta_T, Ki)(\alpha'_V)_V): [\underline{\sigma}]([\mu] \beta(\mu) \left\{ \begin{array}{l} \& \\ \Rightarrow \end{array} \right\} [\dots] \dots \text{CR}(\alpha)(\sigma) \& R_i(\mu, \sigma) \dots)$$

Also hereby, α , the basic verb, is the head of the (complex) verb α' , the form of which is: $\text{CRS/DRS}(\alpha') = [\underline{\sigma}] [\dots] \dots \text{CR}(\alpha)(\sigma) \dots$. It is a concept in σ , and with respect to the other variables a DRS. If the verb α' is already tensed, then the associated CRS/DRS is a DRS, i.e. it is also a DRS with respect to σ .

The general schema for TENSE-application is, for whatever untensed verb, with α as the (complex) verb and $[\kappa] \beta_\kappa$ as the TENSE-DRS:

$$[\kappa] \beta_\kappa \& \alpha(\kappa).$$

By using these general rule schemas we receive interpretations in which all the instances of interpretation of a general quantifier NT are tied to one pre-established event. If we assign the scope of PRES in the following way *[ein Mann/einem Jungen(PRES[jeden Apfel gibt])]*, then for a man and a boy and a certain present event it is true that with respect to each apple this is an event of the man giving the boy the apple. If we apply PRES with even broader scope, in this case nothing is changed because the other NPs are existential and not general. If TENSE has broader scope than a general quantifier NT the interpretation of the NT has to be tied down to the situation fixed by TENSE: it does not make sense to consider whatever apple in the world in a case like this. The domain of the general quantifier has to be restricted to what is present in the situation selected by TENSE. The rules of interpretation of DRSs should take care of this generally: If the scope of an event discourse referent includes other introduced discourse referents, their assignment should be restricted to individuals participating in the event. This notion of participation involves a local aspect and not only a temporal one. An individual is part of a situation or event, if the situation or event is, under some perspective of participation, part of the life history of the individual:

$[x][r]$ participant(x, r) $\Rightarrow [\Delta] x \supset \Delta(r)$; the relation Δ can be any relationship that makes x participate in the event r . For things it usually means at least a local presence at the place of the event or some relevant causal connection with it. This condition about participants has to be a general restriction on assignments for variables of DRSs.

However, this notion of participating in a situation remains rather vague and it might, after all, be better to restrict tensing to the basic verb, i.e.

to the head verb, where it also appears in natural language morphology. This means that TENSE would have smallest scope with respect to the verb's complements. Verb-modifiers, such as manner adverbials (and also instrumental and cooperational adverbials) can be within the scope of TENSE without any problems, like adnominals are within the scope of the determiner (quantifier). This does not preclude that adverbials can also be applied to the tensed verb, which is the case when manner adverbials, instrumental, cooperational, durative and local and directional adverbials are used as appositions to the verbs in *Hans schrieb, und zwar schön*, comparable to adterminal appositions as in *Elisabeth, queen of England*, and adjectives with respect to proper names in English, like *poor* in *poor John*. Certain kinds of adverbials, namely relational adverbials (temporal, concessive, adversative, causal) are regularly applied to the tensed simple or complex verb, especially when they are expressed by adverbial clauses.

An adjective, and generally an adphrase, can be used predicatively with the auxiliary verbs 'to be' and 'to become', or German *sein* and *werden*. It can also be used adnominally, adterminally or adverbially. For these different syntactic uses we have the following DRS-schemas:

$(\textit{sein}_{\text{AUX}}(\alpha_{\text{AD}})_v): [\mathbf{y}] \alpha(v)$

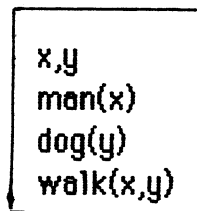
$(\alpha_{\text{ADV}}(\beta_v)_v): [\mathbf{y}] \alpha(v) \& \beta(v)$

$(\alpha_{\text{ADN}}(\beta_N)_N): [\mathbf{y}] \alpha(v) \& \beta(v)$

$(\alpha_{\text{ADT}}(\beta_T)_T): [v] \alpha(v) \& \beta(v)$, with v as the head variable of the DRS of the term β . For adverbials and adnominals we can use functional application. Then the adverbial and the adnominal translate in the following way:

$\alpha_{\text{ADX}}: [\mathbf{P}][\mathbf{y}] \alpha(v) \& P(v)$, whereby $X := V, N$. The auxiliary verb can be translated into $[\mathbf{P}][\mathbf{y}]P(v)$, or simply $[\mathbf{P}]P$.

In the above schemas we made use of the notion 'head verb' or 'head noun' and 'head variable', which is the discourse referent used in the CRS/DRS of the head noun or head verb. These notions are important if we have a complex NP or VP in which several discourse referents occur, as, for example, is the case when a relative clause or prepositional phrase that contains further NPs is part of the complex NP. The DRSs of Kamp's (1984) DRT do not make any difference between head variables and other variables; they are all members of a set of discourse referents. This means that in the DRS the information gets lost that a relative clause is subordinated to the noun which it modifies. The DRS associated with the phrase 'a man who walks a dog' is $\langle \{ \text{man}(x), \text{dog}(y), \text{walk}(x,y) \}, \{x,y\}, \emptyset \rangle$, or in box form:



or linearly: $[x,y] \text{ man}(x); \text{ dog}(y); \text{ walk}(x,y)$

Such a representation does not show that the discourse referent for *a man* is the head variable, and not the one for *a dog*. This information is not only necessary for the syntax, i.e. within sentences, when we construct a sentence compositionally, but it is also necessary on the text level to explain anaphoric relationships between NPs and pronouns, like in the text *Ein Mann, der einen Hund ausführt, steht vor der Tür. Er bellt.* 'A man who walks a dog is standing in front of the door. He barks.' In German (where *Mann* and *Hund* have both male grammatical gender) the pronoun can refer, as far as morphology is concerned to the man, as well as to the dog. Syntactic form requires that it is coreferential with the phrase *ein Mann*, which is the head of the construction. This syntactic requirement makes the text funny, because it says that the man is the one who barks. The pronoun has to get the head variable x as its discourse referent and not the variable y , as the semantics of the verb would suggest. Here syntactic form overrules lexical semantic information. The natural language syntactic form which makes a difference between the status of the referents for the phrases *ein Mann* and *ein Hund* in the above text should be reflected in the DRS associated with the whole noun phrase by providing wide scope for x such that the DRS consists of the discourse referent $[x]$ and a condition on x in which the DRS associated with *der Hund* is included. In the next section the syntax will be formulated in such a way that it takes care of the difference between heads and modifiers or complements. In principle, the syntax of the DRSs is arranged according to categorial structure, and follows basically the methods of Montague Grammar. The semantics will be formulated following Groenendijk and Stokhof 1987 (ms.), who developed a semantics for a dynamic predicate logic, which is a certain form of DRT with the advantage of being compositional.

In the above procedure we reanalyzed the categorial structure (NT, i (VT)) such that the case relationship was linked to the verb and we got (NT(VT, i)). We reached into a complex verb representation from the outside to link the case-relationship by conjunction to the representation of the head verb α . This was a sound procedure because a general form of condition from the verb-MP, i.e. $[x] \alpha(x) \Rightarrow R_1(v,x)$, instantiated with respect to the head variable v of the NT, i -DRS (that is linked to the verb phrase), expresses the case-relationship. This condition was further restricted by the antecedence conditions found in the representation of the

complex verb of which α is the head. In order to avoid such syntactic manipulations (although they were semantically sound), I shall later (3.6) propose as an alternative a purely semantic treatment of the case-information, without an intermediate representation on the DRS-level.

3.5. A version of dependency grammar

I shall now present a method that is a variation of dependency grammar: We build up the verb phrase with all the case relations needed in the sentence. To do this we need global information about which are the cases and which is the order of the terms with respect to the verb. This method allows easily for every scope of Tense.

In sentence production there is an restriction to the order of the NT,*i*'s with respect to each other: In German, the nominative term has to be highest in the order of application, except for a possible (other) topicalized expression (another NT or an adverbial). This means that the NT,*l* has first or second place from the top in the order of application of complements and adverbial to the verb. The main clause word order in German is basically the same as in subordinated clauses, except that the finite verb is in second position instead of in end position. This way the verb phrase is discontinuous in main clauses. Second position is the position after topic position, which is first position and can be filled by verb complements (NPs and Infinitives) or adverbials (including adverbial clauses).

The global information about the cases and the order of terms needed can be expressed and used according to the following **schema of re-analysis** of a sentence in categorial form:

$$\begin{aligned} (\alpha_{T,j}(\beta_{T,j}(\gamma_{T,k}(\delta_{VT} \lambda_{VT} \lambda_{VT} \lambda_{VT}))) &= (\alpha_T(\beta_{T,j}(\gamma_{T,k}(K_i(\delta_{VT} \lambda_{VT,i})))) = \\ (\alpha_T(\beta_T(\gamma_{T,k}(K_j(K_i(\delta_{VT} \lambda_{VT,i} \lambda_{VT,i,j})))) &= (\alpha_T(\beta_T(\gamma_T(K_k(K_j(K_i(\delta_{VT} \lambda_{VT,i} \lambda_{VT,i,j} \lambda_{VT,i,j,k})))))) \end{aligned}$$

For any (tensed) verb δ of the category VT,*K* with the representation $\delta_{\sigma}^* = [X][\sigma] \delta_{\alpha X}, (K_i(\delta_{VT,K}) \lambda_{VT,K \cup i})$, with *X* as the set of variables corresponding to the cases *K*, has the representation $[y] \delta_{\alpha X}^* \& R_i(v,\sigma)$, for $i = i, j, k$. The term-representations are as before, except without the case relationship, i.e. just parallel to the translations of terms in Montague Grammar. Let $\alpha^*, \beta^*, \gamma^* \beta^*$ be the representations of the respective terms involved. The representation of a sentence of the above categorial form then is:

$$(\alpha^*(\beta^*(\gamma^*([\kappa][\mu][y][\sigma] \delta(\sigma) \& R_i(v,\sigma) \& R_j(\mu,\sigma) \& R_k(\kappa,\sigma))))))$$

We can also formulate this without a fixed order of abstraction: If a verb δ is a VT,*K* with the set of case markings *K* and $i \in K$, then

$(\alpha_{NT,i}(\delta_{VT,K})_{VT,K-(i)})$.

The representation then is: $[(X-\{x_i\}) \alpha^*([x_i] \delta^*_x)]$, where δ^* is the DRS of the verb with its case relations according to the set of case markings K. The set of participant variables of the case relationships is $X = \{x_i, x_j, x_k\}$.

According to this method TENSE always has smallest scope. It is possible to apply TENSE not to the head verb, but at any place in the categorial hierarchy. To do this we treat TENSE on a par with NTs. In the above schema for sentence construction with three NTs, TENSE can have NT,k, or NT,k and NT,j, or NT,k, NT,j, and NT,i in its scope. In order to achieve this, the NTs have also be applicable to untensed V. The representation of the untensed head verb δ is $[\sigma] \delta(\sigma)$, and of an untensed verb with cases K it is $\delta^* = [X, \mu] \delta_{\mu, X}$. Then $(K_1(\delta_{V,K})_{V,K \cup i}) = [y][X, \mu] \delta_{\mu, X} \& R_1(v, \mu)$.

A three-place untensed verb δ , e.g., has the representation $[x, y, z, \mu] \delta^* := [x, y, z, \mu] \delta(\mu) \& R_1(x, \mu) \& R_2(y, \mu) \& R_3(z, \mu)$. A tense β has a representation of the form $\beta^* = [P][\sigma] \beta_\sigma \& P(\sigma)$. Then, $(TENSE(\alpha_{V,K})_{VT,K})$ has the representation $[X] \beta^*([\mu] \delta^*_{\mu, X}) = [X][\sigma] \beta_\sigma \& \delta_{\sigma, X}$, where δ^* is the representation of the verb with the set of cases K, and X as the set of participant variables of the respective case relations, and μ as the event variable.

The advantage of this method of construction is that it provides for all possible scopes of TENSE, and that it does not create any binding problems. Its drawback is that it needs global information about which verb complements in which cases are used with the verb in the sentence, in order to construct the verb with the right case relationships.

The advantage of having several possibilities for the scope of TENSE is that this permits us to treat coreference of event-pronouns with the whole content of the scope of TENSE. Such a representation within a scope of TENSE refers to a situation (event). Consider the following examples:

Ein Mann löst jedem Jungen jede Aufgabe. Wie dies geschieht mißfällt dem Lehrer.

'A man solves for each boy every math problem. How this is done is disapproved of by the teacher.'

Here, *dies* 'this' is anaphoric to the whole preceding sentence. A suitable discourse referent is secured by giving tense broadest scope:

$TENSE(\textit{Ein Mann jedem Jungen jede Aufgabe lösen})$.

(Note, that the sentence can also have a fact-interpretations, no matter how broad the scope of TENSE is.)

Ein Mann löst jedem Jungen jede Aufgabe. Das kostet ihn viel Zeit.

'A man solves for a boy every math problem. This takes him much time.' In this example, *das* 'this' is anaphoric to *löst jedem Jungen jede Aufgabe*.

If we let TENSE have this phrase in its scope there is one situation in which a man solves every problem for every boy:

(*Ein Mann*(TENSE(*jedem Jungen jede Aufgabe lösen*))).

Ein Mann löst jedem Jungen jede Aufgabe, was dem jeweiligen Jungen gefällt.

'A man solves for each boy every math problem, which pleases the respective boy.'

Here, *was* 'which' is anaphoric to *jede Aufgabe löst*. If we take only this phrase as the scope for TENSE we refer, for every boy respectively, to a situation in which the man solves every problem for this boy:

(*Ein Mann jedem Jungen*(TENSE(*jede Aufgabe lösen*)))

Ein Mann löst jedem Jungen jede Aufgabe. Das ist nicht immer einfach.

'A man solves for each boy every math problem. This is not always easy.'

Here, *das* 'this' is anaphoric to solving a single problem. The scope for TENSE is smallest:

(*Ein Mann einem Jungen jede Aufgabe* (TENSE(*lösen*))).

The application of TENSE with a certain scope means that the situation described by the phrase within the scope is referred to.

In fact-interpretations, a pronoun can corefer with any VT in the preceding sentence, though not with an untensed verb. TENSE(*jede Aufgabe lösen*), for example, gives rise to different interpretations. The pronoun either refers to the **fact** that there is a situation in which every problem gets solved (i.e. the boy is pleased that there is a situation in which every problem is solved) or to the **situation** itself (i.e. the boy is pleased about the situation in which every problem is solved, for example by the elegance and quickness of the problem solving). If the pronoun corefers with the VT *jede Aufgabe*(TENSE(*lösen*)) it refers to the fact that for every problem there is a situation in which it gets solved.

This means that the pronoun may refer not only to a situations itself but it also may refer to a fact, namely that there are certain situations or constellations of situations. On the DRS-level facts are constants, namely propositions. Pronouns can be coreferential with constants. In a representation of a pronoun the identity with a constant is expressed, for example: [P] P = DRS(*jedem Jungen (jede Aufgabe* (TENSE(*lösen*)))) whereby P is a variable over facts which are with respect to a world non-empty sets of situations in this world, or of pairs of (partial) assignments where the second makes the VT-DRS true on the basis of the first (which is the one that makes the preceding context true). Note, that fact variables are of quite a different type than event (situation) and individual variables. They are of the semantic type "proposition", namely 'true proposition', i.e. under the presupposition that the set of pairs of true making assignments is not empty. (Remind the difference between facts and on the other hand events, processes, states, constellations! Facts are relations between

representations and the world, i.e. true making assignments, but situations, events, states, processes, and individuals are in the world.)

3.6. Non-syntactic linking by case-relationships as conditions on interpretation

Semantically speaking, a case K_i of a nominal term β places an extra condition on the variable of the head verb, namely the interpretation of $R_i(v, \mu)$ with v the head variable of β and μ the variable of the head verb. The cases are thus conditions on every assignment for both these variables. This means, there is no need for formulating these conditions in syntax as we have done above. We can have simple syntactic rules and additional conditions on interpretation. Actually, the lexical frame in the buffer can just be instantiated with the variables of the DRS; it functions as a whole (with the case relationships included) as a condition on every assignment. For a nominal term β and a simple or complex tensed verb α , we have for the categorial structure $(\beta_{T,ki}(\alpha_{VT})_{VT})$ as the associated DRS: $\beta^*(\alpha^*)$ with the condition $R_i(v, \mu)$, whereby $v :=$ variable of the head noun of β , and $\mu :=$ variable of the head verb of α . Hereby, β^* and α^* are the DRSs associated with α and β respectively. In case the verb is tensed, we use a variable P over DRSs in the schemas for nominal terms:

jed- $\beta, i : [P][x] \beta(x) \Rightarrow P$

ein- $\beta, i : [P][x] \beta(x) \& P$

$\beta, i : [P][x] x = \beta \& P$, for β as a proper name.

For a sentences of the categorial form $(\alpha_{T,i}(\beta_{T,j}(\gamma_{T,k}(\delta_{VT}))))$, with α as the head verb, the DRS is simply $\alpha^*(\beta^*(\gamma^*(\delta^*)))$, with the condition: $\delta^*(v) \Rightarrow R_1(\mu, v), R_2(\kappa, v),$ and $R_k(\tau, v)$, and with μ, κ, τ as the head variables of α, β, γ respectively, and v as the head variable of δ . These conditions are fixed within the lexical frame of the head verb in the buffer. This means that in the interpretation of the DRS we take care of the case-conditions as restrictions on the assignments of the respective variables, together with other conditions that might be part of the lexical frames involved, such as the specifications of the R_i -relations. The lexical frames selected with regard to a text, and instantiated by identifying variables with the corresponding variables in the DRS on the basis of variable introduction by determiners and TENSE and by case-information, are conditions on every truthful embedding of the DRS. They represent features of the situations

which are part of the constellation that make a text true. If only conjunctions, and no subjunction, negation, or disjunction is involved, the situation represented by the instantiated frame of the head verb is identical with the constellation. If a subjunction is involved (e.g. because of a universal quantifier), the situations represented by the instantiated verb frame are identical with the situations by which, with the antecedence the consequence is made true. The constellation reported by a subjunction requires that every situation which makes the antecedence true also makes the consequence true.

This method is also available for untensed verbs. Here we have the following schemas for nominal terms:

jed- $\beta, i : [P][\mu][x] \beta(x) \Rightarrow P(\mu)$

ein- $\beta, i : [P][\mu][x] \beta(x) \& P(\mu)$

$\beta, i : [P][\mu][x] x = \beta \& P(\mu)$, for β as a proper name.

Instead of $\alpha^*(\delta^*)$ for a term α and a verb δ , we then have $[\mu] \alpha^*(\delta^*(\mu))$, with the same restrictions on interpretation as above. The case-condition is $\alpha(\mu) \Rightarrow R_1(v, \mu)$ with v and μ as the head variables of the NT, i and the head verb, respectively. These variables are introduced by the noun phrase determiner and by TENSE, respectively.

We will use this method of semantic linking between nominal terms and verbs in the next section.

3. Towards a compositional syntax and semantics of DRSs

Up to now we used the connectives '&' and '=>' for the operations MERGE and SUB between DRSs, which in the special case that no new variables are used in the second part of the operation amount to:

$$[\mu] \xi_\mu \& \zeta_\mu = \langle \{\xi_\mu\}, \{\mu\}, \emptyset \rangle \text{ MERGE } \langle \{\zeta_\mu\}, \emptyset, \emptyset \rangle$$

$$[\mu] \xi_\mu => \zeta_\mu = \langle \{\xi_\mu\}, \{\mu\}, \emptyset \rangle \text{ SUB } \langle \{\zeta_\mu\}, \emptyset, \emptyset \rangle$$

In these cases we have just the well known predicate logic connectives; if the conjunction has as its semantics the intersection of the sets of assignments that make the conjuncts true, it is commutative, not only in this special case, but also in the general case $[\mu] \xi_\mu \& [\nu] \zeta_\nu = \langle \{\xi_\mu\}, \{\mu\}, \emptyset \rangle \text{ MERGE } \langle \{\zeta_\nu\}, \{\nu\}, \emptyset \rangle = [\mu, \nu] \xi_\mu \& \zeta_\nu$. The conjunct is true, if the intersection of verifying assignments is not empty. But the semantics of SUB cannot generally be defined by just an operation on the two respective sets of assignments; rather we have, in the semantic definition, to refer to the variables in the antecedence and in the consequence. In the special case above, truth of the subjunction could be defined by the condition that the set of verifying assignment of the antecedent is comprised by the set of those that verify the consequence. But in general, where new variables may occur in the consequence that definition does not suffice. In the general case $[\mu] \xi_\mu => [\nu] \zeta_\nu = \langle \{\xi_\mu\}, \{\mu\}, \emptyset \rangle \text{ SUB } \langle \{\zeta_\nu\}, \{\nu\}, \emptyset \rangle$, a set of assignments that makes the subjunction true is $\{g \mid \text{for all } f \text{ that deviate from } g \text{ at most in their value for } \mu \text{ and } f \text{ verifies } \xi \text{ it holds that there is an } h \text{ that deviates from } f \text{ in at most the value of } \nu \text{ and that verifies } \zeta\}$. Groenendijk and Stokhof (1987 ms) provide a dynamic semantics in which the interpretation of a formula relative to a preceding text is a relation which is the set of pairs of assignments such that the first member makes true the preceding text and the second makes true the formula on the basis of the first assignment. The conjunction '&' is not commutative in this semantics, except for special cases, because the semantics of the second conjunct is influenced by the semantics of the first conjunct: If for a conjunction ' $\alpha \& \beta$ ' an assignment h makes the first conjunct true then for the second conjunct only an assignment k is admissible that deviates from h in at most those values which it assigns to the new variables of the second conjunct. If β is true for such a k , we say '**k makes β true on the basis of h** '.

In short, the semantics of a formula is, according to Groenendijk and Stokhof, a relation, i.e. a set of pairs of assignments, where the the second member of the pair makes the formula true on the basis of the first

member. The first member is the assignment which made the preceding formula true on the basis of the one that made the pre-previous one true. It is an important point that this semantics makes an essential difference between static expressions (conditions, especially also atomic formulae) and DRSs in which new discourse referents are introduced that can be used further in the text as pronouns. Discourse referents within a condition cannot bind variables outside the condition (i.e. cannot systematically corefer with them); i.e. a condition does not introduce a new discourse referent in a text but only adds restrictions to the assignment of old discourse referents. Semantically a condition is defined by Groenendijk and Stokhof as a formula the assignment relation of which is the identity relation, i.e.

A formula ϕ is a **condition** iff for all $\langle g, h \rangle$, $\langle g, h \rangle \in \|\phi\|$ then $g = h$. Here $\|\cdot\|$ is used for dynamic interpretation.

Thus conditions do not contribute to the dynamics of a text in terms of discourse referents. Next to atomic formulae, all negated formulae and all subjunctives are conditions. The dynamic interpretation of formulae has been introduced by Groenendijk and Stokhof to make possible a compositional construction of DRSs, not different from the syntax of predicate logic, which can now be used as the syntax of DRSs.

The semantics of the conjunction:

$\|\alpha \& \beta\| =_{\text{def}} \{ \langle g, h \rangle \mid \text{there is a } k \text{ such that } k \text{ makes } \alpha \text{ true on the basis of } g \text{ and that } h \text{ makes } \beta \text{ true on the basis of } k \}$.

The semantics of the subjunctive:

$\|\alpha \Rightarrow \beta\| =_{\text{def}} \{ \langle g, h \rangle \mid h = g \text{ and for all } k \text{ that make } \alpha \text{ true on the basis of } h, \text{ there is a } j \text{ that makes } \beta \text{ true on the basis of } k \}$.

The semantics of negation:

$\|\neg\phi\| = \{ \langle g, h \rangle \mid h = g \text{ and there is no } k \text{ with } \langle h, k \rangle \in \|\phi\| \}$.

In order to be somewhat complete, I shall also present Groenendijk and Stokhof's definition for the semantics of disjunction, existential and universal quantification.

The semantics of disjunction:

$\|\phi \vee \psi\| = \{ \langle g, h \rangle \mid h = g \text{ and there is a } k \text{ with } \langle h, k \rangle \in \|\phi\| \text{ or } \langle h, k \rangle \in \|\psi\| \}$. Furtheron we use ' $g[x]h$ ' as short for 'h differs from g in at most the value of x'.

The semantics of the existential quantifier:

$\|\exists x \phi\| = \{ \langle g, h \rangle \mid \text{there is a } k \text{ with } g[x]k \text{ such that } \langle k, h \rangle \in \|\phi\| \}$. In the special case that ϕ does not contain any other new variables, $k = h$. Thus $\|\exists P(x)\| = \{ \langle g, h \rangle \mid \text{with } g[x]h \text{ and } h(x) \in F(P) \}$, where F is the interpretation function.

The **semantics of the universal quantifier**:

$$\| \forall x \phi \| = \{ \langle g, h \rangle \mid h = g \text{ and for all } k \text{ with } h[x]k: \langle h, k \rangle \in \| \phi \| \}.$$

Other than in predicate logic, the following equivalences hold in dynamic predicate logic:

$$\exists x \phi \ \& \ \psi \quad \Leftrightarrow \quad \exists x [\phi \ \& \ \psi]$$

$$\exists x \phi \Rightarrow \psi \quad \Leftrightarrow \quad \forall x [\phi \Rightarrow \psi]$$

In the preceding section, we already made use of these and the following equivalence:

$$\forall x [\phi \ \& \ \psi] \quad \Leftrightarrow \quad \forall x \phi \ \& \ \forall x \psi$$

For more details and comparison with predicate logic cf. Groenendijk and Stokhof (1987 ms).

In what follows I shall not adopt Groenendijk and Stokhof's use of the existential and universal quantifier but instead use a uniform $[x]$, which amounts to the existential quantifier, in order to keep continuity with the previous sections.

The semantics of the conjunction '&' is, other than the one of the predicate logic conjunction, not commutative, because the semantics of the second conjunct depends on whether it contains discourse referents that are newly introduced, next to the ones that have been introduced before. Only if the second conjunct does not contain new discourse referents, we have $h = k$. For changing the order of the two conjuncts (without any semantic change) it is, additionally, necessary that also the first conjunct does not contain any other newly introduced discourse referents than those that also figure in the second conjunct. The conjunction '&' is commutative, i.e. $\alpha \ \& \ \beta = \beta \ \& \ \alpha$, only if both conjuncts contain with respect to the preceding text the same newly introduced discourse referents.

Groenendijk and Stokhof (1987 ms) use total assignments. In order to take into account partiality, as is done in Kamp 1981/84, Heim (1983), which makes true making assignments correspond with situations like in Barwise and Perry's Situation Semantics (1983), we have to think of assignments as partial functions and of h in $g[x]h$ as an extension of the partial assignment g , i.e. $h = g \cup \{ \langle x, h(x) \rangle \}$.

We have the following **classes of phrases** in the grammar:

Nominal phrases or noun phrases: quantified and unquantified ones, with case markings and without case markings.

Verbal phrases or verb phrases: tensed and untensed ones.

Adphrases: adjectival and adpositional (prepositional and postpositional) phrases, relative clauses.

In the **categorial syntax** we have the following **categories**:

1. Common nouns and untensed verbs (basic as well as complex), simply

called: nouns and verbs, i.e. **N**, **V**.

2. Adnominals and adverbials, **AN** and **AV**, which are **N/N** and **V/V**, respectively. Adphrases (adjectives and adpositional phrases generally can be used in these categories). Likewise relative clauses and adverbial clauses can be of type **N/N** and **V/V**, respectively.

3. Auxiliary verbs, **AUX**, which are **V/AD**, i.e. which make a verb when applied to an adphrase.

4. Quantified nouns (incl. proper names) and tensed verbs, also called: nominal terms and verbal terms, i.e. **NT**, **VT**. Special subclasses are the proper names, determiners, demonstratives and pronouns of category **NT**, and the demonstratives and pronouns of category **VT**. They are formed from determiners and nouns, and from Tenses and verbs, respectively. To do this categorically, we need categories for Determiners and Tense, which are **DET** (= **NT/N**) and **TENSE** (= **VT/V**).

5. Appositions, i.e. adterminal modifiers **ANT** (= **NT/NT**) and **AVT** (= **VT/VT**). These can be like under (2) all kinds of adphrases, for example *jung oder alt* 'young or old' in *Jeder Mann, jung oder alt, ist eingeladen*. Also relative clauses can be **ANT**, and adverbial clauses can be **AVT**.

6. It depends on the treatment of cases chosen whether we take **NT_i** or **VT_i** to be categories. If we do the latter, we have the following options:

$(\alpha_{NT,i}(\beta_V)_V)$, or $(\alpha_{NT,i}(\beta_{VT})_{VT}) \Rightarrow (\alpha_{NT}(K_i(\beta_{VT})_{VT,i})_{VT})$, with '=>' symbolizing the re-analysis. Cases thus can be treated as categories **K** (= **NT_i/NT**, or **VT_i/VT**).

The **head** of a verb phrase or a noun phrase is the deepest embedded noun or verb, i.e. the noun or verb which is the base of the construction of the phrase. It determines the category of a construction that can be a modification of the noun or verb (and thus again is a noun or verb), or a specification of the noun or verb (and is thus a quantified noun phrase or tensed verb phrase), i.e. a nominal or verbal term. If an auxiliary is used, Adphrase+Aux together form the deepest embedded verb, i.e. the head verb.

ad 1: Common noun phrases, untensed verb phrases, and adphrases have proper-ties as meanings. Their associated representations are concept represent- ations (CRSs). The associated representations of quantified noun phrases (NTs) without cases and of tensed verb phrases (VTs) without cases are discourse representations (DRSs). The syntax contains morphological case markings (or pre- or postpositions instead) which are two-place relations and thus have associated concept representations. They link the representation of a nominal term to the representation of a verb by means of the relationship indicated by the case marking. They are syntactic functions that achieve a semantic content via the lexical

representation of the verb in question. Semantically they are relations between value assignments to the respective variables of the nominal term and the verb.

ad 2: $(\alpha_{AX}(\beta_X)_X) : \alpha_{AX}^*(\beta^*)$, where α^* and β^* are the representations of α and β , respectively. Hereby, the representation of the adphrase α in the categories AX is: $\alpha_{AX}^* = [P][\mu] P(\mu) \& \alpha^*(\mu)$, for $X := N, V$. P is a variable over properties, expressed here by the noun and verb, respectively. With this the representation of $\alpha_{AX}(\beta_X)$ amounts to $[\mu] \beta^*(\mu) \& \alpha^*(\mu)$.

ad 3: $(\alpha_{V/AUX}(\text{sein}_{AUX})_V)$ has the associated CRS: α^* , where α^* is the CRS of the adphrase α . With the representation of *sein* as $\underline{P}(P)$, and $[P]P(\alpha^*)$ as the representation of the adphrase α in the category V/AUX , P as a variable of properties of properties, and P as a variable of properties, $[P]P(\alpha^*)(\underline{P}(P)) = \alpha^*$.

ad 4: If we construct the DRSs such that the case relations are part of the verb we have the following syntactic rules or schemata with their translations into CRSs or DRSs.

$(\text{ein-DET}(\alpha_{N/NT})) : [P][v] \alpha^*(v) \& P(v)$, with P as an address for a variable of second order, i.e. a variable for CRs.

$(\text{jed-DET}(\alpha_{N/NT})) : [P][v] \alpha^*(v) \Rightarrow P(v)$

For every proper name α :

$\alpha_{NT} : [P][v] v = \alpha \& P(v)$, or with constants for proper names, for example a for α , we have $[P] P(a)$.

The categorematic introduction of determiners as an alternative to the above syncategorematic one is straight forward: $[Q][P][v] Q(v) \& P(v)$, and $[Q][P][v] Q(v) \Rightarrow P(v)$, respectively.

Tensing of verbs is: $(\beta_{TENSE}(\alpha_V)_{VT})$, with the associated DRS $[\kappa] \beta_\kappa \& \alpha(\kappa)$. The categorematic introduction of TENSE is $[P][\kappa] \beta_\kappa \& P(\kappa)$, for a tense β and P as a variable over verb-CRSs. The frames β_κ are given in section 2.3 of this paper.

The categorial structure $(\alpha_{NT,i}(\beta_{VT,i})_{VT})$ is re-analyzed as $(\alpha_{NT}(Ki(\beta_{VT,i})_{VT,i})_{VT})$.

$(Ki(\beta_{VT,i})_{VT,i}) : [\gamma] \dots [\mu] \dots \gamma(\mu) \& R_i(v, \mu) \dots$, whereby γ is the head verb of the verb phrase β , which means that the DRS/CRS/condition β_μ is of the form $[\mu] \dots \gamma(\mu) \dots$.

$(\alpha_{NT,i}(\beta_{VT})_{VT}) = (\alpha_{NT}(\beta_{VT,i}) : \alpha^*(\beta^*))$, whereby β is represented as β^* according to its category marker VT,i , i.e. it has the case-relationship R_i incorporated under the variable of its head verb.

Instead of the syntactic manipulation we can formulate the case relation as a condition on variable assignments. Then the categorial structure $(\alpha_{NT,i}(\beta_{VT})_{VT})$ is re-analyzed as $(\alpha_{NT}(\beta_{VT})_{VT})$ with the condition K_i (cf. section 2.3.6).

If we take the case-relationship to be part of the noun, the DRSs associated with the noun phrases have a variable over relations incorporated. This method requires untensed verbs, tensing has to be done at the end of the sentence or clause construction, and thus TENSE has broadest scope.

The **relative pronoun** *der/die/das* 'who' has the representation $[P][\mu] P(\mu)$, which is a CR without any condition, i.e. its semantics is the set of all pairs $\langle g, h \rangle$ with $g = h$. This is due to the fact that the relative clause is an adnominal or adterminal, which makes the relative pronoun to be an uncomplete adnominal or adterminal: as soon as it is linked with a verb phrase by a case it becomes a complete adnominal, i.e. acquires a condition.

$(\alpha_{RelProN,i}(\beta_{VT})_{AN}) = (\alpha_{RelProN}(\beta_{VT,i})_{VT}) : ([P][\mu] P(\mu))(\beta^*) = [\mu] \beta^*(\mu)$, where $\beta^* = [p][v] \dots \gamma^*(v) \& R_i(p,v) \dots$, with γ as the head verb of β .

Later I shall treat the relative pronoun like every other pronoun. It is then just a variable μ , and thus has the representation $[P] P(\mu)$.

The treatment of **pronouns** generally requires a procedure for determining coreference, a careful formulation of which would require a study of a lot of recent writings in theoretical linguistics in several linguistic schools. I therefore can only give an outline of such a procedure. The **representation of pronouns** is of the form $[P] P(\mu)$, whereby the variable that has to be filled into the address μ must be determined according to the procedure. This procedure takes into account morphological information (grammatical gender and number), global syntactic information, where it still is an open question whether this information has to take into account the surface structure including word order, or the categorial structure, or the level of discourse representation, or which two of these, or even all three. Further, lexical information plays a role, as well as situational information, certainly for demonstrative pronouns. All the different relevant kinds of information can be represented as restrictions on the determination of coreferentiality, or as restrictions on the possible assignments for the pronoun variable μ .

In the previous chapter I discussed different options for dealing with cases. The options were to either connect the cases with the NTs or with the VTs. The connection of cases with tensed verbs (VTs) meant that scope for tense was the smallest possible, which was adequate for many sentence meanings. On the other hand, this created some problems with binding the event variable in a case relationship if the head verb appeared in the consequence of a subjunction. The problems could be overcome, but required a conditionalizing of the case relationship with respect to the antecedence and the consequence of the subjunction involved. Under these conditions the case relationship could be incorporated into the consequence in conjunction with the representation of the head verb. This procedure is alright, but it is not context-free: it depends on the representation structure of the complex verb to which the case relationship has to be linked. Other methods were unproblematic with respect to compositionality. These are all the methods in which the verb is untensed and tensing happens last, after the whole sentence-concept is constructed. In these cases TENSE has broadest scope. These methods can be used by linking the case relationships to the NT, or by linking them to the untensed simple or complex verbs. To provide for a smaller scope for TENSE meets the binding problems mentioned above. But there is one method that does not create any problems for all possible scopes of TENSE, and this is the approach where the verb with all the case relationships necessary in a particular sentence is constructed first, before the NTs are applied in a fixed, or in a free, order. This is a version of the dependency-grammar approach, that has the only disadvantage that one needs global information about the sentence before one can construct the verb that fits the sentence in question (qua valency). In the previous chapter I presented a general procedure of re-analysis of a sentence which results in the construction of the right kind of verb representation. In this chapter I shall use the semantic method of treating case relationships as conditions on variable assignments which are formulated not in syntax but in the instantiated lexical frame of the verb in the buffer. These conditions are activated as soon as the interpretation gets to the respective head-verb conditions in the text-DRS.

Let us now consider an example:

Ein Mann, der seinem Hund liebt, gibt ihm Chappy. Dem Hund gefällt das.

'A man who loves his dog feeds him Chappy. The dog likes that.'

and after that the text with a universal quantifier:

Jeder Mann, der seinen Hund liebt, gibt ihm Chappy. Dem Hund gefällt das.

In the second text, coreference between *his dog* and *the dog* cannot be established in accordance with discourse representation theory or dynamic predicate logic. Even if we assign the same variable to both, the occurrence of the variable in the second sentence will not be bound by the quantifier in the first. It is a case of 'modal subordination', which Roberts 1987 discusses and for which she suggests a syntactic solution, which in this case would amount to analyzing the second sentence as 'If a man gives Chappy to his dog, the dog likes that', and putting this in conjunction with the first sentence. In the latter part of this section I want to present a solution along these lines, though it makes use of conditions on variable assignment which we treat in an extra component, together with the buffer that contains the instantiated lexical frames.

In the above texts we find the pronoun *ihm* that corefers with *seiner Hund*. If we assign to it the same variable as for its antecedent NT, this variable will be bound alright in DRT and dynamic predicate logic. In order to assign a variable to the pronoun we need to make use of global syntactic and morphological information, and sometimes additional lexical information. The function of these global syntactic-morphological properties is to restrict the possibility of assigning referents to the pronoun. The DRS-syntax and semantics provides an additional restriction on what is possible according to natural language syntax and morphology. If we incorporate into natural language syntax logical information about the character of the determiners and the kind of subordinate clauses (whether a clause-construction is a conditional construction or not) and the character of connectives (disjunction or not) and operators (negation, modal or not), all information necessary for restricting coreference will be available there and we would not need an extra DRS-level. Using an intermediate DRS-level just means that these kind of logical information is coded separately, which as a whole makes natural language syntax simpler, without being overburdened by logical properties. It just keeps apart linguistic structures and logical structures, which is handy if one wants to investigate them separately. In the interpretation of sentences they both have to be taken into account.

Since the compositional construction of a sentence or text, and the derivation of the corresponding DRSs, should take place by local operations it seems best to treat coreferentiality in a separate component in which we can code information extracted from global syntactic-morphological and lexical and situational information that restricts coreference. During the derivation of the DRS I shall assign the pronouns addresses for variables which will be filled by the variables that are possible according to the restrictions on the respective pronoun which have been gathered in the component of pronoun interpretation. The pronoun addresses are listed in

this component and in the course of translating the text into a DRS or at the end of this process the variables achieved as the results of the restriction can be substituted into the respective addresses. In this way we get a DRS in which all information about coreferentiality is expressed. But, actually, this is not necessary: we just can use a new variable for every pronoun, and likewise every definite noun phrase, and can use the restrictions on this variable gathered in the component for coreference determination as conditions on the interpretation of these variables. The last option just means that next to the buffer with instantiated lexical information we also have a buffer that holds conditions on the variable assignments of pronouns and definite noun phrases. This additional buffer that functions in interpretation makes it possible to let DRS-syntax be compositional. But such a minimal DRS-syntax does, of course, not include all information necessary for interpretation. Only this syntax together with the lexical buffer and the pronoun buffer hold all information necessary for interpretation. We now treat the above examples by means of a minimal DRS-syntax and the additional buffers. I have part of the lexical buffer, namely references to the case conditions, and the pronoun buffer run parallel with with the sentence derivation. Relative pronouns are treated like other pronouns.

Ein Mann, der seinen Hund liebt, gibt ihm Chappy. Dem Hund gefällt das.
The categorial structure (with adterminal relative clause) is:

((der(seinen Hund(liebt)))(einMann))) (ihm(Chappy(gibt))). (Dem Hund (das(gefällt)))

{ Ein Mann, der seinen Hund liebt }

according to the above categorial structure:

<i>lieben</i> : $[\mu]$ lieben(μ)	<u>Cases:</u>	<u>Pronouns:</u>
<i>liebt</i> , Pres. tense: $[r]$ $r \supset t_0$ & lieben(r)		
<i>sein- Hund</i> : $[x]$ Hund(x) & von(x, κ)		κ : + or - refl.
<i>{ seinen Hund : sein- Hund, K2 }</i>		
<i>seinen Hund liebt</i> : $[x]$ Hund(x) & $[\kappa]$ von(x, κ)	$R_2(x, r)$	
& $[r]$ $r \supset t_0$ & lieben(r)		
<i>{ der: rel. pron., K1 }</i>		
<i>der seinen Hund liebt</i> : $[x]$ Hund(x) &	$R_1(\lambda, r)$	λ : rel., male
$[\kappa]$ von(x, κ) & $[r]$ $r \supset t_0$ & lieben(r)		
<i>Ein Mann, der seinen Hund liebt</i> :		
$[y]$ Mann(y) & $[x]$ Hund(x) &		λ : = y
von(x, κ) & $[r]$ $r \supset t_0$ & lieben(r)		

{*gibt ihm Chappy*:}
 {Chappy = c, proper name}
Chappy gibt: [z] z=c & [s] geben(s) $R_2(z,s)$
 {*ihm: er*, K3}
er: μ
ihm Chappy gibt: [z] z=c & [s] geben(s) $R_3(\mu,s)$ μ : male

Ein Mann, der seinen Hund liebt, gibt ihm Chappy:
 [y] Mann(y) & [x] Hund(x) & von(x, κ) &
 [r] $r \supset t_0$ & lieben(r) & [z] z=c & [s] geben(s) $R_1(y,s)$ μ :=y

The conditions of interpretation are:

lieben(r) $\Rightarrow R_2(x,r)$ & $R_1(\lambda,r)$ λ :=y
 geben(s) $\Rightarrow R_2(z,s)$ & $R_3(\mu,s)$ & $R_1(y,s)$ μ :=y

We incorporate the pronoun conditions into the instantiated lexical frames and get as conditions on variable assignments for the DRS '*[y] Mann(y) & [x] Hund(x) & von(x, κ) & [r] $r \supset t_0$ & lieben(r) & [z] z=c & [s] geben(s)*' the set of additional conditions: {lieben(r) $\Rightarrow R_2(x,r)$ & $R_1(y,r)$, geben(s) $\Rightarrow R_2(z,s)$ & $R_3(x,s)$ & $R_1(y,s)$ }.

{*Dem Hund gefällt das*, with the above categorial form:}
gefällt: [u] $u \supset t_0$ & gefallen(u)
das: κ κ : neutr.
 {*das: das*, K2}
 {Note that position decided between K1 and K2}
das gefällt: [u] $u \supset t_0$ & gefallen(u) $R_2(\kappa,u)$
dem Hund:
 {*dem Hund: d- Hund*, K3}
 {*d- Hund* :}
 μ μ : Hund(μ)
dem Hund das gefällt: $R_3(\mu,u)$
 [u] $u \supset t_0$ & gefallen(u)

For this DRS the lexical conditions of variable assignment are:

{gefallen(u) $\Rightarrow R_2(\kappa,u)$ & $R_3(\mu,u)$ }, and { κ : neutr., μ : Hund(μ)}. Taking this together with the first sentence, ' κ : neutr.' amounts to κ :=variable of *Chappy*, or =variable of *geben* i.e. κ :=z, or κ :=s, and μ :=x, and μ :=x.

The whole text put together has the DRS:

[y] Mann(y) & [x] Hund(x) & von(x,κ) & [r] r > t₀ & lieben(r) & [z] z = c &
 [s] geben(s) & [u] u > t₀ & gefallen(u), with the following conditions on
 variable assignment: {lieben(r) => R₂(x,r) & R₁(y,r), geben(s) => R₂(z,s) &
 R₃(x,s) & R₁(y,s), gefallen(u) => R₂(κ,u) & R₃(x,u); whereby κ: =s, or κ: =z}.

We get thus two different interpretations, depending on which restriction on κ is chosen, namely that the dog likes the act of being given Chappy or that he likes Chappy itself. There is also a third interpretation, the fact-interpretation, in which the respective dog likes it that he is given Chappy. In this case we have in the text representation the same as in the other two interpretations, but in the additional conditions on interpretation: κ: = P, where P is a fact variable, here P = [s] geben (s) & [z] z=c & R₁(y,s) & R₂(z,s) & R₃(x,s), the interpretation of which is not empty.

The second example

Jeder Mann, der seinen Hund liebt, gibt ihm Chappy. Dem Hund gefällt das is analyzed in a parallel fashion, except for the second sentence. The DRS for the first sentence with its conditions on variable assignment is:

[y] Mann(y) & [x] Hund(x) & von(x,κ) & [r] r > t₀ & lieben(r) => [z] z=c &
 [s] geben(s), with the conditions: {lieben(r) => R₂(x,r) & R₁(y,r), geben(s) =>
 R₂(z,s) & R₃(x,s) & R₁(y,s)}.

The second sentence cannot simply be put in conjunction with the first sentence. If we would do that, the variables for the definite noun phrase and the pronoun would not be bound by the quantifiers in the DRS of the first sentence. Rather we have here a case of modal subordination (cf. Roberts 1987). Roberts gives a syntactic treatment, which in our example would require to replace the second sentence by a syntactically explicit subordination in the form of 'If a man who loves his dog gives him Chappy, the dog likes this'. Roberts observed that the integration of a second sentence under a modal operator or under the conditional antecedent (often in conjunction with its consequence or part of it) of the preceding sentence is only allowed when the second sentence can be understood as being connected to the preceding sentence as a rule or as an explication.

This is a kind of text connection, namely connection by explication, that is not a narrative conjunction by which a text precedes from one event to the next. An explication typically does not involve new discourse referents for the text, but rather is an elaboration within a condition and thus is made part of a condition. Examples of explication are:

Every alcoholic gets ill. His liver deteriorates first.

If an arctic penguin gets captured he does not survive. He dies within two years.

An arctic penguin does not survive captivity. He dies within two years.

No arctic penguin survives captivity. He dies within two years.

In standard DRT the pronouns cannot be bound if these texts are just treated as a conjunction of two sentences. With EXPLICATION as an additional text connector these sentences can be properly interpreted. Terminologically, we can distinguish a narrative text connection, which is a conjunction between two narrative DRSs (i.e. DRSs that are not conditions), from an explicational text connection which is a conjunction of two conditions, where the second condition is mostly expressed elliptically such that its antecedent remains unexpressed. In the above sentences the second condition is, respectively:

If an alcoholic gets ill his liver deteriorates first.

If an arctic penguin is captured he dies within two years.

If the DRS of the first sentence is a negative condition, the second sentence cannot be simply integrated under the scope of the negation. But if the DRS of the preceding sentence is a subjunctive condition, the conjunction of the two subjunctives 'p => q' and 'p => r' (or 'p & q => r') amounts to 'p => q & r', as in the Chappy-example, where we may expand the consequence part of the preceding sentence by the second sentence and connect the case conditions of the second sentence to the additional conditions of the representation of the preceding sentence, by adding them to the instantiated lexical frame of *geben* which we find in the buffer (which holds all the additional conditions of variable interpretation). This means that every positive situation that belongs to the constellation of verification of the first sentence, i.e. is a situation of a man who loves his dog and gives him Chappy, gets further specified by the conditions expressed by the second sentence. These are added to the set of conditions that is associated with the DRS of the first sentence. The analysis of the text therefore is:

[y] Mann(y) & [x] Hund(x) & von(x,κ) & [r] r > t₀ & lieben(r) => [z] z=c &

[s] geben(s) & [u] u > t₀ & gefallen(u), with the set of additional conditions on variable assignments:

(lieben(r) => R₂(x,r) & R₁(y,r), geben(s) => R₂(z,s) & R₃(x,s) & R₁(y,s) &

(gefallen(u) => R₂(κ,u) & R₃(x,u)); whereby κ := s, or κ := z, or κ := P)

In this method we have treated information about case-relationships and coreference not in the text-DRS itself but in a parallel buffer which contains additional conditions on the interpretation of the text-DRS, i.e. as additional conditions on assignments. The text-DRSs are very poor; they

contain merely quantifier-information (including TENSE), the variables used in quantification, logical operators, and the lexical items in conditions on the variables. The variables and the lexical items are linked to a buffer with lexical and pronominal information by case-information and identity statements (or substitution of variables from the text into the lexical representations). For languages with cases this means a division between categorial syntactic information on the one hand, and morphological and lexical information, as well as pronominal and anaphoric information on the other. The last kind of information, i.e. the information about coreference, depends on the the first and the second, i.e. on the categorial structure and on morphological and lexical information.

In 2.2. an example with a "missing" accusativ term (or a "hidden" pronoun) was discussed briefly:

Auf dem Fest gab es eine Menge Kuchen. Auch Jan aß.

'On the party there were lots of cake. Also John ate.'

In the DRS for this text I treat the locative adverbials, like time adverbials, as properties of, or relationships between, space-time regions or situations (events, scenes, states), which are conceptualized regions (cf. Bartsch 1983, 1986). The phrase *es gibt* will be treated, like the English phrase *there is*, as introducing a space-time region, at which, in the above case, there is lots of cake. For this purpose I use 'AT' as a semantic primitive. The dative case indicates local use of a preposition (i.e. on), the accusative directional use (i.e. onto). The cases that go with the prepositions will be taken to be part of the respective preposition, i.e. instead of 'auf(x,y) & R₃(y,z)' we simply write 'auf_{loc}(x,z)'. I do not take into account the presupposition introduced by *auch*, namely that also others ate cake and that Jan had a tradition of not eating cake. The DRS will be something like this:

[r] Fest(r) & [z] auf_{loc}(z,r) & [x] AT(x,z) & Menge-Kuchen(x) & [y] Jan = y & [s] Essen(s) & R₁(y,s).

The set of assignments is such that every assignment that makes true that Jan eats in this context already assigns a great amount of cake (to the variable x). In the lexical buffer we have the instantiated meaning postulate for *essen*, in which we find a default R₂-object characterized as portions of something eatable. Further we find in the instantiated MP for *Kuchen* that this is something eatable. This allows the portions of something eatable from the MP of *essen* to be instantiated as parts of the cake introduced by the assignments that make the text true. The 'dynamic' interpretation auf sentences in texts, which builds on the true making assignments of the previous parts of the text, explains why it is not

necessary to use an explicit accusative-phrase in the second sentence of the text example above. If Jan had not eaten cake but something else, this need to be expressed by an accusative term, which will instantiate the portions eaten according to the MP of *essen* in the buffer and thus prevent these to be identified with portions of the cake introduced in the preceding sentence.

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