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A MONTAGUE GRAMMAR FOR A FRAGMENT OF SWEDISH

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Montague grammar is one of the first attempts to strictly and explicitly integrate the semantics of a language with a formal syntactic description of the language. so far, Montague-like approaches have mostly been applied to English. Thus, it could be of a certain interest to try to expand the empirical base of this type of grammar. In this paper, I therefore present a Montague-like treatment of a number of Swedish constructions.

In Montague (1974), Montague presents several different ways of giving a formal semantics for a natural language. Mainly relevant are his three papers "English as a formal language" (*EFL*), "Universal Grammar"(UG) and "The proper treatment of quantification in English" (PTQ). In the present paper, an approach will be chosen that closely resembles the one in PTQ. That is, first a syntax will be given for a fragment of Swedish. The syntax will be of a categorial type (see Ajdukiewicz (1960)), supplemented by syntactical rules that spell out the non-categorial aspects of the syntax. Then the syntax and semantics of an intensional logic is given. Finally, translation rules are formulated that translate syntactically analyzed Swedish expressions of the fragment into formulas of intensional logic.

The differences between the treatment presented here and the one found in PTQ are inspired by the discussion and treatments found in Thomason (1973), Bennett (1974) and Cooper (1975).

SYNTAX

Since the syntax is categorial, we start by developing a set of categories which will be used (i) as indices for sets of basic lexical items in order to produce a lexicon and (ii) as indicators of the arguments and values of a set of syntactic operations which will tell us what strings of basic lexical items are well-formed.

The set of categories (Cat) will be the smallest set such that

- (i) $e, t \in \text{Cat}$
- (ii) If A and $B \in \text{Cat}$, then $A/_n B \in \text{Cat}$, where $/_n$ stands for n number of slashes.

The categories e and t are the base of the recursion. They are the two basic categories from which all others are derived. They are chosen primarily on semantic grounds; e to index the set of entity denoting expressions (of which there are no examples in natural language, only in intensional logic) and t to index the set of truth-value denoting expressions which correspond to sentences in natural language. Semantic - considerations are allowed to play a role in the choice of syntactic categories since we want syntax and semantics to parallel each other as closely as possible.

We can generate derived categories e.g. A/B , $A//B$, $A/B_{/A}$, $A/_{A//B}$ of any degree of complexity; the idea always being that such a category is functional, with the category to the right of the main slash or slashes serving as the argument and the category to the left of the main slash(es) serving as value. When more than one slash is used, this is to distinguish semantically similar but syntactically different categories from each other. Thus, t/e and $t//e$ are semantically similar (functions from entities to truth values) but syntactically different, designating the categories of abstractions and common nouns respectively in this fragment.

THE LEXICON

The categories will now be used to produce a lexicon. This will be done by letting each category A serve as the index of a set of basic lexical expressions B_A . The union of all the sets B_A will serve as the lexical material of the fragment. The lexicon will be very impoverished in that it will contain information only about the graphemic representations, gender and the syntactic category of any B_A .

Except for gender, there is no morphological or phonological information and there is no semantic information. To some extent, the latter point will be remedied by the translation rules and semantics of intensional logic to be presented later. The lexicon is presented in table 1.

For those unfamiliar with Swedish, it should be mentioned that there are two grammatical genders neutrum (n) and utrum (u) and that I have used two

natural genders masculine (m) and feminine(f). Some words like park (u) 'park' are only marked for grammatical gender while others like tjej (f,u) 'girl' are marked for both natural and grammatical gender i.e. feminine and utrum. respectively.

Addition 1

Finally, the lexikon contains some lexical items not found in natural language - the pronominal variables han₀, han₁, honom₀, honom₁, etc. These are necessary to make syntactic binding work and are therefore essentially ad hoc.

The pronominal variables will sometimes be referred to as just variables. The subscripts are removed by syntactic operations and the variables therefore appear as normal pronouns in the sentences generated by the grammar.

Table 1. Lexicon for a Fragment of Swedish

Category Label	Category Definition	Closely related traditional or other designation	Relevant syntactic and translation operation	Basic lexical expressions belonging to the category
synt. translation				
t	t	sentence		none
e	e	Entity expression, logically proper name		none
AB	t/e	abstraction		none
AB/ t	t/e/ _t	complementizer, abstractor	F ₁	{att ₀ , att ₁ ... } that that,
T	t/t/ _e or t/t// _e	term NP	F ₂ , F ₃	{Pelle ^m , Kalle ^m , Lisa ^f , han ₀ , han ₁ } he ₀ he ₁
IV	t/e	intransitive VP, predicate	F ₄	{gå, springa, tala, stiga, förändras} walk run talk rise change
TV	IV/T	transitive VP, 2-place predicate	F ₈	{finna, förlöra, äta, älska, leta efter, påstå find lose eat love seek assert tro raka, ¹ vara believe shave be
CN	t//e	common noun	Q ₁	{man(m.u), tjej(f.u), park(u), fisk(u), man girl park fish enhöring(u), grej(u), pris(n), temperatur(n) unicorn thing price, temperature ordförande(m,u), statsråd(f,n) } chairperson member of government }
IAV	IV/IV	intransitive VP adverb	F ₅	{snabbt, långsamt, frivilligt, antagligen, } fast slowly voluntary probably }
SA V	t/t	sentential adverb	F ₇	{med nödvändighet } necessarily
AD J	CN/CN	adjective	F ₁₀	{gammal, stor, röd, falsk, } old big red false }

ADJ	CN/CN	adjective	F10	Q14	(gammal, stor, röd, falsk) (old big red false)
DET	T/CN	determiner	F 11	Q 15, Q 16 Q 17, Q 18	{ <u>en</u> [-n] varje <u>hans</u> ₀ <u>hans</u> ₁ } a the every his ₀ his ₁
INF	t// // e	infinitive VP			
INF/AB	INF/A B	infinitival complementization	F 12	Q 19	syncategorematic
TTV	TV/T	transitive verb, 3-place predicate	F 9	Q 13	{ <u>ge</u> <u>skicka</u> _ } give, send
IV/INF	IV/INF	intransitive INF-taking VP	F 13	Q 20	{ <u>försöka</u> , <u>önska</u> , ¹ <u>lova</u> _ } try wish promise
TV/INF	TV/INF	transitive INF-taking VP	F 14	Q 21	{ <u>övertala</u> , <u>tvinga</u> , ² <u>lova</u> _ } persuade force give permission
(IV INF)/ _T	(IV/IN F)/ _T	intransitive T-taking INF VP	F 15	Q 22	{ ³ <u>lova</u> _ } promise
T/t	T/t	complementizer, sentence nominaliser	F 16	Q 23	{ <u>att</u> _ } that
ADJ/AB	ADJ/A B	relativizer	F 17	Q 24	{ <u>sådan</u> , <u>som</u> , <u>vars</u> _ } such that whose
IV/ADJ	IV/ADJ	copula	F 18	Q 25	{ ² <u>vara</u> _ } be
IAVP	IAV/ _T	intransitive VP adverb-creating preposition	F ₆	Q 10	{ <u>i</u> _ } in
		conjunction disjunction negation future tense past tense	F 19 F 20 F 21 F 22 F 23	Q 26 Q 27 Q 28 Q 29 Q 30	<u>och</u> syncategorematic <u>eller</u> syncategorematic <u>inte</u> syncategorematic <u>skall</u> syncategorematic(verb) syncategorematic(verb)

SYNTACTIC RULES

The category index of each basic lexical item tells us what categories the item can be combined with and what the category index of the resulting combination will be. However, we also need to know the precise form of the combination, i.e. word order and possible morphological adjustments. In Montague grammar, this task is taken care of by syntactic operations of the following general form:

$$F_{i,j} ((\langle \alpha_A, \tau_{\alpha_A} \rangle, \langle \beta_B, \tau_{\beta_B} \rangle) = \langle \gamma_C, \tau_{\gamma_C} \rangle)$$

where F_i is a syntactic operation, j is a variable binding index, relevant only when the rules involve variable binding, α , β and γ are linguistic expressions of category A, B and C respectively and τ_{α_A} , τ_{β_B} and τ_{γ_C} are the analysis trees (see comments and examples for rule S2) of the expressions α , β and γ respectively.

A syntactic operation, thus, takes analyzed linguistic expressions as arguments and as its value yields their combination in the form of another analyzed linguistic expression. There are two types of syntactic operations: syntactic operations proper $F_1 - F_{25}$ and syntactic suboperations $H_1 - H_5$. Similar syntactic operations are then grouped together in the syntactic rules S1-S20. The division between rules, operations and suboperations is one of convenience and does not correspond to any division between syntax and morphology, although it would be desirable to achieve such a correspondence in the future. Each rule will be followed by comments and examples which hopefully will serve as some clarification of the function of the rule. Each syntactic operation will give rise to a set of well formed expressions of certain category A_i viz. P_A or the set of phrases of category A. The union of all the sets P_A produced by the syntactic operations will be the set of well formed expressions of our fragment of Swedish.

It should be observed that since the rules, through the analysis trees, can make use of any desired structural information, they in a sense combine the generative capacity of the phrase structure rules, transformations and global constraints of transformational grammars. It remains to be seen if such liberality in the formulation of rules will prove to be heuristically valuable or harmful, as it is often claimed within the framework of transformational grammar.

It should also be noted that no consistent effort has been made in the formulation of the present rules to separate those aspects of syntactic structure that determine semantic interpretation, from those aspects (e.g. grammatical gender) that seem to play no or at least a very small role in semantic interpretation. One of the interesting problems for future research is to determine to what extent it would be possible to make such a separation parallel to the desired separation of syntax from morphology.

SYNTACTIC RULES FOR A FRAGMENT OF SWEDISH

$$S1 \quad B_A \subseteq P_A$$

Comments: S1 says that all basic lexical items of category A. are to be counted as well formed phrases of category A.

$$S2 \quad F_i, i \quad (\alpha_i \text{ AB/t } ' \beta_i) = \alpha_i^{[\beta]} \text{ AB}$$

where β must contain some variable han_i , honom_i or hans_i with an index corresponding to the one on α .

Comments: S2 produces abstractions from sentences containing unbound variables. The subscript on α [the abstractor att_i] indicates which variable is being abstracted over. No empty abstraction is allowed, so the subscript on α must correspond to the subscript on some variable in β indicated by the index i on F . β the abstracted sentence is surrounded by square brackets. We have not given the analysis tree of α and β in S2, since they are not necessary for the statement of the rule. Analysis trees are only necessary when the conditions on a rule need to take into consideration the derivation of the expressions operated on. In S2, the conditions can be given in terms of the actual string units operated on, so the analysis trees are left out. In general analysis trees will be left out of the statement of a rule, unless the syntactic information required for the operation of the rule is so complex that they are required for perspicuity.

Example of F_i :

$$F_{1,2}(\text{att}_2, \text{han}_2 \text{ älskar Lisa}) = \text{att}_2 \quad [\text{han}_2 \text{ älskar Lisa}]$$

$$(\text{that}_2, \text{he}_2 \text{ loves Lisa}) = \text{that}_2 \quad [\text{he}_2 \text{ loves Lisa}]$$

$$S3 (1) F_{2,i} (\alpha_T, att_i, [\beta]_{AB}) = \psi_t \quad .$$

where if α is not a variable, ψ is the result of $H_1 (att_i [\beta]_{AB})$ replacing the first occurrence of an i-variable in β by α if the i-variable has the form han_i or honom_i or the possessive form of α if the i-variable has the form sin_i or hans_i and $H_2 (H_1 (att_i [\beta]_{AB}))$ replacing every succeeding i-variable:

han _i		han	hon	den		det
hon		honom	henne	den		det
om _i						
sig _i	in β by	sig	sig	sig	and	sig*
han		han	hen	dess		dess
s _i		s	nes			
sin _i		sin	sin	sin		sin

* according to whether the gender of α is masculine, feminine, neuter or utrum.

$$S3 (2) F_{3,i} (\alpha_T, att_i [\beta]_{AB}) = \psi_t$$

where if α is an i-variable and there are no previous occurrences of i-variables in β , ψ is the result of $H_3 (att_i [\beta]_{AB})$ replacing each occurrence of

han _j		han _i
honom _j	in β by an occurrence of	honom _i
sig _{j9}		sig _i
hans _j		hans _i
sin _j		sin _i

Comments: S3 introduces quantification of abstractions with terms. The rule consists of two syntactic operations F_2 and F_3 used according to whether the term used₁ as quantifying expression is a variable or not. F_2 takes care of non-variable terms and F_3 of variable terms. Two syntactic suboperations H_1 and H_2 are introduced in F_2 and one H_3 is introduced in F_3 . Syntactic suboperations are introduced mainly for convenience so that they can be referred to in succeeding syntactic rules. H_1 replaces the first occurrence of an i-variable by a non-variable term. If the variable is hans_i the term should be put in the possessive form. The

precise statement of how this is carried out, we leave to future work, where the syntactic suboperations could possibly be elaborated into morphological processes. See Källström (1975) for a discussion of some such problems. When the first *i*-variable has been replaced by a term, H_2 replaces the succeeding ones by appropriate pronouns. H_3 does the same job for variable terms as H_1 does for non-variable terms. But, with the restriction that a variable can only be used as a quantifier if there are no previous occurrences of that variable in β . This restriction is necessary to preserve the proper reference relationships. If there are no preceding variables, the quantifying variable in appropriate form simply replaces all the occurrences of the variable whose subscript corresponds to the binding index in $F_{3,i}$

Examples:

(i) $F_{2,0}$ (Pelle, att₀ [han₀ älskar Lisa]) = Pelle älskar Lisa
 Pelle that₀ he₀ loves Lisa Pelle loves Lisa

(ii) $F_{2,1}$ (Pelle, att₁ [han₁ älskar sin₁ tjej]) = Pelle älskar sin tjej
 Pelle₁ that he₁ loves his₁ girl Pelle loves his girl

(iii) $F_{2,3}$ (Pelle, att₃, [Lisa tror att hans₃ tjej älskar honom₃])
 Pelle that₃ Lisa believes that his₃ girl loves him₃
 = Lisa tror att Pelles tjej älskar honom
 Lisa believes that Pelle's girl loves him

(iv) $F_{3,4}$ (han₄ att₃ [han₃ springer]) = han₄ springer,
 he₄ that₃ he₃ runs he₄ runs

(v) $F_{2,5}$ (han₅, att₅ [han₅ springer]) is undefined since han₅
 already occurs in β .

Additional comments: In order to make this rule work, we must assume both an essentially ad-hoc natural gender marking in the lexicon of terms (and common nouns) and a non a, d-hoc marking of grammatical gender. Proper names and words like ordförande (chairperson) and statsråd (member of government) must be assigned natural gender (masculine and feminine) besides their grammatical gender utrum and neutrum if the correct pronominal form is to be chosen. The only reason for this procedure is convenience. Personally, I think natural gender agreement should probably be left out of the syntax and handled pragmatically. A sentence like (vi) where Pelle binds she

could be viewed as pragmatically acceptable if the speaker believes Pelle to be a woman but syntactically acceptable independently of natural gender agreement.

- (vi)

<u>Pelle</u>	tror	att	hon	älskar	<u>Lisa</u>
Pelle	believes	that	she	loves	Lisa

Cooper (1975) provides a semantic treatment of gender where natural gender-agreement is required for an expression to be semantically well-defined. This treatment seems reasonable for sentences involving quantification with terms like the man where biological sex seems to be part of the conventional meaning of the term but much less reasonable for quantification with proper names (sentence (vi)) or terms like statsråd and ordförande where biological sex does not seem to be part of conventional meaning. Here a pragmatic account seems more reasonable. However, as is well known, this is more easily said than done.

$$S4 \quad F_{4,1}(\beta_T, \langle \alpha_{IV}, \tau_{\alpha IV} \rangle) = \beta \alpha'_{\text{t}}$$

where α' is the result of replacing the first word in α by its present tense form + and, (i) in case β is han_i, replacing each occurrence of honom_i and hans_i in α which has not been derived via a separate sentence according to $\tau_{\alpha IV}$ by sig_i and sin_i resp. and (ii) in case β is not a variable and α contains variables, $\alpha' = H_2(\alpha)$ according to the gender of β and (iii) in case β is a variable, han_i and α contains variables free for i , then $\alpha' = H_3(\alpha)$ (see the conditions on H_3 above) and (iv) if α contains the infinitival complementizer att_i, α' is the result of deleting the subscript i on att.

and if α contains be and $\gamma_{BADJ'}$, γ is declined according to the gender if the head common noun in β .

Comments: S4 combines intransitive VP:s (predicates) with terms to yield sentences, whilst giving the finite verb of the predicate present tense form. If the subject term is a variable han_i it allows us to reflexivize all i -variables in α that are exposed to reflexivization, where variable is exposed to reflexivization, if α , the analysis tree of α does not indicate that the variable has been derived via a sentence, if a variable has been derived via a sentence, it can not be reflexivized (see example (iii) below.)

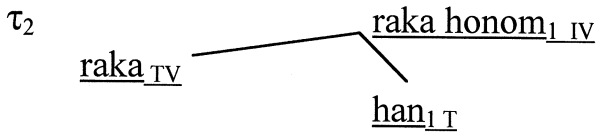
The latter part of S4 states the conditions on variable binding when the argument term β_T is a non-variable or when β_T is an i-variable but there are no preceding i-variables in α . S4 is here a repetition of H_2 and H_3 in S3. It is worth noting that the way S4 is formulated, only variable-terms induce reflexivized forms. These variables must then in turn be bound by making the sentence created by S4 into an abstraction by S2 and then binding the abstraction with a non-variable term by S3 (see the analysis tree in example (iv)). The last clause (iv) allows binding of infinitival clauses by the subject terms (see rule S15 below).

$$(i) \quad F_{4,0} (\langle \text{springa}, \tau_1 \rangle, \quad \text{Pelle}) = \quad \text{Pelle springer} \\ \text{run} \qquad \qquad \qquad \text{Pelle} \qquad \qquad \text{Pelle runs}$$

Here τ_1 plays no role since reflexivization is out of the question.

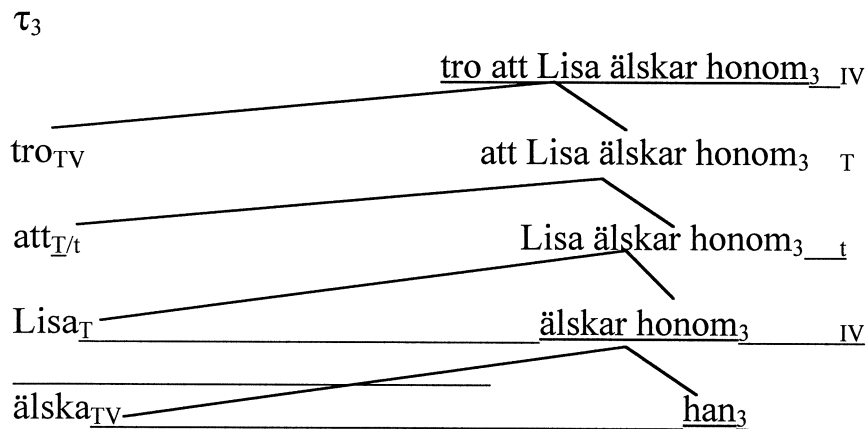
$$(ii) \quad F_{4,1} (\langle \text{raka honom}, \tau_2 \rangle, \text{han}_1) = \text{Han}_1 \text{ rakar sig}_1$$

Here τ_2 plays a role showing that the variable in a han_1 has not been derived via a sentence:



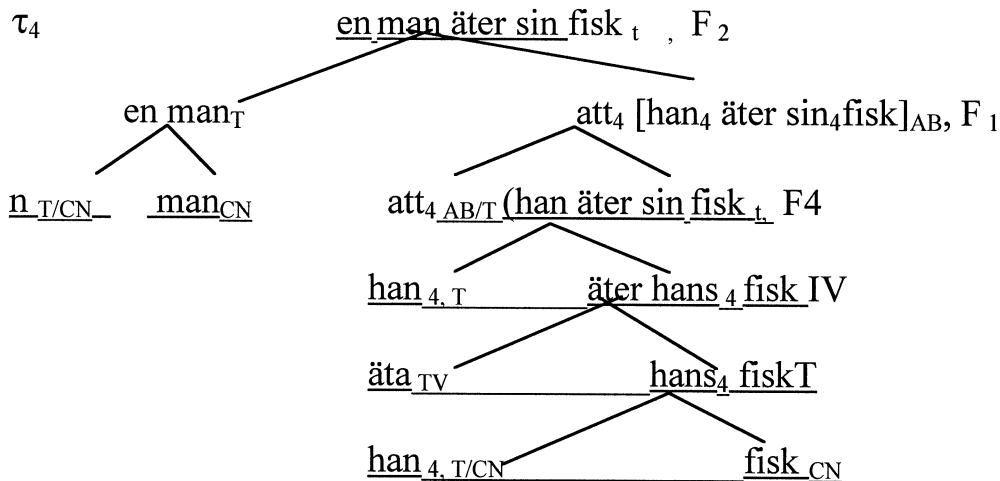
$$(iii) \quad F_{4,3} (\langle \text{tro att Lisa älskar honom}_3, \tau_3 \rangle, \text{han}_2) \\ \text{believe that Lisa loves him} \\ \\ = \text{han}_2 \text{ tror att Lisa älskar honom}_2 \\ \text{he}_2 \text{ believes that Lisa loves him}_2$$

Here the analysis tree τ_3 shows that honom_3 is derived via a sentence. Thus, it cannot be reflexivized and is instead bound by suboperation H_3 .



- (iv) $F_{2,4} (<att_4 [\underline{han_4} \text{ äter } \underline{sin_4} \underline{fisk}] , \tau_4 > , \underline{en \text{ man}}$
 he eats his₄ fish a man
 = en man äter sin fisk
 a man eats his fish

(iv) gives an example of how we can bind a reflexive pronoun with a term by F_2 . The analysis tree τ_4 shows the derivation of the sentence (iv). Reflexivization can take place since han₄ is in the same simple sentence as hans₄ fisk, even though en man is not.



$$S5 \quad F_5(\alpha_{IAV} ' \beta_{IV}) = \beta \alpha_{IV}$$

Comments: S5 produces intransitive verb phrases from intransitive VPs and intransitive VP adverbs.

Examples: $F_5 (\begin{smallmatrix} \text{snabbt,} \\ \text{fast} \end{smallmatrix} , \begin{smallmatrix} \text{springa} \\ \text{run} \end{smallmatrix}) = \begin{smallmatrix} \text{springa snabbt} \\ \text{run fast} \end{smallmatrix}$

S6 $F_6 (\alpha_{IAV/T}, \beta_T) = \alpha \beta_{IAV}$

Comments: S6 produces intransitive VP adverbs from terms

Examples: $F_6 (\begin{smallmatrix} i, \\ \text{in} \end{smallmatrix} , \begin{smallmatrix} \text{parken} \\ \text{the park} \end{smallmatrix}) = \begin{smallmatrix} i \text{ parken} \\ \text{in the park} \end{smallmatrix}$

S7 $F_7 (\alpha_{t/t}, \beta_t) = \beta_{\alpha t}$

Comments: S7 modifies a sentence with a sentential adverb to make a new sentence.

Examples: $F_7 (\begin{smallmatrix} \text{med nödvändighet} \\ \text{necessarily} \end{smallmatrix} , \begin{smallmatrix} \text{Pelle äter} \\ \text{Pelle eats} \end{smallmatrix})$
 $= \begin{smallmatrix} \text{Pelle äter med nödvändighet} \\ \text{Pelle eats necessarily} \end{smallmatrix}$

S8 : $F_{8,i} (\alpha_{TV}, \beta_T) = \alpha' \beta'_{IV}$

where if the first word α_1 in α is a member of $B_{TV/INF}$, β' is inserted immediately after α_1 , where β' is β if β is not han_i in which case β' is honom_i and if any i-variables remain in α then $H_2(\alpha)$ according to the gender of β is a non-variable term and $H_3(\alpha)$ whenever β is a variable term and where if α is påstå or tro β must be the nominalization of a sentence.

Comments: S8 produces intransitive VPs from transitive VPs and terms. If the TV is simple, the term is straightforwardly right-concatenated to the verb. If the TV is complex, the term is put to the right of the first TV/INF. S8 allows both variable and non-variable terms to bind other variables in α_{TV} , subject to the usual restrictions on H_2 and H_3 . The final restriction limits påstå and tro to terms that are sentential nominalizations according to the analysis tree of the term. Another option would have been to create a special syntactic category for verbs like påstå and tro.

Examples: $F_9 \left(\begin{smallmatrix} \underline{ge} \\ \text{give} \end{smallmatrix}, \begin{smallmatrix} \underline{Pelle} \\ \text{Pelle} \end{smallmatrix} \right) = \begin{smallmatrix} \underline{ge} \text{ Pelle} \\ \text{give Pelle} \end{smallmatrix}$

where if α starts with som; ψ is $\beta\alpha$ and otherwise ψ is $\alpha\beta$, where if ψ is $\beta\alpha$, all numerical subscripts indicating which variable in α is bound by β and all square brackets should be deleted.

Comments: S10 combines common nouns with adjectives and relative phrases to create common nouns. Adjectives are put before the CN and relative phrases after the CN. The CN will bind the relative phrase according to the index on F, but the square brackets and subscripts indicating which variable is bound, must be deleted.

Examples: (i) : $F_{10,i} \left(\begin{smallmatrix} \underline{gammal} \\ \text{old} \end{smallmatrix}, \begin{smallmatrix} \underline{man} \\ \text{man} \end{smallmatrix} \right) = \begin{smallmatrix} \underline{gammal} \text{ man} \\ \text{old man} \end{smallmatrix}$

(ii) $F_{10,6} \left(\begin{smallmatrix} \underline{som_6} \text{ [är gammal]}, \\ \text{that}_6 \text{ is old} \end{smallmatrix}, \begin{smallmatrix} \underline{man} \\ \text{man} \end{smallmatrix} \right) = \begin{smallmatrix} \underline{man} \text{ som är gammal} \\ \text{man who is old} \end{smallmatrix}$

S11 $F_{11} (\alpha_{\underline{DET}}, \beta_{\underline{CN}}) = \psi_T$

where ψ is $\alpha\beta$ if α is varje. If α is en, $F_{11} (\alpha\beta)$ is $\text{en } H_4(\beta)$ for $\beta(\text{utrum})$ and $\text{ett } H_4(\beta)$ for $\beta(\text{neutrum})$, where $H_4(\beta)$ is β if β does not initially contain a member γ of B_{ADJ} in which case γ is declined according to the grammatical gender of the head common noun in β .

If α is $\{-\text{en}\}$, $F_{11} (\alpha\beta) = H_5(\beta)$

where if $\beta \in B_{\text{CN}}$, $H_5(\beta)$ is $\beta \text{ en}$ for $\beta(\text{neutrum})$ and $\beta \text{ ett}$ for $\beta(\text{neutrum})$ and if β contains a member of ADJ , $H_5(\beta)$ is the correct definite form of β according to the gender of the head common noun in β . If α is a possessive determiner $F_{11}(\alpha, \beta)$ is $\alpha\beta$ except when β initially contains a member of γ of B_{ADJ} in which case γ is replaced by its definite form.

Comments: S11 creates terms from common nouns. It does this by presupposing a lot of morphological operations which are not clearly defined in S11. This is of course a defect which must be remedied in a more explicit treatment. Even the only operation given semi-explicitly, i.e. the definite form of basic common nouns, in the chosen fragment is faulty. Instead of *ordföranden* as the definite form of *ordförande*, F_{11} , as

it stands, will give ordförandeen with a superfluous e. S11, thus, makes painfully evident the need for a morphological component.

Examples:

(i) F_{11} (varje, tjej) = varje tjej
 every girl every girl

(ii) F_{11} (en, statsråd) = ett statsråd
 a member of government a m of g

(iii) F_{11} (en, gammal pris) = ett gammal pris
 an old price an old price

(iv) F_{11} ((en), gammal man) = den gamle mannen
 an old man the old man

(v) F_{11} (Pelles, stor fisk) = Pelles stora fisk
 Pelles big fish Pelle's big fisk

(vi) F_{11} (en , stor man som är gammal)
 a big man who is old

= den store mannen som är gammal
 The big man who is old

S12 $F_{12, i}$ (att_i [han_i α]_{AB}) = att_i [α]_{INF}

where han_i has been deleted and the first verb in α has been replaced by its infinitive form and in case α contains inte, α 's the result of placing inte before the infinitival form in α '.

Comments: S12 creates infinitive VPs from abstractions by deleting the subject variable in the abstracted sentence and replacing the finite verb by its corresponding infinite form. This is a mere syntactic change, the semantics remains the same, in particular the same i-place as before indicated by the i on att is awaiting binding even though no visible variable holds the place. The negation inte is put in a position which makes it possible to embed a in subordinate position. Example (iii) illustrates how this is used in the derivation of a more complex sentence.

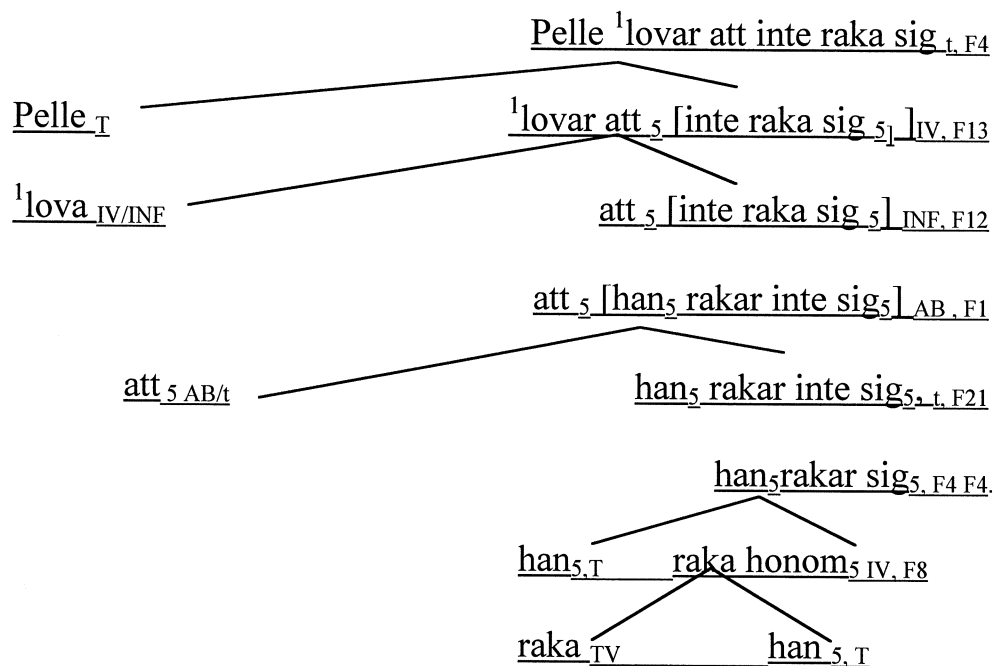
Examples:

$$(i) \ F_{12,1} \ \underline{\text{att}_1 [\text{han}_1 \text{rakar sig}_1]} = \underline{\text{att}_1 [\text{raka sig}_1]} \\ \text{that}_1 \text{ he}_1 \text{ shaves himself}_1 \quad \text{to}_1 \text{ shave oneself}_1$$

$$(ii) \ F_{12,2} \ \underline{\text{att}_2 [\text{han}_2 \text{springer}]} = \underline{\text{att}_2 [\text{springa}]} \\ \text{that}_2 \text{ he}_2 \text{ runs} \quad \text{to}_2 \text{ run}$$

$$(iii) \ F_4 (\text{Pelle}, \text{}^1\text{lova att}_5 \text{ inte raka sig}_5) = \underline{\text{Pelle lovar att inte raka sig}}$$

The analysis tree below shows how F_{12} puts the negation in the right position for embedding:



$$S_{13} \ F_{13} (\alpha_{IV/INF}, \beta_{INF}) = \alpha\beta_{IV}$$

Comments

S13 produces intransitive VPs from infinitival complement taking verbs and infinitival complements.

Examples:

$$(i) \ F_{13} \ (\underline{\text{försöka}}, \text{att}_1 \ \underline{[\text{gå}]}) = \underline{\text{försöka att}_1 [\text{gå}]} \\ \text{try} \quad \text{to}_1 \text{ walk} \quad \text{try} \quad \text{to}_1 \text{ walk}$$

$$(ii) F_{13} (\text{önska att}_2 [\text{raka sig}_2]) = \text{önska att}_2 [\text{raka sig}_1]$$

wish to₂ shave oneself₂ wish to₂ shave oneself₂

$$(iii) F_{13} (\text{lova att}_3 [\text{äta}]) = \text{lova att}_3 [\text{äta}]$$

promise to₃ eat promise to₃ eat

$$S14 F_{14} (\alpha_{TV/INF}, \beta_{INF}) = \alpha \beta_{TV}$$

Comments: S14 produces transitive VPS from infinitives and transitive infinitival complement taking verbs. Rule S8 can then be used to bind the infinitival complement with an object term (see example (iii))

Examples

$$(i) F_{14} (\text{övertala att}_1 [\text{gå}]) = \text{övertala att}_1 [\text{gå}]$$

persuade to₁ walk persuade to₁ walk

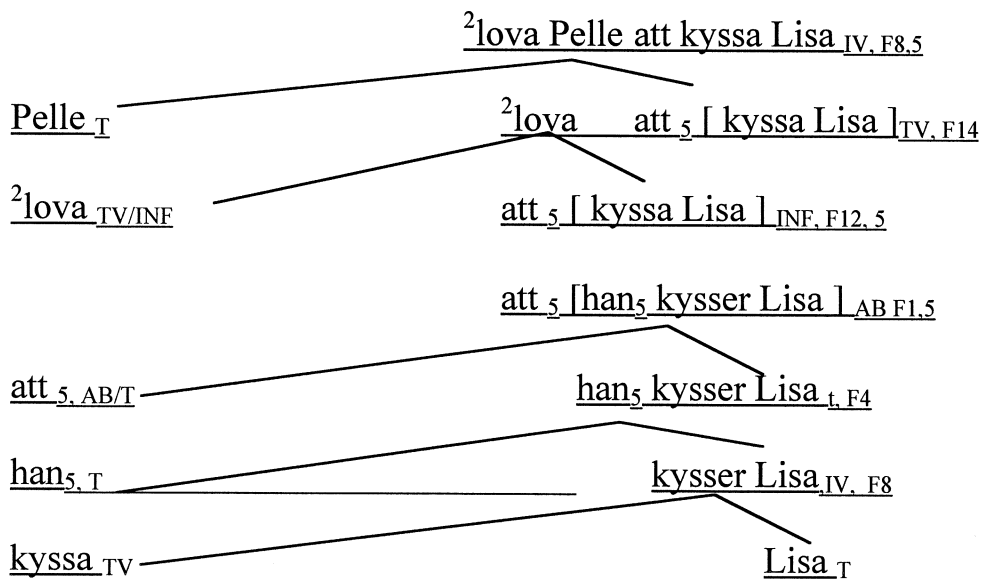
$$(ii) F_{14} (\text{lova att}_5 [\text{gå}]) = \text{lova att}_3 [\text{gå}]$$

give permission to walk give permission to₃ walk

$$(iii) F_{14} (\text{Pelle lova att}_5 \text{ kyssa Lisa}) = \text{lova Pelle att}_3 \text{ kyssa Lisa}$$

Pelle give permission to₅ kiss Lisa give Pelle permission to kiss Lisa

In the analysis tree of (iii) below, we show how F_{14} creates a transitive VP with an infinitival complement which can then be bound by F_8 .



$$S15 F_{15} (\alpha_{IV/INF/T}, \beta_T) = \alpha \beta'_{IV/INF}$$

where β' is β except when β is han_i in which case β' is honom_i.

Comments: S15 produces infinitival complement taking VPs from terms and verbs that take both terms and infinitival complements. Thus, if S15 is contrast to S14 makes it possible for the subject term rather than the subject term to bind the infinitival complement in the VP using rule S4 (see example (iii) below):

Examples:

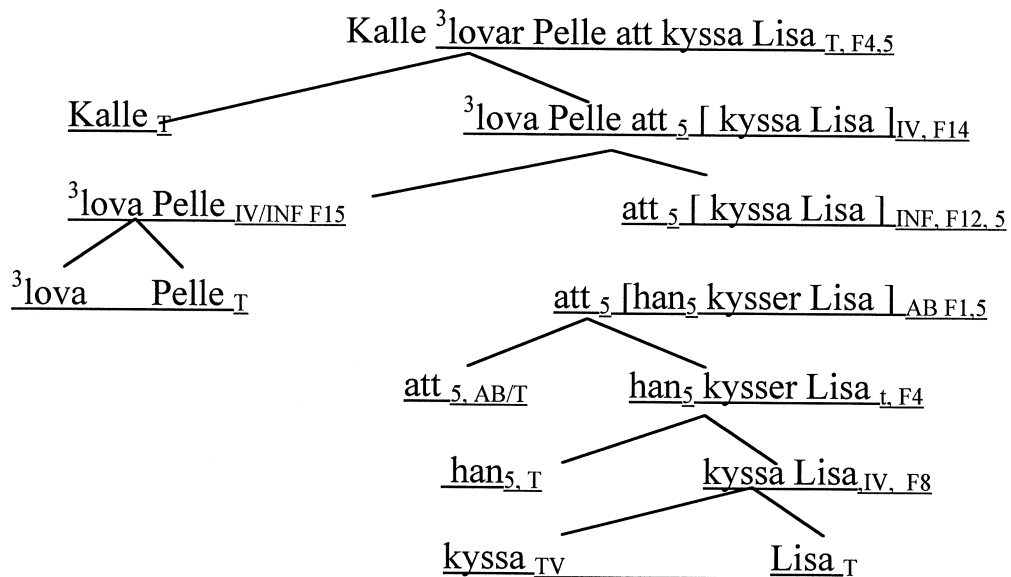
$$(i) F_{15} \quad \begin{array}{c} \text{(^3lova __, \underline{Pelle})} \\ \text{promise \quad Pelle} \end{array} = \begin{array}{c} \text{^3lova \underline{Pelle}} \\ \text{promise Pelle} \end{array}$$

$$(ii) F_{15} \quad \begin{array}{c} \text{(^3lova __, \underline{han_6})} \\ \text{promise \quad he_6} \end{array} = \begin{array}{c} \text{^3lova \underline{honom_6}} \\ \text{promise him_6} \end{array}$$

$$(iii) F_{15} \quad \begin{array}{c} \underline{(\text{Kalle, ^3lova __ Pelle att _5 [kyssa Lisa]})} \\ \text{Kalle \quad promises Pelle to_5 \quad kiss Lisa} \end{array}$$

$$= \begin{array}{c} \underline{\text{Kalle ^3lovar __ Pelle att __ kyssa Lisa}} \\ \text{Kalle promises Pelle to \quad kiss \quad Lisa} \end{array}$$

The analysis tree below shows how by F15 an infinitival complement is created that can be bound by the subject term through F4:



Additional comments: Note the difference between ${}^1\text{lova}_{IV/INF}$ “promise” and ${}^2\text{lova}_{TV/INF}$ “give permission” and ${}^3\text{lova}_{IV/INF/T}$ “promise” as displayed in the following 3 sentences:

(iv) Pelle ${}^1\text{lovade att gå}$ (Pelle promised to go)

(v) Pelle ${}^2\text{lovade Kalle att gå}$ (Pelle gave Kalle permission to go)

(vi) Pelle ${}^3\text{lovade Kalle att gå}$ (Pelle promised Kalle to go)

In (iv) Pelle binds the infinitival complement through F_4 ; in (v) Kalle binds it through F_{14} and F_8 which gives (v) the interpretation Pelle gave Kalle permission to go. Finally, in (vi) the subject term Pelle again binds it through F_{15} and F_4 giving (vi) the interpretation Pelle promised Kalle to go. Thus, our analysis gives us three different verbs lova. I think we have here captured a genuine distinction, especially between (v) on the one hand and (iv) and (vi) on the other hand. The distinction between ${}^1\text{lova}$ and ${}^3\text{lova}$ in (iv) and (vi) might be more spurious.

$$S16 \quad F_{16}(\alpha_{T/t}, \beta_t) = \alpha\beta' \quad T$$

where β' is β if β does not contain inte in which case β' is the result of placing inte before the first verb in β .

Comments: S16 produces sentential NPs with the sentence nominalizer att_{T/t}. In doing this it also arranges the word order with respect to the negation not, so that the nominalized sentence can serve as a subordinate clause with proper word order. It is better to produce sentential NPs from sentences than from abstractions, even though abstractions have nearly the same form as sentential NPs, since sentential need not necessarily contain variable terms. It is not clear how such sentential NPs would be derived if abstractions were used, since abstractions always contain variable terms.

Examples:

$$(i) \quad F_{16} \left(\begin{array}{l} \text{att,} \\ \text{that} \end{array} \quad \begin{array}{l} \text{Pelle springer} \\ \text{Pelle runs} \end{array} \right) = \begin{array}{l} \text{att Pelle springer} \\ \text{that Pelle runs} \end{array}$$

(ii) $F_{16}(\text{att}, \text{Pelle springer inte}) =$
that Pelle runs not

att Pelle inte springer
that Pelle not runs

S17 $F_{17}(\alpha_{\text{ADJ/AB}}, \langle \beta_{\text{AB}}, \tau \rangle) = \gamma_{\text{ADJ}}$

where (i) if α is sådan γ is $\alpha\beta$ or (ii) if α is som γ is the result of deleting the initial abstractor att_i in β and replacing it by som_i and then deleting the first occurrence of han_i or honom_i in β or (iii) if α is vars and β has the form att_i β_1 hans_i $\beta_2\beta_3$, γ is vars_i $\beta_2\beta_1\beta_3$ where β_2 has been permuted with β_1 and hans_i replaced by vars_i, whilst deleting the initial abstractor att_i

*Here β_1 is meant to range over lexical material between att_i and hans_i, β over the remainder of the NP following hans_i and β_3 over the rest of the sentence).

Comments: S17 creates three types of relative modifiers (all of them belonging to category ADJ), from abstractions and the relativizers som, vars and sådan, where vars - a possessive relative - can only be used when the abstraction contains a possessive variable hans_i. We do not need to include sin_i - the possessive reflexive since it, does not seem to be possible to relativize reflexives i.e. it does not seem possible to get a reading of (i) in which the two tokens of mannen (the man) refer to the same person.

(i) Mannen vars mor mannen såg
The man whose mother the man saw

Examples:

(i) $F_{17}(\text{sådan}, \text{att}, [\text{han}, \text{springer}]) = \text{sådan att}_2 [\text{han springer}]$
such that₂ he₂ runs such that he₂ runs

(ii) $F_{17}(\text{som}, \text{att}, {}_3[\text{han}_3 \text{springer}]) = \text{som}_3 [\text{springer}]$
who that₃ he₃ runs who runs

(iii) F17 (som, att₄ [han₄ rakar sig₄] = som₄ rakar sig₄
 who that₄ he₄ shaves himself₄ who₄ shaves himself₄

(iv) F17 (vars, att, [Pelle kysser hans₅ tjej])
 whose that₅ Pelle kisses his girl

= vars, [tjej Pelle kysser]
 whose₅ girl Pelle kisses

(v) F17 (vars, att₆ [hans₆ enhörning springer]) =
 whose that₆ his₆ unicorn, runs

= vars₆, [enhörning springer]
 whose₆ unicorn runs

S18 F₁₈ (α_{IV/ADJ}, < β_{ADJ}, τ>) = αβ_{IV}

provided that τ does not show β to be derived via an abstraction.

Comments: S18 combines the copula vara IV/ADJ with basic adjectives (no relative phrases) to form intransitive VPs.

Examples:

M F₁₈ (vara, gammal) = vara gammal
 be old be old

(ii) F₁₈ (vara, stor) = vara stor
 be big be big

S19 F₁₉ (α_t, β_t) = [α och β]_t

F₂₀ (α_t, β_t) = [α eller β]_t

Comments: S19 creates conjunctions and disjunctions of two sentences

Examples:

(i) F_{19} (Pelle springer, Lisa äter) = Pelle springer och Lisa äter
Pelle runs Lisa eats Pelle runs and Lisa eats

(ii) F_{20} (Pelle springer, Lisa äter) = Pelle springer eller Lisa äter
Pelle runs Lisa eats Pelle runs or Lisa eats

$S_{20} \quad F_{21}(\alpha_t) = \alpha'_t$

where α' is the result of placing inte after the first verb in α .

$F_{22}(\alpha_t) = \alpha''_t$

where α' is the result of replacing the first verb in α by its infinitival form and placing kommer att immediately before it.

$F_{23}(\alpha_t) = \alpha'''_t$

where α''' is the result of replacing the first verb in α by its past tense form.

Comments: F_{21} , F_{22} and F_{23} allow us to negate and change the tense of any sentence into past and future. The formulation of F_{21} also lets us negate future tense and past tense sentences, thus obviating the need for the special rules used for this in PTQ. As usual, we have presupposed morphology where it gets too complicated for a simple statement, as for the past tense above.

Examples:

(i) F_{21} (Pelle springer) = Pelle springer inte
Pelle runs Pelle runs not

(ii) F_{22} (Pelle äter) = Pelle kommer att äta
Pelle eats Pelle will eat

F_{23} (Pelle äter) = Pelle åt
Pelle eats Pelle ate

F₂₁ (Pelle skall äta) = Pelle kommer inte att äta
 Pelle will eat Pelle will not eat

F₂₁ (Pelle åt) = Pelle åt inte
 Pelle ate Pelle ate not

This terminates the syntax of our present fragment of Swedish. The next step will be to correlate the syntax with a semantics. This will be done by first formulating a syntax and a semantics of an intensional logic into which syntactically analyzed expressions of our fragment can be translated and thus indirectly receive their interpretation. It is probably clear to anyone that has had the strength to read through the present rules that they have many deficiencies. The author will therefore gladly welcome all suggestions and comments for ameliorations.

SYNTAX OF INTENSIONAL LOGIC

Types

Following Montague (PTQ), we will now present a tensed intensional logic using a certain amount of type theory. We will first define the set of types of intensional logic. These will correspond to the categories of natural language.

The set of types is to be the smallest set T such that

- (I) e and $t \in T$
- (ii) if a and $b \in T$ then $\langle a, b \rangle \in T$
- (iii) if $a \in T$ then $\langle s, a \rangle \in T$

The two basic types e and t intuitively correspond to entities and truth values respectively; $\langle a, b \rangle$ corresponds to functions from things of type a to things of type b and $\langle s, a \rangle$ is the type of intentions of type a which in turn corresponds to functions from possible worlds to things of type a . Following the definition, some examples of types of the intensional logic will be: $e, t, \langle e, t \rangle, \langle s, t \rangle, \langle s, \langle e, t \rangle \rangle, \dots$

Vocabulary

The vocabulary of the intensional logic will consist of the following symbols:

- (i) Denumerably many variables of each type $\{v \frac{a}{0}, v \frac{a}{1}\}$ where $v \frac{a}{i} \dots$ where $v \frac{a}{i}$ is the i .th variable of type a
- (ii) Infinitely many constants of each type $\{c \frac{a}{0}, c \frac{a}{1}, \dots\}$ where $c \frac{a}{i}$ is the i .th constant of type a

(iii) Connectives: $\sim, \wedge, \vee, \rightarrow, \Leftrightarrow$.

(iv) Quantifiers and operators: $\forall, \wedge, \Box, W, H, \lambda, =, \wedge, \vee$.

(v) Brackets: $), (,], [$.

Rules of formation

The rules of formation or the syntactic rules of intensional logic for every type in the intensional logic characterizes the set of well formed expressions of that type. We call such a set ME_a i.e. the set of meaningful expressions of type a . ME_a is then recursively characterized by the following rules.

- (i) Every variable and constant of type a is in ME_a
- (ii) If $\phi, \psi, _ ME_t$, then $\sim \phi, [\phi \wedge \psi], (\phi \vee \psi), [\phi \rightarrow \psi], [\phi \Leftrightarrow \psi], \phi, W\phi, H\phi, \forall \frac{a}{i} \phi, _ ME_t$
- (iii) If $\alpha _ ME_a$, and $\beta _ ME_b$, then $(\alpha = \beta) _ ME_t$
- (iv) If $\alpha _ ME_a$ then $[\lambda \vee \frac{b}{i} \alpha] _ ME_{\langle b, a \rangle}$
- (v) If $\alpha _ ME_{\langle a, b \rangle}$ and $\beta _ ME_a$, then $\alpha(\beta) _ ME_b$
- (vi) If $\alpha _ ME_a$, then $\wedge^a _ ME_{\langle s, \rangle}$
- (vii) If $\alpha _ ME_{\langle s, a \rangle}$ then $\alpha _ ME_a$
- (viii) Nothing is in any set ME_a except through (i - vii)

Clause (ii) gives us negation, conjunction, disjunction, implication, equivalence in the usual manner, then the necessity, future and past tense operators applied to sentences and finally existential and universal quantification.

Clause (iii) gives us identity between things of any type as long as they are the same type.

Clause (iv) gives us abstraction over variables of any type in an expression of any type. Clause Cv) gives the result of functional application of two types Clause (vi) gives the intension of any type.

Clause (vii) gives the extension of any intensional type and the final clause (viii) guarantees that (i-vii) are the only ways to form meaningful expressions.

For the sake of perspicuity, these rules will sometimes be broken by insertion or omission of square brackets.

SEMANTICS OF INTENSIONAL LOGIC

In giving the semantics of the intensional logic, we will first characterize the set of possible denotations of any type. Second, we will define an intensional model and give semantic rules that show how the model assigns denotations to the expressions of the intensional logic.

The set of possible denotations of a type a

The denotations of any type a of the logic will be constructed from the four sets A , I , J and $\{0,1\}$. A , I , J can be any sets, where A should be regarded as the set of entities, I as the set of possible worlds and J as the set of moments in time. $\{0,1\}$ is the set of truth values where 0 is to be identified with falsehood and 1 with truth. The set of possible denotations of any type a D_a can then be recursively characterized the following way (If X and Y are sets, X^Y denotes the set of functions whose domain is Y and whose range is included in X , and $X \times Y$ denotes the set of all ordered pairs $\langle x, y \rangle$ such that $x \in X$ and $y \in Y$):

- (i) $D_e = A$
- (ii) $D_t = \{0,1\}$
- (iii) $D_{\langle a,b \rangle} = D_b^{D_a}$
- (iv) $D_{\langle s,a \rangle} = D_a^{I \times J}$

Intensional model and semantic rules

The task of the model and the semantic rules is to interpret the expression of intensional logic by assigning them their appropriate denotations.

By an intensional model, we understand a quintuple $\langle A, I, J, \leq, F \rangle$ where (i) A, I, J are nonempty sets and (ii) \leq is a linear ordering of J and (iii) F is a function having as its domain the set of all constants such that $F(c \frac{a}{i}) \in D_{\langle s,a \rangle}$ i.e. assigning to each constant its intension.

If $@$ is such an intensional model $\langle A, I, J, \leq, F \rangle$, we can let an $@$ -assignment of values to variables be a function g having as its

domain the set of all variables such that $g(v \frac{a}{i}) \in D_a$ (i.e. giving each variable a denotation of its own type). By a point of reference $\langle i, j \rangle$, we understand an ordered pair of a world and moment of time belonging to $I \times 3$. By the extension of a meaningful expression α , $\alpha @, i, j, g$, we understand the denotation of α relative to the intensional model $@$, the point of reference $\langle i, j \rangle$ and the variable assignment g .

Semantic rules

The semantic rules give us the extensions of the meaningful expressions of intensional logic. Thus, the extension of a $_ME_a$ can be recursively characterized the following way (iff abbreviates if and only if):

- (i) $c \frac{a}{i}, @, i, j, g$ is $F(c \frac{a}{i})(\langle i, j \rangle)$
- (ii) $v \frac{a}{i}, @, i, j, g$ is $g(v \frac{a}{i})$
- (iii) If $\phi _ Me_t$ then $[\sim \phi] @, i, j, g$ is 1 iff $\phi @, i', j, g$ is 0; and similarly for $\wedge, \vee, \rightarrow, \leftrightarrow$
- (iv) If $\phi _ Me_t$ then $[\phi] @, i, j, g$ is 1 iff $\phi @, i', j', g$ is 1 for all $i': _ I$ and $j' _ J$; $[W \phi] @, i', j, g$ is 1 iff $\phi @, i, j, g$ is 1 for some j' such that $j < j'$ and $[H\phi] @, i, j, g$ is 1 iff $\phi @, i, j, g$ is 1 for some j' such that $j' > j$
- (v) if $\phi _ Me_t$ then $[V v \frac{a}{i} \phi] @, i, j, g$ is 1 iff there exists $x _ D_a$ such that $\phi @, i, j, g'$ is 1 where g' is the $@$ -assignment like g except for the possible difference that $g'(v \frac{a}{i})$ is x and similarly for $\Lambda v \frac{a}{i} \phi$
- (vi) If $\alpha, \beta _ Me_a$ then $[\alpha = \beta] @, i, j, g$ is 1 iff α is $\beta @, i, j, g$
- (vii) If $\alpha _ Me_a$ then $[\lambda v \frac{b}{i} \alpha] @, i, j, g$ is that function h with domain D_b such that whenever $X _ D_b$, $h(X)$ is $\alpha @, i, j, g'$ where g' is as in (v)

(viii) If $\alpha _ Me_{\langle a,b \rangle}$ and $\beta _ Me_a$ then $[\alpha (\beta)]@,i,j,g$ is $\alpha @,i,j,g$ ($\beta @,i,j,g$) i.e. the extension of α taking as an argument of the extension of β

(ix) If $\alpha _ Me_{\langle s,a \rangle}$ then $[\wedge \alpha]@,i,j,g$ is that function h with domain $I \times J$ such that whenever $\langle i, j \rangle$ is in that domain $h (\langle i, j \rangle) = \alpha @,i,j,g$

(x) If $\alpha _ ME_{\langle s,a \rangle}$ then $[\vee \alpha] @,i,j,g$ is $\alpha @,i,j,g (\langle i,j \rangle)$

Finally, if $\phi _ Me_t$ then ϕ is true with respect to $@,i,j$. iff $\phi @,i,j,g$ is 1 for every $@$ -assignment

Comments

Clause (i) gives us the extension of every constant via the function F (see the def. of a model) which gives the intension of the constant which then, in turn, can be applied to a point of reference to obtain the extension for that point of reference.

Clause (ii) gives us the extension of variables via the $@$ -assignment g .

Clause (iii) gives the usual extensions (truth conditions) for propositional connectives.

Clause (iv) gives us the extension of sentences modified by the necessity operator D , the future operator W and the past tense operator H , where o gets the interpretation true in all possible worlds and at all moments of time, W gets the interpretation true at some moment in time succeeding the present one and H gets interpreted true at some moment in time preceding the present one.

Clause (v) gives the extension of existentially and universally quantified sentences.

Clause (vi) gives the extension of identity.

Clause (vii) gives the extension of A-abstracted sentences.

Clause (viii) gives the extension of an expression resulting from the functional application of one expression to another.

Clause (ix) gives the extension of an expression to which the intensional operator has been applied i.e. for such expressions the intension will be the extension.

Clause (x) gives the extension of the expression formed by applying the extension operator to an intension denoting expressions giving the extension of that expression at a certain point of reference. A consequence of (ix) and (x) will be the following $\forall \alpha = \alpha$

CERTAIN USEFUL AUXILIARY NOTIONS AND NOTATION

If $\gamma _ ME_{\langle a, t \rangle}$ then γ denotes the characteristic-function picking out objects of type a , and if $\alpha _ ME_a$ the expression $\gamma (\alpha)$ asserts that the object denoted by a is a member of the set denoted by γ and denotes truth only if this is the case.

If $\gamma _ ME_{\langle a, \langle b, t \rangle \rangle}$, $\alpha _ ME_a$ and $\beta _ ME_b$ then γ denotes a two-place; and $\gamma (\beta, a)$ which is equivalent to $\gamma (\alpha) (\beta)$ asserts that the objects denoted by α and β stand in that relation and denotes truth only if this is the case.

If $\gamma _ ME_{\langle s, \langle a, t \rangle \rangle}$ and $\alpha _ ME_a$ then γ denotes a property and $\gamma \{a\}$ which is equivalent to $[\forall \gamma] \alpha$ asserts that the object denoted by α has the property of γ .

If $\gamma _ ME_{\langle s, \langle a, \langle b, t \rangle \rangle \rangle}$, $\alpha _ ME_a$ and $\alpha _ ME_b$ then γ denotes a relation-in-intension, and $\gamma \{ \beta, \alpha \}$ which is equivalent $[\forall \gamma] [\beta, \alpha]$ asserts that the objects denoted by α and β stand in that relation-in-intension γ

If $\phi _ ME_t$ then $\hat{\vee} \frac{a}{i} \phi$ is to be equivalent with $\lambda v \frac{a}{i} \phi$ and $\hat{\vee} \frac{a}{i} \phi$ is to be $\wedge \hat{\vee} \frac{a}{i} \phi$

If $\alpha = ME_e$ then α^* is to be $\hat{p} [P (\wedge \alpha)]$ where P is a variable $v_i \langle s, \langle \langle s, e \rangle, t \rangle \rangle$.

Beside the variable P , Q and R of type $\langle s, \langle \langle s, e \rangle, t \rangle \rangle$ it is convenient to introduce the following special variable signs instead of our previous sub- and superscripted variables. $\{j, k, l\}$ are distinct constants of type e . $\{u, v\}$ are variables of type e . $\{x_1 \dots x_i \dots y_1 \dots y_i\}$ are variables of type $\langle s, e \rangle$.

P, Q are variables of type $\langle s, \langle \langle s, \langle s, e \rangle, t \rangle \rangle, t \rangle$, p is a variable of type $\langle s, t \rangle$, M is a variable of type $\langle s, \langle e, t \rangle \rangle$, S is of type $\langle s, \langle e, t \rangle \rangle$. G is of type $\langle s, \langle e, f(IAV) \rangle \rangle$, T is of type $\langle s, \langle e, \langle e, \langle e, t \rangle \rangle \rangle \rangle$ and F is of type $\langle \langle s, t \rangle, \langle s, e \rangle, t \rangle$

TRANSLATION AND RESTRICTIONS ON INTERPRETATION

Having set up a syntax and a semantics for an intensional logic, we must now provide a way to give an interpretation of the expressions in our fragment of Swedish. This will be done by providing rules that will translate Swedish expressions which are syntactically analyzed, according to the syntax given above, into expressions of intensional logic. These latter expressions will be interpreted in accordance with the model given above. In this way, the Swedish expressions generated by the fragment will indirectly be provided with an interpretation.

In order to obtain interpretations which are natural for the Swedish expressions being translated, it is necessary to restrict the interpretation of the intensional logic in various ways. We do this by giving so called meaning postulates. The meaning postulates are statements of intensional logic which have to be true in any given interpretation. The meaning postulates will, therefore, restrict the set of possible models for the intensional logic to a set of models which could be called the set of normal models, i.e. the set of models in which the meaning postulates are true.

Translation of categories basic and complex expressions

The basic requirement on the translation is that it should make the categories and syntactical rules of Swedish correspond as regularly as possible to the types and constructions of intensional logic. The aim being to create as much isomorphism between natural language and intensional logic as possible, in order to indirectly achieve isomorphism between natural language and its semantic interpretation.

We therefore introduce a function f which recursively maps the categories of Swedish into the types of intensional logic in the following manner:

- (i) $f(t) = t$
- (ii) $f(e) = e$
- (iii) $f(A/nB) = \langle \langle s, f(B) \rangle, f(A) \rangle$, whenever A and B are categories

Next, we translate all of the basic expressions of the fragment except a few problematic ones into constants of intensional logic. This is done with a fixed biunique function g such that (1) the domain of g is the set of basic expressions of the fragment of Swedish except the basic

T-phrases, the transitive verb lvara and the sentential adverb med nödvändighet and (ii) whenever A is a category, α is of category A and α is in the domain of g, $g(\alpha) = C \frac{f(A)}{i}$. In practice, we will not use Cs with subscripts as constants of intensional logic, but instead use primed basic Swedish expressions, with type designations replacing the numerical subscripts. Thus g (springa_{IV}) will be springa_f(IV)

We now have a mapping of categories into types and a translation of basic expressions (except a few problematic ones). We can therefore turn to complex expressions. The translation of a complex expression is determined recursively on the basis of the translation of its basic parts and its syntactic analysis tree, produced according to the rules S₁-S₂₀.

The translation rules can therefore be regarded as a set of functions Q₁-Q₂₉ mapping syntactically disambiguated Swedish expressions into sets of logically equivalent expressions of intensional logic such that the general form of a *translation* function T_i translating an expression α_A of the fragment of will be $T_i(\alpha_A, \tau) = \alpha \frac{f}{f(A)}$ where τ is the analysis tree of α , A its category and α' , as translation into intensional logic. However, in the statement of the translation rules, τ will be implicit and only explicitly included when its internal structure is relevant to the translation.

TRANSLATION RULES

Rules for basic expressions

T1 (a) $Q_1(\alpha) = g(\alpha)$ whenever α is in the domain of g

(b) $Q_2(\text{Pelle}_T)$, $Q_2(\text{Kalle}_T)$ and $Q_2(\text{Lisa}_T)$ j*, k* and l* respectively.

(c) $Q_3(\text{han}_{IT})$, $Q_3(\text{honom}_iT) = (\hat{P} \{x_i\})$

(d) $Q_4(lvara_{TV}) = \lambda P \lambda x P \{ \{ \hat{y} [{}^v x = {}^v y] \} \}$

(e) $Q_5(\text{med nödvändighet}_{SAV}) = \hat{p} [{}^v p]$

Rules of functional application

T2 $Q_6 (F_{1,i} (\alpha_{AB/t}, \beta_t)) = \lambda v \frac{\leq s, e >}{i} \beta' f(AB)$ where β' is the translation of β , (In general, any primed sequence denotes translation of the corresponding unprimed sequence)

T3 $Q_7 (F_{2,i} (\alpha_T, \underline{att} [\beta]_{AB})) = \alpha' (\wedge \underline{att}_i [\beta])' f(t)$ and the same for $F_{3,i}$.

T4 $Q_8 (F_{4,i} (\beta_T, <\alpha_{IV} \tau >)) = \beta', (\wedge \alpha \wedge) f(t)$

T5 $Q_9 (F_5 (\alpha_{IAV}, \beta_{IV})) = \alpha' (\wedge \beta \wedge) f(IV)$

T6 $Q_{10} (F_6 (\alpha_{IAV}, \beta_{T..})) = \alpha' (\wedge \beta') f(IAV)$

T7 $Q_{11} (F_{8,i} (\alpha_{TV}, \beta_T)) = \alpha' (\wedge \beta') f(IV)$

T8 $Q_{12} (F_{9,i} (\alpha_{TV/T}, \beta_T)) = \alpha' (\wedge \beta') f(TV)$

T9 $Q_{13} (F_{10}, (\alpha_{ADJ}, \beta_{CN})) = \alpha' (\wedge \beta') f(CN)$

T10 $Q_{14} (F_{11}, (\underline{en})_{DET}, \beta_{CN})) = \hat{P} \forall x (\beta' (x) \wedge \{P\}x] f(DET)$

$Q_{15} (F_{11}, (\underline{en})_{DET}, \beta_{CN})) = \hat{P} \forall x (\wedge x (\beta' (x) \Leftrightarrow x=y] \wedge \{P\}y] f(DET)$

$Q_{16} (F_{11}, (\underline{varje}_{DET}, \beta_{CN})) = \hat{P} \wedge x (\beta' (x) \rightarrow \{P\}x] f(DET)$

$Q_{17} (F_{11}, (\underline{hans}_i \text{ }_{DET}, \beta_{CN})) = \hat{x} \circ \hat{P} (\forall y [\wedge x \wedge [[\beta' (x) \wedge H v_{x_o}, v_x] \Leftrightarrow x=y] \wedge \{P\}x]) f(DET)$, where H is a primitive constant of possession found in the intensional logic.

(Since Q_{17} translates expressions with hans_i, before expressions with sin_i or possessive terms have been derived, no separate translation/function is needed for these latter two types of expression).

T11 $Q_{18} (F_{12} (\alpha_{AB})) = Q_6 (\alpha) f(AB) = f(INF)$

T12 $Q_{19} (F_{13} (\alpha_{IV/INF}, \beta_{INF})) = \alpha' (\wedge B \wedge) = f(IV)$

T13 $Q_{20} (F_{14} (\alpha_{IV/INF}, \beta_{INF})) = \alpha' (\wedge B \wedge) = f(TV)$

T14 $Q_{21} (F_{15} (\alpha_{IV/INF}/T, \beta_T)) = \alpha' (\wedge B \wedge) = f(IV/INF)$

T15 Q22 ($F_{16}(\alpha_{T/t}, \beta_t) = \alpha' (^B^A) = f(T)$)
 T16 Q23 ($F_{17}(\alpha_{ADJ/AB} < \beta_{AB}, \tau >) = \beta' f(ADJ) = f(AB)$)
 T17 Q24 ($F_{18}(\alpha_{IV/ADJ}, < \beta_{AB}, \tau >) = \beta' f(IV) = f(ADJ)$)

Rules of conjunction and disjunction

T18 Q25 ($F_{19}(\phi_t, \Psi_t) = [\phi' \wedge \Psi']_f(t)$)
 Q26 ($F_{20}(\phi_t, \Psi_t) = [\phi' \wedge \Psi']_f(t)$)
 T19 Q27 ($F_{21}(\alpha_T, \delta_{IV}) = \sim \alpha' (^ \delta') f(t)$)
 Q28 ($F_{22}(\alpha_T, \delta_{IV}) = W\alpha' (^ \delta') f(t)$)
 Q29 ($F_{23}(\alpha_T, \delta_{IV}) = H\alpha' (^ \delta') f(t)$)

The set of translated expressions in intensional logic is the smallest set provided by Q₁ - Q₂₉.

MEANING POSTULATES

As we have already noted, the interpretation of our fragment of Swedish is done indirectly via the interpretation of those formulas in intensional logic which are the translations of our Swedish expressions. Since we are primarily interested in the interpretation of Swedish expressions, it is, therefore, desirable to restrict the possible models (interpretations) of intensional logic in such a way that our intuitions about the meaning and interpretation of the Swedish expressions is captured in the interpretation of their translational correspondents in intensional logic. We will do this by requiring that the following formulas must be true at every point of reference relative to any model serving as our interpretation.

- (1) Rigid designation for individual constants.
 $\forall u (u = \alpha)$, where α is j, k or l.
- (2) Common nouns except pris and temperatur denote sets of constant individual concepts. $[\delta(x)] - \forall u \exists x 'u)$ where δ translates any CN except pris and temperatur.
- (3) Intransitive verbs except stiga och förändras are extensional. $\forall M \Lambda x [\delta(x) \Leftrightarrow M\{^Vx\}]$ where δ translates any IV except stiga and förändras
- (4) Extensional transitive verbs
 $\forall S \Lambda x \Lambda P (\delta(x, P) \Leftrightarrow P(\hat{y} S \{^Vx, ^Vy\}))$ where δ is a TV/INF, an (IV/INF)/T or a TV except tro, leta efter or vara
- (5) The subject of leta efter is extensional
 $\Lambda P \forall M \Lambda x (\delta(x, P) \Leftrightarrow \{^Vx\} I)$ where δ translates leta efter
- (6) The subject of påstå and tro is extensional $\Lambda p \forall M \Lambda x [\delta(x, p) \Leftrightarrow M\{x\}]$ where δ translates påstå and tro.
- (7) The subject of försöka, önska, lova is extensional $\Lambda P \forall M \Lambda x [\delta(x, P) \Leftrightarrow M\{^Vx\}]$ where δ translates försöka, önska, lova

- (8) Extensionality for prepositions in PIAV

$$VG \wedge P \wedge Q \wedge x \quad [\delta (P) (Q) (x) \Leftrightarrow P(\hat{y}) [[^VG] (^y) (Q) (x)]]$$
 where δ translates i.
- (9) The denotations of all CN:s are in the denotation of grej where grej is a member of CN

$$[\delta (x) \rightarrow \text{grej}'(x)] \text{ where } \delta \text{ is any CN.}$$
- (10) Properties that hold both of the denotation of any member of CN and of any member in the denotation of grej

$$[\delta (P) (x) \Leftrightarrow [P \{x\} \wedge \delta (^{\text{grej}}) (x)]]$$
 where δ translates röd or any member of IAV which has the form i α where α is a term.
 (NB: the preposition i)
- (11) Properties that remain constant under adjectival modification $(\gamma (P) (x) \rightarrow P(x))$ where γ translates gammal, stor och röd but not falsk
- (12) The extensionality of ge and skicka

$$VT \wedge P \wedge Q \wedge x \quad [\gamma (P) (Q)(x) \Leftrightarrow p\{\hat{z} Q \{ \hat{y} [^VT] (^z) (\hat{y}) (^x) \} \}]$$
 where γ translates ge or skicka
- (13) Guaranteeing the correct subject for complements of ¹lova, ³lova and önska

$$VF \wedge X \wedge P \quad (\delta (x,P) \Leftrightarrow . F(x,[^W P(x)]])$$

where σ translates önska and ¹lova and ³lova.

(R.Cooper & S.Peters have pointed out to me that this postulate won't work for certain predicates not in my fragment, like be different from oneself. But since I need something like this postulate and have not yet found a better one, I have kept it in the present fragment).

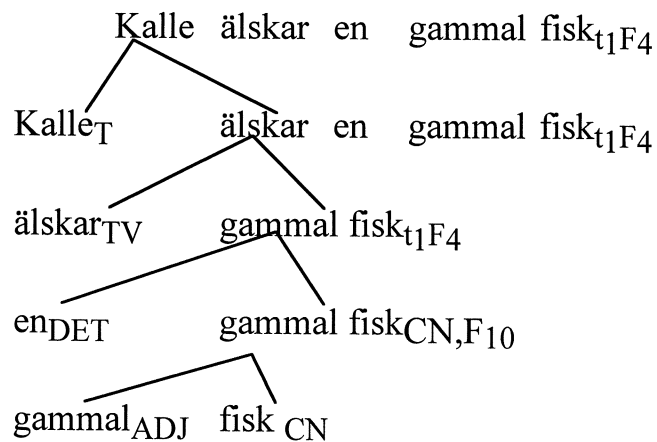
SOME EXAMPLES OF DERIVATIONS

Finally a few examples that illustrate the way the grammar is supposed to work will be given.

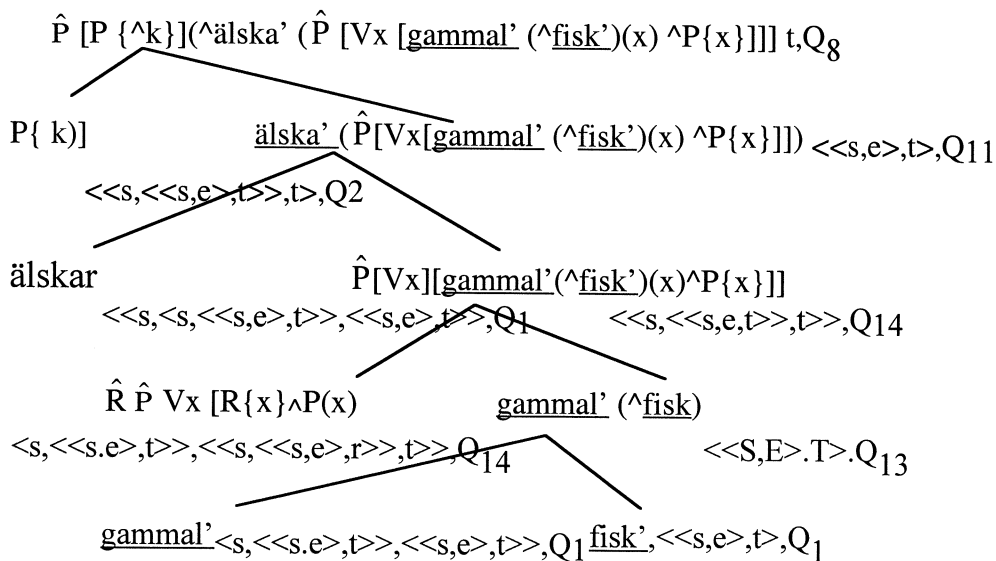
Example one

- (1) Kalle älskar en gammal fisk
Kalle loves an old fish

(a) syntactic analysis



(b) semantic analysis and translation



Comments: We see how the translation is obtained through a step by step application of the translation rules. The translation of the indefinite article en is slightly more elaborate in the tree above than in its translation function Q_{14} . Q_{14} syncategorematically contains β' , the translation of the CN to be modified by en. We have not inserted β' directly but instead as an intermediate step used the variable R to abstract over the CN. The λ -convention is then used to get the CN gammal (\wedge fisk) into the right place. The translation of Kalle is just the application of the superstar convention, given above under auxiliary notation. The final formula

$(P (P (\wedge k)) (\underline{\text{älska}}' (\hat{P} [Vx (\underline{\text{gammal}}' (\wedge \text{fisk}') (x) \wedge P\{x\}]]))$

can be further reduced by applying notational conventions and meaning postulates (MPs). If this is done, we obtain the following formula:

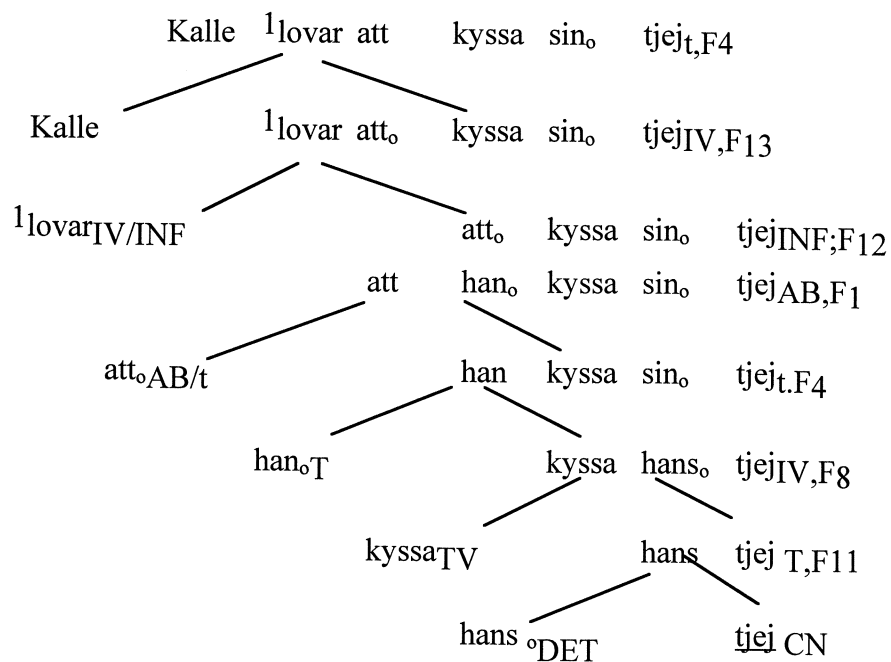
$$\forall u [(\underline{\text{gammal}} (\wedge \text{fisk}') * (u) \wedge \underline{\text{älska}}' * (k,u)]$$

Here a substar $*$ has been introduced to indicate that the predicates have been reduced, in accordance with MP2 and MP4 above, yielding constants of type $\langle e,t \rangle$ and $\langle e \langle e,t \rangle \rangle$ in the intensional logic. The expression $(\underline{\text{gammal}} (\wedge \text{fisk}'))$ has not been analyzed further since gammal is not the type of predicate for which reduction is allowed by MP10.

Example two

(2) Kalle 1lovar att kyssa sin tjejt,F4
 Kalle promises to kiss his girl

(a) Syntactic analysis



(b) Semantic analysis and translation

Since the full type designations of intensional logic in the translation trees are rather cumbersome and unspicuous, we will this time give them as values of the function f which takes categories into types.

$1_{\text{lova}}'(\wedge k, \hat{x}_0 [\text{kyssa}'(x_0 (\hat{P}[\text{Vy} [\wedge x [[[\text{tjej}'] (x) \wedge H_{v_{x_0} v_x}] \Leftrightarrow x=y}] \wedge P\{x\}]]])))] f(t), Q8$

$\hat{P}\{P\{\hat{k}\} \} t(t), Q3 \quad 1_{\text{lova}} (\hat{x}_0 [\text{kyssa}'(x_0, (\hat{P}[\text{Vy} [\wedge x [[[\text{tjej}'] (x) \wedge H_{v_{x_0} v_x}] \Leftrightarrow x=y}] \wedge P\{x\}]]])))] f(\text{IV}), Q19$

$1_{\text{lova}} f(\text{IV}/\text{INF}); Q11 \quad \hat{x}_0 [\text{kyssa}'(x_0, (\hat{P}[\text{Vy} [\wedge x [[[\text{tjej}'] (x) \wedge H_{v_{x_0} v_x}] \Leftrightarrow x=y}] \wedge P\{x\}]]])))] f(\text{AB}=f(\text{INF}), Q6$

$\text{kyssa} (x_0, (\hat{P}[\text{Vy} [\wedge x [[[\text{tjej}'] (x) \wedge H_{v_{x_0} v_x}] \Leftrightarrow x=y}] \wedge P\{x\}]]])))] f(\text{AB}=f(t), Q8$

$\hat{P}\{P\{x_0\} \} f(\text{T}), Q3 \quad \text{kyssa}' (\hat{P}[\text{Vy} [\wedge x [[[\text{tjej}'] (x) \wedge H_{v_{x_0} v_x}] \Leftrightarrow x=y}] \wedge P\{x\}]]])))] f(\text{AB}=f(\text{IV}), Q11$

$\text{kyssa}' f(\text{TV}). Q11 \quad (\hat{P}[\text{Vy} [\wedge x [[[\text{tjej}'] (x) \wedge H_{v_{x_0} v_x}] \Leftrightarrow x=y}] \wedge P\{x\}]]] (\text{T}), Q17$

$\hat{R} \hat{P}[\text{Vy} [\wedge x [[[\text{R}(x) \wedge H_{v_{x_0} v_x}] \Leftrightarrow x=y}] \wedge P\{x\}]]] f(\text{DET}), Q17 \quad \text{tjej}' f(\text{CN}) \quad Q1$

Comments: Again we have elaborated the translation somewhat, by changing the translation of hans_o analogously to the one given above for en. Thus, tjej is brought in via abstraction over the variable R. Similarly the final formula of the translation tree

$$^1\text{lova}(\wedge k, (\hat{x}_o [\text{kyssa}(x_o) (\hat{P} (V_y [\Lambda x [[[\text{tjej}'(x) \wedge H v_{x_o}, v_x] x=y] P\{x\}]])) J)$$

can be further reduced by making use of MP 13, MP 7, MP 4 and MP 2, giving the following formula

$$^o\text{lova}' * (k, [\wedge W[V_y[\Lambda x[[[\text{tjej}'(x) H k, v_x] \Leftrightarrow x=y] \wedge \text{kyssa}' * (k, v_x)]]))$$

Here $^o\text{lova}'$ is introduced as a constant of the intensional logic of type $f(IV/t)$. It is intended to correspond to the variable $F \langle\langle s, t \rangle, \langle\langle s, e \rangle, t \rangle\rangle$ of MP 13 and allows us, via MP 13, to predicate the property to which the subject has the relation denoted by $^1\text{lova}$ of the subject. Thus, one could say that MP 13 codifies our intuition that sentences (i) and (ii) below are synonymous. It also makes clear of whom the property denoted by the embedded infinitival complement is predicated

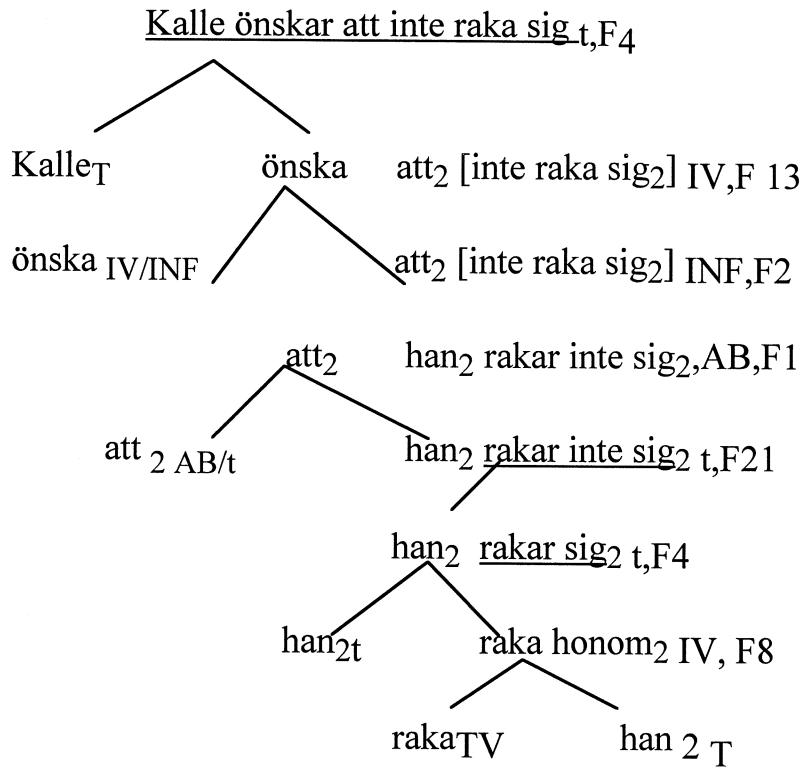
- (i) Jag $^1\text{lovar}$ att gå
I promise to go
- (ii) Jag $^o\text{lovar}$ att jag skall gå
I promise that I will go

Example Three

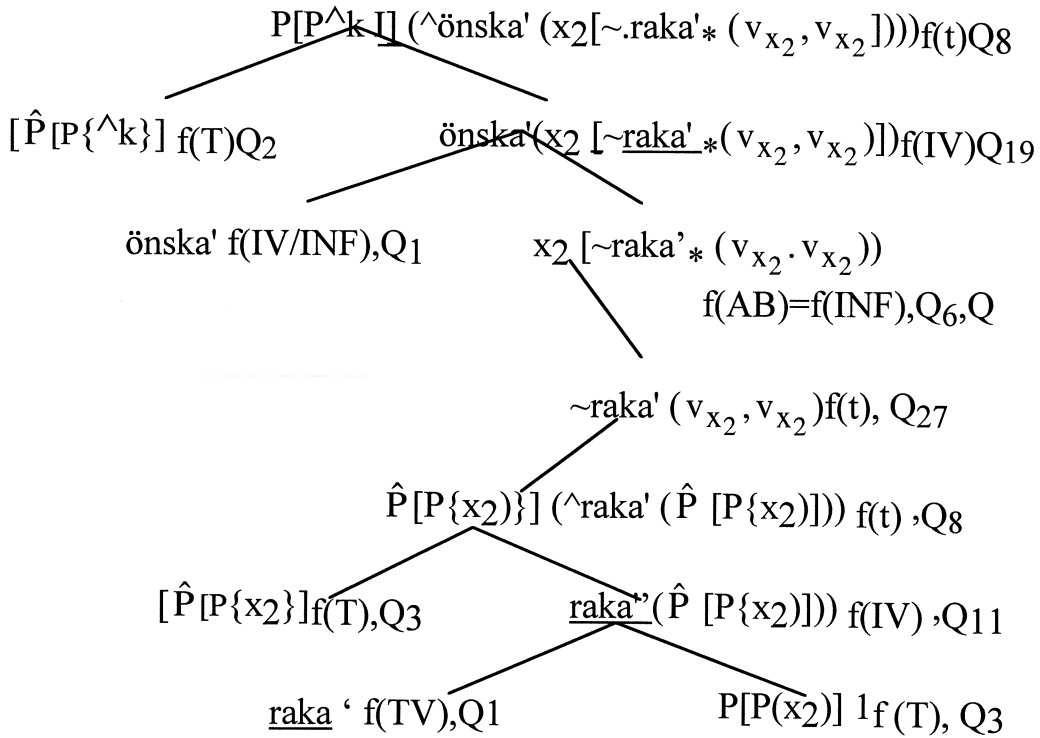
Finally, we give a sentence that for some speakers of Swedish seems to be better without the infinitival complementizer att (that)

Kalle önskar att inte raka sig

(a) Syntactic analysis



(b) Semantic analysis and translation



Comments This can in turn be reduced using MP 7 and MP 13, yielding the following expression.

$\circ\text{önska}' * k_1 [^W++++ (\text{raka}' * k, k)]]$

Again, we introduce a new constant of the intensional logic $\circ\text{önska}_f(\text{IV}/t)$ corresponding to the variable F in MP 13.

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