Grammar of ReALIS and the Implementation of its Dynamic Interpretation

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ReALIS, REciprocal And Lifelong Interpretation System, is a new "post-Montagovian" theory concerning the formal interpretation of sentences constituting coherent discourses, with a lifelong model of lexical, interpersonal and encyclopaedic knowledge of interpreters in its centre including their reciprocal knowledge on each other. First we provide a 2 page long summary of its 40 page long mathematical definition. Then we show the process of dynamic interpretation of a Hungarian sentence (Hungarian is a "challenge" because of its rich morphology, free word order and sophisticated information structure). We show how an interpreter can anchor to each other in the course of dynamic interpretation the different types of referents occurring in copies of lexical items retrieved by the interpreter on the basis (of the morphemes, word order, case and agreement markers) of the sentence performed by the speaker. Finally, the computational implementation of ReALIS is demonstrated.

Povzetek: Predstavljen je sistem ReALIS za dinamično interpretacijo zapletenih stavkov.

1 Introduction

$\Re$eALIS [2] [4], *REciprocal And Lifelong Interpretation System*, is a new "post-Montagovian" [15] [17] theory concerning the formal interpretation of sentences constituting coherent discourses [9], with a *lifelong* model [1] of lexical, interpersonal and cultural/encyclopaedic knowledge of interpreters in its centre including their *reciprocal* knowledge on each other. The decisive theoretical feature of $\Re$eALIS lies in a peculiar reconciliation of three objectives which are all worth accomplishing in formal semantics but could not be reconciled so far.

The first aim concerns the exact formal basis itself ("Montague's Thesis" [20]): human languages can be described as interpreted *formal* systems. The second aim concerns *compositionality*: the meaning of a whole is a function of the meaning of its parts, practically postulating the existence of a *homomorphism* from syntax to semantics, i.e. a rule-to-rule correspondence between the two sides of grammar.

In Montague's interpretation systems a traditional logical representation played the role of an intermediate level between the syntactic representation and the world model, but Montague argued that this intermediate level of representation can, and should, be eliminated. (If α is a compositional mapping from syntax to discourse representation and β is a compositional mapping from discourse to the representation of the world model, then $\gamma=\alpha\circ\beta$ must be a compositional mapping directly from syntax to model.) The post-Montagovian history of formal semantics [17] [9], however, seems to have proven the opposite, some principle of "discourse representationalism": "some level of [intermediate] representation is indispensable in modelling the interpretation of natural language" [14].

The Thesis of $\Re$eALIS is that the two fundamental Montagovian objectives *can* be reconciled with the principle of "discourse representationalism" – by embedding discourse representations in the world model, getting rid of an intermediate level of representation in this way while preserving its content and relevant structural characteristics. This idea can be carried out in the larger-scale framework of embedding discourse representations in the world model *not directly* but as parts of the representations of interpreters' minds, i.e. that of their (permanently changing) information states [3].

2 Definition

The frame of the mathematical definition of $\Re$eALIS (whose 40 page long complete version is available in [4] (Sections 3-4)) is summarized in this section. As interpreters' mind representations are part of the WORLD MODEL, the definition of this model $\Re = \langle U, W_0, W\rangle$ is a quite complex structure where

- U is a countably infinite set: the UNIVERSE
- $W_0 = \langle U_0, T, S, I, D, \Omega, A\rangle$: the EXTERNAL WORLD
- W is a partial function from set I×Tm where W[i,t] is a quintuple $\langle U[i], \sigma[i,t]^{\Pi}, \alpha[i,t]^{\Psi}, \lambda[i,t]^{\Lambda}, \kappa[i,t]^{K}\rangle$: the INTERNAL-WORLD FUNCTION.

The external world consists of the following components:

- U_0 is the external universe ($U_0 \subset U$), whose elements are called entities
- $T = \langle T, \Theta \rangle$ is a structured set of temporal intervals ($T \subset U_0$)
- $S = \langle S, \Xi \rangle$ is a structured set of spatial entities ($S \subset U_0$)
- $I = \langle I, Y \rangle$ is a structured set of interpreters ($I \subset U_0$)
- $D = \langle D, \Delta \rangle$ is a structured set of linguistic signs (practically morph-like entities and bigger chunks of discourses) ($D \subset U_0$)
- $\Omega \subset T \times U_0{}^*$ is the set of core relations (with time intervals as the first argument of all core relations)
- A is the information structure of the external world (which is nothing else but relation structure Ω reformulated as a standard simple information structure, as is defined in [22: 245]; its basic elements are called the infons of the external world
- T, S, I and D are pairwise disjoint, infinite, proper subsets of the external universe U_0 which meet further requirements that cannot be elaborated here.

The above mentioned *internal-world function* W is defined as follows:

- The relation structure W[i,t] is called the internal world (or information state) of interpreter i at moment t
- $U[i] \subset U$ is an infinite set: interpreter i's internal universe (or the set of i's referents, or internal entities); U[i'] and U[i"] are disjoint sets if i' and i" are two different interpreters
- in our approach what changes during a given interpreter's lifespan is not his/her referent set U[i] but only the four relations among the (peg-like [12]) referents, listed below, which are called i's internal functions:
- $\sigma[i,t]\Pi : \Pi \times U[i] \rightarrow U[i]$ is a partial function: the eventuality function (where Π is a complex label characterizing argument types of predicates)[1]
- $\alpha[i,t]\Psi : \Psi \times U[i] \rightarrow U[i] \cup U_0$ is another partial function: the anchoring function (α practically identifies referents, and Ψ contains complex labels referring to the grammatical factors legitimizing these identifications)
- $\lambda[i,t]\Lambda : \Lambda \times U[i] \rightarrow U[i]$ is a third partial function: the level function (elements of Λ are called level labels); the level function is practically intended to capture something similar to the "box hierarchy" among referents in complex Kampian DRS boxes [10] enriched with some rhetorical hierarchy in the style of SDRT [2]
- $\kappa[i,t]K : K \rightarrow U[i]$ is also a partial function: the cursor, which points to certain temporary reference points prominently relevant to the interpreter such as "Now", "Here", "Ego", "Then", "There", "You" etc.

[1] The DRS condition [e: p t r_1 ... r_K] [10] (e.g. [e: resemble now Peter Paul]) can be formulated with the aid of this function as follows (with i and t fixed):
$\sigma(\langle Pred, \pi \rangle, e) = p$, $\sigma(\langle Temp, \tau \rangle, e) = t$, $\sigma(\langle Arg, \psi_1 \rangle, e) = r_1$, ..., $\sigma(\langle Arg, \psi_K \rangle, e) = r_K$.

The temporary states of these four internal functions above an interpreter's internal universe (which meet further requirements that cannot be elaborated here) serve as his/her "agent model" [11] in the process of (static and dynamic) interpretation.

Suppose the information structure A of the external world (defined above as a part of model $\mathfrak{R} = \langle U, W_0, W \rangle$) contains the following infon: $\iota = \langle$PERCEIVE, t, i, j, d, s$\rangle$, where i and j are interpreters, t is a point of time, s is a spatial entity, d is a discourse (chunk), and PERCEIVE is a distinguished core relation (i.e. an element of Ω). The INTERPRETATION of this "perceived" discourse d can be defined in our model relative to an external world W_0 and internal world W[i,t].

The DYNAMIC INTERPRETATION of discourse d is essentially a mapping from W[i,t], which is a temporary information state of interpreter i, to another (potential) information state of the same interpreter that is an *extension* of W[i,t]; which practically means that the above mentioned four *internal functions* (σ, α, λ, κ) are to be developed monotonically by *simultaneous recursion*, expressing the addition of the information stored by discourse d to that stored in W[i,t].

The new value of eventuality function σ chiefly depends on the *lexical items* retrieved from the interpreter's internal mental lexicon as a result of the perception and recognition of the words / morphemes of the interpreter's mother tongue in discourse d. This process of the unification of lexical items can be regarded as the first phase of the dynamic interpretation of (a sentence of) d. In our $\mathfrak{R}$eALIS framework, as will be shown in the next section, extending function σ corresponds to the process of accumulating DRS condition rows [17] containing referents which are all – still – regarded as different from each other.

It will be the next phase of dynamic interpretation to *anchor* these referents to each other (by function α) on the basis of different grammatical relations which can be established due to the recognized *order* of morphs / words in discourse d and the *case*, *agreement* and other markers it contains. In our approach two referents will never have been *identified* (or deleted), they will only be anchored to each other; but this anchoring essentially corresponds to the identification of referents in DRSs.

The third phase in this simplified description of the process of dynamic interpretation concerns the third internal function, λ, the level function. This function is responsible for the expression of intra- and inter-sentential scope hierarchy [21] / information structure [23] / rhetorical structure [9], including the embedding of sentences, one after the other, in the currently given information state by means of rhetorical relations more or less in the way suggested in SDRT [9].

It is to be mentioned at this point that the information-state changing dynamic interpretation and the truth-value calculating *static interpretation* are mutually based upon each other. On the one hand, static interpretation operates on the *representation* of sentences (of discourses) which is nothing else but the output result of dynamic interpretation. On the other hand, however, the above discussed phases of dynamic interpretation (and chiefly the third phase) include subprocesses requiring static interpretation: certain *presuppositions* are to be verified [17].

The interpreter's fourth internal function, cursor κ, plays certain roles during the whole process of dynamic interpretation. *Aspect*, for instance, can be captured in our approach as the resetting or retaining of the *temporal* cursor value as a result of the interpretation of a sentence (→ *non-progressive / progressive* aspect). It can be said in general that the input cursor values have a considerable effect on the embedding of the "new information" carried by a sentence in the interpreter's current information state and then this embedding will affect the output cursor values.

DYNAMIC INTERPRETATION in a ℜeALIS model $\Re=\langle U, W_0, W\rangle$, thus, is a partial function Dyn which maps a (potential) information state W° to a discourse d and an information state W[i,t] (of an interpreter i): $Dyn(d) : \langle \Re, W[i,t]\rangle \rightarrow \langle W°, e°, U°\rangle$, where U°, shown up in the output triple, is the COST of the given dynamic interpretation (coming from presuppositions legitimized by *accommodation* instead of *verification*), and e° is the eventuality that the output cursor points to (e°is to be regarded as representing the content of discourse d). Function Dyn(d) is *partial*: where there is no output value, the discourse is claimed to be ill-formed in the given context. Due to the application of cost, ill-formedness is practically a gradual category in ℜeALIS: a great cost of interpretation qualifies the discourse to be "almost unacceptable".

The STATIC INTERPRETATION of a discourse d is nothing else but the static interpretation of the eventuality referent representing it. Its recursive definition is finally based upon anchoring internal entities of interpreters to external entities in the external universe, and advances from smaller units of (the sentences of) the discourse towards more complex units. We do not intend to enter into details in this paper.

3 Example

The detailed analysis of a Hungarian sentence will serve as an illustration of the process of dynamic interpretation.

Hungarian is a "challenge" because of its very rich morphology and extremely free word order [18], which enables to express subtle differences in meaning [23]. We claim that the very abstract and morpheme-based monostratal ℜeALIS approach to grammar, relying on the four internal functions σ, α, λ and κ (discussed above) and a complex system of *ranked* lexical requirements (which is nearly an apparatus similar to those known from optimality theories [8]), *neutralizes* the difference between languages where the meaning of a sentence can primarily be calculated on the basis of words in a strict order and languages where what are relevant to this calculation are basically morphemes within words and affixes (e.g. case and agreement markers).

How can an interpreter anchor to each other the different types of referents occurring in copies of lexical items retrieved in the course of dynamic interpretation? Let us consider the Hungarian sentence below:

(1) *REQUIREMENTS* (↑) AND *OFFERS* (↓) IN LEXICAL ITEMS

Péter hasonlít ar-ra a magas német úszó-bajnok-ra.
Peter resemble that-onto the tall German swimming-champion-onto
'Peter resembles that tall German swimming champion.'

a. Péter: [e_P: ⇒? e_P' e_P", e_P' : p_{Peter} r_P]
e_P ↑ λ:: ⟨...⟩
e_P" ↑ α:: ⟨...⟩
e_P' ↑ λ:: ⟨⬉.supp⟩↓ e_P
e_P" ↑ λ:: ⟨⬉.cons⟩↓ e_P'
r_P ↑ α:: Pred: ⟨⟨Cat,+2,$X_\varnothing$ ⟩, ⟨Agr,+2,3Sg⟩⟩
↑ α:: Ant: ⟨...⟩
↓ α:: ∅: ⟨⟨Cat,0,PropN⟩, ⟨Case,0,∅⟩, ⟨Agr,0,3Sg⟩⟩

b. hasonlít: [e_{res} : $p_{resemble}$ r_{res}' r_{res}"]
e_{res} ↑ λ:: ⟨...⟩
r_{res}'↑ α:: ArgN: ⟨⟨Ord,-7,Nei⟩, ⟨Cat,+2,N⟩, ⟨Case,+2,∅⟩⟩
↑ α:: ArgD: ⟨⟨Cat,+2,GQD⟩⟩
↓ α:: ∅: ⟨⟨Cat,0,$V_{\varnothing+rA}$⟩, ⟨Agr,0,3Sg⟩⟩
r_{res}" ↑ α:: ArgN: ⟨⟨Ord,+7,Nei⟩, ⟨Cat,+2,N⟩, ⟨Case,+2,rA⟩⟩
↑ α:: ArgD: ⟨⟨Cat,+2,GQD⟩⟩
↓ α:: ∅: ⟨⟨Cat,0, $V_{\varnothing+rA}$⟩⟩

c. arra:
r_{that} ↑ α:: Adj: ⟨⟨Ord,+6,Nei⟩, ⟨Cat,+2,N⟩, ⟨Agr,+2,{3,Sg,rA}⟩⟩
↑ α:: Out: ⟨⟨Gest,+2,Glance⟩, ⟨Dist,+2,Long⟩⟩

d. a(z): [e_{the}: ⇒? e_{the}' e_{the}", σ(⟨Arg, ∅⟩, e_{the}')= r_{the}]
e_{the} ↑ λ:: ⟨...⟩
e_{the}' ↑ α:: ⟨...⟩
e_{the}" ↑ α:: ⟨...⟩
e_{the}' ↑ λ:: ⟨⬉.supp⟩↓ e_{the}
e_{the}" ↑ λ:: ⟨⬉.cons⟩↓ e_{the}'
r_{the} ↑ α:: Adj: ⟨⟨Ord,+5,Nei⟩, ⟨Cat,+2,N⟩⟩
↑ α:: Pred: ⟨⟨...⟩⟩
↑ α:: Ant: ⟨...⟩
↓ α:: Arg: ⟨⟨Cat,0,+Art⟩⟩

e. magas: [e_{tall}: ∧ e_{tall}' e_{tall}", e_{tall}': p_{tall} r_{tall}]
e_{tall}" ↑ α:: ⟨...⟩
e_{tall}'↑ λ:: ⟨⬀.conj⟩↓ e_{tall}"
e_{tall}↑ λ:: ⟨⬀.conj⟩↓ e_{tall}"
r_{tall}↑ α:: Adj: ⟨⟨Ord,+2,Nei⟩,

⟨Cat,+2,N⟩⟩

$\downarrow$ α:: ∅: ⟨⟨Cat,0,A_{color}⟩⟩

f. német: e_{germ}: ∧ e_{germ}’ e_{germ}”, e_{germ}’: p_{German} r_{germ}]

e_{germ}” $\uparrow$ α:: ⟨...⟩

e_{germ}’$\uparrow$ λ:: ⟨⬀.conj⟩$\downarrow$ e_{germ}”

$e_{germ}$$\uparrow$ λ:: ⟨⬀.conj⟩$\downarrow$ e_{germ}”

5th row $r_{germ}$$\uparrow$ α:: Adj: ⟨⟨Ord,+1,Nei⟩, ⟨Cat,+2,N⟩⟩

$\downarrow$ α:: ∅: ⟨⟨Cat,0,A_{nation}⟩⟩

g. úszó-: [e_{sw}: ∧ e_{sw}’ e_{sw}”, e_{sw}’: $p_{swimming}$ r_{sw}]

e_{sw}” $\uparrow$ α:: ⟨...⟩

e_{sw}’$\uparrow$λ:: ⟨⬀.conj⟩$\downarrow$ e_{sw}”

e_{sw} $\uparrow$λ:: ⟨⬀.conj⟩$\downarrow$ e_{sw}”

5th row $r_{sw}$$\uparrow$ α:: Adj: ⟨⟨Ord,+ ⅓,Nei⟩, ⟨Cat,0,N⟩⟩

$\downarrow$ α:: ∅: ⟨...⟩

h. bajnok: [e_{ch}: $p_{champion}$ r_{ch}]

e_{ch} $\uparrow$ λ:: ⟨...⟩

$r_{ch}$$\uparrow$ α:: Pred: ⟨⟨Cat,+5, $X_{\varnothing}$⟩⟩

$\downarrow$ α:: ∅: ⟨⟨Cat,0,ComN⟩, ⟨Case,0,∅⟩, ⟨Agr,0,3Sg⟩⟩)

-ra:

r_{onto}’ $\uparrow$ α:: Stem: ⟨⟨Ord, – ⅛Nei⟩, ⟨Cat,+2, N⟩⟩

r_{onto}”$\uparrow$ α:: Pred: ⟨⟨Cat,+2, X_{-rA}⟩⟩

In ℜeALIS the lexical representation belonging to a morpheme typically contains reference to a predicate (e.g. $p_{champion}$) furnished with argument referents (e.g. r_{ch} above in (1h)), a temporal referent and a referent referring to the fact that “the given predicate holds true” (the eventuality referent e_{ch} refers to the fact that somebody is a champion). In the analysis that this paper provides temporal referents are ignored for the sake of simplicity. As was mentioned earlier, this “eventuality construction” is registered by internal function σ.

The lexical representation belonging to a morpheme should predict about these referents how they will connect to referents coming from other lexical representations retrieved in the course of dynamic interpretation of a sentence when the given morpheme gets into the given sentence. We mean the extension of α, practically responsible for identification, and λ, responsible for scope hierarchy and/or rhetorical relations. Lexical items thus impose “requirements” on the potential intrasentential environments accommodating the given morphemes and provide “offers” for other morphemes’ items to help them (these other morphemes) find them.

In what follows we provide comments on a few (but not all) lexical requirements and offers. Let the verb (*hasonlít* ‘resemble’) be the first (1b), with its 8 row long lexical description. The first row contains the “eventual” representation of the semantic contribution of this verb, which consists of an eventuality referent (referring to the fact that somebody resembles somebody), a predicate referent, a temporal referent (ignored), and two argument referents. What the second row says is that the eventuality referent, which practically represents the piece of information carried by this word-size morpheme) should be linked to some part of the interpreter’s current information state (potentially including pieces of information coming from the sentence being interpreted) by means of an appropriate level label.

According to the third row, the referent belonging to the first argument of the verb (r_{res}’) should be anchored to the referent coming from the lexical description of a morpheme (word) “in the neighbourhood” (‘Nei’) as for word order (‘Ord’), which belongs to the category of nouns (‘⟨Cat,...,N⟩’) and bears the Nominative case, which is unmarked in Hungarian (‘∅’). What the fourth row adds to this complex requirement is that referent r_{res}’ should also be anchored to a referent coming from the lexical item of a morpheme (or word) which can play the role of a generalized-quantifier determiner ‘GQD’ [10]. Let us look at (2f-g) below: the proper name *Péter* is suitable for both roles as it is a noun in the nominative and implicitly includes an article (‘*the* person called Peter’). The fifth row says that lexical item (1b) “offers” a verb with two specific arguments (‘$V_{\varnothing+rA}$’) in 3Sg. On the basis of this characterization referent r_P in lexical item (1a) may find r_{res}’; see (2a) below. The intuitive content of the lexical information conveyed in rows 3-5 is that *who resembles somebody is nothing else but Peter*[2]; the three equations below in (2a, f, g) declare this fact three times, on the basis of different grammatical evidence.

Rows 6-8 characterize the second argument of *hasonlít*. Its referent r_{res}” should be anchored to two different referents: one coming from the lexical description of a noun (‘ArgN’) (2h, x) and another one contained by the item of a determiner-like element (‘ArgD’) (2i, m). In this way the interpreter can identify the person that Peter resembles with one mentioned as “the champion”.

(2) THE CONNECTIONS COMPLETED AMONG “SIMPLE” REFERENTS

a. r_P $\uparrow$α:: Pred: ⟨Cat, Agr⟩$\downarrow$ r_{res}’
b. r_P $\uparrow$α:: Ant: ⟨...⟩$\downarrow$ $r_{Péter}$
c. e_P $\uparrow$λ:: ?$\downarrow$?
d. e_P” $\uparrow$α:: ?$\downarrow$?
e. $e_{res}$$\uparrow$λ:: ⟨⬉.cons⟩$\downarrow$? (assertion!)
f. r_{res}’ $\uparrow$α:: ArgN: ⟨Ord, Cat, Case⟩$\downarrow$ r_P
g. r_{res}’ $\uparrow$α:: ArgD: ⟨Cat⟩$\downarrow$ r_P
h. r_{res}” $\uparrow$α:: Arg: ⟨Ord, Cat, Case⟩$\downarrow$ r_{ch}
i. r_{res}” $\uparrow$α:: Arg: ⟨Cat⟩$\downarrow$ r_{the}
j. r_{that} $\uparrow$α:: Adj: ⟨Ord, Cat, Agr⟩$\downarrow$ r_{ch}
k. r_{that} $\uparrow$α:: Out: ⟨Gest, Dist⟩$\downarrow$ $u_{HansMüller}$
l. r_{the} $\uparrow$α:: Adj: ⟨Ord, Cat⟩$\downarrow$ r_{ch}
m. r_{the} $\uparrow$α:: Pred: ⟨⟨...⟩$\downarrow$ r_{res}”

[2] We call this relation established between two lexical items that show some grammatical sensitivity to each other (e.g. agreement, case marking, adjacency in word order) – *copredication*: they provide two predications about the *same* referent.

n. r_{the} ↑α:: Ant: ⟨...⟩↓ r_a
o. e_{the} ↑λ:: ⟨⬉.cons⟩↓ ? (argument position!)
p. e_{the}’ ↑α:: ?↓ ?
q. e_{the}” ↑α:: ?↓ ?
r. r_{tall} ↑α:: Adj: ⟨Ord, Cat⟩↓ r_{ch}
s. e_{tall}” ↑α:: ?↓ ?
t. r_{germ} ↑α:: Adj: ⟨Ord, Cat⟩↓ r_{ch}
u. e_{germ}” ↑α:: ?↓ ?
v. r_{sw} ↑α:: Adj: ⟨Ord, Cat⟩↓ r_{ch}
w. e_{sw}” ↑α:: ?↓ ?
x. r_{ch} ↑α:: Pred: ⟨Cat⟩↓ r_{res}”
y. r_{onto}’ ↑α:: Stem: ⟨⟨Ord, Cat⟩↓ r_{ch}
z. r_{onto}” ↑α:: Pred: ⟨Cat⟩↓ r_{res}”
aa. e_{ch} ↑λ:: ?↓ ?

Now let us turn to the lexical item that belongs to the noun stem *bajnok* ‘champion’ (1h). According to row 3, a predicate with a nominative argument is to be found because, according to row 4, this stem is a common noun which “seems” to be in the nominative case. Number ‘5’ in row 3, however, “permits” that the requirement in question be satisfied *indirectly*. Numbers like this in the middle of the triples expressing requirements are *ranks*. If this rank is ‘1’, the given requirement must be satisfied in the way described. If the rank is weaker (ρ>1), there are also alternative ways of satisfaction at our disposal, typically with reference to higher ranked requirements (e.g. (1i.row3). Requirement (1h.row3), thus, can be satisfied (2x), but indirectly, due to (2z)).

It is also typical that requirements concerning word order can be satisfied *indirectly*. There are five lexical items in the example that contain requirements demanding that a certain word *immediately precede* the common noun ‘champion’ (see (1c-g)). The adjective expressing nationality is required to be the word adjacent to the noun to the highest degree: rank ‘+1’ expresses this fact in (1f.5). The fraction rank in (1g.5) implies an even stricter neighbourhood but this should be carried out within one word in Hungarian (*úszóbajnok* ‘swimming champion’). The other adjective referring to a personal characteristic, ‘tall’, should remain before ‘German’ because of its rank number ‘2’ in (1e.5). Then the weaker ranks ‘5’ in the lexical item of the definite article (1d.7) and ‘6’ in that of the demonstrative pronoun (1c.2) lead to the following grammatical word order in the prenominal zone in question: *arra a magas német úszóbajnokra* ‘that’ ‘the’ ‘tall’ ‘German’ ‘swimming’ ‘champion’. Alternative orders are ill-formed.

The explanation relies on the ranks discussed above: an adjacency requirement of rank k concerning words w’ and w” can be regarded as satisfied if w’ is adjacent to w”, indeed, or each word ξ between w’ and w” is such that the requirement demanding its being there is of a higher rank n (n<k, or n≤k) or ξ is a dependent of a word like this. We have a hypothesis concerning the nature of UG highly relevant to the efficiency of *implementation*: it is possible to work out a system of adjacency ranks in a way that enables us to check whether there is a *single* “legitimate” word between w’ and w” in the above discussed sense, instead of checking in the case of *all* words between w’ and w” whether they are legitimate “inhabitants” in that zone.

Our next comment concerns the semantic content of the definite article (1d.1), which is represented by eventuality referent e_{the}. Following [3], we assume that ‘the’ organizes the semantic content of a sentence in the form of an implication with the information coming from a certain noun and its “dependents” as its premise (e_{the}’) and the information typically coming from the verb as the conclusion (e_{the}”). What e_{the} expresses, thus, is something like this: “if somebody is a tall German swimming champion (3e, g, h, i), then somebody resembles him (3f)”.

Similarly, the lexical item belonging to the proper name (1a) also contains an implication (e_P) due to the implicit definite article hidden in (Hungarian) proper names (1a.1). Its approximate content will prove to be the following at the end of the successful dynamic interpretation: “if somebody is a person called Peter (1a.1), then (3b) he resembles a tall German swimming champion”.

(3) THE CONNECTIONS COMPLETED AMONG REFERENTS REFERRING TO EVENTUALITIES
a. e_P ↑λ:: ⟨⬉.exp⟩↓ κ^{prev}(Eve) (topic!; „What a surprise!”)
b. e_P” ↑α:: ⟨...⟩↓ e_{the}
c. e_{res}↑λ:: ⟨⬉.cons⟩↓ e_{tall} (e_{res} will represent the *assertion* of the sentence)
d. e_{the} ↑λ:: ⟨⬉.cons⟩↓ e_P’ (argument position!)
e. e_{the}’ ↑α:: Adj: ⟨Ord, Cat⟩↓ e_{tall}
f. e_{the}” ↑α:: Adj: ⟨Ord, Cat⟩↓ e_{res}
g. e_{tall}” ↑α:: Adj: ⟨Ord, Cat⟩↓ e_{germ}
h. e_{germ}” ↑α:: Adj: ⟨Ord, Cat⟩↓ e_{sw}
i. e_{sw}” ↑α:: Adj: ⟨Ord, Cat⟩↓ e_{ch}
j. e_{ch} ↑λ:: ⟨⬉.cons ⟩↓ e_P’

A sentence like the one in (1) is to be embedded in the interpreter’s current information state, converting the double implicative structure into a (one-level) collection of *conjunctions* partly due to the successful anchoring of referents r_P (2b) and r_{ch} (2j-l) to two specific persons (say, Péter Puskás and Hans Müller) and the linking of the main eventuality of the sentence to some previous piece of information (‘κ^{prev}(Eve)’ in (3a) where κ is the cursor function). What we receive in this way can be as follows, for instance: “Péter resembles a tall German swimming champion, Hans Müller; and this fact serves as an Explanation (‘⟨⬉.exp⟩’) [9] for the speaker’s surprise.

4 Implementation

The syntactic background of ReALIS has a “totally” lexicalist nature, which means that the grammar consists only of lexical items and their highly rich descriptions: properties and expectations (offers (↓) and requirements (↑) as used above). Phrase structure trees are not built, the only operation is unification. In this homogenous grammar word order is handled exactly like any other requirement (e.g. case or agreement). This is a more universal approach than applying phrase structure rules, since some languages hardly have any restrictions for word order (but have much more rules about agreement). We have been working on the implementation of this totally lexicalist grammar, which uses ReALIS for semantic analysis and representation.

In the past few years lexicalist parsers have become more and more successful and widely used. They can provide more detailed analysis than any other parser (some of them even have semantic component), and they can handle languages with rich morphology and free word order as well; furthermore, the outputs of these analyses can be parallel, thus machine translation can be achieved more easily. Coverage has been a secondary issue (many of these applications are still in experimental phase), but some of these parsers have actually reached the coverage of parsers using shallow techniques and statistical methods (e.g. the HPSG-based DELPH-IN, [12], or the LFG-based Parallel Grammar, [13]).

The success of lexicalist approaches (not only in theory but in the field of language technology as well) encourages us to keep working on the implementation, and see whether a totally lexicalist approach can be even more successful. A further argument for developing a parser based on ReALIS is the lack of programs which aim at providing detailed analysis and semantic representation, and can handle phenomena like rhetoric relations, discourse functions (topic, focus) and aspect. Finally, we believe that if the semantic representation is detailed enough (and ReALIS is more sophisticated than any earlier one) it can serve as some kind of interlingua, which could make it easier to achieve language-independent machine translation. (Lexicalist approaches like LFG and HPSG usually use transfer-based machine translation, which needs different transfer lexicons for every language pair.)

The first step of the implementation was to create a relational (SQL) database for the lexicon [24], which is universal enough to be able to store any lexical item of any language with all their properties (↓) and requirements (↑). This can be possible because properties are stored as tuples (rows) and not as attributes (columns), and the lexical items (which are also rows in the system) are connected to the relevant features by matching tables. This way we have gained a dynamically expandable system, since we do not have to define all possible properties of every language at the beginning, we can easily add new ones any time without changing the structure of the database.

The parsing begins with finding the main predicate (verb or nominal in Hungarian), then its requirements (↑) have to be satisfied by finding all the necessary elements with the proper features (↓), and then *their* requirements have to be satisfied, etc. The cursor controls the search, and makes sure that every need is fulfilled. Finally, the remaining morphemes have to be legitimized, such as adverbs or adjectives. An important operation is unification, which is responsible for the right matches.

Since our aim is to provide a highly detailed semantic representation, the logical choice was to proceed from the semantics: even the "syntactic" search is directed by the semantic need to find the referents which play a role in the meaning of the sentence [6]. If all the referents which are present in a lexical item's requirements (↑) can be identified with other referents in other lexical items' properties (↓), then the sentence is grammatical, and the proto-DRSs and the identity relations are listed.

In our system lexical items are morphemes (stems and affixes) for two reasons. The practical reason is effectiveness: in the case of agglutinative languages (like Hungarian) the size of the lexicon would be enormous if every possible word form were added. The other – more important – reason is theoretical: the idea of "total" lexicalism is better served by this approach (TLM, Totally Lexicalist Morphology [5]), and higher degree of universality can be achieved. TLM does not follow the usual way by having a morphological component, which first creates the words, and then syntax and semantics can operate on them. In TLM every kind of morpheme can have their own requirements and semantic content (but not all of them actually have). This way a main difference between Hungarian and English can disappear [7], namely that in Hungarian suffixes express e.g. causativity or modality, while in English separate words are responsible for the same roles (there is a similar approach for Japanese [16]).

(4) *Énekel - tet - het - l - ek.*
sing - cause - may - 2sg.obj - 1sg.subj
'*I may make you sing*.'

The "cost" of TLM is that the "usual" information is not cumulated in a word (e.g. the case of a noun), but it can be solved by rank parameters.

Using rank parameters is a crucial point of the theory, and so the implementation. Every expectation can be overridden by a stronger requirement (like in optimality theory); in other words, every requirement can be satisfied directly or indirectly (by fulfilling a stronger need). This way several phenomena can be handled easily, such as word order (see above), or case and agreement (without gathering the information of all the morphemes of a word). Consider the above mentioned construction *hasonlít a bajnok-ra* (resembles the champion-onto), for instance: one of the requirements of the verb *hasonlít* ('resemble') is to find a noun which is in sublative case (*-ra/-re*). It could be satisfied directly if a pronoun was found (e.g. *rám*, sublative form of me, onto-me). In this case direct satisfaction is not possible, since the noun *bajnok* (champion) is in nominative case; but it can be satisfied indirectly, because there is an element, the suffix *-ra* ('onto'), which is identified with the *bajnok* ('champion') by a referent, and this morpheme can meet the verb's expectation.

The implementational significance of the function σ (footnote 1) is that robustness can be achieved by using it. This function makes it possible to separate the referents of an eventuality, such as predicate, time, first argument, second argument, etc. This way we can assign semantic representations to ungrammatical or incomplete sentences as well (when producing complete condition rows fails).

The size of the database is rather small at the moment, but there are applications which do not need a large corpus. The first one we will develop is a system which can find the focus (or foci) of a sentence (the phenomena is very interesting in Hungarian, since the element is marked by a change in word order as well, not only emphasis). Our approach is different from the usual phrase-structure approach, where only a whole phrase can be the focused element. The totally lexicalist method is more appropriate since any word can be the focus (*két*, *okos*, *fiúval*):

(5) *Péter két okos fiú - val találkoz-ott.*
Peter two clever boy-with meet - past
'Peter met two clever boys.'

5 Conclusion

We have demonstrated a new "post-Montagovian" theory of interpretation, called ReALIS. After arguing for its decisive theoretical innovation (the reconciliation of compositionality and some kind of "discourse representationalism") and sketching its definition, we have shown the process of dynamic interpretation of a Hungarian sentence in this framework: how an interpreter can anchor to each other the different types of referents occurring in copies of lexical items retrieved by the interpreter on the basis of the morphemes, word and morpheme order, case and agreement markers of the sentence performed by the speaker. The last section has been devoted to the demonstration of the computational implementation of ReALIS. Due to its "totally" lexicalist (morpho-)syntactic background and ranked lexical requirements, we avoid building phrase structure trees in the course of producing semantic representations. The only operation is unification of lexical constructions. In this "abstract" approach the radical differences between languages like English and Hungarian will practically disappear.

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References

[1] Alberti, G. (2000): Lifelong Discourse Representation Structures, *Gothenburg Papers in Computational Linguistics* 00–5, 13–20.

[2] Alberti, G. (2004): ReAL Interpretation System, in Hunyadi, L., Rákosi, Gy., Tóth, E. (eds.) *Preliminary Papers of the Eighth Symposium on Logic and Language,* Univ. of Debrecen, 1–12.

[3] Alberti, G. (2005): Accessible Referents in "Opaque" Belief Contexts, in Herzig, A., van Ditmarsch, H. (eds.) *Belief Revision and Dynamic Logic*, *ESSLLI 2005*, Heriot – Watt Univ., Edinburgh, 1–8.

[4] Alberti, G. (2008): *ℜeALIS: Interpreters in Worlds, Worlds in Interpreters*, ms. (in Hungarian), János Bolyai Research Scholarship, Hungarian Academy of Sciences.

[5] Alberti, G., Balogh, K., Kleiber, J., Viszket, A. (2002): Towards a totally lexicalist morphology, in Siptár, P., Piñón, Ch. (eds.) *Approaches to Hungarian* 9, 9–33.

[6] Alberti, G., Balogh, K., Kleiber, J., Viszket, A. (2003): Total Lexicalism and GASGrammars: A Direct Way to Semantics, in Gelbukh, A. (ed.) *Proceedings of CICLing2003*, NLCS 2588, Springer-Verlag, 37–48.

[7] Alberti, G., Kleiber, J. (2004): The *GeLexi* MT Project, in Hutchins, J. (ed.): *Proceedings of EAMT 2004 Workshop* (Malta), Foundation for Int. Studies, Univ. of Malta, Valletta, 1–10.

[8] Archangeli, D., Langendoen, T. D. (eds.) (1997): *Optimality Theory: an overview*, Blackwell, Oxford.

[9] Asher, N., Lascarides, A. (2003): *Logics of Conversation*, Cambridge Univ. Press.

[10] Barwise, J., Cooper, R. (1983): Generalized quantifiers and natural language, *Linguistics and Philosophy* 4, 159–219.

[11] Benz, A. (2000): Chains and the Common Ground, in Poesio, M., Traum, D. (eds.) *GötaLog 2000 — Gothenburg Papers in Computational Linguistics* 00–5, 181–184.

[12] Bond, F., Oepen, S., Siegel, M., Copestake, A., Flickinger, D. (2005): Open source machine translation with DELPH-IN. In: *Proceedings of the Open-Source Machine Translation Workshop at the 10th Machine Translation Summit*, Phuket, Thailand, 15–22.

[13] Butt, M., Dyvik, H., King, T. H., Masuichi, H., Rohrer, C. (2002): The Parallel Grammar project. In: *Proc. of COLING 2002 Workshop on Grammar Engineering and Eval.*, Taipei.

[14] Dekker, P. (2000): Coreference and Representationalism, in von Heusinger, K., Egli, U. (eds.) *Reference and Anaphoric Relations*, Kluwer, Dordrecht.

[15] Dowty, D. R., Wall, R. E., Peters, S. (1981): *Introduction to Montague Semantics,* D. Reidel Publishing Company, Dordrecht.

[16] Gambäck, B. (2005): Semantic Morphology. In: *Inquiries into Words, Constraints and Contexts,* CSLI Publications, Stanford, California, 204–213.

[17] Kamp, H., van Genabith, J., Reyle, U. (2004): Discourse Representation Theory, ms. to appear in *Handbook of Philosophical Logic*, source: http://www.ims.uni-stuttgart.de/~hans.

[18] Kiss, K. É., van Riemsdijk, H. (eds.) (2004): *Verb Clusters; A study of Hungarian, German and Dutch*, Linguistics Today 69, Amsterdam / Philadelphia, John Benjamins

[19] Landman, F. (1986): *Towards a Theory of Information,* Foris, Dordrecht.

[20] Partee, B. H. (1996): The Development of Formal Semantics in Linguistic Theory, in Lappin, S. (ed.) *The Handbook of Contemporary Semantic Theory*, Oxford: Blackwell, 11–38.

[21] Reyle, U. (1993): Dealing with Ambiguities by Underspecification: Construction, Representation and Deduction, *Journal of Semantics* 10, 123–179.

[22] Seligman, J., Moss, L. S. (1997): Situation Theory, in van Benthem, J., ter Meulen, A. (eds.) *Handbook of Logic and Language,* Elsevier / MIT Press, Cambridge, Mass., 239–309.

[23] Szabolcsi, A. (ed.) (1997): *Ways of Scope Taking*, SLAP 65, Kluwer, Dordrecht.

[24] Szilágyi, É. (2008): The Rank(s) of a Totally Lexicalist Syntax, in Balogh, K. (ed.) *Proceedings of the 13th ESSLLI Student Session,* 175–184.