THE REALIS MODEL OF HUMAN INTERPRETERS AND ITS APPLICATION IN COMPUTATIONAL LINGUISTICS

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Keywords: Automated Discourse Analysis, Interpretation Modelling, Referents.

Abstract: As we strive for sophisticated machine translation and reliable information extraction, we have launched a subproject pertaining to modelling human interpreters. The model is based on RéALIS, a new “post-Montagovian” discourse-semantic theory concerning the formal interpretation of sentences constituting coherent discourses, with a lifelong model of lexical, interpersonal and cultural / encyclopedic knowledge of interpreters in its center including their reciprocal knowledge on each other. After the introduction of RéALIS, we provide linguistic data in order to show that intelligent language processing requires a realistic model of human interpreters. Then we put down some principles of the implementation (in progress) and demonstrate how to apply our model in computational linguistics.

1 RéALIS: THE THEORY IN THE BACKGROUND

RéALIS, RéciprocAL And Lifelong Interpretation System, is a new “post-Montagovian” (Kamp et al. 2005) theory concerning the formal interpretation of sentences constituting coherent discourses (Asher–Lascarides 2003), with a lifelong model (Alberti 2000) of lexical, interpersonal and cultural/encyclopedic knowledge of interpreters in its center including their reciprocal knowledge on each other (Alberti 2004).

The decisive theoretical feature of RéALIS 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, which is often mentioned as Montague’s Thesis: human languages can be described as interpreted formal systems (we thus does not agree with the viewpoint of Cognitive Grammar: “That no attempt has yet been made to formalize Cognitive Grammar reflects the judgment that the cost of the requisite simplifications and distortions would greatly outweigh any putative benefits” (Langacker 200: 423)). The second aim concerns compositionality, practically postulating the existence of a homomorphism from syntax to semantics. 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. The post-Montagovian history of formal semantics, however, seems to have proven the opposite, some principle of “discourse representationalism” : “some level of [intermediate] representation is indispensable in modeling the interpretation of natural language” (Dekker 2000).

The Thesis of RéALIS 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.

The frame of the mathematical definition of RéALIS (whose 40 page long complete version is available here: http://lingua.btk.pte.hu/realispapers) is summarized here. As interpreters’ mind representation is part of the WORLD MODEL, the definition of this model $\Re = (\cal U, \cal W_0, \cal W)$ is a quite complex structure where
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- \( U \) is a countably infinite set: the \textsc{universe}
- \( W_0 = (U_0, \ T, \ S, \ I, \ D, \ \Omega, \ \lambda) \): the \textsc{external world}
- \( W \) is a partial function from \( I \times T \), where \( W[i,t] \) is a quintuple \( \langle U[i], \sigma[i,t]^1, \alpha[i,t]^2, \lambda[i,t]^3, \kappa[i,t]^4 \rangle \): the \textsc{internal-world function}.

The external world consists of the following components:
- \( U_0 \) is the \textsc{external universe} \((U_0 \subset U)\), whose elements are called \textsc{entities}
- \( T = (T, \Theta) \) is a structured set of \textsc{temporal intervals}
- \( S = (S, \Xi) \) is a structured set of \textsc{spatial entities}
- \( I = (I, Y) \) is a structured set of \textsc{interpreters}
- \( D = (D, \Delta) \) is a structured set of \textsc{linguistic signs} (practically performed morph-like entities and bigger chunks of discourses)
- where \( T \subseteq U_0, \ S \subseteq U_0, \ I \subseteq U_0, \ D \subseteq U_0 \)
- \( \Omega \subseteq T \times U_0^* \) is the set of \textsc{core relations} (with time intervals as the first argument of all core relations)
- \( \Lambda \) is the \textsc{information structure} of the external world (which is nothing else but relation structure \( \Omega \) reformulated as a \texttt{standard simple information structure}, as is defined in Seligman–Moss (1997:245); its basic elements are called \textsc{infons of the external world}
- \( \Psi \) contains the following infon: \( t = \langle \text{PERCEIVE}, \ t, \ i, \ j, \ d, \ s \rangle \), where \( i \) and \( j \) are interpreters, \( t \) is a point of time, \( s \) is a spatial entity, \( d \) is a discourse (chunk), and \textsc{perceive} is a distinguished core relation (i.e. an element of \( \Omega \)).

The above mentioned \textsc{internal-world function} \( W \) is defined as follows:

- The relation structure \( W[i,t] \) is called the \textsc{internal world} (or \textsc{information state}) of interpreter \( i \) at moment \( t \)
- \( U[i] \subseteq U \) is an infinite set: interpreter \( i \)’s \textsc{internal universe} (or the set of \( i \)’s \textsc{referents}, or \textsc{internal entities}); \( U[i'] \) and \( U[i''] \) are disjoint sets if \( i' \) and \( i'' \) are two different interpreters
- what changes during an interpreter \( i \)’s lifespan is not her referent set \( U[i] \) but only the four relations among the (peg-like) referents, listed below, which are called \( i \)’s \textsc{internal functions}:
  - \( \sigma[i,t]^1 : \Pi \times U[i] \to U[i] \) is a partial function: the \textsc{eventuality function} (where \( \Pi \) is a complex label characterizing argument types of predicates)
  - \( \alpha[i,t]^2 : \Psi \times U[i] \to U[i] \cup U_0 \) is another partial function: the \textsc{anchoring function} \((\alpha \text{ practically identifies referents, and } \Psi \text{ contains complex labels referring to the legitimizing grammatical factors})
  - \( \lambda[i,t]^3 : \Lambda \times U[i] \to U[i] \) is a third partial function: the \textsc{level function} (where elements of \( \Lambda \) are called \textsc{level labels}); the level function is intended to capture the “box hierarchy” among referents in complex Kampian DRS boxes (Kamp et al. 2005) enriched with some rhetorical hierarchy in the style of SDRT (Asher–Lascarides 2003)
  - \( \kappa[i,t]^4 : K \to U[i] \) is also a partial function: the \textsc{cursor}, which points to certain temporary reference points prominently relevant to the interpreter such as “Now”, “Here”, “Ego”, “Then”, “There”, “You”

The temporal states of these four internal functions above an interpreter’s internal universe serve as her “agent model” in the process of (static and dynamic) interpretation.

Suppose the information structure \( A \) of an external world (defined above as a part of model \( \Re = (U, \ W_0, \ W) \)) contains the following infon: \( t = \langle \text{PERCEIVE}, \ t, \ i, \ j, \ d, \ s \rangle \), where \( i \) and \( j \) are interpreters, \( t \) is a point of time, \( s \) is a spatial entity, \( d \) is a discourse (chunk), and \textsc{perceive} is a distinguished core relation (i.e. an element of \( \Omega \)). The \textsc{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 \textsc{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 \textsc{extension} of \( W[i,t] \), which practically means that the above mentioned four \textsc{internal functions} (\( \sigma, \alpha, \lambda, \kappa \)) are to be developed monotonically by \textsc{simultaneous recursion}, expressing the addition of the information stored by discourse \( d \) to that stored in \( W[i,t] \).

The new value of \textsc{eventuality function} \( \sigma \) chiefly depends on the \textsc{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 identification of lexical items can be regarded as the first phase of the dynamic interpretation of (a sentence of) \( d \). In our \texttt{Realis} framework, extending function \( \sigma \) corresponds to the process of accumulating DRS condition rows containing referents which are all – still – regarded as different from each other.

It will be the next phase of dynamic interpretation to \texttt{anchor} these referents to each other (by function \( \alpha \)) on the basis of different grammatical relations which can be established due to the recognized \texttt{order} of morphs / words in discourse \( d \) and the \texttt{case}, \texttt{agreement} and other markers it contains. In our approach two referents will never have been \texttt{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 (Reyle 1993) / information structure (Szabolcsi 1997) / rhetorical structure (Asher-Lascarides 2003), 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.

It is to be mentioned 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 (Kamp et al. 2005).

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, respectively). 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 ġeALIS model ġe=(U, W′, W), 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):

\[ \text{Dyn}(d) : (ġe, W[i,t]) \rightarrow (W', e^\circ, U^\circ), \]

where U^\circ, shown up in the output triple, is the COST of the given dynamic interpretation (coming from presuppositions legitimised by accommodation instead of verification), and e^\circ is the eventuality that the output cursor points to (this is the eventuality 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 ġeALIS.

The static interpretation of a discourse d is nothing else but the static interpretation of the eventuality referent that represents it. The recursive definition of static interpretation 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.

2 SENTENCES AND DISCOURSES

Let us take the problem of translation. For example, a Hungarian text (1a) can only be translated by someone who has the Then (1b-c) and Now (1d) cursor values while being aware of the world around him/her.

Example 1: Knowledge about the world and the temporal cursors.

a. Megjelen-t az elnök, de nem válaszol-t a kérdés-ek-re.
b. The President appeared but he/she answered no questions.
c. Der Präsident/Die Präsident-in stell-te sich ein, aber er/sie hat keine Frage-n be-antwort-et.
d. The President will appear but he/she is not going to answer any questions.

In example (2a) below, the temporal cursor will jump (forward), just like the spatial cursor: the fridge is taken to be the one at Peter’s home (2b). When describing states, we shall keep the position of the temporal (and the spatial) cursor (2c). Besides fitting patterns onto the real world, the worldlet concerning the intention of the actor and that of the expectation of the speaker also play a role. The temporal cursor can stand not only in the cumulative phase, but also in the preparation phase of the given eventuality type (2d); the event mentioned in the discourse will never happen but it is there in the worldlet concerning the belief of the Patient.

Example 2: Progressive aspect, imperfective paradox, result state – the interpreter’s cursors and worldlets.

a. Peter travelled home. He drank a beer.
b. Peter travelled home. He wanted to drink a beer but the fridge was empty.
c. Peter was travelling home. He was drinking a beer.

The interpreter has numerous “famous” referents in his/her cultural/encyclopedia knowledge (stored in an appropriate hierarchy structured by functions $\alpha$ and $\lambda$, demonstrated in Section 1), which can be invoked by a name (3a). Although a name can refer to another entity (3b), a rich ontology concerning the world is also available (3c). The interpreter also stores non-logical relations (3d), to be applied while building stories again and again—typically based on already-built similar stories (3d-e)) and while searching for contacts between temporal, eventual and normal referents. Discourse (3e) is ambiguous: if the eventuality referent e$''$ belonging to John’s pushing Peter is taken to stand in a Narrative relation with referent e$'$ of Peter’s falling, the temporal referent t$'$ belonging to e$''$ follows t$'$ (belonging to e$'$) chronologically, whilst if e$''$ is construed as the Reason of e$'$ then t$'$ precedes t$'$ (Asher and Lascarides 2005). A topic cursor can also play a role while building discourses (3f): it is made explicit in Hungarian by the lack or presence of a pronoun which participant is taken to be the topic of a sentence relative to the preceding sentence.

Example 3: Different sorts of knowledge

a. Mozart had a powerful influence on the work of Beethoven. Beethoven knew much of Mozart’s work.

b. J. G. Leopold Mozart (November 14, 1719 – May 28, 1787) was a composer, conductor, teacher, and violinist. Mozart is best known today as the father and teacher of Wolfgang Amadeus Mozart.

c. a I have a half-St. Bernard and half-Scottish Shepherd, a Dalmatian and a parrot. The two dogs often frighten the poor bird.

d. Peter married yesterday. The priest spoke very harshly.

e. Peter fell. John pushed him.

f. Péter-nek van egy unokahúg-a.

Like-Sg3def him/her / That like-Sg3def him/her

‘Peter has a niece. He likes her. / She likes him.’

Our last set of examples concerns the rich and explicit Hungarian system of operators to be interpreted logically (Kiss 2001). Based on his/her background knowledge and the “relevant set” as a part of it, one can infer the presence and place of some unnamed participants from the operator and the named participants of the discourse.

Example 4: Operators and claims about the relevant participants not mentioned in the discourse

a. Tizenkét unokatestvér-em van, de csak Annát és Beá-t hív-t-am meg a születésnapj-i parti-m-ra.

twelve cousin-PossSg1 is but only Ann-ACC and Bea-ACC invite-Past-Sg1 def Perf the birthday-DerAdj party-PossSg1 onto

‘I have twelve cousins but I invited only Ann and Beatrice to my birthday party.’

b. Lát-om, a ti nővér-em-et (bezzeg) meg-hív-t-ad!

see-Sg1 def the sister-PossSg1-ACC (contr.top.) Perf-invite-Past-Sg2 def

‘But, as for my sister, I see that you invited her!’

c. Meg-hív-hat-t-ál volna mindannyunk-át!

Perf-invite-may-Past-Sg2 PastCond all.of-us-ACC

‘You could have invited all of us.’

d. Meglep, hogy a nővér-em-et is meg-hív-t-ad.

surprise that the sister-PossSg1-ACC also Perf-invite-Past-Sg2 def

‘It surprises me that you invited my sister, too.’

Table 1 summarizes the logical impicature of the Hungarian operators (apart from topic (3f), whose interpretation is not of logical nature). Let ‘every’ (4c) be our starting-point: this operator practically retrieves the set of participants mentioned earlier as the ‘relevant set’ e.g. ‘all of us’), and it is claimed that what is predicated is predicated of each member of the relevant set. Operator ‘also’ (4d) refers to the existence of an unnamed participant satisfying what is predicated (at least according to the speaker). The contrastive topic (4b) refers to the existence of an unnamed participant not satisfying what is predicated, whilst the focus (4a) refers to the fact that each unnamed participant is such that he/she/it does not satisfy what is predicated.

Table 1: The system of Hungarian operator meanings ($R_n = R \setminus R_m$, where $R_m$: mentioned participants, $R$: every participant which could have played the role played by the mentioned participants).

<table>
<thead>
<tr>
<th>$\exists x \in R_n$</th>
<th>$P(x)$</th>
<th>$\neg P(x)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>operator ‘also’ (4d)</td>
<td>contrastive topic (4b)</td>
<td></td>
</tr>
<tr>
<td>$\forall x \in R_n$</td>
<td>operator ‘every’ (4c)</td>
<td>focus (4a)</td>
</tr>
</tbody>
</table>

3 PRINCIPLES OF THE IMPLEMENTATION

The most basic data elements represented in the implementation are the referents, which are assigned to the grammatical components during the process of the semantic analysis. In this article, which demonstrates a “work in progress”, we shall only put down the principles of a potential implementation (in a greatly simplified manner), focusing onto the four basic functions ($\sigma$, $\alpha$, $\lambda$, and $\kappa$; see Section 1)
and mention some possible applications of such discourse-analyzing systems.

By default, each part of the sentence has its own referents which do not depend on any referents belonging to other parts of the sentence (the function $\alpha$ will search for dependencies). Most of these referents (belonging to certain interpreters in the richly structured worldlet system defined in Section 1: $r_1, r_2, \ldots$) refer to entities existing in the external world, while other referents can be eventual (e), temporal ($t_i$) or spatial ($s_i$).

An eventual referent must be assigned to all verbs, nouns, adjectives and adverbs (parts of speech which can, in principle, play a predicative role in the sentence). For example, the noun banker and the adjective clever both can be treated as eventualities “being abanker” and “being clever”. Function $\sigma$, taking the label $\Pi$ into account (which, as mentioned in Section 1, contains information on the already-analyzed syntactic structures), assigns the argumental ($r_i$), temporal and spatial referents to the eventual referent of the regent and forms the structure pred(e, t, s, r1, r2, \ldots) (one should note that only a small part of the referents play a significant role in the actual discourse).

The anchoring function $\alpha$ assigns the referents to each other in different worldlets, thereby declaring some referents as identical, which induces an equivalence relation. This process, however, should be aided by an ontology (apart from the information collected during the syntactic analysis) as mentioned in section 2. The ontology can have an arbitrary structure – for example, if we take the basics of psycholinguistics into account, the semantic web of the mental lexicon could be modeled by a neuron network (and, in general, RL could be used to handle lexical semantics). The mental lexicon has multiple dimensions on its own, and these dimensions can be regarded as multiple relation types in the network – or, even more precisely, a network of networks. If we have no ontology at all, only the referents of literally identical syntactic entities (and, in some cases, pronouns) can be anchored to each other.

The ontology is also used when we try to determine whether the discourse being analyzed is coherent or not. In (3d), the computerized equivalent of the semantic web should be used to determine coherence (by using a metric to measure the distance between the concepts (semantic categories) WEDDING and PRIEST). If the (semantic) distance is sufficiently low, the discourse can be regarded as coherent. Of course, if we use RL technology to create our ontology, the semantic proximity between two (or more) concepts must be pre-taught.

Summarizing the above, the actual identity of referents can be determined by using the relation types (such as synonymy, semantic priming etc.) and distance metrics in the network.

The set of temporal referents ($t_i$) can be regarded as a partially ordered set (see, say, (3e)). As we mentioned above, referents can be identified by using a distance metric on the semantic web, thereby fuzzifying the process of determining discourse coherence. Many temporal adverbs are fuzzy by their nature (e.g. nowadays, a long time ago, shortly) and they are not even culturally independent. But even if we only handle well-defined temporal referents, the system still has some important applications (see Section 4 below).

The level function $\lambda$ (practically) assigns the referents to certain worldlets of interpreters (such as those of their beliefs, desires, intentions, dreams). The entities of the external (real) world (model) always exist and they are “seen” and referenced by all interpreters. But during the syntactic analysis, level-changing words (mostly adverbs or particles) are found, expressing modality. “If only Mary had a car! Me, too, could drive it occasionally.”

The phrase “if only” refers to the speaker’s desire, rendering all referents in its scope to a different level, also a different worldlet (expressing a desire of the speaker). Entities on this level do not exist in the real world but the speaker must refer to them in order to express his/her desire.

Certain values of the cursor $\kappa$ can be regarded as quasi-constant since they do not depend on the actual discourse flow directly and, in most cases, they do not need to be set during the analysis. “Then” is set at the beginning of a story and, for example, “You” can point to the user, who (as an agent) must always be considered as an active participant in the discourses being analyzed. Many applications of the system are based on this. We will show some of them in the next section.

4 APPLICATIONS AND PLANS

As we mentioned above, the aim of our 9leALIS model is automatic discourse analysis. To do this, we need to implement all the above-described tasks and functions. But why should an interpreter based on 9leALIS be implemented?

First, expert systems can be created by implementing the 9leALIS model. This depends on the ontology on which the function $\alpha$ is based. The ontologies need not to include everything or be over-
complicated. For example, ontologies concerning a special field combined with the ReALIS model (which is responsible for the syntactic and semantic analysis) could form an expert system or a decision-supporting system together. Questions could be asked or predicates could be stated to the program in a natural language – the system extracts information and prints it in a readable form (preferably also in a natural language, for example, if we want to do machine translation backed by ReALIS).

One possible application of the ReALIS model is to use it as a legal expert system to aid lawyers. Backed by a legal ontology, temporal referents (t) could even be handled in a simplified way (see above), because temporal adverbs tend to be much less fuzzy in legal texts than in general stories. For example, confessions and evidences given by participants of a court case could be analyzed according to the current laws (which are integrated into the ontology) to facilitate judgement, or even laypersons could use the system if they consider taking legal action.

Machine translation, too, can be based on ReALIS. It was already implemented, although in a greatly simplified manner, in its predecessor (Alberti et al. 2004) which was able to translate simple Hungarian sentences into grammatically correct English. In the process of translating entire discourses, however, references always play a key role, as illustrated in Section 2. Translating certain pronouns is only possible after having analyzed large parts of the discourse while recording the position of the topic cursor (3f). The same applies for the tense and aspect system of certain languages. Here, the precise handling of the temporal cursor seems to be far more problematic than in the case of doing a “mere” discourse analysis (e.g. when functioning as an expert system). If the actual position of the temporal cursor can not be exactly reproduced in the target language, the translation process is especially difficult, if at all possible.

5 CONCLUSIONS

We have based a subproject pertaining to the modeling of human interpreters (of our project whose chief aims are machine translation and information extraction) upon ReALIS, Reciprocal And Lifelong Interpretation System (Section 1), because a large scale of linguistic data (Section 2) shows that intelligent language processing requires a realistic model of human interpreters. Then we put down some principles of the implementation (in progress) and sketch how to apply our model in computational linguistics (Sections 3–4).

The initial state of the model of our ideal interpreter’s mind can practically be regarded as an enormous, unstructured set of peg-like referents in Landman’s style (1986), which is then permanently being enriched, due to the input of linguistic information (to be worked up in different ways), with an intricate structure “spanned” by four functions, σ, α, λ and κ, responsible for, respectively, the assignment of eventuality referents to statements about temporal, spatial and “normal” referents (σ), the identification of co-referring ones (α), the decision of a scopal/modal relation system among the referents (λ), and the highlighting of those playing some distinguished role at a certain moment of working up a discourse (κ).

ACKNOWLEDGEMENTS

We are grateful to OTKA 60595 for their financial help.

REFERENCES
