

# ReALIS1.1: The Toolbox of Generalized Intensional Truth Evaluation

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**Abstract**—Our software ReALIS1.1 is primarily intended to supply linguists with a highly intelligent device to build fragments of languages. Then (non-linguist) experts can elaborate a peculiarly “multiplied” database that offers, besides the model of the external world, hundreds of its (appropriately labeled) alternatives. According to the ReALIS theoretical framework we use, these alternative models can all be linked to human agents represented in the world model as their pieces of knowledge, beliefs, desires, intentions, dreams. Finally, (further) users can select lexical items to build sentences, the (generalized) truth-conditional interpretation of which they will be given on the basis of the actual version of the above-sketched “multiplied world model”. Our software serves not only the theoretical purpose of trying out the “pragmalinguistics” theory (by implementing it), but also the practical purpose of collecting and systematizing data in the peculiar structure due to ReALIS, intended to truly capture human intelligence.

**Keywords**—*dynamic discourse semantics; possible worlds; truth-conditional interpretation; presupposition.*

## I. INTRODUCTION

We are working on the implementation of a pragmalinguistics theory, ReALIS (*Reciprocal and Lifelong Interpretation System*), intended to truly capture human intelligence by means of a peculiarly multiplied world model. The implementation of this “intelligent” structure is our primary innovation.

At the moment, it is very important to us that the software, which is permanently developed, has repercussions on the theory, due to the fact that the theory can be tested and sophisticated by means of the software. In a later period the practical purpose of collecting and systematizing data in the peculiar structure due to ReALIS will stand out.

The main difficulties lie with the fact that we are working on a completely general toolbox that utilizes the aforementioned multiplied world model, that is, one which is underspecified in several respects but can be rapidly specified when it is designated for particular purposes. This also holds for the linguistic input; some difficult grammatical phenomena that should be captured in a demanding way are collected in Section VI. Due to the uniform and holistic approach of ReALIS, we cannot afford to use parsers or other devices developed in other projects.

Recursivity is another stubborn problem. Unlimited chains of linguistic expressions can be produced, the elaborated pragmatico-semantic analysis of which leads to proliferation problems.

It is also difficult to register the copies of multiplied entities in almost identical alternative models. We should apply safe and effective but very rapid methods in copying huge databases in a way that makes it possible for us to carry out the relevant differences between them.

Nevertheless, the most difficult task is the safe and systematic treatment of temporal entities, which come from the model of the external world as well as from the alternative models, and also come from the event structure of lexical items and from the discourse structure of sentences to be parsed. We have been led to the conclusion that the utter key to different kinds of systematization problems is utilizing points of time as special “stamps”.

Let us then turn to the structure of the paper. Section II sketches the current version of ReALIS. Then our software ReALIS1.1 is demonstrated through discussing its different kinds of potential users (Section III) and its main use cases for the users we call internal users (Section IV) and for those we call external users (Section V). Section VI demonstrates the analysis of some linguistic examples with the purpose of elucidating our ambition to capture the highest possible level of human intelligence coded in language. We will conclude the paper (Section VII) with some remarks on the status of this “work in progress” among our previous works.

## II. THE CURRENT VERSION OF ReALIS

ReALIS is a theory that immediately relies on Discourse Representation Theory (DRT) [1]. It can thus be introduced as belonging to the family of representational dynamic discourse semantics [1] [2]. Its (forty-page-long) definition is available at [23]. It is intended to reconcile the formal exactness of generative syntaxes with the dynamic approach of optimality theories and DRT, bearing in mind the holistic stance of cognitive linguists [3] [4].

In the post-Montagovian world of formal semantics, Discourse Representation Theory (DRT) [1]—which has offered a revolutionary solution to the resolution problem of (“donkey”) anaphora and attractive visual representations for discourse meaning—is often criticized from “inside” as well as from “outside”, considerably weakening its legitimacy. The internal criticism comes from the world of the dynamic model-theoretic semantics, from the Amsterdam School [5], and pertains to the (mathematically unquestionable) eliminability of exactly this attractive visual representation, insisting on “Montague’s heritage” [6]. The external criticism comes from the Proof-Theoretic School [7], among others (Pollard [8]); they point at the dubious status and construction of possible worlds.

We claim that  $\Re$ ALIS [3] [4] [9]—while considerably relying on the representationalism of DRT in the course of solving a wide range of linguistic problems in order to maximally exploit and develop the excellent facilities provided by this representationalism—offers exactly the radical ontological innovation which lies with the elimination of the above-mentioned two dubious levels of representation, referred to as I and III below in Fig. 1.

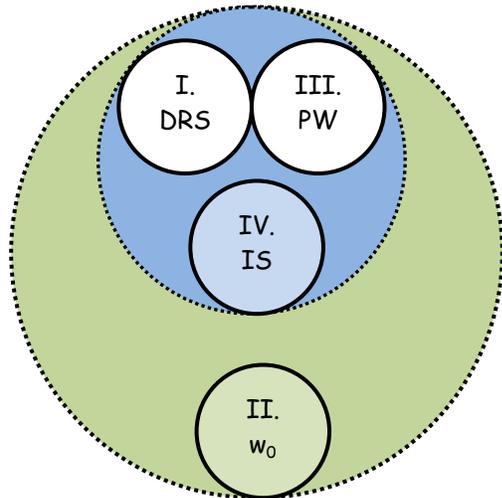


Figure 1. Components / levels of representation in DRT: I-IV; and their re-arranged ontology in  $\Re$ ALIS:

- I. DRS: the semantic representation of sentences constituting coherent texts
- II. Model of the external world (for extensional interpretation)
- III. Possible worlds (for intensional interpretation)
- IV. Interlocutors' information states

$\Re$ ALIS embeds representational levels I and III—more exactly, their relevant content—in the representation of information states (IV), relying on the stance that, as interlocutors obtain information through discourses, their information states are worth regarding as gigantic, lifelong, DRSS. An information state has a double nature: it functions as a “representation” in the above regard while it is used as “what is to be represented” in the interpretation of, say, the intensional sentence types shown in (2b-d) below: it also depends on different persons' information states if these sentences are true, in contrast to sentence (2a), the truth value of which only depends on facts of the external world. Note in passing about the aforementioned “double nature of information states” that modern set theory exactly relies on a similar idea: Sets and their elements must not be mixed up; this does not mean, however, that a set could not serve as an element of another set.

- a. “Ben is bald.”
- b. “Sue knows that/if [Ben is bald]”
- c. “Joe guesses that Sue definitely wants to convince him to take it for granted that [Ben is bald].”

Figure 2. Sentences to be interpreted in different world(let)s.

We are going to illustrate the descriptive and explanatory power of  $\Re$ ALIS by sketching the interpretation of sentence (3a) below, featuring *realize*, which is a factive verb. Hence,

it is a precondition of interpreting the sentence as true (or rather, as “well-formed”) that the Evening Star should coincide with the Morning Star in (the model of) the external world. This means that the entity referred to as the Evening Star by the given astronomer should be the same entity he refers to as the Morning Star. In the approach of  $\Re$ ALIS, this relation is captured formally as demonstrated in (3b) below: the internal entity  $r_{\text{EveningStar}}$  should be anchored to the same external entity as the internal entity  $r_{\text{MorningStar}}$ .

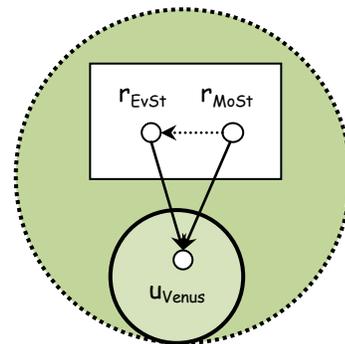


Figure 3. The interpretation of *realize* and the *Venus*-problem  
a. “An ancient astronomer realized that the Evening Star is the same as the Morning Star.”

- b.  $\alpha(r_{\text{EvSt}})$  is-the-same-as  $\alpha(r_{\text{MoSt}})$  (since  $u_{\text{Venus}}$  is-the-same-as  $u_{\text{Venus}}$ )
- c. It does not hold that  $r_{\text{EveningStar}}$  is-the-same-as  $r_{\text{MorningStar}}$  at  $\tau$  in the astronomer's worldlet of astronomic hypotheses
- d. It holds that  $r_{\text{EveningStar}}$  is-the-same-as  $r_{\text{MorningStar}}$  at  $\tau'$ , which is a later point of time in the astronomer's worldlet of astronomic hypotheses

The astronomer himself is not (necessarily) aware of the co-anchoring of the two internal entities at his disposal (in his appropriate worldlet); but the fact of co-anchoring is an external requirement due to the factive character of the verb. Two further requirements to be satisfied in order for sentence (3a) to qualify as true concern two information states of the astronomer at different points of time, independently of the external world: what is to be checked is whether there is a “same-as” relation between the internal entity  $r_{\text{EveningStar}}$  and the internal entity  $r_{\text{MorningStar}}$  in the one information state (3d) while they do not stand in the “same-as” relation in the other one (3c)

All in all, three competing world(let) models should be considered simultaneously (“prism effect”), and three entities—an external one and two internal ones—should be inspected. As the three models are all parts of the one complete model of the history of the external world and all internal reflections associated with it (see Fig. 2 above), in this matrix model (3b-d) can all be checked.

It must be noted that the analysis relies on the same facilities available in the cognitive linguistics framework; see, for instance, Pelyvás [10], who follows Langacker's approach to nominal grounding [11]. The most important tenet of this view is that all nominals are grounded in the “reality” of the Idealized Conceptual Model(s) evoked in the discourse, which is relative to speaker and hearer, rather than directly in objective reality. From the point of view of linguistic analysis the reality that we could call “objective”

(i.e., independent of speakers' and hearers' beliefs) is only of marginal importance...

### III. USERS AND USES

#### A. Internal Users

Our software  $\Re$ ALIS1.1 is primarily intended to supply linguists with a device to build fragments of arbitrary languages of arbitrary morphological types. These fragments can capture such specialties of human languages as, for instance, the compositional cumulation of meaning units [6]. The definable meanings are pragmatico-semantic descriptions that satisfy the relevant definitions of  $\Re$ ALIS [3]. The group of users defined in Section I-A will be referred to as internal users.

#### B. External Users

Those using the developed language fragment will be referred to as external users. In the course of using the software, they can select lexical items to build sentences, the (generalized) truth-conditional interpretation of which they will be given on the basis of a "multiplied world model", which they have themselves constructed or received from "internal" experts [12].

Possible external users may be detectives or judges, for instance, who can have the truth of groups of propositions evaluated. In harmony with our "constructionist" stance, we mean by the aforementioned "generalized truth-conditional evaluation", besides the final *true/false* value, the collection of all the information required to reach this truth value. Our software thus, among others, serves the purpose of collecting and systematizing data in the effective structure  $\Re$ ALIS offers.

### IV. USE CASES PROVIDED FOR INTERNAL USERS

#### A. Defining Relations

Internal users can define an external world  $w_0$ , over the universe of which (consisting of entities  $u_i$ ) they can define relations of different arities [6]. One argument of all these relations is to be a series of disjoint temporal intervals. The software is to "dictate" (through permanent queries) the development of the external world: it requests new and new relations, and in the case of a given relation it requests the provision of (the initial and final points of) temporal intervals (among others).

Such relations can be defined in this way which are homogeneous in the sense that they qualify as true or false "momentarily", i.e., at each internal point of the temporal intervals independently. In Hungarian, for instance, *utazik* 'travel' and *úszik* 'swim' are homogeneous relations while *hazautazik* 'travel home' and *átússza* 'swim across' are heterogeneous. Further, each argument position of a relation can be associated with other relations of the group of relations defined earlier which provide us with restricting information. The agent argument of the Hungarian verb *utazik* 'travel', for instance, can be associated with the restricting relation *ember* 'human'.

#### B. Defining Label Strings of Worldlets

Relative to the set of "worldlets" (small partial models of alternative worlds) defined up to a certain point, the internal user can define (by simultaneous recursion) a new worldlet where the basis of this definition is the singleton consisting of the external world  $w_0$ . Specifically, relative to a worldlet  $w'$ , a worldlet  $w''$  can be determined through a quintuple of labels like the one shown in (4a) below. It defines the worldlet containing a human being's ( $r_{Sue}$ ) knowledge ("maximal" belief); see sentence (2b) in Section II.

$$\begin{aligned} & \text{a. } \langle \text{BEL, MAX, } r_{Sue}, \tau', + \rangle \\ & \text{b. } + / - / \emptyset / 0 / \theta \\ & \text{c. } \langle \langle \text{BEL, med, } r_{Joe}, \tau, + \rangle \langle \text{INT, MAX, } r_{Sue}, \tau', + \rangle \langle \text{BEL, MAX, } r_{Joe}, \tau', + \rangle \rangle \end{aligned}$$

Figure 4. Labeling worldlets.

Alternatives to label BEL are labels INT (intention) and DES (desire), among others. Alternatives to label MAX are lower levels of intensity: e.g., aMX (almost maximal). The fourth member of the label quintuple is polarity; the values of this parameter are listed in (4b) above, but their interpretation is provided later.

The software can show through what kind of defining steps one can reach a worldlet relative to the external world as a fixed starting point. The label string in (4c) above, for instance, defines a worldlet which is to be regarded as the collection of information the status of which can be captured by means of the linguistic expression shown in (2c) in Section II.

#### C. Worldlets, Infons and Polarity Values

Internal users can assign pieces of information to worldlets. This procedure is to be "dictated" by the software as follows.

In the more general case, a point of time should be specified. As a reaction of the software, on the basis of the above-discussed temporal-interval series belonging to the relations, it is written which relations stand between which entities at the given point of time. If the user specifies, besides a point of time, a relation and some entities which occupy certain argument positions of the relation, the task of the software remains the writing of the lacking entities which stand in the given relation with the provided entities at the provided point of time. The unit of this writing process is the external infon [13]: an infon means the piece of information that certain entities stand in a certain relation at the given moment (e.g., Joe loves Sue, or Joe is just traveling).

Internal users can assign an infon (produced in the way sketched above) to an arbitrary worldlet for an arbitrary interval of time. The application of this temporal interval serves the purpose of capturing such factors as the dwindling into oblivion or some re-categorization of pieces of information.

Assigning a group E of infons to a worldlet standing with the external world in the relation provided in (4a) above can be interpreted as follows: Sue perceives information E from the external world and accepts as the current state of her environment. A similar interpretation in the case of the

complex relation provided in (1c) is as follows: Joe suspects that Sue wants to make him to be sure that information E is true (while Sue herself, for instance, does not necessarily believe in the truth of E; nor is E true in the external world).

If the same infon is simultaneously assigned to someone's positive belief-worldlet (see '+' in (4b) above), negative desire-worldlet ('-' in (4b)) and neutral ('0' in (4b)) intention-worldlet, this complex "evaluation" captures this typical situation: the person in question perceives something and accepts its truth, but longs for its opposite without intending to change it (at least at that moment).

It is worth noting in connection with the polarity values listed in (4b) above that if an entity does not stand in the relation 'bald' in the external world, then the infon declaring the given entity's momentary baldness is to be assigned to the experiencer's negative ('-') or 'undefined' ('∅') belief-worldlets depending on the restricting relations, mentioned in Section II-A. Ben, for instance, can be thought by an experiencer to be "not bald" while in the case of the Eiffel Tower its baldness is undefined.

As for the crossed zero in (4b) above, the sentence variants shown in (2b) above illustrate its interpretation and significance. The variant with *that* can be captured by assigning the infon *e* declaring Ben's baldness to the worldlet (in the speaker's information state, i.e., mind) which contains the information that the speaker assumes Sue to qualify as true. The variant with *if*, however, should be accounted for in a slightly different way: what this variant reveals about the speaker's mind is that the speaker thinks that in Sue's mind infon *e* does not belong to a neutral belief-worldlet (one with a '0' polarity value).

#### D. Information Not Coming from Outside

Internal users can also assign information to worldlets indirectly, that is, not on the basis of (the relations of) the external world. This should be "dictated" by the software as follows.

The software should ask for predicate names and argument numbers, and then produce argument places with inserted "new" entities, which the software should also urge the user to anchor to "old" (external or internal) entities (NB their anchoring to any entities is only a possibility). Section II-C, where we defined the procedure of creating infons assigned to worldlets in human minds on the basis of states of affairs in the external world, is worth completing with a short comment. An internal infon does not contain the same entity names as the corresponding external infon does. Instead of identifying them, the correspondence between external and internal entities should be accounted for by anchoring elements of the former group to those of the latter group. In this way, we can explain the cases of misunderstanding where the same external fact is linked to different participants in two experiencers' minds.

#### E. Building the Lexicon

The internal user is given a core lexicon on the basis of the predicates the creation of which was described in II-C; and this core lexicon is enriched with the predicates created in the way described in II-D. Elements of the latter group of

predicates should be associated with meaning postulates [6], by the help of queries of the software.

Note that items of the core lexicon need not be associated with meaning postulates since their interpretation is trivial on the basis of their creation: as they have been created by copying certain "patterns" of the external world, the rule concerning the pattern matching their semantic evaluation is based on is automatic. True perception and pattern matching is the same process, considered from opposite directions.

Let us return to the predicates whose forms are defined in II-D; they should be assigned meaning in the way to be defined in II-F. Before entering into details, it must be noted that this is the crucial innovation of  $\mathfrak{ReALIS}1.1$ , because this is the toolbox which exploits the advantages and results of all the model-theoretic theories, the discourse-representational innovations and the proof-theoretic ideas, and the "diagnosis" of cognitive linguistics on the weaknesses and shortcomings of these three approaches.

What comes from formal semantics [6]? The procedure of pattern matching. Further, the application of interpretational bases used as alternatives to each other ("possible worlds"  $\rightarrow$   $\mathfrak{ReALIS}$ -worldlets). And the consideration of the rate of successful instances of pattern matching compared to the entire set of possible instances of pattern matching.

The idea of operation over the partially ordered system of worldlets is due to Discourse Representation Theory [1] [2]. The step-by-step execution of this operation, referred to as 'accommodation' in DRT, coincides with the proof-theoretic processing of semantic information [7].

The modeling of the following linguistic elements is due to cognitive linguists [10] [11] [15]: *me, you, (s)he, here, there, now, then, these here* (in the context), *those there* (demonstration).

#### F. How to Define Lexical Items

The software should help the internal user (the formal linguist) in assigning (groups of alternative) phonetic forms and meaning postulates to predicate names, besides such straightforward information as (sub)categorization and argument number.

Meaning postulates essentially consist of first-order formulas. The most peculiar element of our method is that each formula like this should be associated with a set of such chains of worldlet labels as the one shown in (1b) above and the information as to which worldlet(s) these chains to be linked to in the course of interpreting sentences (possibilities are the external worldlet, certain worldlets of the selected speaker, addressee, or participants referred to in the sentences, or worldlets which can be identified in the selected context or scope of demonstration (see the last paragraph in Section II-E).

### V. USE CASES FOR EXTERNAL USERS

The external users—who can construct a sentence and specify the speaker, the addressee, the entities assumed to be present in the context (and possibly a subset of those in the scope of some demonstration), the speech time and the time of reference, among others—are given a generalized truth

evaluation. This means that they are given not only a truth value but also all the pragmatic well-formedness conditions of the sentence “performed” in the specified context.

Thus, they can look “inside” all relevant participants’ minds (i.e., the current and possibly some previous information states). They can realize, for instance, if the definite noun phrases are suitable for unambiguously identifying the intended *denotata*. They can also receive information about the success of satisfying other kinds of presupposition. They can detect, through comparing the information provided by the sentence and the information found in the specified interlocutors’ appropriate worldlets, if there might emerge some misunderstanding, lie, bluff, deception [4].

## VI. LINGUISTIC EXAMPLES

### A. Generalized Truth Evaluation

External users are given a peculiarly multiplied data base which contains, besides a relational model of some fragment of (the history of) the external world, several of its alternatives. These alternatives essentially play the role of possible worlds, known from intensional model-theoretic semantics, but they are finite constructions appearing as such parts of information-state models of interlocutors that can be construed as their beliefs, desires, intentions, or any other kinds of fictions (II-B [1]).

This arrangement of worldlets enables us to carry out truth evaluation not only on the basis of the external world, which is necessary and sufficient, for instance, in the case of sentences (5a-a’) below, but also on the basis of internal worldlets, which is obviously necessary in the case of sentences like (5b). The truth of the variants shown in (5b) does not depend on any facts in the external world. It depends on nothing else but Joe’s knowledge, or the knowledge that Sue attributes to Joe. In this latter case, it requires more steps to reach the worldlet which can serve as the basis of truth evaluation (external world model → Sue’s belief → Sue’s hypotheses on Joe’s beliefs); cases like this make it necessary to localize worldlets in the recursive way illustrated in (4c) in II-B. Verbs expressing modal attitude (e.g., *think*, *guess*, *conjecture*, *wish*) and many other expressions (e.g., *according to someone*) can be associated with meaning postulates by means of the tool described in II-F: the essence of their meanings lies with the “direction indicator” function. Such direction indicators help us with finding the worldlets which can serve as the basis of the truth evaluation of the proposition that appears in the appropriate argument positions of the modal verbs or other linguistic expressions in question.

- a. It was snowing.    a’. It has snowed.
- b. (Sue thinks that) Joe knows that it was snowing.
- c. Patty was traveling home.
- d. *That tall Finnish woman* is pretty.

Figure 5. Generalized truth evaluation relying on worldlets.

### B. Past Continuous and Present Perfect

Internal users can work out exacting and sophisticated syntaxes and semantics by the help of the toolbox offered by ReALIS1.1.

The truth value of (5a) above, for instance, can be calculated in the following way: the software should query the values of *then* and *there*, and then it should localize the area of the temporal external world model where pattern matching should be attempted in order to decide if it is snowing “then” and “there” (III).

The truth evaluation of (5a’), however, requires the values of *here* and *now*, and what is to be checked in the external world is whether the landscape is snowy. The meaning postulate of the verb *snow*, thus, contains the determination of the result state (*snowy*), too. Note in passing that (5a’) pragmatically suggests that it is not snowing at the relevant moment while the land is snowy as a result of an earlier snowing.

### C. Progressive Aspect

The truth evaluation of sentence (5c) above also requires a polished and exacting meaning postulation because not only facts of the external world should be taken into account. A progressive sentence like this is also to be evaluated to be true in a case in which Patty never got home but she proves to have been travelling at the moment of *then*, she proves to intend to come home, and the speaker proves to attribute a quite high likelihood to this arrival (II-F) [1]. Thus, the content of certain internal worldlets is to be checked, besides the partial satisfaction of a travelling event in the external-world model.

### D. The Intensional Character of Nicknames

A demanded pragmatico-semantic analysis of nicknames also requires the toolbox sketched in II-F. Who is *Patty* in (5c) above, for instance? Internal users can capture the essence of the task of finding *denotata* by construing nicknames as special predicates the “truth evaluation” of which involves not (only) the external control on the correspondence between official names and nicknames but (also) the worldlets concerned in the following questions: is *Patty* a possible nickname of the speaker for the given person, does the speaker think that the addressee may (also) call her *Patty*, do they know this about each other, and so on. Hence, internal worldlets are to be checked via pattern matching.

### E. (Partially) Subjective Predicates

Example (5d) above illustrates further advantages in meaning postulation of the toolbox demonstrated in II-F. The adjective *pretty*, for instance, is worth regarding as a fully personal and subjective judgment, with no extension in the external world. Nevertheless, (5d) does mean exactly the same as the sentence *I consider her pretty*. The truth of this latter sentence exclusively depends on the speaker while it would be elegant to base the evaluation of sentence (5d) on a somewhat less speaker-dependent calculation. As follows, for instance: (5d) is considered true if *most* persons in the external-world model consider the given lady to be pretty. According to an even more elegant solution, instead of the

entire set of persons, only those *respected* by the speaker are considered. The extension of the verb *respect* is to be checked in the external-world model.

#### F. Demonstration and Anchoring

The demonstrative noun phrase in (5d) illustrates another instance of the necessity for “pragmatically conscious” truth evaluation. *That* asks for the value of the “those there” parameter from the external user. It is elegant to assume that this value is a set of entities, out of which the software should select a unique entity on the basis of the predicates *tall*, *Finnish* and *woman*. Their extensions count in the external world, at least primarily; it is an elegant facility, however, to inspect the speaker’s beliefs as well, or the speaker’s hypothesis about the addressee’s beliefs: sentence (5d) can be evaluated as *true but ill-formed* if, for instance, the speaker intends to refer to a tall Swedish woman about whom they think, incorrectly, that she is Finnish.

### VII. CONCLUDING REMARKS

The current implementation of ReALIS1.1 is a client-server Windows application that has been elaborated in a Delphi environment, which guarantees rapid and flexible development. Access to data is executed via standard SQL commands by means of a relational data-base management system. For this purpose, we currently use Firebird Interbase.

The Prolog basis, applied in the experimental phase of our research [16] [14] [17] [18] [19] [20] [21] [22], has been replaced with Delphi environment, which is more capable of managing large data-bases, developing user-friendly interfaces, and constructing more complex applications. This the radical difference between ReALIS1.1 and the aforementioned works.

The menu items correspond to the services sketched in Section IV. Particular menu items are available to the different kinds of users defined in Section III after checking their identity and authenticity. At some points, the program provides illustrations of the structures constructed by either the system or its users: for instance, parsing trees, systems of worldlets, anchoring relations of entities. Figure 6 below illustrates this last facility.

The software is permanently developed and expanded, exploiting new scientific results; it has repercussions on the theory, due to the fact that the theory can be tested by means of the software.

As our software inherently belongs to a radically new and holistic “pragmalinguistics” theory (Section II), it would be uneasy to compare to softwares based on some different theoretical foundation. We are working on developing tests to evaluate its effectivity.

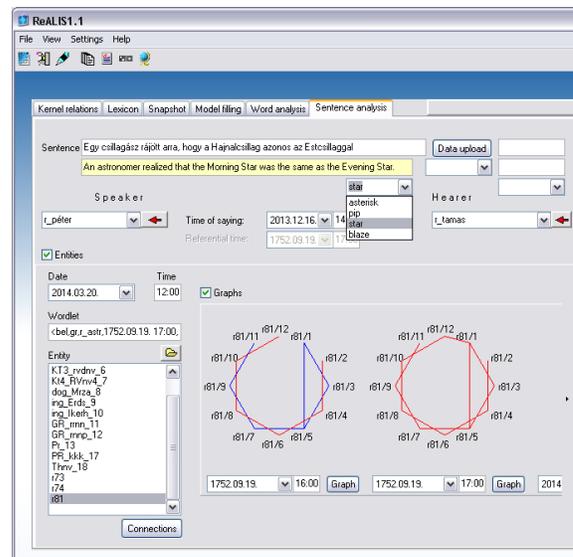


Figure 6. Interpreting the sentence shown in Fig. 3.

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