Plausible Expectations-Based Inference for Semantic Analysis

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Abstract - *We present a project aiming at developing a semantic analyzer based on linguistic and world knowledge. The major sources of knowledge are a semantic dictionary, an ontology, a fact base, and a set of common sense axioms. We show the types of information stored in these resources, and demonstrate how they interact. As a case study, we take a simple but typical dialogue type, in which one of the interlocutors makes a proposal and the other one gives an indirect answer. The task of the analyzer is to interpret the answer as either the acceptance of the proposal or its rejection and, most importantly, to substantiate this interpretation. We show which knowledge is used and what reasoning should be performed in order to understand an indirect answer.*

Keywords: semantic analysis, inference, plausible expectation, indirect speech act

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1. Introduction

The semantic analyzer SemETAP, under development in the Computational Linguistics lab of the Kharkevich Institute for Information Transmission Problems of the Russian Academy of Sciences, is aiming at performing semantic analysis based on both linguistic and extra-linguistic knowledge. This analyzer includes a powerful wide-coverage linguistic processor capable of building coherent semantic structures, a knowledge-extensive lexicon, which contains a variety of types of lexical information, an ontology, which describes general and domain-specific objects and their properties, a repository of ground-level facts, a set of common-sense axioms, and an inference engine [1]-[5].

This paper will demonstrate how this analyzer can help interpret indirect speech acts. Scholars have repeatedly addressed indirect speech acts in the context of pragmatics. The focus of attention has mainly been on the so-called conventional indirect speech acts which center on conventions of language. A typical example of these are questions used as requests (as in *Could you give me a ride?*). As for non-conventional indirect speech acts, which rely heavily on the context and common-sense knowledge, researchers mostly restrict themselves to citing examples, as in [6]:

(1) *Necesito los apuntes de la clase y tú eres el único estudiante que conozco*
'I need the class notes and you are the only student I know'

Here the addressee is expected to understand that the speaker is asking the interlocutor to lend him the interlocutor's class notes, although this is not what was uttered literally. "In indirect speech acts the speaker communicates to the hearer more than he actually says by way of relying on their mutually shared background information, both linguistic and nonlinguistic, together with the general powers of rationality and inference on the part of the hearer" [7, p.61].

It is difficult to model understanding of such speech acts, since they tend to be "open ended, both in terms of propositional content and linguistic form as well as pragmatic force" [8, p.42]. The most direct, if not the only one, way toward the interpretation of such speech acts seems the construction of a model of knowledge shared by the speaker and the hearer supplemented by a mechanism of common sense inferences. Exactly such an endeavor is undertaken in this paper. We will analyze an example of a dialogue in which one participant proposes to the other participant a joint activity and the latter gives an indirect answer (Section 4). Prior to that, we will discuss the inferences that we will be making (Section 2) and consider the knowledge resources we have at our disposal (Section 3).

2. Natural Language Understanding and Implicit Meaning

It is well known that not all information that we extract from text is explicitly conveyed by linguistic means. We will distinguish between (a) the literal content of a text, i.e. the content that can be extracted on the basis of language knowledge (such as the knowledge of morphology, syntax, semantics contained in lexicographic definitions of words, etc.) and (b) its expanded content, which includes the data that can be obtained through interpreting the text in the respective

context and using our knowledge of the world and the communicative situation.

On the other hand, the extent of reliability of information extracted from both the text and the context may vary. The logical science teaches us to make absolutely reliable conclusions. If an assertion that we believe to be true can be refuted by just one counter-example, this assertion should be regarded as false. As far as natural language is concerned, ontologies offer us a vast source of trustworthy inferences. A typical ontology-based inference may look as follows: If Mary is a little girl then she is human and belongs to the subclass of female beings and to the subclass of non-adult beings. Knowledge of lexical meanings of words is another source of logically correct inferences. If it is true for example that John *persuaded* Mary to marry him then it could be concluded that Mary agreed to marry John. If it is known that Bill *pretends* to be ill then it may be concluded that Bill is in good health. These conclusions may be automated if we have analytical definitions of words written in a formal metalanguage to which inference rules may be applied.

It is known however that, in their everyday verbal and thinking activities, people often resort to inferences that are logically far from being perfect. Yet these inferences help us understand coherent texts, including dialogues. Any coherent text contains much implicit information needed for its proper understanding. If this information is not extracted, a coherent text may look as a collection of disconnected sentences gathered together for some enigmatic reason. In most cases, the hearers easily restore implicit information from texts, using plausible expectations rather than logical inferences. Consider the following example.

(2) *The child had been prescribed an antipyretic but the pharmacy was closed.*

Based exclusively on linguistic knowledge contained in the first clause, we find out that the child is sick (medications are prescribed to sick people). From the second clause, we learn that some commercial enterprise (pharmacy) is closed. The conjunction *but* standing between the first and the second clause points to the fact that there is a discrepancy between the two clauses but nothing tells us what it consists of. As long as the hearer fails to understand why the second clause violates the expectations emerging from the first clause, he will consider the whole sentence as anomalous, in just the same way as the sentence

(2a) *The child had been prescribed antipyretics but the library was closed.*

Everything fits together perfectly if we assume that there was no antipyretic medication prescribed to the child at home so it had to be bought at the pharmacy. Anyone who happens to read (2) will understand that there was no relevant medication – but this conclusion does not follow from anything! It is only made on the basis of the fact that it allows one to complete the picture, so that, due to this assumption, the text becomes coherent and sensible.

In example (2) the missing conclusion did not follow from lexical meanings. It was made due to the fact that the hearer was aware of curing routines. Meanwhile, lexical meanings themselves often prompt the hearer for the situation to be expected. So, it does not follow from sentence

(3) *John decided to quit his job*

that John implemented his decision. Yet, (3) activates this expectation, which could either be confirmed by subsequent text (say, *John decided to quit his job and went travelling*) or be disproved and dismissed. Expectations of this kind reflect the hearer's readiness for a certain turn of events. In Section 4, we will elaborate on several such inferences.

3. Knowledge Resources

The semantic analyzer, SemETAP, is constructed as a component of the multifunctional linguistic processor ETAP, which was created by the team of researchers that includes the authors of this paper (see e.g. [9]). It has a variety of options, including a rule-based machine translation system operating between Russian and English, and is supported by a number of advanced linguistic resources – dictionaries, parsers, and a Russian treebank SynTagRus, fully annotated with dependency trees [10].

The semantic analyzer has several sources of knowledge. Linguistic data is contained in ETAP's databases, the most important of which is the Combinatorial dictionary supplied with ample lexicographic information, including lexical functions [11], [12]. World knowledge is presented by several resources – the Ontology, the Repository of individual entitites, and a set of axioms for inferences. The first resource contains the data on classes of things and situations (such as Human, Artifact, CommunicativeEvent, Buying, etc.), whilst the second one contains the data on individual, singular objects or events (like Moscow, France, World War II).

The most important resources for the purposes of this paper are the Combinatorial dictionary, the Ontology and the set of axioms. We will focus on the dictionary and the ontology in this section putting an emphasis on their use in making inferences based on plausible expectations. Axioms will be illustrated in Section 4.

3.1. The Combinatorial Dictionary

Every lexical entry in the combinatorial dictionary is supplied with information of various types: syntactic and semantic features, subcategorization frames, references to the ontology, lexical functions, as introduced in the Meaning ↔ Text Theory of Igor Mel'čuk [13], translational equivalents for a number of languages,

including the UNL interlingua [14], [15], [16]. Importantly, the dictionary entry contains a semantic decomposition of the word produced using the concepts of the ontology. This part of the entry lists inferences that can be made based on the sense of this word, stating the conditions for these inferences to be valid. Logically strict inferences are listed in the section called Implications and plausible expectations are listed in the Expectations section.

The following example that presents four sections of the dictionary entry for the Russian verb *pomogat'* 'to help' in its main lexical sense ('help someone do something') illustrates this material in more detail.

To facilitate understanding, the semantic decomposition zone, as well as the implications and the expectations zones, will be presented in a (quasi)natural language rather than in the formal language designed for this purpose.

Examples: *Kolja pomogaet Mashe izuchat' kitajskij jazyk* 'Nick helps Mary to learn Chinese'. *Kolja pomog Mashe reshit' zadachu* 'Nick has helped Mary to solve the problem.' *On pomog ej sovetom (tem, chto pogovoril s dekanom)* 'He helped her by giving a piece of advice (by talking to the dean)'.

Decomposition: *HELPER helps HELPEE to reach GOAL by doing AID*[1] = 'Human HELPEE has goal GOAL; Human HELPER does action AID; as a result, it is easy for HELPEE to reach GOAL; the fact that HELPER does AID is good for HELPEE'

Implication: If *pomogat'* stands in the past tense and the perfect aspect, then it is implied: HELPEE has reached GOAL. Namely, if *Kolja pomog Mashe reshit' zadachu* 'Nick helped Mary to solve the problem' then *Masha reshila zadachu* 'Mary solved the problem')

Expectation: If *pomogat'* stands (i) in the nonpast tense **or** (ii) in the past tense and the imperfect aspect, then it is expected: HELPEE will reach GOAL. Specifically, if *Kolja pomogaet (pomogal, pomozhet) Mashe reshit' zadachu* 'Nick helps, was helping, will help Mary to solve the problem' then it could be expected that *Masha reshit zadachu* 'Mary will solve the problem').

Obviously, the same is true, *mutatis mutandis,* for the English verb *help,* maybe with the exception of certain subtleties associated with differences between the Russian and the English system of verbal tenses and aspects.

3.2. The Ontology

Let us now move on to the ontology. By way of illustration, we will present here ontological descriptions of three classes connected with each other: we will need them in Section 4.

Class 1 is Organization. This class belongs to the class Agent and, simultaneously, to the class Group. Every Organization has a Chief from the class Human, Staff, also from the class Human, and a Function – an activity that Organization is supposed to carry out.

Class 2 is ClientServingOrganization, which is a subclass of Organization. Class 2 inherits all properties of its superclass Organization (which we do not repeat here, see above) and has certain properties of its own. This class comprises such organizations as movie theater, bakery, hospital, library, public bath, school etc. but does not include such organizations as ministry or city council. The Function of ClientServingOrganizations is to do certain Activity in the interests of the Client, or to ensure that the Client does certain Activity in the Client's own interests. So, the clients eat at restaurants, buy bread in bakeries and receive medical treatment in hospitals. This information is stored in the ontological description of ClientServingOrganizations under hasClientAction slot.

Finally, class 3 is SeafoodRestaurant, belonging to the class ClientServingOrganization. Its function is to prepare and sell to Clients food made from sea species, while the Clients' Activity is to eat this food, being inside the restaurant.

Formally, Ontology entries look as follows:

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Organization(X)
    isA(X,Group)
    isA(X,Agent)
    hasChief(X,Human)
    hasInStaff(X,Human)
    hasFunction(X,Action)

ClientServingOrganization(X)
    isA(X,Organization)
    hasUser(X,OR (Human, Organization))
    hasUserAction(X,Action)

SeafoodRestaurant
    isA(X,ClientServingOrganization)
    isA(X,Place)
    hasUser(X,Human-1)
    hasFunction(X,Preparing&Selling)
    hasAgent(Preparing&Selling,X)
    hasObject(Preparing&Selling,Seafood-1)
    hasAddressee(Preparing&Selling,Human-1)
    hasUserAction(X,Eating-1)
    has Agent(Eating-1,Human-1)
    hasObject(Eating-1,Seafood-1)
    hasLocation(Eating-1,X)
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[1] In FrameNet, the respective semantic role in the frame of ASSISTANCE is called Focal_Entity, which we find a bit too vague.

4. Case Study: an Indirect Answer to a Proposal

We will now consider in detail a specific class of dialogues in which one of the interlocutors suggests that the other interlocutor do something and the latter responds to this suggestion. In the simplest case, the response may be a direct one:

(4a) Speaker A: Will you go to the movies with me?

(4b) Speaker B: Yes, thank you / No, thank you.

Often, however, especially in the case of a negative response, people answer in an indirect way. For instance, the following answers could be expected in response to (4a):

(4c) I have no time to spare.

(4d) I have a lot of things to do.

(4e) I need to prepare for an exam.

(4f) I have no money.

(4g) Today is my father's birthday.

(4e) I don't like movies.

(4f) I have a headache.

(4g) My parents do not permit me to go to the movies with strangers.

We easily interpret all such answers as refusals, but why? How do we know that the interlocutor has not accepted the proposal? The literal meaning of sentences (4c-f) may have nothing to do with A's question, but, by force of Grice's Maxim of Relevance we must proceed from the assumption that each of these sentences indirectly contains the "yes" or the "no" answer. Our goal, then, is to extract this implicit information from any question-answer pair. An important thing is the fact that inferences made in the course of reasoning, are no logical conclusions in the strict sense of the term but are plausible expectations, which we described above. We will demonstrate the way to achieve the goal of extracting the relevant information using the following dialogue (5a-5b) as an example:

(5a) Speaker A: *Let's go to a seafood restaurant!*

(5b) Speaker B: *My doctor has forbidden me to eat fish.*

We will begin with (5a). Let us assume that the proposal contained therein is accepted and try to draw inferences from this assumption. We will show that these inferences are incompatible with the inferences made from (5b). Accepting the proposal implies that (6) will be true.

(6) A and B go to a seafood restaurant.

If it is to be taken literally, (6) reports on a movement which has a seafood restaurant as its destination point. The proposition

(7) 'X goes from P1 to P2'

allows for a number of conclusions. Three events are important here: the action of motion, the end of being located in P1 and the start of being located in P2. These events have different epistemic statuses. While we can derive from (7) three following inferences with absolute certainty:

(7a) at moment t0 X is moving,

(7b) at moment t1<t0 X was located in P1,

(7c) at moment t0 X is not located in P1,

we cannot reliably assert anything about the future location of X in P2, simply because we cannot be sure about any future events. After the start of motion, circumstances may emerge which could prevent X from reaching the destination point. For instance, the object may feel sick and return back home. Yet, in absence of information pointing to unforeseen circumstances it is natural to expect that the destination point will be reached. This is what the circumscription principle by McCarthy [17] suggests: things are as expected unless otherwise specified. This assumption can be formulated as Axiom 1[2].

Axiom1: if Object moves to Place at t0, then it CanBeExpected that Object will be located at Place at t1>t0.

The next step is as follows. What conclusion could be derived from the fact that the goal of motion, the destination point, is reached, and the object is in the restaurant? We remember that, as stated above, the restaurant belongs to the class of Organizations that has users (clients). A relevant property of ClientServingOrganizations is that they are associated with a particular expectation, namely that if an Object is located in such an Organization, it is natural to expect that this Object will be using this Organization according to its intended purpose, i.e. fulfill the role of a client.

The expectation consisting in the fact that a Human who is in a ClientServingOrganization will use it according to its intended purpose belongs to the same class of expectations as the expectation concerning the use of an Instrument. If a text activates the fact that the Subject has an Instrument at his disposal, we should expect that he will be using it according to its intended purpose. If we

[2] For the reader's convenience, the axioms are written in a (quasi)natural language. In the semantic analyzer they are naturally presented in the formal language.

come across a sentence saying that *Father took an axe and went to the woods* than we feel prepared to the fact that father is going to chop wood. Moreover, often the very fact that there is a tool ready presents itself as a nomination of manipulation with this tool. If someone says that he has not taken a violin in his hands for a long time it is to be implied that he hasn't played it for a long time.

The conclusion that a human present in a restaurant is its client is not the only possible one. Another natural assumption could be that this human belongs to the restaurant's staff and is there on duty. Since we are only concerned with plausible expectations, we need not list all feasible situations and can confine ourselves with the expectations most naturally activated in a given situation. Hence, Axiom 2 can be considered to be legitimate:

Axiom 2. If a Human is located in ClientServingOrganization, then it CanBeExpected that Human either is a Client or belongs to Staff.

Another example of using Axiom 2 could be seen in the dialogue (8a-8b):

(8a) Speaker A: *Where is your wife?*

(8b) Speaker B: *She is on the beach.*

A beach is not just a plot of land where a human can be as on any other plot. It is a plot of land intended to be used by humans who swim in the sea bordering on this beach or bathe in the sun. In a way, the beach is, technically, similar to a ClientServingOrganization in that it also has a function and clients.

The next logical step consists in the assumption that if a Human is in a ClientServingOrganization as a client then it is not difficult to predict what he is going to do there if we know the specialization of this Organization. Hence, Axiom 3 can be proposed:

Axiom 3. If a Human is Client at ClientServingOrganization for which its ClientAction is Action, then it CanBeExpected that Human performs Action.

Axiom 3 says that if someone is a Client of a ClientServingOrganization, then he does what clients of such organizations normally do. We saw in Section 3 above that the ontological description of a restaurant includes the information that the actions of its clients consist in consuming the food prepared in this restaurant – in much the same way as the actions of clients of a library consist in reading the books borrowed there.

Axiom 3 can be used even when the speech act to be analyzed is not indirect. For example, dialogue (9a-9b)

(9a) Speaker A: *Where is John?*

(9b) Speaker B: *He is in the hospital*

gives a direct and relevant answer to the posited question. The first sentence asks about John's location and the second sentence specifies a concrete place – hospital. However, the content of the answer is not exhausted by stating the place. The hearer has all reasons to assume that John is receiving medical treatment, and this is an important part of information he has received, which may trigger further units of a conversation (such as *What happened to him?*).

In a similar way, the reply in dialogue (10a-10b)

(10a) *What did you do yesterday?*

(10b) *I went to the theater.*

gives a direct answer: the interlocutor moved to the theater. However, the real pragmatically relevant reply is not the action of movement, but the action determined by Axiom 3 and the ontological description of a theatre: I watched a performance.

Thus, we see that both direct and indirect speech acts use the same inference mechanisms.

There is one more gap between (5a) and (5b) that has to be bridged: (5a) is related to seafood, while (5b) mentions fish, which is not exactly the same. Seafood denotes a larger class that includes two subclasses - fish and shellfish. This is what can be inferred directly from the ontology: if A belongs to the class of Seafood, it belongs either to the class of Fish or Shellfish. What we need now is a general axiom covering disjunction:

Axiom 4. If P is true of (A or B), then CanBeExpected that P is true of A.

For example, if we know that Peter or Bill will come, we can expect that Peter will.

Now, we are prepared to build the following chain of inferences from (6):

(11) Speaker B goes to a seafood restaurant ➔ Speaker B is in a seafood restaurant (by Axiom 1) ➔ Speaker B is Client of a seafood restaurant (by Axiom 2) ➔ Speaker B eats seafood there (by Axiom 3) ➔ Speaker B eats fish there (by Axiom 4).

Let us now return to the reply (5b) and see what inferences it invites.

(5b) Speaker B: *My doctor has forbidden me to eat fish*

Here, we enter the area of modalities, which provide ample space for versatile inferences, many of which are not one hundred percent reliable – especially if deontic modality is concerned.

Let us first of all turn our attention to the fact that expectations generated by modal predicates may vary in their degree. If an order was issued to do some P, then the probability of P taking place is likely higher than if it was a request or a piece of advice. However, at the present stage of our study we abstract away from such differences and only distinguish between two types of inferences: rigid (= 100-percent true conclusions) and soft ones (plausible expectations).

In the area of deontic necessity it is a valid deliberation that if X needs to do P then it can be expected that he will do P. Naturally, if P is lack of action Q (such as expressed by the sentence like *He must not go*) then it is to be expected that Q will not be done. Hence, Axiom 5 is appropriate:

Axiom 5: if Human must perform Action, then CanBeExpected that Human performs Action.

A complication may arise that if the idea of necessity is within the scope of another operator, such as a predicate of communication or opinion, then the imperativeness is suppressed or, in any case, drastically reduced. If A believes or says that B must do P, this does not imply that B really must do P. If however the predicate denotes prohibition or order then the imperativeness is likely not canceled or relaxed, since, in accordance with the semantics of these predicates the Agent has the right to postulate the necessity.

Let us address again the unit (5b). The point of departure here is the dictionary definition for *prohibit*:

(12) *X prohibits Y to do Z* = 'X says to Y that Y must not do Z, X having right to do so'.

In agreement with what has been said above, the following Axiom 6 may be proposed:

Axiom 6: if Human-1 prohibits that Human-2 performs Action, then it CanBeExpected that Human-2 does not perform Action.

When applied to (5a), this axiom brings us to the proposition

(13) 'Speaker B does not eat fish'.

Thus, given the inference chain (11) and (13), we see that propositions (6) and (5b) give rise to contradictory inferences. Hence the hypothesis that the proposal (5a) was accepted should be rejected.

5. Conclusion

Semantic analysis of a coherent text, in particular, a dialogue, requires extraction of implicit information. This task becomes especially relevant when we are confronted with indirect speech acts, so that information conveyed by the text is essentially different from what is literally said. We endeavor to show how understanding indirect speech acts can be automated, using an example of dialogue containing an indirect answer to a question. We have shown that inferences made on the basis of plausible expectations play a key role in this process. Such a model can be implemented within the framework of a linguistic processor that has access to linguistic and word knowledge and is able to make inferences.

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