USING FRAMES IN CAUSAL REASONING

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The 'recognition problem' constitutes the core of every understanding process. Most research in text and story understanding deals with this problem on a higher, i.e. plot level. In the present paper our main interests lie in the lower level recognition processes which help to make explicit the complete causal chain of events by filling in those events and explicating the links between them that are not mentioned explicitly in the text but would be inferred by the reader. The problem of implementing this reasoning mechanism in a natural language understanding system TARLUS is also considered.

Natural language understanding may proceed on quite different levels - from grasping the meaning of a single word to determining the meaning of specific texts in the system of the whole human culture (eg. the texts of Vedas). Therefore it is understandable that when starting to develop a natural language understanding (NLU) system it must be taken into consideration how 'deeply' the system should understand language, i.e. which units it must be able to recognize and operate with. Within NLU systems a definite subdomain of systems may be brought out, namely text and story understanding systems which take into account also regularities of building up the text. There exists a wide spectrum of differences among text and story understanding system builders with regard to such items as text comprehension, depth of understanding, representational issues, etc. (cf. Charniak, 1981; Lehnert et al, 1981; Schank et al., 1980; Rieger, 1979; etc.).

The main task of NLU system TARLUS may be seen in formulating and simulating on the computer these regularities (linguistic as well as interactive, cf. Õim, 1981; Попов, 1981) that enable the reader to decide on the basis of events and situations immediately described in the text that one has to do with complex, 'higher' level units (called hyper-events and hypersituations, respectively). They need not be mentioned in the text explicitly (Charniak, 1978) but their salient features are contained in that text (or can be derived from it). In other words, we see our task in bridging the gap between understanding the meaning of a sentence, on the one hand, and comprehending the text on the plot-unit level, on the other hand. Our second task arises directly from the first one - it is to develop a suitable representation for simulating these regularities with the help of the computer. In TARLUS we have proceeded from the idea of organizing knowledge of the system in the form of frames.To this end a suitable representation system is under development (Литвак,1982). In connection with the last task it should be borne in mind that this representation ought to reflect the regularities of text understanding by humans but it should be kept apart from the claims as to in which form these processes go on in human beings (Winograd, 1980 has dealt quite profoundly with the problems arising from such confusion of domains).

1. Representing knowledge in TARLUS

First some words about TARLUS knowledge representation which is necessary for understanding the following material.

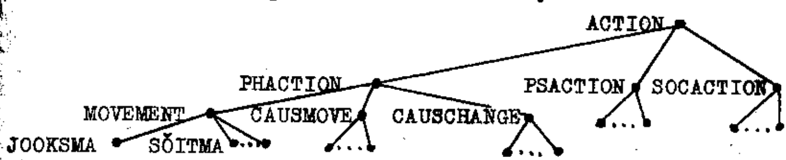
The output of TARLUS Linguistic Processor is the tree of syntactico-semantic dependencies (or trees in the case of multivariant analysis).It serves as the input to the next module of analysis - Interpreter - which must perform the following tasks:

1) generate a network of frames corresponding to the dependency tree;

2) link these networks of frames into an integral network for the text.

In Interpreter the frame corresponding to the root of the dependency tree is activated in the TARLUS basis of frames (i.e. a frame is instantiated) and the slots of that frame are filled in according to the list of slots of the prototype. This proceeds either on the basis of the dependency tree or when the tree does not contain information required, on the basis of previously obtained information, i.e. by combining pieces of information from the tree with the information already stored in the memory of the system.

All the frames in TARLUS basis of frames fall into two groups: terminal (they have no subordinates) and conceptual. Some of these frames are 'marked' and belong to the category of hyperframes the identification of which can be viewed as the main task of the system. Terminal and conceptual frames constitute a hierarchy built up on property inheritance principle. Here is a fragment of the hierarchy:



The structure of all the frames is similar containing, on the one hand, a list of slots in the form of attribute-value pairs and, on the other hand, there are various attached procedures connected either with definite slots of a frame or with a frame as a whole.

The following is a representation of the conceptual frame MOVEMENT and the terminal frame SÕITMA 'to go by...' (both representations are incomplete as we shall give a more detailed treatment of some of their slots in 2.2.).

MOVEMENT

SUP: PHACTION
AG: REQ (LIVBEING)
INSTR: REQ (THING, ANIMAL)
LOC, LOCFR, LOCTO, DIR, ITIN } REQ (PHOBJ, PLACE)
TM, TMFR, TMTO, DUR } REQ (TMSPEC)

SÕITMA
SUP: MOVEMENT
AG: REQ (PERSON)
INSTR: REQ (THING, ANIMAL)
DEF: (LIIKLUSVAHEND)
a vehicle

Any frame may have included in it procedure of two kinds:
1) type procedures (eg. REQ (UIRE)) containing those predicates which must hold about the values of the arguments that are put in VALUE of the same slot; DEF(AULT) denotes a variant which holds when nothing else is said about an argument's value;
2) attached procedures checking
i) whether the frame contains a minimally required combination of slots for this frame to be 'successively' used. The frame SÕITMA 'go by ...' minimally requires the presence of the slot AG and fixed combinations with the slots INSTR, GOAL, LOC, LOCTO, LOCFR, DIR, e.g.

(1) AG+INSTR
JAAN SÕITIS AUTOGA
Jaan went by car/Jaan drove a car

(2) AG+GOAL
JAAN SÕITIS EMA VAATAMA
Jaan went (by means of a vehicle) to see his mother

(3) AG+LOCTO
JAAN SÕITIS TALLINNA
Jaan went (by means of a vehicle) to Tallinn

(4) AG+DIR
JAAN SÕITIS METSA SUUNAS
Jaan went (by means of a vehicle) towards the forest

(5) AG+LOCFR
JAAN SÕITIS TARTUST TALLINNA
Jaan went (by means of a vehicle) from Tartu to Tallinn

but they cannot allow such combinations of slots as

(6) AG+LOCFR
JAAN SÕITIS TARTUST
Jaan went (by means of a vehicle) from Tartu

ii) the suitability of available candidates for filling in the slots with respect to the hierarchy of frames and the order of property inheritance.

The slots considered so far belong to the group of so-called 'variable slots'. Their task is to establish a pointer from one frame to another. But sometimes it is necessary to have more than one pointer to a frame because in the sentence

(7) MEES KÄSKIS TÜDRUKUL MINNA TUPPA

The man ordered the girl to go into the parlour

TÜDRUK (girl) is simultaneously REC of the frame KÄSKIMA (order) and AG from the frame MINEMA (go). For this purpose some slots in TARLUS are supplied with a second pointer in the form of the slots AG from, PAC from, REC from.

2. Causal reasoning and text coherence

2.1. A system that claims to understand a text must do more than merely produce a representation for each sentence. Inferences must be generated to fill in implicit information and causal connections to tie together individual conceptualizations must be made. One of the most difficult and most interesting problems in natural language processing concerns the generation of inferences (Lehnert, 1981:147).

In attempting to answer the questions about the origin and nature of inferences one becomes involved in problems of human memory organization. Inferences are made not only on the basis of knowledge about the world (Lehnert, 1981:147) but also on the basis of human linguistic and interactive knowledge (Õim, 1981). The problem can be formulated this way: how must this knowledge be organized and represented so that appropriate reasoning mechanisms can have access to relevant information as needed? In other words, this problem can be seen as organizing close interaction of two subsystems of an understanding system: memory subsystem, on the one hand, and reasoning system, on the other hand (Litvak et al.,1982). There are two components which make up the systems 'reasoning capabilities'. One component - so-called distributed reasoning - consists of those local procedures and rules which are connected with single concepts (frames). They represent a fixed subpart of a frame and are triggered when the corresponding concept is activated.

Secondly, text(discourse)-understanding systems require the presence of more global and centralized reasoning procedures which constitute an independent subsystem alongside the knowledge (in the traditional sense) subsystem. These procedures represent typical structures of (human) reasoning in certain meaningful situations. To describe them different representational units and structures are required.

In the present paper an attempt is made to describe only the first type of reasoning mechanism in TARLUS, i.e. the procedures of reasoning are depicted which operate on data and procedures contained in single frames.

One of the tasks of frames is to generate a **complete** causal chain of events by filling in those events that are not explicitly mentioned in the text but would be inferred by any knowledgeable reader. This representation should be generated partially in the process of reading the text, and partially during the process of hyperframe identification. The possibility to explicate this complete causal chain of events is based upon the assumption of coherence of the text. Coherence may be understood as the feature of the text in the case of which between all the actions and events described in the text there exist implicit (causal) relations where a following action/ event is seen as a realization of the goal of a preceding action and becomes (with respect to the action/event considered) its consequence. The components pointing out the goal-sequence relationship are given as quite detailed in structures of the corresponding actions and therefore they may be (and in most cases are) not explicated in the text. But when need arise to make this chain explicit, first, information to fulfil in these structures must be looked up in the text, and secondly inferences must be made to determine the coherence of the text.

Sentence

(8) He slipped and broke his arm-bone

may be regarded as a condensation for a more extended sentence (9) where the consequential part has been explicated

(9) He slipped CONSEQ : he fell CONSEQ :... he broke his arm-bone

2.2. The 'exactness' of sentence (9) is redundant in the sense that from sentence (8) all the missing links can be recovered unambiguously but in a NLU system these links (or the possibility to reconstruct them) must be represented explicitly. For this purpose the frames of TARLUS contain, in addition to 'variable slots' also various 'procedural slots'. The latter differ from the former in the following aspects:

i) their fillers are mostly frames denoting actions or situations;

ii) there are two different procedures connected with these slots:

  a) a procedure of looking up from the sentence/text analysed the fillers of the variable slots of that particular procedural slot;

  b) a procedure for assembling parts of structures that can be used in other frames or procedural slots for making inferences.

Let us consider sentence (10) and its representation (11)

(10) TA PALUS MUL SULLE MEELDE TULETADA, ET SA KÕIKIDELE TEATAKSID, ET KOOSOLEK TOIMUB REEDEL

He asked me to remind you to inform the others that the meeting will be held on Friday

(11) PALUMA (ask)
    AG: TEMA (he)
    REC: MINA (I)
    CONT: MEELDE TULETAMA (remind)
        AG: MINA (I)
        REC: SINA (you)
        CONT: TEATAMA (inform)
            AG: SINA (you)
            REC: TEISED (the others)
            CONT: TOIMUMA (be held)
                PAC: KOOSOLEK (meeting)
                TM: REEDE (Friday)

As can be seen from (11) the slot CONT is (usually) filled in with frames denoting actions, and there can be several embedded CONTs in one frame. And in the case of such embedded CONTs the fillers of its variable slots must be found from the text (or the possibility of their transfer from one CONT into another ascertained).

2.3. In TARLUS the causal chain of events is made explicit with the help of the procedural slots GOAL, CONSEQ and SETTING. GOAL indicates the goal of an action, CONSEQ

points out the situation which holds after an action has been performed, SETTING brings out the conditions which must have been satisfied for that action to be successfully performed. The contents of the slots GOAL and CONSEQ coincide in most cases but are used differently in the process of reasoning:
i) the slot CONSEQ is bidirectional, i.e. from an action we can learn what its consequences are, but at the same time it enables us too, to determine which action is responsible for these consequences. E.g. the consequence of PANEMA (put, place) is that an object is located somewhere, and from the fact that some object is located somewhere it can be inferred that it had been placed/put there earlier. This may be represented as

```
(12) PANEMA (put, place)
          ...
        CONSEQ : LOCATION
                    PAC=OBJ from PANEMA
                    LOC=LOCTO from PANEMA
     ASUMA (be located)
     when PAC=A THING
     then SETTING : PANEMA (put, place)
                       AG=undefined
                       OBJ=OBJ from ASUMA
                       LOCTO=LOC from ASUMA
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The slot GOAL is used only undirectionally, i.e. we know usually what the goal of an action is; but goals of what activity does an action itself represent is remembered only on rare occasions, and even then this goal is only recoverable through the slot CONSEQ of the action;
ii) the structures of the slot CONSEQ can be used as independent structures after being filled in with concrete data, the structures of the slot GOAL cannot be used in this way;
iii) usually any substructure of the slot GOAL can be transferred under the slot CONSEQ of the same frame in the default sense. Besides, CONSEQ contains more substructures than GOAL. For example, both GOAL and CONSEQ of VIIMA (take to) have the structure

```
(13) LOCATION
         PAC=OBJ from VIIMA
         LOC=LOCTO from VIIMA
```

which shows that the object being taken to a place is located

at that place, but CONSEQ contains in addition to (12) also
(14) LOCATION

PAC=AG from VIIMA

LOC=LOCTO from VIIMA

which points to the fact that the person taking that object somewhere is also located at the same place where the object taken to is located.

CONSEQ includes in itself various 'mediating' consequences as well. E.g. KÄSKIMA (order) has its CONSEQ a substructure

(15) KOHUSTUS (obligation)

PAC=REC from KÄSKIMA

CONT=CONT from KÄSKIMA

but the slot GOAL has a weaker variant of the same structure

(16) ACTION

AG=REC from KÄSKIMA

CONT=CONT from KÄSKIMA

The job of the slot SETTING is, on the one hand, to help establish the coherence of the text by checking contradictory assertions during the analysis of the text and, on the other hand, when interpreter has accepted a frame SETTING serves as the basis for making inferences about the situation which was to hold before the corresponding action would take place. If we learn by checking this slot that in the preceding text nothing was said about the participants of an action and their relations then it is quite natural to assume that things are the way as presented in the text. Now if there is a sentence in the text

(17) POISS VÕTTIS LETILT TAHVLI ŠOKOLAADI

The boy took a bar of chocolate from the counter

and nothing whatsoever had been said in the preceding text about chocolate or its location then TARLUS has to assume a situation

(18) VÕTMA (take)

...

SETTING: DEF (LOCATION

PAC=TAHVEL ŠOKOLAADI (a bar of chocolate)

LOC=LETT (counter))

and starts looking for confirmation or rejection of that assumption in the following text. If the text does not contain any information that would either reject or confirm that assumption then after reading through the whole text TARLUS can use (18) as a reliable piece of knowledge. Should following text contain anything challenging (18), this SETTING will be removed and new information inserted.

In which way does SETTING help establish coherence of the text? We proceed from the assumption that SETTING as well as GOAL and CONSEQ are a means of explicating default reasoning implicit in the text as 'default reasoning may well be the rule, rather than exception, in reasoning about the world, since normally we must act in the presence of incomplete knowledge' (Reiter, 1978:216). It means that using procedures incorporated in these slots is an inevitable part of the process of recovering the complete causal chain of events implicitly present in the text. To make it more understandable let us consider the following text:

(19) 1. A man entered a shop.
2. He was the only customer there.
3. The man asked the shop assistant to show him some 'Canon' photocameras.
4. As the shop assistant had just sold the last camera in the shop she went to the store to fetch some new ones.
5. At that time the man pocketed a hand-calculator lying on the counter.
6. When the shop assistant returned with the goods she noticed that the calculator was missing.
7. She ordered the man to return it.
8. Instead of that the man seized a camera from the counter and ran out of the shop.

From the last sentence it can be inferred that the stolen camera was located on the counter. But how did it happen to be there? By using the slot SETTING we can reconstruct part of the chain of events this way: SETTING of seize is that an object is located somewhere; SETTING of be located is that the object had been placed at that place (counter) by somebody; SETTING of be placed is that the object had been located somewhere else. When looking for any information about an earlier location of the camera sentence 4 tells us that they were in the store. The task now is to find out how/ in which way/ the camera was transferred from the store to the counter. Sentence 4 tells us that the shop assistant went to fetch new cameras from the store, and sentence 6 adds that she returned to the shop with some cameras. It means that the location of the cameras is somewhere in the shop and sentence 8 fills in that location, namely counter.

It must be borne in mind, of course, that all this reasoning is true in the default sense, i.e. no contradictory information is discovered in the text. The above said brings us to the main principle underlying the use of SETTING: if the SETTING of the action under analysis does not coincide with the information already available from the text then that earlier information must be changed if it is possible to recover the chain of mediating events/situations. If this cannot be done then either the text is incoherent or the implemented rules for explicating the causal relationship are incomplete.

2.4. In addition to the implicit goals contained in the actions themselves there can also be in the text so-called 'higher level' goals for which these implicit goals play the role of mediators. For example, the immediate goal of SÕITMA 'to go by...' can be represented as

(20) SÕITMA

...

GOAL:DEF (LOCATION

PAC=AG from SÕITMA

LOC=LOCTO from SÕITMA

In the sentence

(21) JAAN SÕITIS SAARELE LINDE VAATLEMA

Jaan went to the island (in order) to watch birds

this immediate goal (to be located) is maintained in the process of text interpretation as it enables us to understand how the higher level goal 'watch birds' may have arisen. And this latter goal may in turn be a mediator for a yet higher level goal. Such a multilevel organization of goals is a typical feature of natural language texts. TARLUS does not have yet any means for representing this type of hierarchies in its model of the world. At the same time it is quite obvious that the presence of such hierarchies in the text makes it inevitable to supply a text understanding system with a corresponding mechanism for extracting a plausible interpretation of that text.

3. Conclusion

The 'recognition problem' constitutes the core of every understanding process. Therefore it is quite understandable that a lot of works have been devoted to this problem (Wilensky, 1981; De Jong, 1979; Гаазе-Раппопорт и др., 1981). But as a rule these researches deal with the recognition of the structure of a story on a relatively high, plot level. The lower level recognition processes are replaced on a large scale by ad hoc technical artifices. Our main interests lie in the lower level recognition processes the strategies of processing which are determined to a high degree by the direct linguistic contents of the text itself. It should also be noted that there is one point which makes this kind of recognition quite important theoretically: namely, it requires close cooperation of two subsystems of an understanding system - knowledge (memory) subsystem and reasoning subsystem. In the present paper we tried to show how this cooperation is (and can be) implemented in the NLU system TARLUS.

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ИСПОЛЬЗОВАНИЕ ФРЕЙМОВ В ПРИЧИННО-СЛЕДСТВЕННОМ ВЫВОДЕ

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Резюме

Понимание естественного языка может происходить на различных уровнях, начиная с распознавания значений отдельных слов и кончая оперированием значениями общезначимых для человеческой культуры текстов. Поэтому при создании системы понимания естественного языка необходимо отчётливо представлять единицы, которыми при данном уровне понимания необходимо оперировать.

Основной задачей системы TARLUS является моделирование процессов распознавания некоторых гиперсобытий, т.е.событий относительно более высокого уровня, о которых идёт речь во входном тексте без явного их указания. При этом речь идёт о распознавании на относительно низком уровне, непосредственно надстраивающемся над языковой структурой текста.

Организация знаний в системе TARLUS основана на использовании фреймов. Слоты фреймов подразделяются на декларативные и процедуральные. В последних содержатся процедуры либо данные для глобальных процедур, позволяющие генерировать новые фреймы, с помощью которых осуществляется связывание фреймовых представлений отдельных предложений в единую структуру.

Более подробно рассматривается использование слотов GOAL, SETTING и CONSEQUENCE, в которых содержится информация о цели, необходимых предусловиях и следствиях действия, соответствующего данному фрейму.

В слоте SETTING помещаются процедуры, проверяющие возможность выполнения действия. В случае возникновения противоречий между содержащейся в предыдущем тексте информацией и предусловиями, необходимыми для успешного выполнения данного действия, текст считается противоречивым. Если в предыдущем тексте отсутствуют явные указания на выполнение предусловий (полностью или частично), то процедуры слота SETTING построят и свяжут с сетью фреймов текста дополнительные фреймы, указывающие на выполнение предусловий в их отсутствующей части. Однако эти фреймы имеют пониженный приоритет истинности, т.е. могут гаситься явной информацией из дальней-

шего текста. Слот SETTING позволяет проводить обратный, т.е. от следствий к причинам и предусловиям, вывод.

В слоте CONSEQUENCE помещаются процедуры, позволяющие проводить прямой вывод. С их помощью строятся фреймы, соответствующие непосредственным следствиям данного действия. Обработка этих фреймов аналогична той, что производится в слоте SETTING.

Фреймы, созданные процедурами слотов SETTING и CONSEQUENCE, используются в процессе распознавания гиперфреймов, соответствующих гиперсобытиям, при наличии "несвязностей" во входном тексте. Слот GOAL, в котором указываются типичные цели совершения данного действия, используется лишь в случае выяснения целей. Информация, содержащаяся в нём, так же, как и в случае слотов SETTING и CONSEQUENCE, может гаситься эксплицитной информацией из текста.