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PRONOUN RESOLUTION IN SNePS

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I. PROJECT GOAL

The purpose of the current project is to design and implement a pronoun resolution component in SNePS. Due to the time limit and the limit of the current system, I have only concentrated on **personal pronouns** in input sentences in this project, and I have tried not to interact with the pronoun resolution in belief spaces that was already implemented in the grammar.

II. ASSUMPTIONS

In this project, I have made the assumption that in the course of comprehending a discourse, the listener is building a **Discourse Model (DM)**. DM is defined in Sidner (1983), and informally stated here as a mental model constructed by the listener about the input discourse, containing **Discourse Items (DIs)** (concepts) evoked by the discourse processed so far, etc. DIs in a DM all have a certain **Degree of Activatedness** (or foregroundedness), which changes from moment to moment during discourse processing.

I have also made the assumption that the speaker and the listener will usually observe the cooperative principle during the conversation (Clark & Clark 1977), thus on the one hand, the speaker will use reduced linguistic forms (e.g. pronouns) to refer to DIs that he/she assumes to be highly activated in the listener's DM; on the other hand, the listener will tend to find the referent for a reduced linguistic form among DIs with higher degree of activatedness.

III. APPROACH

1. Based on the above assumptions, the pronoun resolution task in this project is approached by modeling the listener's DM (but see section VIII. 8.) Thus, DIs evoked recently enough in previous discourse are kept in a focus list (called **focuslist** below), ordered at any particular point of time according to their degree of activatedness at that point of time.

The degree of activatedness of a DI at a particular point of time in discourse is determined by the following factors in this project:

a. the syntactic and semantic role this DI played in the clause where it was last evoked. (I have incorporated different kinds of information into this factor, and we might want to break it down in the future.) So far I have considered the following syntactic-semantic categories:

- e_subj (subject in existential clauses)
- subj (subject in non-existential clauses)
- d_obj (non-reflexive direct object)
- ind_obj (non-reflexive indirect object)
- by_agent (agent in passive clauses)
- reflex_obj (reflexive object)
- cl (proposition)
- vp (verb phrase) (not used now)
- pos_subj (possessor in subject NP)

pos_d_obj (possessor in d_obj NP)
pos_ind_obj (possessor in ind_obj NP)
pos_by_agent (possessor in by_agent NP)

with the categories more to the top having more effect in raising the activatedness of a DI. Some of the categories (e.g. e_subj and those possessor categories) are not used for the current grammar due to the limitation of the grammar's ability of parsing sentences with these categories. And other categories need to be added (e.g. locatives) in the future. The reason for distinguishing d_obj/ind_obj with reflex_obj is explained in IV. 2.

b. whether this DI is evoked in a main or embedded clause (I think DIs evoked in a main clause should have more activatedness than those evoked in a embedded clause);

c. how long ago this DI was last evoked (cf. Givon's referential distance). The longer it is, the less activated this DI will be.

2. When a pronoun is encountered in the input sentence, an attempt will be made to resolve this pronoun against a DI in a set of possible referents. This set of possible referents are decided (in this project) on the bases of the syntactic role of or rather the case of this pronoun (It should be based on other things as well, see VIII. 10.). The way of deciding the set of possible referents for a certain pronoun encodes the syntactic constraints on pronouns. For our current grammar and for the types of sentences this grammar can handle now, the following is the rule to get grammatically possible referents for a pronoun:

<i>syntactic role of pronoun</i>	<i>possible referents</i>
nominative	DIs in focuslist
reflexive	subject of current clause
accusative	DIs in focuslist - subject of current clause
possessive	DIs in current clause + DIs in focuslist

The semantic features (gender and number) of the pronoun are going to be matched to that of the possible referents until a match is found. If a match is not found, then in the case of reflexive pronouns, the input clause will be considered ungrammatical and thus rejected. In the other cases, the pronoun will simply be left unresolved.

IV. REPRESENTATION FOR DIS EVOKED BY PRONOUNS

Right now the item referred to by a pronoun will have one of the following two different representations in the network:

1. Same representation as the DI that the pronoun is resolved to, i.e. no separate representation is built for the pronoun, if the pronoun is unambiguously resolved to a DI (i.e. it is considered not possible to refer to any other DIs)

2. Separate representation from the DI that the pronoun is resolved to, if

- a. the pronoun is a reflexive pronoun. It is claimed that the listener builds separate intensional objects for reflexive pronouns (see Shapiro 1986).
- b. the pronoun cannot be resolved unambiguously at the moment it is encountered. In these cases a base node will be build for the pronoun in the network, and an equivalence relation will be built between the base node for the pronoun and the node for the DI that the pronoun is resolved to.

V. DATA STRUCTURE OF FOCUSLIST, ETC.

1. Global Variables

This project used several global lisp variables explained below. **In the following, the terms "node" and "DI" are used interchangeably, and so are the terms "weight" and "degree of activatedness".**

a. focuslist

implemented as a lisp list, whose elements are also lists, each representing a **node** or **DI**, of the form (node-name gender number gram-sem-info weight).

values of node_name :

whatever name for that DI in the semantic network, usually mn (n is an integer), unless that DI was mentioned by a pronoun whose referent cannot be found, or if the node represents an intensional individual referred to by a reflexive pronoun. In that case the the node_name is bn (n is an integer)

values of gender : m, f, none

values of number : sing, plur

values of gram(matical)-sem(antic)-info :

e_subj, subj, d_obj, ind_obj, by_agent, reflex_obj, cl, vp, pos_subj, pos_d_obj, pos_ind_obj, pos_by_agent (see VIII. 7. for comments)

value of weight : [1E-10, 9]

DIs in focuslist are distinct, and always in decreasing order of their weight (i.e., a DI with higher degree of activatedness will be ordered before the less activated DIs in focuslist).

b. newnodes

DIs explicitly mentioned in the current input clause, implemented as a lisp list, whose elements are also lists, each representing a DI, of the same form (node-name gender number gram-sem-info weight) as the nodes in focuslist.

c. prons

list of DIs which are evoked by a pronoun in the current clause and which are not resolved immediatedly (thus have to be resolved at the end of a clause). Each element of prons is of form (node_name pronoun_case). Note the the node_names also occur in newnodes.

d. cl_type

clause type, indicating whether the current clause is a main clause or an embedded clause.

2. Constants

weightlist -- indicates how much a certain grammatical-semantic category contributes to the activation of a DI when it is mentioned in that category.

<i>gram-sem category</i>	<i>weight</i>
e_subj	9
subj	8
d_obj	7
ind_obj	6
by_agent	4
reflex_obj	3
cl	2
vp	1
pos_subj	0.098
pos_d_obj	0.097
pos_ind_obj	0.096
pos_by_agent	0.095

emb_cl -- factor used to reduce DIs' weight if they are mentioned in an embedded clause.

onecl_away -- factor used to reduce the weight of DIs in focuslist from clause to clause.

maxcl_focus -- maximum number of clauses such that a DI mentioned that number of clauses ago is still in Cassie's Discourse Model (still in focuslist).

min_weight -- minimum weight an DI can have in focuslist. ($\text{min_weight} = \text{onecl_away}$ to the power of maxcl_focus .) If a DI's weight becomes less than **MIN_WEIGHT**, it will be taken out of focuslist (no longer considered to be an activated item in Cassie's discourse model).

safe_distance -- the difference between the weight of 2 DIs (by the time the second DI was mentioned) which is considered to be big enough such that a pronoun can be resolved to the first DI unambiguously although the 2 DIs have the same semantic features.

VI. ALGORITHM (or changes made to the current grammar)

(The numbers below do not reflect the levels of the grammar)

0. at the beginning of conversation with user, initialize focuslist to nil.

1. in state *s*, set register *clause_type* to "main".

2. in state *rulep* or *svt* (at the beginning of parsing each clause):

2.1. initialize *newnodes* and *prons* to nil.

2.2. if the state is *svt*, set and send down *clause_type* to "embedded".

3. before pushing to *npp* from *clause* or *o* or *pag*, send down the correct case for pronoun according to the state; if the current state is *o*, also send down also the semantic features (gender, number) of the subject.

4. in *npdet* (same level as *npp*), compare the case for pronoun sent down by *clause* or *o*

or *pag*, with the actual case of input pronoun:

- 4.1. if the pronoun is rightfully in reflexive case, and if the semantic features of the pronoun match those of the subjects, build a base node for the reflexive pronoun, and establish equivalence relation between this node and the node for the subject. Lift up the semantic features of the pronoun
 - 4.2. if the pronoun is rightfully of other cases, try to resolve the pronoun:
 - 4.2.1. get possible referents for the pronoun according to the rules specified in (III. 2.)
 - 4.2.2. go through the list of referents:

If the pronoun can be resolved unambiguously to a referent (i.e. there is no other referent in the referent list which has the same semantic features; or the other referents with the same semantic features have a weight different (smaller) enough from that of the candidate referent), then the pronoun is resolved to that referent, no separate node is build for the pronoun, and the node name of the found referent is returned. Otherwise returns nil.
 - 4.3. If the pronoun can be resolved unambiguously, lift up the semantic features of the pronoun; if the pronoun can not be resolved unambiguously, build a base node, lift up the semantic features of the pronoun as well as a register *np_type* indicating that the current NP is an unresolved pronoun.
5. in *clause*, *o* and *pag*, when popping back from *npp*:
 - 5.1. add a new node to *newnodes*, of the form (node_name gender number gram_sem_info weight). Node_name is obtained from the * register, gender and number from registers lifted by *npdet*, gram_sem_info from the current state of the grammar, and weight from the weightlist.
 - 5.2. if the *np_type* register lifted by *npdet* indicates that the NP is a unresolved pronoun, also add a node to *prons*, of the form (node_name pronoun_case).
 6. in *rulep*, after popping back from *clause*:
 - 6.1. add the node representing the proposition to *newnodes*.
 - 6.2. resolve the pronouns left unresolved by *npdet*:
 - 6.2.1. examine each node in *newnodes*:

if it is an unresolved pronoun (in that case its name is in *prons*), get the list of possible referents according to the rules specified in (III. 2.). If a referent is found in the list of referents, build an equivalence relation between the pronoun node and the referent node, and replace the name of the pronoun node in *newnodes* by the name of the referent node. If no referent is found, output message "no referent is found for the pronoun", and do nothing to *newnodes*.
 - 6.2.2. do pragmatic checking on the interpretation of pronouns (not implemented, see VIII. 9, 13)
 - 6.3. update focuslist:
 - 6.3.1. reevaluate the weight of nodes in *newnodes*: if the current clause is an embedded one, reduce the weight of all nodes by the factor *emb_cl*.
 - 6.3.2. if the current clause is a main clause, delete the node representing the last proposition in focuslist (so that it won't be able to be referred to as "it" later).
 - 6.3.3. append *newnodes* and focuslist to make a new focuslist.
 - 6.3.4. reorder the nodes in the new focuslist in decreasing order of their

weight.

6.3.5. if a node occurs more than once in focuslist (e.i. a DI is rementioned in current clause), delete the node with the same name but with smaller weight.

6.3.6. reduce the weight of all nodes in focuslist by the factor of `onecl_away`.

7. in *svt*, do the same thing as in 6, except 6.1. (*svt* is to push to a sentential object, so the node for the proposition conveyed by the main clause is not available yet).

VII. A FEW NOTES

1. My use of the focuslist and the decision about what goes into focuslist are different from Sidner's approach. Using Sidner's approach, DIs that are evoked in a clause would remain in focuslist for only one clause period, unless they are referred to by a pronoun in the immediate following clause or in previous discourse (i.e. they have achieved once the status of what she called "the current discourse focus"). Thus she wouldn't be able to handle cases like "John married Lucy. But he is a jerk. He doesn't care about her at all." During the process of the third clause, Lucy is not in the "alternative focuslist" (see Sidner 1983) since she is not evoked in the previous clause (i.e. the second clause); she is not "the current discourse focus" (John is), and she is not in "the old focus stack" because she has never achieved the "current discourse focus" status -- so the pronoun "she" would have no referent to resolve to.

2. The presence/absence of competitor (i.e. when we try to find a co-referent DI for a pronoun, whether there are more than one DIs in focuslist with the same matching semantic features and similar weight) was originally thought as to affect the activatedness of a DI. However, in this project, its effect is on the representation for a pronoun, i.e. if there is a competitor, the pronoun will have a separate node and have an equivalence relation between this node and the node it resolves to, whereas if there is no competitor present, the pronoun will not have a separate node in the network.

3. As it is implemented now, the program will handle nouns that can have more than one gender as shown by the following example:

Bill saw a professor.

She(He) is nice.

At the end of the first clause, the node for professor in focuslist will have both male and female as the possible gender; at the end of second clause however, since the pronoun "she" is resolved to the professor, the node representing the professor in focuslist will only have female (male) as gender according to the gender of the pronoun. Thus in the following discourse, if this particular professor is being referred to by a pronoun again, only "she" ("he") can be used.

4. Reflexive pronouns, unlike other pronouns, will have their "own" nodes in focuslist (different node from the nodes of their antecedent), so that later on it can be referred to as a separate intensional object.

5. Nodes representing generic concepts in focuslist will have the number feature of the surface form of the generic terms as they occurred in the input clause. Because it is more likely for people to say "A dog is an animal. It ..." or "Dogs are animals. They ...". It is less like for them to say "A dog is an animal. They ...", and impossible for them to say "Dogs are animals. It ..." (with "it" referring to dogs.)

VIII. PROBLEMS AND LIMITATIONS OF THIS PROJECT

1. The current project is not handling possessive pronouns only because the case frame for possessives was not available at the time I designed the project. However, some thought has been given to as how to find the possible referents for a possessive pronoun if there is one, so it should not be difficult to handle possessive pronouns once the decision is made in the grammar as how to handle possessives in general.

2. The current project does not handle reflexives in input questions (e.g. "Who likes himself?") because I did not work with the generation part of the grammar, and this kind of questions involve, in the generation part of the grammar, finding all the nodes for those individuals which have the same gender and number as the reflexive pronoun, and which are the agent of action "like", and which have an equivalence relation to a base node which is the object of the action "like".

3. Also since I did not work on the generation part of the grammar, I did not keep track of the DIs mentioned by Cassie in her own output sentences. So if we have the following piece of conversation with Cassie:

User: Who dislikes Lucy?

Cassie: John dislikes Lucy.

User: He is stupid.

Cassie will not be able to find the referent for John (unless John already has the highest weight among male individuals in focuslist).

4. Another problem due to the fact that the generation grammar has not been dealt with in this project: with the following input

John likes Lucy.

It is wonderful.

The grammar will build the correct network for the second sentence, treating the proposition about John's loving Lucy as an object, and "wonderful" as a property of that object. But the sentence generated as the output response is not grammatical.

5. Because I did not work on proper interfacing with the pronouns in belief space (I merely avoided it), with the following input:

Bill is sweet.

John believes that he is rich.

Cassie can only interpret "he" as referring to John but not to Bill.

6. All the constants used in this project need to be checked against empirical evidence.
7. We have coded in the representation of DIs in focuslist the grammatical-semantic information. This is useful for processing parallel structures like "John entered the room and turned on the light", where the listener obviously has to remember the syntactic role of John in the first clause in order to fill in the subject gap in the second clause. But this kind of information should not be present for DIs mentioned a while ago. So the gram-sem-info for DIs with low weight in focuslist is obsolete. Maybe we want to change the implementation for DIs in focuslist to not include this gram-sem-info, and store this info for DIs in the just processed sentence somewhere else.
8. The focuslist is only part of the listener's discourse model. It records only the DIs and their degree of activatedness, but not much of the "episodic" relationship among them. That information is actually in the semantic network, which is a permanent structure. So the current project cannot be viewed as doing a complete modeling of the listener's discourse model.
9. Because the current system does not have enough power of making pragmatic reasoning which is needed in pronoun resolution, the problems like the one below are left unsolved:

John hurt Bill.
He cried.

-- the current pronoun resolution algorithm assigns more weight to the DI playing the role of subject than the DI playing the role of direct object, so "he" above will be resolved to John instead of Bill, which is wrong. Assigning weight the other way around would solve this problem but would create other problems. It seems that in English, the weight of subjects and the weight for objects are not clearly distinguishable, and in a lot of cases we have to depend on pragmatic reasoning to get the right referent. In our project, the weight assigned to subject and that assigned to object are very close, so it will always require pragmatic reasoning before the final decision about the referent of the pronoun if both the subject and the object of the same clause are semantically plausible referents for a pronoun (room is left in this project for doing pragmatic reasoning).

10. When the parsing grammar becomes more sophisticated, we should not only add to the new part of the grammar to handle pronoun cases there (e.g. in prepositional phrases, different types of embedded clauses, etc.), but also try to consider more factors which would be available then in pronoun resolution. For instance, in the following example, cues provided by the verbs ("criticize" vs. "apologize") and the conjunction ("because") are crucial in determining the referent of the pronoun:

Bill criticized John because he is late. (he = John)
Bill apologized to John because he is late. (he = Bill)

Of course the pragmatic knowledge has to be present here.

11. When the system is more sophisticated, we should also consider the DIs "implicitly evoked" in a clause. Thus when the word "concert" is mentioned, the things that are closely related to a concert should acquire certain degree of activatedness in discourse model. This is useful to handle cases like:

We went to a concert last night. They played Beethoven No.9.
(they = the musicians who are related to concert)

This involves manipulating focuslist, which is not hard, we can just add to the focuslist the DIs that are implicitly evoked, assign them a low weight, and check them when the referent for a pronoun cannot be found among the recently explicitly evoked DIs. However, which and how many DIs should be considered implicitly evoked by a certain linguistic form is very hard to decide.

12. A good discourse model should be able to help finding in the network the right node for definite noun phrases and even for proper names. If we have the above mentioned ability of manipulating implicitly evoked DIs, and if the input sentence contains the word "Bill", Cassie would be able to pick the right individual for "Bill" even if there is more than one individuals named Bill in her belief space: if the Snerg is a high weighted node in focuslist, then the node representing Bill (Rapaport) will, as an implicitly evoked DI, be considered as the person the word "Bill" is referring to (not the Bills in any other Groups or Departments). Similarly, if John's house is mentioned, the things that are semantically closely related to that house should acquired certain degree of activatedness in discourse model. Thus when "the door" is mentioned in the immediate following discourse, it will be understood as the door of Johns house instead of some other doors.

13. So far we have been only concerned with what Grosz and Sidner (1986) called attentional structure of discourse, not at all about the intentional structure of discourse which should be playing an important role in **guiding** the way of finding the right referent for a pronoun. In fact, making pragmatic checking after we resolve (temporarily) the pronouns for a clause does not seem to be what people do. People's pragmatic knowledge and their expectations developed from the previous discourse will lead them in finding the right referent while processing a clause in the following discourse, instead of checking at the end of a clause, after the referent for the pronoun is found, the correctness of the the pronoun resolution. For details see Grosz and Sidner (1986).

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