A dependency-based approach to anaphora annotation

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Abstract. The paper describes a novel approach to the resolution of pronominal anaphora, where a hierarchy of linguist-written Constraint Grammar rules are used to add relational tags to anaphoric tokens in running text. The system exploits function-marked dependency trees provided by a CG parser, and performs semantic tagging of pronouns as an intermediate step, based on verbo-nominal selection restrictions harvested from a collocation corpus. News text evaluation results are provided and compared across different anaphora types.

Keywords: Anaphora, rule-based annotation, dependency grammar, NLP, Constraint Grammar, semantical tagging of pronouns

1 Introduction

Anaphora are notoriously difficult to annotate in running text. Like dependencies or tree structures, anaphora fall into the realm of structural, rather than morphosyntactic annotation. Though subject to morphological restraints such as number and gender agreement between referent and antecedent, anaphora are hard to resolve without both a structural analysis and a semantic knowledge base. In an effort to capture relational tendencies rather than rules, most automatic systems for anaphora resolution use so-called salience weights, as suggested by Lappin & Leass (1994). which allow the computation of co-reference likelihood from local feature sets. Lappin & Leass draw the necessary annotational information from a post-edited Slot Grammar parser for English (McCord 1989), but the co-reference assignment is not in itself rule-driven. Similarly, Ferrández, Palomar & Moreno (1998) use a Spanish tagger and their own SUG parser (Slot Unification Grammar) to provide syntactic information. The two systems report a pronominal anaphor recall of 86% and 83% for English and Spanish, respectively. In spite of this impressive performance, and though we agree in principle on the choice of relevant features and functions, we believe that local and structural salience criteria, as well as semantic features, should be exploited explicitly in a rule-based fashion, optimally using syntactic dependency links and to-be-assigned anaphoric relations in parallel, within one and the same formalism.

We prefer dependency links to the otherwise information-equivalent constituent tree structures, because the former – at a methodological level - provide a more direct linking of tokens, and are thus structurally more akin to the phenomenon of anaphora as such. Also, token-to-token links are easier to follow across sentence boundaries than information encoded in constituent structure. The dependency-based anaphora resolution method described in this paper is an extension of the Constraint Grammar (CG) formalism (Karlsson et al 1995), implemented with a modified version of GrammarSoft's open source CG3 compiler. The anaphora module builds on automatically analyzed output from the PALAVRAS parser (Bick 2000), which provides both morphosyntactic tags and full dependency trees. Like PALAVRAS itself, our anaphor module draws on linguist-written rules, albeit with a context window spanning 5 sentences rather than one, as would be the norm for ordinary syntactic tree structures.

One of the most quoted anaphora resolution systems, and one that is fully automatic, with no need of input correction, is Mitkov's MARS system (Mitkov et al. 2002), reported to recover between 55% and 87% (upper bound) of pronominal co-referents, depending on text type. MARS builds on Mitkov's original semiautomatic method (Mitkov 1998). which computes antecedent likelihoods using morphosyntactic constraints such as gender, number and definiteness, but also the semantic feature of animacy and syntactic scope constraints inspired by Lappin & Leass (1994), ruling out contained, containing and co-argument antecedents. The 2002 version adds the instruments of pronoun-to-pronoun references, function overlap and antecedent frequency. Though the MARS system is described as "knowledge-poor", the newer version does employ a Constraint Grammar-related dependency parser (FDG, Tapanainen & Järvinen, 1997) to instantiate these different criteria on antecedent candidates. Thus, the difference between MARS and our own CG approach does not so much reside in the criteria used, or in the depth of input analysis, but in the way anaphoric relations are *assigned:* Our grammar does not only exploit dependency edge labels (syntactic functions), but follows dependencies with explicit rules and – most important – generalizes the dependency formalism as a special type of relation, adding anaphoric relations of different kinds with the same kind of rule apparatus we employ for dependency and ordinary syntactic Constraint Grammar. Mitkov's principles have been adapted for Brazilian Portuguese in the RAPM system (Chaves & Rino 2008), with a reported success rate of 67% for 3rd person pronouns on raw text. Like MARS, RAPM uses input from a syntactic parser, but the criteria used for scoring are not identical. Thus, RAPM emphasizes gender and number of named entities and stresses impeding factors (rather than only restrictive and preferential), while not making use of the noun animacy feature.

2 Anaphora types

The concept of anaphor covers a wide range of phenomena, but hinges on the presence of co-reference between one referent and another, the antecedent. In the prototypical direct anaphor, the antecedent will be a introduced into the discourse as a definite noun phrase with a clause level function, and then re-referenced in a thema-rhema fashion.. In cataphoric constructions, a place-holder coreferent may also precede a related full-referent noun phrase. Finally, the antecedent may lack a textual manifestation altogether, as in deictic constructions or imperative clause possessives. The prototypical anaphor-relation is a direct individual relation between a pronoun and an np, but recent research has also focused on indirect and assossiative anaphor, where Vieira et al. (2007) report 30% correct resolution for Portuguese, zero-anaphora or abstract pronominal anaphora (Navaretta & Olsen 2008).

In our present work, we have focused on pronominal anaphora rather than np-co-reference, mostly because the "information deficit" that machine analysis faces in pronouns is worse than that in np's, and we had applications in mind, like machine translation (MT), that depend on anaphora resolution at a very basic, even inflexional level. For instance, Romance possessives agree in number and gender with the possessee, while Germanic possessives agree with the possessor, and it is thus necessary to resolve the possessor-antecedent of Portuguese words like "seus" or "sua" in order to arrive at the correct English translation as "her", "his", "their" etc. Similarly, the gender of personal pronouns will often be grammatical rather than biological, and depend on the gender of the antecedent in the *target* language. And often a Romance language like Portuguese will lack a subject pronoun altogether, relying on verbal inflexion alone. Peral & Ferrández (2002) addressed this issue for the Spanish-English language pair, reporting 89% detection and 81% resolution for Spanish zero—anaphora, and 80% / 82% correctly resolved 3rd person personal pronouns for the two languages, respectively.

Pronominal classes differ with regard to scope and syntactic reach, suggesting different resolution strategies, and resulting in considerable differences in disambiguation rules. All in all, we distinguish between the following types:

1. **Relative pronouns:** the most common Portuguese relative, 'que' lacks the number- and gender-traces necessary for translation into, e.g., German. Also, semantic subject or object constraints for the relative clause's verb may depend on full resolution of the que-antecedent. Que-anaphora typically have a short syntactic reach and good annotator performance may be expected.
2. **Reflexive pronouns:** With the exception of impersonal use, 'se' almost always refers to an entity in the same clause, though the latter may be without a surface manifestation, or itself a pronoun to be resolved[1].
3. **Possessive pronouns:** Possessive anaphora are less local than relatives and reflexives. They may have an antecedent in the same clause (usually, its subject), but may also point to a higher level clause or another sentence.
4. **Personal pronouns**, both strong forms and clitics, have the potentially longest anaphoric reach of all pronoun types, with the exception of zero-anaphora, and the antecedent will typically occur in another clause (matrix clause or coordinated clause), or in the preceding sentence. A special subclass are 'o' abstract anaphora referring to actions or events.
5. **Demonstrative pronouns**, covering certain cases of non-prenominal usage, i.e. where the pronoun fills an argument slot, have a fairly short range, either

1 Chaining of anaphora-links is a separate issue for our grammar to be discussed in detail later. Locally, one anaphoric pronoun may serve as a "mediator" for a long-distance anaphoric relation to a full antecedent

as apposition or anaphoric subject, but since relations are often abstract or even vague, this class was only experimentally treated here.

6. **Adverbial pronouns:** Used as relatives, 'onde', 'quando' and 'como' can be treated by the same rules as type-1 relatives. Among the deictics, 'lá' is special in that there actually may be a textually-manifest, local or temporal, antecedent[2].

In our actual annotation scheme, co-reference is marked as token based ID-reference tags, in the same fashion dependency relations are marked in the PALAVRAS input parses we use. Thus, "ID:14 R:poss:5" means that token 14 (ID:14) has an anaphoric relation (R:) of type 'possessive' (poss) to token number 5. The four non-adverbial classes have their own type marker ('R:rel', R:refl', 'R:poss', 'R:dem' and the default 'R:ref'), while adverbial pronouns may be either 'rel' (relative) or 'ref' (default). External "antecedents", e.g. 2nd person, are attached to the null-token 0.

So far, we only tag one non-pronominal type of co-reference between surface tokens – predicatives ("R:pred"), i.e. the nexus (small clause) relation between subject complement and subject, or object complement and object. This type of relation-marker is a kind of instantiation of pre-existing syntactic function tags (@SC and @OC) and also serves to improve on syntactic structure - as a secondary dependency link, since the primary link will attach both functions only to the main verb, not to the semantic co-referent, ignoring the small clause relation ('subject IS subject complement' and 'object IS object complement').

As a pro-drop language, Portuguese allows for non-expressed subjects, which can be regarded as a kind of zero-form pronouns, incorporated into the finite verb, and agreement-coded in its person-number inflexion. In these cases, we introduce a link between the verb and its extra-clausal surface subject antecedent. The link is called r:subj from subject to verb, and r:e-subj (ellipsed subject) in the direction from verb to subject. The resulting anaphora links are the potentially longest ones treated here, since the surface antecedent may lie several sentences back, with several sentence-root verbs sharing the same subject referent.

3 The grammar

Our anaphora grammar is implemented as a separate CG module to be run on CG-compatible, syntactically analyzed input with dependency links. The existing PALVRAS input grammar can thus be regarded as a black box, and could in principle be replaced with another live system – or a treebank. The current grammar has about 200 rules, divided into a preparatory section (1/3) and the anaphora section itself (2/3). The main function of the preparatory section is to add information (tags) central to anaphora resolution, marking for instance:

- defintiteness of noun phrases (£np-def and £np-idf)

2 Since they behave similarly across languages, adverbial pronouns are not a big problem in MT, though identifying real-world referents may be of interest for other NLP applications.

- top-subjects (£top-subj, the subject immediately governed by the root-verb)
- animacy traces, more precisely ±HUM tags (£hum/£non-hum), for pronouns

Since PALAVRAS provides semantic prototype tags for nouns, as well as sophisticated named-entity annotation, animacy information is readily available for nouns, while animacy information for personal, possessive and reflexive pronouns has to be recovered through a combination of verbal selection restrictions and dependency links. PALAVRAS provides some indirect clues, such as certain valency classes, e.g. <vq> for que-governing cognitive verbs, and a not-fully implemented <vH> marking for human-subject potentiality. In order to include object and prepositional complements, and to achieve broad lexical coverage[3], we used dependency collocations from the DeepDict lexicon (Bick 2009) to extract *Framenet*-like selection restriction information, generalizing the semantic prototype class of collocates into a few major classes that were then used to create verbal selection tags, for instance <fACC/food:30>, meaning that a given verb has a 30% probability of a direct object (ACC) of the food class. These tags allow us to classify verbs, and to add animacy traces to their pronoun complements. In the rule example below, a +human-threshold of minimum 70% (H>70) triggers a £hum tag for the pronoun dependent (PERS @P<) of the preposition 'com' (PRP-COM) in a prepositional object (@PIV), as in "falava com ela.":

(1) ADD (£hum) TARGET PERS + @P<
    (p @PIV LINK 0 PRP-COM LINK p (<fPRP-com/H>70>)) ;

Other functions of the preparatory section are to add additional clause boundary markers, and to restructure and correct certain dependencies, based on the added semantic knowledge and unification principles, the important topics being relative clause attachment and the coordination of clauses. Since we use gender/number unification, a few rules are also dedicated to contextually resolving morphological underspecifications, such as M/F (male/female) for proper nouns, and 1st /3rd person singular for verbs in the subjunctive.

The rules of the main section are ordered so that more specific contexts for a given anaphoric relation override more general ones. For instance, semantically restricted rules generally precede definiteness restricted rules and syntactically, subject-searching rules and top-level rules have hight priority. Distance weighting is implicit by scanning antecedent candidates right to left until one fulfills all conditions in the relevant rule. Currently, the maximum scan scope includes up to 2 sentences left of the target sentence (though this is a variable that could easily be changed). Relations longer than this limit can usually be recovered by relation propagation, using antecedents that are themselves pronouns, or subject-incorporating verbs, as stepping stones. Rule 2a sets an anaphoric relation (ref) for a 3rd person personal pronoun (PERS3) in the nominative (NOM) if the grammar has already marked it as human (£hum) and if is a direct dependent (p) of a declarative (STAtement) top verb. The TO

3 Statistical safety thresholds were used, so rarer verbs are not necessarily covered from DeepDict. However, the grammar formalism allows the grammarian to enlarge the lexical set for any tag by defining corresponding sets manually in the grammar.

field searches for the antecedent left of the sentence boundary (*-1 >>> LINK **1W) and defines it to be either a definite noun phrase head, a top-level subject or a subject-less top-level verb, whatever is found closest to the target and fulfills the conditions of gender-number-agreement ($$GN) and human animacy[4].

(2a) SETRELATION (ref) TARGET @SUBJ + $$GN
(0 PERS3 + NOM) (0 (£hum)) (p @FS-STA)
TO (*-1 >>> LINK **-1W DEF-HEAD + $$GN OR TOP-SUBJ + $$GN
OR (<nosubj> @FS-STA) LINK 0 N-HUM-PERSON OR V-HUM) ;

A relatively specific rule like 2a will precede a less specific one, like 2b, which targets the same type of pronoun in subordinated clauses. 2b looks for the nearest GN-unifying subject left of the targets own clause (<clb> = clause boundary), with the added condition that the antecedent candidate (A) must not govern the target pronoun (_TARGET_) as a child/grandchild dependent (*c) .

(2b) SETRELATION (ref) TARGET @SUBJ + $$GN (0 PERS3 + NOM)
TO (*-1 <clb> LINK **-1WA @SUBJ + $$GN LINK NOT *c _TARGET_)

Rule 2c covers elliptic-subject-anaphora and adds two relation tags, one on verb (e-subj), one on the subject antecedent (subj). The rule links a top-level verb with the closest top-level subject – if it is a +HUM noun phrase (N-HUM) of the right number.

(2c) SETRELATIONS (e-subj) (subj) TARGET IND + $$NUMBER
(NONE c @SUBJ&) (0 (<fmc>)) (0 V-HUM)
TO (*-1W TOP-SUBJ + $$NUMBER LINK 0 N-HUM) ;

Rules 2d-e, finally, show how anaphora links are propagated from a pronoun antecedent to that pronoun's own antecedent (2d), or via a verbal "stepping-stone" to an elliptic-subject antecedent (2e)[5]:

(2d) SETRELATION (ref) TARGET PRON TO (r:ref PRON LINK r:* (*)) ;
(2e) SETRELATION (pred) TARGET PRON TO (r:pred V LINK r:e-subj (*)) ;

A special challenge were external referents, such as impersonal "subject" use of "se" or addressee-referring 3rd person pronouns in interviews/dialogue ("seu"), where the antecedent position "0" was used, as well as abstract anaphora with clausal antecedents, where the antecedent marker was tagged on verbs. Since the system strives to handle both European and Brazilian Portuguese, post-nominal Brazilian 'dele/dela' pronouns are also classified and resolved as possessive anaphora.

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4 The rule follows standard CG3 shorthand for positions and LINKing, with 0 meaning "same token" and '-' meaning 'left'. Ordinarily a global search (*) would stop if any condition fails, but **W will continue to search the whole window span until all conditions are found true.

5 R:* means 'any relation type', and (*) means "any token", so the propagation rules have no added conditons on the final, real antecedent – they just follow the stepping-stone link.

4 Evaluation

Annotation systems with hand-written rules tend to have a slow learning curve, and while performance evaluation can aid development by identifying problematic areas, it can be difficult to judge when the method's potential is sufficiently realized for a final evaluation. Thus, on the one hand, our anaphora system is ready for evaluation because it covers a wide range of anaphora types and is robust enough for raw input, on the other hand we have identified many problems that we think our method can solve in principle, but which we haven't had the time to address yet.

We used internet text, news and Wikipedia articles for development, and three text chunks from VEJA (~ 3,000 tokens) for the final evaluation, with a fourth 3000+ token sample, where only personal pronouns were evaluated. The few cataphoric cases were possessives and counted in that pronoun class. Propagating links were followed to the final antecedent.

Since pronouns and head verbs are robustly PoS tagged, and hence easily identifiable for our relation mapping rules, false positives are rare, meaning that performance can be reliably measured by recall alone, which was roughly identical to precision and F-score. Only for nominal predications and np-coreference, will precision also depend on errors in syntactic function labels. Of these, only the former were included, since there were few clear cases of the latter, few rules, and an overweight of simple appositions.

n=3064	Text 1 Rec. %	Text 2 Rec.%	Text 3 Rec. (/ Pr.) %	Text 4 Rec.	All Rec. (/ Pr.) %
Personal pronouns (n=38)	100	(n=0)	85.7	77,7	83.7
Possessives[6] (n=34)	100	58.3	89.4	-	79.4
Relative pronouns[7] (n=35)	90	81.8	100	-	91.4
Pronoun *se* (n=22)	77.7	66.6	85.7	-	77.2
Zero-subjects (n=74)	54.5.	68.4	82.3	-	70.6
Predicatives (n=86)	77.4	70	88.5 / 81.5	-	80.2 / 77.5

Two words of caution are in order: First, a “soft” evaluation method was used (output inspection). Second, the relatively low incidence of relevant anaphora types (partially compensated by using extra data for personal pronouns), and the considerable cross-text variance in performance limits the statistical representativeness of our preliminary results, which also seem to be quite text type dependent. For example, the first text was an interview, with 1st and 2nd person forms, and syntactically “false”

6 In this category we counted both ordinary “seu” possessives, and Brazilian postnominal “dele”, “dela” etc.

7 Adverbial relatives, i.e. “onde”, “quando”, “como” etc. with a relative antecedent, were included in this category

subjects from pre-added interviewer/-ee names, interfering with subject-involving anaphora. Still, results are encouraging, and in the range of pronoun resolution figures quoted for the English (MARS) and Portuguese (RAPM) systems cited above.

A closer look at individual pronoun types reveals that relative pronouns were easiest to resolve, while zero-subject-anaphora were the most difficult, the reason likely being the short links of the former and the long ones of the latter, which could only partly be remediated by following anaphora links from one verb to the next.

5. Conclusion

We have shown that a Constraint Grammar-based method for anaphora resolution can be very effective not only in exploiting, in a malleable and precise way, various types of syntactic and semantic information from a parser, but also in adding and adapting such information to better suit the needs of an anaphora annotator. Given the fact that rules can be molded to cater for a wide variety of structures and text types, and that existing semantic information could be used much more specifically, we believe that there is substantial room for grammar improvement. Computed as an average of all types, accuracy in our pilot evaluation was an encouraging 81.3% for non-demonstrative pronominal anaphora (86.8 when counting only surface pronouns), but future work should include a thorough evaluation against a larger, human-annotated gold corpus.

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Appendix: Annotation sample

The following raw annotation example has the following fields (which could easily be converted into an xml format):

- Word form
- [base form] (lemma)
- <secondary and semantic tags>
- POS and MORPHOLOGY/INFLEXION
- @SYNTACTIC FUNCTION
- #dependency from->to (sentence-relative IDs)

The preparatory tags added by the anaphora grammar are in green, either £-prefixed, or inserted among the secondary <> tags. Running (non-relative) IDs are in blue, while the primary anaphora tags are marked R:type, in red, and ID-linked. The text was de-tagged and contracted in a few places, and som tag types were removed, to increase legibility.

Fabinho [Fabinho] <hum> PROP M S @SUBJ> £top-subj #6->12 **ID:369** **R:subj:402**
$, #7->0
estudante [estudante] <Hprof> N M/F S @N<PRED £np-idf #8->6 **ID:371** **R:pred:369**
de [de] <np-close> PRP @N< #9->8
psicologia [psicologia] <domain> N F S @P< £np-idf #10->9
$, #11->0
leu [ler] <predco> <cjt-head> <fmc> <vH> <mv> <+ACC-non-hum> V PS S 3S IND VFIN @FS-STA #12->0
Freud [Freud] <hum> PROP M S @<ACC #13->12
e [e] <co-fmc> <co-fin> KC @CO #14->12
levou [levar] <nosubj> <cjt> <fmc> <mv> <vN> <+ACC-non-hum> V PS S 3S IND VFIN @FS-STA #15->12 **ID:378** **R:e-subj:369**
suas [seu] <poss 3S> <si> DET F P @>N #16->17 **ID:379** **R:poss:369**
lições [lição] <per> <act-d> N F P @<ACC £np-def #17->15

para [para] PRP @<ADVL #18->15
a [o] <artd> DET F S @>N #19->20
cama [cama] <furn> N F S @P< £np-def #20->18
$. #21->0
</s>

Aos 29 anos, ...
raspou [raspar] <nosubj> <cjt-head> <fmc> <vH> <mv> V PS S 3S IND VFIN @FS-STA #6->0 **ID:390** **R:e-subj:369**
os pêlos do corpo, fingindo ter 13, e
abriu [abrir] <nosubj> <cjt> <fmc> <vH> <mv> <+ACC-non-hum> V PS S 3S IND VFIN @FS-STA #18->6 **ID:402** **R:e-subj:369**
a boca, implorando por colo.
</s>

Suas [seu] <poss 3S> DET F P @>N £hum £CLB #1->2 **ID:409** **R:poss:369**
babás [babá] <Hprof> N F P @SUBJ> £top-subj £np-def £top-subj #2->3 **ID:410** **R:subj:414**
acreditaram [acreditar] <predco> <cjt-head> <fmc> <vH> <mv> <+ACC-hum> V PS/MQP P 3P IND VFIN @FS-STA #3->0
e [e] <co-fmc> <co-fin> KC @CO #4->3
o [ele] PERS M S 3S ACC @ACC> £hum #5->6 **ID:413** **R:ref:369**
consolaram [consolar] <nosubj> <cjt> <fmc> <vH> <mv> V PS/MQP P 3P IND VFIN @FS-STA #6->3 **ID:414** **R:e-subj:410**
$. #7->0
</s>

Fabinho [Fabinho] <hum> PROP M S @SUBJ> £top-subj #1->2 **ID:416** **R:subj:424**
acreditou [acreditar] <predco> <cjt-head> <fmc> <vH> <mv> <+ACC-hum> V PS S 3S IND VFIN @FS-STA #2->0
ser [ser] <vK> <mv> <vN> V INF @ICL-<ACC #3->2
adulto [adulto] <jh> ADJ M S @<SC #4->3 **ID:419** **R:pred:416**
e [e] <co-fmc> <co-fin> KC @CO #5->2
consolou- [consolar] <nosubj> <cjt> <hyfen> <fmc> <vH> <mv> V PS S 3S IND VFIN @FS-STA #6->2 ID:421 R:e-subj:416
as [elas] PERS F P 3P ACC @<ACC £hum #7->6 **ID:422** **R:ref:410**
$. #8->0
</s>