Abstract

We describe a recently developed corpus annotation scheme for evaluating parsers that avoids shortcomings of current methods. The scheme encodes grammatical relations between heads and dependents, and has been used to mark up a new public-domain corpus of naturally occurring English text. We show how the corpus can be used to evaluate the accuracy of a robust parser, and relate the corpus to extant resources.

1 Introduction

The evaluation of individual language-processing components forming part of larger-scale natural language processing (NLP) application systems has recently emerged as an important area of research (see e.g. Rubio, 1998; Gaizauskas, 1998). A syntactic parser is often a component of an NLP system; a reliable technique for comparing and assessing the relative strengths and weaknesses of different parsers (or indeed of different versions of the same parser during development) is therefore a necessity.

Current methods for evaluating the accuracy of syntactic parsers are based on measuring the degree to which parser output replicates the analyses assigned to sentences in a manually annotated test corpus. Exact match between the parser output and the corpus is typically not required in order to allow different parsers utilising different grammatical frameworks to be compared. These methods are fully objective since the standards to be met and criteria for testing whether they have been met are set in advance.

The evaluation technique that is currently the most widely-used was proposed by the Grammar Evaluation Interest Group (Harrison et al., 1991; see also Grishman, Macleod & Sterling, 1992), and is often known as ‘parseval’. The method compares phrase-structure bracketings produced by the parser with bracketings in the annotated corpus, or ‘treebank’, and computes the number of bracketing matches $M$ with respect to the number of bracketings $P$ returned by the parser (expressed as precision $M/P$) and with respect to the number $C$ in the corpus (expressed as recall $M/C$), and the mean number of ‘crossing’ brackets per sentence where a bracketed sequence from the parser overlaps with one from the treebank and neither is properly contained in the other.

Advantages of parseval are that a relatively undetailed (only bracketed), treebank annotation is required, some level of cross framework/system comparison is achieved, and the measure is moderately fine-grained and robust to annotation errors. However, a number of disadvantages of parseval have been documented recently. In particular, Carpenter & Manning (1997) observe that sentences in the Penn Treebank (PTB; Marcus, Santorini & Marcinkiewicz, 1993) contain relatively few brackets, so analyses are quite ‘flat’. (The same goes for the other treebank of English in general use, SUSANNE; Sampson, 1995). Thus crossing bracket scores are likely to be small, however good or bad the parser is. Carpenter & Manning also point out that with the adjunction structure the PTB gives to post noun-head modifiers (NP (NP the man) (PP with (NP a telescope))), there are zero crossings in cases where the VP attachment is incorrectly returned, and vice-versa. Conversely, Lin (1995) demonstrates that the crossing brackets measure can in some cases penalise mis-attachments more than once; Lin (1996) argues that a high score for phrase boundary correctness does not guarantee that a reasonable semantic reading can be produced. Conversely, many phrase...
boundary disagreements stem from systematic differences between parsers/grammars and corpus annotation schemes that are well-justified within the context of their own theories. PARSEVAL does attempt to circumvent this problem by the removal from consideration of bracketing information in constructions for which agreement between analysis schemes in practice is low: i.e. negation, auxiliaries, punctuation, traces, and the use of unary branching structures.

However, in general there are still major problems with compatibility between the annotations in treebanks and analyses returned by parsing systems using manually-developed generative grammars (as opposed to grammars acquired directly from the treebanks themselves). The treebanks have been constructed with reference to sets of informal guidelines indicating the type of structures to be assigned. In the absence of a formal grammar controlling or verifying the manual annotations, the number of different structural configurations tends to grow without check. For example, the PTB implicitly contains more than 10000 distinct context-free productions, the majority occurring only once (Charniak, 1996). This makes it very difficult to accurately map the structures assigned by an independently-developed grammar/parser onto the structures that appear (or should appear) in the treebank. A further problem is that the PARSEVAL bracket precision measure penalises parsers that return more structure than the treebank annotation, even if it is correct (Srinivas, Doran & Kulick, 1995). To be able to use the treebank and report meaningful PARSEVAL precision scores such parsers must necessarily ‘dumb down’ their output and attempt to map it onto (exactly) the distinctions made in the treebank. This mapping is also very difficult to specify accurately. PARSEVAL evaluation is thus objective, but the results are not reliable.

In addition, since PARSEVAL is based on measuring similarity between phrase-structure trees, it cannot be applied to grammars which produce dependency-style analyses, or to ‘lexical’ parsing frameworks such as finite-state constraint parsers which assign syntactic functional labels to words rather than producing hierarchical structure.

To overcome the PARSEVAL grammar/treebank mismatch problems outlined above, Lin (1995) proposes evaluation based on dependency structure, in which phrase structure analyses from parser and treebank are both automatically converted into sets of dependency relationships. Each such relationship consists of a modifier, a modifiee, and optionally a label which gives the type of the relationship. Atwell (1996), though, argues that transforming standard constituency-based analyses into a dependency-based representation would lose certain kinds of grammatical information that might be important for subsequent processing, such as ‘logical’ information (e.g. location of traces, or moved constituents). Srinivas, Doran, Hockey & Joshi (1996) describe a related technique which could also be applied to partial (incomplete) parses, in which hierarchical phrasal constituents are flattened into chunks and the relationships between them are indicated by dependency links. Recall and precision are defined over dependency links.

The TSNLP (Lehmann et al., 1996) project test suites (in English, French and German) contain dependency-based annotations for some sentences; this allows for “generalizations over potentially controversial phrase structure configurations” and also mapping onto a specific constituent structure. No specific annotation standards or evaluation measures are proposed, though.

2 Grammatical Relation Annotation

In the previous section we argued that constituency-based evaluation for parser evaluation has serious shortcomings. In this section we outline a recently-proposed annotation scheme based on a dependency-style analysis, and compare it to other related schemes. In the next section we describe a 10K-word test corpus that uses this scheme, and also how it may be used to evaluate a robust parser.

Carroll, Briscoe & Sanfilippo (1998) describe an annotation scheme in which each sentence in the corpus is marked up with a set of grammatical relations (GRs), specifying the syntactic dependency which holds between each head and its dependent(s). The annotation scheme is application-independent, and takes into account language phenomena in English, Italian, French and German. The scheme is based on EAGLES lexicon/syntax working group standards (Sanfilippo et al., 1996), but refined within the EU 4th Framework SPARKLE project (see <http://www.ilc.pi.cnr.it/sparkle/w1 prefima>) extending the set of relations proposed there.

2 Note that the issue we are concerned with here is parser evaluation, and we are not making any more general claims about the utility of constituency-based treebanks for other tasks, such as statistical parser training or in quantitative linguistics.
When the proprietor dies, the establishment should become a corporation until it is either acquired by another proprietor or the government decides to drop it.

- cmod(when, become, die)
- ncssubj(die, proprietor, _)
- ncssubj(become, establishment, _)
- xcomp(become, corporation, _)
- mod(until, become, acquire)
- ncssubj(acquire, it, obj)
- arg_mod(by, acquire, proprietor, subj)
- cmod(until, become, decide)
- ncssubj(decide, government, _)
- xcomp(to, decide, drop)
- ncssubj(drop, government, _)
- dobj(drop, it, _)

Figure 1: Example sentence and GRs (susanne rel3, lines G22:1460k-G22:1480m).

For brevity, we give an example of the use of the GR scheme here (figure 1) rather than duplicating Carroll, Briscoe & Sanfilippo’s description of it. The set of possible relations (i.e. cmod, ncssubj, etc.) is organised hierarchically; see figure 2. The most generic relation between a head and a dependent is dependent. Where the relationship between the two is known more precisely, relations further down the hierarchy can be used, for example mod(fier) or arg(ument). Relations mod, arg_mod, clausal, and their descendants have slots filled by a type, a head, and its dependent; arg_mod has an additional fourth slot initial_gr. Descendants of subj, and also dobj have the three slots head, dependent, and initial_gr. The x and c prefixes to relation names differentiate clausal control alternatives.

The scheme is superficially similar to a syntactic dependency analysis in the style of Lin (1995). However, the scheme contains a specific, fixed inventory of relations. Other significant differences are:

- the GR analysis of control relations could not be expressed as a strict dependency tree since a single nominal head would be a dependent of two (or more) verbal heads (as with ncssubj(decide, government, _)
- ncssubj(drop, government, _)

- any complementiser or preposition linking a head with a clausal or PP dependent is an integral part of the GR (the type slot);

- the underlying grammatical relation is specified for arguments “displaced” from their canonical positions by movement phenomena (e.g. the initial_gr slot of ncssubj and arg_mod in the passive it is either acquired by another proprietor);

- semantic arguments syntactically realised as modifiers (e.g. the passive by-phrase) are indicated as such—using arg_mod;

- conjuncts in a co-ordination structure are distributed over the higher-level relation (e.g. in become until either acquired or decides there are two verbal dependents of become, acquire and decide, each in a separate mod GR);

- arguments which are not lexically realised can be expressed (e.g. when there is pro-drop the dependent in a subj GR would be specified as Pro);
GRs are organised into a hierarchy so that they can be left underspecified by a shallow parser which has incomplete knowledge of syntax.

In addition to constituent structure, both the PTB and SUSANNE contain functional, or predicate-argument annotation, the former particularly employing a rich set of distinctions, often with complex grammatical and contextual conditions on when one function tag should be applied in preference to another. For example, the tag TPC ("topicalized")

"— marks elements that appear before the subject in a declarative sentence, but in two cases only: (i) if the fronted element is associated with a *T* in the position of the gap. (ii) if the fronted element is left-dislocated [...]" (Bies et al., 1995: 40). Conditions of this type would be very difficult to encode in an actual parser, so attempting to evaluate on them would be uninformative. Much of the problem is that treebanks of this kind have to specify the behaviour of many interacting factors, such as how syntactic constituents should be segmented, labelled and structured hierarchically, how displaced elements should be co-indexed, and so on. Within such a framework the further specification of how functional tags should be attached to constituents is necessarily highly complex. Moreover, functional information is in some cases left implicit, presenting further problems for precise evaluation. Table 1 gives a rough comparison between the types of information in the GR scheme and in the PTB and SUSANNE. It might be possible semi-automatically to map a treebank predicate-argument encoding to the GR scheme (taking advantage of the large amount of work that has gone into the treebanks), but we have not investigated this to date.

### Table 1: Rough correspondence between the GR scheme and the functional annotation in the Penn Treebank (PTB) and SUSANNE.

| Relation       | PTB          | SUSANNE     |
|----------------|--------------|-------------|
| dependent       | –            | –           |
| mod             | TPC/ADV etc. | p etc.      |
| ncmode          | CLR/VOC/ADV etc. | n/p etc. |
| xmode           | LGS         | a           |
| cmode           | –           | –           |
| arg mod         | SBJ         | s           |
| arg             | –           | –           |
| subj            | –           | –           |
| nsubj           | –           | –           |
| xsubj           | –           | –           |
| csubj           | –           | –           |
| subj or dobj    | –           | –           |
| comp            | –           | –           |
| obj             | –           | –           |
| dobj            | (NP after V) | o           |
| obj2            | (2nd NP after V) | –   |
| iobj            | CLR/DTV     | i           |
| clausal         | PRD         | –           |
| xcomp           | e           | –           |
| ccomp           | j           | –           |

The mean number of GRs per corpus sentence is 9.72. Table 3 quantifies the distribution of relations occurring in the corpus. The split between modifiers and arguments is roughly 60/40, with approximately equal numbers of subjects and complements. Of the latter, 40% are clausal; clausal modifiers are almost as prevalent. In strong contrast, clausal subjects are highly infrequent (accounting for only 0.2% of the total). Direct objects are 2.75 times more frequent than indirect objects, which are themselves 7.5 times more prevalent than second objects.

The corpus contains sentences belonging to three distinct genres. These are classified in the original Brown corpus as: A, press reportage; G, belles lettres; and J, learned writing. Genre has been found to affect the distribution of surface-level syntactic configurations (Sekine, 1997) and also complement types for individual predicates (Roland & Jurafsky, 1998). However, we observe no statistically signifi-
Table 2: Frequency of each type of GR (inclusive of subsumed relations) in the 10K-word corpus.

| Relation      | # occurrences | % occurrences |
|---------------|---------------|---------------|
| dependent     | 4690          | 100.0         |
| mod           | 2710          | 57.8          |
| ncmod         | 2377          | 50.7          |
| xmod          | 170           | 3.6           |
| cmod          | 163           | 3.5           |
| arg_mod       | 39            | 0.8           |
| arg           | 1941          | 41.4          |
| subj          | 993           | 21.2          |
| ncssubj       | 984           | 21.0          |
| xsubj         | 5             | 0.1           |
| csubj         | 4             | 0.1           |
| subj_or_dobj  | 1339          | 28.6          |
| comp          | 948           | 20.2          |
| obj           | 559           | 11.9          |
| dobj          | 396           | 8.4           |
| obj2          | 19            | 0.4           |
| iobj          | 144           | 3.1           |
| clausal       | 389           | 8.3           |
| xcomp         | 323           | 6.9           |
| ccomp         | 66            | 1.4           |

Table 3: GR accuracy by relation.

| Relation      | Precision (%) | Recall (%) | F-score (%) |
|---------------|---------------|------------|-------------|
| dependent     | 75.1          | 75.2       | 75.1        |
| mod           | 73.7          | 69.7       | 71.7        |
| ncmod         | 78.1          | 73.1       | 75.6        |
| xmod          | 70.0          | 51.9       | 59.6        |
| cmod          | 67.4          | 48.1       | 56.1        |
| arg_mod       | 84.2          | 41.0       | 55.2        |
| arg           | 76.6          | 83.5       | 79.9        |
| subj          | 83.6          | 87.9       | 85.7        |
| ncsbj         | 84.8          | 88.3       | 86.5        |
| xsubj         | 100.0         | 40.0       | 57.1        |
| csubj         | 14.3          | 100.0      | 25.0        |
| subj_or_dobj  | 84.4          | 86.9       | 85.6        |
| comp          | 69.8          | 78.9       | 74.1        |
| obj           | 67.7          | 79.3       | 73.0        |
| dobj          | 86.3          | 84.3       | 85.3        |
| obj2          | 39.0          | 84.2       | 53.3        |
| iobj          | 41.7          | 64.6       | 50.7        |
| clausal       | 73.0          | 78.4       | 75.6        |
| xcomp         | 84.4          | 78.9       | 81.5        |
| ccomp         | 72.3          | 74.6       | 73.4        |

significant difference in the total numbers of the various grammatical relations across the three genres in the corpus.

3.2 Parser Evaluation

We replicated an experiment previously reported by Carroll, Minnen & Briscoe (1998), using a robust lexicalised parser, computing three evaluation measures for each type of relation against the 10K-word test corpus (table 3). The evaluation measures are precision, recall, and F-score (van Rijsbergen, 1979) of parser GRs against the test corpus annotation.

GRs are in general compared using an equality test, except that we allowed the parser to return mod, subj and clausal relations rather than the more specific ones they subsume, and to leave unspecified the filler for the type slot in the mod, iobj and clausal relations. The head and dependent slot fillers are in all cases the base forms of single head words, so for example, ‘multi-component’ heads such as the names of people and companies are reduced to a single word; thus the slot filler corresponding to

\[^6\]The F-score is a measure combining precision and recall into a single figure. We use the version in which they are weighted equally, defined as \(2 \times \text{precision} \times \text{recall} / (\text{precision} + \text{recall})\).

\[^7\]The implementation of the extraction of GRs from parse trees is currently being refined, so these minor relaxations should be removed soon.

Bill Clinton would be Clinton. For real-world applications this might not be the desired behaviour—one might instead want the token Bill Clinton—but the analyser could easily be modified to do this.

The evaluation results can be used to give a single figure for parser accuracy—the F-score of the dependent relation—precision and recall at the most general level, or more fine-grained information about how accurately groups of, or single relations were produced. The latter would be particularly useful during parser/grammar development to identify where effort should be expended on making improvements.

4 Conclusions

We have outlined and justified a language and application-independent corpus annotation scheme for evaluating syntactic parsers, based on grammatical relations between heads and dependents. The scheme has been used in the EU-funded SPARKLE project (see <http://www.ilc.pi.cnr.it/sparkle.html>) to annotate English, French, German and Italian corpora, and for evaluating parsers for these languages. In this paper we have described a 10K-word corpus of English marked up to this standard, and shown its use in evaluating a robust parsing system. The corpus and evaluation software that can be used
with it will shortly be made publicly available online.

Acknowledgments

This work was funded by UK EPSRC project GR/L53175 ‘PSET: Practical Simplification of English Text’, CEC Telematics Applications Programme project LE1-2111 ‘SPARKLE: Shallow PARsing and Knowledge extraction for Language Engineering’, and by an EPSRC Advanced Fellowship to the first author. We would like to thank Antonio Sanfilippo for his substantial input to the design of the annotation scheme.

References

Atwell, E. (1996) Comparative evaluation of grammatical annotation models. In R. Sutcliffe, H. Koch & A. McElligott (Eds.), Industrial Parsing of Software Manuals, 25–46. Amsterdam: Rodopi.

Bies, A., Ferguson, M., Katz, K., MacIntyre, R., Tredinnick, V., Kim, G., Marcinkiewicz, M., Schasberger, B. (1995) Bracketing guidelines for Treebank II style Penn Treebank Project. Technical Report, CIS, University of Pennsylvania, Philadelphia, PA.

Carpenter, B. & Manning, C. (1997) Probabilistic parsing using left corner language models. In Proceedings of the 5th ACL/SIGPARSE International Workshop on Parsing Technologies. MIT, Cambridge, MA.

Carroll, J., Briscoe E. & Sanfilippo, A. (1998) Parser evaluation: a survey and a new proposal. In Proceedings of the International Conference on Language Resources and Evaluation, 447–454. Granada, Spain. Available online at <ftp://ftp.cogs.susx.ac.uk/pub/users/johnca/lre98-final.ps>.

Carroll, J., Minnen, G. & Briscoe E. (1998) Can subcategorisation probabilities help a statistical parser? In Proceedings of the 6th ACL/SIGDAT Workshop on Very Large Corpora. Montreal, Canada. Available online at <http://xxx.lanl.gov/abs/comp-lg/9806013>.

Charniak, E. (1996) Tree-bank grammars. In Proceedings of the 13th National Conference on Artificial Intelligence, AAAI-96, 1031–1036.

Collins, M. (1996) A new statistical parser based on bigram lexical dependencies. In Proceedings of the 34th Meeting of the Association for Computational Linguistics, 184–191. Santa Cruz, CA.

Gaizauskas, R. (1998) Special issue on evaluation. Computer Speech & Language.

Gaizauskas, R., Hepple M. & Huyck, C. (1998) Modifying existing annotated corpora for general comparative evaluation of parsing. In Proceedings of the LRE Workshop on Evaluation of Parsing Systems. Granada, Spain.

Grishman, R., Macleod, C. & Sterling, J. (1992) Evaluating parsing strategies using standardized parse files. In Proceedings of the 3rd ACL Conference on Applied Natural Language Processing, 156–161. Trento, Italy.

Harrison, P., Abney, S., Black, E., Flickinger, D., Gdaniec, C., Grishman, R., Hindle, D., Ingria, B., Marcus, M., Santorini, B. & Strzalkowski, T. (1991) Evaluating syntax performance of parser/grammars of English. In Proceedings of the Workshop on Evaluating Natural Language Processing Systems. ACL.

Leech, G. & Garside, R. (1991) Running a grammar factory: the production of syntactically analysed corpora or ‘treebanks’. In S. Johansson & A. Stenstrom (Eds.), English Computer Corpora: Selected Papers and Bibliography, Mouton de Gruyter, Berlin.

Lehmann, S., Oepen, S., Regnier-Prost, S., Netter, K., Lux, V., Klein, J., Falkedal, K., Fovry, F., Estival, D., Dauphin, E., Compagnion, H., Baur, J., Balkan, L. & Arnold, D. (1996) TSNLP — test suites for natural language processing. In Proceedings of the International Conference on Computational Linguistics, COLING-96, 711–716. Copenhagen, Denmark.

Lin, D. (1995) A dependency-based method for evaluating broad-coverage parsers. In Proceedings of the 14th International Joint Conference on Artificial Intelligence, 1420–1425. Montreal, Canada.

Lin, D. (1996) Dependency-based parser evaluation: a study with a software manual corpus. In R. Sutcliffe, H-D. Koch & A. McElligott (Eds.), Industrial Parsing of Software Manuals, 13–24. Amsterdam, The Netherlands: Rodopi.

Marcus, M., Santorini, B. & Marcinkiewicz (1993) Building a large annotated corpus of English: The Penn Treebank. Computational Linguistics, 19(2), 313–330.

Roland, D. & Jurafsky, D. (1998) How verb subcategorization frequencies are affected by corpus choice. In Proceedings of the 17th International Conference on Computational Linguistics (COLING-ACL’98), 1122–1128. Montreal, Canada.

Rubio, A. (Ed.) (1998) International Conference on Language Resources and Evaluation. Granada,
Spain.

Sampson, G. (1995) *English for the Computer*. Oxford, UK: Oxford University Press.

Sanfilippo, A., Barnett, R., Calzolari, N., Flores, S., Hellwig, P., Leech, P., Melero, M., Montemagni, S., Odijk, J., Pirrelli, V., Teufel, S., Villegas M. & Zaysser, L. (1996) *Subcategorization Standards*. Report of the EAGLES Lexicon/Syntax Interest Group. Available through eagles@ilc.pi.cnr.it.

Sekine, S. (1997) The domain dependence of parsing. In *Proceedings of the 5th ACL Conference on Applied Natural Language Processing*, 96–102. Washington, DC.

Srinivas, B., Doran, C., Hockey B. & Joshi A. (1996) An approach to robust partial parsing and evaluation metrics. In *Proceedings of the ESSLLI’96 Workshop on Robust Parsing*. Prague, Czech Republic.

Srinivas, B., Doran, C. & Kulick, S. (1995) Heuristics and parse ranking. In *Proceedings of the 4th ACL/SIGPARSE International Workshop on Parsing Technologies*. Prague, Czech Republic.

van Rijsbergen, C. (1979) *Information Retrieval*. Butterworth, London.