Extraction of semantic representations from syntactic CMU link grammar linkages

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Abstract

A method for generating a Discourse Representation Structure (DRS) semantic representation from the output of the Carnegie Mellon University (CMU) link grammar parser is presented. The techniques used in extracting information from the link grammar representation and construction of the DRS are detailed. The system is a major component of the EU funded ViSiCAST (Virtual Signing: Capture, Animation, Storage and Transmission) project [1] for presenting English text as sign language presentations.

1 Introduction

An overall architecture for an English text to sign language system is discussed in (Safar & Marshall 01). In the syntactic stage, the text is parsed by the CMU (Carnegie Mellon University) link grammar parser (Sleator & Temperley 91). The most appropriate parse linkage is manually chosen and from this a Discourse Representation Structure (DRS) is generated. The DRS is then fed as input to a Head-Driven Phrase Structure Grammar (HPSG) sign synthesis component. This linguistic analysis is linked to animation technology to drive a virtual human via a Signing Gesture Markup Lanugage (SiGML), that is an XML-compliant representation of gestures (Elliott *et al.* 00; Kennaway 01) and is based on the refined HamNoSys (Prillwitz *et al.* 89) sign notation. At intermediate stages user intervention is supported to allow enhancement of the translation and to correct errors.

This paper discusses the manipulation of CMU link grammar parses in order to generate appropriate semantic representations. In so doing, the stategy follows the methodology of van Eijk and Kamp (vanEijck & Kamp 97) and Blackburn and Bos (Blackburn & Bos 99) and applies and extends these techniques to the output of a large scale syntactic parser such as that of the CMU parser. The current implementation of this system subcomponent is illustrated in Fig 1.

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2 The Semantic Module

Discourse Representation Theory (DRT) (Kamp & Reyle 93; vanEijck & Kamp 97) is used as the intermediate representation of meaning for English to Sign Language translation. Our formulation of DRSs extends the use of proposition labeling to be potentially as expressive as underspecified flat semantic formulations which have been employed in the Verbmobil project (Copestake *et al.* 95). Isolation of tense/aspect phenomena and determination of anaphoric relationships in DRSs also facilitate synthesis of appropriate sign language presentation. However, sign languages such as British Sign Language (BSL) differ from English in requiring quantifier scope and prepositional phrase attachment to be unambiguously determined. Hence, user-intervention prior to and during DRS generation determines a fully-specified representation from which a higher quality signed presentation can be synthesised.

A DRS is a two part construction involving a list of variables denoting the nominal discourse referents and conditions (a collection of propositions which capture the semantics of the discourse), illustrated in the top right window of Fig. 1.

Fig 2 illustrates the architecture of the CMU linkage to DRS conversion. The main component of this architecture is the Link Dictionary which maps each kind of CMU link to a λ-DRS definition. λ-DRSs are λ-expressions, which may contain embedded DRSs or may take these as arguments. These λ-DRSs are concatenated to form a sequence of unevaluated λ-expressions, which is later reduced using functional application (β-reduction). When no further β-reduction

Figure 1: The current implementation

can be performed, a mergeDRS operation builds the complex DRS for the sentence by repeatedly merging partial DRSs as in (Blackburn & Bos 99). The merge (⊗) operator combines two DRSs by taking the union of the two universes and concatenating the conditions (Bos *et al.* 94).

Figure 2: Linkage to DRS transformation

The input linkage is re-ordered and is 'parsed' by a Definite Clause Grammar (DCG) whose structure is similar to a conventional phrase structure grammar but whose input 'string' is the list of links of a CMU linkage. The main function of the DCG is to help determine the order of λ-DRSs so that later β-reduction and DRS merge operations generate the appropriate DRS.

3 CMU link grammar

English text is input to the CMU parser (Sleator & Temperley 91). The CMU link grammar parser is a robust and extensive lexically driven parser in which the dictionary defines an ordered collection of link anchors for each root lexical form. These are matched with similar anchors of other lexical forms to characterise a syntactic relationship between a pair of words of a sentence - a link. The parser's output is (possibly a number of) a set of links - a linkage - which characterise a syntactic parse for a sentence The diagrammatic form of such a linkage is shown in the top left window of Fig. 1, however the relational form is represented as a collection of n-tuples (one tuple per link) in which the third, fifth and seventh items indicate word m is connected by link X to word n (see Fig. 3).

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[[m, 1, 2, A, A, A, 3], [m, 2, 1, Ds, Dsu, D*u, 3],
 [m, 3, 0, Wd, Wd, Wd, 3], [m, 1, 3, M, Mp, Mp, 4],
 [m, 1, 5, D, Dmc, Dmc, 6], [m, 2, 4, J, Jp, Jp, 6],
 [m, 1, 6, R, R, R, 7], [r m, 1, 7,Ss*b, Ss*b, S, 8],
 [m, 6, 3, Ss, Ss, S, 9], [m, 1, 9, MV, MVp,MVp, 10],
 [m, 1, 10, ON, ON, ON, 11]]
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Figure 3: Reordered CMU Linkage

np1(Sent, Det@Noun) ⟶ det(Sent,Det),n2(Sent,Noun).
np2(Sent,Det@(Adjp@N)) ⟶ adj(Sent,Adjp),np2(Sent,Det@N).

n2(Sent,PP@Noun) ⟶ n(Sent,Noun), pp(Sent,PP).
pp(Sent,Prep@NP) ⟶ mp(Sent,Prep), np2(Sent,NP).

vp(Sent,Lab,PP@VP) ⟶ v1(Sent,Lab,VP), modp(Sent,Lab,PP).
modp(Sent,Lab,PP) ⟶ mod(Sent,Lab,PP).
mod(Sent,Lab,Prep@NP)⟶ mvpp(Sent,Lab,Prep), np2(Sent,NP).
mod(Sent,Lab,Prep@NP) ⟶ mvptemp(Sent,Lab,Prep),ntempphrase(Sent, NP).
ntempphrase(Sent,Det@(Adjp@NP)) ⟶ adj(Sent, Adjp),ntemp(Sent,NP), dummydet(Sent,Det).
ntempphrase(Sent,Det@NP) ⟶ ntemp(Sent,NP),dummydet(Sent,Det).

Figure 4: example DCG productions for nominal and verbal links

4 The Definite Clause Grammar

A context free Prolog Definite Clause Grammar (DCG) is used to process the linkage. In practice this serves no parsing function, as the collection of CMU links now have a standard ordering. However, the DCG determines the priority of beta-reduction application of λ-DRSs associated with different link types. Thus it determines the combination of λ-DRSs as they are passed back up through the DCG rules to sentence level as illustrated in Fig 4. For example, the production for *np1* illustrates that the λ-DRS it generates is the concatenation of λ-DRS for *det* applied to the λ-DRS for *n2*.

In addition, provision within the DCG to embed Prolog code allows other NLP algorithms such as anaphoric pronoun resolution to be performed simultaneously with DRS generation (though this is omitted here).

5 Link Dictionary and DRS construction

In practice, link reordering and the DCG are essentially supportive to the main DRS generation task for which development of the Link Dictionary is a major undertaking. Following van Eijk and Kamp (vanEijck & Kamp 97) and Blackburn and Bos (Blackburn & Bos 99) determiners, nouns and intransitive verbs are defined as the λ-DRSs shown in Fig 5(a).

A determiner introduces a DRS

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drs( [ X ] , [ exists(X) ])
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which eventually is merged with two other DRSs, one resulting from the noun associated with the determiner and the other resulting from the sentence verb. Thus, for a sentence 'A talk followed.', the retrieved λ-DRSs are combined into a DRS sub-expression as shown in Fig 6.

β-reduction binds the noun λ-DRS to N which is then applied to the local DRS variable X to incorporate the noun and associate it with the DRS referent. Then reduction with the verb λ-DRS binds it to V which again is applied to the local determiner DRS variable X. In this way the internal DRS variables of each of the fragments are associated with the same DRS individual X. The two merge operations subsequently combine these three DRS fragments into a single DRS.

The form of dictionary entries have to produce a consistent framework. The forms for nouns and intransitive verbs we call *fnDRSvar* as they are functions which take a single DRS variable as their argument. The form for a determiner we call *BindDRS2* as it expects two *fnDRSvar* λ-DRSs as arguments. β-reduction of a *BindDRS2* with a *fnDRSvar* produces a *BindDRS1* form which requires further reduction with a *fnDRSvar* to form a complete DRS.

In order that a more complicated nominal description is consistent with this framework, its result must be a *fnDRSvar* λ-DRS so that it can be applied to a determiner's DRS variable. The λ-DRS for an adjective (Fig 7(b)) has to accept a *fnDRSvar* λ-DRS and generate a *fnDRSvar* λ-DRS which also incorporates the adjectival information. For example, for the noun phrase 'a short talk', the combination of the λ-DRS for its A and

Figure 5: Link dictionary entries

Figure 6: Reduction (a) -> (b) and Merging (b) -> (c) of λ-DRS for 'a talk followed'

Dsu links is shown in Fig 7. This resulting form is a *fnDRSvar* and is incorporated into the determiner's DRS as described above. The DCG production for *np2* (see Fig 4) retrieves the adjectival *A* link first and then the following determiner noun *D*su link, but produces as its result the β-reduction order Det@(Adjp@N) giving priority to reduction of the adjective noun λ-DRSs.

In a comparable manner, a noun modifying prepositional phrase (e.g. 'a talk with some questions') must reduce to a *fnDRSvar* λ-DRS comparable to a simple noun. Such Link Dictionary

Figure 7: Reduction and Merging (a) -> (b)of λ-DRS for 'short talk'

Figure 8: Comparison of coverage

entries are illustrated by the entry for *with* in Fig. 5(b). The head of such phrases are prepositions at the right end of MP and MG links. The λ-DRS for prepositions thus must accept the determiner based DRS for the embedded noun-phrase and the modified noun on the left end of the MP/MG link and produce a *fnDRSvar* λ-DRS as its result.

More accurately, the λ-DRSs which accept a *fnDRSvar* form and produce a modified *fnDRSvar* form as a result are more general than this. For an arbitrary form F, they map an F form to another F form. For verb modifying prepositional phrases this generality is required. A comparable link dictionary entry for verb modifying preposition links achieves a similar affect to that for nouns. For intransitive verbs this accepts and generates a *fnDRSvar* form. For transitive verbs, however, the same preposition λ-DRS accepts a *BindDRS1* form (a determiner based DRS for the PP's noun phase) and produces as its result a *BindDRS1* form which incorporates the preposition. This can then be reduced with the object incorporated verb phrase. The DCG productions for verb components in Fig 4 are slightly more complex, as the first argument for the preposition is an event label standing for the main sentential proposition (rather than the noun referent in the noun modifying PP case). These productions introduce event labels which are passed as arguments into the link dictionary entries for incorporation into λ-DRSs. (However, at the expense of complicating the λ-DRSs, they could be handled using further λ-abstraction).

6 Current State and Future Work

Currently, the Prolog implementation of this work handles approximately 50% of the CMU link types though this is focused upon the more commonly utilised link types. Fig 8 summarises the coverage of linguistic phenomena in comparison with Blackburn and Bos' implementation (Blackburn & Bos 99). However, the framework of Link Dictionary definitions presented here is fully general, allowing multiple adjectives, multiple embedded noun modifying prepositional phrases, multiple verb modifying prepositional phrases and relative clauses in arbitrary combinations.

7 Conclusion

We have illustrated how the methodology of van Eijk and Kamp (vanEijck & Kamp 97) and Blackburn and Bos (Blackburn & Bos 99) can be applied and extended to produce a large scale DRS generation component which exploits the extensiveness of the CMU link grammar parser. We detailed the regularity in these original formulations for Link Dictionary entries involving λ-DRSs and how this regularity has guided extension to incorporation of a wider range of constructions.

References

(Blackburn & Bos 99) P Blackburn and J Bos. *Representation and Inference for Natural Language. A First Course in Computational Semantics. Volume II.* http://www.coli.uni-sb.de/~bos/comsem/book1.html, 1999.

(Bos *et al.* 94) J Bos, E Mastenbroek, S McGlashan, S Millies, and M Pinkal. *A Compositional DRS-based Formalism for NLP Applications. Report 59.* Universitaet des Saarlandes, Saarbruecken, 1994.

(Copestake *et al.* 95) A Copestake, D Flickinger, R Malouf, S Richemann, and I Sag. Translation using minmal recursion semantics. In *Proceedings of 16th Internat. Conf. on Theoretical and Methodological Issues in Machine Translation*, 1995.

(Elliott *et al.* 00) R Elliott, JRW Glauert, JR Kennaway, and I Marshall. The development of language processing support for the visicast project. In *Assets 2000. 4th International ACM SIGCAPH Conference on Assistive Technologies.* New York, 2000.

(Kamp & Reyle 93) H Kamp and U Reyle. *From Discourse to Logic. Introduction to Model theoretic Semantics of Natural Language, Formal Logic and Discourse Representation Theory.* Kluwer Academic Publishers, Dordrecht, 1993.

(Kennaway 01) JR Kennaway. Synthetic animation of deaf signing gestures. In *The Fourth International Workshop on Gesture and Sign Language Interaction, Gesture Workshop 2001 (GW2001)*, City University, London, UK, 2001.

(Prillwitz *et al.* 89) S Prillwitz, R Leven, H Zienert, T Hanke, J Henning, *et al. Hamburg Notation System for Sign Languages - An Introductory Guide.* International Studies on Sign Language and the Communication of the Deaf, Volume 5., Institute of German Sign Language and Communication of the Deaf, University of Hamburg, 1989.

(Safar & Marshall 01) E Safar and I Marshall. The architecture of an english-text-to-sign-languages translation system. In *submitted simultaneously to RANLP 2001*, 2001.

(Sleator & Temperley 91) D Sleator and D Temperley. *Parsing English with a Link Grammar.* Carnegie Mellon University Computer Science technical report CMU-CS-91-196, 1991.

(vanEijck & Kamp 97) J. van Eijck and H. Kamp. Representing discourse in context. In J. van Benthem and A. Ter Meulen, editors, *Handbook of Logic and Language.* Elsevier, 1997.