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 Language (SiGML), that is an XML-compliant representation of gestures (Elliott *et al.* 00; Kennaway 01) based on the refined HamNoSys (Prillwitz *et al.* 89) sign notation.

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.

2 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 entries indicate that word m is connected by link X to word n.

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[[m, 2, A, 3], [m, 1, Dsu, 3], [m, 0, Wd, 3], [m, 3, Mp, 4],
 [m, 5, Dmc, 6], [m, 4, Jp, 6], [m, 6, R, 7], [r m, 7, Ss*b, 8],
 [m, 3, Ss, 9], [m, 9, MVp, 10], [m, 10, ON, 11]]
```

3 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-
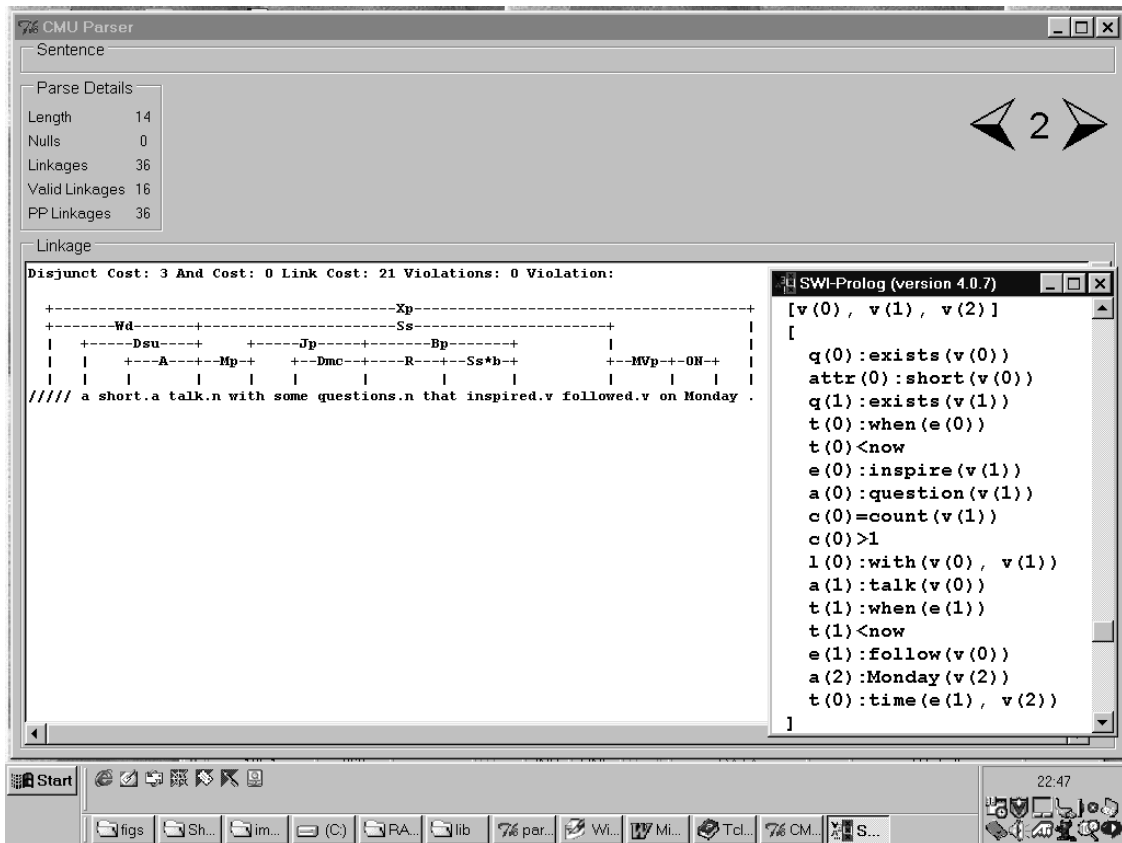
Figure 1: The current implementation

expressions, which is later reduced using functional application (β-reduction). When no further β-reduction 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 ($\otimes$) operator combines two DRSs by taking the union of the two universes and concatenating the conditions (Bos *et al.* 94).
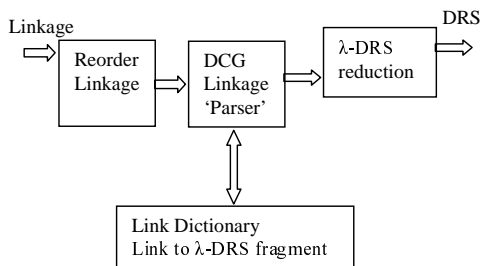

Figure 2: Linkage to DRS transformation

4 The Definite Clause Grammar

The input linkage is 'parsed' by a Definite Clause Grammar (DCG) whose structure is similar to a conventional phrase structure grammar but whose input

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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 3: DCG rules for nominal and verbal links

Determiner (e.g. 'a')
left end of any of {D,DG} links

$\lambda N. \lambda V.$ (

X
q(j) : exists(X)

$\otimes$ N @X $\otimes$ V@X)

Noun (e.g. 'talk')
right end of any of {Wd,O,Cr,SI,JG,J} links

$\lambda Q.$ (

a(k) :talk(Q)

)

Verb (intransitive) (e.g. 'followed')
right end of any of {I*d,I} links

$\lambda Y.$ (

t(m) :when(e(n)) t(m) < now e(n) : follow(Y)

)

a

Adjective (e.g. 'short')
left end of any of {A,TA,AN,DT} links

$\lambda N. \lambda Q.$ merge (

attr(k) :short(Q)

$\otimes$ N@Q)

Preposition (e.g. 'with')
left end of any of {Mp,Mg} links

$\lambda subordDRS. \lambda N. \lambda Q.$ subordDRS @
$\lambda R.$ merge(

l(k) :with(Q,R)

$\otimes$ N@Q)

b

Figure 4: Link dictionary entries

'string' is the list of links of a CMU 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 β-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 3. 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*.

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 4(a).

As illustarted in Fig 4(a), the entry for a determiner introduces a λ-DRS paramterised by two other λ-DRSs,

$\lambda N.\lambda V.drs(\ [\ X\ ]\ ,\ [\ exists(X)\ ]\ \otimes N@X \otimes V@X)$

one resulting from the noun associated with the determiner and the other resulting from the sentence verb. The λ-DRSs for links associated with nouns and intransitive verbs, the Link Dictionary entries are also illustrated in 4(a), though these have been instantiated for particular lexical items ('talk', 'followed'). Thus, for a sentence 'A talk followed.', the sequence of retrieved λ-DRSs is subsequently reduced and then merged to produce a DRS sub-expression as shown in Fig 5. 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 forms 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 6(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 Dsu links is shown in Fig 6. This resulting form is a *fnDRSvar* and is incorporated into the determiner's DRS as described above. The DCG production for *np2* (see Fig 3) retrieves the adjectival A link first and then the following determiner noun Dsu link, but produces as its result the β-reduction order Det@(Adjp@N) giving priority to reduction of the adjective noun λ-DRSs.
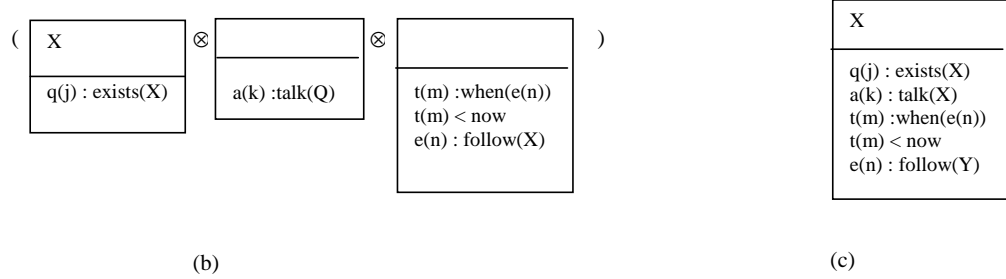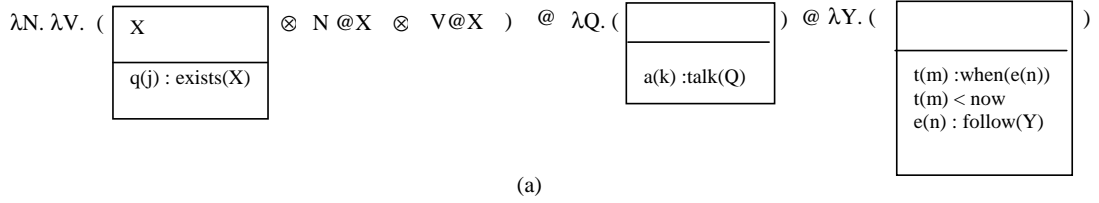
In a comparable manner, a noun modifying preposi-

λN. λV. (
$\boxed{\begin{array}{c} X \\ \hline q(j) : exists(X) \end{array}}$
⊗ N @X ⊗ V@X) @ λQ. ($\boxed{\begin{array}{c} \\ \hline a(k) :talk(Q) \end{array}}$) @ λY. ($\boxed{\begin{array}{c} \\ \hline t(m) :when(e(n)) \\ t(m) < now \\ e(n) : follow(Y) \end{array}}$)

(a)

($\boxed{\begin{array}{c} X \\ \hline q(j) : exists(X) \end{array}}$ ⊗ $\boxed{\begin{array}{c} \\ \hline a(k) :talk(Q) \end{array}}$ ⊗ $\boxed{\begin{array}{c} \\ \hline t(m) :when(e(n)) \\ t(m) < now \\ e(n) : follow(X) \end{array}}$)

(b)

$\boxed{\begin{array}{c} X \\ \hline q(j) : exists(X) \\ a(k) : talk(X) \\ t(m) :when(e(n)) \\ t(m) < now \\ e(n) : follow(Y) \end{array}}$

(c)

Figure 5: Reduction (a) -> (b) and Merging (b) -> (c) of λ-DRS for 'a talk followed'

λN. λV. ($\boxed{\begin{array}{c} X \\ \hline q(j) : exists(X) \end{array}}$ ⊗ N @X ⊗ V@X) @

(λN. λQ. merge ($\boxed{\begin{array}{c} \\ \hline attr(k) :short(Q) \end{array}}$ ⊗ N@Q) @ λY. ($\boxed{\begin{array}{c} \\ \hline a(k) :talk(Y) \end{array}}$))

(a)

λN. λV. ($\boxed{\begin{array}{c} X \\ \hline q(j) : exists(X) \end{array}}$ ⊗ N @X ⊗ V@X) @ λQ. ($\boxed{\begin{array}{c} \\ \hline attr(k) :short(Q) \\ a(k) :talk(Q) \end{array}}$)

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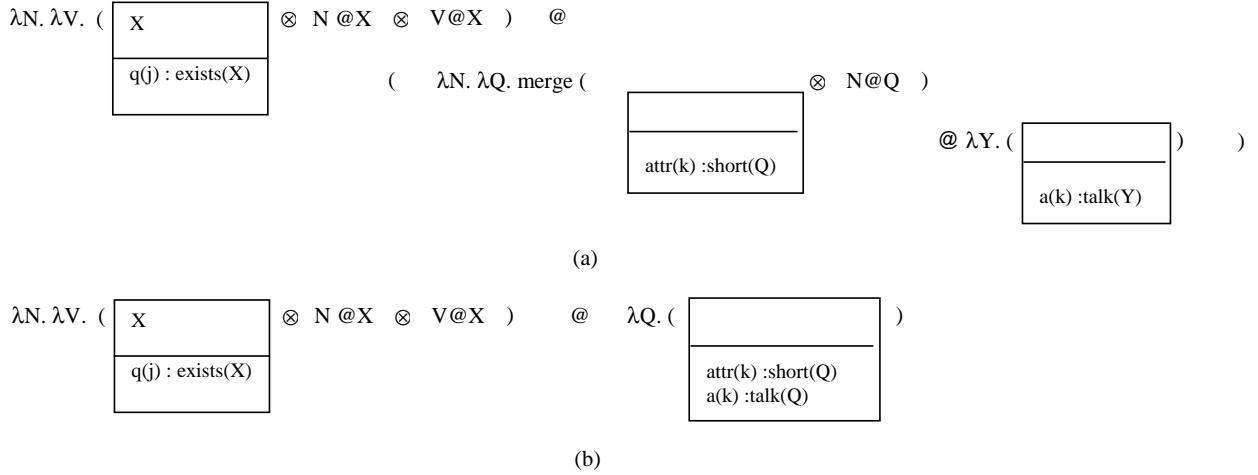
Figure 6: Reduction and Merging (a) -> (b)of λ-DRS for 'short talk'

tional phrase (e.g. 'a talk with some questions') must reduce to a *fnDRSvar* λ-DRS comparable to a simple noun. Such Link Dictionary entries are illustrated by the entry for *with* in Fig. 4(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 *fn-DRSvar* 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 *Bind-DRS1* form which incorporates the preposition. This can then be reduced with the object incorporated verb phrase. The DCG productions for verb components in Fig 3 are slightly more complex, as the first argument for the preposition is an event label standing for the main sentential proposition (rather than the

Blackburn&Bos, 1999		Extension to large scale implementation
• Transitive • Intransitive • Negated simple present	Verbs	• Auxiliaries (temporal and negated) • Ditransitive • Stems instead of full forms in lexicon (extracted temporal information) • Passives
• Common • Proper	Nouns	
• Universal • Indefinite	Determiners	• Numbers • Demonstrative
• Personal • Relative pronoun in subject type relative clauses	Pronouns	• Relative pronoun in object type relative clauses • Interrogative pronouns • Expletive 'there'
	Adjectives Adverbs	• Noun modifiers (adjectival and nominal and multiple) • Predicatives • Adverbs to other adverbs (modifying predicatives)
• Noun modifiers • Simple prepositions • Two arguments	Prepositions	• Verb modifiers • Complex prepositions (e.g.: in front of) • 3 arguments
• Declarative • Coordination	Sentences	• Imperative • Interrogative (wh, yes-no) • Polite requests (e.g.:Would you…?)

Figure 7: Comparison of coverage

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. The left-hand column of Fig 7 summarises the coverage of linguistic phenomena of Blackburn and Bos' implementation (Blackburn & Bos 99) and the right hand column details the additional phenomena handled by our implementation. In addition, 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.

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