An Education and Research Tool for Computational Semantics

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Abstract

This paper describes an interactive graphical environment for computational semantics. The system provides a teaching tool, a stand alone extendible grapher, and a library of algorithms together with test suites. The teaching tool allows users to investigate the properties of various semantic formalisms (e.g. Intensional Logic, DRT, and Situation Semantics), and their interaction with syntax.

1 Introduction

The CLeARS tool (Computational Linguistics Education and Research Tool in Semantics) was developed as part of the FraCaS project, LRE 62-05, which aimed to encourage convergence between different semantic formalisms. Although formalisms such as ‘Montague-Grammar’, DRT, and Situation Semantics look different on first sight, they share many common assumptions, and provide similar treatments of many phenomena. The CLeARS tool allows exploration and comparison of these different formalisms, enabling the user to get an idea of the range of possibilities of semantic construction. It is intended to be used as both a research tool and a tutorial tool.

The first part of the paper shows the potential of the system for investigating the properties of different semantic formalisms, and for teaching students formal semantics. The next section outlines the library contents and the system architecture, which was designed to reflect convergence between theories. The result is a highly modular and, we believe, a highly flexible system which allows user programs to be integrated at various levels. The final part of the paper describes the grapher which was designed as a stand alone tool which can be used by various applications.

2 A Tutorial System for Computational Semantics

As a tutorial tool, CLeARS allows students to investigate by themselves certain formalisms and their relationship. It also provides the possibility for the teacher to provide interactive demonstrations and to produce example slides and handouts.

In this section we will show how a user could interactively explore the step-by-step construction of a semantic representation out of a syntax tree. The following figures show the initial display for the sentence “Anna laughs” in ‘Montague Grammar’ (‘(_app(2,1)) and compositional versions of DRT (λ-DRT (‘_) and C-DRT of (‘)).

The user controls a derivation by moving to particular nodes in the derivation tree and by using either mouse clicks or a pull-down menu. The menu provides the option of fully processing the current node (and the nodes below it), or performing single derivation steps (e.g. intensional

\[ \otimes \] is the symmetric merge operation in λ-DRT, which puts together two DRSs by unioning the discourse universes and the conditions.
operator cancellation, quantifier storage, and DRS merging). Figures 3 and 4 show possible final representations for the examples above. The different graphical outputs shown here are controlled by the user via parameter setting.

3 Comparing theories

A major use of the tool is for comparison of different semantic theories. To this end facilities are provided for simultaneously building up representations using different formalisms. Furthermore there are translation routines among some semantic formalisms, making easy comparison of various results possible. In figure 3 we show a translation from a DRS to a formula in Predicate Logic. As our system is controlled by parameters, controlling the choice of semantic formalism, parser, grammar, syntax-semantics mapping etc. the user can also try out several thousand different parameter settings and comparing their different results.

4 The Library

Because such a tutorial system as described above has to be based largely on standard routines and algorithms that are fundamental for the area of computational semantics, a secondary aim of the project was to provide a set of well documented programs which could form the nucleus of a larger library of reusable code for this field. For program documentation we largely followed the approach taken in LEDA (?).
4.1 Tools for Semantic Construction

The library currently contains a selection of lambda reduction routines (including routines based on unification and on substitution plus alpha-conversion), routines for performing functional composition, routines for performing quantifier storage (Cooper storage (?) and nested Cooper storage (?)), a simple and a feature based phrase structure grammar and a DCG parser, a feature based Categorial Grammar with an incremental parser, a couple of syntactic lexicons, various sets of lexical macros for different semantic formalisms (currently including Compositional DRT (?), λ-DRT (?), Logic of Generalised Quantifiers, and Intensional Logic (?)), as well as translation routines from representations in DRT to formula in Predicate Logic or Situation Semantics. There are also modules for mapping from syntax trees to semantic representations using rule-to-rule based mappings, or mapping via syntactic templates.

The routines concerned with the interface to the grapher CLiG consist of translation routines from the Prolog representations of the semantic formalisms to the CLiG syntax and parameters to manipulate the display format, such as stacking of reduction steps or drawing boxes around specific nodes, as you can see in figure 3. It is intended to extend the library with routines for semantic construction driven by semantic types, and to integrate a wider range of grammars, parsing strategies and pronoun resolution strategies.

4.2 Modularisation Principles

One of the aims in building the tool was to show where semantic formalisms converge. Thus there was theoretical motivation as well as practical motivation in making sure components of the system were shared wherever possible. Achieving this was not entirely trivial however, since many of the changes required in moving between formalisms cut across natural modularisation boundaries. For example, use of intensional logic rather than first order logic requires a change in the quantifier discharging rules, and even in the lambda reducer (the natural way of reducing an intensional expression involves interleaving of beta-reductions with intensional operator cancellation).

The solution adopted was to use parameterised modularisation. Whenever some part of the code needed to be different, a parameterised level was introduced at that point. At run time, the parameter setting chooses the correct module.

The parameterised approach involves some small costs due to indirection (instead of calling e.g. a β-reducer directly, a program first calls a routine which chooses the β-reducer according to the parameters). But with these parameterisation layers we provide natural points where the system can be extended or modified by the user. The approach also prevents ‘generalisation to the worst case’ which is often seen in other approaches to modularisation. For example, the parser calls a parameterised level which chooses how to annotate nodes, so that the syntax trees only have the information required for the particular syntax-semantics strategy being used. The result is a system which provides several thousand possible valid combinations of semantic formalisms, grammar, reducer etc. using a small amount of code.

5 The graphical interface

Another major part of our work on the educational tool was the development of a general graphical browser or grapher for the graphical notations used in computational linguistics, especially those in computational semantics such as trees, Attribute-Value-Matrices, EKN (?) and DRSs. Two other design points which were especially important were the extendibility of the grapher for future applications and the possibility of interaction between the user, the grapher and the underlying application. The grapher was written in Tcl/Tk, a programming system for developing graphical user interfaces (see (?)). This system has the further advantage of providing a translation routine from graphic canvases into Postscript. Using this feature way we produced all figures in
this paper with the CLEARS tool. Graphical structures are described using a description string, a plain text hierarchical description of the object to be drawn without any exact positioning information. The next example describes a simple tree consisting of a mother node S and the two daughter nodes NP and VP. The graphical result of this description is shown in figure 6.

```
{tree
  {plain-text "S"}
  {plain-text "NP"}
  {plain-text "VP"}}
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Furthermore CLIG can display interactive graphical structures which allow the user to perform actions by clicking on mouse-sensitive regions in the display area. The grapher and an underlying application therefore can behave in a way that the grapher is not only a way to visualise the data of the application, but also could be seen as a real interface between user and application.

The mode of interactivity is totally under the control of the application currently using the grapher.

6 Availability of the system

The system is available at the ftp address: ftp.coli.uni-sb.de:/pub/fracas or on the WWW at the URL http://coli.uni-sb.de~maier/clears.html. For further and more detailed information on the results of the FraCaS project, you should read (?) or (?). These papers are electronically available at the same ftp-directory as the CLEARS tool. You should also have a look at the FraCaS homepage on the WWW at URL http://www.cogsci.ed.ac.uk:80~fracas/

7 Conclusion

Initial reactions to demonstrations of the educational tool suggest that it has the potential to become a widely used educational aid. We also believe that the programs implemented and documented in this work provide the nucleus of a larger library of reusable programs for computational semantics. Our current plans are to test the system with a wide class of users to discover areas requiring extension or modification. A longer term aim would be to integrate the system with existing grammar development environments.