A General Architecture for Text Engineering (GATE) – a new approach to Language Engineering R&D

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1 Introduction

An increasing number of research and development efforts have recently positioned themselves under the banner Language Engineering (LE). This signals a shift away from well-established labels such as Natural Language Processing (NLP) and Computational Linguistics. Examples include the renaming of UMIST’s Department of Language and Linguistics (location of the Centre for Computational Linguistics) as the Department of Language Engineering, and the naming of the European Commission’s current relevant funding programme Language Engineering (the previous programme was called Linguistic Research and Engineering). The new journal of Natural Language Engineering

\footnote{The University of Manchester Institute of Science and Technology, Manchester, UK}
is another example.

We shall argue here that this shift is more than simple TLA-fatigue. The new name reflects a change of emphasis within the field towards:

- increasing use of quantitative evaluation as a metric of research achievement;
- renewed interest in statistical language models and automatically-generated resources;
- increasing availability and use of large-scale resources (e.g. corpora, machine-readable dictionaries);
- a re-orientation of language processing research to large-scale applications, with a concomitant emphasis on predictability and conformance to requirements specifications (i.e. emphasis on engineering issues).

Section 2 expands on these points, and the rest of the report then argues that this shift requires a more general approach to LE research and development, centred on the provision of support software in the form of a general architecture and development environment specifically designed for text processing systems. Under EPSRC grant GR/K25267 the NLP group at the University of Sheffield are developing a system that aims to implement this new approach (Wilks, Gaizauskas 1994). The system is called GATE – the General Architecture for Text Engineering.

GATE is an architecture in the sense that it provides a common infrastructure for building LE systems (rather like the frame of a building or the interface specifications for the bus and peripherals of a computer). It is also a development environment that provides aids for the construction, testing and evalu-

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2The editorial of the first issue also discusses the new name (Boguraev, Garigliano, Tait 1995).

3TLA: three-letter acronym

4The Engineering and Physical Science Research Council, UK funding body.
ation of LE systems (and particularly for the reuse of existing components in new systems).

Section 3 describes the architecture. Section 4 describes an initial application of GATE to collaborative research in Information Extraction (IE). Appendix A discusses three existing systems:

- ALEP (Simpkins 1992), which turns out to be a rather different enterprise from ours;
- MULTEXT (Thompson 1995a; Ballim 1995; Finch, Thompson, McKelvie 1995), a different but largely complementary approach to some of the problems addressed by GATE, which is particularly strong on SGML support and elements of which we intend to integrate with GATE;
- TIPSTER (ARPA 1993a), whose architecture (Grishman 1995) has been adopted as the storage substructure of GATE, and which has been a primary influence in the design and implementation of our system.

Appendix B is a preliminary design and implementation document for GATE.

2 Current trends in Language Engineering R&D

We noted at the outset a recent trend towards re-positioning language processing R&D as Language Engineering. This should not be taken to imply or require the death of [Computational] Linguistics! The shift is quite possibly one of from theory to practice. This section examines the background and consequences of the trend.
Packing up the toys

Several commentators have characterised the broad trend of AI approaches to language as tending towards the “toy problem syndrome”, expressing the view that AI has too often chosen to investigate artificial, small-scale applications of the technology under development. These “toy” problems are intended to be representative of the work involved in building applications of the technology for end-user or “real-world” tasks, but scaling up problem domains from the toy to the useful has often shown the technology developed for the toy to be unsuitable for the real job.

For example, one of the present authors began a large-scale Prolog grammar project in 1985 (Farwell, Wilks 1989): by 1987 it was perhaps the largest DCG (Definite Clause Grammar) grammar anywhere, designed to cover a linguistically well-motivated test set of sentences in English. Interpreted by a standard parser it was able to parse completely and uniquely virtually no sentence chosen randomly from a newspaper. We suspect most large grammars of that type and era did no better, though reports are seldom written making this point.

The mystery for linguists is how that can be: the grammar appeared to inspection to be virtually complete – it had to cover English, if thirty years of linguistic intuition and methodology had any value. It is a measure of the total lack of evaluation of parsing projects up to that time that such conflicts of result and intuition were possible, a situation virtually unchanged since Kuno’s large-scale Harvard parser of the 1960’s (Kuno, Oettinger 1962) whose similar failure to produce a single, preferred, spanning parse gave rise to the AI semantics and knowledge-based movement. The situation was effectively unchanged in 1985 but the response this time around has been quite different,
characterised by:

- use of empirical methods with strict evaluation criteria;
- renewed interest in performance-based models of language, and a corresponding renewal and extension of statistical techniques in the area;
- increased provision and reuse of large-scale data resources;
- greater emphasis on the development of prototype applications of NLP technology to large-scale problems.

**Measuring results with numbers**

With hindsight it may seem obvious that computational linguistics, in the sense of computer programs that seek to exploit the results of linguistic research to make computers do useful things with human language, should be subject to empirical criteria of effectiveness. The big problem, of course, is determining precisely what the criteria of success should be. Should we collect video tapes of Star Trek and measure our efforts in comparison to the Enterprise's lucid conversational computer? There is now a substantial literature on this question (Crouch, Gaizauskas, Netter 1995; EAGLES 1994; Galliers, Sparck Jones 1993; Palmer, Finin 1990; Sparck Jones 1994), and more practical solutions to the evaluation problem have emerged in a number of areas.

Participants in the TIPSTER programme and the MUC (Message Understanding Conference, an information extraction competition) and TREC (Text Retrieval Conference, an information retrieval (or ‘document detection’) competition) competitions (ARPA 1992, 1994), for example, build systems to do precisely-defined tasks on selected bodies of news articles. Human analysts

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5There is, of course, at least one other sense, that of using computational tools to aid linguistic research.
are employed to produce correct answers for some set of previously unseen
texts, and the systems run to produce machine output for those texts. The
performance of the systems relative to human annotators is then measurable
quantitatively. Quantitative evaluation metrics bring numerically well-defined
concepts like precision and recall, long used to evaluate information retrieval
systems, to language engineering.

It seems likely that the linking of quantitative performance metrics to funding,
as is the case in the U.S., has fostered a culture willing to pursue any meth-
ods that are effective in these terms even where theoretical purity suggests a
different route. Whether this is a good or a bad thing is left as an exercise for
the reader. We note, however, that the recent successes of speech recognition
technology arose in a similar culture (Church, Mercer 1993).

The U.S. model is not without significant disadvantages, however, principally:

1. a tendency to exclude novelty as sites all focus on one set of tasks;

2. the high cost of producing evaluation data and administering competitive
evaluation.

In the IE field (1) is evident in the current bias towards template-filling, an
application designed at the behest of the U.S. intelligence community.

Regarding (2), analysis of the funding required for a European equivalent to the
American programmes has led the European Commission to reject comparative
evaluation (Cencioni 1995).

We shall argue in section 3 below that both of these problems can be offset
while retaining the benefits of empirical evaluation.

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6Machine Translation systems had, of course, always been subject to rigorous evaluation
from its earliest days (Lehrberger, Bourbeau 1988), but this tradition did not spread further
until recently.
Performance vs. competence

A related phenomenon is the increasing use of statistical techniques in the field (Jelinek 1985; Church, Mercer 1993). Instead of an introspective process of investigation into the underlying mechanisms by which people process language (or, in Chomsky’s terms, their competence), statistical NLP attempts to build models of language as it exists in practical use – the performance of language. (Rens Bod’s thesis contains an extended discussion of this distinction – Bod 1995.)

Statistical methods have had significant successes, and the debate once thought closed by Chomsky’s ‘I saw a fragile whale’ is now as open as it ever has been. Most part-of-speech taggers now rely on statistics (Leech, Garside, Atwell 1983; Robert, Armstrong 1995) and it seems possible that parsers may also go this way (Church 1998; Magerman 1994, 1995; Briscoe, Carroll 1993), though more conventional methods are also increasing in quality and robustness (Strzalkowski, Scheyen 1993).

It is possible that there is a natural ceiling to the advance of performance models (Wilks 1994), but the point of relevance for this report is that the jury is still out on performance vs. competence. Thus, as well as a host of competing linguistic and lexicographic theories, LE is home to a thoroughgoing paradigm conflict. Two important consequences ensue.

First, empirical measurement of the relative efficacy of competing techniques is even more important. Secondly, hybrid models are becoming common, implying a growing need for the flexible combination of different techniques in single systems. Numbers of techniques that have poor performance alone may sometimes be combined to produce a whole greater than the sum of the parts (Wilks, Guthrie, Guthrie, Cowie 1992; Bartell, Cottrell, Belew 1994).
Reusing resources in practice

In common with other software systems, LE components deploy both data and process elements. The quality, quantity and availability of shared data resources has increased dramatically during the late 1980s and 1990s\(^7\).

The sharing of processing (or algorithmic) resources remains more limited (Cunningham, Freeman, Black 1994), one key reason being that the integration and reuse of different components can be a major task. For example, the ESPRIT project PLUS devoted substantial effort to reusing a theorem prover from IBM’s STUF system for parsing an HPSG grammar (Black ed. 1991). The COBALT project (Rocca, Black, Cunningham, Zarri, Celnik 1993) failed to locate a reusable shallow analysis engine with a cost-benefit profile for reuse superior to reimplementation (Black, Cunningham 1993). The CRISTAL project planned to reuse results from those projects but again platform specificity had a negative impact (Cunningham, Underwood, Black 1994). Section\(^2\) noted the increase in scale of the problems that LE research systems aim to tackle. In parallel with this trend, the overhead involved in creating a full-scale IE system, for example, is also increasing. For many research groups the costs are prohibitive. Any method for alleviating the problems of reuse would make a significant contribution to LE research and development.

On a smaller scale, the typical life-cycle of doctoral research in AI/NLP is:

- have an idea;
- reinvent the wheel, fire and kitchen sinks to provide a framework for the idea;

\(^7\)Extensive discussion of the repositories (LDC, CLR, MLSR etc.) of corpora and lexicon resources and their holdings up to 1994 can be found in (Wilks et al. 1996). More recent developments concerning ELRA (the European Linguistic Resources Association can be found in Elsnews 4.5 (November 1995).
• program the idea;
• publish;
• throw the system to the dogs / tape archivist / shelfware catalogue.

A framework which enabled relatively easy reuse of past work could significantly increase research productivity in these cases.

Nuts and bolts

With the increasing scale of LE systems, software engineering issues become more important. Just as the construction of the Severn Bridge was a rather different order of problem from that of laying a couple of planks across a farmland ditch, the development of software capable of processing megabytes of text, written by idiosyncratic wetware\(^8\), in short periods of time to measurable levels of accuracy is a quite different game from that, say, of providing natural language interaction for the control of a robot arm that moves blocks on a tabletop (Winograd 1972). The nuts and bolts are a lot bigger, and may even be of a completely different fabric altogether. This type of issue has been solved successfully in other areas of computer science, e.g. databases. Failure to address software-level robustness (as opposed to the robustness of the underlying NLP technology), quality and efficiency will be a barrier to transferring LE technology from the lab to marketplace.

Some other requirements relating to the technological foundations of these systems also arise. Module interchangeability (at both the data and process levels), a kind of ‘software lego’ or ‘plug-and-play’, would allow users to buy into LE technology without tying them to one supplier. (In a different domain this was the message of the Open Systems movement. Let’s hope we don’t

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\(^8\) Journalists.
emulate their success!) Also desirable are easy upgrade routes as technology
improves. In addition to the reasons noted above, precise quantification of
performance measures are also needed to foster confidence in the capability of
LE applications to deliver, and robustness and efficiency for large text volumes
are prerequisites for many applications. Software multilinguality and operat-
ing system independence are also issues. Finally, maximising cross-domain
portability will favourably impact delivery costs. (See (Grishman 1995) for a
similar review of these points.)

Gridlock on the super-highway

Our discussion of trends in LE concludes with two major LE application ar-
eas, Information Extraction (IE) and Machine Translation (MT), which both
exhibit the trends discussed above.

Recent years have seen significant improvements in the quality and robustness
of LE technology. Rapid improvement in robustness (the ability to deal with
any input) and quality are evident in the leading systems (Jacobs ed. 1992;
ARPA 1992; ARPA 1993b; Strzalkowski, Scheyen 1993; Magerman 1995). In
this year’s MUC-6 competition (Sundheim 1995a,b; Onyshkevych 1995a,b)
initial results indicate that named-entity recognition can now be performed
by machines to performance levels equal those of people (ARPA 1996; Wakao,
Gaizauskas, 1995). The result is that applications of the technology to large-
scale problems are increasingly viable.

IE is intended to deal with the rapidly growing problem of extracting meaning-
ful information from the vast amount of electronic textual data that threatens
to engulf us. Scientific journal abstracts, financial newswires, patents and
patent abstracts, corporate and government technical documentation, elec-
Electronic mail and electronic bulletin boards all contain a wealth of information of vital economic, social, scientific and technical importance. The problem is that the sheer volume of these sources is increasingly preventing the timely finding of relevant information, a state of affairs exacerbated by the explosive growth of the Internet (Kroll 1994; Thompson 1995b).

Existing information retrieval (Salton 1989) solutions to this problem are a step in the right direction, and the industry supplying IR applications can expect to continue in its current healthy state.

IR systems, however, attempt no analysis of the meaningful content of texts. This is a strength of the approach, leading to robustness and speed, but also a weakness, as the information represented by the texts is retrieved in the format of the texts themselves – i.e. in the ambiguous and verbose medium of natural language.

Extraction of information in definite formats is an obvious solution and one which can only be achieved through the application of LE technology.

The IE community have been leaders in quantitative evaluation (ARPA 1993b). Statistical methods are widely used, but so is more conventional CL (ARPA 1993). The need for systematic reuse of both data and processing resources has been recognised, and work funded to facilitate this, and the importance of software engineering matters noted (TIPSTER 1994).

A similar situation is evident in MT research. Nyberg, Frederking, Farwell, Wilks (1994) note the continuing importance of evaluation for MT; Nirenburg, Mitamura, Carbonell (1994) propose that the multi-approach, multi-paradigm nature of the field be embodied in ‘multi-engine’, or ‘adaptive’ MT systems.
3 GATE

The previous section argued that the new name, *Language Engineering*, reflects changes of territory for natural language R&D, and drew out a set of requirements for LE systems. We believe that these requirements may best be met by the provision of dedicated support software for researchers and applications developers, in the form of an *architecture* and *development environment*, and we have developed an initial version of such a system, called GATE - a General Architecture for Text Engineering.

GATE is an *architecture* in the sense of providing a common infrastructure for building LE systems. An analogy is the hardware architecture of a PC: provided a manufacturer of, say multi-media controller cards follows the published specification of the PC bus, BIOS etc., the card should work in any machine. Further, the card should be able to rely on certain common services provided by the PC architecture.

GATE is a *development environment* because it provides a variety of data visualisation, debugging and evaluation tools (with point-and-click interface), and a set of standardised interfaces to reusable components. It supports the development of LE systems in a way analogous to the support for program development provided by compilers, libraries, debuggers and syntax-aware editors.

GATE will be available free for research purposes, and is intended to grow and develop in response to the needs of the UK and European LE communities. Its design incorporates results from related European and US initiatives and bridges the infrastructural work of the two.

The rest of this section:
• casts the constraints on LE systems identified in section 2 as requirements for GATE;
• gives an overview of the architecture in the context of the requirements;
• describes the arrangements for collaborative work on IE using the initial distribution of GATE;
• gives a roadmap of future development of the system.

More detail on GATE can be found in Appendix B, and on related work in Appendix A.

Summary of requirements

A general architecture for LE R&D should:

• support collaborative research;
• support hybrid systems, ‘plug-and-play’ module interchangeability, and easy upgrading;
• support the reuse of existing and future algorithmic components and data resources, whether they be the results of PhD projects or multinational strategic initiatives;
• contribute to software-level robustness, quality and efficiency;
• contribute to portability across problem domains and application areas;
• support comparative evaluation, preferably at lower cost than the US programmes and without stifling innovation;
• contribute to software portability across languages and across operating systems and programming languages.
Architecture overview

GATE presents LE researchers or developers with an environment where they can use tools and linguistic databases easily and in combination, launch different processes, say taggers or parsers, on the same text and compare the results, or, conversely, run the same module on different text collections and analyse the differences, all in a user-friendly interface. Alternatively, module sets can be strung together to make e.g. IE, IR or MT systems. Modules and systems can be evaluated (using e.g. the Parseval tools), reconfigured and reevaluated – a kind of edit/compile/test cycle for LE components.

![Figure 1: The three elements of GATE](image)

GATE comprises three principal elements (figure 1):

- a database for storing information about texts and a database schema based on an object-oriented model of information about texts (the GATE Document Manager – GDM);
- a graphical interface for launching processing tools on data and viewing and evaluating the results (the GATE Graphical Interface – GGI);
• a collection of wrappers for algorithmic and data resources that inter-operate with the database and interface and constitute a Collection of REusable Objects for Language Engineering – CREOLE.

GDM is based on the TIPSTER document manager, and the initial implementation supplied by the Computing Research Lab at New Mexico State University (whose help we gratefully acknowledge). It is planned to enhance the SGML capabilities of this model, possibly by exploiting the results of the MULTEXT project (we thank colleagues from ISSCO and Edinburgh for making available documentation and advice on this subject). See Appendix A for details of the relationship between GATE and these (and other) projects.

GDM provides a central repository or server that stores all information an LE system generates about the texts it processes. All communication between the components of an LE system goes through GDM, insulating parts from each other and providing a uniform API (applications programmer interface) for manipulating the data produced by the system. Benefits of this approach include the ability to exploit the maturity and efficiency of database technology, easy modelling of blackboard-type distributed control regimes (of the type proposed by: Boitet, Seligman 1994; section on control in Black ed. 1991) and reduced interdependence of components.

GGI is in development at Sheffield. It is a graphical launchpad for LE subsystems, and provides various facilities for viewing and testing results and playing software lego with LE components: interactively stringing objects into different system configurations.

All the real work of analysing texts (and maybe producing summaries of them, 9Where very large data sets need passing between modules other external databases can be employed if necessary.)
or translations, or SQL statements...) in a GATE-based LE system is done by CREOLE modules.

Note that we use the terms *module* and *object* rather loosely to mean interfaces to resources which may be predominantly algorithmic or predominantly data, or a mixture of both. We exploit object-orientation for reasons of modularity, coupling and cohesion, fluency of modelling and ease of reuse (see e.g. Booch 1994).

Typically, a CREOLE object will be a wrapper around a pre-existing LE module or database – a tagger or parser, a lexicon or ngram index, for example. Alternatively objects may be developed from scratch for the architecture – in either case the object provides a standardised API to the underlying resources which allows access via GGI and I/O via GDM. The CREOLE APIs may also be used for programming new objects.

The initial release of GATE will be delivered with a CREOLE set comprising a complete MUC-compatible IE system (to begin with, more of a pidgin than a creole!). Some of the objects will be based on freely available software (e.g. the Brill tagger (Brill 1994)), while others are derived from Sheffield’s MUC-6 entrant, LaSIE\(^{10}\) (Gaizauskas, Humphreys, Wakao, Cunningham 1995; Gaizauskas, Humphreys, Wakao, Cunningham 1996). This set is called VIE – a Vanilla IE system. See section 4 for an overview. CREOLE will expand quite rapidly during 1996, to cover a wide range of LE R&D components (such as those currently available at the ACL-sponsored Natural Language Software Registry at DFKI\(^{11}\)), but for the rest of this section we’ll use IE as an example of the intended operation of GATE.

\(^{10}\)Large-Scale IE.

\(^{11}\)URL: http://cl-www.dfki.uni-sb.de/cl/registry/draft.html
The recent MUC competition, the sixth, defined four IE tasks to be carried out on Wall Street Journal articles. Sheffield’s system did well, scoring in the middle of the pack in general and doing as well as the best systems in some areas. Developing this system took 24 person-months, one significant element of which was coping with the strict MUC output specifications. What does a research group do which either does not have the resources to build such a large system, or even if it did would not want to spend effort on areas of language processing outside of its particular specialism? The answer until now has been that these groups cannot take part in large-scale system building, thus missing out on the chance to test their technology in an application-oriented environment and, perhaps more seriously, missing out on the extensive quantitative evaluation mechanisms developed in areas such as MUC. In GATE and VIE we hope to provide an environment where groups can mix and match elements of MUC technology from other sites (including ours) with components of their own, thus allowing the benefits of large-scale systems without the overheads. A parser developer, for example, can replace the parser supplied with VIE.

Licencing restrictions preclude the distribution of MUC scoring tools with GATE, but Sheffield will arrange for evaluation of data produced by other sites. In this way, GATE/VIE will support comparative evaluation of LE components at a lower cost than the ARPA programme (partly by exploiting their work, of course!). Because of the relative informality of these evaluation arrangements, and as the range of evaluation facilities in GATE expands beyond the four IE tasks of the current MUC, we should also be able to offset the tendency of evaluation programmes to dampen innovation.

Similarly we aim to make collaboration between research groups much easier. Sites specialising on different LE subtasks can combine their efforts into bigger
application-oriented systems with minimal overhead. We hope that we can help the community squeeze a little more research time out of industrially-oriented projects by cutting down on the time spent integrating research work into demonstrator systems.

Working with GATE/VIE, the researcher will from the outset reuse existing components, the overhead for doing so being much lower than is conventionally the case – instead of learning new tricks for each module reused, the common APIs of GDM and CREOLE mean only one integration mechanism must be learnt. And as CREOLE expands, more and more modules and databases will be available at low cost. We also endorse object orientation (OO) in this context, as an enabling technology for reuse (Booch 1994), and hope to move towards sub-component level reuse at some future point, possibly providing C++ libraries as part of an OO LE framework (Cunningham, Freeman, Black 1994).

As we built our MUC system it was often the case that we were unsure of the implications for system performance of using tagger X instead of tagger Y, or gazetteer A instead of pattern matcher B. In GATE, substitution of components is a point-and-click operation in the GGI interface. (Note that delivered systems, e.g. EC project demonstrators, can use GDM and CREOLE without GGI – see below.) This facility supports hybrid systems, ease of upgrading and open systems-style module interchangeability.

Of course, GATE does not solve all the problems involved in plugging diverse LE modules together. There are two barriers to such integration:

- incompatibility of representation of information about text and the mechanisms for storage, retrieval and inter-module communication of that information;
- incompatibility of type of information used and produced by different
GATE enforces a separation between these two and provides a solution to the former based on the work of the TIPSTER architecture group (TIPSTER 1994). Because GATE places no constraints on the linguistic formalisms or information content used by CREOLE objects, the latter problem must be solved by dedicated translation functions – e.g. tagset-to-tagset mapping – and, in some cases, by extra processing – e.g. adding a semantic processor to complement a bracketing parser in order to produce logical form to drive a discourse interpreter. As more of this work is done we can expect the overhead involved to fall, as all results will be available as CREOLE objects. In the early stages Sheffield will provide some resources for this work in order to get the ball rolling, i.e. we will provide help with CREOLEising existing systems and with developing interface routines where practical and necessary. We are confident that integration is possible (partly because we believe that differences between representation formalisms tend to be exaggerated) – and others share this view, e.g. the MICROKOSMOS project (Beale, Nirenburg, Mahesh 1995), which seeks to integrate many types of knowledge source in a useable whole, as well as the LexiCadCam experience at New Mexico (Wilks, Guthrie, Slator 1996) which sought to provide core lexical information as needed in a range of user-specified formats.

GATE is also intended to benefit the LE system developer (which may be the LE researcher with a different hat on, or industrialists implementing systems for sale or for their own text processing needs). Using GATE for the delivery of a system is illustrated in figure 2. A delivered system comprises a set of CREOLE objects, the GATE runtime engine (GDM and associated APIs) and a custom-built interface (maybe just character streams, maybe a Visual Basic Windows GUI, . . . ). The interface might reuse code from GGI, or might be developed from scratch.
The LE user may upgrade by swapping parts of the CREOLE set if better technology becomes available elsewhere. This model for the commercialisation of LE technology is already beginning to operate in the US, where a number of organisations are preparing TIPSTER-compatible modules for sale or distribution for research. (These organisations include NMSU, SRA, HNC, University of Massachusetts, Paracell, Logicon (Dunning 1995, personal communication).) All TIPSTER-compatible modules will also work with GATE as GATE itself is designed to be a TIPSTER-compatible system. Thus the pool of easily reusable LE resources available to researchers and developers using GATE has the potential to become a large, rich set of modules from a good proportion of the LE community world-wide. Also, it may well become the case that organisations purchasing LE software will require TIPSTER compatibility (this will be true of US government organisations, for example).

At the software engineering level GATE:
• contributes to robustness and quality by providing a mature infrastructure;
• contributes to efficiency via the design of the TIPSTER text model and by access to fast database technology underlying GDM.

As regards operating system independence, GDM and GGI will initially be available for Linux, SunOS, Solaris 2 and other UNIX platforms as required, but will avoid using UNIX-specific facilities. A Windows version may follow at some point (see the roadmap section below). CREOLE portability is more difficult. GATE places no constraints on the implementation languages and platforms of CREOLE objects, so they may or may not be portable.

GATE cannot eliminate the overheads involved with porting LE systems to different domains (e.g. from financial news to medical reports). Tuning LE system resources to new domains is a current research issue (see also: the LRE DELIS and ECRAN projects; Evans, Kilgariff 1995). The modularity of GATE-based systems should, however, contribute to cutting the engineering overhead involved.

Collaboration using GATE and VIE

Sheffield will support collaborative work using GATE/VIE for LE research groups (typically academic groups), businesses with IE needs and producers of lexicons and dictionaries. The three groups are technology, data and resource providers respectively, contributing CREOLE modules, test data (e.g. manually extracted information and the relevant source texts) and machine-readable language resources (e.g. dictionaries). The projected benefits for participants include:

• comparative quantitative evaluation of candidate technologies for IE;
- technology providers may specialise on components of the IE task, avoiding the overhead of providing a complete IE system while still working within the framework of a complete NLP application;
- data providers (typically industrial concerns) get access to IE technology applied to their particular textual problem domains;
- resource providers can assess the performance of their products and increase the market for them by encouraging their use in applied IE systems.

Note that there will be no requirement to supply source code for contributed modules, and that intellectual property and other rights will be safeguarded by appropriate legal agreements.

Roadmap

Our first goal for GATE is to provide a prototype of the architecture along with a set of CREOLE objects for doing MUC-style information extraction. GATE/VIE 1.0 will be available at the start of 1996 to research groups and development projects who wish to participate in IE systems development. We will at that point solicit contributions of CREOLE replacements for VIE modules, and data sets from organisations with IE needs.

Initial versions will run under UNIX and X11 only, and support the gcc C[++] compilers and Tcl 7.4 / Tk 4.0 (Ousterhout 1994) and higher.

Subsequent developments will concentrate on expanding the set of CREOLE objects in order to:

- exemplify the use of GATE in other application areas, e.g. MT, CALL, Speech research;
• make GATE a standard resource repository via CREOLE wrappers for LE resources like lexicons, grammars etc. (possibly in collaboration with the newly-formed European Language Resources Association).

Sheffield will contribute resources to integration of other sites’ components to start with.

On the technical side issues include:

• 16 bit character support;
• internationalisation of system messages to increase ease of use for non-native English speakers (probably taking into account the results of LRE project 61-003 GLOSSASOFT (Hudson 1995));
• evaluation and revision of the GGI interface, and the addition of further data visualisation and debugging facilities;
• SGML support;
• portability to other platforms.

We envisage considerable input from other research groups and welcome criticism and comment on our implementation (and offers of work!).

4 VIE, a Vanilla Information Extraction system

As originally envisaged (Wilks, Gaizauskas 1994), GATE will be distributed with a set of CREOLE objects that together implement a complete information extraction system capable of producing results compatible with the MUC-6 task definitions. This CREOLE set is called VIE, a Vanilla IE system, and it
is intended that participating sites use VIE as the basis for specialising on sub-tasks in IE. By replacing a particular VIE module – the parser, for example – a participating group will immediately be able to evaluate their specialist technology’s potential contribution to full-scale IE applications. Sheffield has access to the MUC-6 scoring tools (and the PARSEVAL software) and will run periodic evaluations of various VIE-based configurations.

It is envisaged that LE research groups (typically academic research groups) supply modules to replace parts of VIE. Businesses with IE needs can also participate in the programme by contributing test sets and task definitions. Resource builders like dictionary publishers will be approached to supply research versions of their online texts.

The most recent MUC competition, MUC-6, defined four tasks to be carried out on Wall Street Journal articles:

- named entity (NE) recognition, the recognition and classification of definite entities such as names, dates, places;
- coreference (CO) resolution, the identification of identity relations between entities (including anaphoric references to them);
- template element (TE) construction, a fixed-format, database-like enumeration of organisations and persons;
- scenario template (ST) construction, the detection of specific relations holding between template elements relevant to a particular information need (in this case personnel joining and leaving companies) and construction of a fixed-format structure recording the entities and details of the relation.

VIE is an integrated system that builds up a single, rich model of a text which is then used to produce outputs for all four of the MUC-6 tasks. Of course this model may also be used for other purposes aside from MUC-6 results
generation, for example we currently generate natural language summaries of the MUC-6 scenario results.

Put most broadly, and superficially, VIE’s approach involves compositionally constructing semantic representations of individual sentences in a text according to semantic rules attached to phrase structure constituents which have been obtained by syntactic parsing using a corpus-derived context-free grammar. The semantic representations of successive sentences are then integrated into a ‘discourse model’ which, once the entire text has been processed, may be viewed as a specialisation of a general world model with which the system sets out to process each text.

Features which distinguish the system are:

- an integrated approach allowing knowledge at several linguistic levels to be applied to each MUC-6 task (e.g. coreference information is used in named entity recognition);
- the absence of any overt lexicon – lexical information needed for parsing is computed dynamically through part-of-speech-tagging and morphological analysis;
- the use of a grammar derived semi-automatically from the Penn TreeBank corpus;
- the use and dynamic acquisition of a world model, in particular for the coreference and scenario tasks;
- a summarisation module which produces a brief natural language summary of scenario events.

VIE will be available with the initial release of GATE.
5 Conclusion

We have argued that the language processing field is in a state of rapid change, and that the focus is shifting to large-scale applications and systems that are beginning to produce marketable solutions. The new emphasis has generated a new name – *Language Engineering*.

We suggest that a new approach to software support for LE R&D should be developed to parallel this shift. We have proposed an architectural solution – GATE – grounded on previous work in the area.

GATE aims to be a standard architecture for LE systems. Standards, of course, must sell themselves – imposition rarely works (whether in computer science or in real life!).

We hope that the LE community will endorse our argument for an LE support architecture, and that our implementation will be strong enough to fulfil the promise of the idea.

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APPENDICES

A Related work

We discuss three systems here, ALEP, MULTEXT and the TIPSTER Architecture.

ALEP

ALEP (Simpkins 1992) is an EC project which aims to provide an Advanced Language Engineering Platform – superficially a similar goal to ours. The approaches are quite different, however. ALEP is an advanced system for developing and manipulating feature structure knowledge-bases under unifi-
cation. Also provided are several parsing algorithms, algorithms for transfer, synthesis and generation (Schütz 1994). As such it is a system for developing particular types of data resource and for doing a particular set of tasks in LE in a particular way. ALEP does not aim for complete genericity (or it would be in the business of providing algorithms for Baum-Welch estimation, or fast regular expression matching, or ...). Supplying a generic system to do every LE task is clearly impossible, and prone to instant obsolescence in a rapidly changing field. GATE, in contrast, is a shell, a backplane into which the whole spectrum of LE modules and databases can be plugged. Components used within GATE will typically exist already – our emphasis is reuse, not reimplemention. Our project is to provide a flexible and efficient way to combine LE components to make LE systems (whether experimental or for delivered applications) – not to provide ‘the one true system’, or even ‘the one true development environment’: ALEP-based systems might well provide components operating within GATE.

The ALEP enterprise, then, is orthogonal to ours – there is no significant overlap or conflict.

**MULTEXT**

MULTEXT (Ballim 1995; Thompson 1995b; Finch, Thompson, McKelvie 1995) is another EC project, whose objective is to produce tools for multilingual corpus annotation and sample corpora marked-up according to the same standards used to drive the tool development. Annotation tools under development perform text segmentation, POS tagging, morphological analysis and parallel text alignment. The project has defined an architecture centred on a model of the data passed between the various phases of processing implemented by the tools.
MUL TEXT is based on SGML, the Standard Generalised Markup Language (Goldfarb 1990). SGML works by adding extra information to texts in a standard format. For example, the (rather short) news article

Reuter
Dog bites man.
Newshound implicated.

might appear in SGML as

<DOC>
<HEADERS>Reuter</HEADERS>
<SENT>Dog bites man.</SENT>
<SENT>Newshound implicated.</SENT>
</DOC>

Markup is between chevrons, ‘<’ and ‘>’; slashes signify the end of a marked-up entity. The language is information-neutral (the tags ‘DOC’, ‘SENT’ etc. are not part of the language definition) and is encoded in whatever character set the source text originates in (e.g. ASCII).

The MUL TEXT architecture is based on a commitment to TEI-style (the Text Encoding Initiative (Sperberg-McQueen, Burnard 1994)) SGML encoding of information about text. The TEI defines standard tag sets for a range of purposes including many relevant to LE systems. Tools in a MUL TEXT system communicate via interfaces specified as SGML document type definitions (DTDs – essentially tag set descriptions), using character streams on pipes – an arrangement modelled after UNIX-style shell programming. This UNIX flavour was also apparent in provision for record/field encoding (records = lines of text; fields = whitespace-separated character groups) of markup as
an interchangeable alternative to SGML (though this was dropped from later
versions of the tools), and in provision of an SGML-aware version of `sed`, the
UNIX pattern search and replace tool. Organisational problems have, unfor-
tunately, led to an early termination of the project, but the tools and the
architecture they run in will still be completed and distributed for research
purposes.

MULTEXT endorses the view that SGML is an appropriate and flexible lan-
guage for the splitting and recombination of text analysis elements. A tool
selects what information it requires from its input SGML stream and adds
information as new SGML markup. An advantage here is a degree of data-
structure independence: so long as the necessary information is present in its
input, a tool can ignore changes to other markup that inhabits the same stream
– unknown SGML is simply passed through unchanged. A disadvantage is that
although graph-structured data may be expressed in SGML, doing so is com-
plex (either via concurrent markup, the specification of multiple legal markup
trees in the DTD, or by rather ugly nesting tricks to cope with overlapping,
aka “milestone tags”). Graph-structured information might be present in the
output of a parser, for example, representing competing analyses of areas of
text.

Another feature of MULTEXT is a set of abstract data types (ADTs) for all
tool I/O (Ballim 1995) supported by a single shared API (Application Pro-
gram(mers’) Interface) for access to the types. An executive (the tool shell)
glues tools together in particular configurations according to user specifi-
cations. The shell may extract sub-trees from SGML documents to reduce the
I/O load where tools only require a subset of a marked-up document.

The ADT set forms an object-oriented model\textsuperscript{13} of the data present in a marked-

\textsuperscript{13}OO in the sense of using inheritance and data encapsulation.
up document. Example classes include Sentence, SentenceBlock (sequence of sentences), LexicalWord (word plus definition from a lexicon). The ADT model reflects the type of processing available in the tool set – there is a type TaggedSentence, for example, but not a ParsedSentence.

Finally, MULTEXT has developed some general support infrastructure for handling SGML and for parallelising tool pipelines. A query language for accessing components of SGML documents is defined and API in support of this language provided. For example a program might specify parts of a document by the pattern \texttt{DOC/*/s} which refers to all \texttt<s> objects under \texttt<DOC> tags – all SGML-marked sentences in the document. Additionally SGML-aware versions of various UNIX utilities are in development. Parallel execution may be supported at the level of single tools via a program that distributes pipelined operations over a set of networked machines.

MULTEXT is implemented for the UNIX platform. Access to tools is as unitary programs and via the tool shell; the SGML query language is supported by a C API. The consortium has declared an intention to make implementations generally available, and although the project is finishing early due to logistic difficulties, most tools and the support shell will continue development at ISSCO for release early in 1996.

Summary:

- MULTEXT tools operate on SGML streams.
- An object model of the data in those streams is defined, along with
- an API to access the data.
- An API and query language for accessing components of SGML documents is provided along with
- various useful SGML-aware tools.
TIPSTER II

The TIPSTER programme in the US, currently in its second phase, has also produced a data-driven architecture for NLP systems (Grishman, Dunning, Callan 1995; TIPSTER Architecture Committee 1994). Like MULTEXT, TIPSTER addresses specific forms of language processing, in this case information extraction and document detection (or information retrieval – IR). As will become clear below, however, TIPSTER’s approach is not restricted to particular NL tasks.

Whereas in MULTEXT all information about a text is encoded in SGML, which is added by the tools, in TIPSTER a text remains unchanged while information is stored in a separate database in the form of annotations. Annotations associate portions of documents (identified by sets of start/end byte offsets or spans) with analysis information (attributes), e.g.: POS tags; textual unit type; template element. In this way the information built up about a text by NLP (or IR) modules is kept separate from the texts themselves. In place of an SGML DTD an annotation type declaration defines the information present in annotation sets, for example a set of values for MUC-style organisation template elements. Figure 3 shows an example from (Grishman, Dunning, Callan 1995). SGML I/O is catered for by API calls to import and export SGML-encoded text.

The definition of annotations in TIPSTER forms part of an object-oriented model that deals with inter-textual information as well as single texts. Documents are grouped into collections, each with a database storing annotations and document attributes such as identifiers, headlines etc. Collections are the first-class entities in the architecture. The model also describes elements of
IE and IR systems relating to their use, with classes representing queries and information needs.

The TIPSTER architecture is designed to be portable to a range of operating environments, so it does not define implementation technologies. Particular implementations make their own decisions regarding issues such as parallelism, user interface, or delivery platform. An implementation in C and Tcl (Ousterhoot 1994) from CRL (the Computing Research Lab, New Mexico State University) implements client-server operation (using Tcl-dp), a server database manager fielding requests from client modules.

This implementation is available now and includes both C and Tcl APIs. It is not currently portable beyond UNIX, though Tcl/Tk is becoming available on Windows and Macintosh.
The architecture was the result of unpaid collaboration between a large number of ARPA-supported sites in the US.

**Comparison of MULTEXT and TIPSTER**

Both projects propose architectures appropriate for LE, but there are a number of significant differences. We discuss seven here, then note the possibility of complimentary interoperation of the two.

1. MULTEXT adds new information to documents by augmenting an SGML stream; TIPSTER stores information remotely in a dedicated database. This has several implications. Firstly, TIPSTER can support documents on read-only media (e.g. CD-ROMs, which may be used for bulk storage by organisations with large archiving needs, even though access will then be slower than from hard disk). Secondly, TIPSTER avoids the difficulties referred to earlier of representing graph-structured information in SGML. From the point of view of efficiency, the original MULTEXT model of interposing SGML between all modules implies a generation and parsing overhead in each module. Later versions have replaced this model with a pre-parsed representation of SGML to reduce this overhead. This representation will presumably be stored in intermediate files, which implies an overhead from the I/O involved in continually reading and writing all the data associated with a document to file. There would seem no reason why these files should not be replaced by a database implementation, however, with potential performance benefits from the ability to do I/O on subsets of information about documents (and from the high level of optimisation present in modern database technology).

2. A related issue is storage overhead. TIPSTER is minimal in this respect, as there is no inherent need to duplicate the source text (which
also means that it works naturally with read-only media like CD-ROMs). MULTEXT potentially has to duplicate the source text at each intermediary stage, although this might be ameliorated by shifting to a database implementation.

3. TIPSTER’s data architecture is process-neutral – the objects in the model are generic to all information that is associated with definite ranges of text. (The more concrete aspects of the architecture to do with IE and IR model the objects involved in user interaction with such systems.) MULTEXT’s model is tool-specific, as noted above (although the underlying representation language, SGML, is information-neutral).

4. There is no easy way in an SGML-based system to differentiate sets of results (i.e. sets of markup) by e.g. the program or user that originated them. In general, storing information about the information present in an SGML system (or meta-information) is messy. This is a problem for MULTEXT but not for TIPSTER. A related point is that TIPSTER can easily support multi-level access control via a database’s protection mechanisms – this is again not straightforward in SGML.

5. Distributed control is easy to implement in a database-centred system like TIPSTER – the DB can act as a blackboard, and implementations can take advantage of well-understood access control (locking) technology. How to do distributed control in MULTEXT is not obvious.

6. TIPSTER provides no tools or databases, but many sites are already committed to TIPSTER-compatibility, so the set of modules available in the framework will grow over time. MULTEXT is based around a set of tools and reference corpora annotated accordingly.

7. Working implementations of TIPSTER have been available for some months now; MULTEXT will be distributed in 1996.
Interestingly, a TIPSTER system could function as a module in a MULTEXT system, or vice-versa. A TIPSTER storage system could write data in SGML for processing by MULTEXT tools, and convert the SGML results back into native format. Also, the extensive work done on SGML processing in MULTEXT could usefully fill a gap in the current TIPSTER model, in which SGML capability is not fully specified (plans are currently being formed in the US to address this problem – input from European experience would seem advisable). Integration of the results of both projects would seem to be the best of both worlds, and we hope to achieve this in GATE.

Note that we believe that SGML and the TEI must remain central to any serious text processing strategy. The points above do not contradict this view, but indicate that SGML should not form the central representation format of every text processing system. Input from SGML text and TEI conformant output are becoming increasingly necessary for LE applications as more and more publishing adopts these standards. This does not mean, however, that flat-file SGML is an appropriate format for an architecture for LE systems. This observation is born out by the fact that TIPSTER started with an SGML/TEI architecture but rejected it in favour of the current database model, and that MULTEXT has gone halfway to this style by passing pre-parsed SGML between components.

B GATE – design and implementation

Note: this appendix is a preliminary version of design and implementation documentation for GATE and VIE. It is a) incomplete and speculative, and b) repeats some material from earlier sections of the report.
Architecture overview

GATE is based on a combination of the TIPSTER and MULTTEXT models. The centrepiece of the architecture is a TIPSTER-style document management database, chosen for reasons of efficiency, maturity of implementation and ease of extensibility. The current TIPSTER model provides hooks for the incorporation of SGML support but has not fully developed this aspect of the architecture (see above). We plan to capitalise on the work done in MULTTEXT to augment the SGML capabilities of the TIPSTER architecture, probably via the development of a unified API. This unification will not be available in the initial release of GATE (early 1996), however.

GATE will form a bridge between the American work and the European work on SGML and conformance to the TEI guidelines and DTDs.

Components

GATE comprises three principal components (see figure [4]):

**GDM** – the GATE document manager, based on the TIPSTER document manager with added SGML capabilities (and using an implementation from CRL at NMSU, whose assistance we gratefully acknowledge);

**GGI** – the GATE graphical interface, a development tool for LE R&D, providing integrated access to the services of the other components and adding visualisation and debugging tools;

**CREOLE** – a Collection of REusable Objects for Language Engineering: the set of modules integrated with the system. CREOLE comprises wrappers for existing modules, which may or may not require changing, plus modules developed explicitly for GATE compliance. Some objects are process-orientated, some data-oriented.
The first distribution of GATE will be configured as a support tool for collaborative R&D in Information Extraction by the inclusion of a CREOLE set that implements a full-scale MUC-compatible IE system (called VIE, the Vanilla IE system – see section 4).

![Diagram of GATE components]

**GDM** – the GATE Document Manager  
**GGI** - the GATE Graphical Interface  
**CREOLE** - a Collection of REusable Objects for Language Engineering

**Figure 4: The three elements of GATE**

MULTEXT integration will involve:

- creating CREOLE object wrappers for the tool set;
- providing SGML I/O and SGML manipulation via and API based on the MULTEXT work.

**Integrating CREOLE objects**

As noted above, GATE is *not* a system for doing LE, but a backplane to assemble processing modules and databases to form LE systems (whether experimental or for end-user delivery). The analogy here is with extensible com-
puter hardware architectures – expansion cards in a PC, for example. Just as producing a card to do fast video off a VESA bus or to drive a serial line from an ISA slot means conforming to the protocols defined by those architectures, so integrating LE objects in GATE (i.e. producing a new member of CREOLE) imposes some interface constraints. These constraints are in the form of functions that must be available for GDM and GGI, and are described here.

When the user initiates a particular CREOLE object via GGI (or when a programmer does the same via the GATE API when building an LE application) the object is initialised using the standard calls provided in the CREOLE wrapper. The object then runs, obtaining the information it needs (document source, annotations from other objects) via calls to the GDM API. Its results are then stored in the GDM database and become available for examination via GGI or to be the input to other CREOLE objects.

Figure 5 shows the two ways to provide the CREOLE wrapper functions. Packages written in C or in languages which can be used as libraries with C linkage conventions can be compiled into GATE directly as a Tcl package (see Ousterhout 1994 chapter 31). This is tight coupling (route 2 in the diagram). Alternatively the underlying implementation of services can be via an executable (loose coupling, route 1). This executable is then called by the CREOLE wrapper code. In either case the implementation of CREOLE services is completely transparent to GATE.

CREOLE wrappers encapsulate information about the preconditions for a module to run (data that must be present in the GDM database) and post-conditions (data that will result). This information is needed by GGI – see below. Note that aside from the information needed for GGI to provide access to a module, GATE compatibility equals TIPSTER compatibility – i.e. there will be very little overhead in making any TIPSTER module run in GATE.
In addition to the macro requirements on CREOLE integration described above, GDM imposes constraints on the I/O format of CREOLE objects, namely that all information must be associated with byte offsets and conform to the annotations model of the TIPSTER architecture (see appendix [A]). The principal overhead in this process is making the components being integrated use byte offsets, if they don’t already do so. Where components use SGML, I/O filters will convert markup to the TIPSTER style.

As we noted above CREOLE objects may be data-orientated. It is our intention to integrate as large a set of LE data resources as possible within GATE in order to reduce the overhead of installing and understanding the software interfaces of these resources. For example, the Wordnet thesaurus (Miller, Beckwith, Fellbaum, Gross, Miller 1993) will be given a CREOLE wrapper encapsulating the C API as a GATE service. Grammars, lexica, gazetteers – all are candidates for CREOLE integration, and as the set expands GATE can
become a standard resource repository for LE data as well as LE processing modules.

**GGI**

GGI is a graphical tool that encapsulates the GDM and CREOLE resources in a fashion suitable for interactive building and testing of LE components and systems. The philosophy is to provide a rich set of tools including but not limited to the CREOLE modules. So, for example, access to a KWIC tool or the WordNet interface is included, as well as taggers, parsers, etc. from CREOLE.

GGI is intended for developers. Delivered systems built on GATE will not generally use GGI (though they may be able to reuse parts of the interface for their own front-ends).

GGI adopts the OSF Motif look and feel, provided via the Tcl/Tk toolkit (as used, for example, in Netscape).

**GGI**

The current version of the interface is has gone through several redesign iterations based on feedback on initial prototypes.

Launching CREOLE processes is done via a partially connected graph of possible paths through the processes embodied by the systems and modules menus.

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14Tcl/Tk will be available in native look and feel for PC/Windows and Macintosh some time in 1996, so GATE may at that point be able to migrate to these platforms.
of 0.1. The idea is that each module that is applicable to the LE task under development (IE, MT, ...) is given a button in a large canvas window. Clicking the button will run the process associated with the button. Figure 6 shows a small example. Here we have a choice of whether to run the Brill or POST taggers, both of which may produce results required by the BUChart parser, or the Xerox tagger which will not produce results appropriate to the parser.

![Figure 6: GGI objects graph example](image)

Interestingly, this arrangement for viewing and launching chains of LE modules quite closely parallels the *braided evaluation* model proposed in (Crouch, Gaizauskas, Netter 1995). This suggests that implementation of the evaluation schemes discussed there and in (Galliers, Sparck Jones 1993; Sparck Jones 1994) might be facilitated by GATE.

\(^{15}\)Thanks particularly to Kevin Humphreys for this idea.
The first task facing a user is to open a collection. It is not mandatory to then open a specific document – functions may be run on whole collections as well as single documents (though it may be appropriate to have a warning dialog box as large batched runs “may take a little while”). There is a file menu in the top left corner, with open collection leading to a list of collections, followed by a list of documents.

This is a view of the system as a set of processes that may be linked in pipelines in various ways. The permissible paths through the graph depend on the data that a module requires as its input. GATE systems are built from combinations of modules chained together. These chains may be represented by highlighted paths through the graph (e.g. selecting LaSIE from a systems menu would highlight the arcs connecting the various LaSIE object nodes). Clicking a module within a chain will then run all those in the remaining portion of the chain.

Visual information regarding the data present in the system is represented in two ways: by colour-coding of the module buttons and by colour-coding of the result (with an associated colour key).

The module buttons change colour depending on whether the data that the process produces is present or not:

- **green** ready to run, data not present;
- **amber** requires data from a previous stage to run;
- **red** data available (process has already been run successfully on current document / collection.

Clicking on a green button runs the relevant CREOLE object (via a pop-up dialog if options need setting); clicking on amber generates a menu of possible preceding modules to run; click red and a menu of results to view is displayed.
An optional pop-up launched from the file menu displays the output of modules as they run.

Given that the set of CREOLE modules will be large it will be necessary to allow a large screen space for the graph, and for it to be X and Y scrollable. Perhaps processing stages should be collapsible. Note that the implementation of the display will be non-trivial, and will require the use of some drawing algorithm like that used in daVinci (Frölich, Werner 1994).

Further information regarding the data produced by CREOLE objects is delivered by colour-coded displays of documents, e.g. a text might be displayed with coreference chains displayed in green. Each type of result also specifies a colour key, to be displayed on a bar with the result viewer.

The implementation of the processes graph should be via configuration information supplied with each CREOLE wrapper – i.e. there should be no information hard-coded into GATE regarding different modules. This might be achieved for example by each object registering its name, version and result type. It should also be possible to specify standard ways for results to be displayed (via an annotation type/colour key table, for example). These details need more work.

16 Each object then also specifies a set of preconditions in the form of regular expressions matching these annotations, e.g. the Brill tagger might store

- brill-0.1 pos\_tags

and a parser that required the tags to run might then specify

- brill-\* pos\_tags, or
- \* pos\_tags, or
- (brill)—(post)-\* pos\_tags.
Implementation technology

GATE is implemented in a mixture of Tcl/Tk and C[++] . The glue between the various components is Tcl, a script language developed specifically for systems integration (Ousterhout 1994). In common with other script languages, like Perl or the Bourne shell plus UNIX utilities, Tcl provides high-level constructs and facilities that greatly simplify the implementation of simple systems. Unlike other script languages, Tcl also has an extremely clean C interface, allowing seamless integration of C[++] libraries with Tcl scripts. GATE’s own code, then, is Tcl or C[++] (though this in no way restricts the implementation technology used in CREOLE modules – see above).

Another reason for choosing Tcl is the Tk package that comes with it. Tk is a Tcl library that encapsulates the MOTIF X-Windows toolkit. Whereas programming X via C is a black art that has spawned legions of expensive and complex screen-painting utilities, scripting Tk is a simple interactive process. The initial GGI prototype was coded in less than a week by a novice Tk programmer.

Tcl/Tk are public domain and are under active development by Sun Microsystems. Forthcoming changes include cross-platform portability across UNIX/X, MS-Windows and Macintosh.

The GDM API, then, is a set of Tcl calls. These calls are generally also available in C[++] .

All GATE systems are 8-bit clean, and may therefore be used with languages that can be represented by 1 byte character sets. Multi-byte character support is highly desirable (probably via the UNICODE standard). A route to 16 bit capability might be via a replacement for the Tcl string functions (maybe
using the Tools.h++ library (Keffer 1995)) and via reimplementation of the Tk text widget (or integration of CRL’s Motif widget).