EC-Canada Exploratory Collaborative Activity EC-CA 001 : 76099

EUCALYPTUS

A European/Canadian LOTOS Protocol Tool Set

Final Report

Contents

Chapter 1

Scientific and technical progress

1.1 Participants

The first year of the Eucalyptus project involved the following participants:

For Grenoble: In the VERIMAG laboratory, six researchers have contributed to the Eucalyptus project:

- Pr. Joseph Sifakis: project management
- Dr. Hubert Garavel: project management, improvement of the Cæsar and Cæsar.adt tools, design of the toolset interface
- Dr. Laurent Mounier: improvement of the Aldébaran tool, design of the toolset interface
- Alain Kerbrat: improvement of the Aldébaran tool and development of the graphical interface
- Radu Mateescu: improvement of the Cæsar.adt tool
- Mihalea Sighireanu: improvement of the Cæsar.adt tool

For Liège: At University of Liège, six researchers have contributed to the Eucalyptus project:

- Pr. André Danthine: project management
- Dr. Guy Leduc: project management, supervision of assessments of tools, convergence of tools, Lotos enhancements
- Charles Pecheur: design of the Apero tool, design of the toolset interface, Lotos enhancements, management of the Eucalyptus server

- France Bierbaum: assessments of the XEludo and Tetra tools
- Michel Jankowski: assessments of the Cæsar, Cæsar.adt, and Aldébaran tools
- Luc Léonard: assessment of the Smile tool, Lotos enhancements

For Ottawa: The Ottawa participation in Eucalyptus is supported by the Telecommunications Research Institute of Ontario (TRIO). The following researchers have contributed to Eucalyptus:

- Pr. Luigi Logrippo: project management
- Jacques Sincennes: improvement of the XEludo environment, design of the toolset interface

For Montréal: The Montréal participation in Eucalyptus is supported by the IDACOM-NSERC-CWARC Industrial Research Chair on Communications Protocols at the University of Montreal of which Gregor v. Bochmann is the chairholder. The support has been approved by the steering committee of the chair in March 1993. The following researchers have contributed to Eucalyptus:

- Pr. Gregor v. Bochmann: project management
- Pr. Rachida Dssouli: collaboration
- Daniel Ouimet: collaboration
- Omar Bellal: improvement of the Tetra tool, design of the toolset interface

1.2 Task reports

This section reflects the decomposition in tasks provided by the workplan attached to the Contract (technical annex I, section 2.1). These tasks are summarized below:

Task number	*Task name*	*participants*
0	Management and coordination	Grenoble
1	Tool assessment	Liège
2	Tool improvement	Grenoble, Ottawa, Montréal
3	Tool convergence	Grenoble, Liège, Ottawa, Montréal
4	Tool integration	Grenoble, Ottawa, Montréal

The following sub-sections report the activities carried out in the performance of these tasks.

1.2.1 Activities performed in Task 0 (Management and coordination)

Management and administration are carried out by Grenoble, with a deliberate attempt to avoid excessive administrative overhead.

As a deliberate choice, most of the communication between the Eucalyptus partners is done using electronic mail.

Being responsible for the tool assessments, Liège has set up and manages an FTP server in its premises, whose purpose is to have a common repository for storing the last releases of the Eucalyptus tools and reports.

In spite of the geographical distance between Canada and Europe, the cooperation was really effective. Three meetings per year have been organized (more frequently than initially foreseen in the Technical Annex):

- a two-day kick-off meeting, held on March, 3–4, 1993 in Liège
- a one-day meeting, held on September, 10, 1993 in Montréal
- a one-day meeting, held on January, 11, 1994, in Madrid
- a one-day review, held on May, 5, 1994, in Liège
- a presentation of Eucalyptus to North-American industrialists, held on June, 13, 1994, in Ottawa

- a final review, held on November, 29, 1994, in Grenoble

In the context of Task 0, Grenoble was in charge of writing the minutes of these meetings [EUCA/GR/01] [EUCA/GR/03] [EUCA/GR/04] and editing the periodic progress reports [EUCA/GR/05] [EUCA/GR/09].

Reports

[EUCA/GR/01] H. Garavel, *Minutes of the 1st* EUCALYPTUS *meeting – Liège, March the 3rd and 4th 1993*. 13 pages. In French.

[EUCA/ULg/03] F. Bierbaum, *Liège's comments on document EUCA/GR/01 – Current Situation*. 3 pages. In French.

[EUCA/GR/03] H. Garavel, *Minutes of the 2nd* EUCALYPTUS *meeting – Montréal, September the 10th 1993*. 7 pages. In French.

[EUCA/GR/04] H. Garavel, *Minutes of the 3rd* EUCALYPTUS *meeting – Madrid, January the 11th 1994*. H. Garavel. 8 pages. In French.

[EUCA/GR/05] EUCALYPTUS project. *Periodic Progress Report*. February 1994.

[EUCA/GR/09] EUCALYPTUS project. *Final Report*. February 1995.

1.2.2 Activities performed in Task 1 (Tool assessment)

Assessment of LITE

Before assessing the EUCALYPTUS toolset components, Liège has evaluated another existing LOTOS toolset, denoted LITE 3.0, which has been developed within the ESPRIT LOTOSPHERE project and distributed by ITA (Information Technology Architecture BV).

The evaluation effort focused on SMILE, which is the symbolic simulator of LITE and also its most consequent and useful tool. SMILE happened to be time and memory consuming. When faced with Liège's OSI95 LOTOS specification (2200 lines of data types + 2200 lines of processes), it took 4 hours and 270 Mb of swap-space to unfold two steps in the specification [EUCA/ULg/01].

Assessment of CADP

The first EUCALYPTUS tools evaluated by Liège are the CADP tools (CÆSAR.ADT + CÆSAR + ALDÉBARAN) from Grenoble (W version of January the 29th 1993) [EUCA/ULg/04]. The conclusions are summarized hereafter:

- CÆSAR.ADT, the data type compiler, is able to support very large abstract data type specifications. Its only shortcomings are:
  - It does not support the formal data types definitions and the actualizations;
  - Values of complex abstract data types cannot be enumerated.
- CÆSAR, the model generator, works perfectly on medium sized LOTOS specifications. On large ones, and in particular on large constraint-oriented ones, such the Liège's OSI95 specifications, CÆSAR currently faces difficulties. The most important limitation is the explosion of the size of the intermediate model (Petri Net) used by CÆSAR. Some solutions have been suggested such as the interleaving of the optimization and generation phases of CÆSAR to prevent the Petri Net from getting too large.
- As regards ALDÉBARAN, the model verifier, no problem was detected except in the minimization of the Labelled Transition System model modulo the testing equivalence.

Assessment of XELUDO

The assessment of the XELUDO toolkit (version 5.0a1.1 of November the 16th 1993) [EUCA/ULg/07] showed some limitations on very large and complex specifications such as the OSI95 LOTOS specification.

Liège was not able to really apply the step-by-step execution tool ISLA, nor the symbolic expansion tool SELA, due to problems such as lack of memory, error comments leading to the abort of the tool or time-consuming executions.

Simulations of parts of the specification were possible however. Moreover, other subtools such as the value expression editor or the user-defined constants facility, reveal to be of great help to the user.

Assessment of TETRA

Some problems encountered when assessing the TETRA toolkit (version 2.1 of October the 27th 1994) [EUCA/ULg/10] are direct outcomings of the ones highlighted for the XELUDO tools, simply because the TETRA tools use the file of PROLOG facts generated by ISLA. Even for a reduced part of the OSI95 specification, few results have been derived. Very limited traces and test cases reached the end of the processing.

Reports

[EUCA/ULg/01] C. Pecheur, L. Leonard, *Evaluation of* LITE*, a Toolset for* LOTOS. March 1993, 11 pages.

[EUCA/ULg/04] F. Bierbaum, M. Jankowski, *Assessment of the* CÆSAR/ALDÉBARAN *toolset on the OSI95* LOTOS *specifications.* October 1993, 24 pages.

[EUCA/ULg/07] F. Bierbaum, *Assessment of* XELUDO *toolkit on the OSI95* LOTOS *specification.* April 1994, 23 pages.

[EUCA/ULg/10] F. Bierbaum, *Assessment of* TETRA *toolkit on the OSI95* LOTOS *specification.* November 1994, 16 pages.

1.2.3 Activities performed in Task 2 (Tool improvement)

Activities in Grenoble

Grenoble spent considerable efforts in improving the CADP (CÆSAR/ALDÉBARAN) toolset [EUCA/GR/02]. This effort was motivated by the results of the tool assessment evaluation by Liège, Grenoble's own experience in dealing with large LOTOS descriptions, and the remarks of many other users.

In addition to the LOTOS descriptions provided by Liège, Grenoble has applied its tools to various case-studies of significant complexity, such as:

- the *Plain Old Telephony System* (POTS) developed by SICS (Sweden), which was chosen as a common example by all the EUCALYPTUS partners;
- the *Flight Warning Computer* (FWC) of Airbus A330/340 specification developed by Aerospatiale (France);
- the Transit Node example, inspired from the LOTOS description of a message router elaborated in the RACE project SPECS;
- a Memory Cache protocol, which served as a common example in the ESPRIT-BRA project REACT.

New versions of the CADP have been released: version X in September 1993, version Y in May 1994, version Z-delta in January 1995.

These successive versions provided significant improvements on the previous version W of January 1993. The main improvements are listed below:

Improvements of the CÆSAR.ADT tool:

1. The "front-end" part of CÆSAR and CÆSAR.ADT have been modified to deal properly with parameterized types. The previous front-end, developed in 1987, was based on an early version of the LOTOS standard and did not allow renaming and actualization to be combined simultaneously. The new front-end of CÆSAR and CÆSAR.ADT is now fully compatible with ISO 8807 standard.
2. The conventions for interfacing the C code automatically generated by CÆSAR and CÆSAR.ADT with the external C code provided by the user have been improved, so as to generate unique names by default. Therefore, it is no longer necessary to insert special comments in the LOTOS specifications to solve the conflicts created by operation overloading.

3. The C code generated by CÆSAR.ADT for structured types was improved. Record types are now implemented with a minimal number of bits. Practically, this optimization reduces of $\approx 40\%$ the size (in bytes) of structured types. In some cases, this size is divided by 8!
4. The C code generated by CÆSAR.ADT for constant and macro-definitions was improved. Additional checkings were added to detect recursive constant and macro definitions, and to override various limitations of the standard C compiler available on SUN workstations.
5. It is now possible for the user to define iterators; this allows a precise control on the range of value domains.
6. Missing libraries (like `OCTETSTRING`) were added and bugs were fixed in existing libraries.
7. The code generation issue for parameterized types has be studied in depth. Subtle problems occur when parameterization and explicit constructors are mixed. A set of static semantic constraints has been defined, which characterizes the cases where code generation for parameterized types is meaningful. It should be implemented in a future version of the CÆSAR and CÆSAR.ADT tools.

Improvements of the CÆSAR tool:

1. The algorithm used by CÆSAR to generate the Petri Net was modified in order to avoid a combinatorial explosion that sometimes occurred with the "disable" operator of LOTOS. The problem was faced on the first LOTOS specification provided by Liège.
2. The same algorithm was also modified in order to avoid the generation of many useless transitions which are later destroyed during the optimization phase (optimization V4). The modified algorithm gives good results on various large LOTOS programs such as POTS and FWC. It also improves the compile-time detection of constants.
3. The state vector of CÆSAR was reorganized in order to reduce its size, thus allowing more states to be stored. The average gain in size is of 21.5%. Additionally, the part of this state vector where it is possible to compute safely a hash-code was extended from 18% to 81%, therefore reducing the number of potential collisions and improving the speed of the simulation phase.
4. An option was added to CÆSAR in order to specify where temporary files are to be stored. This option solves a problem faced by Liège.

5. An option was added to CÆSAR in order to generate the LTS corresponding to a given process (by default, the LTS corresponding to the full LOTOS specification is generated).

6. Serious problems have been faced when dealing with the LOTOS description of the OSI95 Enhanced Transport Service provided by Liège. This description is highly constraint-oriented and contains hundreds of parallel processes, which leads to an explosion of the Petri Net generated by CÆSAR. Yet, it should be mentioned that several significant subsets of this description have been successfully verified using CÆSAR, and that no other existing LOTOS seems capable to handle this description entirely.

   In order to avoid the Petri Net explosion, major changes in CÆSAR's algorithms and data structures have been undertaken. New optimizations (mentioned above) have been introduced to generate smaller Petri Nets. Also, a "compositional" approach has been proposed, which consists in alternating Petri Net generation and Petri Net optimization phases. This approach has been implemented, first for basic LOTOS, then for full LOTOS. It is currently under test.

Improvements of the OPEN/CÆSAR tools:

1. The OPEN/CÆSAR environment was extended with a new module, implementing a "generic state table". Using this module, various tools have been developed.

2. The "`generator`" tool allows to produce the Labelled Transition System (LTS) corresponding to a LOTOS description; this LTS is represented using the BCG format (see below). The "`reductor`" tool offers the same functionality, but performs on-the-fly reduction for the $\tau^*.a$-bisimulation (which preserves all safety properties).

3. The "`exhibitor`" tool searches for execution sequences matching a given pattern. This tool can be seen as a complement of the TETRA tool developed by Montréal.

4. The "`albator`" tool performs on-the-fly comparison, modulo strong bisimulation, of a LOTOS description wrt a LTS or a Büchi automaton.

5. Various strategies have been implemented in OPEN/CÆSAR for producing diagnostic sequences. For instance, the aforementioned tools are now able to exhibit the shortest execution sequences which satisfies or refutes the property under consideration.

6. The programming interfaces of OPEN/CÆSAR have been modified, in order to be fully independent from LOTOS, so as to allow other languages and compilers to be connected to OPEN/CÆSAR.

Improvements of the ALDEBARAN tool:

1. New options have been added to Aldébaran which search for the presence/absence of deadlocks and livelocks.
2. New comparison algorithms (based on Binary-Decision Diagrams) have been introduced.
3. Facilities to support compositional ("divide and conquer") and symbolic verification have been added to Aldébaran. This gives good results practically; for instance, using compositional verification, the REL/rel protocol can be verified in 27 minutes on a SparcServer 10, whereas it takes 1:16 hour using "ordinary" reachability analysis techniques.
4. Renaming and hiding facilities have been added to Aldébaran, which allow to hide or rename the labels of a LTS or a Lotos description without modification or re-compilation.
5. Many bugs were fixed in the Aldébaran tool.

Introduction of the BCG tools: Finally, the verification tools based on the Bcg format have been integrated into the Cadp toolbox and in Eucalyptus toolset (although they have not been developed in the Eucalyptus framework).

Activities in Liège

In this task, Liège has entirely rewritten its abstract data types (ADT) pre-processor Dafy tool. The new tool, called Apero (a loose acronym for Act one PrE-pROcessor) improves the pre-processing functionality of Dafy, and extends it with a concept of infinite virtual library. Apero is thus based on two complementary tools:

- Apero.syn: a pre-processor that catches and expands some language extensions into standard LOTOS,
- Apero.lib: a library generator which extends the standard library mechanism, giving access to non-finite collections of generic data types (records, enumerated types, etc.).

Both tools rely on a generic text transformation algorithm and on externally specified transformation rules. On one hand, this facilitates the modification of the provided extensions and library types. On the other hand, this allows several alternative transformation rules for the same set of facilities, where the translated specification is tuned for several environments (human reading, compiler, simulator, etc.).

The common text transformation algorithm is derived of "Macro By Example", a macro processing formalism used in the Scheme language. An elementary transformation rules consists of a pair <source pattern, target pattern>. The source pattern is matched against the source text and the corresponding target pattern is then expanded into target text. A variable binding mechanism allows parts of the source text to be transferred to the target text.

APERO has been developed using the language ML (NJ/SML 0.93). ML is a strongly typed functional language, which eases the complex manipulation of symbolic structures that have to be implemented.

A preliminary prototype, offering only the library extension mechanism, had been previously developed. This work has been published [Pec93].

The preliminary studies and the design phase for APERO have been carried during March, April and May 93. June to December have been fully devoted to the programming effort.

A first working version of the APERO tool was available at the beginning of January 1994. A first version of the APERO package, with working definition files and documentation for the APERO tools [EUCA/ULg/05, EUCA/ULg/06], was distributed among the project partners at the beginning of February 1994. Documentation for the provided language extensions [EUCA/ULg/08] was ready before the review meeting in Liège in May 1994.

During the last semester of 1994, the APERO package has been enhanced in several ways, leading to a new version of the tool: APERO 2.00. The new release offers some improvements to the APERO language, faster translators and a richer collection of offered language facilities (library types and syntax extensions). The support for downstream tools has also been improved (see Task 4).

Activities in Ottawa

All the components of the XELUDO environment have been improved during the EUCALYPTUS cooperation:

1. Following the recommendations of Liège, ISLA has been improved especially concerning its evaluation engine:
    - Both bottom-up and top-down evaluators have been enhanced.
    - A narrower with tracing capabilities has been added. It is currently used by SELA to increase its efficiency. The on-going development of the interface will make it available to the user in a more interactive way (in particular,

for specific evaluations aimed at exercising the ADT part of a specification, and for the use of unbounded values with ISLA).

- Work was performed on the inference engine to allow it to execute larger specifications.

2. Work was done to integrate the Sela and Goe tools into the XEludo environment.

3. Sela has undergone major restructuring concerning execution control, allowing interruption and permitting to monitor the evolution of the expansion. The capability of exporting symbolic execution trees has been added.

4. The Goal-Oriented Execution tool (Goe) has been extended to full Lotos. Work has been carried out on the translation of Dynamic Derivation Paths (DDP) into SDP (Static Derivation Path) to ameliorate the inter-operability of Goe and Isla.

Additionally, Ottawa fixed various bugs: the syntax analyzer was repaired to make it process special identifiers properly and to be "case insensitive" as required by the Lotos ISO standard.

Ottawa also worked on the documentation aspects: a reference guide and on-line manual pages have been written for XEludo. Ottawa also provided assistance to Liège in setting up and running XEludo.

Activities in Montréal

At the beginning of the Eucalyptus project, a first version of Montréal's Tetra tool was available. This version of Tetra was implemented on top of an old version of Ottawa's XEludo. Tetra uses the internal representation of Lotos specifications produced by the Lotos compiler of the XEludo environment, as well as its inference engine and data evaluator.

Because these components of XEludo have been significantly improved in the last versions of the toolset, it was necessary to modify Tetra accordingly.

In the framework of Eucalyptus, Tetra has been completely adapted to the new version of the XEludo system, and this adaptation has been tested.

The Tetra tool has also been reorganized for better modularization. The use of the XEludo parts used in Tetra is now clearly and better identified. Some of the debugging activity was conducted together with Ottawa and allowed for the correction of some bugs in both tools.

Special needs of Tetra, such as the translation of external observed actions from Lotos format to their corresponding internal format, were taken into consideration by Ottawa.

A new feature has been implemented which allows for the analysis of traces written in separate files, in addition to traces compiled together with the reference specification. The specifier can perform different operations on these traces as loading, deleting and displaying without having to each time compile the entire specification.

The Tetra tool is now able to accept a trace generated by any other tool of the toolset respecting a common format. The trace is then analyzed by Tetra with respect to a reference specification, and an inference path to be used by the XEludo tool is generated. This path is used by XEludo to replay the analyzed trace.

Finally, the user graphical interface of Tetra has been improved and integrated to the graphical interface of the toolset. On-line documentation has also been written.

Publications

[GT93] H. Garavel, Ph. Turlier, Cæsar.adt: un compilateur pour les types abstraits algébriques du langage Lotos. In R. Dssouli, G. v. Bochmann, eds, Actes du Colloque Francophone pour l'Ingénierie des Protocoles CFIP'93 (Montréal, Canada), September 1993.

[Pec93] C. Pecheur, *VLib: infinite virtual libraries for LOTOS*, in A. Danthine, G. Leduc, P. Wolper, eds, Protocol Specification, Testing and Verification, XIII, Elsevier Science Publishers (North Holland), Amsterdam, 1993, 29-44.

Reports

[EUCA/GR/02] H. Garavel, *Contribution of Grenoble to the progress of the* Eucalyptus *project*. September 1993, 21 pages. In French.

[EUCA/UO/01] J. Sincennes, *Subset of* Lotos *accepted by* Isla *and related restrictions*, July 1993. In French.

[EUCA/ULg/05] C. Pecheur, *APERO Language Reference Version 1.0*. February 1994, 14 pages.

[EUCA/ULg/06] C. Pecheur, *APERO Tools User's Guide*. February 94, 10 pages.

[EUCA/ULg/08] C. Pecheur, *APERO Definitions User's Manuals*. April 94, 29 pages.

1.2.4 Activities performed in Task 3 (Tool convergence) and Task 4 (Tool integration)

Tasks 3 and 4 took place sequentially and contributed to the development of the unified Eucalyptus toolset, first by improving all tools separately, then by integrating them into the common graphical user interface.

For the sake of simplicity and readability, the results of these tasks are presented together.

Adoption of common file naming conventions

At the beginning of the Eucalyptus project, the inter-operability of the different tools was limited by a number of practical details. Many compatibility problems have been fixed during the project.

For instance, the tools did not follow the same conventions for file names: different file suffixes ("`.lotos`", "`.lot`", "`.l`") were used for Lotos files; some tools allowed ADT libraries to be included from files with suffix "`.lib`" whereas some other did not implement this feature.

The Cæsar, Cæsar.adt, Open/Cæsar, Apero, and XEludo tools have been modified: at present, each tool can accept Lotos files and ADT libraries with the same conventions as the other tools. Library source files used by the other tools are handled without further modifications.

Adaptation of APERO to CÆSAR.ADT and ISLA

Cæsar.adt and Isla handle data types in a different way and therefore impose different criteria for accepting a specification. To handle this fact, the specifications that APERO generates are tuned for the corresponding environments.

While Apero 1.00 could generate specifications that were accepted by each tool, those generated by Apero 2.00 are furthermore optimized for those tools, in terms of specification size and complexity of evaluation.

Mutual adaptation of XELUDO and TETRA

Ottawa made significant changes to the XEludo environment in order to allow the integration of foreign tools, and especially Tetra. The most important improvements are the following:

- structural reorganisation and modularisation;

- creation of "sub-tools", including a filename tool for navigation into directories and file selection;
- improvement of the value expression editor;
- creation of a manipulation tool for constants;
- addition of various widget management functionalities, including a library for drawing vertical trees.

With the assistance of Ottawa, Montréal has upgraded TETRA to the new XELUDO kernel and integrated TETRA in the XELUDO environment.

Definition of a common format for execution sequences

As foreseen in the Technical Annex of the EUCALYPTUS contract, the EUCALYPTUS tools can now inter-operate closely.

Verification tools such as ALDÉBARAN and OPEN/CÆSAR can discover "faulty" execution sequences, i.e., execution sequences that do not correspond to a permitted behavior of the service or the protocol under consideration.

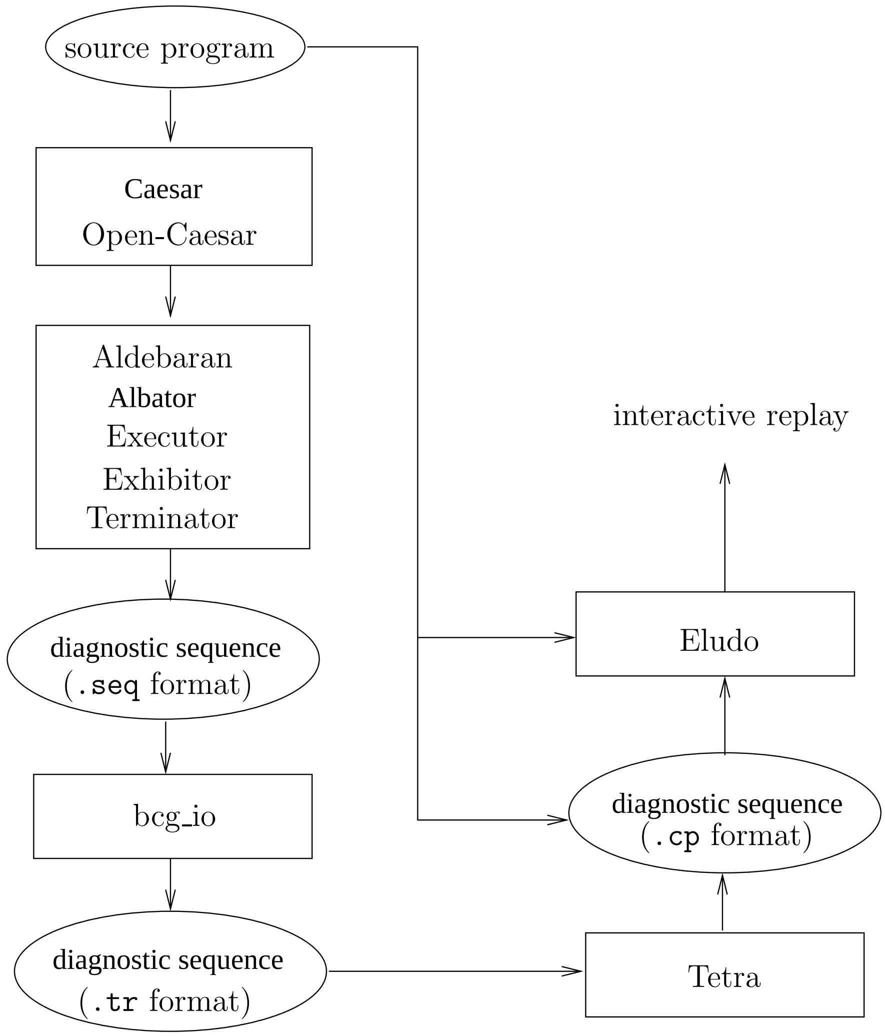
It is now possible to replay and examine these faulty execution sequences using the XELUDO and TETRA tools, which provide better error diagnosis than ALDÉBARAN and OPEN/CÆSAR, since they operate at the level of the LOTOS source text (and not at the level of LTS).

To implement the cooperation between the EUCALYPTUS tools, the following mechanism have been implemented:

- A common format for execution sequences, the "`.seq`" format, was defined; ALDÉBARAN and the OPEN/CÆSAR tools (`albator`, `executor`, `exhibitor`, and `terminator`) have been modified so as to generate this format.
- The `bcg_io` tool allows to translate the `.seq` format into 12 different formats, including a trace format, the "`.tr`" format, accepted by TETRA. This format uses a LOTOS-similar syntax and was jointly developed by Grenoble, Montréal, and Ottawa.
- The TETRA tool can analyze this trace and generate a behaviour suitable to be handled by XELUDO. This analysis is based upon the added capability of the new XELUDO kernel (modified in order to parse the `.tr` format and reconstruct LOTOS events). TETRA generates a checkpoint file (encoded to a "`.cp`" format) which communicates to XELUDO the information necessary to re-execute traces. The definition of the `.cp` format was jointly developed by Montréal and Ottawa.

- Then, XEludo can replay this trace, if started with the checkpoint file as argument (instead of a specification like it would for a normal simulation session).

The communications between these tools can be represented as follows.



Definition and implementation of a common graphical user interface

In order to integrate all existing tools in a coherent toolset, common graphical user interface (GUI) was developed.

In 1993, Grenoble has defined the requirements for the graphical interface of the Cæsar, Cæsar.adt, Aldébaran, and Open/Cæsar tools [EUCA/GR/02]. Liège did the same for the Apero tool [EUCA/ULg/02].

The X-windows system (version X11R5) was selected by the Eucalyptus consortium, because the graphical interface of ISLA is based on X11R5.

Grenoble has experienced various environments for developing graphical user interfaces, namely MOTIF and associated libraries, INTERVIEWS, GRIF and XTPANEL. As a result of this evaluation, the XTPANEL tool developed at Stanford University was selected and adopted by all the partners of the EUCALYPTUS project.

Grenoble developed a prototype user interface (based on XTPANEL) for the ALDÉBARAN tool. This prototype was sent to all the partners to illustrate the capabilities of XTPANEL.

On this basis, the EUCALYPTUS meeting in Madrid (January 1994) determined the general appearance of the GUI and fixed the schedule for its realization.

All the EUCALYPTUS partners have contributed to the development of the GUI, which lasted from March 1994 to December 1994. The code resulting from this collective activity consists in 5,500 lines of the XTPANEL language.

Due to geographical distances between the partners, the GUI has been developed in a "distributed" way, using the communication facilities provided by the Internet: electronic mail and file transfers.

In order to avoid version conflicts arising from different partners modifying the same files at the same time, a common software repository in Liège has been set up, and an access discipline (based on a "message passing" protocol) has been strictly enforced by the partners.

The following table lists the contributions of the partners to the development of the GUI.

version of the GUI	*date*	*contributing partner*
0.5	Mar 1	Grenoble
0.6	Mar 8	Liège
0.61	Mar 14	Liège
0.7	Mar 18	Ottawa
0.71	Mar 24	Ottawa
0.72	Mar 25	Ottawa
0.73	Mar 25	Liège
0.8	Apr 4	Montréal
0.9	Apr 16	Grenoble
0.91	Apr 20	Liège
0.92	Apr 25	Liège
0.93	May, 2	Liège
0.94	May, 3	Grenoble
0.95	June, 2	Grenoble
0.96	June, 6	Ottawa
0.97	June, 8	Montréal
0.98	June, 14	Liège
0.98.1	June, 20	Ottawa
0.99	Aug, 5	All partners
0.991	Aug, 12	Montréal
0.992	Nov, 3	Montréal
0.993	Nov, 18	Liège
0.994	Nov, 19	Ottawa
0.995	Nov, 25	Grenoble
0.996	Nov, 26	Grenoble
0.997	Dec, 8	Grenoble
0.998	Dec, 31	Liège

Adaptation of the tools to the graphical user interface

Grenoble has adapted the CÆSAR, CÆSAR.ADT, ALDÉBARAN, and OPEN/CÆSAR tools to the GUI. In some cases, special options have been introduced in these tools in order to be launched from the GUI. In November 1994, the BCG tools have also been introduced in the EUCALYPTUS, which brought significant changes to the GUI.

Liège has worked on the integration of APERO under the GUI, from March to May 1994, and then for adapting the GUI to APERO 2.00 in November 1994. A particular effort has been done to make the cascaded execution of APERO and other tools as seamless and transparent as possible.

Montreal has developed a graphical user interface for the TETRA tool. This interface was developed using XTPANEL and shares the same conventions as the EUCALYPTUS toolset.

Ottawa has modified XEludo, so as it can be launched with greater flexibility from within the Eucalyptus toolset. The processing of execution diagnostics has been modified to allow redirection. Not being present by default anymore, they may still be sent to screen or logged to file for reporting execution problems. A warning popup tool has been added for execution messages that cannot be ignored by the user, regardless of the selected diagnostic mode.

Liège and Ottawa have improved the job control mechanism of the Eucalyptus toolset interface. It permits tools launched by the GUI to be terminated in a more predictable fashion (such as when the GUI is terminated, or on specific demand). Finer control over foreground and background jobs was obtained.

Reports

[EUCA/ULg/02] C. Pecheur, *Interface Specification for ADT Pre-processing Tools*. June 1993, 5 pages.

[EUCA/GR/02] H. Garavel, *Contribution of Grenoble to the progress of the* Eucalyptus *project*. September 1993, 21 pages. In French.

1.3 Dissemination of results

1.3.1 Publications

The EUCALYPTUS project has a good international visibility. It was presented in several international workshops and conferences, including the following:

- Charles Pecheur presented a paper describing the principles of the APERO tool during the *13th IFIP Symposium on Protocol Specification, Testing and Verification (Liège)* organized by André Danthine, Guy Leduc and Pierre Wolper in May 1993.

- Hubert Garavel presented a paper describing the improvements of the CÆSAR.ADT tool during the *Colloque Francophone pour l'Ingénierie des Protocoles CFIP'93 (Montréal)* organized by Rachida Dssouli and Gregor v. Bochmann in September 1993.

- Luigi Logrippo presented the use of the EUCALYPTUS tools for mobile telephony (GSM systems) during the *Jacques Cartier Workshop (Grenoble)* organized by Gregor v. Bochmann, Norman Hutchinson, Michel Riveill and Joseph Sifakis.

- Hubert Garavel presented the achievements of the EUCALYPTUS project during the *Jacques Cartier Workshop (Grenoble)* organized by Gregor v. Bochmann, Norman Hutchinson, Michel Riveill and Joseph Sifakis.

1.3.2 Tutorials

- Joseph Sifakis, Hubert Garavel and Guy Leduc gave a one-day tutorial on formal verification techniques during the *13th IFIP Symposium on Protocol Specification, Testing and Verification* (Liège, September 1993).

- Guy Leduc gave a one-day tutorial on LOTOS during the *Conference on High-Performance Networks HPN'93* (Grenoble, June 1994).

1.3.3 Software distribution

As the EUCALYPTUS project terminated in December 1994, it has not been possible yet to distribute the complete toolset.

However, some of the tools improved during the EUCALYPTUS project have been distributed.

The new versions of the CÆSAR/ALDÉBARAN toolset have been released. The toolset is now installed in 93 sites.

Similarly, the XELUDO toolset is now installed in about 70 sites.

1.3.4 Tool demonstrations

In 1994, a special effort was accomplished by the EUCALYPTUS partners in order to demonstrate the EUCALYPTUS tools.

In June 1994, Ottawa organized a special "EUCALYPTUS day" intended to industrialists of the telecommunication field. LOTOS and the EUCALYPTUS tools have been presented. Liège and Grenoble also participated to this meeting.

The EUCALYPTUS tools have also been demonstrated during international conferences such as:

- High Performance Networks HPN'94 (Grenoble, France, June 1994)
- Computer-Aided Verification CAV'94 (Stanford, USA, June 1994)
- CONCUR'94 (Uppsala, Sweden, August 1994)
- COST 247 meeting (Evry, France, September 1994)
- FORTE'94 (Bern, Switzerland, 1994)
- Jacques Cartier Workshop (Grenoble, France, December 1994)

1.3.5 Standardization activities

Also, the EUCALYPTUS participants are taking part into the revision of the LOTOS standard that is currently in progress within ISO. This standardization effort aims at enhancing LOTOS with new features (ISO/IEC JTC1/SC21/WG1 New Work Item on "Extended LOTOS").

The EUCALYPTUS partners have attended the ISO meetings in Madrid (January 1994) and Southampton (July 1994) and provided significant written contributions, which have been included as annexes in the ISO working document for Extended LOTOS:

- Annex A: Interrupts (L. Logrippo)
- Annex C: Typed gates (H. Garavel)
- Annex E: Time extensions (G. Leduc)

- Annex H: Extended data types (Ch. Pecheur)
- Annex K: Six improvements (H. Garavel)

[EUCA/GR/06] H. Garavel, *On the Introduction of Gate Typing in* E-LOTOS, Feb. 1994.

[EUCA/GR/07] H. Garavel, *Six improvements to the process part of* LOTOS, Jul. 1994.

[EUCA/ULg/09] C. Pecheur, *A Proposal for Data Types for* E-LOTOS, Aug. 1994, 21 pages.

[EUCA/ULg/09b] C. Pecheur, *A Proposal for Data Types for* E-LOTOS*, second version*, Nov. 1994, 27 pages.

1.3.6 Relations with other European projects

The EUCALYPTUS project is related to several past and ongoing European projects:

- **ESPRIT 5341 OSI95 "High-Performance OSI protocols with multimedia support on HSLANs and B-ISDN"**: The LOTOS descriptions developed by Liège in OSI95 have been used as benchmarks to assess the EUCALYPTUS tools. Parts of the description of the OSI95 service have been formally verified.
- **ESPRIT-BRA 6021 REACT "Building Correct Reactive Systems"**: Grenoble is also a member of REACT and has applied the EUCALYPTUS tools to the Memory Cache protocol worked out in REACT. It is worth mentioning that the only computer-aided verification of the Memory Cache protocol was performed using the EUCALYPTUS tools; all other approaches relied on manual proof.
- **ESPRIT-BRA 7166 CONCUR2 "Calculi and Algebras of Concurrency"**: the verification tools of the EUCALYPTUS toolset have been modified so as to generate the FC2 automaton format used in CONCUR2. This should allow a joint use of CONCUR2 and EUCALYPTUS tools on LOTOS descriptions.
- **COST 247 "Verification and Validation for Formal Descriptions"**: Grenoble and Liège actively participate to this action. Guy Leduc is the Belgian representative. Hubert Garavel is the French representative and chairs the Working Group 1 devoted to LOTOS and Extended LOTOS.

1.4 Conclusion

Formal description techniques like Lotos were defined to allow a precise and unambiguous description of complex reactive systems. Lotos features are especially useful in describing large protocols and services.

To be effective, formal description techniques need to be supported by software engineering tools, which allow to execute, simulate, and verify the formal descriptions.

During the past decade, a number of software engineering tools for Lotos have been developed. The Eucalyptus project has capitalized this experience and built upon past developments.

During the project, pre-existing tools have been assessed on realistic case-studies, and significantly improved; new tools have also been developed. All the tools have been interfaced and integrated into a common graphical user interface.

Based on Lotos, a powerful and sound formal language, the Eucalyptus toolset combines tools with advanced features to offer a wide spectrum of functionalities. It has already been applied to useful problems of the telecommunication field: such as test-case generation for GSM systems, detection of feature interaction in telephony systems, and verification of an ATM switch fabric.

From the European side, all the objectives mentioned in the Technical Annex have been fulfilled. In many ways, the original expectations have been surpassed. For instance, Liège has developed the Apero tool, which was not foreseen in the Technical Annex. Similarly, Grenoble has included the Bcg tools in the Eucalyptus toolset.

From the Canadian side, the software developments have also been more important that initially expected. The XEludo environment has been deeply modified, and an important part of the Tetra tool has been rewritten.

The cooperation between Canadian and European partners has been excellent and will be pursued in the framework of Eucalyptus-2, the two-year extension of the project. Eucalyptus-2 will also provide the opportunity to disseminate widely the results achieved during the past two years.

Chapter 2

Financial situation

PLEASE REFER TO THE ATTACHED COST STATEMENTS PROVIDED BY GRENOBLE AND LIEGE