Progress Report 01
ConsRel, Fapesp Project 2004/14107-2
Logical Consequence and Combinations of Logics — Fundaments and Efficient Applications

Period: April 1st, 2005 to March 30th, 2006

Main Researcher: Walter Carnielli (CLE/IFCH-UNICAMP)

Resumo

This is the initial Report of the ConsRel Project covering the activities developed during the period from April 1st, 2005 to March 30th, 2006. As the initial proposal of this Project was written in English, we thought it appropriate to write the corresponding progress reports in English as well. The first section contains a brief summary of this Report in Portuguese.

Sumário

O Projeto ConsRel trata da investigação acerca das relações de consequência, enfocando diversas vertentes:

1. estudar a questão da expressividade das relações de consequência dentro de padrões específicos, tais como aspectos qualitativos versus quantitativos;
2. investigar as formas gerais de semânticas formais (isto é, semânticas formuladas com precisão matemática e para as quais se possa dispor de métodos ou técnicas de caráter formal, em particular algébrico ou categorial);
3. investigar os métodos e técnicas de combinação (síntese) de sistemas lógicos ou de relações de consequência;
4. investigar os métodos e técnicas de decomposição (análise) de sistemas lógicos.

O Projeto, em resumo, se constitui dos seguintes módulos:

- Módulo 1: Fundamentos de Combinação de Sistemas Lógicos (*Task 1: Fundamentals of Combining Logics*);

- Módulo 2: Apectos Computacionais das Combinação de Sistemas Lógicos e Demonstração Automática de Teoremas (*Task 3: Computational Aspects of Combinations of Logics and Theorem Proving*);
- Módulo 3: Lógicas Quânticas e Algoritmos (*Task 3: Quantum Logics and Algorithms*).

Informações adicionais encontram-se disponíveis na página do Projeto: http://www.ime.usp.br/~consrel

Fazemos aqui uma breve descrição, quantitativa e qualitativa, a respeito dos principais resultados atingidos dentro de cada "Task" no periodo de 01/04/2005 até 30/03/2006. Para uma avaliação qualitativa deve-se consultar a Seção 2. Para uma descrição das atividades organizadas a partir dos membros componentes do Projeto deve-se consultar a Seção 3.

Dentro da **Task 1: Fundamentals of Combining Logics**, coordenada por Marcelo Coniglio, foram publicados 16 artigos relativos às diferentes linhas de pesquisa deste módulo. Alguns destes artigos tratam de questões conceituais das traduções de sistemas lógicos e de suas conseqüências nos processos de combinação. Outros artigos tratam da questão da decomposição de sistemas lógicos em componentes mais simples. Também foram obtidas relações entre as lógicas paraconsistentes e as lógicas modais. O uso de conceitos de teoria de categorias no contexto de combinação de sistemas lógicos foi também explorado. Finalmente, foram obtidos resultados sobre quantificadores modulados.

Dentro da **Task 2: Computational Aspects of Combinations of Logics and Theorem Proving**, coordenada por Marcelo Finger, foram publicados 12 artigos, relacionados às questões de aproximação de lógicas, provadores automáticos eficientes de teoremas e inferência sensível a recursos. Todos estes artigos são ligados a questões da inferência dedutiva, incluindo inferência demonstrativa e usos da noção prática de inferência

Dentro da **Task 3: Quantum Logics and Algorithms**, coordenada por Walter Carnielli, dois artigos foram produzidos: um deles investigando o conceito provadores algébricos de teoremas, proposto no próprio Projeto (como "Polynomial Ring Proof Procedures" (introduced in [Car01]) e que faz uso da estrutura dos corpos de Galois finitos de tal forma a reduzir questões de demonstrabilidade a questões de solução de equações polinomiais.

O segundo artigo produzido dentro desta "Task" diz respeito ao modelo de *máquinas de Turing paraconsistentes*, discutindo o conceito de estados emaranhados e de paralelismo quântico, importantes características dos algoritmos quânticos eficientes.

Dois eventos foram organizados no âmbito do Projeto (veja na Seção 4).

Podemos afirmar que o primeiro ano do Projeto representou um substantivo pogresso termos qualitativos e quantitativos, em total concordância com os objetivos estipulados. A notação $\boxed{\text{[Ref]}}$ denota que a referência [Ref] corresponde a uma publicação produzida pelos membros do Projeto durante o período.

1 Introduction

The first year of the ConsRel Project has been a very productive year. On the one hand, several papers have been published or submitted for publication. On the other hand, a first version of an open source theorem prover has been released. Furthermore, two events have been organized in the scope of the Project, with very good repercussion in the community. Not many MSc and PhD students have had the opportunity to finish their work in the context of the Project, but there are several students will have their final defense happening in the coming years, hopefully within the duration of the Project.

We have established a webpage for the Project at the following address:

`http://www.ime.usp.br/~consrel`

in which most, if not all, of the papers published within the context of the Project can be found.

The structure of this Report is as follows: The rest of this section recalls the Project's setting, describing its domain, goals and the structure in which the Project tasks were divided. In Section 2 reports the achievements in each of the Project tasks. In Section 3 details how each member of the Project has contributed to its goals. Section 4 describes the two workshops organized in the scope of the Project in its first year. And finally, in Section 5 work in progress is discussed, and the directions of the Project in its continuation are plotted. The notation [Ref] denotes that the reference [Ref] corresponds to a publication produced by Project members within the period reported.

1.1 The Domain of the Project

The Project ConsRel deals with the topic of Logical Consequence and Combinations of Logics. This wide topic allows us to deal with many subjects, and we have chosen to concentrate on the following:

- The study of methods for combining logics. This encompasses the ways logics can be put together to generate more complex systems, as well as the ways a logic can be decomposed into simpler ones. The combination procedures can vary and generate a single logic, as in the fibring or in the possible-translations approach, or the process can be asymptotic and generate a class of logics, as in the families of logics that approximate classical logic.

- The study of practical applications of combinations of logics, which covers the fields of theorem proving, AI, belief revision and in the study of novel models of computation, such as quantum computation and quantum algorithms.

To cover this wide spectrum we face the problem of combining logics from the mathematical, computational and conceptual points of view.

1.2 The Goals of the Project

As we have stated in the Project proposal, the aims of this Project are directed towards the following aspects of combination of logics:

1. To study the fundamental issues of combining logics, covering the following points:
   - Specific methods for combining logics, such as *fusion*, *products* and *fibring*.
   - Algebraic and categorial aspects of logic combinations, such as *Blok-Pigozzi algebraization*.
   - Formal semantics for logic combination, such as *possible-translations semantics* and *society semantics*.
2. The study of computational aspects of logical combination, addressing the following topics:
   - Approximations of classical logic and the development of approximate theorem provers.
   - Belief Revision and its relation with the notions of relevance generated by approximation processes.
   - Logics *with* uncertainty, as opposed to logics that reason *about* uncertainty. These logics of practical interest can be modeled as a combination of classical logics with probability theory or with fuzzy logics.
3. The study of particular logics of interest resulting from combination of logics, namely:
   - Quantum Logics, which are connected to mathematical questions on Hilbert Spaces, Lie Algebras and Topology.
   - Quantum algorithms which, from the standpoint of combination mechanisms, can be seen as superpositions of classical models.

1.3 The Structure of the Project

To achieve the goals mentioned above, the Project was divided into three main tasks, each of which by its turn subdivided into several subtasks, as follows.

Task 1: Fundamentals of Combining Logics, coordinated by Marcelo Coniglio. Subtasks:

- Subtask 1.1: Combinations of Logics and their Applications
- Subtask 1.2: Splitting and Algebraizing Logics
- Subtask 1.3: Algebraic Semantics for Modal Logics

– Subtask 1.4: Algebraic and Categorial Aspects of Logical Consequence

Task 2: Computational Aspects of Combinations of Logics and Theorem Proving, coordinated by Marcelo Finger. Subtasks:

– Subtask 2.1: Polynomial-Time Approximations of Classical Propositional Logic

– Subtask 2.2: First-Order Approximate Inference

– Subtask 2.3: Resource Sensitive Inference

– Subtask 2.4: Automatizing Paraconsistent Inference

Task 3: Quantum Logics and Algorithms, coordinated by Walter Carnielli. Subtasks:

– Subtask 3.1: Quantum Computation and Quantum Logics

– Subtask 3.2: Polynomial Ring Proof Procedures

– Subtask 3.3: Paraconsistent Turing Machines

1.4 Human Resources of the Project

As it is usual in projects of wide range involving people from different institutions and from several levels and distinct backgrounds, there were some adjustments in the human resources component of the Project:

- The student Eudenia Xavier Meneses (DCC-IME-USP) left the Project for personal reasons.
- The student Paulo Petrillo (IFCH-UNICAMP) finisehd his Master Thesis, and is no longer at UNICAMP.
- João Marcos is no longer a Post-Doc Student, as he obtained a position at the Federal University of Rio Grande do Norte, and from now on figures in the main research team.
- Luís Sbardellini will be considered a Ph.D. student, as he decided to enroll in a new doctorate in Mathematics at IME- USP.
- New Master students were incorporated into the Project: Anderson Araujo (IFCH- UNICAMP), Rafael Rodrigues Testa (IFCH- UNICAMP), Rodrigo Podiack (IFCH- UNICAMP), Alberto Leopoldo Batista Neto (IFCH-UNICAMP) and Teófilo de Sousa Reis (IFCH- UNICAMP).
- A new Ph.D. student was also incorporated into the Project: Luiz Henrique Silvestrini (IFCH- UNICAMP).
- Two new external participants have manifested interest into collaborating with the Project: Jorge Petrucio Viana (IM-UFF, Rio de Janeiro) and Eduardo Fermé (Universidade da Madeira, Portugal).

The updated group of researchers consists from now on of the following people:

Project Coordinator

- Walter Carnielli (IFCH and CLE – UNICAMP)

Task Coordinators

- Marcelo Coniglio (IFCH and CLE – UNICAMP)
- Marcelo Finger (DCC-IME-USP)

Researchers

- Itala D'Ottaviano (IFCH and CLE – UNICAMP)
- Hércules de Araujo Feitosa (MAT-UNESP-Bauru)
- Odilon Otávio Luciano (MAT-IME-USP)
- João Marcos (DIMAp/ CCET- UFRN)
- Hugo Mariano (MAT-IME-USP)
- Flavio Correa da Silva (DCC-IME-USP)
- Renata Wassermann(DCC-IME-USP)
- Angela Weiss (MAT-IME-USP)

Post-Doc Students

- Milton Augustinis de Castro (IFCH – UNICAMP)

PhD Students

- Juan Carlos Agudelo Agudelo (IFCH-UNICAMP) (name in publications: Juan Carlos Agudelo)
- Juliana Bueno (IFCH-UNICAMP) (name in publications: Juliana Bueno-Soler)
- Rodrigo de Alvarenga Freire (IFCH-UNICAMP)
- Carlos Hifume (IFCH-UNICAMP)
- Joselyto Riani (DCC-IME-USP)
- Luís Sbardellini (IME- USP)
- Adolfo Gustavo Serra Seca Neto (DCC-IME-USP)
- Luiz Henrique Silvestrini (IFCH- UNICAMP)

MSc Students

- Anderson Araujo (IFCH- UNICAMP)
- Alberto Leopoldo Batista Neto (IFCH- UNICAMP)
- Rodrigo Podiack (IFCH- UNICAMP)

- Guilherme Rabello (MAT-IME-USP)
- Rafael Rodrigues Testa (IFCH-UNICAMP)
- Teófilo de Sousa Reis (IFCH- UNICAMP)

External Participants

- Jean-Yves Béziau (Université de Neuchâtel, Switzerland)
- Carlos Caleiro (IST, Lisbon)
- Alexandre Costa-Leite (Université de Neuchâtel, Switzerland)
- Eduardo Fermé (Department of Mathematics and Engineering, Universidade da Madeira, Portugal)
- Dov Gabbay (King's College, London)
- Paulo Mateus (IST, Lisbon)
- João Rasga (IST, Lisbon)
- Amilcar Sernadas (IST, Lisbon)
- Cristina Sernadas (IST, Lisbon)
- Jorge Petrucio Viana (IM-UFF, Rio de Janeiro)

2 Report by Tasks

Task 1: Fundamentals of Combining Logics

Task coordinator: Marcelo Coniglio

This task is devoted to the development of a general theory of combination of logic systems, from a theoretical point of view.

During the period being analyzed, a satisfactory amount of achievements were reached concerning this task.

Several papers were produced by members of the team, in collaboration with external members of the projects and other researchers. Some of these papers were published, other were submitted for publication and some were released as electronic preprints.

On the other hand, several stages of a book on combinations of logics under preparation by members of this Task have being completed.

Additionally, an special session on Combination of Logics was organized within the Second Indian Conference on Artificial Intelligence (ICAI'05), with the participation of several members of the team (see Section 4).

The research developed in this period concerned the four subtasks, and it can be classified into two main lines: Firstly, some general conceptual issues about combination and representation of logic systems were addressed. Second, some efforts were devoted to the analysis of specific techniques for composing (splicing) and decomposing (splitting) logic systems.

Subtask 1.1: Combinations of Logics and their Applications

With respect to this subtask, a general discussion about the concept of translation between logics and the preservation of meta-properties was conducted. The main conclusion is that, in order to recover a logic system from its fragments, the usual notion of logic translation should be strengthened, ensuring that some basic meta-properties are preserved. The results appeared in the following articles:

> [Con05] Marcelo E. Coniglio. The Meta-Fibring Environment: preservation of meta-properties by fibring. *CLE e-Prints*, Vol. 5(4), 2005. Available at http://www.cle.unicamp.br/e-prints/vol_5,n_4,2005.html

> [Con06] Marcelo E. Coniglio. Towards a Stronger Notion of Translation Between Logics. *Manuscrito*, 28(2):231–262, 2005.

The first one is a preprint which will be soon submitted to an international journal.

Some investigations were made with respect to the distinction between splitting and splicing logics. It was observed that some combination methods can be seen as working in both directions: bottom up (splicing) and top down (splitting). The results of this research were divulged in the paper

> [CC05] Walter A. Carnielli and Marcelo E. Coniglio. Splitting Logics. In S. Artemov; H. Barringer; A. Garcez; L. Lamb and J. Woods, editors, *We Will Show Them! Essays in Honour of Dov Gabbay*, vol. 1, pp. 389–414. College Publications, 2005.

In the area of fibring, the main advances were obtained concerning simple logics, that is, the fibring of propositional-based logics. With respect to first-order and higher-order logics, as well as the other topics mentioned in the original proposal for this subtask, the research was mainly devoted to revise and unify the results already obtained by members of the Project and/or external collaborators of the Project. The refinements obtained were included in a preliminary version of a book (in preparation) about combination of logics, written by Walter Carnielli, Marcelo Coniglio, Dov Gabbay (King's College, London), Paula Gouveia (IST, Lisbon) and Cristina Sernadas (IST, Lisbon). Two members of the team (Walter Carnielli and Marcelo Coniglio) were at Lisbon in 2005 and 2006, respectively, working with his coauthors at IST on the above mentioned book. As a result, important progress was obtained, and a first draft will we ready at the beginning of 2007.

In the preprint [Con05] mentioned above the dual of the collapsing problem, called *anti-collapsing problem* was studied. This phenomenon is related to some limitations of the usual fibring, avoiding the obtainment of some useful interaction properties. In that article, a new form of fibring sequent calculi

was proposed. The anti-collapsing problem of fibring was also studied with respect to the combination of conjunction and disjunction. The results obtained appeared in the following article:

> [BC05] Jean-Yves Béziau and Marcelo E. Coniglio. Combining Conjunction with Disjunction. In Bhanu Prasad, editor, *Proceedings of the 2nd Indian International Conference on Artificial Intelligence (IICAI 2005)*, pp. 1648–1658. Pune, India, 2005.

The combination of logics presented by means of matrix semantics was also studied. As a result of the research, a technique (the first occurring in the literature for this kind of logics, to the best of our knowledge), called *plain fibring*, was obtained. The results appeared in the following article:

> [CF05] Marcelo E. Coniglio and Víctor L. Fernández. Plain fibring and direct union of logics with matrix semantics. In Bhanu Prasad, editor, *Proceedings of the 2nd Indian International Conference on Artificial Intelligence (IICAI 2005)*, pp. 1590–1608. Pune, India, 2005.

One negative result was obtained for this subtask, namely that the techniques previously used for the combination of normal modal logics cannot be directly applied to the combination of non-normal modal logics with neighborhood semantics. This result was presented in the following paper.

> [FF05] Rogerio Fajardo and Marcelo Finger. How not to combine modal logics. In Bhanu Prasad, editor, *Proceedings of the 2nd Indian International Conference on Artificial Intelligence (IICAI 2005)*, pp. 1629–1647. Pune, India, 2005.

Additionally, a different glance to the problem of combination of logics was given in the realm of this Project.

On the one hand, the relationship between modal and paraconsistent logics originated a research in this direction.

A paracomplete logic is a logic having at least one model according to which neither some statement nor its negation are satisfied. On the other hand, a paranormal logic is a logic that is both paraconsistent and paracomplete. It was proved that nearly every normal modal logic admits to some latent paranormality: it is paracomplete with respect to a negation defined as an impossibility operator, and paraconsistent with respect to a negation defined as non-necessity. This results appeared in the article below.

> [Mar05a] João Marcos. Nearly every normal modal logic is paranormal. *Logique et Analyse*, 48(189/192):279–300, 2005.

On the other hand, the interplay between classical and paraconsistent logics were investigated through a concrete application to differential calculus. Specifically, the study was developed in the context of da Costa's paraconsistent differential calculus. This calculus is based on da Costa's paraconsistent set theory CHU_1, governed by the paraconsistent predicate calculus with equality $C_1^=$. Extensions of several results of the classical differential calculus to this context were given. Using the concept of paraconsistent super-structure, a Transference Theorem from the classical differential calculus into da Costa's paraconsistent differential calculus was obtained. These results are summarized in the paper below.

> [DoF05] Itala M.L. D'Ottaviano and Tadeu Fernandes de Carvalho. Da Costa's Paraconsistent Differential Calculus and a Transference Theorem. In Bhanu Prasad, editor, *Proceedings of the 2nd Indian International Conference on Artificial Intelligence (IICAI 2005)*, pp. 1559–1678. Pune, India, 2005.

Finally, a Special Session called "Logical Consequence and its Combinations" was organized as part of the "2nd Indian International Conference on Artificial Intelligence" (IICAI-05) held in Pune, India, in December 20-22, 2005 (see Section 4)

Subtask 1.2: Splitting and Algebraizing Logics

Some interesting progress was obtained for this subtask, mainly concerning the development of a general theory of Possible-Translations Semantics (PTS). The use of the language of category theory helped to better understand the universality behind the process, motivating the study of products (or, in general, limits) of logic systems. Some results of the research developed by members of the team can be found in the paper [CC05] mentioned in Subsection 2.

On the other hand, a proposal for applications of PTSs for algebraizing logics was given. The results of this line of research are described in the following paper:

> [BuC05] Juliana Bueno-Soler and Walter A. Carnielli. Possible-translations algebraization for paraconsistent logics. *Bulletin of the Section of Logic* 34(2):77–92, 2005.

Another line of research in this subtask was explored, namely through the utilization of accessible categories in the study of Blok-Pigozzi algebraizable logics. This research capitalizes on the studies developed in [FC04]. The basic idea is that colimits of filtered diagrams of objects in a given category of logic systems correspond to "gluing compatible partial information". Thus, the finitely presented objects are the "fundamental bricks" of the accessible category, because any object is a gluing of these basic pieces. The results obtained in the first stage of this research were reported in the following preprint:

[AFLM06a] Peter Arndt, Rodrigo A. Freire, Odilón O. Luciano and Hugo L. Mariano. On the category of algebraizable logics. *CLE e-Prints* Vol. 6(1), 2006. Available at http://www.cle.unicamp.br/e-prints/vol_6,n_1,2006.html

This paper was submitted for publication in an international journal.

Subtask 1.3: Algebraic Semantics for Modal Logics

The goal of this subtask is the study of abstract consequence operators and generalized (or modulated) quantifiers (such as 'generally', 'rarely', 'most', etc.), and their relationship to other logics, in particular, to modal logics. One aspect of the Project is to study algebraic semantics for such logics.

The advances in this subtask were important, and some articles were produced.

Using the notion of modulated logics, a general characterization of natural quantifiers as universals present in any natural language was obtained. Thus, the modulated quantifiers can be investigated within the framework of those universals. The main results obtained in this research were divulged in the article below.

[GF05] Maria C. Cabrini Grácio and Hércules de Araujo Feitosa. Modulated Logics: Implications in a fragment of the theory of natural language ("Lógicas moduladas: implicações em um fragmento da teoria da linguagem natural", in Portuguese). *Revista Eletrônica Informação e Cognição*, 4(4), 2005.

In a more philosophical vein, da Costa's theories of truth and quasi-truth were investigated. A formal definition of pragmatic truth –the da Costa's quasi-truth– was introduced. Additionally, some results related to a paraconsistent logical system, which could be used as the underlying logic for theories of quasi-truth, were obtained. The results obtained in this research are described in the following paper:

[HD06] Carlos Hifume and Itala M.L. D'Ottaviano. On da Costa's theories of truth and quasi-truth (*Sobre teorias da verdade e a quase-verdade de da Costa*, in Portuguese). In M. E. Quilici Gonzalez and M. C. Broens, editors, *Encontro com as ciências cognitivas*. Unesp, 2006 (in print).

Finally, abstract consequence operator were investigated. Specifically, the cumulative (non-monotonic) consequence operators were analyzed, as well as translations between them. Some conditions which guarantee the existence of a conservative translation between cumulative logics were obtained. These results are described in the paper below.

[SD05] Mauro C. Scheer and Itala M.L. D'Ottaviano. Cumulative consequence operators and translations between cumulative logics ("Operadores de conseqüência cumulativos e traduções entre lógicas cumulativas", in Portuguese). *Revista Informação e Cognição*, vol. 1, 2005.

Subtask 1.4: Algebraic and Categorial Aspects of Logical Consequence

This subtask was originally designated to obtain applications of accessible categories to the study of categorial combination of logics, with emphasis in fibring and possible-translations semantics. Several interesting results were obtained in this direction, but also other studies were developed in related directions, as will be described below.

Firstly, it was explored the possibility of using the theory of accessible categories in the study of categories of logics. In the first stage of this research the attention was focused on the category of finitary structural logics and its subcategory of algebraizable logics. A preliminary report of the results obtained are described in the preprint below.

[AFLM06b] Peter Arndt, Rodrigo A. Freire, Odilon O. Luciano and Hugo L. Mariano. A global glance on categories in Logic. Submitted for publication.

On the other hand, it was observed that the splitting of a given logic L into sublogics L_i can be seen as a covering of L by these sublogics, in an appropriate category of logics. From this, it is possible to apply the related language of Grothendieck topologies and then, with the obtained notion of sheaf, we are able to relate logics (=filtered colimits of finitely presentable logics) and sheaves within the category of presheaves (=colimits of contravariant hom functors of finitely presentable logics). The results of this research can be found in the following paper.

[AFLM05] Peter Arndt, Rodrigo A. Freire, Odilón O. Luciano and Hugo L. Mariano. Fibring and Sheaves. In Bhanu Prasad, editor, *Proceedings of the 2nd Indian International Conference on Artificial Intelligence (IICAI 2005)*, pp. 1679–1698. Pune, India, 2005.

From a different perspective on the categorial foundations of consequence relations, the properties of the ordered rational number object in toposes were studied from the point of view of *Local Set Theory* (cf.[Bel88]). This theory allows to study general properties of toposes by means of a higher-order intuitionistic logic. Along the research, a topos version of Cantor's back and forth theorem was obtained. Using this, it was proved that the ordered structure of the rational numbers is a minimal effectively homogeneous structure, that is, it can be embedded in every other effectively homogeneous ordered structure. The results obtained were published in the following article:

[SC06] Luís A. Sbardellini and Marcelo E. Coniglio. Some Results on Ordered Structures in Toposes. *Reports on Mathematical Logic*, 40:181–198, 2006. Preprint available at *CLE e-Prints* Vol. 5(5), 2005.
http://www.cle.unicamp.br/e-prints/vol_5,n_5,2005.html

Task 2: Computational Aspects of Combinations of Logics and Theorem Proving

Task coordinator: Marcelo Finger

This task deals with the study of the computational and practical aspects of combination of logic systems.

This task has seen great progress in several of its subtasks, which includes the acceptance for publishing of papers in good journals and conferences and the production of the first version of an open source theorem prover for formally inconsistent logics.

Subtask 2.1: Approximations of Classical Propositional Logic

The main result is this area concerns the expansion presented on the frontiers of approximation. Until very recently, all forms of approximation processes in logic concerned some form of redefinition on the notion of classical negation. This was in conformity of the paraconsistent nature of those approximations, namely that all intermediate logics that approximated classical logic admitted some form of non-trivializing inconsistency.

A recent result by Finger and Wassermann expanded the frontiers of approximation, so as to admit approximations of classical logic by weakening any set of classical connectives, not only negation. This result is published in the following paper

[FW06] Marcelo Finger and Renata Wassermann. The universe of propositional approximations, *Theoretical Computer Science*, Volume 355, Issue 2, 2006, Pages 153-166.

A second result obtained in this field concerned the approximation of classical modal logics, which involved the work of MSc Student Guilherme Rabello. An initial result was published in the Wollic2005 conference.

[RF05] Guilherme Rabello and Marcelo Finger. *Approximations of Modal Logic K*. In: 12th Workshop on Logic, Language, Information and Computation, 2005, Florianópolis p. 23-32.

This work is being extended to approximations of generic modal logics, not only modal logic K, which has been submitted for publication.

Another important result was obtained concerning the existence of polynomial approximations of classical logic. This involves controlling the approximation process not over connectives, but over the use of the cut rule in a calculus in which it was not eliminable. The initial results were published in a conference.

[Fin04] Marcelo Finger. Polynomial approximations of full propositional logic via limited bivalence. In *9th European Conference on Logics in Artificial Intelligence (JELIA 2004)*, LNAI vol. 3229, pages 526–538, 2004.

Further results were obtained on this direction and the result was accepted for publication in a journal.

[FG06] Marcelo Finger and Dov Gabbay. Cut and pay. *Journal of Logic, Language and Information*, 2006. Accepted for publication.

A new topic for this subtask is the issue of responsive environments. Responsive environments are physical surroundings whose components change their behaviour to accommodate the presence of people as well as other components. Work on this trail tries to manage such responsive environments whereby each component is dynamically assigned a software agent – these are autonomous and reactive/proactive programs that communicate via message-passing. Arbitrary functionalities can be encoded in such agents, reflecting the capabilities of the components they represent, as well as extending them. Ours is a flexible and scalable approach allowing the gradual population of an environment with physical devices and their corresponding agents.

This research line has generated the following article:

[SV05] Flavio Soares Correa da Silva and Wamberto Vasconcelos. Agent based management of responsive environments. In: *Congress of the Italian Association of Artificial Intelligence*, 2005, Milan. Proceedings of AI*IA. 2005.

On the practical side, this subtask is producing a Multiple Strategy KE-tableau prover, through the implementation work of Adolfo Neto. A first version of such tableau can be found in

`http://gsd.ime.usp.br/ adolfo/projetos/KEMS.zip`

Several papers were written based on that implementation.

[SNF05a] Adolfo G. S. Seca Neto and Marcelo Finger. Implementing a Multi-Strategy Theorem Prover. In: SBC 2005 ENIA – V Encontro Nacional de Inteligência Artificial, 2005, São Leopoldo, RS. Anais do V Encontro Nacional de Inteligência Artificial, 2005.

[SNF05b] Adolfo G. S. Seca Neto and Marcelo Finger. Using Aspect-oriented Programming in the Development of a Multi-strategy Theorem Prover. In: II Jornada do Conhecimento e da Tecnologia do UNIVEM, 2005, Marília. II Jornada do Conhecimento e da Tecnologia do UNIVEM, 2005.

Also related to theorem proving is the following work (but this is not yet implemented in the system)

[Fin05] Marcelo Finger. DAG Sequent Proofs with a Substitution Rule. In: S. Artemov; H. Barringer; A. S. d'Avila Garcez; L.C. Lamb; and J. Woods. (Org.). We will show Them! – Essays in Honour of Dov Gabbay's 60th birthday. London, 2005, v. 1, p. 671-686.

Subtask 2.2: First-Order Approximate Inference

This subtask has not being developed due to the fact that the student assigned for it, Eudenia Menezes, has left the Project for personal reasons.

We hope to obtain further developments on this subtask in the near future, with the work of Joselyto Riani that is starting now.

Subtask 2.3: Resource Sensitive Inference

On this topic, several works related to robotics and use of inference in practical cases have been developed. We stress the application of this line of research in the area of computer and educational games which has generated several papers in several national and international conferences, involving many of the Project participants. The main ones are the following:

[SWMBF05] Flavio Soares Correa da Silva, Renata Wassermann, Ana Cristina Vieira de Melo, Leliane Nunes Barros, and Marcelo Finger. Intelligent mobile multi-robotic systems: Some challenges and possible solutions. In *2nd International Conference on Informatics in Control, Automation and Robotics (ICINCO)*, Barcelona, Spain, 2005.

[SJ05] Flavio Soares Correa da Silva and Tiago Motta Jorge. Towards Complex Reasoning Agents for Action Games. In: WJOGOS 2005, São Paulo. 2005.

This line has already generated a journal paper as well.

[Sil05] Flavio Soares Correa da Silva. Towards a Logic of Perishable Propositions. *Applied Intelligence*, v. 23, n. 2, p. 121-130, 2005.

Subtask 2.4: Automatizing Paraconsistent Inference

This subtask has been very productive. To start with, the KE Multi-Strategy tableau system implemented in Subtask 2.1 is being adapted to several paraconsistent logics. One of them, called Mbc, is know as the minimal logic of formal inconsistency, and the adaptation of the KEMS theorem prover for a wider class of logic has started with this logic. This work is being published in a conference, see below.

> Adolfo Gustavo Serra Seca Neto and Marcelo Finger. Effective Prover for Minimal Inconsistency Logic. To appear in IFIP AI 2006 in Santiago, Chile, in August 2006.

In another (but related) line of research within this subtask, a new hierarchy of analytical tableaux systems, called $TNDC_n$, adequate for da Costa's paraconsistent logics C_n, were obtained. In this approach, the consistency operator $\circ$ as well as other connectives related to C_n are defined as primitive instead of defined operators. Additionally, a version of Cut Rule for the $TNDC_n$ systems was obtained. The results were published in the reference below.

> [DC05] Itala M.L. D'Ottaviano and Milton A. de Castro. Analytical tableaux for da Costa's hierarchy of paraconsistent logics C_n. *Journal of Applied Non-Classical Logics*, 15(1):69–103, 2005.

Task 3: Quantum Logics and Algorithms

Task coordinator: Walter Carnielli

This task has the purpose of studying studying Quantum Logics and Quantum Computation, and their application to to the modeling of quantum computation in a wide range.

Paul Benioff's model is the first to mention quantum mechanics principles in connection with Turing machines (cf. [Ben80]). For several reasons Benioff's model was not accepted, however, as a good model of quantum computation.

The idea that the effects of quantum computation could supply a greater computational power was suggested by Richard Feynman in 1981 (cf. [Fey82]). He raised the question whether the phenomena of quantum mechanics could be efficiently simulated in a classical Turing machine, and presented good reasons for a negative answer. He thus speculated that, to achieve and efficient simulation, we would need computers working in accordance with the laws of quantum mechanics, but he did not define any appropriate model.

Feynman's intuition was then formalized by David Deutsch in 1985 (cf. [Deut85]) and in another model in 1989 (cf. [Deut89]) known as *quantum circuits* (CQs).

Quantum computation received a great impetus with the discoveries of efficient quantum algorithms by Peter W. Shor in 1994 (cf. [Sho94, Sho97]) and by Lov K. Grover (cf. [Gro97]).

There are a great number of mathematical, logical and philosophical problems to be solved or clarified in the quantum domain.

To start with, the notion of "qubit" is mathematically very simple: a qubit is a quantum system whose states are described by a two-dimensional Hilbert space, but is able to exist in a superposition of Boolean states and to be entangled with states of other qubits as well. This complications add, on the one hand, serious epistemological and mathematical difficulties to understand and to deal with quantum systems, but on the other hand offer formidable possibilities of using quantum systems to what concerns information, and on thinking about totally new notions of algorithms (see, e.g., [dCFK92, Gol74, Gol84]).

An interesting problem is to investigate Hilbert-space realizations for paraconsistent quantum logics and to study other Kripke semantical interpretations for them. Possible worlds in the Kripke interpretation can be interpreted as possible pieces of information about the physical system, and the cases violating the principle of non-contradiction (that is, paraconsistent states) are related to ambiguous states of knowledge. Another interesting approach, as done by [MS], was to work on quantum logics based an original exogenous approach. Such exogenous approach is related to the society semantics introduced in [CL99] and to the possible-translations semantics proposed in [Car97] for paraconsistent logic.

Subtask 3.1: Quantum Computation and Quantum Logics

This subtask is of more conceptual nature, and was planned to take advantage of the several particular objectives attained in the Subtasks 3.2 and 3.3. According to the Schedule, only Subtask 3.2 was planned for the First Semester and Second Semester. However, some advances on Subtask 3.3 were also gained.

Subtask 3.2: Polynomial Ring Proof Procedures

Algebraic proof systems are proof systems in general adequate for propositional logics that take advantage of algebraic methods, results and machinery. Algebraic methods are in principle useful alternatives for automated proof procedures and constitute apt tools to obtain results in proof complexity based on algebraic methods.

The method of the Polynomial Ring Proof Procedures (introduced in [Car01]) makes direct use of the structure of finite Galois fields, reducing provability to solving polynomial equations over finite fields.

It is expected that a proof environment for logical inferences based on the Polynomial Ring Calculus will be also implemented.

The paper

> [Car05] Carnielli, W. A. Polynomial ring calculus for many-valued logics. Proceedings of 35th International Symposium on Multiple-Valued Logic. IEEE Computer Society. Calgary, Canadá, 2005. Available from *CLE e-Prints* Vol. 5(3), 2005.
> http://www.cle.unicamp.br/e-prints/vol_5,n_3,2005.html

obtained a new "all-purpose" algebraic proof method applicable to general truth-functional sentential logics, with emphasis on many-valued logics (and for classical propositional logic PC). A very interesting byproduct is that the method is also applicable to some non-truth-functional logics, provided they can be characterized by two-valued dyadic semantics in the sense of [CCCM05].

The resulting mechanizable proof method obtained is of interest for automatic proof theory, and for investigating questions on complexity.

Subtask 3.3: Paraconsistent Turing Machines

The classical way of expressing instructions of a Turing machine by means of quadruples gives raise to the notions of deterministic Turing machine (when there is at most one instruction beginning with a given ordered pair) and non-deterministic ones (where there is a conflict of instructions, and the instruction to be executed is chosen by external means, for instance probabilistically, in the case of probabilistic Turing machines). In both cases, the machine executes a single instruction at each time, ensuring the "consistence" in every computation step.

The behaviour of a deterministic Turing machine M with input n can be axiomatized following a procedure defined by Boolos and Jeffrey in [BJ74]. The theories obtained for non-deterministic Turing machines by this method are contradictory — contradictions arise because the theories do not take into account the necessity to choose just one instruction to be executed at each time.

What is interesting, and it is the main presupposition of this Subtask, is that there is a strong interdependence between the definition of general versions of Turing machines and the underlying logical machinery that one starts from. The underlying logic can be substituted by a subclassical logic (in our first attempts, by a paraconsistent one), or in more general terms by a logic of formal inconsistency. The logical consequences of the new theory would define what is called a *Paraconsistent Turing machine*.

Subtask 3.3 proposes to investigate the model of Paraconsistent Turing machines following the procedure described above. In particular, it is intended to establish relationships with other models for computability, including quantic Turing machines.

The most palpable achievement of this Subtask was the paper :

> [AC05] J.C. Agudelo and W.A. Carnielli. Quantum Algorithms, Paraconsistent Computation and Deutsch's Problem. In Bhanu Prasad, editor, *Proceedings of the 2nd Indian International Conference on Artificial Intelligence (IICAI 2005)*, pp. 1609–1628. Pune, India, 2005.

presented at IICAI'05 in Pune, India, and published in the conference proceedings.

In that paper a new model of *paraconsistent Turing machines* was proposed, discussing the concepts of entangled states and quantum parallelism which are

important features for efficient quantum algorithms. We provided a new solution to the so-called Deutsch's problem by means of paraconsistent Turing machines, and discussed the role such machines for expressing computational properties of quantum phenomena.

Additionally, the Master Thesis of Juan Carlos Agudelo ("Computação Paraconsistente e Computação Quântica") is being finished at IFCH- UNICAMP, and the student had his project for a PhD grant approved by FAPESP (process 2005/04123-3). The student Paulo R. Petrillo also finished his Master Thesis ("Raciocínio Difuso via Lógicas Moduladas: Uma solução ao Paradoxo do Sorites") at IFCH- UNICAMP.

3 Report by Members

We now expose, for each member of the Project, which were their main contributions to the Project.

Project Coordinator

- Walter Carnielli (IFCH and CLE – UNICAMP)
  Journal papers: [BuC05].
  Conference papers: [AC05, Car05].
  Book Chapters: [CCCM05, CC05].
  Student supervision: Juan Carlos Agudelo Agudelo (PhD), Rodrigo de Alvarenga Freire (PhD), Paulo Petrillo (MSc).
  Courses and seminars:
  - Talk in the "I World Congress on Universal Logic" (UNILOG '05), Montreux, March 31-April 3, 2005:
    Polynomial Ring Calculus for Logical Inference.
  - Tutorial in the "I World Congress on Universal Logic" (UNILOG '05), Montreux, March 31-April 3, 2005:
    Many-valued Semantics.
  - Talk in the "35th International Symposium on Multiple-Valued Logic" of the IEEE Computer Society, Calgary, Canada, May 19-21, 2005:
    Polynomial Ring Calculus for Many-valued Logics.
  - Talk in the Workshop "Semantics and Meaning", CLE-UNICAMP, Campinas, July 25-28, 2005:
    Minimalist modalities as a solution to Fitch's paradox of knowability.
  - Talk in the "Primeira Mini-Escola de Lógica da PUC-Rio", (PUC-Rio), Rio de Janeiro, September 12-14, 2005:
    The paradox of cognoscibility: escapes and consequences (*O paradoxo da cognoscibilidade: escapes e conseqüências*, in Portuguese).

– Talk in the "2nd Indian International Conference on Artificial Intelligence" (IICAI-05), Pune, India, December 20-22, 2005:
Quantum Algorithms, Paraconsistent Computation and Deutsch's Problem.
– Talk in the "2005-06 Association for Symbolic Logic Winter Meeting", New York, USA, December 27-30, 2005:
Deconstructing logics by means of possible-translations semantics.

Events organization:

– Workshop "Semantics and Meaning", CLE-UNICAMP, Campinas, July 25-28, 2005, with the participation of Saul Kripke.
– Special session: "Logical Consequence and its Combinations", in the "2nd Indian International Conference on Artificial Intelligence" (IICAI-05), Pune, India, December 20-22, 2005.

Reviews

– Review for "Computing Reviews" of the book *Rippling: Meta-Level Guidance for Mathematical Reasoning* (A. Bundy, D. Basin, D. Hutter and A. Ireland), Cambridge Tracts in Theoretical Computer Science No. 56, Cambridge Univesity Press, 2005.
– Review for "Logic and Logical Philosophy" of the book *Alfred Tarski: Life and Logic* (Anita Burdman Feferman and Solomon Feferman), Cambridge University Press, Cambridge, UK, 2004. To appear in "Logic and Logical Philosophy" volume 15 (2006), 89–94.

Task Coordinators

- Marcelo Coniglio (IFCH and CLE – UNICAMP)
Journal papers: [SC06, Con06].
Conference papers: [BC05, CF05].
Book Chapters: [CCCM05, CC05].
Student supervision: Wagner Sanz (PhD), Alberto Leopoldo Batista Neto (MSc).
Courses and seminars:
  – Talk in the Workshop "Semantics and Meaning", CLE-UNICAMP, Campinas, July 25-28, 2005:
  Splitting logics: factoring logics into simpler components.
  – Mini Course in the "Primeira Mini-Escola de Lógica da PUC-Rio", (PUC-Rio), Rio de Janeiro, September 12-14, 2005:
  Combination of Logics (*Combinação de Lógicas*, in Portuguese).
  – Talk in the "2nd Indian International Conference on Artificial Intelligence" (IICAI-05), Pune, India, December 20-22, 2005:
  Plain Fibring and Direct Union of Logics with Matrix Semantics.

– Talk in the "2005-06 Association for Symbolic Logic Winter Meeting", New York, USA, December 27-30, 2005:
Meta-translations and fibring.
– Seminar in the "Logic and Computation Seminar", Center for Logic and Computation, Instituto Superior Técnico, Lisbon, February 24, 2006:
Plain fibring of Matrix Semantic.

Events organization: Workshop "Semantics and Meaning", CLE-UNICAMP, Campinas, July 25-28, 2005, with the participation of Saul Kripke.

- Marcelo Finger (DCC-IME-USP)
  Journal papers: [FG06, FW06].
  Conference papers: [Fin05, FF05, RF05, SNF05a, SNF05b, SWMBF05].
  Student supervision: Adolfo Seca Neto (PhD), Guilherme Rabello (MSc), Rogerio Fajardo (MSc).
  Courses and seminars: Talk in the Workshop "Semantics and Meaning", CLE-UNICAMP, Campinas, July 25-28, 2005:
  DAG Sequent Proofs with a Substitution Rule.

Researchers

- Angela Weiss (MAT-IME-USP)
  Angela is currently studying the decidability of a combined modal logic **S4**×**S4**, and results are expected soon.

- Flavio Correa da Silva (DCC-IME-USP)
  Journal papers: [Sil05].
  Conference papers: [SJ05, SV05, SWMBF05].
  Student supervision: Tiago Motta Jorge (MSc), Flavio Shigueo Yamamoto (PhD).

- Hércules de Araujo Feitosa (MAT-UNESP-Bauru)
  Journal papers: [GF05].
  Courses and seminars: Talk in the Workshop "Semantics and Meaning", CLE-UNICAMP, Campinas, July 25-28, 2005:
  A propositional version of the logic of plausibility (*Por uma versão proposicional da lógica do plausível*, in Portuguese).
  Student supervision: Maria Matulovic da Silva Fadel (MSc).

- Hugo Mariano (MAT-IME-USP)
  Conference papers: [AFLM05].

Preprints: [AFLM06a, AFLM06b].
Courses and seminars: Talk in the Workshop "Semantics and Meaning", CLE-UNICAMP, Campinas, July 25-28, 2005:
On filtered colimits of algebraizable logics.

- Itala D'Ottaviano (IFCH and CLE – UNICAMP)
  Journal papers: [DC05, SD05].
  Book chapters: [HD06].
  Student supervision: Juliana Bueno, Carlos Hifume and Mauro Scheer (PhD).
  Post-doc supervision: Milton Agustini de Castro.
  Courses and seminars:
  - Talk in the Workshop "Semantics and Meaning", CLE-UNICAMP, Campinas, July 25-28, 2005:
    Da Costa's paraconsistent differencial calculus and a transference theorem.
  - Talk in the "12th Workshop on Logic, Language, Information and Computation" (WoLLIC 2005), Florianópolis, Brazil, July 19-22, 2005:
    Analytical Tableaux for da Costa's Paraconsistent Logics C_n.

- Odilon Otávio Luciano (MAT-IME-USP)
  Conference papers: [AFLM05].
  Preprints: [AFLM06a, AFLM06b].
  Courses and seminars: Talk in the Workshop "Semantics and Meaning", CLE-UNICAMP, Campinas, July 25-28, 2005:
  Hom sweet hom: a note on a result of Borceux-Janelidze's "Galois theories".

- Renata Wassermann(DCC-IME-USP)
  Journal papers: [FW06].
  Student supervision: Joselyto Riani.
  Courses and seminars:
  - Talk in the Workshop "Semantics and Meaning", CLE-UNICAMP, Campinas, July 25-28, 2005:
    Using relevance to speed up inference - some empirical results (joint work with Joselyto Riani).
  - Mini Course in the "Primeira Mini-Escola de Lógica da PUC-Rio", (PUC-Rio), Rio de Janeiro, September 12-14, 2005:
    Approximations of Logics (*Aproximações de Lógicas*, in Portuguese).

Post-Doc Students

- Milton Augustinis de Castro (IFCH – UNICAMP)
  Journal papers: [DC05].
  Courses and seminars: Talk in the Workshop "Semantics and Meaning", CLE-UNICAMP, Campinas, July 25-28, 2005:
  Analytical tableaux and sequent calculus for da Costa's hierarchy of paraconsistent logics C_n, $1 < n < \omega$.

- João Marcos (IFCH-UNICAMP and IST, Lisbon)
  João is no longer a Post-Doc Student since he got a position at the Federal University of Rio Grande do Norte. Besides this, he continues working for the Project.
  Journal papers: [Mar05a].
  Courses and seminars:
  - Tutorial in the "I World Congress on Universal Logic" (UNILOG '05), Montreux, March 31-April 3, 2005:
    Multiple-Conclusion Logics.
  - Seminar in the "Logic and Computation Seminar", Center for Logic and Computation, Instituto Superior Técnico, Lisbon, April 8, 2005:
    Paraconsistency, many-valuedness, modality.
  - Seminar organized by the "Grupo de Lógica, Inteligência Artificial e Métodos Formais" (LIAMF), Department of Computer Science, São Paulo University, São Paulo, 2005:
    When is a logic characterized by truth-tables?.
  - Talk in the Workshop "Semantics and Meaning", CLE-UNICAMP, Campinas, July 25-28, 2005:
    What is a non-truth-functional logic?

- Luís Sbardellini (IFCH-UNICAMP)
  Luís is no longer a Post-Doc Student since he decides to start a PhD in Mathematics at The University of São Paulo. Besides this, he continues working for the Project.
  Journal papers: [SC06].
  Courses and seminars: Talk in the Workshop "Semantics and Meaning", CLE-UNICAMP, Campinas, July 25-28, 2005:
  Homogeneity of the Dedekind real numbers in topoi (*Homogeneidade dos reais de Dedekind em topoi*, in Portuguese).

PhD Students

- Adolfo Gustavo Serra Seca Neto (DCC-IME-USP)
  Conference papers: [SNF05a, SNF05b]

Software Production: An open source theorem prover, written in java, available at `http://gsd.ime.usp.br/ adolfo/projetos/KEMS.zip`

- Carlos Hifume (IFCH-UNICAMP)
  Book chapters: [HD06].
  Courses and seminars: Talk in the Workshop "Semantics and Meaning", CLE-UNICAMP, Campinas, July 25-28, 2005:
  Pragmatic truth, logic and models (*Verdade pragmática, lógica e modelos*, in Portuguese).

- Eudenia Xavier Meneses (DCC-IME-USP)
  Eudenia left the Project.

- Joselyto Riani (DCC-IME-USP)
  Joselyto is currently finishing his courses in his PhD, studying approximations of first-order logic.

- Juan Carlos Agudelo Agudelo (IFCH-UNICAMP)
  Conference papers: [AC05].
  Courses and seminars:
  - Seminar organized by the "Group for Theoretical and Applied Logic" (GTAL), CLE-UNICAMP, Campinas, 2005:
    Introduction to quantum computation (*Introdução à computação quântica*, in Portuguese).
  - Talk in the Workshop "Semantics and Meaning", CLE-UNICAMP, Campinas, July 25-28, 2005:
    Logics for quantum mechanics (*Lógicas da mecânica quântica*, in Portuguese).

- Juliana Bueno (IFCH-UNICAMP)
  Journal papers: [BuC05].
  Courses and seminars: Talk in the Workshop "Semantics and Meaning", CLE-UNICAMP, Campinas, July 25-28, 2005:
  Finite algebraizability and a simple proof-theory for the hierarchy P_n and I_n.

- Rodrigo de Alvarenga Freire (IFCH-UNICAMP)
  Conference papers: [AFLM05].
  Preprints: [AFLM06a, AFLM06b].
  Courses and seminars: Talk in the Workshop "Semantics and Meaning", CLE-UNICAMP, Campinas, July 25-28, 2005:
  Galois theories in Logic (*Teorias de Galois em Lógica*, in Portuguese).

MSc Students

- Guilherme Rabello (MAT-IME-USP)
  Conference papers: [RF05].

- Paulo Petrillo (IFCH-UNICAMP)
  Paulo has finished his MSc in Philosophy and will leave the Project.
  Courses and seminars: Talk in the Workshop "Semantics and Meaning", CLE-UNICAMP, Campinas, July 25-28, 2005:
  Fuzzy reasoning via Modulated Logics (*Raciocínio Difuso via Lógicas Moduladas*, in Portuguese).

External Participants

- Amilcar Sernadas (IST, Lisbon)

- Alexandre Costa-Leite (Université de Neuchâtel, Switzerland)

- Carlos Caleiro (IST, Lisbon)
  Book Chapters: [CCCM05].

- Cristina Sernadas (IST, Lisbon)

- Dov Gabbay (King's College, London)
  Journal papers: [FG06].

- Jean-Yves Béziau (Université de Neuchâtel, Switzerland)
  Conference papers: [BC05].

- João Rasga (IST, Lisbon)

- Paulo Mateus (IST, Lisbon)

4 Events Organized within the Project

The Workshop "Semantics and Meaning" (SEME'05) was organized at the Centro de Lógica, Epistemologia e História da Ciência (CLE- UNICAMP) in Campinas, SP, around the visit of Prof. Saul Kripke to Campinas. Kripe is considered to be one of the greatest living philosophers, and the Workshop concentrated in the philosophical and logical aspects of his work, also discussing topics connected with formal and informal semantics and combinations of logics (including the possible-translations semantics, fibring, etc) and related philosophical issues.

The Workshop was chaired by Walter Carnielli, and the Program Committee counted with Oswaldo Chateaubriand (PUC-RJ), Newton C.A. da Costa (USP/UFSC), Marcelo Finger (USP). In the Organizing Committee served Marcelo E. Coniglio (UNICAMP) and Itala M.L. D'Ottaviano (UNICAMP)

(SEME'05) was held in the period 25 –28 July, 2006, sponsored by FAPESP. Full information is available from the homepage:

http://www.cle.unicamp.br/seme_2005/

A Special Session called "Logical Consequence and its Combinations" was organized within the important "2nd Indian International Conference on Artificial Intelligence" (IICAI-05) held in Pune, India, in December 20-22, 2005. During the session, organized within the scope of the ConsRel Project, the following papers of members of the Project were presented:

[AC05] J.C Agudelo and W.A. Carnielli. Quantum Algorithms, Paraconsistent Computation and Deutsch's Problem.
[AFLM05] P. Arndt, R.A. Freire, O.O. Luciano and H.L. Mariano. Fibring and Sheaves.
[BC05] J.-Y. Béziau and M.E. Coniglio. Combining Conjunction with Disjunction.
[CF05] M.E. Coniglio and V.L. Fernández. Plain fibring and direct union of logics with matrix semantics.
[DoF05] I.M.L. D'Ottaviano and T. Fernandes de Carvalho. Da Costa's Paraconsistent Differential Calculus and a Transference Theorem.
[FF05] R. Fajardo and M. Finger. How not to combine modal logics.

The papers were published in an special volume. The realization of the session was a very important fact, because it was possible to establish contacts with members of an important and active scientific community from Asia, which deserves a close attention. Several members of the Project attended the conference. The webpage of the event is the following:
http://www.iiconference.org/iicai05/lcc.html

5 Future Work: Next Steps and Work in Progress

Task 1: Fundamentals of Combining Logics, coordinated by Marcelo Coniglio.

– Subtask 1.1: Combinations of Logics and their Applications.

With respect to this subtask, several topics are expected to be developed. On the one hand, we plan to continue analyzing the consequences of the dichotomy collapse/anticollapse of the method of fibring. In particular, the notion of extension of logics preserving meta-properties will be studied. On the other hand, we expect to expand the conceptual analysis of translations between logics and representation of logic systems. Finally, the study of the relationship between modal logic and logics of formal inconsistency in the context of combination of logics will be continued.

- Subtask 1.2: Splitting and Algebraizing Logics.

  We expect to develop a formal study of Possible-Translations Semantics, with the aim of obtaining general results of preservation of properties of the factor (component) logics through the combination process. Application to algebraizing logics are expected.

- Subtask 1.3: Algebraic Semantics for Modal Logics.

  Starting from the notion of "quasi-truth", some main results towards non-classical model theory are planned to be obtained, in the direction of constituting a "theory of pragmatic models" or "theory of quasi- models".

  As a second job, the question of the existence of a conservative translation from intuitionistic into classical logic will be tackled here; the solution to this question would open several avenues with technical and conceptual relevance.

- Subtask 1.4: Algebraic and Categorial Aspects of Logical Consequence.

  This subtask is mainly devoted to the use of tools from category theory for representation and combination of logics. We plan to continue the different lines of research already initiated. In particular, together with external participants of the Project, the possibility of using polycategories as a conceptual framework for representing logic systems and their combinations will be studied. As a particular issue, it is expected that the result of homogeneity of the ordered structure of rational numbers in toposes can be extended to the ordered structure of Dedekind real numbers in toposes.

- **Task 2: Computational Aspects of Combinations of Logics and Theorem Proving**, coordinated by Marcelo Finger.

  - Subtask 2.1: Polynomial-Time Approximations of Classical Propositional Logic

    In this subtask we expect to explore the work in two directions. On the one hand, we will study approximations "from above" for classical logic, a strategy usually related to theorem disproving, or SAT. Also, we plan to study approximations for a larger set of modal logics.

  - Subtask 2.2: First-Order Approximate Inference

The work in this subtask is just starting and involves studying probabilistic methods for the approximation of first-order inference.

- Subtask 2.3: Resource Sensitive Inference

  Future steps in this task aims at studying application of logics and AI techniques to the design of automated agents in computer games.

- Subtask 2.4: Automatizing Paraconsistent Inference

  Here, the future developments lie in the adaptation of the KE-tableau in development to several logics of formal inconsistency. We also plan to enlarge this subtask to contemplate tableau systems for modulated logics, and to investigate the problem of obtaining (in a semi automatic way) complete and adequate tableau systems from appropriate valuation semantics.

- **Task 3: Quantum Logics and Algorithms**, coordinated by Walter Carnielli.

  - Subtask 3.1: Quantum Computation and Quantum Logics

    In this subtask we plan to investigate the relationship between logic systems and models of quantum computation, so as to clarify the role of the underlying logic in such models. A second trend is to analyze the role of some essential quantum characteristics in the development of efficient quantum algorithms. The student Juan Carlos Agudelo Agudelo just obtained a Ph.D. grant from FAPESP and part of his research interests are related to this Subtask and to the third one in this Task.

  - Subtask 3.2: Polynomial Ring Proof Procedures

    The work in the direction of this subtask is just in its first steps. The approach of the "Polynomial Ring Proof Procedures´´ is a new idea, with unfolding, on the more technical side, into theorem proving for classical and non-classical logics, algebrization of logics and applications to quantic gates in quantum computation; on the more conceptual side, it may also illuminate some philosophical discussion on the work of Boole in formalizing logic.

  - Subtask 3.3: Paraconsistent Turing Machines

    The intention towards future steps in this subtask is to improve the models of Paraconsistent Turing Machines proposed in previous steps in such a way as to get closer of the models of quantum computing. This would help to clarify how much quantum computation can be expressed by means of paraconsistent computation, at the same offering a new interpretation of quantum computing by means of the paradigm of paraconsistency.

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[AC05] J.C. Agudelo and W.A. Carnielli. Quantum Algorithms, Paraconsistent Computation and Deutsch's Problem. In Bhanu Prasad, editor, *Proceedings of the 2nd Indian International Conference on Artificial Intelligence (IICAI 2005)*, pp. 1609–1628. Pune, India, 2005.

[AFLM05] P. Arndt, R.A. Freire, O.O. Luciano and H.L. Mariano. Fibring and Sheaves. In Bhanu Prasad, editor, *Proceedings of the 2nd Indian International Conference on Artificial Intelligence (IICAI 2005)*, pp. 1679–1698. Pune, India, 2005.

[AFLM06a] P. Arndt, R.A. Freire, O.O. Luciano and H.L. Mariano. On the category of algebraizable logics. *CLE e-Prints* Vol. 6(1), 2006. Available at http://www.cle.unicamp.br/e-prints/vol_6,n_1,2006.html

[AFLM06b] P. Arndt, R. A. Freire, O. O. Luciano and H. L. Mariano. A global glance on categories in Logic. Submitted for publication.

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