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Preface

Computer Science Logic (CSL) is the annual conference of the European Association for Computer Science Logic. The conference series started as a programme of International Workshops on Computer Science Logic, and then from its sixth meeting became the Annual Conference of the EACSL. The 15th Annual Conference (and 20th International Workshop), CSL 2006, took place during September 25–29, 2006. It was organized by the Department of Computer Science, University of Szeged. Previous CSL conferences were held in Karlsruhe (1987), Duisburg (1988), Kaiserslautern (1989), Heidelberg (1990), Bern (1991), San Miniato (1992), Swansea (1993), Kazimierz (1994), Paderborn (1995), Utrecht (1996), Aarhus (1997), Brno (1998), Madrid (1999), Fischbachau (2000), Paris (2001), Edinburgh (2002), Vienna (2003), Karpacz (2004) and Oxford (2005).

The suggested topics of the conference included automated deduction and interactive theorem proving, constructive mathematics and type theory, equational logic and term rewriting, automata and formal logics, modal and temporal logic, model checking, logical aspects of computational complexity, finite model theory, computational proof theory, logic programming and constraints, lambda calculus and combinatory logic, categorical logic and topological semantics, domain theory, database theory, specification, extraction and transformation of programs, logical foundations of programming paradigms, verification of security protocols, linear logic, higher-order logic, nonmonotonic reasoning, logics and type systems for biology.

In response to the Call for Papers, a total of 132 abstracts were submitted of which 108 were accompanied by a full paper. The International Programme Committee accepted 37 papers for presentation and inclusion in these proceedings. The Programme Committee invited lectures from Martín Escardó (Birmingham), Paul-André Melliès (Paris), Luke Ong (Oxford), Luc Segoufin (Orsay) and Mirosław Truszczyński (Lexington, KY).

The Ackermann Award is the EACSL Outstanding Dissertation Award for Logic in Computer Science. The 2006 Ackermann Award was presented to Balder ten Cate and Stefan Milius at the conference.

These proceedings contain the texts of 4 invited lectures and the 37 accepted papers and the report of the Ackermann Award Committee whose members were J. Makowsky (President of EACSL), D. Niwiński (Vice-President of EACSL), S. Abramsky, B. Courcelle, E. Grädel, M. Hyland, and A. Razborov.

I would like to thank everybody who submitted a paper to the conference and all members of the Programme Committee and their subreferees for their excellent cooperation in the evaluations of the papers. Finally, I would like to thank my colleagues Zolt Gazdag, Szabolcs Iván and Zoltán L. Németh for their technical assistance during the preparation of these proceedings.

The conference was sponsored by the Department of Computer Science, University of Szeged, the Hungarian Academy of Science, the Fund for Research and Education in Informatics, the Fund for Szeged and the Nokia Hungary, Ltd.

Szeged, July 2006

Zoltán Ésik

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Functorial Boxes in String Diagrams[★]

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Abstract. String diagrams were introduced by Roger Penrose as a handy notation to manipulate morphisms in a monoidal category. In principle, this graphical notation should encompass the various pictorial systems introduced in proof-theory (like Jean-Yves Girard’s proof-nets) and in concurrency theory (like Robin Milner’s bigraphs). This is not the case however, at least because string diagrams do not accomodate *boxes* — a key ingredient in these pictorial systems. In this short tutorial, based on our accidental rediscovery of an idea by Robin Cockett and Robert Seely, we explain how string diagrams may be extended with a notion of *functorial box* depicting a functor transporting an inside world (its source category) to an outside world (its target category). We expose two elementary applications of the notation: first, we characterize graphically when a faithful balanced monoidal functor $F : \mathbb{C} \longrightarrow \mathbb{D}$ transports a *trace operator* from the category $\mathbb{D}$ to the category $\mathbb{C}$, and exploit this to construct well-behaved *fixpoint operators* in cartesian closed categories generated by models of linear logic; second, we explain how the categorical semantics of linear logic induces that the exponential box of proof-nets decomposes as two enshrined boxes.

1 Introduction

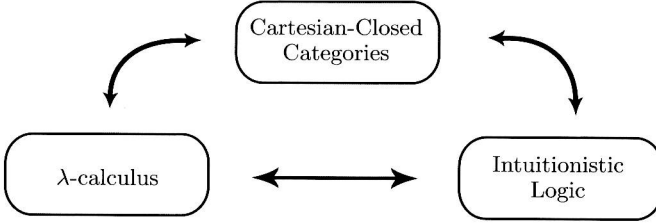
The origins. Although the process was already initiated in the late 1960s and early 1970s, very few people could have foreseen that Logic and Computer Science would converge so harmoniously and so far in the two areas of *proof theory* and *programming language design*. Today, about forty years later, the two research fields are so closely connected indeed, that any important discovery in one of them will have, sooner or later, an effect on the other one. The very existence of the conference *Computer Science Logic* bears witness of this important and quite extraordinary matter of fact.

The convergence would not have been as successful without the mediation of *category theory* — which made an excellent matchmaker between the two subjects, by exhibiting the algebraic properties underlying the mathematical models (or denotational semantics) of both proof systems and programming languages. At the end of the 1970s, a few people were already aware that:

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- intuitionistic logic as articulated in proof theory,
- the λ -calculus as implemented in programming languages,
- cartesian closed categories as investigated in category theory

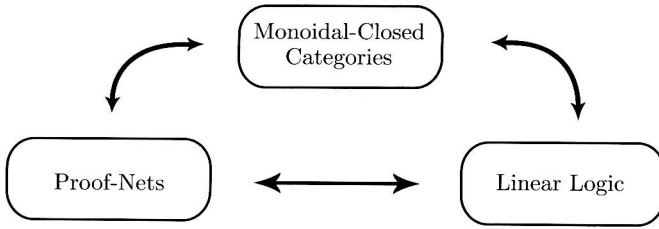
are essentially the same object in three different guises — see for instance Jim Lambek and Phil Scott’s monograph [34]. The idea circulated widely in the community, so that a few years later, in the mid-1980s, the following trilogy of concepts has become prominent:



A linear world opens. The year 1985 was then a turning point, with the discovery of linear logic by Jean-Yves Girard. This single discovery had the quite extraordinary effect of refurbishing every part of the subject with new tools, new ideas, and new open problems. In particular, each of the three concepts above was reunderstood in a linear fashion. In effect, Jean-Yves Girard [18,19] introduced simultaneously:

1. a sequent calculus for linear logic, which refines the sequent calculus for Intuitionistic Logic defined by Gerhard Gentzen in the 1930s — in particular, every derivation rule in intuitionistic logic may be translated as a series of more “atomic” derivation rules in linear logic,
2. a graphical syntax of proofs, called *proof-nets*, which refines the term syntax provided by λ -terms — in particular, every simply-typed λ -term may be translated as a proof-net, in such a way that a β -reduction step on the original λ -term is mirrored as a series of more “atomic” cut-elimination steps in the associated proof-net,
3. a denotational semantics of linear logic, based on *coherence spaces* and *cliques*, which refines the model of dI-domains and stable functions defined by Gérard Berry [7] for the purely functional language PCF, a simply-typed λ -calculus extended with a fixpoint operator, a conditional test on booleans, and the main arithmetic operations. People like Robert Seely [45], Yves Lafont [31] and François Lamarche [33] realized very early that the construction amounts to replacing a cartesian closed category (of dI-domains and stable maps) by a *monoidal closed category* (of coherence spaces and cliques) equipped with a particular kind of *comonad* to interpret the *exponential modality* (noted !) of linear logic.

From this followed a new and refined “linear” trilogy, which became prominent in the early 1990s:



A puzzle in string diagrams. I started my PhD thesis exactly at that time, but in a quite different topic: Rewriting Theory, with Jean-Jacques Lévy at INRIA Rocquencourt. Although I devoted all my energies to exploring the arcanae of my own subject, this culminating in [38,39], I was astonished by the elegance of linear logic, and by the extraordinary perspectives opened by its discovery. Indeed, our emerging field: the semantics of proofs and programs, was suddenly connected to something like mainstream mathematics: linear algebra, representation theory, low-dimensional topology, etc.

My interest was reinforced after a discussion with Yves Lafont, who revealed suddenly to me that *multiplicative* proof-nets, and more generally, his own notion of *interaction nets* [32] are specific instances of a graphical notation invented by Roger Penrose [43,44] to manipulate morphisms in monoidal categories; and that this notation is itself connected to the works by Jean Bénabou on bicategories [4], by Ross Street on computads [47], and by Albert Burroni on polygraphs and higher-dimensional rewriting [13]. Then, André Joyal and Ross Street published at about the same time two remarkable papers [27,28] devoted to *braided monoidal categories* and *string diagrams*. This elegant work finished to convince me... Indeed, I will start this tutorial on string diagrams by giving a very brief and partial account of the two articles [27,28] in Section 2.

Now, it is worth recalling that a proof-net is called *multiplicative* when it describes a proof limited to the *multiplicative* fragment of linear logic. Since multiplicative proof-nets are instances of string diagrams... there remains to understand the “stringy” nature of *general* proof-nets — that is, proof-nets not limited to the multiplicative fragment. A serious difficulty arises at this point: general proof-nets admit *exponential boxes* which depict the action of the exponential modality ! on proofs, by encapsulating them. Recall that the purpose of the modality ! is to transform a “linear” proof which must be used exactly once, into a “multiple” proof which may be repeated or discarded during the reasoning. So, by surrounding a proof, the exponential box indicates that this proof may be duplicated or erased. The trouble is that, quite unfortunately, string diagrams do not admit any comparable notion of “box”. Consequently, one would like to extend string diagrams with boxes... But how to proceed?

The lessons of categorical semantics. Interestingly, the solution to this puzzle appears in the categorical semantics of linear logic, in the following way. In the early 1990s, Martin Hyland and Gordon Plotkin initiated together with their students and collaborators Andrew Barber, Nick Benton, Gavin Bierman, Valeria de Paiva, and Andrea Schalk, a meticulous study of the categorical structure