

## Preface

This special issue is indeed quite special, at the point that some of its articles drift out of the usual scope of Information and Computation. It is so special because the scientific journey of the person to whom it is dedicated on his 60<sup>th</sup> birthday, Prof. Giuseppe Longo, is an extraordinary one. This journal issue tries to cover some of the main stages of his scientific career and it would have been incomplete if it did not include some of the latest interests of Longo's research. As such, it must cross the usual borders of Information and Computation to roam within epistemology and cognitive sciences.

Let us try to summarize below the main stages of Longo's scientific career. Longo obtained his degree in Mathematics in 1971 at the University of Pisa with a master thesis under the supervision of Giorgio Ausiello on the axiomatic study of the complexity of computation of recursive functions.<sup>1</sup> Shortly after he was granted a position in applied mathematics at the same university. At that time, he was generally interested in the application of mathematical theories to theoretical computer science, as well as in foundational aspects of mathematics. On the latter aspect, an important role was played by the seminar on Logic organized by Ennio De Giorgi at the Scuola Normale Superiore of Pisa, where original set-theoretic frameworks for the foundation of mathematical analysis were discussed and developed. The seminar was crucial for the logical training of Giuseppe Longo.

His research became more focused on functional languages and  $\lambda$ -calculus at the end of the 70's, with his seminal work with Roger Hindley on the very notion of  $\lambda$ -model and with Henk Barendregt on equational theories. Crucial to this development were the two years spent at the beginning of the 80's as a visiting professor in Oxford, Berkeley, and Boston. This stage of Longo's research is here represented by the article *Applications of Infinitary Lambda Terms* by Henk Barendregt and Jan Willem Klop where they tackle some problems of infinitary  $\lambda$ -calculus, e.g., definability and recursiveness, that Longo studied for  $\lambda$ -calculus at the beginning of his career.

Influenced by the work of Yuri Ershov and Dana Scott on higher-order recursion theory and domain theory, Longo became increasingly interested in the *semantics* of the  $\lambda$ -calculus. For instance, he worked with Mario Coppo, Mariangiola Dezani, and Furio Honsell on filter models and with Kim Bruce on provable type isomorphisms and the solution of domain equations. This stage of Longo's research is here represented by the article *On the completeness of order-theoretic models of the  $\lambda$ -calculus* by Furio Honsell and Gordon Plotkin, addressing completeness and consistency questions in various classes of models and various sets of sentences.

All this experience deepened Longo's firm belief in the fundamental role played by mathematical theories in the study of theoretical computer science. This is why he first struggled to create and finally opened in 1981 the first course in Mathematical Logic in a Computer Science curriculum in Italy, at the University of Pisa. Longo's office at the Department of Computer Science of the University of Pisa, in these years, is a real crossroads of international researchers, making of it an ideal place, for all his students, to learn and discuss the most recent and innovative ideas at the intersection between Logic and Computer Science.

During this period, through the work of Per Martin-Löf and Jean-Yves Girard, Longo became increasingly interested in Type Theory and in the formalisation of its models through Category Theory. On this topic, he had fruitful interactions with some of his students leading

---

<sup>1</sup>The first PhD program started in Italy in 1982.

in particular to the publication of a book with Andrea Asperti in 1991. Along with its scientific activity, Longo has been an active editor promoting the interaction between mathematics and computer science. In particular, in 1990 he founded the journal *Mathematical Structures in Computer Science* that soon became one of the reference journals in theoretical computer science.

At about the same time, a second period in the United States in Pittsburgh and Palo Alto made Longo steer his researches toward more practical issues, namely to the study of the typing problems raised by programming languages, especially object-oriented ones. His starting point was the *partial equivalence relations* model he had been studying with Eugenio Moggi. Based on this model, he proposed with Kim Bruce an interpretation of record types and subtyping which are key notions in the understanding of object-oriented languages. Later, with Giuseppe Castagna and Giorgio Ghelli, he worked on typing issues of multi-methods and dynamic dispatch. With Luca Cardelli, he studied the semantics of second order polymorphism and subtyping. Finally, with Serguei Soloviev and Kathleen Milsted, he studied the coherence of the subtyping relation in a second-order  $\lambda$ -calculus and its interpretation as an entailment relation. This stage of Longo's research is represented here by the article *Session Types for Object-Oriented Languages* by Mariangiola Dezani-Ciancaglini, Sophia Drossopoulou, Dimitris Mostrous, and Nobuko Yoshida, where they enrich a type system for object-oriented languages with a typing discipline to ensure the safety of two parties conversations, dubbed sessions.

At the turn of the century, Longo, in collaboration with his students Gabriele Santini and Frédéric De Jaeger, revived an old interest in higher-order recursion theory and more generally in the computational representation of mathematical entities such as real numbers and continuous functions. This research, initiated by, among others, Turing, Grzegorzczyk, Lacombe, Banach, and Mazur, and later by Abbas Edalat and Klaus Weihrauch, saw Giuseppe Longo to renew his interest in domain theory and resort to techniques that are nowadays extensively used in this research topic. This stage of Longo's research is represented here by Abbas Edalat's contribution *A computable approach to measure and integration theory* where domain theory is used to define a computational framework for Lebesgue's measure and integration theory, which foreshadows more general applications of domain theory in probability theory and functional analysis.

Longo has always been interested in epistemology and cognitive sciences, as his 1987 writings on Weyl and "Das Continuum" witness. This interest became more and more predominant after Longo's move, in 1989, from the University of Pisa to the *École Normale Supérieure* in Paris, where he enjoyed an extraordinary interdisciplinary environment. Stimulated by this milieu Longo started in the mid 90's an interdisciplinary reflection on the use of Mathematics in the foundation of the cognitive processes. In particular Longo, among others, observed that the study of concurrency and distribution was making the focus of computing drift from a sequential and logical universe to a geometrical and temporal one. Therefore he wondered whether the same drift could be observed and applied to study the cognitive processes in and by other disciplines. This was to become at the end of the decade the main research interest of Longo, as it is witnessed by the proposal in 1999 of the interdisciplinary project "Geometry and Cognition". This proposal was the starting point of a new research group led by Longo at the *École Normale Supérieure* on Complexity and morphological information which focused on some foundational problems that lie at the frontier between Mathematics, Physics, and Biology. To represent this recent stage of Longo's scientific interests, the reader will find in this special issue the article *Semiclassical analysis and sensitivity to initial conditions*

by Thierry Paul that deals with epistemological issues of the relation between classical and quantum physics or unpredictability and determinism, drawing a parallel between quantum physics and theoretical computer science.

This long scientific journey that goes “From Type Theory to Morphological Complexity”<sup>2</sup> and that we try to outline in this special issue, is not the result of hazard or of a simple change of mood or of interests. Instead it is the visionary but somehow natural outcome of the curiosity of an outstanding researcher that tries to apply his past experience to unexplored lands. This is clearly shown by Longo’s article that opens this special issue, which is somewhat a guide through the scientific journey of the author and, thus, through this special issue itself. In particular in this article Longo reviews various notions of “determination” and “incompleteness” that arise in computing, physical, and biological systems to arrive at the concept of *anti-entropy*, developed jointly with Francis Bailly, a concept that offers a new perspective on the modelling of biological systems. More generally, this article shows how to transpose results observed in Logic and Computer Science to Physics and Biology, and makes a parallel of similar evolution patterns that can be found in all these disciplines. The article describes a journey from—as the title goes—exact sciences to life phenomena, in a continuous interplay between Computing, Physics, and Biology.

During his scientific career, Longo has attracted and inspired an important number of students. He directed or co-directed the PhD thesis of Simone Martini (1988), Andrea Asperti (1989), Giorgio Ghelli (1989), Stefano Berardi (1989), Roberto Amadio (1991), Antonio Bucciarelli (1993), Roberto Di Cosmo (1993), Giuseppe Castagna (1994), Roberto Bellucci (1996), Chen Gang (1998), Frédéric de Jaeger (2003), Matteo Mossio (2006), Boris Saulnier (2006), Mathieu Hoyrup (2008), and Cristóbal Rojas (2008). On behalf of them and of the many others who were under his influence at the very beginning of their research activity (to mention a few: Paola Giannini, Furio Honsell, Eugenio Moggi, Pietro Di Giannantonio, and Franco Barbanera), we want to thank Giuseppe Longo for his tuition, guidance, and example, and wish him many more years of fruitful research.

*Roberto Amadio, Andrea Asperti, and Giuseppe Castagna*

---

<sup>2</sup>In celebration of Longo’s 60<sup>th</sup> birthday, a colloquium with this title was held in Paris in June 2007 and was at the origin of this special issue.