Theoretical computer science: The early years

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Throughout the years Sixties and early Seventies of the last century we witnessed the evolution of the field of computing from computer technology to computer science

- on one side: a relentless evolution of various generations of electronic technologies (from tubes to integrated circuits) and of computing architectures (from mainframes to personal computers and networked systems)

- at the same time: the development of theoretical studies (definition of formal models, of design principles, of analysis techniques) with the aim to design correct and efficient systems and applications.

In the first phase, formal models and mathematical approaches derived from mathematical theories introduced in the first half of the XXth century

- computability
- logic
- abstract algebra

are extended and applied to the new human artifacts: computing machines, computer programs, computation processes

Some examples.

1) Models of computation

Computability --> Machines, algorithms (Turing, Church, Markov, ...)

Neural nets --> Regular events (Mc Culloch & Pitts, Kleene)

1955-56 Mealy and Moore machines

1956 "Automata studies", Shannon and McCarthy Eds., Princeton

1959 Non deterministic automata (Rabin & Scott)

1963 Random access machines (Shepherdson & Sturgis)

1964-66 "Automata Theory", Caianiello Ed.

1966 Functional languages: CUCH (Böhm & Gross)

1966 Control structures: the theorem of Böhm & Jacopini

1967 "Computation. Finite and Infinite Machines", M. Minsky

2) Syntactic properties of programs

Computability, logic --> Rewriting systems (Post)

Abstract algebra --> Theory of semigroups (Thue)

1956-1959 Formal grammars (Chomsky)

1959 Metalanguages: Backus Normal Form (Backus-Naur Form)

1960 Algol 60 Report

1964 "Formal Language Description Languages for Computer Programming", Working Conference of IFIP-TC2

1960-1965 Classes of languages and automata (Oettinger, Schützenberger, Myhill, Kuroda, Greibach)

1969 "Formal Languages and Their Relation to Automata", Hopcroft & Ullman

3) Semantic properties of programs

Computability --> λ-calculus, combinatory logic

Logic --> Predicate calculus, Herbrand universe

Algebra --> Lattice theory

1960 Operational semantics of functional languages (McCarthy)

1964 Attribute grammars (Knuth)

1964 Toward a formal semantics (Strachey)

1969 Axiomatic semantics (Floyd, Hoare)

1970 Mathematical semantics (denotational s.) (Scott)

1972 Fix-point semantics (Manna, Cadiou, Vuillemin)

1972 Algebraic semantics (Nivat)

4) Computational complexity

Computability --> Turing machines, recursiveness concepts (reductions, completeness, degrees, ...)

1960 Step counting functions (Rabin)

1965 Complexity classes based on Turing m. (Hartmanis & Stearns)

1965 Easy = polynomial time computable (Edmonds)

1966 Machine independent axiomatic complexity (Blum)

1971 Analysis of algorithms (Knuth)

1971-72 Reductions and NP-completeness (Cook, Karp)

1974 "The Design and Analysis of Computer Algorithms" Aho, Hopcroft,Ullman

A new science is being born

“There was a very special spirit in the air; we knew that we were witnessing the birth of a new scientific discipline centered on the computer” (Richard Karp)

"Attribute grammars were born in the exhilarating days of the mid-60s when a great many fundamental principles of computer science were beginning to be understood. An enormous number of ideas were floating in the air, waiting to be captured in just the right combinations that would prove to be powerful sources of future energy" (Donald Knuth)

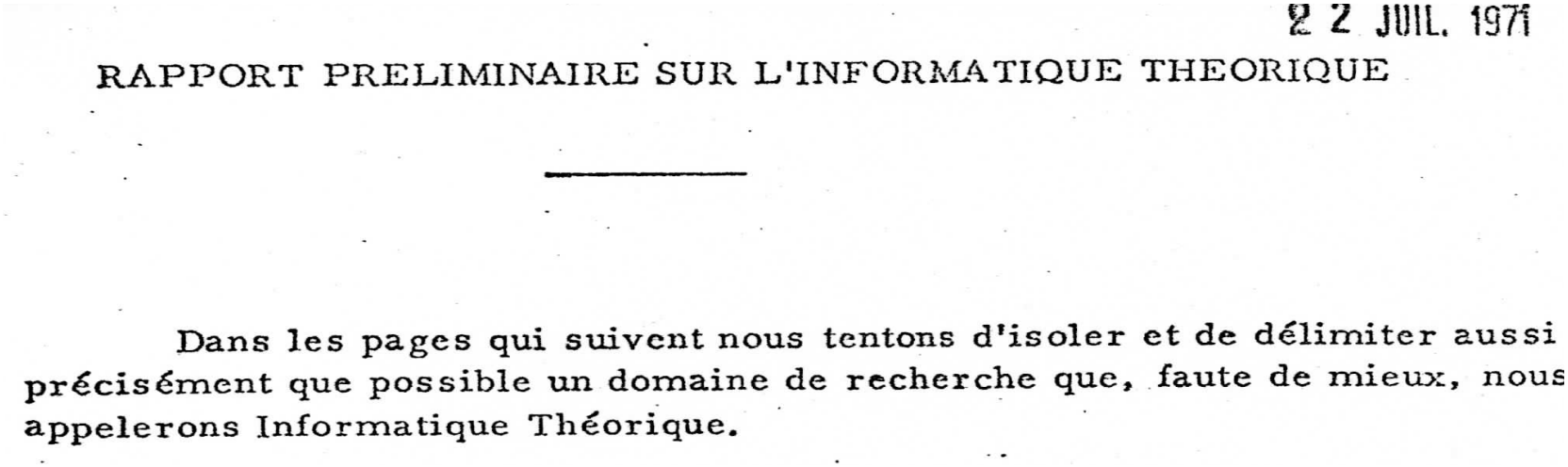
1968 - ACM creates SIGACT, the Special Interest Group devoted to "Automata and Computability Theory" (now "Algorithms and Computation Theory"!) - Founder: Patrick Fisher.

1969, May - SIGACT organizes in Los Angeles the "Symposium on Theory of Computing" (first STOC!)

Conference Chair: P. Fisher

PC: M. Harrison (Chair), R. Floyd, J. Hartmanis, R. Karp, A. Meyer, J. Ullman

1971, July - Maurice Nivat, Louis Nolin and Marcel-Paul Schützenberger publish the "Rapport préliminaire sur l'informatique théorique", the first attempt to define the new field of theoretical computer science: a twelve pages document prepared at Paris VII and sent to officials of the European Commission.



22 JUIL. 1971

RAPPORT PRELIMINAIRE SUR L'INFORMATIQUE THEORIQUE

Dans les pages qui suivent nous tentons d'isoler et de délimiter aussi précisément que possible un domaine de recherche que, faute de mieux, nous appelerons Informatique Théorique.

In the words of Maurice Nivat the document is
"aimed at the definition of what can be called Theoretical Computer Science, i.e. the chapter of Computer Science which uses mathematical and logical tools to clarify and study the notion of computation"

In other words the document defines what IS theoretical computer science...

Three domains:

- Algorithms: computation models (parallel, multilevel memories), design techniques (e.g. divide-and-conquer), analysis of algorithms (worst case, average case), computational complexity
- Automata and formal languages: codes (error-correcting etc.), finite automata and regular languages, pushdown automata and context free languages, non-deterministic automata, tree languages and tree automata
- Formal semantics of programming languages: program verification (Floyd, pre- and post- conditions), program transformation (recursive vs iterative), program schemes, approaches based on λ-calculus (Scott) and on combinatory logic (Nolin)

... and what IS NOT theoretical computer science: domains related to computer science whose aim is not to study and establish properties of the notion of computation but just to make use of such notion.

- Numerical analysis
- Control and system theory
- Operations research
- Graph theory
- Artificial intelligence

NOTE: Operating systems are not explicitely considered as one of the domains of theoretical computer science (although theoretical work on such problems as scheduling, paging, storage allocation etc. was so important for mainframe systems) but it is claimed that, "in view of the work of Dijstra, Wirth and Naur, operating systems will become one of the most privileged domains of such science".

1972, February - A meeting in Brussels sets the basis for the creation of the European Association for Theoretical Computer Science.

1972, July - Maurice Nivat organizes in Paris the conference on "Théorie des Automates, des Langages et de la Programmation" (first ICALP!)

Conference Chair: M.-P. Schützenberger

PC: M.-P. Schützenberger (Chair), C. Böhm, S. Eilenberg, P. Fisher, S. Ginsburg, G. Hotz, M. Nivat, L. Nolin, D. Park, M. Rabin, A. Salomaa, A. van Wijngarden

At the same time, in Eastern Europe:

1972, August - Andrzej Blikle organizes in Warsaw the International Symposium on "Mathematical Foundations of Computer Science" (first MFCS!)

Conference Chair: Helena Rasiowa

PC: Helena Rasiowa (Chair), Z. Pawlak (Vice-Chair), S. Turski (Vice Chair), A. Blikle, P. Dembinski, A. Mazurkiewicz, E. Orlowska, A. Salwicki, A. Waligorski, J. Winkowski

NOTE: First ICALP official languages: English, French, German

First MFCS official languages: English, Russian

1972: 'Annus mirabilis' of theoretical computer science

Pillars of tcs:

- Programming: "Structured Programming" (Dahl, Dijkstra, Hoare)

- Algorithms and data structures: invention of B-trees (Bayer & McCreight), linear algorithms on graphs based on DFS (Tarjan)

- Databases: Proceedings of the Courant Symposium on "Data Base Systems" (Codd's relational model)

- Semantics: Courant Symposium on "Formal Semantics" (Scott)

- Program verification: "ACM Conference on Proving Assertions about Programs" (Milner's LCF - Logic for Computable Functions)

- Logic programming: PROLOG (Colmerauer)

- Computational complexity: IBM Symposium on "Complexity of Computer Computations" (Karp's NP-completeness)

Maurice Nivat:
Building a Scientific Community

Maurice Nivat (left) with his mentor
Marcel-Paul Schützenberger in 1972

Through his energetic efforts in a few years (1971-1975) Maurice Nivat set the scientific European scene of theoretical computer science.

The Association.

From: Maurice Nivat, The True Story of TCS, *Theoretical Computer Science*, Special Issue for TCS 40th Anniversary.

"It begins in 1968, the year of the big turmoil in French universities, I had got my doctoral degree in 1967 with a dissertation on Chomsky languages prepared under the supervision of Marcel-Paul Schützenberger who had been appointed as one of the four directors of the institute IRIA ... I was sitting as a member on a panel of a dozen people gathered by OECD to think about the future of the new discipline called in English Computer Science and in French Informatique which was developing fast though only a few people really knew what was the thing about.

In this panel I met an Italian fellow, Alfonso Caracciolo di Forino, ... who was active inside the European Community (EEC) trying to have a European software institute created with the major computer manufacturers of that time in Europe, the Italian Olivetti, the British ICL, the German Siemens, and the French Bull company...

And that is when chatting after a meeting he told Schützenberger and myself that, maybe, it would be possible to create a European entity dealing with the theoretical aspects of computer science since theory can be pursued with little money and does not raise the unsolvable financial and economic problems which were at stake when talking about European cooperation in the software industry. He suggested that we create a European association.

1971, June: Maurice Nivat, Louis Nolin and Marcel-Paul Schützenberger propose to EEC an international cooperation among European Universities in the field of theoretical computer science with the aim to favour harmonization in education and scientific cooperation.

1971, July - Rapport préliminaire sur l'informatique théorique

1972, January - Meeting in Brussels upon initiative of Maurice Nivat, chaired by Alfonso Caracciolo from the 26th to the 28th.

Participants: researchers from six countries: Belgium, France, Germany, Great Britain, Italy, The Netherlands.

Aim: to build a European 'organization' (similar to EMBO, the European Molecular Biology Organization)

Scope: defined by Nivat's report on 'informatique théorique' + two documents prepared by Böhm and by de Bakker

Budget requested: 80.000 USD per year (expected to grow up to 200.000 USD) - The organization of a conference and the publication of a bulletin and of a journal were already considered.

First name: Institut Européen d'Informatique Théorique.
Ambitious goal: to have both 'associated institutes (universities and research labs) and individual members'

Soon it appeared that the EMBO experience could not be followed and the project was changed to a simple scientific association:
Association Européenne d'Informatique Théorique (AEIT)

On September 4, 1972 the European Association for Theoretical Computer Science and its Statutes were approved by the King of Belgium. First president Leo Verbeek.

Maurice Nivat will be President from 1973 to 1977.

The conference

1972, June - Maurice Nivat organizes the "Colloque sur la Théorie des Automates, des Langages et de la Programmation" (officially considered the First ICALP) that takes place in Paris (in the premises of IRIA) from July 3rd to July 7th.

The schools

1973, May - Maurice Nivat and Jean-Paul Crestin organize the first Ecoles de Printemps d'Informatique Théorique (EPIT) at Bonsacre.
Subject: 'Langages algebriques' (context-free languages).
Still going on after 45 years!
Last EPIT (2019): 'Données, logique et automates', organized by A. Gheerbrant, L. Libkin, L. Segoufin, P. Senellart, C. Sirangelo at Luminy.

The Bulletin

1973, December - First issue of the Bulletin of AEIT-EATCS edited by Maurice Nivat and published by IRIA.

- Idea to create something similar to SIGACT NEWS.
- Envisage the exchange of information between the two communities (Europe and US)


association européenne
d'informatique théorique

european association for theoretical computer science

BULLETIN N° 1 décembre 1973

The Journal

1973, June - Maurice Nivat sends a letter to all EATCS members regarding his contact with Einar Fredriksson of North Holland in view of the creation of a journal devoted to theoretical computer science.

Synergy between EATCS and the journal.

The idea we came to was that the Association could appoint say 5 members of the future Editorial Board among whom hopefully one would be the Managing editor and that these 5 people would discuss with North Holland the numerous questions to be solved : other members of the editorial board, scope of the journal etc...

.....

1975, June - The first issue of the journal Theoretical Computer Science is published.

First Editorial Board Consisting of 18 among the world most authoritative scientists in theory of computing:

Maurice Nivat (editor in chief), Mike Paterson (associate editor), Jaco de Bakker, Corrado Böhm, Erwin Engeler, Robin Milner, David Park, Arto Salomaa, Arnold Schönage (Western Europe), Jiri Becvar, Zdzislaw Pawlak (Eastern Europe), Michael Rabin (Israel), Ron Book, Michael Harrison, Richard Karp, Albert Meyer, Jeff Ullman (US), Andrei Ershov (Soviet Union), Shigeru Igarashi (Japan).

First volume Contributions from outstanding researchers including some highly cited papers(*).

Algebraic algorithms (Paterson, Schönage, Strassen, ...)
Developmental languages (Ehrenfeucht, Rozenberg, ...)
Combinatorial properties of codes (Restivo)
Complexity of Boolean functions (Harper, Savage ...)
Stable sorting (Preparata)
Formal languages (Book, Greibach, Karhumäki, van Leeuwen, Wood)
Unification in typed lambda-calculus (Huet)*
Call-by-name, call-by-value and lambda-calculus (Plotkin)*
NP-completeness of graph problems (Garey, Johnson and Stockmayer)*

In the meantime in Italy ...

How developed tcs in Italy in the early days?

A milestone:

International School of Physics on "Automata Theory", Ravello, 1964

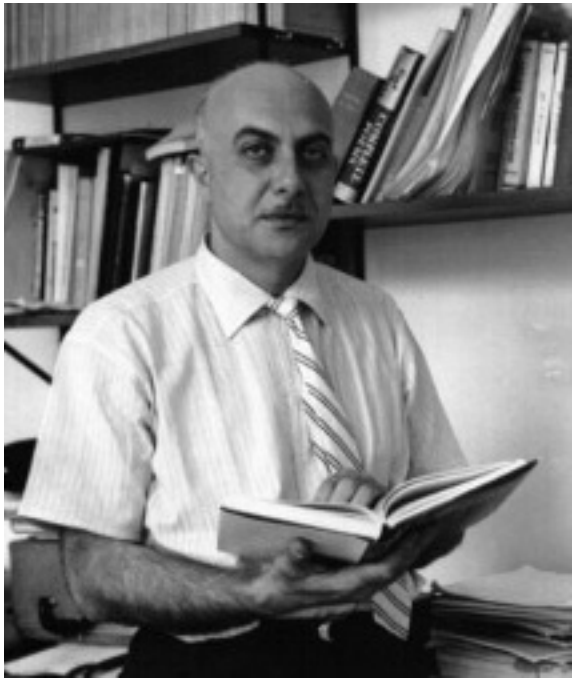
Main topics: Automata and formal languages (codes, probabilistic automata, Markov chains, ...)

Computability (recursive functions, Turing machines, Markov algorithms, λ-calculus, ...)

Graphs (graph algorihms, codes and graphs, ...)

Brain models (neural nets, ...)

Organized by: E. Caianiello, Istituto di Fisica Teorica, Naples



Edoardo Caianiello, founder of the CNR Laboratory of Cybernetics

Lecturers: M. Arbib, C. Berge, R. Büchi, M. Davies, M. Gross, M.-P. Schützenberger, W. McCulloch, M. Nivat, L. Nolin, M. Rabin, L. Verbeek

Italian participants:

C. Böhm & W. Gross, INAC-CNR: Introduction to CUCH

A. Caracciolo di Forino, CSCE-CNR: Markov algorithms

V. Amar & G. Putzolu, L.R.E. Olivetti: Regular events

M. Borillo, P. Camion, EURATOM: Graph algorithms

+

C. Berge, International Computation Centre: Graphs and codes

Important role of CNR in the Sixties : able to catch new research directions that could not find space in the academic world (at that time strongly centralized under the control of traditional disciplines)

The 'Laboratorio di Cibernetica' (Arco Felice): how excellent research teams can grow out of the the failure of an ambitious research program: "Essentially the program of cybernetics, although extremely interesting, was too ambitious and the results that were achieved were indeed disappointingly modest with respect to the expected goal. The program originally was to describe neural nets, to design mathematical models of the nervous system and from this to derive an explanation of high level mental functions such as learning, intelligence and even consciousness but the study and understanding of the central nervous system did not develop as expected ... Eventually from cybernetics a series of specific disciplines developed, each one with its own language and its own goals" (Aldo de Luca)

The 'Istituto per le Applicazioni del Calcolo' (Rome): side by side with excellent applications of numerical calculus Böhm, Gross and Jacopini developed new research directions in λ-calculus, combinatory logic, CUCH, LISP

"In that period I was interested to find the 'best' computation model among Turing machines, Post production systems, Markov algorithms, Curry's combinatory logic (CL) and Church's lambda-calculus (LC). The fundamental idea was to transform the 'winning' model into a powerful and synthetic programming language. The paper that is at the base of structured programming was born from the examination of the structures of some Universal Turing Machines, together with Jacopini's intuition that the necessary restrictions might have been represented in terms of flow diagrams. At the same time I was convinced that indeed with CUCH, a fusion of CL and LC, I had found the best abstract machine" (Corrado Böhm)

Corrado Böhm and Alfonso Caracciolo di Forino in 1968

The 'Centro di Studi sulle Calcolatrici Elettroniche' (since 1970: 'Istituto di Elaborazione dell'Informazione', Pisa): after the project of constructing the CEP machine various research directions developed covering not only various fields of computer science but also most domains of computation theory: Markov algorithms, pattern recognition, algorithms and data structures, theory of programming, ecc.

The leading role of Pisa in theoretical computer science was further enhanced when in 1969-1970 the first degree in computer science was created. More generally the creation of degrees in computer science determined the birth of important groups in various Universities in the early Seventies.

At the end of 1971 acivity starts to create an Italian association in the field of heoretical computer science (also as a reaction to the attempt by Antonio Ruberti to gather all computer scientists under the umbrella of system theory).

1971, October: First meeting in Florence with the aim to:

- prepare for the meeting in Brussels organized by Caracciolo
- create the Gruppo Ricercatori di Informatica Teorica (GRIT)

Comitato promotore del GRIT

Böhm (Torino), Degli Antoni, Somalvico (Milano), Pinzani (Firenze), Luccio, Montanari (Pisa), Ausiello, Venturini (Roma), de Luca, Lauria (Naples)

1971, December: Survey of research in theoretical computer science in Italy.

Scienza dell'Informazione, Turin (Böhm, Dezani, Ronchi della Rocca, Simone, ...): λ-calculus, information structures, theory of programming

Elettronica e Cibernetica, Milan (Degli Antoni, Bertoni, De Michelis, Maiocchi, ...): automata and formal languages, program verification

Politecnico di Milano (Crespi Reghizzi, Della Vigna, Ghezzi, Sami, ...): relational databases, context-free languages, syntax directed translation, Petri nets

Istituto Matematico, Florence (Aguzzi, Cesarini, Pinzani, Soda, ...): theory of programming

Istituto di Elaborazione dell'Informazione-CNR + Istituto di Scienza dell'Informazione, Pisa (Aiello, Albano, Caracciolo, Carlucci, Grasselli, Levi, Luccio, Martelli, Montanari, Sirovich, Sprugnoli, ...): Markov algorithms, semantic information processing (QA systems, problem solving, program semantics), algorithms for image recognition, data structures (hashing), heuristics for optimization problems

Istituto per le Applicazioni del Calcolo-CNR, Rome (Ausiello, Jacopini, Longo, Miola, Venturini, ...): abstract computational complexity, functional languages, symbolic computation systems, automatic deduction

Laboratorio di Cibernetica-CNR, Arco Felice (de Luca, Germano, Maggiolo Schettini, Termini, ...): fuzzy sets, Markov algorithms

Gruppo di Cibernetica c/o Istituto di Fisica Teorica, Naples (Aloisio, Lauria, Trautteur, ...): neural models, automata, recursiveness, computational complexity

1972, February - Böhm elected President of GRIT, Montanari Secretary. GRIT started to edit a Bulletin and organized the first events in which the Italian theory community gathered.

First Congress of 'Informatica Teorica', Pisa, March 1973

Invited talks + ten contributions addressing formal power series, syntax directed translation, extensions of grammars to abstract structures, recursive program schemes and computation rules, λ-calculus and Scott's approach to semantics

Second Congress of 'Informatica Teorica', Mantova, November 1974

Invited talks + ten contributions addressing information structures, weighted context free grammars, partitioning and search problems, fix point approach to dynamic programming, unification in theorm proving, subrecursive classes.

NOTE: A long story leading to the current groups GII and GRIN. Theoreticians had a leading role in this process.

In 1973 GRIT became a subgroup of a group involving all Italian computer scientists (GRI). In 1979 a larger group of researchers (GRIS) has been created, including computer scientists from Faculties of Sciences and Faculties of Engineering and also researchers in system and control theory. Aim of GRIS: coordinate projects to be submitted to the CNR organism that provided funding to the field of computer science and system science: GNASII (not much money but important role in creating collaborations at national level).

When funding from CNR was replaced by funding from MIUR (PRIN projects) Italian computer scientists split again and gave birth to GII (researchers operating in Faculties of Engineering) and GRIN (researchers operating in Faculties of Sciences).

The role of EATCS

EATCS had an important role in

- creating the scientific identity of the field of theoretical computer science in Europe
- building a scientific community way beyond European borders (including researchers from US, Canada and Japan)
- promoting and coordinating conferences and scientific events
- promoting journals and publications

AND, when European research projects started,

- supporting the birth of projects and networks.

After the first steps done by Maurice Nivat (1973-1977), Arto Salomaa (1979-1985) and Grzegorz Rozenberg (1985-1994) had a very strong impact on the growth of EATCS in terms of membership (in some years increased up to about 2000 members), activity (sponsorship of conferences, series of publications), visibility (size and dissemination of the Bulletin), authority (creation of the Gödel Prize) and impact (promotion of theory in EU research programs).

Josep Diaz (1997-2002) created the EATCS Award, strengthened the ties between EATCS and Brussels and established tighter connections with ACM (creation of the Dijkstra Award, ICALP and STOC co-located in Crete in 2001).

All Presidents contributed somehow to bring EATCS where it is now.

Awards

- EATCS recognitions:

EATCS Award, Presburger Award for young researchers, EATCS Fellows, EATCS Distinguished Dissertation Award

- Assigned in collaboration with ACM and other organizations:

Gödel Prize, Dijkstra Prize, Alonzo Church Award

- Best papers at conferences

IPEC Nerode Prize

Best ICALP Paper, Best ICALP Student Paper

Best ESA Paper, Best ESA Student Paper

Best MFCS Paper, Best MFCS Student Paper

Best ETAPS Paper, Best ICGT Paper

Conferences

Beside ICALP and ICALP Workshops, every year > 10 conferences in cooperation with EATCS (MFCS, FCT, ESA, LICS, CSR, DISC, SAGT, COMPLEXIS, MODELSWARD, CIE, ETAPS, CIAC, RP etc.).

Publications

- The Bulletin
- ICALP Proceedings (until 2017) (Springer)
- Monographs in Theoretical Computer Science (Springer), started in 1984, > 60 volumes
- TCS???

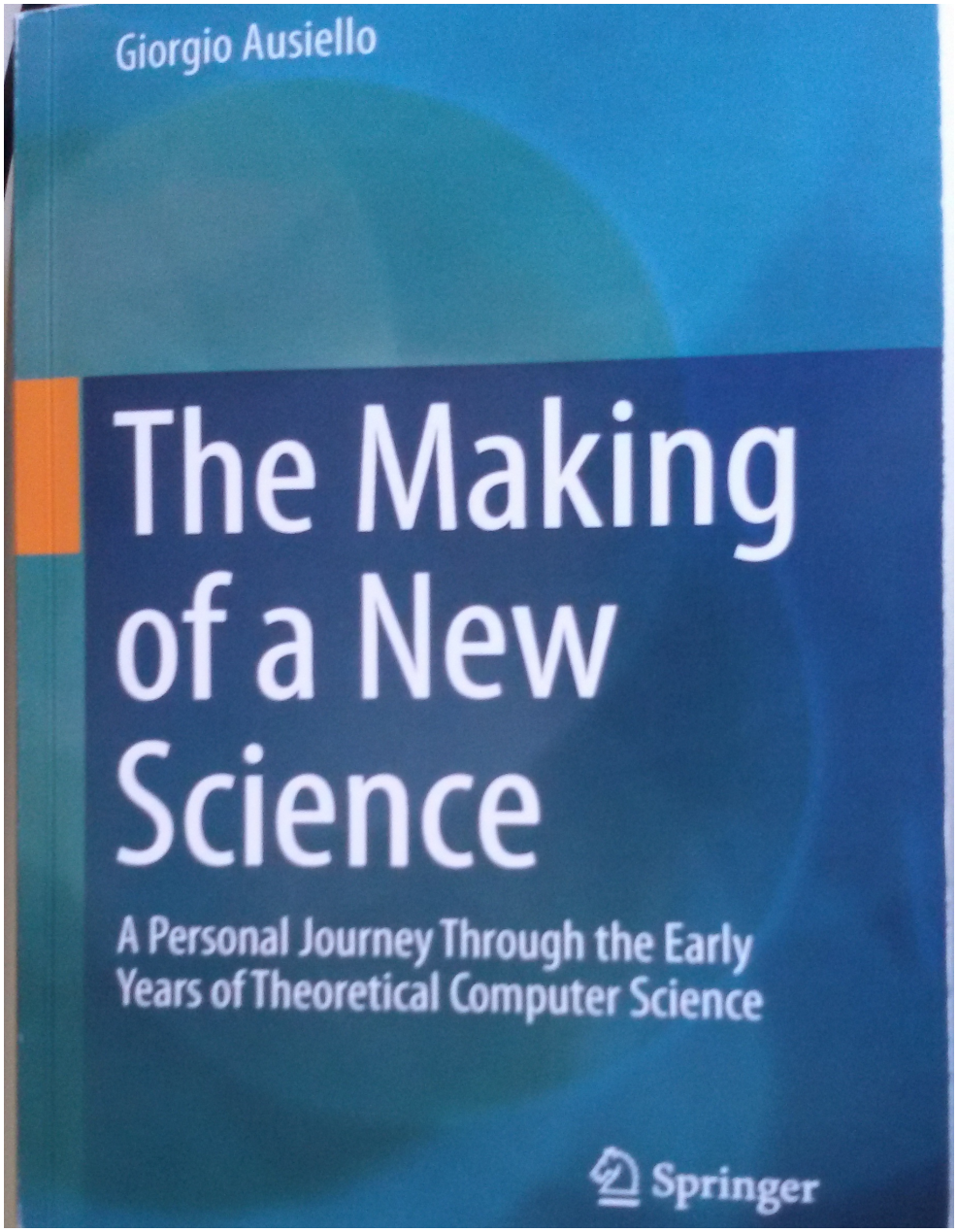
When the journal Theoretical Computer Science was created it was conceived as the journal of EATCS and EATCS should play a major role in its editorial policy. Note: in 1976 Nivat agrees with North Holland that the subscription rate for EATCS member could be 10 (ten!) dollars.

In fact from volume 12 to volume 80 the journal carried the words 'The journal of the EATCS' on the front cover.

At the end of the 1990s this special relationship came to an end.
- adoption of a more open attitude toward all journals devoted to theoretical computer science
- concern about the pricing policy adopted by the publisher, that in the meantime had changed from North Holland to Elsevier.

Chapters

Currently:
- Italian Chapter (President Angelo Montanari)
- Japanese Chapter (President Ryuhei Uehara)
- Russian Chapter (President Nikolay Vereshchagin)


Giorgio Ausiello
The Making of a New Science
A Personal Journey Through the Early Years of Theoretical Computer Science
Springer

What is it about?

It's a story about how this new scientific discipline has developed in approximately twenty years, from 1965 to 1985 in front of my eyes of young researcher.

It's also a story about people (mathematicians, computer scientists, engineers), about how they

- came together in the aim of answering basic theoretical questions concerning computing and introduced a common language and a basic set of formal concepts

- established schools, conferences, journals, series of publications

- created an international research community and collaborated in research efforts through interuniversity agreements and through joint international research programs.

Two threads somewhat intertwined:

- My 'personal journey' that started in Rome (4th floor of the CNR building) and moved first to US and then to other research centers in Italy, France, other European countries
- The scientific events (schools, conferences), the journals, the international forms of cooperation that in those years contributed to create the theoretical computer science community

In this picture we may identify:

- the figures of (some of) the great scientists that have built the theory of computing, and
- the various subfields of theory of computing, as they were developing as a consequence of the evolution of systems and applications (and ... according to fashionable trends).

Outline, topics, major subfields addressed

(1967-68) - Research at INAC (now IAC-CNR): lambda-calculus, non-numeric computing, LISP (the first LISP interpreter implemented in Italy), algebraic manipulation systems

(1969-70) - Research in Berkeley: computability, abstract computational complexity, design and analysis of algorithms, first STOC

(1971) - The Italian scene: Naples, Pisa, Milan, Turin, Rome

(1972-75) - The European scene: Theoretical computer science in France, Holland, Germany, UK, Poland (first ICALP, first MFCS, creation of Lecture Notes in Computer Science, creation of the journal Theoretical Computer Science, foundation of EATCS)

(1976-77) - Data structures, program structures: Structured programming, program transformations, abstract data types, relationships between syntax, semantics and complexity of languages

(1978-79) - Optimization and approximation: Interfaces between operations research and theoretical computer science, complexity of optimization problems, approximability of hard optimization problems

(1980-81) - Database theory: Normal forms, data dependencies, design of relational databases, conceptual design, ER model.

(1982-85) - The first European long term research programs: The Japanese Fifth Generation Project, the Alvey Programme, ESPRIT, the Basic Research Actions, international cooperation and cooperation with industry

In conclusion:

John von Neumann:

"The sciences do not try to explain, they hardly even try to interpret, they mainly make models"

Donald Knuth:

"The best practice is inspired by theory"