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# Unifying Theories of Programming

7th International Symposium, UTP 2019


Dedicated to Tony Hoare on the Occasion of His 85th Birthday

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Tony Hoare

## Preface

This volume contains papers presented at UTP 2019, the 7th International Symposium on Unifying Theories of Programming, held in Porto, Portugal, on October 8, 2019. The event was co-located with the Third World Congress on Formal Methods Europe. Established in 2006, the UTP symposium series aims at bringing together researchers interested in the fundamental problem of the combination of formal notations and theories of programming. The theories define, in various different ways, many common notions, such as abstraction, refinement, composition, termination, feasibility, locality, concurrency, and communication. Despite these differences, such theories may be unified in a way that greatly facilitates their study and comparison. Moreover, such a unification offers a means of combining different languages describing various facets and artifacts of software development in a seamless, logically consistent, way.

This edition of the UTP symposium is in honor of Sir Tony Hoare, on the occasion of his 85th birthday. The papers presented here were invited, and friendly refereed, original contributions sought from the UTP community. One of the papers is from the distinguished invited speaker Tony Hoare himself. Nine other additional papers compose this volume, covering several aspects of Unifying Theories of Programming.

Tony's contributions to Computer Science have been extremely influential. In what follows we revisit some of his major lifetime achievements. A full account can be found in the excellent biographical chapter "Insight, Inspiration and Collaboration" by Jones and Roscoe, published in "Reflections on the Work of C.A.R. Hoare" on the occasion of Tony's 75th birthday in 2009, from which we borrow some biographical information presented in the sequel.

Charles Antony Richard Hoare was born on January 11, 1934, in Colombo, Sri Lanka. After his family returned to England, he attended the Dragon School, Oxford and King's School, Canterbury before going to Oxford University to obtain his highest official academic qualification, an MA in Classical Greats (1952–1956). He studied Latin and Greek, both the languages and their literature. This was followed by Ancient History and Philosophy. It was philosophy that stimulated his interest in logic and the foundations of mathematics. It also stimulated his interest in computers as a tool for studying the philosophy of the mind, and in particular human intelligence.

Tony earned professional qualifications as an interpreter of Russian (1956–58) and as a Statistician (1958–59). He exercised his Russian as an intern at Moscow State University (1959–60), and on many subsequent visits to the Soviet Union (or Russia) and to Armenia. It was in Moscow that Tony is reported to have invented Quicksort. On his return to England in 1960 where he joined the small computer manufacturer Elliott Brothers, he would bet his manager that his algorithm would usually run faster than Shellsort, which Tony had been tasked with implementing for the Elliott 503. He held the posts of Programmer, Chief Engineer, and Researcher (1960–68). He famously led the team (including his wife Jill) that wrote one of the first ALGOL 60 compilers, which stimulated his interest in formal language definition. His experience with

ALGOL led to advocating simplicity in language design, to “enable good ideas to be elegantly expressed” and to “maximise the number of errors which cannot be made, or if made, can be reliably detected at compile time.” He then led a much larger failed project to write an operating system for the Elliott 503 Mark II, which stimulated his life-long interest in concurrency.

After Elliott Brothers was taken over in 1968, Tony decided to leave and apply for the Chair of Computing Science at the Queen’s University of Belfast, and to his surprise he was appointed (1968–77). He set up the University’s first undergraduate degree in Computer Science, at first joint with Mathematics. He selected Program Verification as the topic for his first academic publication, and for his entire subsequent academic research career (thirty-two years). He reckoned that Verification was a topic not likely to be of interest to industry until after he had retired. So he would never have to compete with more generously funded industrial research. And his prediction was quite correct.

In 1977, Tony left Belfast with regret, to return to Oxford University as Professor of Computation (1977–99). There he learned denotational semantics from Joe Stoy and domain theory from Dana Scott. After two years of pure research, he set up a Master’s degree at Oxford in Computation, and much later an undergraduate degree (at first joint with Mathematics, then with Engineering).

Tony’s first retirement job was in Cambridge with Microsoft Research (1999–2017) where he stimulated an International Grand Challenge Initiative in Verified Software. Since his second retirement, he has been an unpaid visitor at Microsoft Research and an Honorary Member of the Cambridge University Computing Laboratory.

There is no doubt that Tony’s contributions to programming have been extremely influential. The “Axiomatic Basis” is one of the most influential papers in Computer Science, which paved the way for reasoning entirely non-operationally about program correctness stepwise. Just as important, the ideas presented in “Structured Programing” have had a major impact on software design.

Concurrency has been a life-long research interest of Tony, having initially been inspired by problems found in operating system design. The beginnings of CSP could be seen emerging in “Parallel Programming: An Axiomatic Approach,” where Tony approached shared variable concurrency with his monitor proposal. The first version of “Communicating Sequential Processes,” the CACM paper from 1978, proposed an extension of Dijkstra’s language of guarded commands with point-to-point communication. The algebra of CSP appeared with the 1985 book of the same name after years of collaborative work with Roscoe and Brookes. CSP would be at the core of the occam programming language, which was prominently used in the context of the transputer, a chip created at inmos. It was used both for programming and as a medium for specification of hardware, serving as a basis for formal verification of the FPU of the transputer, for example. Since then, other programming languages have adopted communication primitives inspired by those of CSP.

Later in 1984, He Jifeng would join Tony in Oxford until 1998. This collaboration led to the extremely ambitious endeavor of creating a relational framework in which a wide range of programming languages, such as imperative, logical, and concurrent, could be given semantics, ultimately culminating in the publication of the book *Unifying Theories of Programming*, which is the *raison d’être* of the UTP symposium

series started in 2006. Since then, several contributions have been made to incorporate other aspects, such as: angelic nondeterminism, aspect orientation, event-driven programs, model checking, object orientation, references and pointers, probabilistic programs, real-time programs, reversible computation, synchronicity, timed reactive programs, and transaction processing, to name a few. The UTP has also been embedded in a variety of theorem provers, providing the modern engineer with tools for engineering trustworthy software and systems.

More recently, Tony has revisited algebra as the central unification approach to programming, exploring the interplay between geometrical constructions and algebraic deductions in programming, the interactions and symmetries of space, time, and causality in concurrency. These lie at the foundation of any truly unifying approach to computational modeling and programming. And who, if not Tony, would have the authority to address them?

We are very grateful to Ana Cavalcanti, Jim Woodcock, and Huibiao Zhu for trusting us the honor of organizing the 7th UTP symposium. In doing so we have invited authors of the highest calibre to celebrate Tony's many lifelong contributions to the state of the art in the UTP. We thank all the authors for their contributions, and the Program Committee members for their excellent work in the friendly review process. We are indebted to all the members of the Organizing Committee of the Third World Congress of Formal Methods Europe, led by José Nuno de Oliveira. We are also indebted to EasyChair that greatly simplified the assignment and reviewing of the submissions as well as the production of the material for the proceedings. Finally, we thank Springer for their cooperation in publishing the proceedings.

*On his 85th birthday, we salute Tony!*

October 2019

Pedro Ribeiro  
Augusto Sampaio



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