– A quarter of a century of CONCUR –

Report on the 2014 and 2015 editions of the Conference on Concurrency Theory

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The international Conference on Concurrency Theory (CONCUR), which was launched in 1990 by the eponymous ESPRIT BRA project, reached an important milestone in 2015: its quarter of a century. The event was celebrated twice: first during the 25th edition of the conference, held in Rome in September 2014, and then during its 26th edition, held in Madrid in September 2015, which actually marked CONCUR's 25th anniversary. It may be noted that both editions took place in capital cities of Mediterranean countries, witnessing the deep rooting of Concurrency Theory in Italy and its active development in Spain. This brings back to mind an old remark by Robin Milner, to the effect that Concurrency Theory, originated in Northern Europe in the late 70's, was progressively extending its scope towards the Mediterranean, so that its epicentre was "moving South".

We give next two separate recounts of CONCUR 2014 and CONCUR 2015, with some back and forth excursions from one to the other.

1 Report on CONCUR 2014

The 25th CONCUR conference (CONCUR 2014) took place in Rome, Italy, from the 2nd to the 5th of September 2014. The conference was co-chaired by Paolo Baldan and Daniele Gorla. It was organised by the University of Padova and the University of Rome "La Sapienza", which hosted the event in its Faculty of Engineering, beautifully located in the historic centre of Rome.

To mark the 25th edition of CONCUR, the conference programme included an invited presentation by Tony Hoare, one of the main founders of Concurrency Theory in the UK, together with Robin Milner. Tony gave an inspirational talk on his itinerary as a computer scientist and on the history of Concurrency Theory, showing how its development had been closely intertwined with that of the CONCUR conferences. He concluded by delineating future perspectives in the field.

The conference programme was further enhanced by the lively and enlightening invited talks by Javier Esparza (Technische Universität München, Germany), Jane Hillston (University of Edinburgh, UK), Catuscia Palamidessi (INRIA Saclay and LIX, France) and Vasco Vasconcelos (Universidade de Lisboa, Portugal). The abstracts of the five invited talks are reproduced below.

The following satellite workshops were affiliated with CONCUR 2014:

- EXPRESS/SOS 2014: the Combined 21st International Workshop on Expressiveness in Concurrency and 11th Workshop on Structured Operational Semantics;
- BEAT 2014: the 3rd International Workshop on Behavioural Types, organised by COST Action IC1201 (BETTY);
- FOCLASA 2014: the 13th International Workshop on the Foundations of Coordination Languages and Self-Adaptation;
- PV 2014: the Workshop on Parameterized Verification;
- TRENDS 2014: the 3rd IFIP WG 1.8 Workshop on Trends in Concurrency Theory.

Moreover, CONCUR 2014 was co-located with two events that further enriched the Roman week: the 8th IFIP Conference on Theoretical Computer Science (IFIP-TCS) on September 1st-3rd, and the 9th Symposium on Trustworthy Global Computing (TGC 2014) on September 5th and 6th.

1.1 Abstracts of invited talks

Tony Hoare (Microsoft Research, Cambridge)
Laws of Programming: The Algebraic Unification of Theories of Concurrency
I began my academic research career in 1968, when I moved from industrial employment as a programmer to the Chair of Computing at the Queens University in Belfast. My chosen research goal was to discover an axiomatic basis for computer programming. Originally I wanted to express the axioms as algebraic equations, like those which provide the basis of arithmetic or group theory. But I did not know how. After many intellectual vicissitudes, I have now discovered the simple secret. I would be proud of this discovery, if I were not equally ashamed at taking so long to discover it.

Jane Hillston (LFCS, School of Informatics, University of Edinburgh)
The Benefits of Sometimes Not Being Discrete
Discrete representations of systems are usual in theoretical computer science and

they have many benefits. Unfortunately they also suffer from the problem of state space explosion, sometimes termed the curse of dimensionality. In recent years, research has shown that there are cases in which we can reap the benefits of discrete representation during system description but then gain from more efficient analysis by approximating the discrete system by a continuous one. I will motivate this approach, explaining the theoretical foundations and their practical benefits.

Javier Esparza (Fakultät für Informatik, Technische Universität München, Germany)

Deterministic Negotiations: Concurrency for Free

We give an overview of recent results and work in progress on deterministic negotiations, a concurrency model with atomic multiparty negotiations as primitive actions.

Vasco Thudichum Vasconcelos (LaSIGE, Faculty of Sciences, University of Lisbon)

The Progress of Session Types

Session types can be traced back to 1993, when Kohei Honda presented "Types for dyadic interaction" in the 7th edition of this conference. Session types aim at modelling generic, meaningful structures of interaction. We have seen applications to concurrent, message passing systems, or in functional languages equipped with channel operations but also to object-oriented systems, where session types mediate access to objects' methods. Also, recent developments revealed deep connections between session types and linear logic. By the turn of the millennium, communication had become a central concern in computational systems. Types that capture the interaction patterns of a collection of participants find multiple applications these days, including the conventional verification of source code conformance against types, or, when the above seems not possible, the monitoring of running code against types, signalling divergences or providing for adaptation measures. They may as well be used for code generation, mechanically laying down the whole communication code, to be manually completed with the "computational" code, or for testing code against communication traces extracted from types. There are also important models of computation that pose difficulties to session types as we know them. These are systems whose assumptions lie outside those that underlay session types. I recall distributed systems with nodes that may die, and the actor system of computation.

Catuscia Palamidessi (INRIA and LIX, Ecole Polytechnique)

Generalized Bisimulation Metrics

The bisimilarity pseudometric based on the Kantorovich lifting is one of the most popular metrics for probabilistic processes proposed in the literature. However, its application in verification is limited to linear properties. We propose a generalization of this metric which allows to deal with a wider class of properties, such

as those used in security and privacy. More precisely, we propose a family of metrics, parametrized on a notion of distance which depends on the property we want to verify. Furthermore, we show that the members of this family still characterize bisimilarity in terms of their kernel, and provide a bound on the corresponding metrics on traces. Finally, we study the case of a metric corresponding to differential privacy. We show that in this case it is possible to have a dual form, easier to compute, and we prove that the typical constructs of process algebra are non-expansive with respect to this metrics, thus paving the way to a modular approach to verification.

1.2 Social events

The rich technical programme of the conference was completed by a wonderful social programme, diving into Italian art and opera music.

On the opening day of the conference, a welcome reception was organised in the cloister of the venue. The reception was enlivened by a fine opera concert. Thanks to the warmth of the season, the performance could take place outdoors. The attendees, comfortably seated on one side of the cloister, could then benefit at the same time from the *arias* and the open air, enjoying the beauty of the location.

On the following day, the excursion led the participants to the historic town of Tivoli on the Monti Tiburtini hills. The highlight of the visit was the walk through to the grandiose Villa d'Este and its magnificent gardens, renowned for their fountains and water sculptures. Unfortunately the weather, which had been sunny and summerish at the start of the week, turned quite grey and wet on that day, and the rain was pouring heavily by the time we entered the gardens. Although slightly uncomfortable, especially for those wearing sandals, this monsoon episode contributed to render the atmosphere of these extraordinary gardens totally "watery", and the scenery possibly even more stunning than it usually is. The conference dinner took place in a Natural Grotto Terrace nearby, from which one could enjoy a breathtaking view on the Tivoli Waterfall (but fortunately, the dinner tables were laid inside). After the conference banquet, Jos Baeten recalled the history of the CONCUR conference since its start in 1990. The conference was an emanation of the European project CONCUR, which was one of the five Basic Research Actions on concurrency of the 2nd Framework Programme for Research and Development in Information Technologies (ESPRIT), 1987-1992. The CONCUR project, started in 1989, focussed on process algebras and aimed at the unification and extension of the various existing theories of concurrency. The first CONCUR conference, chaired by Jos Baeten and Jan Willem Klop, took place in Amsterdam in 1990, hosted by CWI and the University of Amsterdam. Jos listed the different locations in which the following editions of CONCUR were hosted, mostly in European countries, but also in the US, Canada and Argentina.

Finally Jos announced that, starting from 2015, the proceedings of CONCUR would be published according to the principle of open access in the series of LIPIcs volumes.

After this historical account, the two chairs Paolo Baldan and Daniele Gorla gave the statistics of the 2014 edition of CONCUR: 35 papers out of 124 submissions had been selected for presentation at the conference. The two chairs then awarded Natsuki Urabe and Ichiro Hasuo as the authors of the best paper, entitled *Generic Forward and Backward Simulations III: Quantitative Simulations by Matrices*. Finally, David de Frutos Escrig announced the 26th CONCUR conference, to take place the following year in Madrid, Spain.

A one year leap that will be rendered here by a simple jump to the next line...

2 Report on CONCUR 2015

The 26th CONCUR Conference (CONCUR 2015) was held in Madrid, Spain, from the 1st to the 4th of September, 2015. It was co-chaired by Luca Aceto and David de Frutos Escrig, and hosted by the Universidad Complutense de Madrid. This year the conference was jointly organized with the 12th International Conference on Quantitative Evaluation of Systems (QEST 2015), the 13h International Conference on Formal Modeling and Analysis of Timed Systems (FORMATS 2015), the 10th International Symposium on Trustworthy Global Computing (TGC 2015), and the International Symposium on Web Services, Formal Methods and Behavioural Types (WS-FM/BEAT 2015).

The five parallel conferences were further enlightened by a constellation of satellite workshops, resulting in a large global event named "Madrid meet 2015":

- EPEW 2015: the 12th European Workshop on Performance Engineering;
- FOCLASA 2015: the 14th International Workshop on Foundations of Coordination Languages and Self-Adaptation;
- EXPRESS/SOS 2015: the Combined 22nd International Workshop on Expressiveness in Concurrency and 12th Workshop on Structured Operational Semantics;
- HSB 2015: the 4th International Workshop of Hybrid Systems and Biology;
- TRENDS 2015: the 4th IFIP WG 1.8 Workshop on Trends in Concurrency Theory;
- PV 2015: the 2nd Workshop on Parameterized Verification;

- YR-CONCUR 2015: the 6th Young Researchers Workshop on Concurrency Theory.

To celebrate CONCUR's 25th anniversary, a keynote speech had been kindly commissioned from Matthew Hennessy, who had also featured among the invited speakers of CONCUR 1990. Matthew was one of the pillars of the Edinburgh concurrency group in the early days of Concurrency Theory (late 70s – early 80s). After leaving Edinburgh at the end of 1985, he built a very successful concurrency group at the University of Sussex, before moving back to his home country and joining Trinity College Dublin in the late 2000's. To date, he is one of the most influential researchers in Concurrency Theory and process calculi in particular.

Matthew's speech started off as a classical invited presentation, revisiting the established notion of transaction in a new "cooperative" perspective, dropping the usual requirement of isolation. Half way, the talk was interleaved with a journey back in time to the 1st edition of CONCUR in 1990, whose programme and contents may be found here:
http://rd.springer.com/book/10.1007%2FBFb0039045.
By swiftly going through the programme, Matthew pointed out the presence at CONCUR 1990 of several research themes - as well as of several researchers - which are still very much on the scene of Concurrency Theory these days. This led him to address the assembly with a number of provocative questions: What have we done since then? Which open problems have been solved, and new problems uncovered? Which new subjects and techniques have emerged? This question stirred several reactions from the audience, as may be expected. It was underlined that many research issues, models and applications had made their appearance or had grown to maturity since that time, in anticipation of (or in response to) the spectacular evolution of the computing environment towards an ever more distributed and communication-intensive one. After this somewhat nostalgic interlude, Matthew resumed his technical talk on co-operating transactions, offering an excellent illustration of the impressive panoply of techniques developed for process calculi since their appearance 35 years ago.

Besides Matthew's keynote speech, CONCUR 2015 featured five other very inspiring invited talks, by Gianluigi Zavattaro (Università di Bologna, Italy), joint invited speaker with TGC 2015, James Worrell (University of Oxford, UK), plenary speaker at Madrid meet 2015, Mohammad Reza Mousavi (Halmstad University, Sweden) and Alexandra Silva (Radboud University, The Netherlands). The abstracts of all invited talks are listed below.

Since CONCUR moved to an open-access publication of its proceedings in LIPIcs, starting from 2015, all invited and contributed papers of CONCUR 2015 may be freely accessed from the conference web site:
http://mafalda.fdi.ucm.es/concur2015/.

2.1 Abstracts of invited talks

25TH ANNIVERSARY SPEECH

Matthew Hennessy (Trinity College Dublin, Ireland)
Behavioural Equivalences for Co-operating Transactions
Relaxing the isolation requirements on transactions leads to systems in which transactions can now co-operate to achieve distributed goals. However in the absence of isolation it is not easy to understand the desired behaviour of transactional systems, or the extent to which the other standard ACID properties of transactions can be maintained: atomicity, consistency and durability. In this talk I will give an overview of some recent work in this area, outlining semantic theories for a process calculus which has been augmented by a new construct for co-operating transactions.

Gianluigi Zavattaro (Università di Bologna, Italy)
Automatic Application Deployment in the Cloud: from Practice to Theory and Back
The problem of deploying a complex software application has been formally investigated in previous work by means of the abstract component model named Aeolus. As the problem turned out to be undecidable, simplified versions of the model were investigated in which decidability was restored by introducing limitations on the ways components are described.

In this paper, we take an opposite approach, and investigate the possibility to address a relaxed version of the deployment problem without limiting the expressiveness of the component model. We identify three problems to be solved in sequence: (i) the verification of the existence of a final configuration in which all the constraints imposed by the single components are satisfied, (ii) the generation of a concrete configuration satisfying such constraints, and (iii) the synthesis of a plan to reach such a configuration possibly going through intermediary configurations that violate the non-functional constraints.

James Worrell (University of Oxford, UK)
Reachability Problems for Continuous Linear Dynamical Systems
It is well understood that the interaction between discrete and continuous dynamics makes hybrid automata difficult to analyse algorithmically. However it is already the case that many natural verification questions concerning only the continuous dynamics of such systems are extremely challenging. This remains so even for linear dynamical systems, such as linear hybrid automata and continuous-time Markov chains, whose evolution is detemined by linear differential equations. For example, one can ask to decide whether it is possible to escape a particular location of a linear hybrid automaton, given initial values of the continuous variables. Likewise one can ask whether a given set of probability distributions is reachable

during the evolution of continuous-time Markov chain.

This talk focusses on reachability problems for solutions of linear differential equations. A central decision problem in this area is the Continuous Skolem Problem, which asks whether a real-valued function satisfying an ordinary linear differential equation has a zero. This can be seen as a continuous analog of the Skolem Problem for linear recurrence sequences, which asks whether the sequence satisfying a given recurrence has a zero term. For both the discrete and continuous versions of the Skolem Problem, decidability is open.

We show that the Continuous Skolem Problem lies at the heart of many natural verification questions on linear dynamical systems. We describe some recent work, done in collaboration with Chonev and Ouaknine, that uses results in transcendence theory and real algebraic geometry to obtain decidability for certain variants of the problem.

In particular, we consider a bounded version of the Continuous Skolem Problem, corresponding to time-bounded reachability. We prove decidability of the bounded problem assuming Schanuel's conjecture, one of the main conjectures in transcendence theory. We describe some partial decidability results in the unbounded case and discuss mathematical obstacles to proving decidability of the Continuous Skolem Problem in full generality.

Mohammad Reza Mousavi (Halmstad University, Sweden)
From Concurrency Theory to Testing Cyber-Physical Systems
We review and compare three notions of conformance testing for cyber-physical systems. We begin with a review of their underlying semantic models and present conformance-preserving translations between them. We identify the differences in the underlying semantic models and the various design decisions that lead to these substantially different notions of conformance testing. Learning from this exercise, we reflect upon the challenges in designing an "ideal" notion of conformance for cyber-physical systems and sketch a roadmap of future research in this domain.

Alexandra Silva (Radboud University, The Netherlands)
Applications of Automata and Concurrency Theory in Networks
Networks have received widespread attention in recent years as a target for domain-specific language design. The emergence of software-defined networking (SDN) as a popular paradigm for network programming has led to the appearance of a number of SDN programming languages seeking to provide high level abstractions to simplify the task of specifying the packet-processing behavior of a network.

Previous work by Anderson et al. introduced NetKAT, a language and logic for specifying and verifying the packet-processing behavior of networks. NetKAT provides general-purpose programming constructs such as parallel and sequential

composition, conditional tests, and iteration, as well as special-purpose primitives for querying and modifying packet headers and encoding network topologies. In contrast to competing approaches, NetKAT has a formal mathematical semantics and an equational deductive system that is sound and complete over that semantics, as well as a PSPACE decision procedure. It is based on Kleene algebra with tests (KAT), an algebraic system for propositional program verification that has been extensively studied for nearly two decades. Several practical applications of NetKAT have been developed, including algorithms for testing reachability and non-interference and a syntactic correctness proof for a compiler that translates programs to hardware instructions for SDN switches. In a follow-up paper the coalgebraic theory of NetKAT was developed and a bisimulation-based algorithm for deciding equivalence was devised. The new algorithm was shown to be significantlymore efficient than the previous naive algorithm, which was PSPACE in the best case and the worst case, as it was based on the determinization of a nondeterministic algorithm. Along with the coalgebraic model of NetKAT, the authors presented a specialized version of the Brzozowski derivative in both semantic and syntactic forms. They also proved a version of Kleene's theorem for NetKAT that shows that the coalgebraic model is equivalent to the standard packet-processing and language models introduced previously. They demonstrated the real-world applicability of the tool by using it to decide common network verification questions such as all-pairs connectivity, loop-freedom, and translation validation—all pressing questions in modern networks.

This talk will survey applications of automata theory, concurrency theory and coalgebra to problems in networking. We will suggest directions for exploring the bridge between the two communities and ways to deliver new synergies. On the one hand, this will lead to new insights and techniques that will enable the development of rigorous semantic foundations for networks. On the other hand, the idysiocransies of networks will provide new challenges for the automata and concurrency community.

2.2 Social events

The exciting scientific programme of Madrid meet 2015 was accompanied by most enjoyable social events. Apart from a single storm that passed as suddenly as it had arrived on the evening before the start of CONCUR, the weather was consistently sunny and dry for the whole week, and particularly on the reception and on the excursion days. Since many of the recommended hotels were located in the city centre, close to Plaza Moncloa, several participants also took advantage of the climate to reach the conference venue on foot: this made for a pleasant 30 minute walk, mostly along a convenient pedestrian path.

The welcome reception was held on the 1st day of the conference at Real

Jardín Botánico Alfonso XIII, close to the Faculty of mathematics at UCM. After a welcoming speech by David de Frutos Escrig, the participants were offered a full body-and-mind treat in the form of delicious tapas and a fine open air concert by a local string quartet. The concert featured pieces by Luigi Boccherini, Joaquín Turina and Eduardo López-Chávarri.

On the following evening, a guided visit to "Madrid de los Austrias" was offered by "Ayuntamiento de Madrid". On Thursday afternoon, a wonderful excursion to the ancient fortified city of Toledo was organised, ending with the conference dinner. The weather was perfect for the occasion (as witnessed by the photoreportage `http://mafalda.fdi.ucm.es/madrid2015/socialEvents.htm`): bright blue sky, high visibility, warmth without heat. Participants were offered a most interesting guided tour across the old town, which is rich of testimonies of its glorious past (roman, medieval, imperial) and very well preserved. One of the highlights of the tour was the visit to Synagogue of El Transito in the Jewish Quarter. Indeed, Toledo is known as the "City of the Three Cultures", having presented a historical co-existence of Christians, Muslims and Jews. In particular its Jewish community had been the most important of Spain. After a stop at a superb viewpoint on a high spot, facing the old town and dominating the river Tagus, the participants were led to the restaurant site, itself very well located. There they could enjoy the sunset on a large terrace overlooking the hills, where they were served a cocktail with a variety of appetizers, before being invited to take seats inside for a savory dinner made of local specialties.

The dinner ended with a short speech by the chairs Luca Aceto and David de Frutos Escrig, who presented the best paper awards and gave the figures for this edition of CONCUR: out of 93 full paper submissions, 33 were selected for presentation at the conference. The best paper award went to the article *Unfolding-based Partial Order Reduction*, by Cesar Rodriguez, Marcelo Sousa, Subodh Sharma and Daniel Kroening.

3 Epilogue

The 1st CONCUR conference was held in 1990 to mark the end of the first year of the ESPRIT Basic Research Action 3006 CONCUR (Theories of Concurrency: Unification and Extension), which started on September 1, 1989. Twenty five years after its creation, CONCUR has kept its momentum, consolidated its reputation and established itself as the reference annual conference for researchers in the field of Concurrency Theory. In some sense, we could say that the benefits of the ESPRIT BRA's, which have no analogue in the current European Programmes, are still to be felt today and hopefully will still be for many years to come.