

# The Legacy of Stefania Gnesi

## From Software Engineering to Formal Methods and Tools, and Back

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### The Early Years

Stefania Gnesi was born in Livorno in 1954. She studied Computer Science at the University of Pisa, where she graduated *summa cum laude* in 1978.

During her studies at ISI, which was the University of Pisa's Institute for Computer Science, a young discipline at that time, Stefania became interested in the continuing challenge associated with the production of software, namely to demonstrate that the developed software is actually doing what is expected to do, a challenge made harder in many cases by the fact that the expectations themselves are not precisely expressed. This has kept her busy ever since.

To face this challenge her very first steps in research, towards the end of her university studies, of purely theoretical nature, proved very valuable. In a publication in the *Journal of the ACM* [63] (not bad for a first journal paper!), resulting from her thesis under the supervision of Prof. Ugo Montanari, it is shown that finding the solution of a dynamic programming problem in the form of polyadic functional equations is equivalent to searching a minimal cost path in an and/or graph with monotone cost functions. An important computational application of this result is that the solution of a system of functional equations can always be reduced to the problem of searching a minimal cost solution tree in an and/or graph.

### Software Engineering

After short periods as consultant in industry and teaching Mathematics and Computer Science in a secondary school, Stefania joined the Distributed Systems group of Norma Lijtmaer at the *Istituto di Elaborazione dell'Informazione* (IEI), a predecessor of the *Istituto di Scienza e Tecnologia dell'Informazione* (ISTI) of the Italian National Research Council (CNR). There she first became interested

in bridging theory and practice in Software Engineering. Her participation in the European project *The Draft Formal Definition of ANSI/MIL-STD-1815A Ada* was centered around executing the Ada language's operational semantics by means of a logic programming approach, which resulted in a publication in the very first European Software Engineering Conference (ESEC 1987) [35].

In this context, it is worthwhile to recall that for over a decade, starting from the mid-nineties, Stefania taught Software Engineering courses at the Universities of Siena and Florence.

## Formal Methods and Tools

Towards the end of the eighties, Stefania initiated her career-long involvement in Formal Methods and Tools. By participating in the EU project LOTOSPHERE, Stefania developed an increasing interest in temporal logic, and especially in the newly developed formal verification technique of model checking, the research area to which Stefania has contributed the most. First and foremost the study of the relations between process algebras and adequate (action-based) temporal logics, resulting in publications in the 2nd International Conference on Formal Description Techniques for Distributed Systems and Communication Protocols (FORTE 1989) [37] and in the 3rd International Workshop (now a Conference) on Computer Aided Verification (CAV 1991) [29], as well as in the 4th volume of the international journal on *Formal Methods in System Design* [40].

Again, her interest in bringing together theory and practice pushed her to co-organize, at the IEI-CNR in Pisa, in December 1992, an ERCIM Workshop on Theory and Practice in Verification, gathering several prominent researchers in the field from Europe and overseas. Also the first toolkit to which Stefania contributed, namely JACK (Just Another Concurrency Kit) [22], was developed during these years, resulting in a publication in the 1st International Workshop (now a Conference) on Tools and Algorithms for Construction and Analysis of Systems (TACAS 1995) [28]. A few years later, she was involved in one of the first applications of model checking to railway control systems in the context of an industrial collaboration, resulting in a publication in the International Conference on Dependable Systems and Networks (DSN 2000) [59], succeeded by other related experiences inside the EU project GUARDS [20], and by several other projects in the railway domain as well as in other domains, for example addressing mobile and service-oriented architectures and computing in the EU projects AGILE [1,48] and SENSORIA [10,38] that ran from 2002 to 2010.

Many of these and subsequent projects led to the introduction of a number of tailored model-checking tools. In fact, JACK was followed by toolsets like HAL, resulting in a publication in the 10th International Conference on Computer Aided Verification (CAV 1998) [49], SAM, witnessed by a publication in the International Workshop on Current Trends in Applied Formal Methods (FM-Trends 1998) [39], and the KandISTI family members FMC, CMC, UMC and VMC, resulting in publications in the *ACM Transactions on Software En-*

*gineering and Methodology* [48,38] and in the international journal *Science of Computer Programming* [9], among others.

## Requirements Engineering / Natural Language Processing

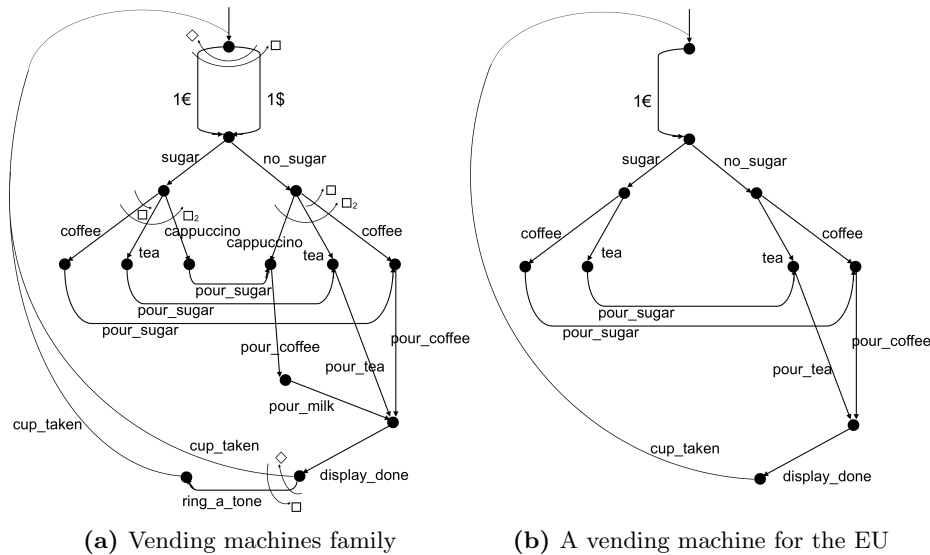
In parallel to her interest in Formal Methods and Tools, and still closely looking at the early stages of software development, Stefania became interested in Requirements Engineering and in particular in the formalization of software requirements written in natural language. This triggered pioneering work on the automatic translation of behavioural requirements into her favourite temporal logic ACTL, by means of Natural Language Processing (NLP) techniques, at that time still in their infancy, as well as the application of such NLP techniques to support the semantic analysis of requirements specified as Use Cases. This research led to publications in the 4th International Workshop (now Working Conference) on Requirements Engineering: Foundation for Software Quality (REFSQ 1998) [30] and in the 10th Anniversary IEEE Joint International Conference on Requirements Engineering (RE 2002) [36].

In the end, this turned out to be a prolific line of research, in particular when steered in the direction of using NLP techniques to evaluate the quality of requirements documents, in terms of absence of ambiguous requirements, vague requirements, underspecification, etc., as witnessed by yearly publications in the International Requirements Engineering Conference since 2015 and in the international journals *Requirements Engineering* [47], *IEEE Software* [43] and *Empirical Software Engineering* [45]. The QuARS tool developed at ISTI-CNR, first presented in a special issue on Automated Tools for Requirements Engineering of the international journal on *Computer Systems Science & Engineering* [65] and in the 23rd IEEE/ACM International Conference on Automated Software Engineering (ASE 2008) [23], was also used for this purpose inside the EU projects MODTRAIN/MODCONTROL [24]. QuARS continues to be in use, as witnessed by recent tool demos during the 2nd Workshop on Natural Language Processing for Requirements Engineering (NLP4RE 2019) [64] and the 23rd International Systems and Software Product Line Conference (SPLC 2019) [41].

## Software Product Lines

A more recent scientific community to which Stefania has made several important contributions is that of Software Product Line Engineering (SPLE), a field of research that she joined through her involvement in the EUREKA project CAFÉ. Also in this area, she applied her knowledge and skills on formal modelling and analysis, this time to so-called product families. It all started with a contribution on testing in the 5th International Workshop on Software Product-Family Engineering (PFE 2003) [21], a predecessor of the annual Software Product Line Conference (SPLC), in which Stefania has published a paper almost every year this decade. She has been a member of the Steering Committee of SPLC from 2014 to 2018.

However, her main contributions to SPLE concern Modal Transition Systems with variability constraints to serve as behavioural variability models [4], with associated action-based and variability-aware temporal logics [2] and model-checking algorithms and tools [3], which culminated in a publication in the *Journal of Logical and Algebraic Methods in Programming* [13], followed recently by a study of the model’s expressiveness in the international journal *Science of Computer Programming* [12]. Curiously, one of her most cited SPLC contributions is the toy example of a family of coffee machines, published in the 12th International Software Product Line Conference (SPLC 2008) [33], which was reused in numerous subsequent papers in the field. In Figure 1, we reproduce the coffee vending machine example.



**Fig. 1.** Classical coffee vending machine example reproduced from [33]

## Formal Verification and Applications

As head of the Formal Methods and Tools (FMT) laboratory of ISTI–CNR for almost two decades, from December 2002 until July 2019, Stefania also touched upon other research streams that have been pursued by members of the lab. These were typically characterized by Formal Verification and analysis as well as Applications to system designs made precise by formal modelling.

Example research streams include: Stochastic modelling and analysis, resulting in publications ranging from the 5th IEEE International Symposium on High-Assurance Systems Engineering (HASE 2000) [60] to the *Journal of Rail*

*Transport Planning & Management* [7]; Groupware, resulting in publications in the 27th International Conference on Software Engineering (ICSE 2005) [19] and in the *Journal of Logic and Algebraic Programming* [11]; Security, witnessed by publications in the 7th International Conference on Formal Methods for Open Object-Based Distributed Systems (FMOODS 2005) [25] and in the Proceedings of the MEFISTO project on Formal Methods for Security and Time [61]; Web Services, witnessed by a publication in the 4th IEEE European Conference on Web Services (ECOWS 2006) [17]; Telecommunications, witnessed by a publication in the 10th International Conference on Feature Interactions in Telecommunications and Software Systems (ICFI 2009) [18]; Collective Adaptive Systems and Smart Cities, in particular smart transportation in the form of bike-sharing systems, resulting in various publications, even touching upon Machine Learning [8,16,5], in the context of the EU project QUANTICOL; Business Process Modelling, witnessed by publications in the Demo Track of the 15th International Conference on Business Process Modeling (BPM 2017) [51] and in the journal of *Data & Knowledge Engineering* [26] in the context of the EU project Learn PAd.

The recent participation of the FMT lab in the Shift2Rail EU project AST-Rail can be seen as a recognition of the vast experience of the lab in Formal Methods, Formal Verification and Tools, and in particular in Applications to the Railway domain. A specific workstream of ASTRail was concerned with an assessment of the suitability of formal methods in supporting the transition to the next generation of ERTMS/ETCS railway signalling systems, triggered by the fact that the Shift2Rail initiative considers formal methods to be fundamental to the provision of safe and reliable technological advances to increase the competitiveness of the railway industry. Indeed, Stefania and her colleagues from the FMT lab have co-authored numerous authoritative papers on the subject throughout the last decade [34,44,32,31,15,6,42]. Moreover, due to several strong links to railway signalling industries, Stefania was chosen as CNR representative in the Italian railway technology district DITECFER, from 2011 to date.

## Conclusions

The international attitude of Stefania's professional activity may also be concluded, besides her participation in the above mentioned European projects, from her participation in international bodies. To begin with, we recall her long-standing activities in the ERCIM working group on Formal Methods for Industrial Critical Systems (FMICS). After the success of the aforementioned ERCIM Workshop on Theory and Practice in Verification held in Pisa in December 1992, Stefania co-founded FMICS, making it the oldest active ERCIM working group. Stefania is an FMICS board member ever since and she chaired the board from 2002 to 2005. Initiated in 1996, next year the annual FMICS conference will celebrate its 25th edition. Stefania co-edited a book that surveys over a decade of award-winning collaborative work within the FMICS working group, presenting

a number of mainstream formal methods used for designing industrial critical systems [62]. Also, at FMICS 2003, she was invited to present an overview of current research on formal methods in her research group [53].

Furthermore, Stefania is member of the board of the association Formal Methods Europe (FME) for over 15 years now and deputy chair since 2004. Currently, she is responsible for overseeing FME’s flagship conference series on Formal Methods, which this year was organized as the 3rd World Congress on Formal Methods, featuring a colloquium in honour of Stefania’s 65th birthday in which many of the contributors to this Festschrift participated.

The experience of Stefania in organizing workshops and conferences was exercised many times in events hosted in Pisa and in Florence under her guidance, including FM 2003, SEFM 2010, IFM & ABZ 2012, VaMoS 2013, SPLC 2014, FMICS-AVoCS 2016, and the upcoming REFSQ 2020. She also chaired the Program Committee of leading workshops and conferences in her fields of research, such as FMICS, SEFM, VaMoS, SPLC, FASE, FMSPLE, AVoCS and—of course—FM, resulting in several co-editorships of special issues of renowned journals [57,56,27,58,52,50,32,55,15,14,54], among which *Formal Aspects of Computing* and the *International Journal on Software Tools for Technology Transfer*, of which she is an editorial board member.

Last but not least, since 2013, Stefania co-organises the FormaliSE conference series affiliated with the International Conference on Software Engineering (ICSE). FormaliSE is an annual conference on Formal Methods in Software Engineering and as such yet another expression of Stefania’s constant attention to inject formality into Software Engineering, thus returning to where she started: from Software Engineering to Formal Methods and Tools, and Back.

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