# Lecture Notes in Computer Science　12857

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# Software Architecture

15th European Conference, ECSA 2021
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Proceedings

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# Preface

The European Conference on Software Architecture (ECSA) is the premier European conference that provides researchers and practitioners with a platform to present and discuss the most recent, innovative, and significant findings and experiences in the field of software architecture research and practice.

This 15th edition of ECSA focused on the role of software architecture in the next generation of software-enabled systems that aim at addressing societal challenges, such as health, climate, sustainability, mobility, diversity, and future production. These challenges raise questions such as how can software architecture contribute to building and sustaining systems of the future? What automation, tools, and techniques do software architects and engineers need in order to ensure architectures developed are adaptable, evolvable, verifiable, and meet their quality and functional requirements?

Due to the ongoing COVID-19 pandemic, this edition of ECSA was held virtually during September 13–17, 2021, with participating researchers and practitioners from all over the world. The core technical program included a main research track, three keynote talks, and an industry track. Moreover, ECSA 2021 offered a doctoral symposium track with its own keynote, a diversity, equity and inclusion track with its own keynote and a tool and demos track. ECSA 2021 also encompassed six workshops on diverse topics related to the software architecture discipline, such as erosion and consistency, formal approaches for advanced computing, etc. Lastly, ECSA 2021 featured a journal-first track partnering with the Journal of Software and Systems and the IEEE Software Magazine. A selection of revised and extended contributions from all these other tracks are included in the companion proceedings, published in another Springer volume.

For the main research track, ECSA 2021 received 58 submissions in the two main categories: full and short research papers. Based on the recommendations of the Program Committee, we accepted 11 papers as full papers and 5 additional papers as short papers. Hence, the acceptance rate for full research papers was 19% for ECSA 2021. For the industrial track, we received 10 submissions and accepted 5 of them. The conference attracted papers (co-)authored by researchers, practitioners, and academics from 23 countries (Australia, Austria, Belgium, Brazil, Colombia, Czech Republic, Finland, France, Germany, India, Italy, Japan, the Netherlands, New Zealand, Norway, Poland, Portugal, Spain, Sweden, Switzerland, Turkey, UK, and USA).

The main ECSA program had three keynotes. Edward Lee from Berkeley (USA), author of textbooks on embedded systems, digital communications, and, more recently, on philosophical and social implications of technology, talked about "Determinism" in engineering and science. Eoin Woods from Endava (UK), former editor of the IEEE Software "Pragmatic Architect" column and co-author of the well-known software architecture book "Software Systems Architecture", talked about "Software Architecture for a Digital Age". Mats Gejnevall of Minnovate (Sweden), who is widely known

thanks to his work with the Open Group enhancing The Open Group Architecture Framework (TOGAF), talked about "Enterprise Architecture in an Agile World."

We are grateful to the members of the Program Committee for their valuable and timely reviews. Their efforts formed the basis for a high-quality technical program for ECSA 2021. We would like to thank the members of the Organizing Committee for successfully organizing the event with several tracks, as well as the workshop organizers, who made significant contributions to this year's successful event.

We thank our sponsor Springer for funding the best paper award of ECSA 2021 and supporting us with publishing the proceedings in the Lecture Notes in Computer Science series. Finally, we thank the authors of all the ECSA 2021 submissions and the attendees of the conference for their participation.

The preparation and organization of ECSA 2021 took place during an unprecedented time in our history, a pandemic situation that has affected us all over the world. We thank the support of the software architecture community that, despite this dramatic situation, continued with advancing the field of software architecture through their scientific submissions to ECSA, while staying flexible as the Organizing Committee had to organize an all-online conference.

September 2021                                                    Stefan Biffl
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# Abstracts of Keynotes

# Determinism

Edward Lee

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**Abstract.** Uncontrolled and unintended nondeterminism has been a persistent problem for concurrent, parallel, and distributed software. Recent trends have improved the situation by replacing threads and remote procedure calls with publish-and-subscribe busses, actors, and service-oriented architectures, but even these admit nondeterminism and make building deterministic programs difficult. One approach is to abandon determinism, recognizing that software has to handle unpredictable events, communication networks with varying reliability and latencies, unpredictable execution times, and hardware and software failures. In this talk, I will argue to the contrary, that determinism becomes even more valuable in unpredictable environments. Among its many benefits, determinism enables systematic testing, shifts complexity from application logic to infrastructure, enables fault detection, facilitates composability, and more. The key is to understand that determinism is a property of models, not of physical realizations. In engineering, our primary goal is to coerce the physical world to match our models. In contrast, in science, the primary goal is to coerce the models to match the physical world. In this talk, I will examine what we mean by "determinism" in engineering, science, and a bit in philosophy. Whether a model is deterministic or not depends on how one defines the inputs and behavior of the model. I will conclude by outlining a practical deterministic model well suited for concurrent, parallel, and distributed software. I will describe a realization of this model in a coordination language called Lingua Franca.

**Keywords:** Concurrency · Distributed Systems · Determinism

**Biography.** Edward A. Lee has been working on embedded software systems for 40 years. After studying and working at Yale, MIT, and Bell Labs, he landed at Berkeley, where he is now Professor of the Graduate School in EECS. His research is focused on cyber-physical systems. He is the lead author of the open-source software system Ptolemy II, author of textbooks on embedded systems and digital communications, and has recently been writing books on philosophical and social implications of technology. His current research is focused on a polyglot coordination language for distributed real-time systems called Lingua Franca that combines features of discrete-event modeling, synchronous languages, and actors.

# Software Architecture for a Digital Age

Eoin Woods

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**Abstract.** The COVID-19 pandemic has increased the pace of digitisation of many areas of our lives, but this is a process that has been underway for some years. We really are living in a "digital age" where many companies outside the traditional technology area, such as John Deere and GE, are building intelligent, connected digital "platforms" for their customers or their entire industry segments. Building these platforms is a very different process to building traditional enterprise applications and has to accommodate constant change, constant learning based on rapid feedback from the operational use of the platform. So software architecture needs to change too, in order to meet the challenges of building intelligent, connected platforms that are constantly in use. In this talk I will explain the challenges that software architects face in the era of digital platform development, the techniques that we are using today to meet those challenges and suggest how I think software architecture will evolve further as a result of the experience we are gaining.

**Keywords:** Software architecture · Continuous architecture · Digital platforms · Digital transformation

**Biography.** Eoin Woods is the CTO of Endava, a technology company that delivers projects in the areas of digital, agile and automation. Prior to joining Endava, Eoin has worked in the software engineering industry for 20 years developing system software products and complex applications in the capital markets domain. His main technical interests are software architecture, distributed systems and computer security. He is a former editor of the IEEE Software "Pragmatic Architect" column, co-author of the well-known software architecture book "Software Systems Architecture" and was the recipient of the 2018 Linda M. Northrup Award for Software Architecture, awarded by the SEI at Carnegie Mellon University.

# Enterprise Architecture in an Agile World

Mats Gejnevall

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**Abstract.** There is an ongoing demand for the size and timescale of architectures to become ever shorter. This in turn is resulting in a tendency for enterprises to skip the development of architectures, which in turn is resulting in some high-profile IT failures because of the unanticipated consequences of what appeared to be minor changes. Enterprise Architecture recognizes the need to recursively break down the architecture into more granular levels that can be architected following an Agile approach. Partitioning the architecture work is key for Agile delivery and implies the definition of creating increments based on the enterprise priorities. These smaller pieces, that cover a specific area of the organization, can then be more easily specified and implemented following an agile approach. Enterprises have adapted the agile concepts for the business development for the same reasons and are evolving their business in increments. That has to match with creating architectures and solutions in agile ways. Since the American Department of Defense (DoD) is allowing agile acquisition of solutions, there is a need to ensure that these solutions will deliver the value that is expected. Enterprise Architecture will be one of the important building blocks in that process.

**Keywords:** Enterprise architecture · Agile · Iterative

**Biography.** Mats is working with business development using enterprise architecture as one of the methods. Working environment is often sectors like Government, Telco, Supply Chain and Defence either transforming them to Enterprise Architecture work practices or leading and performing enterprise architecture work as both a business and IT architect. The last 15 years Mats has been involved with the Open Group enhancing The Open Group Architecture Framework (TOGAF) and creating related guides. Lately Mats has been involved in creating guides on how enterprise architects could use agile practices. Frequently, he has the pleasure of teaching architecture methods and being a speaker at international conferences on Enterprise Architecture.

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