

CURRICULUM VITAE

Marco Villani

Biographical data

Born in Bologna (Italy), 11th December 1967

Married, with two children

Studies:

1992: Italian Laurea (M.Sc.) in Physics, with honors (*magna cum laude*), University of Bologna.

1986: diploma di maturità (high school diploma), Liceo classico "M.Minghetti" of Bologna (final mark 60/60)

Current affiliation:

Department of Physics, Computer Science and Mathematics of University of Modena and Reggio Emilia – Associate professor (“Professore associato”), since November 2015

RESEARCH EXPERIENCE

Professional roles

Since November 2015

He is **associate professor** in S.S.D. INF01 – Computer Science, at the **Department of Physics, Computer Science and Mathematics** of the University of Modena and Reggio Emilia. His main research interests concern the application of the concepts typical of complex systems to interdisciplinary topics, as the fields of technological systems, environment, health and social sciences.

October 2011 - October 2015

Researcher and assistant professor in S.S.D. ING/INF-05 – Computer Science and Engineering, at the **Department of Physics, Computer Science and Mathematics** of the University of Modena and Reggio Emilia.

January 2005 – September 2011

Researcher and assistant professor in S.S.D. ING/INF-05 – Computer Science and Engineering, at the Department of Communication and Economics of the University of Modena and Reggio Emilia, where he leads the **Simulation and Modelling Laboratory**

May 1997 – December 2004

Researcher at the Montecatini Environmental Research Centre in Marina di Ravenna (CRA) where, as **supervisor of the Modeling and Simulation Laboratory**, he performed research activities in non-linear mathematical models. The activities ranged from simulation of cellular cultures, to control of fermentation processes, to simulation of fluids-dynamics phenomena and bioremediation, to theoretical and mathematical interpretation of data coming from molecular biology; a part of the activity was achieved by means of parallel computers.

September 1995 – May 1997

Collaborator at the Montecatini Environmental Research Centre in Marina di Ravenna (CRA), where he worked for the development of mathematical models of non-linear systems. In particular, the main activity regarded the simulation of bio-remediation phenomena of polluted soils.

June 1995 – August 1995

Software developer for the company “Advanced Computer Systems S.p.A.” in Milano (now belonging to the group “Artificial Intelligence Software S.p.A.”), within the project of computerization of the Hospital of Trento.

November 1994 – June 1995

Winner of the scholarship Enea n. 25 on “Parallel Computation and Tomographical Imaging” at the centre E. Clementel in Bologna; he developed a software for the reconstruction of tomographical images, implemented on Cineca’s parallel computer CRAY T3D.

July 1993 – October 1994

Collaborator at the Health Physics Departments at the hospital “S.Orsola-Malpighi” as software developer for the reconstruction of tomographic images based on “Maximum Likelihood” algorithms.

Participation to projects

Hereafter, the main projects in which he participated, as well as his operative roles, in the sphere of systems simulation and modelling, are listed. A particular attention will be devoted to the presentation of the CETRA project of which he was the Supervisor. The projects under corporate funding are not reported.

2025-2026: leader of the computational area, within the departmental project (FAR2025). The activity of the computational team concerned the development of the computational and modelling capabilities of the research area of the Department of Physics, Informatics and Mathematics.

2023-2024: leader of the computational area, within the departmental project (FAR2023). The activity of the computational team concerned the development of the computational and modelling capabilities of the research area of the Department of Physics, Informatics and Mathematics.

2019-2020: leader of the computational area, within the departmental project (FAR2019). The activity of the computational team concerned the development of the computational and modelling capabilities of the research area of the Department of Physics, Informatics and Mathematics.

2018-2020: member of the project SECREDAS – Cyber security for Cross Domain Reliable Dependable Automated Systems (GA 783119) within the H2020-ECSEL framework

2012-2014: leader of the modelling group, within *Emergence by Design* project (EU-FET 284625 - the overall value of 3 million euro). The activity of the modelling team (lead by Marco Villani and Roberto Serra) concerned the development of indexes and tools based on information theory, aiming to detect the presence of dynamically relevant parts (“relevant sets”) able to influence and drive the behavior of the whole system.

2008-2010: researcher, within the *DICE* project (of the overall value of 2 million euro), funded by “Fondazione di Venezia”. The project is oriented towards the design of novel proteins, non-existing in nature.

2005-2007: researcher within MIUR 2982/Ric *MITICA* project (of the overall value of 4 million euro). The activity concerned the development of models of gene regulatory networks and of the relative simulation software.

2004-2007 leader of the whole **CETRA Project** - Complexity Education for TRainers (EU, Leonardo project) and **leader** of the **UNIMORE unit**, the project’s main contractor. The project successfully ended, leading to concrete results as the publication of the book “Educating managers in complexity” and the development of an on-line course on complex networks.

2004-2006: researcher (and **supervisor** of the **Simulation and Modelling Laboratory**) of the **UNIMORE unit**, which leaded the European project *ISCOM* (European VI Framework Program, FET IST-2001-35505 - overall value of 2 million euro): Information Society as a COMplex System, successfully concluded. The activity consisted in the development of process innovation models and in the design, realization, test and use of a simulation environment.

2002-2004: study of the glioblastoma by means of microarrays (Miur, FISIR 1509): **researcher** (and **supervisor** of the **Modeling laboratory**) of the **CRA unit**, involved in the bioinformatics and modeling activities of the project. The main contractor was the ASL of Bologna Nord.

2001-2003: study of the alpha-lipoic acid, a natural antioxidant useful in medical applications (Miur, PNR 7992): **researcher** (and **supervisor** of the **Modeling laboratory** of the **CRA unit**), involved in the bioinformatics and modeling activities of the project. The main contractor was the ASL of Bologna Nord.

1998-2000: *COLOMBO* project (EU, Esprit Project, project 24907): **researcher** (and **supervisor** of the **Modeling laboratory**) of the **CRA unit**, which was the main contractor of the entire project. Development of the prototype of a system based on cellular automata for the simulation of the bio-remediation of polluted soils on parallel architectures. It has been the principal European project of bio-remediation in the modeling sector. It obtained excellent evaluations and proved good results in tests.

1997-2002: technologies for the environmental remediation of contaminated soils (Murst PNR 15, overall value of 15 billion – Italian lira); **researcher** and **supervisor** of the **Modeling laboratory** of the **CRA unit**, which was involved in different tasks. The main contractor was Hera (Ravenna).

1995-96: *Capri* – subproject *CABOTO* project (EU, Esprit project): **researcher** within the **CRA unit**, which was the main contractor of the entire project. It was preparatory for the Colombo project and it successfully demonstrated the effectiveness of the approach based on cellular automata for the simulation of bio-remediation.

TEACHING EXPERIENCE

Professor in charge

- **“Complex Systems” (LMCS - 42 teaching hours)** – a.y. 2018-2019, 2019-2020, 2020-2021, 2021-2022, 2022-2023, 2023-2024, 2024-2025, 2025-2026, 2026-2027
- **“Computer science” (ECOF - 24 teaching hours)** – a.y. 2015-2016, 2016-2017, 2017-2018
- **“Computer science” (MATE - 72 teaching hours)** – a.y. 2012-2013, 2013-2014, 2014-2015, 2015-2016, 2016-2017, 2017-2018, 2018-2019, 2019-2020, 2020-2021, 2021-2022, 2022-2023, 2023-2024, 2024-2025
- **“Computer science” (MATE – module of 24 teaching hours)** – a.y. 2025-2026, 2026-2027
- **“Computer science” (CHIM - 24 teaching hours)** – a.y. 2012-2013, 2013-2014, 2014-2015, 2015-2016, 2016-2017, 2017-2018
- **“Learning and evolution in artificial systems” (INFO - 48 teaching hours)** – a.y. 2012-2013, 2013-2014, 2014-2015, 2015-2016, 2016-2017, 2017-2018, 2018-2019, 2019-2020, 2020-2021, 2021-2022, 2022-2023, 2023-2024, 2024-2025, 2025-2026
- **“Artificial Intelligence” (INFO - 72 teaching hours)** – a.y. 2024-2025, 2025-2026
- **“Knowledge management” (SCO - 42 teaching hours)** – a.y. 2009-2010, 2010-2011, 2011-2012
- **“Modelling and simulations” (ECOS and later DIMSI - 63 teaching hours)** – a.y. 2007-2008, 2008-2009, 2009-2010, 2010-2011, 2011-2012
- **“Computer science” (SCO and later CLEIGI - 56 teaching hours)** – a.y. 2005-2006, 2006-2007, 2007-2008, 2008-2009
- **“Simulation: models and methodologies” (EGRI - 64 teaching hours)** – a.y. 2003-2004, 2004-2005, 2005-2006, 2006-2007
- **“Applied computer science” (SCO - 48 teaching hours)** – a.y. 2004-2005

Legend of acronyms

LMCS: Courses taught for the master degree in “Informatics”

MATE: Courses taught for the bachelor's degree in Mathematics

INFO: Courses taught for the bachelor's degree in Computer Science

ECOF: Courses taught for the bachelor's degree in “Economy and finance”

CHIM: Courses taught for the bachelor's degree in Chemistry

DIMSI: Courses taught for the master degree in “Dynamics of trades and business strategies”

ECOS: Courses taught for the master degree in “Economy and Complex Systems”

CLEIGI: Courses taught for the bachelor's degree in “Economy and computer science for the business management”

EGRI: Courses taught for the master degree in “Economy and Innovation management”

SCO: Courses taught for the bachelor's degree in “Communication sciences”

Marco Villani has supervised several M.Sc. and Ph.D. theses at the Universities of Bologna and Modena/Reggio Emilia. He has held several seminars in universities and research centres. He has been coordinator of the COMETA project (a special course on bio-inspired computation, 20 teaching hours for selected high school students) and participated to the departmental “Computer Science Behind the Scenes” initiative.

SERVICE

- **Responsible** of the Simulation and Modelling Laboratory of the Communication and Economy department of the University of Modena and Reggio Emilia (2006-2011)
- **Delegate** of the researchers on Communication and Economy faculty (2006-2011)
- **Member** of the intercourse board of the master degree EGRI and CLEIGI courses (2007-2011)
- **Member** of the Doctorate School in Information and Communication Technologies (2009-2022)
- **Member** of the Doctorate School in Computer and Data Science for Technological and Social Innovation (CDS-TSI) (2022-today)
- **Chairperson** of the “Commissione Paritetica Docenti-Studenti” (Joint Commission Teachers-Students) of the FIM department (2015-2018)
- **President** of the master's degree in computer science - Department of Physics, Informatics and Mathematics (2018-today)

CONFERENCES AND SEMINARS

Marco Villani has been invited speaker at conferences and workshops in Europe and US. Among them, we can mention:

- **“Asymmetrical Division in Populations of Protocells”** July 2024 – talk at “2nd Workshop on Molecular Communication Approaches for Wetware”, satellite workshop of The 2024 Conference on Artificial Life (ALIFE 2024), Copenhagen, Denmark, 22-26 July 2024
- **“Reaction networks in protocells”** September 2017 – talk at “Synthesizing (a kind of) Life” international workshop and focus group - Konrad Lorenz Institute, Klosterneuburg, Austria; 24-30 September 2017
- **“Resilience and the structure of complex systems”** 16 May 2016: talk at “EnSIR International Workshop - Enhancing social infrastructures resilience to cope with natural disasters”- Modena, 16-17 May 2016
- **“The Search for Candidate Relevant Subsets of Variables in Complex Systems”** - 29 January 2016: talk at “Organization and criticality in complex systems” workshop organized by the AIRS – the Italian Systems Society - Bologna (IT)
- **“Chemical reaction networks in protocells”** 25 February 2013 – talk at “COOL EDGE Workshop 2013 - the Origin of Life”- CERN, Genève, 25 February – 1 March 2013
- **“A Dynamical model of cell differentiation”** February 2012: talk at the “Workshop on Mathematics for the Dynamics of Multilevel Systems”- Venice
- **“Information processing in technological and social systems”**, Maggio 2010, Roma (IT) – seminar on Complexity Education at Ministry of Economic Development
- **“A Dynamical Model of Exaptation processes”**- February 2010, Trento (IT) - CIFREM seminars
- **“A dynamical model of exaptive innovation processes”** September 2009: talk at “Exaptation as a source of innovation, creativity and diversity in evolutionary sciences” international workshop - Gargnano del Garda (IT)
- **“Understanding the logic of gene regulation from microarray data”** June 2009: talk at EURISBIS’09 European Regional Meeting of the International Society for Business and Industrial Statistics” international conference – 30 May-3 June 2009, Cagliari (IT)
- **“Spontaneous development of concentration gradients”** March 2008: talk at “Protocell modelling workshop” - 10-12 March 2008 - Venice (IT)
- **“Educating managers in complexity”** July 2007: talk at “The management of complexity, the complexity of management (Complexity, management and education)” - 12 July 2007 - Reggio Emilia (IT)
- **“A theory-based dynamical model of innovation processes”** January 2007: talk at "Workshop on aspects of Social and Socio-Environmental Dynamics" - 21-24 January 2007 - Arizona State University (Phoenix, USA)
- **“Complex behaviors in an agent-based model of innovation processes”** June 2006: talk at "The Information Society as a Complex System " - 12-16 June 2006 Venice (IT)
- **“Innovation models in social systems”** May 2005: talk at “3rd Lake Arrowhead Conference on Human Complex Systems”, 18-22 May 2005, Lake Arrowhead (California – U.S.A.)
- **“Which role for innovation models in social systems?”** April 2005: talk at "Innovation in social systems" - Reggio Emilia (IT)

AWARDS

Thesis

1993 Marco Villani's M.Sc. thesis has been honored by the SIF (Italian Physics Society) as the best thesis with applications from Informatics to Physics in the Academic Year 1991-92

Best paper awards

- **2013:** ECAL, European Conference on Artificial Life (Taormina, Italy)
 - Villani, M., Filisetti A., Benedettini, S., Roli, A., Lane, D., Poli, I. & Serra, R. (2013): The detection of intermediate-level emergent structures and patterns. In P.Liò, O.Miglino, G. Nicosia, S.Nolfi & M. Pavone (eds): Advances in Artificial Life, ECAL 2013, pp. 372-378. MIT Press
- **2010:** ECCS, European Conference on Complex Systems (Lisbon, Portugal)
 - Filisetti, A., Serra, R., Villani, M., Fuechslin, R., Packard, N., Kauffman, S.A. & Poli, I. (2010): A stochastic model of catalytic reaction networks. In proceedings of ECCS 2010, (European Conference on Complex Systems). CD-Rom Track E, paper p29
- **2009:** WIRN, Workshop on Neural Networks (Vietri sul Mare. Salerno, Italy)
 - Barbieri, A., Villani, M., Serra, R., Kauffman, S.A. & Colacci, A. (2009): The influence of noise on the dynamics of random boolean networks. In B. Apolloni, S. Bassis & C. Morabito (eds): Neural nets WIRN09. Amsterdam: IOS Press: 11-18
- **2006:** ACRI - Cellular Automata for Research and Industry (Perpignan, France)
 - Villani, M., Serra, R., Ingrami, P. & Kauffman, S.A. (2006): Coupled random boolean networks forming an artificial tissue. In El Yacoubi, S., Chopard, B. & Bandini, S. (eds): ACRI 2006. Berlin: Springer Lecture Notes in Computer Science 4173, 548-556

Poster: honorable mention

- **2009:** ECCS, European Conference on Complex Systems (Warwick - UK)
 - Filisetti A., Serra, R., Carletti T., Villani, M., Poli I. (2009): Non linear protocell models: Synchronisation and Chaos.

ORGANIZATION ACTIVITIES

Scientific committees, editorial board

- **Member** of the ECLT (European Centre for Living Technology - Venice) **Science Board** (2023 - today)
- **Member** of the **Editorial Board** of Multi- and Cross-disciplinary Complexity (specialty section of Frontiers in Complex Systems) (October 2023 - today)
- **Member** of the **Review Board** of Frontiers in Artificial Intelligence (October 2023 - today)
- **Member** of the **National Board** of AI*IA (Italian Association for Artificial Intelligence) (2009-2011)
- **Fellow** of the European Centre for Living Technologies (ECLT - Venice) (March 2016 – today)

Guest editor for special issues

- Roberto Serra, Rudolf Füchslin, Erik Schultes, Marco Villani *Complex Systems Models in Biology and Medicine: Generic Properties and Applications*, special issue of the journal “Computational and Mathematical Methods in Medicine” (January 2014)

Conference and special issue organization

- **Chairman** and **Co-organizer** of WIVACE2023 (Italian workshop on artificial life and evolutionary computation) to be held in Venice, Italy, 6 – 8 September **2023**
- **Chairman** and **Co-organizer** of WIVACE2018 (Italian workshop on artificial life and evolutionary computation) held in Parma, Italy, 10 – 12 September **2018**
- **Chairman** and **Co-organizer** of WIVACE2017 (Italian workshop on artificial life and evolutionary computation) held in Venice, Italy, 19 – 21 September **2017**
- **Chairman** and **Co-organizer** of the international workshop “DySCS - Dynamical Structures in Complex Systems: an information theoretic perspective”, satellite of the European Conference on Complex Systems (Lucca Italy, 25 September **2014**).
- **Guest editor** of “Complex Systems Models in Biology and Medicine: Generic Properties and Applications”, special issue of the journal “Computational and Mathematical Methods in Medicine” (January **2014**)
- **Chairman** and **Co-organizer** of WIVACE2012 (Italian workshop on artificial life and evolutionary computation) held in Parma, Italy, 20 – 21 February **2012**
- **Chairman** and **Co-organizer** of “The dynamics of biological networks”, special session of the WIRN2010, 20th Italian Workshop on Neural Networks (Vietri sul Mare, Salerno, Italy, 27-29 may **2010**)
- **Chairman** and **Co-organizer** of the workshop “Complexity, Evolution and Emergent Intelligence”, satellite of the XI international conference on artificial intelligence of the Italian Association for Artificial Intelligence (Reggio Emilia, Italy, 11 December **2009**)
- **General chairman** of the workshops of the XI international conference on artificial intelligence of the Italian Association for Artificial Intelligence (Reggio Emilia, Italy, 9-12 December **2009**)
- **Chairman** and **Co-organizer** of WIVACE2008 (Italian workshop on artificial life and evolutionary computation) held in Venice, Italy, 8 – 10 September **2008**

- **Chairman and Organizer** of the international workshop “The management of complexity, the complexity of management - Complexity, management and education” (Reggio Emilia, Italy, 12 July **2007**)

He has been also session chair in several international conferences and workshops.

Conference program committee member

Marco Villani has been member of the Program Committee for the following conferences:

- **ACSMoPar** (Advances in Complex Systems: Modelling and Parallel Implementation Workshop) satellite workshop of the 14th International Conference on Computational Science and Its Applications (ICCSA), 2014
- **AI*IA** (Italian association for Artificial Intelligence), editions 2009, 2011, 2013, 2015, 2017, 2018, 2019
- **ALIFE** (the International Conference on the Synthesis and Simulation of Living Systems) 2016, 2018, 2021, 2023, 2024, 2025
- **BigDaCI** (International Conference on Big Data Analytics, Data Mining and Computational Intelligence) 2016, 2018, 2019, 2022, 2023, 2024, 2025, 2026
- **ECAL** (European Conference on Artificial Life) 2013
- **Evo*** 2020, 2021, 2022, 2023, 2024, 2025, 2026
- **EvoCOMNET** (the "Application of Nature-inspired Techniques for. Communication Networks and other Parallel and Distributed Systems") 2016, 2018
- **DATA** (International Conference on Data Science, Technology and Applications) 2018, 2019, 2020, 2021, 2023, 2024, 2025, 2026
- **GECCO** 2018, 2020, 2021
- **HPCMS** (High Performance Computing in Modelling and Simulation), international satellite workshop of PDP (Euromicro international conference on Parallel, Distributed and network-based Processing) 2014, 2015
- IEEE International Conference on Computational Intelligence in Bioinformatics and Computational Biology (IEEE **CIBCB 2019**)
- **ISA** (International Conference on Intelligent Systems and Agents), editions 2012, 2013, 2014, 2015
- **LOD** 2018 (4th International Conference on machine Learning, Optimization and Data science), LOD 2019, 2021, 2022, 2023, 2024
- **MOD2017** (3rd International Conference on Machine learning, Optimization & big Data) 2017
- **PDEIM** (ACM Workshop on Parallel and Distributed Evolutionary Inspired Methods) 2017, 2018
- **PDP2018** (international conference on Parallel, Distributed, and Network-Based Processing) 2018
- **SMLC** (Synthetic Modeling of Life and Cognition) 2013
- **WIRN** (Italian Workshop on Neural Networks), editions of 2010, 2011, 2012, 2013
- **WIVACE** (Italian workshop on artificial life and evolutionary computation), editions of 2008, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2021, 2022, 2023, 2024, 2025, 2026

General public conferences

- **Chairman** and **Co-organizer** of the exhibition “Artificial life and self-organization phenomena” during the Researchers night at Reggio Emilia, 24 September **2010**. Here he also held the **seminar** “Artificial life and complexity”
- **Co-organizer** of the “Tuesday of the Science” series of public lectures at Minerbio (Bologna), March and April **2008**. He also held the **public lecture** “Artificial beings”
- **Co-organizer** of the “Wednesday of the Science” series of public lectures at Minerbio (Bologna), February and March **2007**. He also held the **public lecture** “The networks we are embedded in”

Refereeing

Marco Villani is referee for the following international journals (at least once, since 2002):

Artificial Life
Entropy
JASSS - Journal of Artificial Societies and Social Simulation
Journal of Supercomputing
Journal of the Royal Society Interface
Natural Computing
Neural Networks
Neurocomputing
Origins of Life and Evolution of Biospheres
Physica A
Trends in Genetics
Transactions on Modeling and Computer Simulation

External referee for PhD thesis

The Hebrew University of Jerusalem, 2012

Society memberships

Marco Villani is member of the **AI*IA**, Italian Association for Artificial Intelligence, where is served as member of the steering committee of **AI*IA**, (from September 2009 to December 2011). He is also member of SIREN (Società Italiana Reti Neuroniche – Italian Society for Neural Networks) and CSS (Complex Systems Society).

RESEARCH INTERESTS

Marco Villani's main research interests are in complex systems comprehension and modelling. Since his master thesis work Marco Villani is interested in understanding the possible presence of universal patterns of organization in complex systems (generally defined as systems composed by many non-linearly interacting parts). This research field currently allows a stimulating interdisciplinarity, ranging from prebiotic replicators, differentiation processes, multicellularity, protocells to the design of evolved artificial objects. Key questions are how robust structures develop and in which ways these structures can incorporate and elaborate information. Therefore Marco Villani's researches span on a number of different disciplines, being he convinced that the most interesting things in present-day science are taking place at their interconnected borders. Following this line, the recent research activities of Marco Villani have mainly focused on:

1. protocell dynamics
2. gene regulatory networks
3. cell differentiation
4. search for dynamical structures in complex systems
5. others

Protocell dynamics

Protocells are cell-like structures, simpler than present-day cells, which can undergo fission and duplication for purely physico-chemical reasons, which contain some chemicals responsible for protometabolism (i.e. maintenance and growth) and a rudimentary form of genetics. My colleagues and I have theoretically investigated the synchronization between the fission of the container and the doubling of genetic material (a situation necessary to achieve sustained growth of a population of protocells), that under very general hypotheses results an emergent property of the system. We have demonstrated that even chaotic replicator dynamics, at the molecular level, can lead to a synchronized behavior at the level of populations. We are now investigating the role of collectively autocatalytic sets (ACSs) of chemicals and of the protocell membrane in supporting the protocell dynamics.

Gene regulatory networks

Regulation of gene expression in a cell is a complex process, with many feedbacks between proteins, genes, different kinds of RNA. While there are several detailed studies of such networks, we are looking at the generic properties of this kind of systems. This kind of approach, pioneered by Stuart Kauffman, has been appropriately called "Complex Systems Biology" by Kunihiro Kaneko. In this field we obtained several significant results:

- we compared a simple model of genetic regulatory networks with experimental data from c-DNA microarray and we have shown that the model is able to describe the distribution of the size of the perturbations of expression levels induced by the knock-out of a single gene. This has been one of the first cases where the model of random boolean networks was proven able to account for experimental data on gene expression levels
- by means of simulations and analytical methods we showed that these data allow one to draw inferences concerning the dynamical regime of the analyzed organism (the *Saccharomyces Cerevisiae*), that resulted very near to a critical state (sometimes referred to as "the edge of chaos")
- we developed a model where both genes and proteins are present

Cell differentiation

One of the major challenges in complex systems biology is that of providing a general theoretical framework to describe the phenomena involved in cell differentiation, i.e., the process whereby stem cells, which can develop into different types, become progressively more specialized. We developed an abstract dynamical model of cell differentiation that has proven able to reproduce the most relevant features of the process ((i) different degrees of differentiation, (ii) stochastic differentiation, (iii) deterministic differentiation, (iv) limited reversibility, (v) induced pluripotency, (vi) induced change of cell type). Remarkably, all these characteristics depend on the introduction of noise processes in an otherwise deterministic system; the notion of TES (threshold ergodic set) has been developed to formally describe the underlying mechanisms.

Search for dynamical structures in complex systems

Complex systems very often show some forms of organization that cannot be understood by referring to the emergence of simple hierarchical models. In most interesting cases one is faced with complicated situations, sometimes referred to as "tangled hierarchies", where a clear-cut hierarchy of levels, with a unique well-defined direction of information flow cannot be found. In these systems levels lose a great part of their explicative power, whereas groups of variables and recurring pattern of interactions become the main interesting objects to detect and monitor in order to understand the systems' dynamics. Very often researchers use and then analyze a network representation of the system itself, discarding in such a way the possibility of taking into account many-to-many relationships and even worse not analyzing the dynamic behavior of the system components. On the contrary (or by integrating the network based analysis) relevant information can be extracted by observing the system behavior, via information-theoretic and statistical techniques, combined with dynamical systems methods. We developed methods and tools for identifying the dynamical structures ("relevant sets") inside complex systems and their interactions, responsible for the organization and functioning of the system; this approach could also provide powerful technological tools for monitoring and controlling systems, by identifying early warning signals and possibly making sense of system changes, providing the capacity to discriminate changes that are able to influence the distribution of the relevant sets and therefore the system's dynamics, from those changes that are not able to initiate a similar effect.

Others

I just briefly mention other researches realized during my activities:

- Agent-based models of innovation processes
- Models of exaptation processes
- Evolving boolean networks to perform selected tasks
- Cellular automata models of soil bioremediation
- Cellular automata models of cell cultures growth and transformation
- Neural network applications for the prediction of secondary structure of proteins

PUBLICATIONS

Book - author

1. Serra, R., Villani, M. (2017) *Modelling Protocells - The Emergent Synchronization of Reproduction and Molecular Replication*. Springer Netherlands pp. 182 ISBN 978-94-024-1158-4
2. Serra, R., Villani, M. (2026) *Protocells and the Origin of Life*. Springer Netherlands pp. 203 ISBN 978-3-031-91763-9

Book - editor

3. Marco Villani, Roberto Serra, Stefano Cagnoni (eds.) *Artificial Life and Evolutionary Computation* Springer Berlin Heidelberg 2024, ISBN 978-3-031-57430-6, pp. 410
4. Stefano Cagnoni, Marco Mirolli, Marco Villani (eds.) *Evolution, Complexity and Artificial Life* Springer Berlin Heidelberg 2014, ISBN 978-3-642-37576-7, pp. 280
5. Roberto Serra, Marco Villani, Irene Poli (eds.): *Artificial Life and Evolutionary Computation: Proceedings of Wivace 2008* World Scientific Publishing Company 2009 (ISBN 9789814287449), pp. 350
6. Marco Villani (ed.), *Educating managers in Complexity*, Aracne Editore, Roma 2007, pp.364

Marco Villani is also the author or co-author of over 120 publications, including scientific journals, book chapters, and conference proceedings. Of his conference proceedings publications, five have received international recognition (four awards for best paper and one honorable mention for best poster). His master's thesis was also awarded by the SIF (Italian Physical Society) as the best thesis of the year for applications from Computer Science to Physics

Modena, September 1, 2026