Preface

TOWARDS A SCIENCE BASE FOR ENTERPRISE INTEROPERABILITY

In a turbulent world, where technological evolution has surpassed even the most imaginary scenarios predicted a few years ago, interoperability among organizations and their systems remains an intangible and elusive challenge. Since the 1970s when its first definition appeared in Webster’s Dictionary, interoperability has been considered a critical capability of organisations and their systems, promising a significant increase in their productivity and efficiency. As a result, interoperability in its legal, organizational, semantic, and technical context appears as a key enabler for organisations, processes, and systems in the public and private sector.

Enterprise Interoperability (EI) suggests that organisations can seamlessly interoperate with others, removing barriers to collaboration, fostering a new networked business culture, and transferring and applying the research results in industrial sectors. It is defined as the capacity of two or more organizations or enterprises, including all the systems within their boundaries and the external systems that they utilize or are affected by, to cooperate seamlessly over a sustained period of time to pursue common objectives. Whereas in the past it was considered that interoperability could not be addressed unless the technical, semantic, and organisational repercussions were resolved across all levels of an organization, today this vision has been extended, foreseeing that interoperability will be fully achieved only when the benefits brought by the new technology paradigms are also harvested, including those of the Future Internet, Internet of Things, Internet of Services, Cloud Computing, and Social Networks.

During the last decade, Enterprise Interoperability has been recognized as a well-established technology and applied research domain, studying the problems related with the lack of interoperability in organizations and proposing novel methods and frameworks for better performance in depth of time. Substantial progress has been made through European Union and nationally funded research in a number of areas, yet the lack of scientific foundations in the interoperability domain seem to hinder unlocking its real value and full potential to all its stakeholders, from researchers to industry and SMEs. Such a scientific orientation would document the existing knowledge and open the pathway for systematic and repeatable solutions to identified problems without the danger of repeating research or missing opportunities for application.

The creation of a science base for Enterprise Interoperability has been one of the targets of the ENSEMBLE project – a collaborative support action implemented between 2010 and 2012 by a consortium consisting of the National Technical University of Athens, the Italian National Research Council, Coventry University, UNINOVA, and Intrasoft International. The core handful of experts from the ENSEMBLE consortium were supported by a larger team of enterprise interoperability researchers and practitioners stemming from the Future Internet Enterprise Systems research cluster (FInES) from the European
Commission, creating a team of more than 100 contributors to the task of laying the foundations of a new scientific domain: the Enterprise Interoperability Science Base (EISB).

In order to understand the potential impact of Enterprise Interoperability Science Base on systems and services, one may consider that after many years of developing software architectures and services, there is currently little concern on native interoperability design. Despite the plethora of available interoperability solutions and best practices, the actual task of making newly designed software interoperable is solely assigned to the designers and the developers of this software, as a set of abstract specifications to abide with until the final release of the product or service, without much specific support in tools or methods. Until now, the principal tools that have emerged for addressing the interoperability challenges are the various standards that seek to govern the development of information systems and their operation. However, such standards are usually linked with specific market sectors, application areas, or technology trends, and thus have a limited time span, a static nature, and quite often different interpretations amongst technology vendors and users.

The Enterprise Interoperability Science Base aims to shed light on the underlying body of knowledge in the interoperability domain. The overall objective in establishing a corresponding Science Base is to formulate and structure the knowledge gained through pragmatic research in the domain over the last decades in order to avoid repeating research and missing opportunities for application. With such an approach, enterprises from the software industry can decouple research from technology and develop fundamental knowledge on complex environment integration. Traditional industrial domains benefit from dedicated methods for assessing the interoperability of enterprise systems and applications, positioning themselves within the interoperability problem space, and finding more fit solutions targeting the exact interoperability problem identified. Software Engineering products and results can be thus made “interoperable by design” in any ecosystem rather than being embedded at the development or configuration stages.

In this quest for scientific recognition, the key challenges that Enterprise Interoperability will have to include further substantiation of value, strong engagement and support by industry, sustainable research in the domain through appropriate curricula, as well as further coordination of the efforts undertaken by many stakeholders and neighbouring disciplines.

**OBJECTIVE OF THE BOOK**

This title aims at providing the latest research advancements and findings for the scientific systematization of the Enterprise Interoperability knowledge, such as core concepts, foundational principles, theories, methodologies, architectures, assessment frameworks, and future directions. It brings forward the ingredients of this new domain, proposing its needed formal and systematic tools, exploring its relation with neighboring scientific domains, and prescribing further steps for eventually achieving the thrilling goal of laying the foundations of a new science.

These research findings are organized along the following main areas of contribution:

- Presenting the scientific foundational principles of Enterprise Interoperability, by means of envisaged structure and current state of the art. This way a new set of concepts, theories, and principles is designed, with a view to long-term problem solving as opposed to short-term solution provisioning.
• Analysing the neighboring scientific domains. Since interoperability is a multi-disciplinary domain, new research challenges are also bound to touch Complexity Science, Software Engineering, Design Science, and Service Science approaches.
• Presentation of novel approaches for Enterprise Interoperability, by means of frameworks, models, methods, and tools to assist enterprises in achieving more interoperable processes, systems, and information resources.
• Envisioning future research to tackle interoperability problems and activities that need to be collectively undertaken by stakeholders with different backgrounds in a logical time frame in order to eventually lead to the general recognition of the scientific rigor of enterprise interoperability.

TARGET AUDIENCE

The target audience of this book includes (1) researchers and practitioners in the interoperability domain, (2) university students and professors of computer and management sciences, (3) representatives of the ICT industry engaged in interoperability solutions, software design and deployment projects, and modelling methods, as well as industry in general, applying interoperability solutions, and (4) policy makers and decision drivers at local, national, or international levels.

ORGANISATION OF THE BOOK

The book is composed of 14 chapters, structured in 3 sections. The first section is titled “Scientific Foundations of Enterprise Interoperability” and includes 4 chapters laying the foundational framework for enterprise interoperability, describing its proposed structure, giving a full-breadth view of and analyzing relations to other scientific domains. Section 2 is titled “Advanced Methods and Tools for Enterprise Interoperability,” including approaches for designing and building new enterprise interoperability tools for researchers and practitioners, thus giving some initial directions for deploying new methods and tools for tackling interoperability in a systematic way. The third section on “Perspectives and Future Research Directions for Enterprise Interoperability” includes 4 chapters presenting more holistic, groundbreaking approaches for interoperable organizations and systems, leading to further research and development of the science base.

Scientific Foundations of Enterprise Interoperability

Section 1 contains 4 chapters devoted to presenting foundational principles of enterprise interoperability and the core elements of the science base under development. Analysing its structure, the state of the art, its relation to scientific domains, and giving evidence of the overall value of interoperability for the enterprise, the authors in this section contribute to a better understanding of what is the Science Base and why it is important for industry and research.

Chapter 1, presented by Keith Popplewell representing the ENSEMBLE project team, analyses the structure of Enterprise Interoperability Science Base as defined in this project, based on analysis of its purposes, the knowledge already available from pragmatic research, and the lessons learned, both on in-
teroperability and the theoretical structure of a science base. The resulting scientific base is now evolving from the body of knowledge used for its initial population to embrace new research results and issues.

In chapter 2, Koussouris, Mouzakitis, and Lampathaki, from the National Technical University of Athens team of the ENSEMBLE project, provide the current state of the art and the Taxonomy of Scientific Areas that comprise the Enterprise Interoperability domain. Further, the chapter presents the core elements of a framework assessing an organization’s readiness to deploy interoperable solutions and services.

Chapter 3 is about presenting the relation of Enterprise Interoperability with other scientific domains. In this chapter, Agostinho, Jardim-Goncalves, and Steiger-Garcao recognize that any scientific field exists in an ecosystem of neighboring domains and present a methodology to identify EI’s relationship with its neighbors, thus supporting the foundations of EI Science Base. It can be agreed that formalisms like logic and mathematics are an integrant part of every science, but others also share relationships such as application fields’ boundaries, methodologies, techniques, or even tools.

Chapter 4 by Loukis, Charalabidis, and Diamantopoulou analyses the theoretical foundations of the multi-dimensional business value of interoperability among enterprise information systems and reviews the quite limited empirical literature on it. Next, it presents an empirical study of the business value generated by the adoption of three main types of information systems interoperability standards: industry-specific, proprietary, and horizontal-XML. The study is based on a large dataset from 14065 European firms (from 25 countries and 10 sectors) collected through the e-Business Watch Survey of the European Commission.

**Advanced Methods and Tools for Enterprise Interoperability**

Section 2 of the book attempts to present novel approached for Enterprise Interoperability by means of innovative methods and tools for diverse industrial sectors, covering several aspects of enterprise issues, as well as organizational, semantic, and technical aspects. This way, the 6 chapters of this section act complementarily to the basic foundational principles of the Science Base, extending and giving “body” to its initial directions.

In chapter 5, Robert Woitsch from BOC Asset Management, Austria, presents Meta Modeling as a proven technology to enable interoperability by introducing conceptual models enabling computer-based processing for both machine interpretation and human-oriented information value creation. This chapter introduces (a) concept models as an instrument for interoperability, (b) the meta model approach as a flexible but stable platform, and (c) hybrid modeling as an approach to flexibly compose the conceptual integration. After discussing this theoretical background, the chapter introduces meta modeling merging patterns as different realization scenarios of hybrid modeling. Each scenario is supported differently by the underlying meta modeling platform ADOxx®.

Chapter 6, by Alexakis, Bauer, Britsch, and Kölmel, shows how Anything Relationship Management (xRM) can increase interoperability in many-to-many (n:n) relationships. Building upon relationship management theory, the authors categorize different types of relationships and link them with fitting IT solutions. They then introduce the xRM concept, present the EU research project GloNet, and propose three technical xRM approaches (collaboration spaces, integration of external services, and synchronization framework) in order to improve social network interoperability, services interoperability, and data interoperability. The chapter closes with a conclusion, an example of application, and a research outlook.
Chapter 7 by Münch et al. is a collective work of fourteen authors, stemming from the ComVantage European research project, presenting an infrastructure approach for virtual enterprises and discussing its impact with respect to the mobile maintenance domain. The approach focuses on data and process interoperability – core areas of enterprise interoperability. Regarding the interorganisational access to enterprise data, they propose a semantic abstraction layer that is completely decentralised and therefore meets the key requirement of virtuality. The execution of business processes and workflows across organisational boundaries are addressed by the unique App Orchestration Concept.

In the direction of Interoperable Process Engineering Systems, Armijo and Sorli from TECNALIA R&I in Spain, present in chapter 8 an approach covering the product life cycle. The approach is rooted on the Business Process Management (BPM) discipline and leverages process optimization through the systematic modeling and reengineering of business processes accompanied by supporting interoperable and configurable eco-services, which are conceived as sustainability-aware services designed to optimize some aspects of the product life-cycle through eco-constraints management.

Moving from production management to the health sector, chapter 9 discusses new interoperability approaches in the area of medical information and relating systems and processes. In this chapter, Yuksel, Dogac, Taskin, and Yalcinkaya provide a survey and analysis of the interoperability standards and profiles that can be used to integrate Personal Health Records with a variety of healthcare applications and medical data resources, including Electronic Health Record systems to enable access of a patient to his own medical data generated by healthcare professionals, personal medical devices to obtain the patient’s instant physiological status, and clinical decision support services for patient-physician shared decision making.

Closing the section of novel methods and tools, chapter 10 by Saripalle and Demurjian discusses how to attain Semantic Enterprise Interoperability through Ontology Architectural Patterns. The authors’ intent in this chapter is to enable the definition of ontologies leveraging Software Design Pattern (SDP) concepts to more effective design ontologies that are structurally and semantically interoperable. To support this, the chapter proposes Ontology Architectural Patterns (OAPs), which are higher-level abstract reusable templates with well-defined structure and semantics to conceptualize modular ontology models at the domain model level, so that they are then able to capture semantics that are easier to reconcile across constituent systems for an enterprise application.

**Perspectives and Future Research Directions for Enterprise Interoperability**

The third section of the book is focusing at more generalized, forward looking, theoretical approaches towards extending the Enterprise Interoperability Science Base in the future. Going from advanced infrastructures, such as the Interoperability Service Utility, to new frameworks for assessing Enterprise Interoperability, to new formalisations for interoperability as a whole, the authors in this section underline the need for continued, focused work towards concrete objectives for science and practice.

Chapter 11, by Matzakou, Sarraipa, Markaki, Ergazakis, and Askounis, presents an extension to the notion of Interoperability Service Utility (ISU) – an advanced infrastructure introduced by the Future Internet Enterprise Systems community some years ago. The authors suggest an enhanced ISU that would serve as a mediator among the incompatible enterprise information systems, providing semantic harmonization of the exchanged knowledge and a fertile ground for achieving Enterprise Interoperability and collaboration. The authors’ proposition and methodology can be useful to any stakeholder in the
enterprise field, giving useful directions for any other similar implementation – thus contributing to the scientific aspects of Enterprise Interoperability.

With the goal of contributing to the establishment of the scientific foundations of interoperability, chapter 12 by José C. Delgado presents a multidimensional interoperability framework, conceived in a generic, bottom-up approach. The basic tenet is to add an interoperability dimension (based on the concepts of compliance and conformance) to an enterprise architecture framework with lifecycle and concreteness as its main dimensions, forming a universal core framework. This core is then provided with an extensibility mechanism, based on a concerns dimension, into which the specific characteristics of applications and their domains can be added to instantiate the framework, now in an application-driven fashion. The use of partial compliance and conformance reduces coupling while still allowing interoperability, which increases adaptability, changeability, and reliability, thereby contributing to a sustainable interoperability.

In chapter 13, Goranson and Cardier report on elements of a research plan developed for a US program, towards increasing the scientific elements of interoperability. A key aspect they adopt is that external operations of enterprises are integrated using lowest common denominator standards. The net result is that we are somewhat worse off now because current integration technology is a matter of conformance. So, in order to allow enterprises to be as novel, agile, and productive as they could be, a radical advance is required, one based on breakthroughs in the underlying science used by enterprise engineers.

Chapter 14 is authored by the editors of this book. In this chapter, Charalabidis, Lampathaki, and Jardim-Goncalves give the overall achievements of the ENSEMBLE project, which opened the way for the Enterprise Interoperability Science Base. Adding to the ingredients of the science base, the chapter goes beyond the interoperability structure, areas, formalisations, and neighboring sciences to discuss the overall picture and overarching enterprise interoperability laws. Furthermore, the chapter gives an outlook of the next steps needed to be taken by academia, research, industry, and policy makers to advance the state of the science base.

CONCLUSION

Enterprise Interoperability is a promising domain of research and practice, providing enterprises with methods, systems, and services to allow them to enjoy the merits of technical, semantic, and organization interoperability. Enterprise interoperability integrates several sub-domains of information and management sciences, while also interacting with several neighboring domains – such as complex systems, networks, and service sciences.

Although delivering ideas and solutions for more than a decade, enterprise interoperability is not yet considered a rigid scientific domain, able to offer deterministic diagnosis and problem solving at the enterprise domain, by following standardized practices. Mostly relying on standards that need to be adopted—often forcing enterprises to accept the minimum “common denominator”—interoperability practitioners are in need of a more systematic approach to common problems.

This book is gathering innovative approaches, mostly stemming from the Future Internet Enterprise Systems cluster and the ENSEMBLE project, in order to give out a holistic approach for developing a Science Base for Enterprise Interoperability. This way, this title presents the various elements needed for a new scientific domain: definition of the Enterprise Interoperability areas, formal problem and solution
description methods, assessment tools and metrics, systematization of empirical evidence, as well as
relations with neighboring domains.

The first steps have been made towards giving birth to a new scientific domain, able to revolutionize
the way enterprises organize themselves, develop and utilize information systems, structure informa-
tion and knowledge, and finally prosper or reorganize. It is now the research and practice communities,
from industry, academia, and policy making, that may or may not take these initial developments further
towards realization and externalization. Then, enterprise interoperability science base might be the first
attempt of conceiving this “science of collaboration” that covers data, systems, processes, organizations,
and above all, human beings.

At least, for Enterprise Interoperability, *iacta alea est* …

_Yannis Charalabidis_

*University of the Aegean, Greece*

_Fenareti Lampathaki*

*National Technical University of Athens, Greece*

_Ricardo Jardim-Goncalves*

*Centre of Technology and Systems (CTS) – UNINOV, Portugal*