31. Manufacturing and Engineering in the Information Society: Responding to Global Challenges

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This introductory paper to the DIISM'04 volume explains the DIISM problem statement and applies principles of architecture descriptions for evolutionary systems (IEEE 1471-2000) to the information infrastructure for engineering and manufacturing. In our vision, knowledge and skill chains depend on infrastructure systems fulfilling missions in three kinds of environments: the socio-industrial domain *of society and its production systems as a whole, the* knowledge domain *for a scientific discipline, and the* sectorial domain, *which includes the operational entities (companies, organizational units, engineers, workers) in engineering and manufacturing.*

The relationships between these different domains are captured in a domain paradigm. *An information infrastructure that enables responses to global challenges must draw on a wide range of both industrial and academic excellence, vision, knowledge, skill, and ability to execute. Responses have a scope, from the company, the* factory floor *and the engineering office to* external *collaboration and to* man-system *collaboration. In all scopes a system can offer services to different operational levels:* operations, *development or* engineering, *and* research. *The dimensions of scope and service level are briefly explained in relation to the architecting of an infrastructure. Papers are grouped according to their contribution to an infrastructure scenario or to an infrastructure component.*

Keywords: architecture, engineering, information infrastructure, manufacturing

1. INTRODUCTION

The context of engineering and manufacturing has witnessed a striking expansion: from the product at the workshop during the workday of the craftsman, towards the portfolio of products and services, the resource base, and the business processes of the globally operating virtual enterprise. Simultaneously, the *set of information-based tools,* supporting the knowledge and skill chain has expanded: from the paper, pen and ruler to computer-and-communications aided applications for a growing range of functions ('CCAx'), with their impacts ranging from the core manufacturing process, over intra- and inter-enterprise integration, to the supply chain and the total life time of the extended product.

Computer-and-communications applications do well support many of the engineering, manufacturing and business functions that are key to manufacturing excellence and product success. But still, the engineering and manufacturing knowledge and skill chain shows many inefficiencies and hurdles. Therefore research and technology development on information infrastructure is ongoing, addressing a.o. information architectures, methodologies, ontology, advanced scenarios, tools and services. This research is driven by the insight that throughout an integrated life cycle of products and enterprises, the manufacturing knowledge and skill chain sources information from globally distributed offices and partners, and combines it with situational awareness, local knowledge, skills and experience to initiate decisions, and to deliver solutions. Hence the top-level objective of the information infrastructure: responding to global challenges by enhanced knowledge and skill chains.

However, how to design the information infrastructure that manages knowledge, information, data, and related services and tools that are shared by the different autonomous entities collaborating and seeking solutions in the socio-economic fabric in a finite global environment? Because the collaborators are part of different enterprises and economies, the information infrastructure is not regarded as a long-term differentiator in the business strategy of any enterprise. The infrastructure rather is a common enabler for the globalizing enterprise networks and professionals. For these entities, the common services matter at different levels of aggregation: for the external collaboration, for the teams and machine devices working in the factory or office, and for each person working in one or more enterprises. Hence the scope of this volume: information infrastructure systems and services for any level of aggregation in the engineering and manufacturing knowledge and skill chain.

2. AN INFRASTRUCTURE PROBLEM?

A series of IFIP TC5 WG 5.3/5.7 working conferences has been dedicated to the design of the information infrastructure systems for manufacturing (Yoshikawa and Goossenaerts, 1993; Goossenaerts *et al.*, 1997; Mills and Kimura, 1999; Mo and Nemes, 2001, Arai *et al.*, 2005). At this 6th working conference, building on recent research results and the results reported at and discussed at the previous conferences, contributions demonstrated a combination of breadth and depth, academic focus and industrial relevance. While multiple and more capable components are being developed, global challenges are being articulated, as well as roadmaps to overcome them. The Millenium Development Goals and the Kyoto Protocol are two examples. The connectedness of the global fabric is widely recognized but is in contrast with our inability to enact concerted practices that deliver the required results. Unless a sound information infrastructure gets deployed, the chaining of the problem solving scenarios will meet problems of quality, of interoperability of data, and of the scaling and combination of knowledge. How to offer continuity of service, the ubiquitous reuse of data and knowledge, and continuous interoperability while responding to new challenges, as companies compete, stakeholders evolve and new technologies emerge?

Contributions to this volume address components and scenarios of future knowledge and skill chains, as seen from the viewpoints of expert researchers in engineering, manufacturing and information technology. Traditionally, in industry, the integration of such components and scenarios is performed at companies. Today, and for the future, the globality and connectedness of the economic fabric and its problems oblige the research community to also address these chains supportive of improving the state of 'manufacturing industries as a whole'.

3. ARCHITECTING THE INFRASTRUCTURE

Architecture is defined in IEEE 1471-2000 (IEEE, 2000) as 'the fundamental organization of a system embodied in its components, their relationships to each other, and to the environment, and the principles guiding its design and evolution'. Every system has an architecture that can be recorded by an architectural description (AD) consisting of one or more models. The viewpoints for use selected by an AD are typically based on consideration of the concerns of the stakeholders to whom the AD is addressed.

Modeling techniques support communication with the systems stakeholders, prior to system implementation and deployment. Methodologies and tools come available for the model driven building and deploying of information systems and information infrastructures.

The relevance of architecting for the infrastructure addressed in DIISM derives from its life cycle focus: architecting is concerned with developing satisfactory and feasible systems concepts, maintaining integrity of those system concepts through development, certifying built systems for use and assuring those system concepts through operational and evolutionary phases. This is important as the domain of engineering and manufacturing is immensely complex, diverse and evolving. Where infrastructure sub-systems fulfill missions in different scopes, these systems should co-evolve and their architectures be aligned. Their AD's should be based on stable viewpoints.

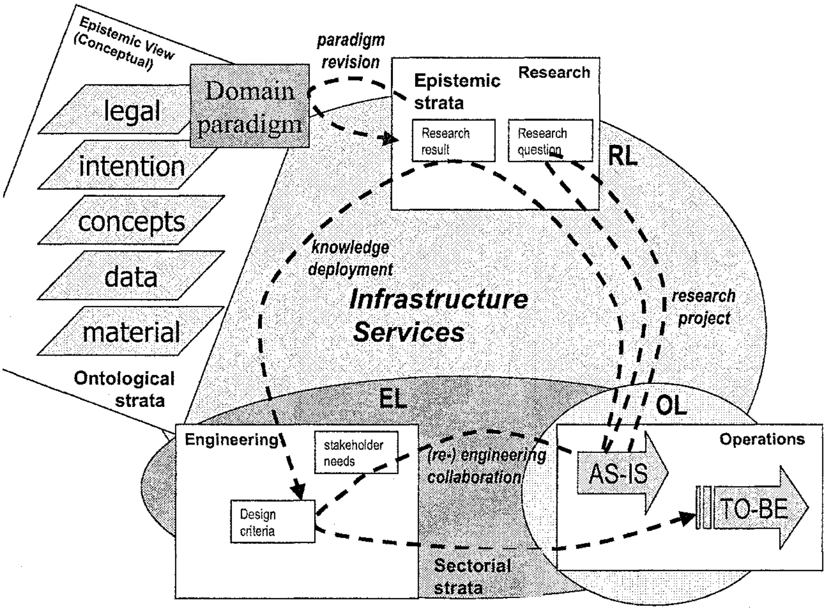

Figure 1. Three operational levels to serve

The four different scopes for which scenarios must be supported are the *natural & socio-economic domain* (DP – domain paradigm), the *external collaboration* (EC) between enterprises, the *factory floor* (FF), and the *man-system collaboration* (MS). In each scope systems evolve under a result focus: outcomes are defined, problems and stakeholder needs are observed and analyzed in the AS-IS, requirements update and design deliver an extended or new specification, development and implementation deliver the TO-BE operational system which is monitored for the occurrence of new problems. The assets involved in system evolution include natural capital, knowledge, data and models, human capital, social capital and financial capital.

Each of the four views in Figure 1 offers services to the above scenario of systems evolution. The *epistemic view* offers an *ontological stratification* that structures the design space within which intentions, models and operational systems evolve. The *research view* offers *epistemic stratification* (one strata per scientific discipline such as logistics, mechanics, chemistry, and ergonomy) that structures the discipline knowledge and derived design criteria (constraints) that must be met in modifying or creating the operational system. The *engineering view* merges constraints and contributions from ontological and epistemic strata to obtain new operational capabilities. In the *operations view* repeating tasks are performed, in accordance with the models developed. Operations must comply with the hard laws of nature (as studied in the natural sciences), and the soft laws of the socio-economic fabric (social sciences), while deploying the technology at hand. Both the engineering and operations view show *sectorial stratification* that is evident in the industrial differentiation of the modern society.

Assuming that a stable (meta-) model of the epistemic view exists, and that it rarely needs overhauls, the remaining infrastructure services are classified into three levels: *Operations Level (OL):* for the AS-IS operations (engineering or manufacturing processes); (Re-) *Engineering Level (EL):* for the (re-) engineering collaborations linking AS-IS operations and development for certain context to achieve the TO-BE operations; and *Research Level (RL):* research and the deployment of scientific knowledge pertaining to OL processes and EL collaborations.

4. INFRASTRUCTURE DESIGN AT DIISM 2004

Each infrastructure sub-system is a software intensive system that could be developed using the widely used 4+1 view model of (Kruchten, 1995). The alignment of the architecture descriptions of these infrastructure sub-systems would benefit from a maximal reuse across those views, in accordance with the subsidiarity principle.

The best opportunities for such reuse are in the epistemic view, which covers Kruchten's logical and process views for the system of systems that we can call a socio-industrial eco-system, and in the research view. The domain paradigm would consist of universally applicable models. The domain paradigm embodies the ontological stratification of the natural & socio-economic domain, the epistemic stratification of our (scientific) knowledge, and the separation of operations, engineering and research scenarios in our activities.

Two papers address this conceptual architecture and generic infrastructure components. These contributions address viewpoints or services that in principle can be shared by all scopes (society, external collaboration, factory floor and man-system collaboration).

Shu Qilin and Wang Chengen address a framework of product lifecycle model that comprises three parts: product information model, process model based on product life cycle, and extended enterprise resource model. They then describe the relationship and formation of product models at different stages and propose an integrated information architecture to support interoperability of distributed product data sources. Gonsalves and Itoh propose a technology-neutral integrated environment for system performance estimation during the requirement analysis and design phases, i.e. much before the implementation phase. The authors use a generic core life cycle of system development, consisting of three phases: system modelling, performance evaluation and performance improvement.

With the availability of reusable domain-level infrastructure components, the focus in the scopes of EC, FF and MS is on their differentiating aspects and scenarios. This volume contains contributions on External Collaborations, the Factory Floor Infrastructure and the Man-System Collaboration.

Wiesinger addresses engineering level services for external collaboration. He presents the software solution "Workbench" for the planning of large logistics networks as well as for the network structures of the facilities in an enterprise. The "Workbench" ensures a better information flow and provides a basis for Factory planning. It enables planners who lack expert planning knowledge.

Three papers address engineering and operation level services for the factory floor. Muljadi *et al.* describe an ontology for the development of a feature library. Requirements are derived by considering both the designer's intention and the extraction of manufacturing information for process plans generation.

Kato *et al.* propose a planning method for linear object manipulation, especially knotting. Topological states of a linear object are described and transitions between states are defined. Possible sequences of state transitions are generated, from which, one can choose an adequate path from the initial state to the objective state. Furthermore, a method to determine the grasping points and a planning method are proposed. A system based on the proposed methods is demonstrated.

Using the concept of Activity-Based Costing, Narita *et al.* propose an accounting method of production cost for machine tool operation. The cost factors considered in the research are the electric consumption of machine tool components, coolant quantity, lubricant oil quantity, cutting tool status and metal chip. The cost prediction system is embedded into a virtual machining simulator.

Technical architecture and the infrastructure life cycle are addressed in two papers. Takata *et al.* describe an implementation of the Integrated Process Management System, which includes manufacturing process management for building parts, and also construction process management at construction site. To observe the flow of the building parts, RFIDs are stuck to all parts to be managed, and several checkpoints are introduced within the coherent process through part-manufacturing and building construction. The requirements of the RFID directory services are also discussed.

Sugitani *et al.* propose the effective tools of operation standardization for mass production of a new product. The cycle of operation standard consists of three stages of design, improvement and evaluation. It is divided into seven steps, that is, decision, communication and understanding, observance, supervision, notice, decision again, and evaluation. The proposed seven tools of operation standardization (OS7) correspond to these steps. These tools help to realize mass production of a new product and to stabilize a product quality much earlier.

5. POST CONFERENCE GAPS

To better respond to global challenges, business, engineering and manufacturing decision making must introduce new criteria and develop new tools for operations design, improvement and evaluation. DIISM 2004 has further explored the multiple issues and approaches to address them. Over the past decade, while globalization has been studied as a driver for competitiveness, the international community has articulated desirable outcomes, including social and environmental, and it has achieved consensus about global development goals, such as the Millenium Development Goals, and environmental targets, such as the Kyoto Protocol. Suddenly the pre-competitive and post-competitive phases of the knowledge production process (Yoshikawa, 1993) can be addressed in a much more mature socio-technical global environment. A new performance paradigm is being shaped. It recognizes the broad context within which production capabilities develop, and the enabling role of "manufacturing industries as a whole" in achieving development goals. Knowledge that is produced in the pre- and post-competitive phases is best considered a global public good. The result focussed management of this knowledge (see Kimura, 2005 for critical issues) by the multiple product life cycle stakeholders, is a major challenge requiring a dedicated collaborative effort of public-private partnerships.

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