Shop floor Systems Integration Reference Frameworks & Life-cycle Support Tools

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Abstract

This paper describes the components and functionalities of a Modelling Workbench (MW) to be used within the context of the so-called Purdue Enterprise Reference Architecture (PERA) methodology. The different life-cycle phases of an enterprise integration project and the model building blocks provided are presented and described. A short description of the proposed pre-standard ENV 40 003 basic reference model, which provides the context for the so-called executable models, is first presented. This is followed by an explanation of the use of the MW within the context of the Purdue Enterprise Reference Architecture life-cycle support. While most of the issues discussed in this paper are confined to the shop floor environment and related applications, the general underlying concepts are relevant to manufacturing systems in general.

Keywords

Enterprise Reference Architectures, Executable Models, Life-cycle, Modelling, Enterprise Integration

1. INTRODUCTION

The research work presented in this paper was undertaken in parallel with and drawing from work done in the course of two ESPRIT projects (EP-5478 Shop-Control and EP-8865 Real-I-CIM), and it mainly concerns the construction of a Modeling Workbench (MW) supporting different activities within the context of enterprise integration projects. This MW provides the systems integrator with a set of "Lego" type components that can be used to model the actual manufacturing floor under different interacting perspectives of views (e.g. information systems, manufacturing equipment and company organization). Simulation runs may then

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follow this modeling activity, allowing alternative design solutions to be evaluated and compared. Further stages in the integration project life-cycle, such as component stepwise testing and integration or components replacement for system upgrade are also supported [Schulte, Ferreira, Soares].

Regardless of the need for the above described support to modelling & simulation activities which are typical of a consultancy project, a most important issue remains open, and that is the actual "usability level" of the MW for each phase of the integration project life-cycle. This usability threshold is directly related with the abstraction level required from the user while using any type of tool, and if the correct balance is not achieved it may happen that *the best* tool may remain unused.

While the research work undertaken falls within the broad scope of enterprise modelling, the MW was developed with the aim of supporting the complete shop floor applications life-cycle. The MW will be presented in the context of the Purdue Enterprise Reference Architecture (PERA) [Williams], highlighting the different life-cycle phases and the model building blocks provided. This explanation starts by introducing the concept of executable model, with a short description of the proposed pre-standard ENV 40 003 basic reference model [CEN]. This is followed by a presentation of the MW in the context of the PERA life-cycle support to enterprise integration activities. The discussion of relevant issues that arise when building a usable tool set to support the enterprise integration life-cycle closes this paper.

The issues tackled here are confined to the scope of the so-called shop floor control or manufacturing execution systems level, and to the corresponding functions / applications. The underlying concepts used in the course of the explanation can be nevertheless of general use in manufacturing.

2. FRAMEWORK FOR ENTERPRISE MODELING [CEN]

The pre-standard ENV 40 003/1990 CIM Systems Architecture - Framework for Enterprise Modeling, comprises three dimensions which cover the concepts needed for enterprise modeling: the first is concerned with the development and evolution of the model, starting from a statement of the requirements to a processable or executable model, this dimension being the Model of an enterprise; the second is concerned with the structure and behaviour of a model which considers appropriate aspects of an enterprise, this being the dimension of View; the third dimension is concerned with the degree of particularization which identifies the set of possible models, this is the dimension of Genericity. Whereas the last two dimensions are related with the actual modelling views and modelling strategy, the first one in inherently related with the actual model life cycle. This means that the Model or the Model components derived from the ENV 40 003 should ultimately be computer executable thereby enabling the daily execution of enterprise tasks.

The Enterprise Model Execution and Integration Services (EMEIS in figure 1) appear, at the most general level, as a set of services allowing the interpretation of a model or model components for the operation of Manufacturing Technology Components (entities required to carry out the manufacturing processes, i.e. physical operations). Both this model or model components were previously developed in a Model Development Environment, which makes use of the Model Development Services, (MDS).

The EMEIS include General IT Services, these being used as a platform upon which specific services are built. These services deal with the functionalities required for the use of a model or functionalities that are specific to manufacturing or enterprise systems integration. The boundary between MXS and General IT Services is not rigidly defined, the application programs are components of the EMEIS and may provide a service or just be a user of services.

It is likely that, seen from the viewpoint of a user, vendor or system integrator, a particular EMEIS will comprise both General IT services and enterprise integration-specific services, these having been derived from General IT capabilities available and from enterprise integration-specific requirements.

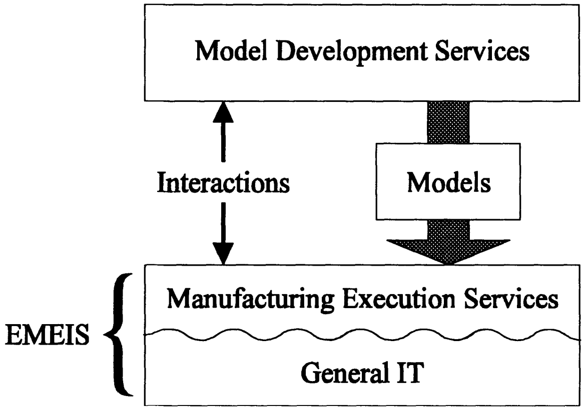


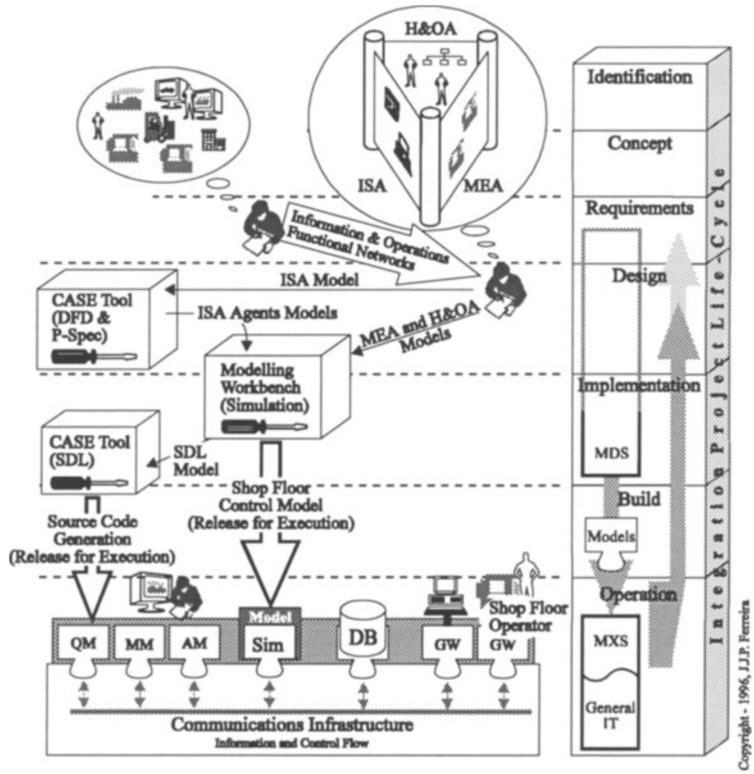
Figure 1 - ENV 40 003 basic reference model.

This very simplified representation of EMEIS and its IT support can be refined into three basic components (please refer to figures 1 and 2) which are now described. The Model Execution Services (MXS) embed services which transform a model component into an executable application entity. These services interpret (or instantiate) the model component as a "model-based executable entity", thus converting it into a "runnable" application. These services are dependent on the modeling technique used. The MXS operation services are built by all the particular IT services that an integration project would require above existing General IT services. General IT services are obviously independent from the modelling technique used. The General IT Services are also not dependent on the integration project. These services can be characterised as systems that provide: portability of applications, internetworking between heterogeneous systems, and distribution transparency where processing is distributed.

3. THE MODELING WORKBENCH, A MODELING ENVIRONMENT FOR THE LIFE-CYCLE SUPPORT

3.1 Introduction

The best use of the life-cycle concept implies that results obtained for each project phase should be adequately reused in the immediately following phase(s) [Williams]. However, this objective is not easy to accomplish as the different tools used in the various life-cycle phases, e.g. requirements analysis or performance evaluation, are very seldom able to communicate. This section will show how this problem was tackled by using an integrated modelling workbench (MW) in the context of the PERA methodology. This MW is based on a off-the-shelf object-oriented material flow simulation tool [Simple++]. This tool has been further enhanced in the course of previous work to incorporate Information Systems Architecture modelling as well as techno-organizational modelling capabilities [Ferreira, Martins, Soares]. Whereas in the former case the user is provided with the means to formally describe and simulate the actual software system and architecture, in the latter case the user is able to model the human & organizational aspects of the interaction with the shop floor information system. An integrated tool set covering these three different but complementary aspects in manufacturing, i.e. machines, computers and people, was therefore achieved.



Legend: ISA - Information Systems Architecture, MEA - Manufacturing Equipment Architecture, H&OA - Human and Organizational Architecture, SDL- Specification and Description Language, QM -Quality Management, MM - Maintenance Management, AM - Alarms Management, Sim - Simulator-based scheduling and control, DB - Database, GW- Shop Floor Gateway, MDS - Model Development Services, MXS - Model Execution Services, IT - Information Technology services

Figure 2 - The Modeling Workbench in the Context of the PERA

Figure 2 portrays the different phases and activities encompassed by the Purdue Enterprise Reference Architecture (PERA) [Williams], as well as the proposed use of the available integrated tool set for the life-cycle support to enterprise integration projects [Soares, Martins, Ferreira]. As illustrated, the work undertaken during the requirements analysis phase produces a document set containing both the (manufacturing) operations and the (management/ control) information functional networks. As proposed by PERA, this network structure information is then used in the design of the three implementation architectures, i.e. information systems architecture (ISA), human and organizational architecture (H&OA) and manufacturing equipment architecture (MEA), which are shown in figure 3.

3.2 Design Phase

At this point of the design phase, the integrated modelling environment available provides the user with the adequate means to model the Information System Architecture (ISA). The first step is to use a DFD-based CASE tool [TeamWork] to build an agent-based description [Martins]. During this phase, the designer is also provided with a set of building blocks to support the MEA [Simple++] as well as the H&OA design [Soares]. As shown in figure 2, the ISA agent-based model built using the CASE tool is then imported into the MW as an SDL (Specification and Description Language) model [Belina]. An integrated model reflecting the three implementation architectures, as well as their interfaces and interactions is therefore obtained. This model may then be tested, verified and evaluated within the modelling and simulation environment provided by the MW (figure 2 and 3).

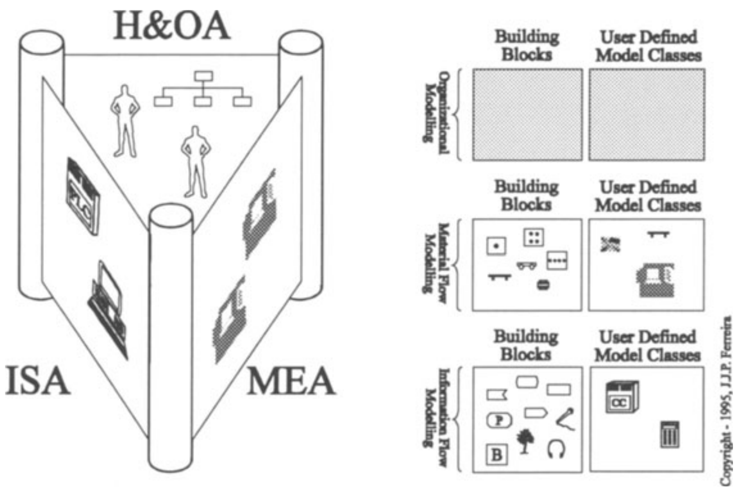


Figure 3- Modeling Building Blocks

3.3 Implementation Phase

In the context of the ENV 40 003, these models must now be converted into their executable version, so that they may be able to run on top of the Model Execution Services (MXS in figure 1). The next phase, implementation, reuses to their maximum extent the models built during the previous design phase, thereby providing three complementary results: interacting software models of information management and control system components (ISA); activities reflecting human with the information system (H&OA); shop floor resources layout and material flow control models (MEA).

During this phase, the ISA agent-based SDL specification is exported into an SDL case tool, which provides all the means for generation of executable code. On the other hand, the previously built MEA material flow simulation control model is released for execution and can be reused to control the everyday shop floor operations. Finally, the results of the techno-organizational evaluation work should provide some insight on crucial and increasingly acknowledged organizational issues, i.e. the third implementation architecture built of organizational units (e.g. cells, lines, working group, etc.) as well as on their interactions.

3.4 Build and Operation Phases

Figure 4 focus on the two last life-cycle phases. On top of a general purpose infrastructure providing distributed communication facilities, a set of Manufacturing Execution Services (MXS) is available to facilitate the model release for operation.

Whereas software application models defined for the ISA may be used to generate the actual executable C/C++ code, the MEA control model which is used in the actual control of everyday manufacturing operations runs on top of the Simple++ simulator (Sim in figures 3 and 4). The MEA model is also used for a graphical animated shop floor monitoring display.

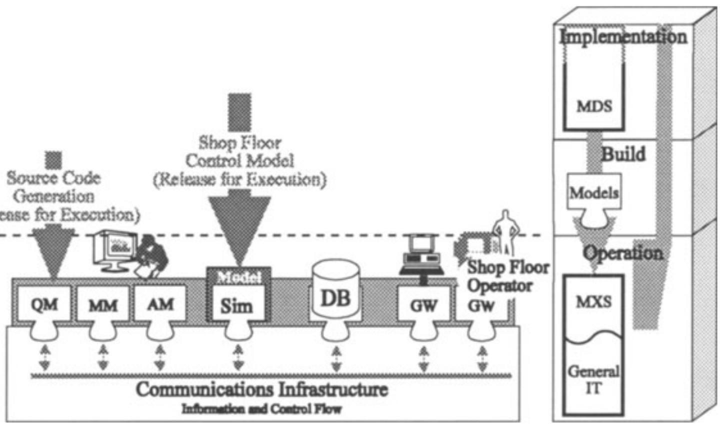


Figure 4 - Model Building and Operation

4. THE MODELLING WORKBENCH USERS

Along the PERA life-cycle the end-user has a most special role. However, when referring to enterprise model users, four types of people are involved: the modellers, the analysts/ consultants, the managers (or decision makers) and the operators, while keeping in mind that an individual user may belong to more than one of these types [Fraser]:

- modellers are usually skilled in methods that originate in science, engineering or information technology;
- managers make business decisions on the basis of (implicit or explicit) models and their analysis, based on their analysis expertise;
- finally, the operators carry out activities which are the results of business decisions, and they might require to visualize parts of the model to generate a set of activities needed for themselves or to execute their work.

The end-user relevance in the modelling life-cycle is usually disregarded, a possible reason for this fact being his lack of ability in the use of modelling languages. This problem should consequently be addressed, since the use of an adequate modelling language will grant both the analyst and the modeller the possibility of making the best use of the end-user expertise in its often very specialised domain.

In this context, one of the current concerns is to encourage the end-user involvement in the early stages of the modelling process by providing adequate modelling languages. The use of these languages combined with industry specific reference models should both foster the user involvement in the modelling process and significantly reduce the time needed for the model construction.

5. CONCLUSIONS

This paper has presented a contribution to solving technological problems raised by enterprise integration projects. The integration of different off-the-shelf tools supports projects right from the analysis and design stage. A very important problem is yet to be solved, this being the interaction with the end-user. In the design and in the subsequent phases, the end-user interaction with the involved concepts may be achieved through demonstrations within the MW simulation environment. In the requirements analysis phase this interaction is however not yet covered, and becomes more critical since problem understanding needs to be achieved and documented through the use of a common modelling language.

6. REFERENCES

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7. BIOGRAPHY

João José Pinto Ferreira was born in 1964. He holds a degree in Electric Engineering by the University of Porto (1987) as well as MSc degree by the University of Porto (1991) and a PhD degree by University of Porto (1995).

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José Manuel Mendonça holds a degree in Electric Engineering by the University of Porto (1977) and received his PhD degree by Imperial College, London (1986).

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