MMS Virtual Manufacturing Devices generation : The Paris subway example

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Abstract

European research projects about CIM like CIM-OSA advise for the information system analysis the use of the entity-relationship formalism, and for the communication implementation, the MMS standard. At the logical level of this analysis which describes the data organisation we take into account both database and communication aspects. The logical analysis must generate the database structures and the MMS configuration of all devices, which corresponds to physical step. According to the CIM-OSA concept, we developed a process which allows to generate the VMD of each equipment by the information system study. We finally present its application for the communication system design of an underground station.

Keywords

MMS, CIM-OSA, Information System

1 INTRODUCTION

The CIM (Computerised Integrated Manufacturing) concept implies to reduce the functional independence of the different devices which compose a manufacturing system. So each entity has to take into account the global environment in which it is working for its own processing. This integration leads to many information exchanges between machines and their control systems. Industrial communications specificity and equipment heterogeneousness have

required the definition of a standard at the application layer of OSI model (Open System Interconnection). Called MMS (Manufacturing Message Specification), it specifies the format of data supported by equipment and the services which allow their exchanges as well.

The aim of our work is to generate the communication system implementation in manufacturing environments without creating new modelling tools. Thus we follow the recommendations of CIM-OSA project (Open System Architecture) to configure each device modelled by MMS from the information system study.

We first describe MMS principles. Then, we remember the CIM-OSA concept bases, especially its information view and its integrating infrastructure. We then present how to translate an entity-relationship model into MMS syntax and the dedicated tool we developed. In the framework of an important contract between the CRAN and the Paris underground company (RATP : Régie Autonome des Transports Parisiens), we used this approach to define and integrate experimentally virtual devices in an MMS context.

2 THE MMS STANDARD (ISO 9506/1)

2.1 Introduction

ISO (International Standard Organization) has defined the OSI model which allows the heterogeneous equipments interconnection. In this model, the user interacts with the communication system through the application layer where he can find a set of specialized service groups. One of them, MMS, has been defined in order to meet the communication requirements in the manufacturing industry (Brill, 1991). MMS offers services for data communication between manufacturing devices and provides a common set of commands. This guarantees the communication of individual components in open systems.

This standard uses an abstract object modelling technique in order to fully describe the MMS device model and the MMS service procedures. The objects and their attributes as well as their respective operations are described.

This object modelling technique is a formal tool which helps understand the intent and effects of MMS services better than any kind of verbal description. The relationship between services and objects, and vice versa, is formally described in the standard. By implementing MMS, a real system maps the concepts described in the model to the real device.

An object is then represented by a data structure. MMS defines a number of object classes. Each object is a class instance and constitutes an abstract entity which exhibits some specific features and may be affected by some MMS services and operations. For each class a name is given by which it may be referenced.

2.2 The Virtual Manufacturing Device

The Virtual Manufacturing Device (VMD) serves as a model to represent the behavior of a real device. A VMD is an abstract representation of the common characteristics of all real manufacturing devices and represents the externally (from the network) visible behavior relevant to MMS. All standardized services refer to this virtual device which has to be mapped to real functions. MMS only describes the effects of the services on the VMD and does not prescribe a specific implementation or transformation to real functions.

2.3 The ten MMS service groups

A service group comprises those services described in the standard which all refer to the same object or object group. The name of each service is fixed by the standard. A reference to a service therefore consists of the name and the corresponding parameters. A reference to a service makes up the functionality of MMS. For example, variable management services allow to read, write, and send alarms (*InformationReport*); program management services allow the remote control of applications (*start, stop, kill, reset, ...*).

2.4 MMS companion standards

The specificity of industrial communications has led to define a general model allowing devices to dialogue : it is the MMS standard. The continuous evolution of the standardisation has enabled a definition of MMS model subclasses according to the needs of each machine communications : these subclasses are called companion standards. So the behavior of robots (ISO 9506/3), CNC (ISO 9506/4), programmable controllers (ISO 9506/5), ..., is defined. Thus, constructors can unambiguously propose standardized models of their products. Note that companion standards are also defined to describe functionalities such as production management, supervising, ...

2.5 Main interests

MMS is very interesting for RATP. For such a large company, the important number of devices of the same type leads it to be, either dependent on one vendor in order to improve applications homogeneousness, or confronted with interworking problems between several constructor solutions. Then it is difficult to evolve in the first case because one completely depends on the constructor improvements, and in the second case because any modification throws the whole architecture back into question. MMS solves these problems, irrespective of constructor specificities, improving this way applications portability, modularity and re-usability. Development costs are minimized by using the VMDs which are specific to the company, which really become reference models allowing the application multiplication. For example, all programmable controllers, whichever their trademark, will present the same user interface for communication.

3 CIM-OSA METHODOLOGICAL INTEGRATION CONCEPT

3.1 Introduction (Kosanke, 1990) (Vernadat, 1990)

The AMICE consortium (European Computer Integrated Manufacturing Architecture) proposes an open architecture called CIM-OSA and the associated methodology. It is based on a modelling framework which specifies three principles :

- the instantiation which proposes to build a particular model of the firm from partial models, the latter expressed in terms of basic generic constructions.

- the derivation which induces first to model the firm needs, then the design specifications, and finally the implementation description.
- the generation which suggests to model according to four views : functional (Jorysz, 1990a) (Kosanke, 1992), informational (Jorysz, 1990b), resources (Vliestra, 1991) and organisation (Jorysk, 1991) (Russel, 1991).

An Integrating Infra-Structure (IIS) (Klittich, 1990) (Querenet, 1991) allows, according to the instantiation principle, the execution of the particular implementation models, using a set of services (information, business, front-end and common) generally used in manufacturing systems. Specific Functional Entities (SFE) represent all the functions dedicated to one application (database access, application programs management, human interactive dialogue, machine control). Figure 1 shows how a SFE group is connected to an IIS, through front-end services.

Figure 1 CIM-OSA models execution by the Integrating Infrastructure (Hou, 1993)

3.2 Study location in the CIM-OSA context

Our goal is to define, from the production system informational analysis, the configuration of devices towards the communication system. Coherence between both systems must be

guaranteed. So, we focus on implementation description modelling level (grey shading, figure 2).

At this level, the information view specifies the database structure, and the resources view the manufacturing equipment configuration (data addresses, ...). But we can note the lack of relationships between these two views, yet logically linked.

CIM-OSA recommends to describe the information view the use of entity-relationship formalism, especially the M* methodology (Vernadat, 1989). At the level of implementation description, the conceptual model and its external schemes are only expressed with a kind of SQL (Standard Query Language) in order to establish the internal information system scheme. Concerning the resource view, MMS has been selected to represent and access to the communicating production devices. So we propose to establish links allowing to obtain MMS objects from the data logic model (figure 2).

Figure 2 Relationships between information and resource views

A piece of information can also be located on both physical supports, because the database is able to refresh directly its table questioning the VMD and *vice versa*. But how can we interface the MMS and SQL services which respectively access either to a VMD or to a

database ? Figure 3 shows how to design an information system which uses both SQL and MMS. It also shows the different accesses. For instance :

- Applications such as statistics or expert systems for diagnosis, only ask the database,
- Industrial devices refresh their VMD in real-time through a simple mapping operation,
- Production system control management uses information located in database and or in VMD.

Figure 3 SQL and MMS derivation of the logical data models

4 HARMONIZATION BETWEEN THE COMMUNICATION AND THE INFORMATION SYSTEM

4.1 Introduction

According to CIM-OSA, the information system study is modelled by using the entity-relationship formalism while MMS uses an object modelling. Hence, the survey consists of the interface description between these two kinds of models. A set of translation rules has been proposed to obtain MMS objects through data models and reciprocally : regarding the Reverse Engineering concept, this reverse translation corresponds to the restructuring study which is defined as the transformation of a representation kind into another, at the same abstraction level (Rekoff, 1985). MMS objects transformed into entities can be directly integrated in the information system study at the logical level.

Obtaining MMS objects through entity-relationship models must be achieved without knowing the MMS standard because the information system designer is not advised *a priori* on the MMS standard. So we have developed a software which allows this translation. The MERISE (Tabourier, 1983) (Tardieu, 1983) method has been chosen because it uses the

extended entity-relationship formalism and provides communications and data processing models.

4.2 The translator (Rondeau, 1993)

The translator software is integrated in the MEGA tool which respects the MERISE specifications. Two applications are added in the MEGA environment : ERtoMMS and ERtoMMS* :

- ERtoMMS translates the entity-relationship model created with the MEGA tool, in the MMS syntax. This software has allowed to valid the set of the rules of translation .
- ERtoMMS* achieves the same function as ERtoMMS but includes the organization of communications since it is able to analyze MERISE communication models. This software provides the application topology, the configuration needed to MMS equipment and the information flows.

The configuration of each equipment towards the communication is taken dynamically on another software called ConfMMS. ERtoMMS* issues files which contain all information for setting each MMS equipment. These files are downloaded on each equipment. ConfMMS, implemented on each equipment installs VMD, opens channels, configures channels, initiates the communications and sends different messages periodically (as *InformationReport* service) according to the information contained in each file. Figure 4 gives a summary of the global study which allows to build the communication system through the logical study. It illustrates the process between the conception level and the implementation level and its interaction since an evolution of the conception level affects the implementation level directly.

Figure 4 Interface between information and communication systems

5 APPLICATION TO THE PARIS UNDERGROUND

5.1 Introduction

RATP (Régie Autonome des Transports Parisiens) daily accomodates over five million people using several hundred railway kilometres to serve Paris an its immediate suburbs. So, the efficiency of this company greatly conditions social and economic aspects of the French capital. It implies a continuous pursuit of structural, organizational, and technological improvements. Two sets separated by the boarding quay can be briefly identified : the "rail" part which manages the flow of subway trains, and the "station" part which manages the travellers flow. That is our application topic.

The main constituent elements of a subway station are escalators, automatic gates, video security systems, telephonic terminals, travellers information systems, ventilation devices, automatic toll systems, ... Today, RATP has to renew an important part of its station control devices. In fact, they are old design equipments : relay boards, ... dating back to the seventies. The continuous evolution of the stations led to selective and/or unduplicatable upgradings which have induced a huge heterogeneity of these devices, which puts a considerable brake on new developments and especially the maintenance of these devices.

At such an enterprise scale, redesigning station control must be achieved in a particular context. The Paris underground has over two hundred stations which are managed by several thousand control devices. The solutions which will be selected will have to take into account the past experience, have a sufficient life duration and consider the RATP gigantism. A first study made by the company presents the list of requirements which will allow the development of a new network architecture offering New Station Services (N2S project).

In this framework, the CRAN (Research Center for Automatic control of Nancy) and RATP have concluded a contract in order to make optimal choices regarding previous criteria. Main objectives consist in designing a modular, portable and re-usable control, as independent of materials as possible. Whatever and wherever they are, accepted equipments have of course to communicate in a standardized way. So that their possible heterogeneusness do not constraint this communication. Such massive changes naturally require to have a good functional and informational knowledge of the system. Then the first solutions, after a prototyping phase, have to be technologically validated and possibly adjusted in a retro-engineering context.

5.2 The N2S architecture

Remember that we are focused on the "station" part, setting the "rail" part aside. Stations are gathered in autonomous sectors which are integrated in the underground line. One sector is managed from an operational center, called "Link Center". The latter generally integrates one station of its sector. The N2S architecture presents three levels :

- Level 1 : Station. Station controllers oversee equipments from a supervisor, using video screens, telephones, etc, ... They can momentarily delegate their functions to the upper level;
- Level 2 : Link Center. The controller has the same function as the station, but also remote security and control functions at the sector level;
- Level 3 : Operational headquarters. The functions of the control are centralized here : supervision, maintenance and security centers which assume a global management.

5.3 Objectives

This brief presentation shows how large this hierarchical system is, and it also presents the multiplication of identical functionalities. So it is natural to think that control cannot be designed for each station for example, but have to be considered in a global way for them all. It is also this large scale which explains that equipments choices lead to heterogeneous solutions. They guarantee the evolution of the system and the independence of enterprise towards its suppliers.

Therefore, a sufficient abstraction level is necessary for the control to be generic, hence reusable. Taking into account material considerations must be put off as late as possible. So, equipments have to be virtualized, and working on standardized images is required. Thus, control genericity can be guaranteed, harmonizing the information presentation and access. This virtualization has also to allow to work in an homogeneous communication environment, using a standardized common language.

Then, in this context, the system analysis can be started, in order to understand the existing system and to consider its evolution. Firstly, the functions to be implemented must be identified, before bringing up the informations they need. This analysis, weighty regarding the size of the system, have to follow a rigorous methodology which we present now.

5.4 Informational study (Rondeau, 1993)

A Link Center controls several underground stations. On the other hand, a station works with a single Link Center. Station and Link Center can control several programmable controllers. Each of the latter supports functionalities such as escalators, video, ... management. Figure 5 shows a macroscopic view of the station informational model, but details the escalator object. For the escalator function, the conceptual data model brings up the following information :

Escalator_Name : Exclusively identifies the escalator.

Escalator_Control : Contains a number which identifies the escalator supervisor. This number also allows to know where the programmable controller has to send the escalator image when an alarm is triggered off.

Escalator_Order : Contains the supervisor order to carry out on the escalator (Up order, down order, stop order).

Escalator_Status : Contains the escalator physical state : Stop, Up, Down, and its logical state : available (to receive an order).

Escalator_Failure : Mentions escalator defects (Emergency stop, fire state, fire detection, breakdown, 48V lack, local control).

Escalator_Camera : Number of the camera which affords to visualize the escalator.

5.5 Organisational communications modelling

Arrows which join up boxes, materialize communications between physical entities, and thus the ones which exchange messages two by two can be identified (figure 6). Then informational study exploitation make it possible to specify the real data supported by these messages and the induced constraints (figure 7).

Figure 5 Station informational model

Figure 6 Station organisational communication model

Figure 7 Escalator supervising organisational model

5.6 Conclusion

According to the term of these analyses, the system is now functionally and informationally well controlled. Their exploitation has yet to be carried out, with regards to expected objectives : modularity, genericity and control re-usability on different heterogeneous devices. Their virtualization allows to guarantee these objectives and to define standardized communications by the use of MMS.

6 THE MMS SITES CONFIGURATION

6.1 The VMD construction

The VMD definition, for each RATP device, is an important step of the study because it allows to standardise their access, and hence to establish a uniform profile of control applications. Thus, the VMD must not be modified because a complete revision of control programs should be required. From organisational communication models, which describe the relationships between functional and physical entities, five VMD families can be listed : maintenance, security, Link Center, station and programmable controller. In this paragraph, we will only present a partial view of the programmable controller VMD according to the informational model described on figure 5. Process control functions such as escalator management, video, etc... correspond to MMS domains. This allows to gather information which are characteristic of a specific activity, increasing in this way applications modularity and evolutivity. For example, adding an escalator only induces to specify a new escalator domain instance on the programmable controller VMD which controls it. This domain is defined as following :

Object : Domain

Key Attribute : Domain name (=Name)

Attribute : Control

Attribute : Order

Attribute : Status

Attribute : Failure

Attribute : Camera

All objects are defined as named variable class MMS objects whose types are simple or complex. For example, Escalator_Failure attribute is composed of six boolean fields as described in paragraph 5.4. So, a VMD elaboration consists in defining its attributes, possibly gathering them into a domain, then typing them. Thus the key attribute of an escalator domain always respects the EM_stationname_index syntax, where *EM* represents the escalator initials, *stationname* mentions the station where it is standing, and *index* is a number which differentiates several escalators located in a same station.

This job finished, VMD modelling could still be improved, using other MMS objects as semaphores. They could be applied in order to manage escalator read-write access which can be controlled either by a station or a Link Center. But taking these objects into account is at present impossible, because they are not implemented by all constructors.

6.2 MMS service identification

Apart from context management services (*Initiate*, *Conclude*, ...) which are essential to communicate in an MMS environment, required MMS services identification is specified from the organisational communication model shown on figure 6. Each message defined in this model induces the use of one or several MMS services we list in following chart.

Messages	Actions	MMS Services	Clients	Servers
Process Control	To refresh state graphs receptivities	Write	Station, LC ¹ , Security, PC ²	PC ²
Process Supervision	To read input/output of state graphs	Read	Station, LC ¹ , Security, PC ² , Maintenance	PC ²
Alarm	To diffuse failures	Information Report	Station, LC ¹ , Security, PC ² , Maintenance	PC ²
Device Supervision	To identify manufacturing equipment	Identify	Maintenance	PC ²
	To observe manufacturing equipment status	Status	Maintenance	PC ²
Remote maintenance	To clear manufacturing equipment	Start, Stop, Reset	Maintenance	PC ²

1 : Link Center, 2 : Programmable Controller

6.3 Experimental Validation

The second step of the CRAN/RATP contract consists in testing all the devices in an real context (figure 8). So, an experimental platform has been developed and implemented in underground stations. This platform gathers :

- a PC microcomputer (located in the "Goncourt" station) which monitors with an Intouch Supervisor a Siemens programmable controller whose main function is to control an escalator of the same station;

- a second PC microcomputer (in the "République" station) which corresponds to a link center of the line 11. It means that the link center can control both "Goncourt" and "République" station escalators. (Those which belong "République" are managed by a Télémécanique programmable controller);
- then, a third PC microcomputer located in Noisy-le-Grand (Operational headquarters) supervises all escalators and calculates statistics about breakdowns which may occur, using Excel histograms.

A part from environmental problems, we have also validated inter-station communications which are supported by optic fibbers, and the RAMEAU (FDDI RATP network) routability in order to be able to have stations information available at headquarter level.

Figure 8 RATP platform

7 CONCLUSION

We have modelled for the RATP company the station functioning and the information which have to be exchanged. According to the CIM-OSA concept, and without choosing any software or hardware, MMS has been presented and proposed in order to harmonise the communications between a link center, a maintenance center, a station and its components. An experimental platform has been physically integrated. The objectives are reached, the control genericity is clearly demonstrated. This application was constrained by technological limitations which are inherent to the newness of the MMS implementations. That will be quickly resolved by the manufacturing device constructors. Today, when RATP invites tenders, they take into account this approach and all station equipment models that we have defined. Our collaboration goes on about both fieldbuses implementation and network management.

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