MANUFACTURING APPLICATION INTEGRATION SCHEME USING ISO 15745 AND IEC 62264

Emmanuel delaHostria

Rockwell Automation
Mayfield Heights, Ohio, U.S.A.

Abstract: A common challenge in the integration of processes, resources, and information exchanges across manufacturing operations within an enterprise involves selecting resource interfaces to support interoperability of the operations. By combining the integration approaches of ISO 15745 (application integration framework) and of IEC 62264 (enterprise-control system integration), a scheme to delineate these interoperability interfaces is proposed. The scheme extends the IEC 62264 generic activity model beyond the manufacturing operations management domain and the ISO 15745 integration model beyond the operations automation domain.

Keywords: interfaces, standards, ISO, systems integration, object modeling techniques.

1. INTRODUCTION

Within a manufacturing application, the integration of the key aspects - processes, resources and information, continues to present a challenge as industries try to achieve their goals of cost-effective operations and profitability. One approach to integrating these various aspects is to construct an integration model that enables the application developer to distinguish the required interfaces and to state concisely the configuration of the interfaces to support interoperability.

In chapter 2, a manufacturing application hierarchy, based on IEC 62264, is used to illustrate both the functional and resource hierarchies, along with the activity domains and the information structures exchanged among the resources. In chapter 3, an application integration scheme, based on ISO 15745, is described. In Chapter 4, an application's requirements are mapped to a set of required interoperability interfaces. References to the interfaces and their required settings are organized in profiles. Chapter 5 outlines how a set of application interoperability profiles are used to describe the integration of multiple applications at different levels of a hierarchy. Conclusions and some future work are noted in Chapter 6.

2. APPLICATION HIERARCHY WITHIN A MANUFACTURING ENTERPRISE

In this paper, an application hierarchy is considered as a combination of functional and resource hierarchies within an enterprise. The scheme uses the functional hierarchy model defined in IEC 62264-1. The resource hierarchy model used is an extension of the IEC 62264-1 equipment hierarchy model, where the materials, the personnel, and other items used in the manufacturing activities are included.

2.1 IEC 62264 – Enterprise-control system integration standard

A joint working group of IEC SC65A and ISO TC184/SC5 recently developed a multi-part standard, based on the S95 specifications (ANSI/ISA S95.00.01, 2000 and ANSI/ISA S95.00.02, 2001), that defines an information exchange framework to facilitate the integration of business applications and manufacturing control applications, within an enterprise.

In the IEC 62264 framework (IEC 62264-1, 2003), the applications within a manufacturing enterprise are structured as a hierarchy of activity domains, where each level in the hierarchy denotes a group of functions that are performed to support a specific operational level of an enterprise. In addition, the IEC 62264 standard also defines an equipment hierarchy that distinguishes in which physical grouping and at which organizational level a piece of equipment is being used.

2.2 Functional hierarchy

In Figure 1, the business planning and logistics activities occupy the top level of the functional hierarchy, Level F4. The next level, Level F3, is comprised of the manufacturing operations management activities.

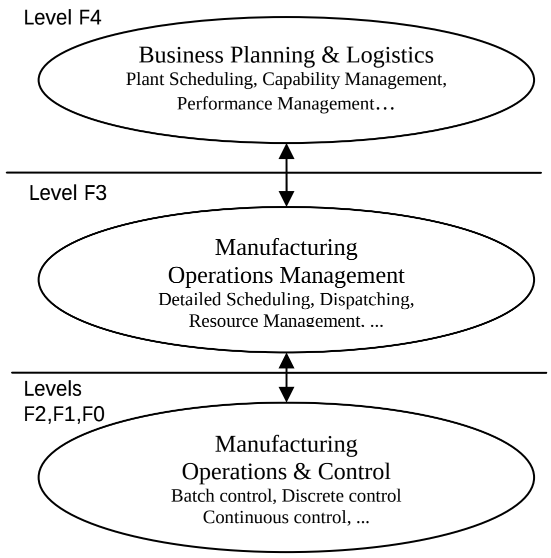

Fig. 1. Functional hierarchy per IEC 62264, Enterprise-control system integration

The lower Levels F2, F1 and F0 comprise all the activities of manufacturing operations, automation, control, and physical transformations. In IEC 62264, the business applications at Level F4 and the manufacturing operations and control applications at

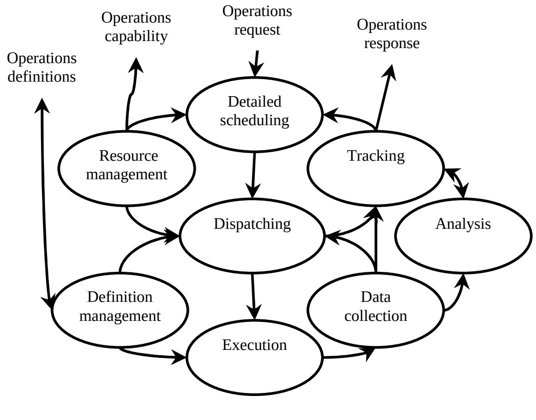

Fig. 2. Level F3 Generic activity model per ANSI/ISA S95.00.03, Enterprise-control system integration.

Level F2 (and below) are integrated using the information structures and exchanges managed by Level F3 activities, applications, processes, resources, and functions. These information structures are also specified in the IEC 62264 standard (IEC 62264-2, 2004).

Examples of Level F3 manufacturing operations management activities include production, maintenance, product quality testing, and material handling. In the S95 standard (ANSI/ISA S95.00.03, 2005) that has been submitted to become Part 3 of IEC 62264, a generic activity model is specified for these Level F3 activities (see Figure 2).

2.3 Resource hierarchy

The IEC 62264 standard also defines an equipment hierarchy (see Figure 3), where each level in the hierarchy denotes a group of equipment that are allocated to perform functions associated with a set of activity domains within the functional hierarchy. The equipment groupings are also organized by the physical extent of the associated set of activities.

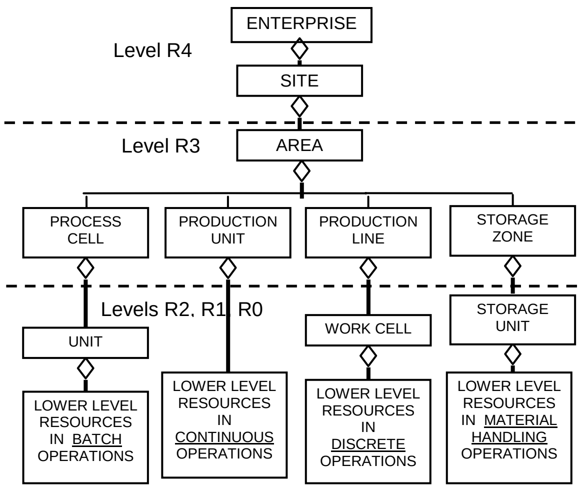

Fig. 3. Equipment hierarchy within an enterprise per IEC 62264, Enterprise-control system integration.

For example, the class representing the *Enterprise* at Level R4 may consist of one or more *Sites*, where each *Site* is distinguished by geographical location and may consist of one or more *Areas*. A class *Area* at Level R3 may consist of one or more work centers whose operational nature differs by industry.

In the pharmaceutical, food processing and beverage industries, the work center is called a *process cell* while in the oil and chemical processing industries, a work center is called a *production unit*. For the automotive and machining industries, a *production line* is the work center. In the material handling industries, an example of a work center is a *storage zone*.

In many enterprises and industries, the functional and resource hierarchies tend to align closely with each other and the references to the various levels of both hierarchies become equivalent. In this proposed integration scheme, each level within an application hierarchy of an enterprise is denoted either by a resource or a functional level.

3. INTEGRATION SCHEME FOR A MANUFACTURING APPLICATION

Within each level of an application hierarchy, a set of applications are deployed to provide the functions required at that level. For each application, a set of resources are used to conduct the related processes and to perform the information exchanges. In the proposed scheme given in this paper, the ISO 15745 integration framework intended for Level F2 is extended to cover the other levels in an application hierarchy.

3.1 ISO 15745 – Application integration framework standard

In ISO TC184/SC5, Working Group 5 developed a standard method (ISO 15745-1, 2003) to describe the interfaces required to integrate the resources in an application. In this standard framework, a set of integration models are constructed using UML (UML V2.0, 2004) and these models are used to identify the interfaces required to support interoperability. The selected settings of the interfaces that match the application requirements are expressed in terms of interoperability profiles, where the templates for the profiles are XML schemas (Rec-XML-20001006, 2000).

An integration model of a manufacturing application consists of several aspects - a set of processes with associated sets of resources that perform a set of information exchanges to support the execution of the processes. A UML class diagram illustrating this composition is shown in Figure 4.

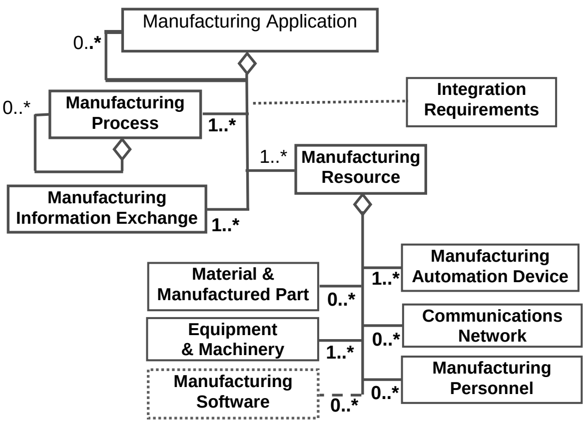

Fig. 4. Class diagram of an integration model based on ISO 15745, Application integration framework

3.2 Interfaces denoted by integration models

For each main class (manufacturing process, manufacturing resource, and manufacturing information exchange) within a complete integration model of a manufacturing application, a corresponding type of component integration model is defined in ISO 15745.

Further, each type of component integration model consists of a set of UML diagrams to represent both the static and dynamic relationships among the various resources, processes, and information exchanges.

For example, a UML sequence diagram is used to represent the transfers of material and information among the devices, equipment, and personnel involved in the process under control. At the transfer points, the types and number of required interfaces are identified.

4. INTEROPERABILITY REQUIREMENTS OF A MANUFACTURING APPLICATION

4.1 Interoperability of resources

In Figure 4, a set of manufacturing resources are considered to be integrated within a process when the required flows of material, information and energy are realized.

The integration requirements posed by the manufacturing process include many aspects, such as, the quantities, qualities, sources, destinations, and transfer rates of the items in the flows. Other aspects, such as, the cost, safety, security, and environmental compatibility to realize the flows are also essential in forming the integration requirements.

The qualifier[1] class *Integration Requirements* in Figure 4 lists the constraints on the interfaces of each manufacturing resource needed to support the processes of a manufacturing application. These constraints also relate to the sequence and timing of the information exchanges among the resources.

Each flow can be modeled as a detailed UML sequence diagram (one of many in the set of

[1]A *Qualifier* class in UML represents a relationship modifier. In Figure 4, the *Aggregation* relationship is further constrained by the *Integration Requirements* class.

diagrams in a resource integration model) showing the resources (or UML actors) involved, the items exchanged among these resources, and the time-related properties (e.g. initiation, ordering, synchronization, completion) of the transfers.

Each transfer between resources can be associated with a type of interface that is configured and deployed in each resource participating in the transfer.

Examples of these interface types are software interfaces for application programs, mechanical interfaces for material transfers, human-machine interfaces for operator commands and displays, electrical interfaces for power supplies, network interfaces for devices, etc.

The configuration for each interface is expressed in terms of a set of required services, each offered with a certain grade of service and a specific quality of service, as defined in the interface's specification.

To support the required flows of material, energy, or information, each resource shall have a set of interfaces where each required interface is a particular type and configured to handle the associated flow. The collection of the configuration settings for all the required interfaces of a particular resource is captured in an interoperability profile corresponding to the type of resource. The profile is constructed using a template defined, as an XML schema, in ISO 15745 (see Figure 5).

For each set of manufacturing resources associated with a particular process, a corresponding set of resource interoperability profiles delineates the full set of interfaces and associated settings to support a particular process.

The coordination of the resources to enable the manufacturing process execution is captured in terms of the information structures exchanged and the sequence and timing of these information exchanges among the resources. References to specifications or standards that describe the types of resource interfaces used in performing the exchanges, the information structures, and the sequences of exchanges required for process coordination are captured in an information exchange interoperability profile. In ISO 15745, a template for an information exchange interoperability profile, similar to Figure 5, is also defined.

The combination of the set of interoperability profiles for all the resources and the set of interoperability profiles for all the information exchanges needed to support the required flows of a particular manufacturing process is defined in ISO 15745 as a process interoperability profile.

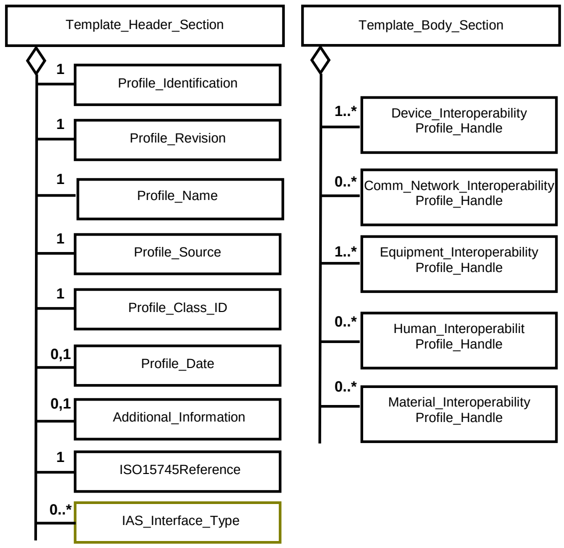

Fig. 5. Resource interoperability profile template per ISO 15745, Application integration framework

4.2 Templates for interoperability profiles

ISO 15745 defines the standard templates for constructing different types of interoperability profiles. All templates have a common structure, i.e., a sub-template for a profile header and a sub-template for a profile body (see Figure 5). The contents of a profile header includes a profile's name, a list of interface types described in the profile body, a template's revision date, a profile's revision date, and other information needed for distinguishing and handling profiles. The contents of a profile body differ by type of interoperability profile, but normally includes for each listed interface, either a set of parameter values chosen for the selected parameters defined in the interface's specifications or a set of reference URLs pointing to a set of interoperability profiles. A template has an optional integrity signature element to verify the header and body elements in a profile.

In ISO 15745, the standard templates are defined in terms of XML schemas and the interoperability profiles can be expressed in the form of XML files.

4.3 Interoperability of processes

The required flows of material, information and energy between any two processes are enabled when their respective sets of manufacturing resources that are involved in the cross-process flows, can support a collection of interfaces which are configured to support the cross-process flows. The interoperability of the two processes is determined by the interoperability of their respective resources and the associated information exchanges used to perform inter-process coordination.

The resource interfaces and their configurations, required to support the cross-process flows and the associated information exchanges for inter-process coordination, are included as additional resource and information exchange interoperability profiles in the respective process interoperability profile of each process. The additional profiles for each process may include either additional interface types or configuration settings needed to support the complete set of cross-process flows. These resource and information exchange profiles can be distinguished by the role of the enumerated interfaces, i.e., either (a) as used within a process (intra-process) or (b) as used between two processes (inter-process).

4.4 Integration within an application

At some level within an application hierarchy, each manufacturing application has an integration model described as a set of manufacturing processes that cooperate to accomplish the objectives of the application, see Figure 4. The interoperability of all the processes within an application, determines the degree of integration within such application.

The combined set of process interoperability profiles for both intra-process and inter-process flows includes all the interfaces needed to meet an application's integration requirements. This set of process interoperability profiles is an extended form of an ISO 15745 application interoperability profile.

In the steps leading to the construction of an application interoperability profile, several component integration models are generated, including those that show the roles of the resources, the directions of, sequences of, and timings of the transfers of materials, energy, and information for both intra-process and inter-process flows.

5. INTEGRATION WITHIN AN APPLICATION HIERARCHY

The scope of the ISO 15745 application integration framework standard is concerned with manufacturing applications on the plant floor, situated at Levels F2 and below, within an application hierarchy.

The scope of the IEC 62264 enterprise-control system integration scheme is concerned with the activities and the information structures at Level F3.

In this paper, these two integration schemes are extended and combined to integrate applications either within a particular level or at different levels of an application hierarchy. ISO 15745 integration models are applied above Levels F2 and IEC 62264 activity model is extended to other levels.

5.1 Integration of applications within the same level in a hierarchy

In this scheme, the integration of two manufacturing applications within Level F2 of an application hierarchy is described in terms of ISO 15745 process interoperability profiles that support cross-process flows between the two applications. When the IEC 62264 activity modeling framework is extended to Level F2, the processes associated with the cross-application flows are modeled in terms of generic activities - *move*, *make*, *test*, and *fix* , along with a set of information structures and associated sequences of information exchanges, similar to Figure 2. At Level F2, each integrated application will have a set of intra-process and inter-process interoperability profiles.

Following this scheme, the IEC 62264 operations management activities at Level F3 are grouped into a set of processes which are further organized into a set of applications. By extending the ISO 15745 integration framework to model Level F3 applications, resource interoperability profiles are constructed for other types of resources, such as, mainframe computing units, local and wide area networks, manufacturing operations management personnel, and Level F3 software. Similarly, each F3 application has an associated set of intra-process and inter-process ISO 14745 interoperability profiles that support cross-process flows among the F3 applications.

The integration of applications within the F1 and F4 levels, are also denoted in terms of extended ISO 15745 interoperability profiles associated with activities and resources, at these levels, modeled using an extended IEC 62264 scheme.

5.2 Integration of applications at different levels in a hierarchy

When integrating two applications each located at different levels of an application hierarchy, the respective processes of these applications are expected to satisfy a set of inter-process interoperability profiles. In particular, a set of inter-process interoperability profiles represent the integration of Level F3 to Level F2 applications. Another set of profiles is used to denote integration of Level F2 to Level F1 applications.

In Figure 6, examples of Level F2 applications, such as, *Supervisory Control and Data Management, Asset Health Assessment* and *Maintenance Execution and Tracking* are modeled as composed of several processes. The *Asset Health Assessment* application is composed of the following processes - *Decision Support, Prognostics,* and *Health Assessment.* The *Asset Health Assessment* application interoperability profile consists of the inter-process interoperability profiles corresponding to its constituent processes.

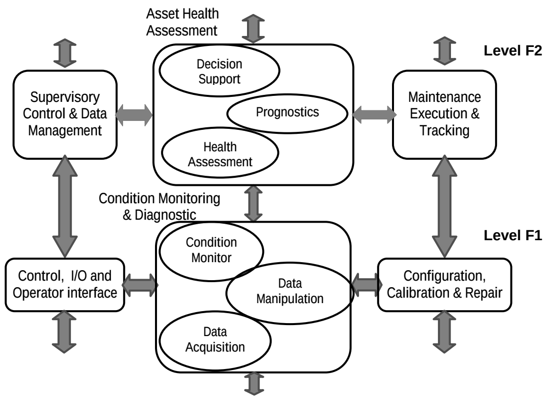

Fig. 6. Integration within and across levels within an application hierarchy

At Level F1, a *Condition Monitoring and Diagnostics* application is composed of the following processes – *Condition Monitor*, *Data Manipulation* and *Data Acquisition*. For instance, the interfaces required to support the cross-process flows between a *Health Assessment* process of the *Asset Health Assessment* application and a *Condition Monitor* process of the *Condition Monitoring and Diagnostics* application are listed in their respective inter-process interoperability profiles.

5.3 Integration requirements in terms of interoperability profiles

The integration requirements for each application at every level in an application hierarchy are represented by its application interoperability profile. Each profile supports not only the interoperability of the processes within an application and but also their interoperability with the other processes in the other applications at various levels of the hierarchy. In this scheme, the likelihood of interoperability of applications in an application hierarchy is ascertained by comparing their associated application interoperability profiles.

Interoperability profiles expressed in XML can be compared in terms of their contents and structures. Applications with matching profiles indicate their consistent use of compatible interfaces types. Each resource interoperability profile in every process interoperability profile must be matched by a corresponding set of proposed resources intended to meet the requirements of an application hierarchy.

6. CONCLUSION

The extensions of and combined use of IEC 62264 and ISO 15745 standards provides a manufacturing application designer or an enterprise system integrator with a scheme to identify and to describe the key interfaces that will support the interoperability requirements, (a) within an application at some level, (b) between applications at the same level, and (c) between applications at different levels, of an application hierarchy used to model an enterprise.

The interfaces and the associated configuration settings, that identify the selected options in the interface specifications, are summarized in a set of application interoperability profiles using XML. The templates are defined by ISO 15745 using XML schemas. By using harmonized UML-based integration models for the applications, processes, resources and activities at the various IEC 62264 levels within the functional and the resource hierarchies in an enterprise, one can use a common set of interoperability templates to describe the suite of profiles that enumerate the set of interfaces required to achieve interoperability and integration within a manufacturing application hierarchy.

Future work will include the development of systematic matching techniques and the use of this combined approach to address application interoperability requirements across enterprises participating in one or more supply chains.

REFERENCES

ANSI/ISA S95.00.01, (2000) *Enterprise-control system integration - Part 1: Models and terminology*. ISA, Raleigh, North Carolina, U.S.A.

ANSI/ISA S95.00.02, (2001) *Enterprise-control system integration - Part 2: Object model attributes*. ISA, Raleigh, North Carolina, U.S.A.

ANSI/ISA S95.00.03, (2005) *Enterprise-control system integration - Part 3: Activity models for manufacturing operations management*. ISA, Raleigh, North Carolina, U.S.A.

IEC 62264-1, (2003) *Enterprise-control system integration - Part 1: Overview and model terminology*. IEC, Geneva, Switzerland

IEC 62264-2, (2004) *Enterprise-control system integration - Part 2: Data objects and attributes*. IEC, Geneva, Switzerland

ISO 15745-1, (2003) *Industrial automation systems and integration – Open systems application integration framework - Part 1: Generic reference description*. ISO, Geneva, Switzerland

Rec-XML-20001006, (2000) *Extensible Mark-up Language, 2nd Edition*. W3C, Cambridge, Massachusetts, U.S.A.

UML V2.0 , (2004) *Unified Modeling Language Specification, Version 2.0*. OMG, Needham, Massachusetts, U.S.A.