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Manufacturing automation programming language environment overview (MAPLE)

Aperçu d'un environnement pour un langage de programmation pour les industries manufacturières (MAPLE)

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FOREWORD

The International Organization for Standardization (ISO) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The main task of ISO technical committees is to prepare International Standards. In exceptional circumstances a technical committee may propose the publication of a Technical Report of one of the following types:

– type 1, when the required support cannot be obtained for the publication of an International Standard, despite repeated efforts;

– type 2, when the subject is still under technical development or where for any other reason there is the future but not immediate possibility of an agreement on an International Standard;

– type 3, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example).

Technical Reports of types 1 and 2 are subject to review within three years of publication, to decide whether they can be transformed into International Standards. Technical Reports of type 3 do not necessarily have to be reviewed until the data they provide are considered no longer to be valid or useful.

ISO/TR 12186, which is a Technical Report of type 3, was prepared by Working Group 4 (Manufacturing Programming Environment) of Subcommittee 5 (Communications and Architecture) of Technical Committee 184 (Industrial Automation Systems and Integration).

This document is being published in the form of a Technical Report because it is intended to provide an informative (rather than normative) overview of the Manufacturing Automation Programming Language Environment (MAPLE). Subsequent parts of this document will detail the specific elements (such as architecture, services, and libraries) that will fulfill the general MAPLE requirements.

Manufacturing automation programming language environment overview (MAPLE)

1 INTRODUCTION

This Technical Report describes the requirements for a Manufacturing Automation Programming Language Environment (MAPLE). This environment will provide a common support facility for multiple, independent programming languages for manufacturing devices and controls and as such is intended to increase the productivity of its various users. This report is intended for the technical committees, subcommittees, and working groups of those standardization bodies whose scope includes items that are required by the MAPLE, and who are interested in contributing towards the development of such a MAPLE.

This MAPLE has been specified to address the following problems that have been recognized in the domain of manufacturing application programming languages for automated production:

- Manufacturing presents a diversity of tasks with widely varying requirements and constraints. Often, addressing these tasks requires programming. Because of the diversity of requirements and constraints, a variety of manufacturing application programming languages has been found necessary.

- Typically, each manufacturing application programming language has its own unique environment of development methodologies, development, debug and simulation tools, and run-time services.

- As a result, it is only with difficulty that an application developer or designer may coordinate the use of differing manufacturing languages for the individual tasks of a complete project, though this is a common need.

- Similarly, it is with great difficulty that systems engineers and integrators combine programs developed using different manufacturing languages, because they use or require different run-time services.

To address these problems, a manufacturing application programming language environment (MAPLE) is specified. This MAPLE is a structured set of capabilities that connects the objects such as data used in CIM to the required user oriented tools.

Figure 1 illustrates this connection. The Objects consist mainly of such items as part machining programs, parts lists, geometric descriptions of parts, manufacturing schedules or such complex objects as virtual manufacturing devices. A major requirement on these objects is that they conform with certain data interface specifications, which allow the MAPLE to access these objects. User Oriented Tools typically consist of Application Programs such as manufacturing language editors and schedulers for manufacturing resources, or programs for the display of data, or the simulation of manufacturing sequences as specified by a machining or material handling program. Again, all User Oriented Tools are required to conform with User Interface Service specifications to MAPLE. Some of the User Oriented Tools, such as language editors, use the MAPLE without being part of it, while a number of routing services for such tasks as display of data or data conversion are so universally used and sufficiently generic that they are included in standard libraries of the MAPLE and, as such, form an integral part of MAPLE.

The MAPLE user usually communicates with one of the User Oriented Tools. In a manner totally transparent to him, the User Oriented Tools avail themselves of the services that the MAPLE can provide, by issuing specific MAPLE commands, such as Fetch Data, Display Data or Simulate operations specified by machine program commands.

In its simplest form, MAPLE responds to these commands by performing compatibility checks between data formats and User Oriented Tools' requirements on data formats. In a more complex case, MAPLE responds by first selecting an appropriate secondary User Oriented Tool, such as a display service, checking data compatibility, and then sending the data from the primary User Oriented Tool to the secondary User Oriented Tool.

This MAPLE will support:

- design and development of programs written in application programming languages;

- operation and management of manufacturing production software.

The following are examples of the types of users considered:

a) users of MAPLE standards such as:
   1) developers of MAPLE tools;
   2) developers of CAE systems;
   3) developers of manufacturing application languages;

who will provide tools for:

b) users of MAPLE tools such as:
   1) product designers;
   2) process planners;
   3) manufacturing plant designers;
   4) station level device programmers;
   5) system engineers and integrators;
   6) installation engineers;
   7) production engineers;

who, in turn, will provide key information, tasks and resources to:

c) end-users of MAPLE such as:
   1) machine tool operators;
   2) material handler operators;
   3) cell and shop supervisors;
   4) maintenance personnel;
   5) production schedulers;

for operating the production process.

2 MAPLE SCOPE

The need exists for the programming of several types of functions at the Station, Cell and Section level (Levels 2, 3, and 4) of the ISO 10314 Shop Floor Production Model. These functions include managing and controlling the equipment in the work Station, coordinating work Stations in a Cell, and supervising the activities of Cells in a Section as well as the communication between entities at the Station and higher levels.

The general requirements for the MAPLE are that it provides a structured environment for application programs to control, command, co-ordinate and supervise any type of automated manufacturing equipment. MAPLE will not monitor or control manufacturing activities, but will provide the tools for the programming of different types of equipment, and conform to existing and foreseeable manufacturing practice.

2.1 Scope

The scope of the MAPLE covers the areas of Product Design, Product Production, and Management and Control for discrete parts manufacturing.

This covers a wide variety of manufacturing data and languages such as, for example, STEP (Express) in the product design area, the ANSI Input Language, CLData, IRData and Communication Protocols in the product manufacturing area and Function Blocks and Ladder Diagrams in the control area.

Many programs like CAD/CAM compilers, interpreters, data conversion and/or manipulation programs will be used. While the MAPLE will support the use and execution of such programs, the development, test and maintenance of such programs are to be outside of the current scope of MAPLE.

Within this domain the MAPLE should support the economic installation, integration and use of manufacturing automation software packages by providing:

- logical positioning of major manufacturing related software functions within the architecture developed in ISO 10314-1 (the reference model for shop floor production standards);

- interface specifications for data transfer between elements in the architecture;

- data storage specifications for data held and shared by applications in the architecture;

- user interface specifications which will reduce the unnecessary, and confusing, differences between applications and support their "transparent" integration, as perceived by the manufacturing user.

Since the requirements are complex and vary depending on the views of different users, this document will provide a broad requirements overview for MAPLE from which requirements for specific subjects and users can be developed in detail in future documents.

2.2 Types of Objects to be Supported

The objects to be supported by the MAPLE can be derived through an inspection of the MAPLE users and include, but are not limited to:

- virtual devices (such as terminals, stations, displays and indicators);
- programmable controllers (PCs);
- numerically controlled (NC) machines;

- robots;
- inspection machines;
- automated guided vehicles (AGVs);
- machining centers;
- material handling systems;
- cell controllers.

2.3 Functions to be Supported

The functions to be supported by the MAPLE arise from the needs of the MAPLE user and include, but are not limited to:

- motion (displacement), manipulation and transport;
- machine settings (such as feed rates, speeds, ON/OFF);
- computation of product geometry parameters and workpiece parameters;
- equipment parameter adjustment;
- computation of cutting conditions;
- selection and ordering of cutting, auxiliary and measuring tools;
- workholder selection;
- production equipment selection;
- equipment/cell/station command and co-ordination (short term reactive scheduling);
- communication between devices and interface with operators;
- process control for parts processing (such as heat anodizing);
- preparation of process documentation (such as routing sheets);
- manufacturing process route development;
- job and task description;
- shop floor organization/coordination/supervision.

To achieve the highest possible degree of automation, components at the Station level should communicate with other entities in the enterprise. This is required for control and monitoring of the equipment to ensure that it is performing according to plans, that problems are detected at the earliest possible time, and that timely data are supplied to support decision processes throughout the enterprise. In addition, Equipment and Station level control programs require many parameters from other parts of the enterprise on which to base control decisions. The standardization of data formats and interface protocols at these levels will enable flexible interfacing among all entities in the enterprise.

Equipment parameters are initially set up depending on the type of processes performed, the type of tools used, and the type of parts handled. Most of these parameters are established from knowledge bases of empirical data (for example, machining data), but require adjustments based on actual data (for example, from vision systems or adaptive control systems) as the process progresses. The programming of these data acquisition and parameter adjustment functions will greatly enhance the performance of the automated equipment.

The functions to be programmed at the Cell and Section levels deal mainly with planning, control, coordination, dispatching and supervision. The main task of these programs is to make sure the equipment at lower levels can function as planned. To achieve this MAPLE has to ensure that all the objects needed for that purpose are available in the right place at the right moment. In the case of NC machining centers, for example, these objects include the workpiece to be machined, the necessary tools to fixture it and to machine it, geometrical and technological information about those tools, and the required NC program. Upon successful completion of a task, the higher level is so notified. When, for one reason or another, the system does not achieve its goal, it should report this to higher levels and if possible take action to solve the problem. This task requires data gathering, processing and analyzing capabilities of the system for data coming from upper and lower levels.

2.4 Activities to be Supported

In order to improve the productivity of the various users of the MAPLE it is not only necessary to provide them with a set of integrated tools that make them more efficient in their individual tasks, but it is also necessary to remove the necessity for manual intervention in what can be automated operations. A number of activities should be supported to aid in this matter. The following is a non-exhaustive list of such activities:

- requirements analysis;
- analytical modelling;
- functional and interface specification;
- prototyping;
- program development and testing;
- quality assurance;
- generation of user documentation;
- user training;
- problem report generation and tracking;
- maintenance and tracking of schedules.

3 REQUIREMENTS FOR A MAPLE

3.1 General Requirements

The MAPLE is required to improve the integration opportunities experienced by manufacturing enterprises. This is to be achieved by specifying an environment (the MAPLE) which effectively eliminates many of the human and hardware interface problems throughout the design, development, use and maintenance of manufacturing automation software. At the same time, the MAPLE must be flexible enough not to constrain the development of innovative manufacturing applications software, or to restrict the user in configuring unique collections of software products to meet individual needs. For the end-users of MAPLE listed in 1. the MAPLE will be transparent.

Figure 2 illustrates the major elements generally required in an automated manufacturing enterprise.

In specifying the requirements for a MAPLE that encompasses these elements, it is helpful to consider the needs from the factory operation viewpoint, which can be translated into:

- the data handling viewpoint, and
- the application software development viewpoint.

Each of these viewpoints are developed further in the following sections.

3.1.1 Requirements from a Data Handling Viewpoint

3.1.1.1 Data Handling

Various application programs are used in the operation of an automated manufacturing system, each of which requires different programming languages. These programs have to be connected with each other via communication of manufacturing data in order to realize integration and efficiency in manufacturing.

The role of MAPLE is to offer a common support facility for this data communication.

The following are the principal requirements for the MAPLE:

- data passing;
- data description;
- data presentation, including visualization;
- data storage and retrieval;
- data editing/manipulation;
- data input.

The last item is required when the user manipulates the manufacturing data in the MAPLE, not while the application program is running.

Some of the above requirements for the MAPLE have to be further investigated and adapted to the characteristics of manufacturing activities.

3.1.1.2 Data Passing

Manufacturing data passing leads to requirements for communication within systems. They include, but are not limited to:

a) standard means and tools for
   1) schema conversion,
   2) communication protocols,
   3) management of distributed controllers,
   4) description for communication functions;

b) reliable timely communication between systems that ensures simultaneous, cooperative and multi-structured control on the factory floor.

3.1.1.3 Data Description

The MAPLE is required to include a manufacturing data entity definition, including both syntax and semantics. Control methods and sequences of the production facilities on the factory floor and behaviors seen from simulations should be described in the data dictionary that provide semantics of the manufacturing data, which will be managed by MAPLE. Furthermore, the MAPLE has to treat a meta description for syntax usage of datalike executable codes.

Data description must also provide tools to ensure the data consistency among different data sets. Non-production data closely related to the product should, for convenience, be supported by the MAPLE.

3.1.1.4 Data Presentation

Visualization is the most essential aspect of data presentation and includes the following requirements:

- schema conversion for 2D/3D graphic data and text data;
- a graphic interface package to connect application programs and common display devices;
- display devices for 3D objects.

3.1.1.5 Data Storage and Retrieval

A distributed data base and distributed data processing are some of the key technologies used in automated manufacturing. Accordingly, requirements for data base technology as shown below are also essential in a MAPLE:

a) security;
b) authorization;
c) integrity;
d) verification;
e) schema control/data conversion;
f) support for distributed data bases including
   1) data directory,
   2) redundancy for resilience,
   3) back up capability.

3.1.1.6 Data Editing

Besides the general functionalities of data processing, MAPLE has to support:

a) graphic data manipulation such as
   1) graphics editing, cooperating with text editing,
   2) data conversion between 2D and 3D graphic data;

b) use of source code of application programs and their compilation.

3.1.1.7 Data Input

This is concerned with the human interface, and includes:

- dictionaries of key words and icons;
- user interface for screen layout;
- user interface for procedures.

3.1.2 Requirements from an Application Software Development Viewpoint

Abstract definitions of manufacturing devices, including their communication capabilities, matching real devices on the shop floor are also required. Application software development has, so far, been realized independently from these aspects, which has created many problems for programmers, developers, integrators and others to meet the requirements of application programs: the processing of the right data, at the right time, in the right place.

it may be impossible to establish international standards for supporting tools for application program development in each specific manufacturing area. In some cases the following are not part of MAPLE; however, as general requirements, MAPLE should support application program development at more general levels. MAPLE also should establish a common facility for the support of application program development in each particular automated manufacturing application. The following items are essential requirements:

- specification of application programs as described in 3.1.2.1;
- processing description as described in 3.1.2.2.

3.1.2.1 Specification of Application Programs

Specifications are concerned with the total enterprise model. The total tasks of the specified manufacturing application are analyzed, structured and decomposed into subtasks. Some of the specifications are given as the requirements (desire) to application programs to be developed, describing what should be done and where.

These requirements are analyzed and converted into detailed requirements, and finally into specifications of application programs. In this process, some of the requirements (what is to be done) may include the processing operations and/or sequences on when the information and/or capabilities of resources required to perform the tasks are to be taken into consideration. These sequences describe how tasks should be done and are concerned with the information processing description that is explained in the next section.