Transactions on Information and Communications Technologies vol 8, © 1995 WIT Press, www.witpress.com, ISSN 1743-3517

Some problems of knowledge based control of manufacturing systems using open communication

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Abstract

A rather simplified and seemingly naive definition of Intelligent Control of Flexible Manufacturing Systems (FMS) means a continuous or frequent observation and evaluation of the status and condition of the system performance, decision making based on the evaluation results and on pre-defined knowledge, and then the operation according to the decisions. In the case of so-called normal operation, which runs according to the given schedules there is no special need for intelligence, neither for interactions to modify the operation, but the above given procedure may help [1] if any kind of disturbance or irregularity happens, what is rather common in the case of highly sophisticated, complex systems. The negative effects of most of such events can be managed using the above given mechanisms. Our paper gives details on our research efforts where we intend to control flexible manufacturing systems using programs based on a Real-time expert system shell on one hand, and taking into consideration the requirements of openness of up-to-date systems on the other hand. This way Open System Interconnections (OSI) are used in networking. The basis of our work is a knowledge based simulation system which helps in scheduling and in real time control of FMS. Some system descriptions and application examples will be given, too.

1 Introduction

Recent discrete manufacturing and/or assembly systems (partly or fully FMS) are more and more often using MAP/MMS (Manufacturing Automation Protocol, Manufacturing Message Specification) [4] because this technology is widely available from many vendors and really gives a safe and open solution according to the demands of OSI (Open System Interconnection). Many users do

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not exactly know that they have such interconnections, they just enjoy the features of MAP. We must also say the MAP or related solution is still rather expensive.

On the other hand so called intelligent control is getting to be a general demand. There is a vivid discussion in literature and in private communications among control engineers about the existence and need of intelligent control.

Some experts claim that there is nothing that really could be called intelligent control [3]. Most of them are speaking only about process control, and not about discrete manufacturing (FMS: Flexible Manufacturing System) or robot control, however the control tasks and problems of manufacturing systems are basically similar to those of batch-like process control. Now, without going into discussions in this issue we accept the need and necessity of intelligent control which we intend to solve by means of knowledge based (KB) systems, which we often call expert systems. We also say that some commercial expert systems provide good problem description and software development tools where the programming is closer to the problem to be solved and to the user to have to support with limited Real-time facilities [2].

To speak about Real-time control we need all scheduling data, as the starting and finishing date of all operations of all equipment (machine-tools, robots, transfer units, as, AGV, etc.) together with the possibilities of downloading (CNC) control programs to all equipment, and to accept and evaluate different signals from them, etc.

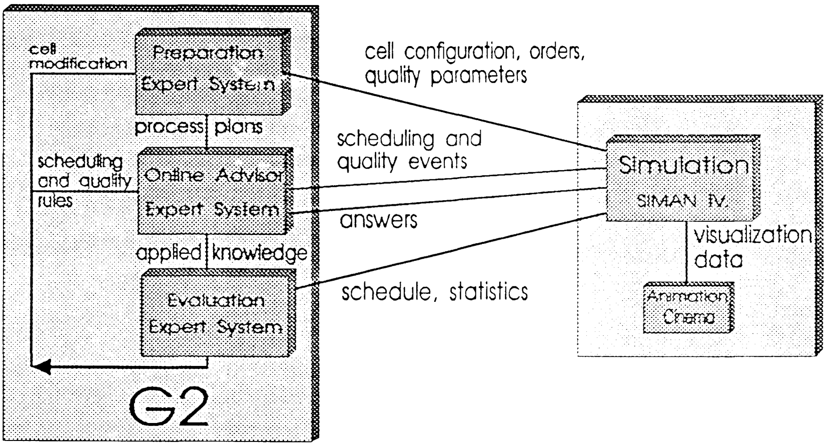

Figure 1. SimSched-Q system: traditional simulation surrounded with 3 expert system within one shell

We had developed a knowledge based simulation system called SimSched-Q (Kovács[6]). In the SimSched-Q system the simulation was implemented in a world-wide accepted, but 'traditional' simulation/animation system called SIMAN IV. It was surrounded by expert system modules (preparation, on-line quality and scheduler advisor and evaluation) implemented in the same

G2 Ver. 3.0 object-oriented Real-time expert system shell (Fig. 1). The structure and the functionality of the system were designed and developed in a way that later the simulation might be changed to a real FMS environment, and the ES would be a cell-controller. The prototype application was developed with the real data (layout, capacities, process plans, machine parameters, etc.) of the Pilot FMS of the Technical University of Budapest. In the ES the application specific and independent parts were separated.

The second chapter will discuss the communication problems of expert systems in CIM/FMS applications and give a problem decomposition. Later on there is a brief description of the features of the MAP based Virtual Manufacturing Device model in intelligent control. Finally there is a presentation of the detailed basic definitions, and the way we went on to end up with something what we call "intelligent robot cell controller with open communication".

2 Expert systems and communication

The practical problems of the communication of expert systems in CIM applications can be divided into two parts. One is the hardware-software connection (physical) and the other is the logical one between the controller(s) and controlled devices. This decomposition was very useful both in the design and implementation phase during the last projects of our CIM Laboratory. If this decomposition is not so sharp it may occur many problems during the development and specially later in maintenance.

There are relatively easy programming interfaces (etc. C/C++) in most available ES shells. These interfaces provide data transfer and communication possibilities with external tasks, stations, etc. They support clear and easy programming to reach objects, to call procedures, to set and get variables, etc.. The interfaces are dedicated to specific software tools of the ES and they are general towards the external world without being able to take into account the requirements of the given application. So nearly each (CIM) implementation requires special software development to cover this gap between the external world and the ES.

Clearly the communication functions depend on the capabilities of the expert system. The way of learning and knowledge handling determine the logical levels of the communication. Three different types of working mode of an intelligent cell-controller in a CIM environment are shown in Fig. 2. are different levels of the communication (Nacsa [7]). These levels are implemented - of course - within the same protocol. This picture just explains the different possible meanings of given messages. The lowest level has the basic control and data acquisition type messages. The other two levels have messages if and only if the 'intelligence of the cell controller is not hidden'. Hidden intelligence means in this term that the knowledge based technology is applied only inside the cell controller and it has no specific actions via the communication channel. A typical example of the hidden case if a KB system is built up on the top of a traditional control system using its original communication. The knowledge acquisition and the so-called knowledge communications were separated. The first one contains specific data for modifying or verifying the knowledge of the given controller. When a KB system shares its knowledge (new or modified rules) it belongs to the knowledge communication level [5]. The communication messages of the most real and pilot KB applications belong to the lowest, possibly to the middle logical level.

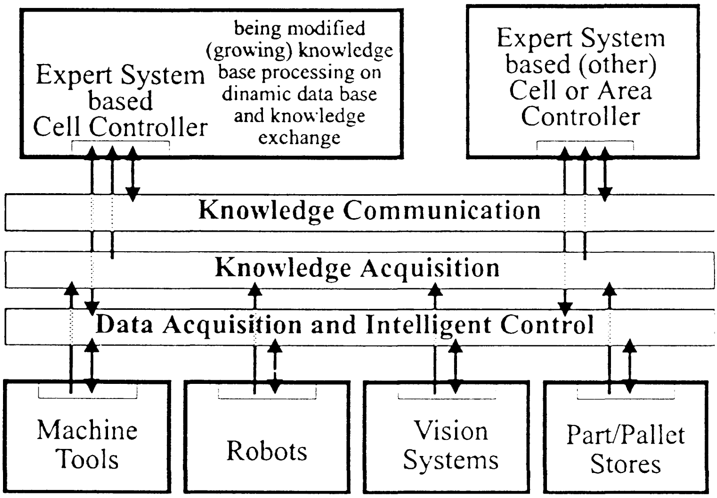

Figure 2. Different logical communication levels of an intelligent cell controller

3 Virtual Manufacturing Device

Going back to the so-called physical connection there are many alternatives. Most controller and controlled device vendors offer good (proprietary) solutions to communicate and also vendor independent standards are available.

Also in the CIM area there are more accepted models or modelling tools to describe the objects of an FMS. In the communication point of view the most promising one is the object oriented view of the so-called MMS (Manufacturing Message Specification), which is originally an application layer protocol in the MAP OSI networks. MMS gives a so-called VMD (Virtual Manufacturing Device) view about each resource of the FMS. Fig. 3. shows a simple, but rather general type of VMD :a robot VMD. It was realised that this specification is good on the higher level of the FMS (Nagy [8]) to give a communication oriented view about the network elements and their resources.

In a VMD it is possible to create, read and write different types of variables, to up- and download domains which can be programs or machine data, to start and stop different tasks (with program invocations) and to handle events.

The object-oriented view of MMS allows to design the VMD model of a certain device, and it is immediately possible to use this model as a specification of the communication where the services (what one can do with a given object of the VMD) are defined and they are working in the MAP networks.

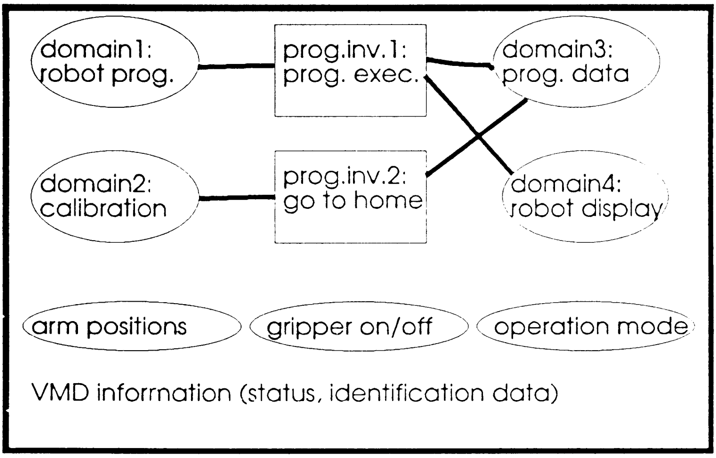

Figure 3. Virtual Manufacturing Device model of a robot (an example)

4 An experimental KB control system with OSI

As the goal of this work is to provide Real-time, intelligent control of CIM (FMS) systems the next step was to apply all development results given in the previous sections and to integrate the independently working and tested software-hardware modules.

As a first experimental set-up (Fig. 4.) a rather simple configuration was chosen. From earlier projects a Mitsubishi robot was available with serial DNC connection to a PC that had a MAP interface. The trivial TIC-TAC-TOE game was served by the robot according to the following manner: a user could play against the G2 system. Of course it is not a problem for that such a system needed. But this well-known game is able to demonstrate very clear the 'intelligent' features of the control. On the other hand the full capability of the MAP networking was used.

The structure of the demo shows that between the ES and the robot a special gateway was developed. It couples the G2 system interface (called GSI) to the MMS standard communication. In this case it was the 'gap software' mentioned in the second chapter. This special gateway of the G2 allows to development any discrete manufacturing applications to develop in G2 using MMS standard interface without the need of modification of the interface In the demo version the gateway supports the context management and some program invocation management services.

Transactions on Information and Communications Technologies vol 8, © 1995 WIT Press, www.witpress.com, ISSN 1743-3517

For this solution a special object hierarchy MLGO (MMS like G2 objects) and procedure set were needed within the G2 to let the other part of the knowledge base to handle the MMS interface.

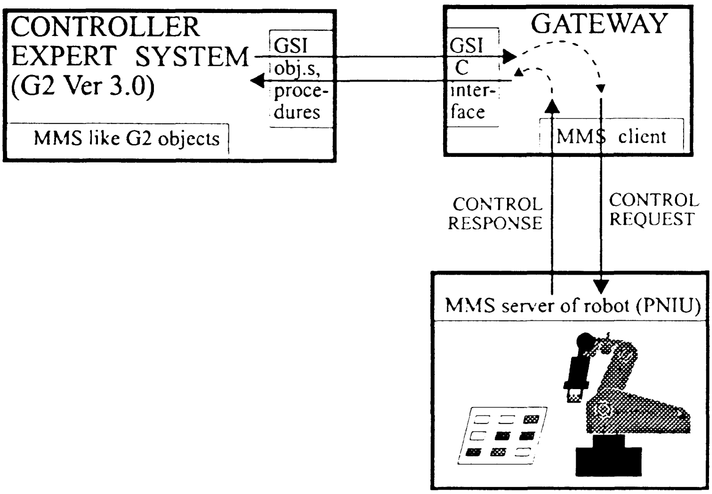

Figure 4. KB control of a robot with OSI

Two solutions were examined. In a work of a student [9] it was examined how can build up the complete MMS object structure within the G2. It took a lot of efforts and gave a relative complicate and not too useful structure. Because of the different services and their parameters many

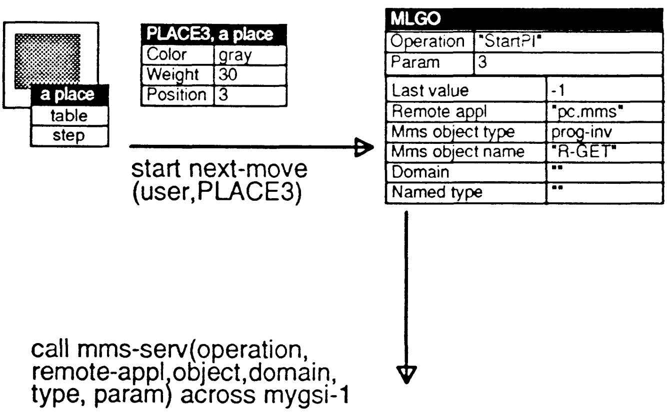

Figure 5. Realisation of MMS within the G2

external procedure calls were defined. All implemented MMS services have their own GSI procedures and all MMS object types have their internal G2 object description. The complexity of the inner structure was the same as the MMS itself. The second solution reduced the necessary objects and procedures to some general terms. It uses limited number of external GSI procedure calls also, but give a rather general (few limitations) interface towards MMS.

Fig. 5. shows a simple example of the method. When the user wants to take a box to a given place push the button of the mouse above the *place*. A G2 'user-defined-action' belongs to the place which starts the *next-move* procedure. It will pick up the parameters of a *start-program-invocation* MMS service from the MLGO and call the GSI *mms-serv* external procedure that send the request to the robot across the gateway.

5 Conclusions

The paper deals with intelligent Real-time control of FMS. As example the simulation of a real FMS and then a robotics cell (where the robot is defined as a virtual manufacturing device (VMD)) controlled by a Real-time computer system is presented. The control software is implemented using a Real-time expert system shell (G2).

We made some research and development in MAP/MMS/VMD problems, and the application possibilities of expert systems was studied in the OSI communication point of view. An interfacing problem was solved when the G2 system and the MAP/MMS network were connected to reach Real-time intelligent control.

6 Acknowledgement

This work was partly supported by the Hungarian Research Fund (OTKA), projects T 4122 and T 14549. The authors are specially grateful to Gergely Nagy PhD student.

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