INTELLIGENT CONTROL OF MANUFACTURING SYSTEMS USING OPEN COMMUNICATION

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Abstract: Knowledge based or 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. This kind of process is applied if any kind of disturbance or irregularity happens, what is rather common in the case of highly sophisticated, complex systems (Smith, et al., 1992). Our paper deals with the control of flexible manufacturing systems using programs based on a real-time expert system environment taking into consideration the requirements of openness of up-to-date systems.

Keywords: Expert systems, Manufacturing systems, Communication protocols, Knowledge-based control, Integration

1. INTRODUCTION

Recent discrete manufacturing and/or assembly systems (FMS/FMA) are more and more often using MAP/MMS (Manufacturing Automation Protocol, Manufacturing Message Specification), as estimated (Brill and Gram, 1991), 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 not exactly know that they have such interconnections, they just enjoy the useful features of MAP. It should be also admitted that the MAP or related solutions are still rather expensive.

MMS is a network protocol that gives a tool to describe the manufacturing specific features of different industrial resources, as CNC, robot, PLC, etc. At the same time MMS provides a modeling method of resources from the communication point of view, and it implements the communication messages, too. It is close to the OO (object oriented) methodology as different objects have different type of services in MMS.

On the other hand the so called intelligent control is getting to be a general demand. There is a vivid discussion in literature and in private communications on control engineers about the existence and need of intelligent control (Franklin et al., 1994).

Some experts claim that there is nothing that really could be called intelligent control. 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 it is acceptable the need and necessity of intelligent control which is intended to solve by means of knowledge based (KB) systems. It is a well known fact also that some commercial expert systems provide good problem description and software development tools where the programming is closed to the problem to be solved and to the user as well. There is a support with limited real-time facilities. too (Laffey et al. 1988).

To speak about real-time control all scheduling data is necessary, 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.

2. A KNOWLEDGE BASED HYBRID SIMULATION SYSTEM

A knowledge based simulation system called SimSched-Q (Kovács et al., 1993) was developed in the CIMLab last years. In the SimSched-Q system the simulation was implemented in a world-wide accepted, but 'traditional' simulation/animation system called SIMAN with Cinema animation. It was surrounded by expert system modules implemented in the same G2 Ver. 3.0 object-oriented real-time expert system (ES) shell.

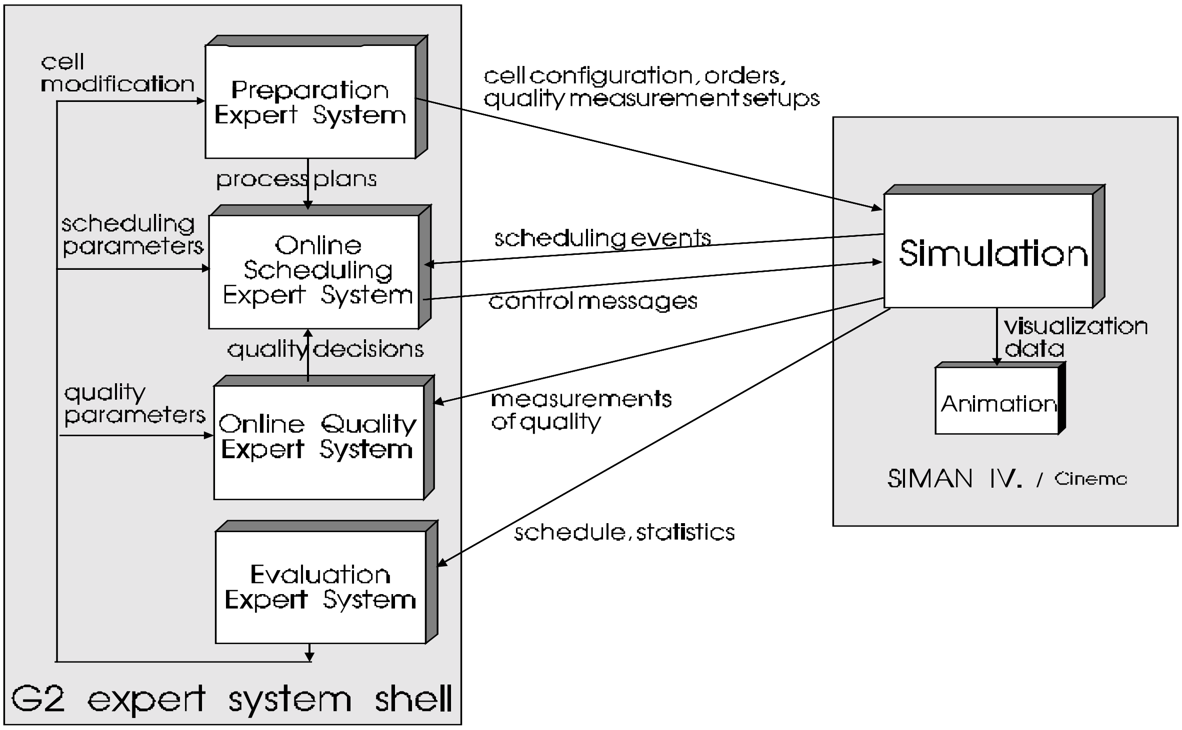

Fig. 1. SimSched-Q system: traditional simulation surrounded with expert systems within one shell

There are four ESs: two of them are shallow coupled with the simulation (Preparation and Evaluation), two of them are deep-coupled (Quality and Scheduler advisors). The study in this paper refers only to the scheduler as resulting schedule data are the basic input for intelligent control. 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 the real-time 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. This system contains four ‘holon-like’ cells (storage with AGV, measurement, assembly and metal-cutting) on a network. The application specific and independent parts were separated in the ESs.

The next 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 one may call "intelligent robot cell controller with open communication".

3. REAL-TIME COMMUNICATION WITH EXPERT SYSTEMS

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 the decomposition had not been done so sharply, many problems may occur during the development and specially in maintenance later on.

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 and different levels of the communication of an intelligent cell-controller in a CIM environment are defined. (Nacsa and Kovács, 1994). These levels are implemented - of course - within the same protocol. The lowest level (Data Acquisition and Control Level) has the basic control and data acquisition type messages. The other two levels (Knowledge Acquisition and Knowledge Communication 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 for a hidden case is 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) it belongs to the knowledge communication level (Buta and Springer, 1992). The communication messages of the most real and pilot KB applications belong to the lowest, possibly to the middle logical level.

4. THE OBJECT ORIENTED VIEW OF MMS

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 modeling tools to describe the objects of an FMS. One of the most promising tool is the MMS. It was also realized that this specification is good on the higher level of the FMS (Nagy and Haidegger, 1994) to give a communication oriented view about the network elements and their resources.

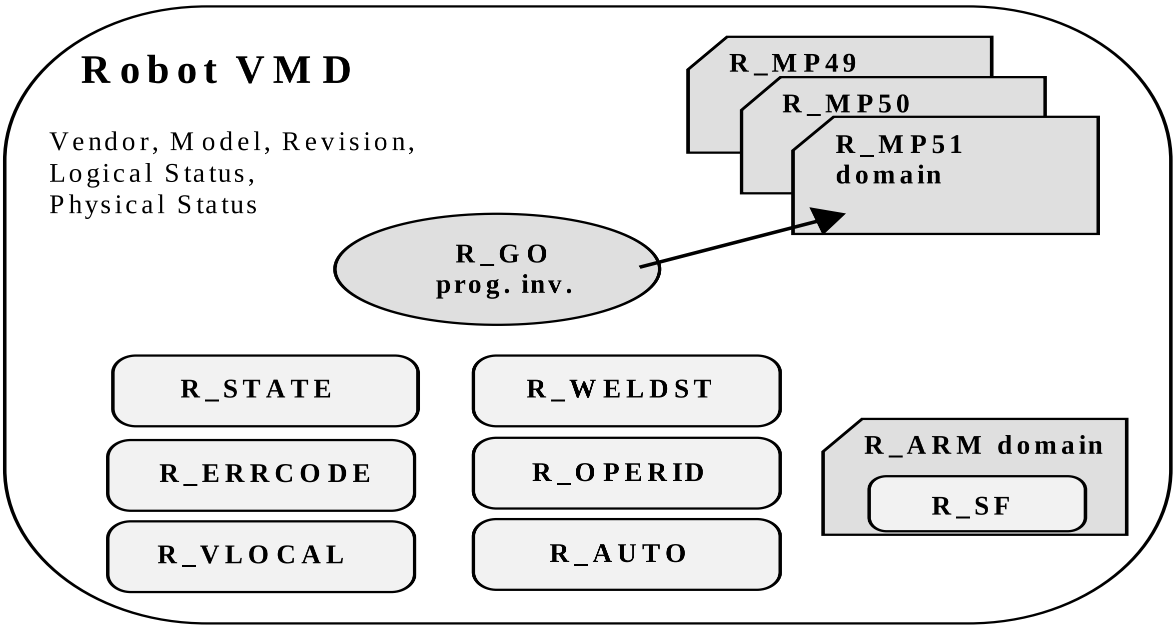

Fig. 2. Virtual Manufacturing Device model of a robot (an example)

MMS gives a so-called VMD (Virtual Manufacturing Device) view about each resource of the FMS. Each resource in an MMS network is defined as a VMD. Fig. 2.

shows a simple, but rather general type of VMD :a robot VMD.

The VMD object itself has some general attributes, as physical and logical status, vendor and model name, etc. The VMD contains additional objects to define the resource specific elements as the domains, program invocations, variables and some more but not widely used attributes as events, semaphores, journals, etc. 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 are working in the MAP network.

5. AN EXPERIMENTAL OSI ROBOT CONTROL SYSTEM

As the goal of this work was 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. All the experiments of the coupling the KB system from the project mentioned in the chapter 2. were used.

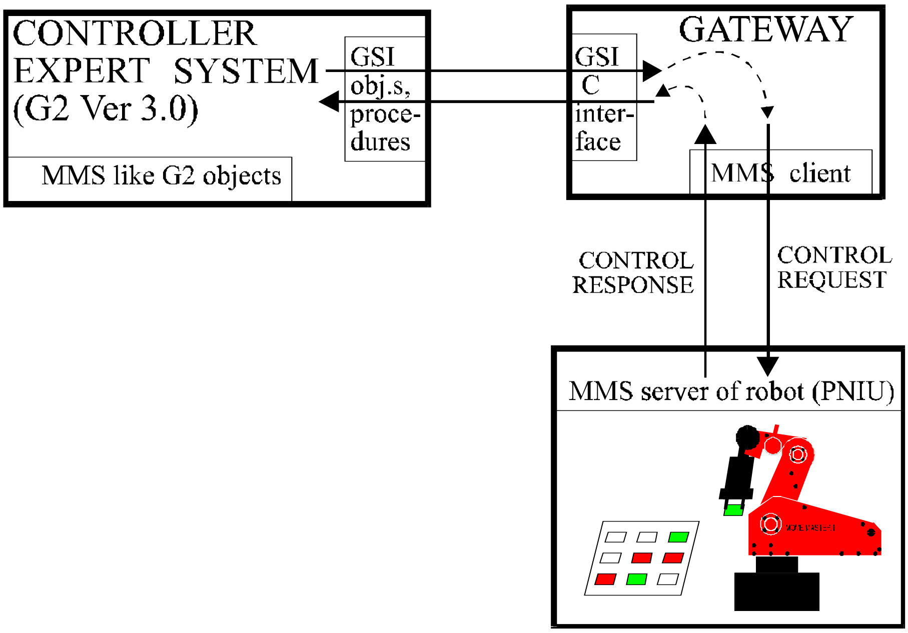

Fig. 3. Knowledge Based control of a robot with OSI network

As a first experimental set-up (Fig. 3.) a 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 clearly the 'intelligent' features of the control. On the other hand the full capability of the MAP networking was used.

The structure of the setup shows that a special gateway was developed between the ES and the robot. 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 develop 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.

Two solutions were examined. In a work of a student (Tömösy, 1994) it was examined how the complete MMS object structure can be built up within the G2. It took a lot of efforts and gave a relatively complicated and not too useful structure. Because of the different services and their parameters many external procedure calls were defined with complicate parameter sets. 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. It did not give a clear and easy-to-use tool for the G2 user.

The second solution reduced the necessary objects and procedures to some general terms. It uses limited number of external GSI procedure calls also, but gives a rather general (few limitations) interface towards MMS. Other MMS Application Enablers in the market use similar solutions. A special object hierarchy within the G2 called MLGO (MMS-like G2 Objects) was defined. MLGO is coupled to the MMS network by means of some special procedures via the GSI of G2. This way the user (who is the developer of the control system in G2) is able to handle all remote resources via the MMS network from his G2 application using MLGO.

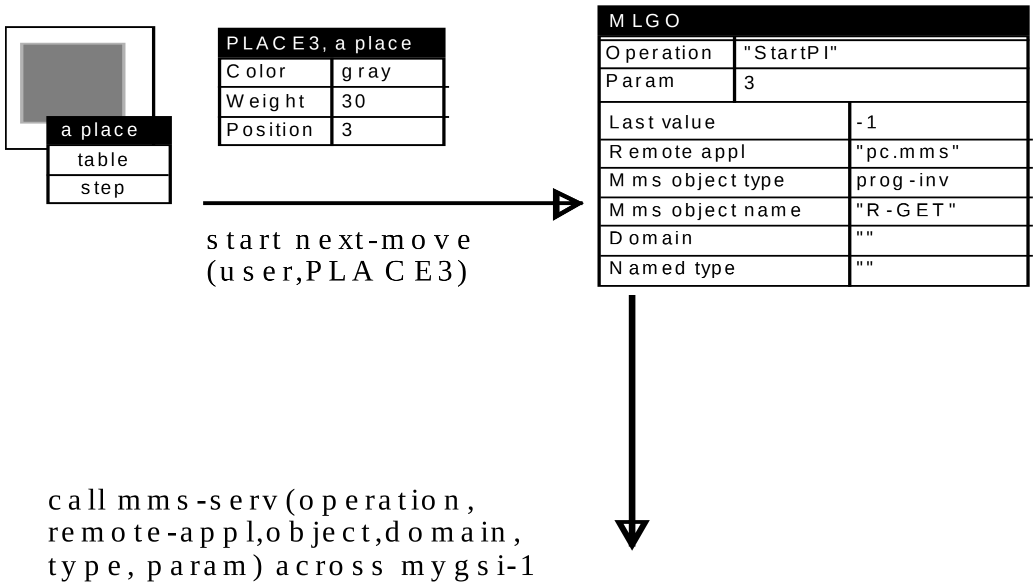

Fig. 4. Realization of MMS within the G2 system

Fig. 4. 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.

6. CONCLUSIONS

The paper deals with intelligent real-time control issues of FMS. As an 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).

Some research and development tools around MAP/MMS/VMD problems were made, and the application possibilities of expert systems were 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.

These results could be very useful and promising in the future when they will be applied for more complex and sophisticated large scale manufacturing and assembly systems which hardly can be designed and controlled without applying simulation and expert systems.

7. ACKNOWLEDGMENT

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8. REFERENCES

Brill M., Gramm U.: MMS: MAP application services for the manufacturing industry, *Computer Networks and ISDN Systems*, 1991, **21,** pp. 357-380

Buta P, Springer S: Communicating the knowledge in knowledge-based systems, *Expert systems with applications*, 1992, **5,** pp. 389-394

Franklin G., Meystel A. et al.: private discussion by e-mail in Architectures for Intelligent Control Systems Discussion List, 1994 <AICS-L@UBVM.CC.BUFFALO.EDU>

Kovács G. L. et al.: Integrated application of Real-time expert systems for FMS evaluation and control, *Applications of Artificial Intelligence in Engineering VIII* , ed. Rzevski, Pastor, Adey, Vol.2, pp. 835-847, Elsevier, 1993

Laffey T.J. et al: Real-time knowledge based systems, *AI Magazine*, 1988, **9**, 1, pp.27-45

Nacsa J., Kovács G.L.: Communication problems of expert systems in manufacturing environment, in AIRTC'94 (ed. Crespo), pp. 377-381, *Preprints of the Symposium on Artificial Intelligence in Real-time Control*, Valencia, Spain, 1994, IFAC

Nagy G., Haidegger G.: Object Oriented Approach for Analysing, Designing and Controlling Manufacturing Cells, in AUTOFACT'94 (ed. Moody), pp. 12/1-10, *Proceedings of AUTOFACT'94*, Detroit, USA, 1994, SME

Smith P.E. et al: The use of expert systems for decision support in manufacturing, *Expert systems with applications*, 1992, **4,** pp. 11-17

Tömösy Gy.: *Implementation of MMS services into an expert system*, unpublished diploma work, MTA SZTAKI, Budapest, 1994, (in Hungarian)