

# Logical Communication Levels in an Intelligent Flexible Manufacturing System

János Nacsa

(nacsa@sztaki.hu)

Computer and Automation Research Institute ([www.sztaki.hu](http://www.sztaki.hu))

Budapest, Hungary

**Abstract:** In most cases in intelligent manufacturing applications the communication functions depend on the capabilities of the intelligent tool (e.g. expert system). Three different types of working mode and different logical levels of the communication of an intelligent cell-controller in a CIM environment is shown in the paper. These levels are implemented - of course - within the same protocol. After this concept the paper explains the connection between these logical levels and the communication protocols and ontologies. Finally a simulation tool introduced in the second part of the paper was developed to examine the effects of the different communication messages and to analyse how the different type of messages can be measured in a real Flexible Manufacturing System (FMS) environment.

**Key words:** distributed artificial intelligence, knowledge communication, flexible manufacturing system

## 1. INTRODUCTION

The practical problems of the communication of expert systems (ES) in CIM (Computer Integrated Manufacturing) applications can be divided into two parts. One is the hardware-software connection (physical) and the other one is the logical connection 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 many problems may occur during the development and specially in maintenance later on.

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There are relatively easy programming interfaces (etc. C/C++) in most available ES shells. These interfaces provide data transfer 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 the gap between the external world and the ES.

## 2. LOGICAL COMMUNICATION LEVELS

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 levels of the logical communication among intelligent controllers in a CIM environment were defined [6] as are shown in Fig. 1. Typically the messages of these three logical levels are coded in the same way, are using the same protocols and are mixed according to the communication features of a given manufacturing environment.

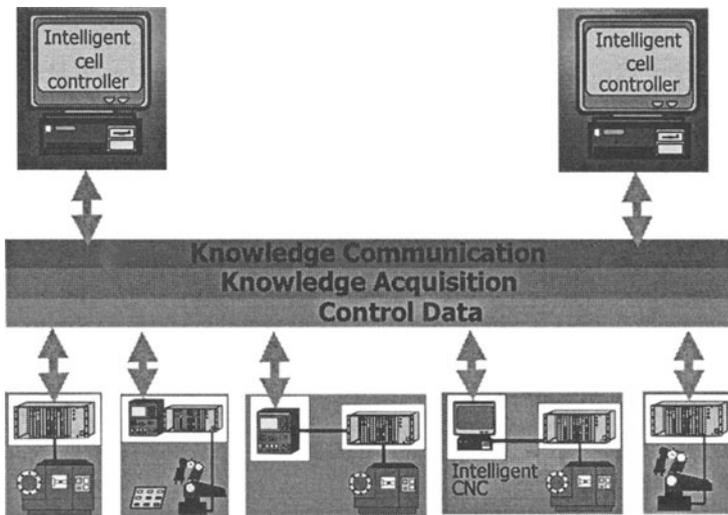


Figure 1. Three logical communication levels

- There is no intelligence in the CIM environment.
- All the AI solutions in the system are working individually, so there is no logical connection among them.
- The intelligent systems co-operate with each other in a hidden mode. 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 is a KB system is built up on the top of a traditional control system using its original communication.

On the higher logical levels the Knowledge Acquisition and the so-called Knowledge Communication levels were separated. These other two levels have messages if and only if the 'intelligence of the cell controller is not hidden'.

In the case of Knowledge Acquisition, the intelligent node/module initiates special data acquisition to update, validate or grow its knowledge. According to the general accepted terms: one can say about passive knowledge acquisition - where only existing data are collected remotely - and active knowledge acquisition - where also remote procedures are activated to get the necessary data.

When a KB system shares its knowledge (new or modified) it belongs to the Knowledge Communication level as Buta and Springer named it [1]. In this case the different intelligent nodes/modules ask/answer to each other as agents.

It must be stated that the communication messages of most real and pilot KB based applications for FMS control belong to the lowest, possibly to the middle logical level.

### **3. KNOWLEDGE SHARING VERSUS LOGICAL LEVELS**

In an environment where the different nodes want to share their knowledge, they have to "understand" each other. It is a big problem of the common understanding if the logical meaning of the different facts, objects and data are different in the different modules and subsystem. It is specially true in the manufacturing systems where the complexity of the individual elements are high and the terminology even among the different human field-experts is not the same. In the literature it is known as ontology problem [3].

Analysing the different knowledge sharing models and initiatives 4 different levels of ontologies can be distinguished:

1. There is no ontology - sub-symbolic or procedural representation is used in the module.
2. Closed ontology - the module can not share its knowledge with others.
3. Individual ontology - the module has a special - typically procedural - API to provide some achievement of its knowledge.
4. Junction ontology - the module can share its knowledge with others.

The Table 1. shows the correlation between the level of ontologies and the logical level of communication introduced here:

*Table 1. Logical levels and ontologies*

	closed	individual	junction
control data	+	unnecessary	unnecessary
knowledge acquisition	cumbrous	+	unnecessary
knowledge communication	not possible	cumbrous	+

It is clear that a nearly one-to-one mapping can be found, so the experimental levelling of the logical messages proves its usability.

#### **4. COMMUNICATION PROTOCOLS VERSUS LOGICAL LEVELS**

In the world of FMSs there are many different types of protocols for different purposes, unfortunately there are more protocols than necessary. In this chapter the different protocols are examined in the communication point of view: how they determine the meaning of the messages.

The communication nodes can be active or passive; clients, servers or none of them (peer to peer). These categories are not related to the content of the communication and are handled typically in lower layer protocols. Three types of protocols can be distinguished:

- Traditionally CNCs and robots are closed from the network point of view. Their proprietary DNC channel allows only minimal information exchange.
- In the 90s many message based protocols came to the front that were based on the object oriented technology (e.g. CORBA) or similar (e.g. MMS). In these solutions in the network point of view the manufacturing devices seem to be virtual devices.
- The intelligent agent based experimental systems are using the speech act communication that has many features of human communication origin. The most important agent communication

language is the KQML (Knowledge Query and Manipulation Language [2]).

The main difference in the knowledge communication between the message based and speech act types of protocols is that the first one does not contain any information how to process the given message [4].

Table 2. shows again the correlation between the different types of protocols and the logical level of communication:

Table 2. Logical levels and types of protocols

	procedural	message based	speech act
control data	+	+	unnecessary
knowledge acquisition	+	+	+
knowledge communication	not possible	cumbrous	+

In this case the mapping is not one-to-one, but the levels approximately fit the types of protocols.

## 5. SIMULATION OF COMMUNICATION IN AN FMS

Introducing the logical communication levels they can be used to examine the distribution of the intelligence in a CIM environment. To start this evaluation a previously developed FMS simulation system [5] was utilised.

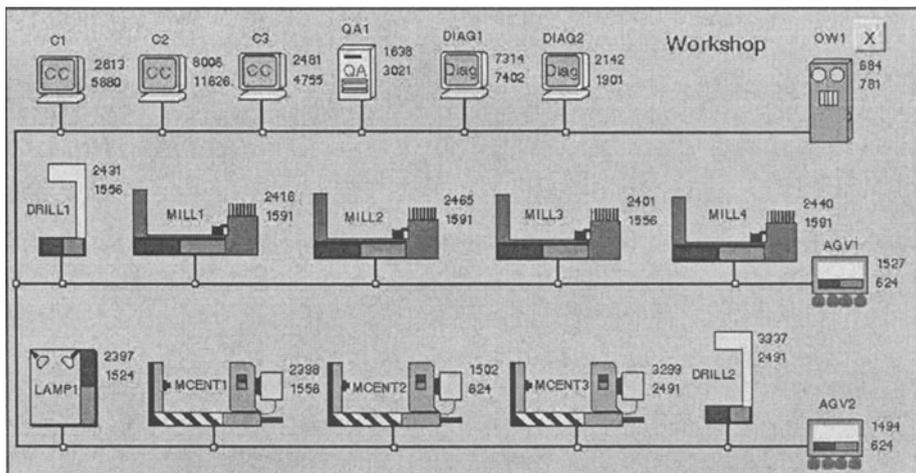


Figure 2. FMS used during the simulation tests

The experimental FMS (Fig. 2) contains 3 machining centers, 4 mills, 2 drills and 1 measuring machine served by 2 AGVs. This FMS is controlled via 3 cell controllers plus 1 quality assurance and 2 diagnostics PCs. The outside world is modelled by a single node. Some devices were set as "intelligent" either as knowledge acquisition or knowledge communication node or both. Different random sources filled the system with messages.

The effects of the different disturbances (machine down, quality problems, unexpected order etc.) could be analysed with this simulation system, and - among others - the flux of the different logical level messages can be visualised.

## 6. CONCLUSIONS

Three levels of experimental categorisation was introduced for the different manufacturing messages in a CIM environment. The correlation of these levels and the ontologies and protocols were analysed.

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## 8. BIOGRAPHY

János Nacsa is a research associate of the CIM Laboratory of the Computer and Automation Research Institute, Budapest, Hungary. He published more than 50 papers and led different research projects. His research topics are open systems and application of artificial intelligence in manufacturing.