BUILT-IN INTELLIGENT CONTROL APPLICATIONS OF OPEN CNCs

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Abstract: Artificial intelligent methods are increasingly used within computer integrated manufacturing (CIM) applications. Real-time expert system environments are good tools to develop intelligent controllers. The first part of this paper summarises some problems of the application of artificial intelligence and expert systems within the CIM area. Then a new open European CNC architecture (OSACA) is introduced. The third part of the paper shows the knowledge based, intelligent control application in the OSACA environment evaluated by a prototype solution.

Keywords: Communication control applications; Expert systems; Flexible manufacturing; Open systems

1. Introduction

Taking a look at the lists from a decade ago (e.g. Wright and Bourne, 1988) which tried to summarise the commercial needs for the new machine tools it is clear that in many respects great, positive changes have happened. Here are some important features proving the evolution:

- the number of scrap parts are reduced following the initial set-up
- the accuracy of parts manufactured is increased
- the set-up time is reduced by designing parts for easy set-up
- the total cost for part fabrication is reduced
- machine throughput is increased
- machine downtime is reduced
- the range of possible geometries for finished parts is increased
- tooling time is reduced through better operation planning
- the time between part design and fabrication is reduced

The next list contains some aspects where the results are not that successful:

- the skill level required for machine set-up and operation did not reduce as expected
- in spite of the high number of diagnostic features, the controller is not able to adapt its work according to the recovered situations
- run-time intelligent error correction is still missing even when the reason of the error is detected
- quality of information and efficiency of information exchange did not increase between the human and the machine tool controller
- diversity of information type among the controllers or the upper level devices is limited (e.g. only, program transfers, status information and start/stop signals).

As a result of the comparison of the two lists one can say that the machine tool controllers are more powerful in sensors and computer capacity. They also have more built in functions (e.g. online animation-simulation, easier NC program validation and modification), yet they haven't increased their intelligence compared to the expectations of a decade ago.

In many manufacturing companies and other organisations hundreds of expert systems have been developed to solve a wide variety of problems

(Liebowitz, 1990, Smith at al. 1992). There are successfully implemented real-time and industrial solutions which have saved money for the customer e.g. at Ford Powertrain Operations (Gensym and Ford, 1996) but there are also several manufacturing companies, that are not using expert systems at all (Wong at al. 1994).

2. 'Intelligent' CNC

In an ideal scenario to the intelligent machine tool (Wright and Bourne, 1988) the human mechanist was nearly replaced by the controller: *„We must therefore acknowledge that the degree of intelligence can be gauged by the complexity of the input and/or the difficulty of ad hoc in-process problems that get solved during a successful operation. Our unattached, fully matured intelligent machine tool will be able to manufacture accurate aerospace components and get a good part right the first time"*. They told that an intelligent machine tool had the CAD data, the materials and the set-up plans as inputs and could produce correctly machined parts with quality control data as outputs.

During the last decade many efforts have been made to get closer to this ideal scenario, but the way of information processing within the CNC did not change too much. Knowledge processing and other artificial intelligence methods has not appeared within the controllers. Special heuristic rules, problem solving strategies, learning capabilities and knowledge communication features are still missing from the controllers.

The new requirements of the integration of manufacturing means the effective use of knowledge ranging from design to production and maintenance (Kim 1995). In a workshop of the future the control system should properly process information with the varying environment (e.g. location and pose of workpieces or internal lubricants) and be able to handle in an intelligent way unexpected events (e.g. chipping problems, tool errors) which means at least intelligent adaptation capability but also enlarging the knowledge level case-based reasoning and learning from the experiences as well.

As a summary Suh (1995) gives a very good definition to the intelligence in this domain: *An intelligent manufacturing process is defined as the process that has the ability to self-regulate and/or self-control to manufacture the product within the design specification*.

Moving towards the reasons of the lack of meeting the requirements in the above definition there is an important distribution comparing the intelligent solutions mapped to the level of the factory. There is an intensive work for intelligent sensors (Monostori, 1993) at the sensor level and for intelligent cell-controllers with different type of intelligent subsystems (e.g. scheduler, quality assurance, diagnostics) (Mezgár and Kovács, 1994). In the controller/workstation level very few applications can be found and it is very strange comparing the 10 year old ideal scenario mentioned earlier.

Taking a look to the present controllers a very important reason can be found. All the controller vendors offer their products in a nearly black box solution, there are no tools and interfaces to add further user written tasks and subsystems into the basic controller.

The parts manufactured by CNC machines are so wide in range and have so many complicated factors (Raggenbass and Reissner, 1995) that the specifications of the new machine tools are getting extremely different and strongly depend on the applications and the customers' further needs and habits. This requires more flexibility and openness also for the machine tool control systems. Because of the ever growing adaptation work at each final applications, more and more programming of the NC controllers, modifications and enlargements of the functionality should be done by the staff of the application integrator and of the machine tool builder.

3. New open CNC controllers

Manufacturing has constantly been a technological domain, in which the industry was driven to apply the current high-tech from computer and control area. It is no surprise, that the Open Systems concept has also diffused into the manufacturing area, and factory managers are often referencing the open manufacturing systems. The terms and definitions are far less exact as the terms applied in the operating systems environment, but by now, the change of the global manufacturing paradigms (Kovács 1996, Saygin and Kilic 1996) are directing our focus on the key user aspects of openness.

The booming market for industrial automation led to a vendor dominating situation: dozens, or rather hundreds of controller manufacturers (vendors) are developing, implementing and installing different solutions for automation tasks. The problem with that arises, when there are a large number of incompatible products, when the controllers can not cope with the frequently needed updates, when service, maintenance and repair costs are scoring high, and personnel to work with those many controllers are decreasing in number.

To cope with this situation, some early developments have started in many countries, and also in Hungary. In national reports, the guidelines for compatibilty, interoperability and standardised solutions (GYKFT 88) and the requirement specifications for the next generation of CNC controllers had been set in a harmonised way with the GM initiated Manufacturing Automation Protocol (MAP) project. The conclusions from these projects and reports were coinciding with those, being prepared by American, Japanese and other European teams (e.g. the EC sponsored CNMA projects, the MITI project in Japan).

The need for a new and open CNC architecture was emerging at many other places around the world. One of the most important work was done from 1992 within the frame of the European project named OSACA (Open System Architecture for Control Applications) (Pritschow and Sperling, 1994.). This project is still running in its third phase and the most important results are: an analysis of the state-of-the-art and future requirements of NC controllers, a reference architecture, a general and platform independent API for inner CNC and outside communication and a configuration system supporting the possible machine tool vendors.

Similar efforts are going on in Japan under the IROFA Consortium, and in the U.S. within the TEAM and ICON projects (ICON 1997). The ICON mission will be accomplished by developing a Manufacturing Operating System (MOS) with published Application Programming Interfaces (APIs).

4. The OSACA communication

Fig. 1 shows the system platform developed in the OSACA project. The picture shows that on the top of the basic components (e.g. hardware, operating system, communication medium) a special OSACA API was defined. All the applications named Architecture Objects (AOs) in OSACA can use and reach all the services of the basic components and each others via the API. This object oriented API fulfils the interoperability, portability, scaleability and interchangeability requirements of an open controller in the sense of communication (Lutz and Sperling, 1995). So this API means full portability and hardware/operating system independence for the applications and presently existing on many different platforms (e.g. WinNT, Solaris, VxWorks, OS2) and communication media (e.g. TCP/IP, shared memory, serial line).

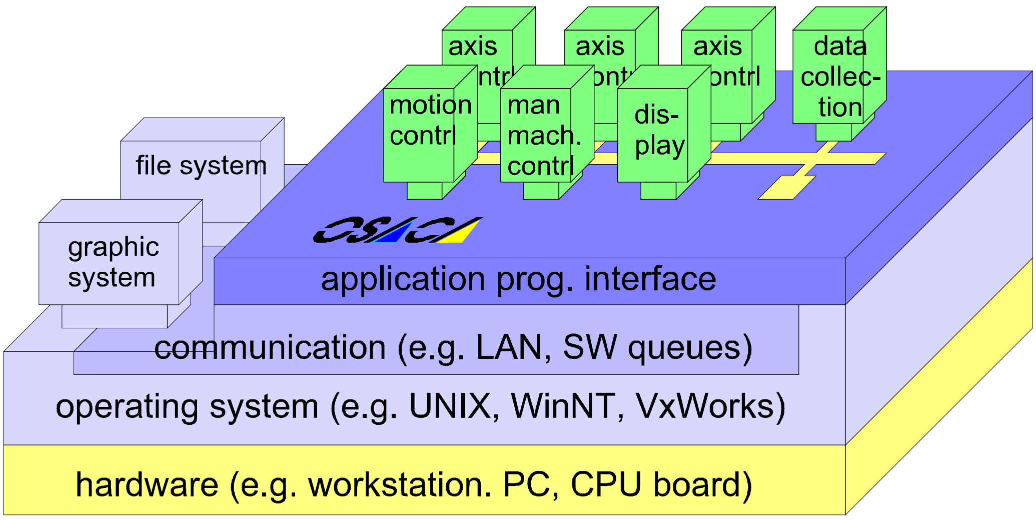

Fig. 1 The OSACA system platform with 7 different Architecture Objects

The OSACA API supports in the same way the data communication among different tasks within the same environment and among different ones. So called shortcuts are used within one environment to solve time critical data exchange.

The API builds up from three layers: a message transport system (MTS), an application services system (ASS) and communication object manager (COM). The MTS offers basic services for sending and receiving of messages and can be realised on a given platform in many different tools (e.g. LAN connection, mailbox, serial line) according the needs of the given system. All the connection management among the platforms are handled by the MTS. The ASS assembles and disassembles the applications messages, encodes and decodes them if necessary. The shortcuts are handled by the ASS, too. The application programmer can reach the API using the COM. Each AO has its own communication objects which can be reached via the COM. Presently three main classes have been implemented: variables, events and processes.

Another result of the OSACA project, the reference architecture for open control system, among others describes which functionality is offered by which AOs by defining attributes and services for each AO. The performance and the functionality of a given AO will easily be scaleable keeping the guidelines of the reference architecture.

A simple educational and test OSACA

demonstration software has been developed by the WZL Laboratory of Aachen, which is one of the OSACA partners. The main aim of this software is to introduce the OSACA configuration management. It consists of three simple OSACA applications: axis control (AS), motion control (MC) and a man-machine control (MMC) in addition to the configuration tasks. In the demo it is possible to set the X, Y, Z absolute co-ordinates and the override. All the three applications run as independent tasks communicating according to the OSACA specification even when they do not perform the real tasks (e.g. AC, MC). This demo was set up under MS Windows NT 4.0 over TCP/IP.

The open architecture supports more effective integration of user defined special modules in general, so among others, applications using AI techniques can also be easily added to the CNC architecture. This view led to the examination of the integration of the G2 Real-Time Intelligent Environment (Gensym, 1996) to the OSACA platform. G2 is available on many different platforms and has one of the most real industrial applications all over the world among the expert systems, so it seemed to be logical to match it with the OSACA's platform independent open controller philosophy.

5. A prototype intelligent man-machine interface

As a prototype of intelligent applications within the OSACA environment, the MMC task of the WZL demo was replaced in our laboratory to a G2 based MMC which applies also rules for its control task. To solve the connection a special interface has been developed which connects the G2 Real-Time Environment to the OSACA using the Gensym System Interface (GSI) over TCP/IP which provides an external task based C interface to the G2. Within this interface task the OSACA C++ based communication API was built together with the GSI (Fig. 2).

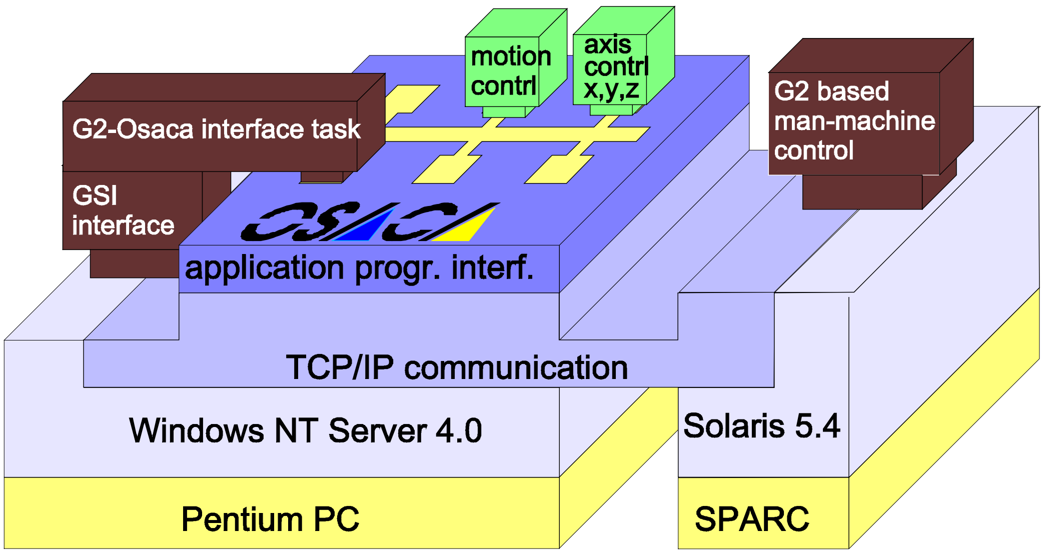

Fig. 2 The prototype version of the OSACA based intelligent man machine control using G2

In the prototype application the G2 is running on a SUN Sparc workstation under Solaris 5.3, because that platform was available during the development. Either the Windows NT or the Solaris platform can be used later on to be able to put the intelligent software parts (G2 itself and the GSI based OSACA gateway) onto the same machine.

The OSACA communication presently allows three classes of objects: variables, events and processes. On the other hand GSI supports a wide range of communication solutions with its three types of external communication categories (i.e. setting and getting external variables, calling external procedures and invoking internal procedures from the external system). So all OSACA communication classes and their methods can be solved easily by choosing a solution within the GSI to be able to map the OSACA objects into the G2 inside world. Any OSACA communication variables (e.g. end positions of X, Y, Z and the override of the intelligent MMC demo program) concern a G2 variable and when the G2 user changes the value of any such variable, an automatic mechanism provides its updating through the GSI and the OSACA communication. The following rule shows that as an example: *whenever any axis AX receives a value and when the gsi-interface-status of g2-osaca-interface = 2 then start set_axis (the string of AX, the value of AX).*

While the original WZL demo allows very limited control actions (because of the limited number of the presently available OSACA variables), only simple KB control system can be built. Control constraints can be implemented using G2 rules (e.g.*: if the value of x_axis >= 3500 and the value of override >= 100 conclude that the value of override = 100).*

6. Conclusions, future plans

A basic problem of using artificial intelligence means, as e.g. expert systems to be built into the CNC is to solve the interfacing of the AI tool and the other parts of the CNC. The new generation of CNC, which provides open APIs permits putting the intelligent subsystems into the controller. An early example with intelligent man-machine interface of an OSACA based CNC illustrates the suggested solution. The development of more sophisticated applications are being under consideration.

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