The Enhanced Machine Controller (EMC): An Open Architecture Controller for Machine Tools

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In 1980, nearly half of the world's machine tools were manufactured in the U.S. Today, the U.S. market share has fallen to 10%. Since machine tool technology is considered critical for both civilian and military uses, it is important to recapture some of this market. The controller is the critical component of a machine tool which can change its capabilities. More flexible controllers will produce higher quality parts at lower cost. Currently, world market competition is based on proprietary hardware. The goal of the EMC project is to shift the controller competition from proprietary hardware to software that runs on widely accepted platforms, an area where the U.S. still has a commanding lead.

It has become widely recognized that one way of achieving this goal is to develop an open architecture controller. The NCMS (National Center for Manufacturing Sciences) Next Generation Controller project just issued a formal release of the SOSAS (Specification for an Open System Architecture Standard). NIST (National Institute of Standards and Technology) is well on the way to alpha site testing of its Enhanced Machine Controller (an implementation of parts of the SOSAS). In May of this year, an Air Force Title 3 program issued a Request for Proposal for an Open Architecture Machine Tool Controller. The Department of Energy TEAM (Technology Enabling Agile Manufacturing) has initiated a Intelligent Closed-Loop Controller project in order to produce an open architecture intelligent controller for manufacturing applications. A number of projects in corporate research labs and universities are exploring concepts for open architecture machine tool controllers.

The European ESPRIT OSACA project is entering the fourth year of a five year project to develop a commercial version of an open system architecture controller. Seimens, a member of the OSACA consortium (that also includes COMAU, NUM, Index, and other control vendors and machine tool manufacturers) is reported to have introduced an open architecture controller as a commercial product this summer.

Several U.S. firms are marketing controllers advertised to be open architectures. Some questions are: "How open is open?" "How fine a granularity is there in the open architecture?" Does open mean that the user can change a few parameters in control loops? Or does open mean that new sensors can easily be interfaced? Or that sensor values are readily accessible for archiving, or for introduction into control loops? Or that there exists a port to a local area network? Or that systems can be inexpensively upgraded? Or that software modules can be easily designed and safely introduced into the machine controller by educated users, or third party software suppliers, in order to achieve user designed functionality, such as thermal error correction, chatter control, tool ID verification, or force sensitive feedrates?

These are questions that have occupied those interested in open system architecture controllers since before the beginning of the Next Generation Controller project. They are still topics of hot debate throughout the controller builder and user community today.

The EMC

The NIST Enhanced Machine Controller (EMC) has taken the path of providing an architecture that is open at the functional module level of granularity. The operational EMC currently being developed and tested at NIST consists of a Host Machine Executive that includes a real-time operating system, surrounded by a set of Application Program Interfaces for a trajectory generator, a servo interface, a part program interpreter, an operator interface, and a PLC (Programmable Logic Controller) interface.

Support software will include a toolkit to allow a user to easily configure a system and select appropriate components. The toolkit will include software versions of selected components so that the designer will be sure that the system meets specification before purchasing any components.

The EMC is based on the NIST RCS (Real-time Control System) intelligent system architecture and all the RCS software modules will be fully documented and eventually published as open software.

EMC Goals

The goals of the Enhanced Machine Controller (EMC) project are:
1. To work with industry to develop open system interface standards that reduce costs and improve quality of machine controllers for U.S. manufacturers.
2. To demonstrate and test an open system architecture controller on machines for a retrofit and a high-end application.
3. To work with industry to foster the commercial development of open architecture controllers based on interface standards that enable agile manufacturing.

Approach

The EMC concept will be demonstrated by building controllers aimed at two different market segments: retrofit applications and high-end applications. For each controller implementation, a working system will first be developed at NIST. Then, each controller will be field tested at several beta sites in real production environments.

NIST will work closely with machine tool users, machine tool builders, and control component manufacturers. A collaboration consortium is being established though Cooperative Research and Development Agreements (CRADA). Requirements and needs of the consortium's members will be solicited through regular meetings and technical interactions during the course of the project.

Public domain open system interface standards will be developed to allow control vendors to construct a baseline controller, extend the baseline controller through the addition of new components, modify the controller to handle new applications, access low-level functions and data, and improve machine diagnostics. These interfaces will be documented, and public domain source code will be provided as part of this documentation to assist manufacturers to develop and use controllers based on these interfaces.

Benefits

Reduced costs

1. Development costs will be reduced because commonly available off-the-shelf components will be available from multiple sources. Therefore, less engineering time will be required to design systems and integrate components.
2. Training costs will be reduced because the look and feel of operator interfaces can be made user selectable by machine operators to mimic controllers with which they are familiar.
3. Maintenance costs will be lower because of multi-vendor sourcing of parts and systems, reduced lead time for components, and reduction in inventory of special components.
4. Integration costs will be reduced because sensors and software upgrades can easily be added to enhance capabilities.
5. Programming costs will be contained because a variety of legacy programming language dialects can be easily supported.
6. System and software development costs can be reduced through system configuration and software engineering tools.

Improved Performance

7. A large pool of potential developers will provide innovative technology.
8. Thermal and geometric error compensation can be added to improve accuracy.
9. Contouring rates can be increased.
10. Shorter part programs will result from using non-uniform rational B-splines (NURBS) as a representation for specifying paths.
11. Safety will be improved by allowing tool verification selection.

Progress

A preliminary version of the EMC has been implemented in the NIST Automated Manufacturing Research Facility on a vertical milling machine. A variety of tests have been performed demonstrating thermal and geometric error correction. A second version EMC is implemented on a mini-mill. This version is being used to develop generic interfaces and messaging protocols for the open system architecture.

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