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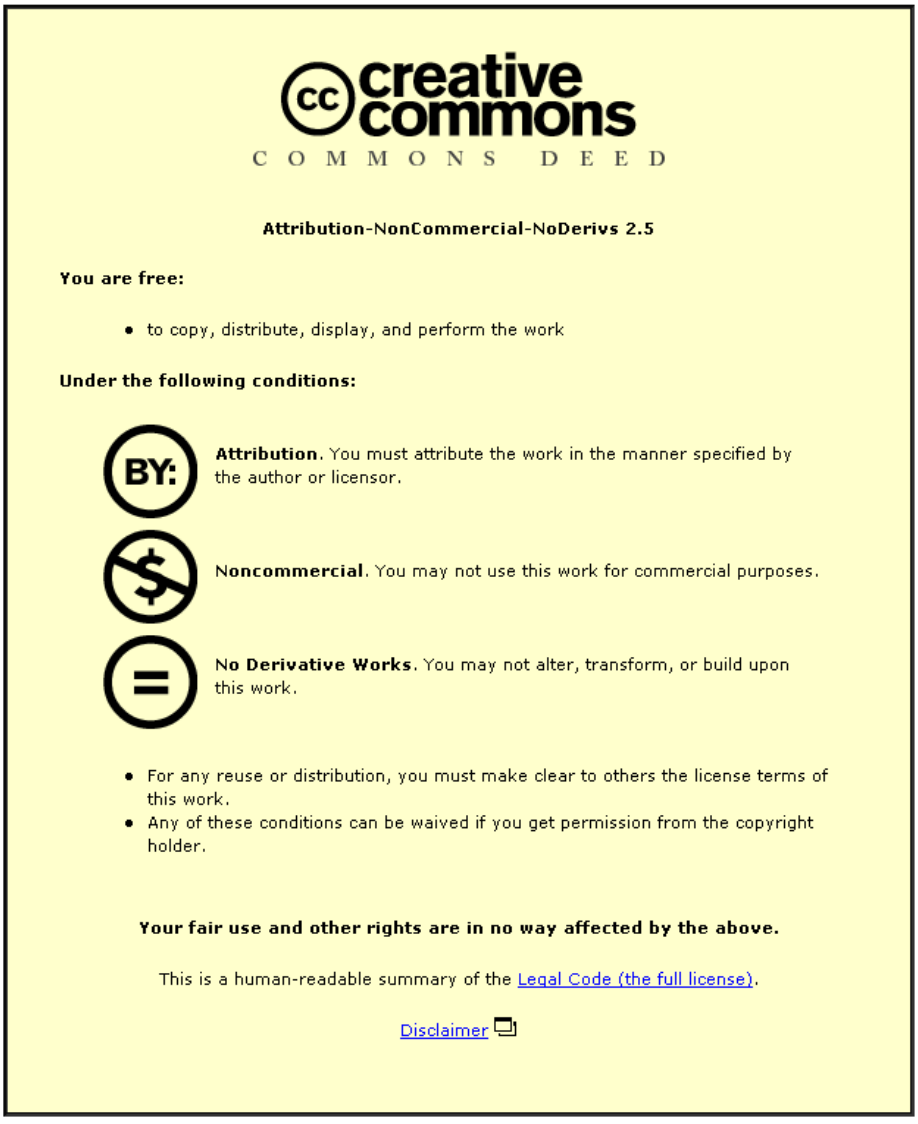

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MODULAR SYSTEMS RESEARCH GROUP

ADVANCED ARCHITECTURE

FOR

UNIVERSAL MACHINE CONTROL

Special Progress Report for ACME Conference 1991

Grant Reference:	GR/F 13492
Grant Period:	01/01/89 to 31/12/91
Principal Investigators:	Prof R.H.Weston
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	Dr P.R.Moore
	Mr R.Harrison
Collaborators:	Quin Systems
	BYG Systems
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ACME RESEARCH CONFERENCE 1991

Grant Ref No: **GR/F 13492**

Grant Title: **Advanced Architecture for Universal Machine Control**

1 THE PROBLEM

Computer control of machines is now commonplace in industrial, commercial and domestic situations. Digitally controlled equipment is available from many sources and can be configured in various ways to produce software controlled industrial machines. However, despite major technological developments in real-time control there is still a pressing need for a methodology to facilitate its widespread utilization. The variety of equipment available and range of manufacturers involved has resulted in the emergence of a great many techniques and standards relating to communication, information exchange and programming. However, where standards exist they are often de facto and non-conformity is common.

The performance capabilities of computer controlled machines should reflect the state-of-the-art with respect to the enabling technology. Progress both in technical and commercial terms can be rapid, with frequent changes in the leading suppliers. No single supplier is likely to have the expertise or resources to develop and maintain a leading position as the source of all the items needed to create integrated systems. A system builder wishing to optimize his design must therefore use proprietary building blocks from a number of different sources. However, this means that large amounts of time and effort must be allocated to the development of custom software to integrate different manufacturer's equipment. The alternative is to limit the choice to known items from a restricted range of suppliers, but the associated risks are well known. At best, the system builder is likely to be cut off from the progress of the technology and at worst he may be unable to obtain equipment support and supply.

2 PROJECT AIMS

The objective of the current research project is to create a software environment which, when used in conjunction with an appropriate selection of proprietary machine control components, will facilitate the design, programming and control of a wide range of real-time machines. The components include design aids, simulation tools and control hardware and it must be emphasised that the project is not concerned with creating more of these, which literally hundreds of different companies are already doing, but is seeking to create an environment in which existing components can be used together in a generalised and coherent way.

Creating this software environment, which we have called the Universal Machine Control (UMC) system, involves work in three main areas.

Firstly, a reference architecture is being evolved which describes the functional and hierarchical arrangement of the elements which form the run-time control system.

Secondly, modular control system elements are being created which may be viewed as the software building blocks of a UMC system. "Handlers" are a particular type of building block and are used to interface the proprietary components discussed above into the UMC environment. An important part of

the research involves investigating the common command and communication requirements which exist within particular component families. This knowledge allows the handler software to be hierarchically structured to include code which is common or generic to all the handlers for a particular component family.

Thirdly, system configuration tools are being provided. UMC gives the user freedom to configure machine systems in almost any manner, and in order to effectively utilise this freedom visualisation tools are required which aid evaluation and optimisation of alternative machine configurations.

3 RESEARCH PROGRESS

3.1 Derivation of the Reference Architecture

Current research is investigating ways of enhancing the basic UMC system created during the previous ACME project to enable its use on a wider range of machines. To accommodate these enhancements several revisions and additions have been made to the reference architecture.

An interface link has now been established between the computer systems which run UMC network and the Department's Ethernet network, which currently supports 31 workstations. This link is an important step towards providing hierarchical monitoring facilities and also towards expanding the reference architecture to cope with multiple machines. With these objectives in mind, some of the data structures have been revised, making all machine, task and handler data readily accessible to all tasks, handlers and external enquiries.

The network link means that a Sun workstation can now be used to start up and monitor UMC control software running on an OS-9 target system. Monitoring is via a new shell utility which provides information about a machine's task processes, axes, ports and synchronisation events.

3.2 Creation of Modular Control System Elements

3.2.1 Extension of the UMC Approach to Rotary Machines

To facilitate control of a wider range of machine types, UMC capabilities have been enhanced in the areas of motion definition and axis synchronization. Task level commands have been implemented for high level specification and control of programmable transmission (cam and gear) functions. This has involved making a survey of servo controller suppliers to determine common and unique controller features. A task facility has been written which allows a task program to read a cam or gear data table directly from an ASCII file. These data files can now be prepared using a commercial motion specification package called Motion (supplied by Limacon). To enable UMC users to use this package a utility was written which converts the output files produced by Motion to a format suitable for input into UMC.

The above work has also led to an examination and restructuring of the generic handler and user task library software. This included standardising the task/handler communications and moving some of the decision making from the handlers to the tasks. The main benefits of the changes are code simplification and reduction, both of which will aid future software enhancement.

3.2.2 Implementation of a Distributed Version of UMC

Work has begun on a distributed version of UMC where the control software will run on more than one processor. Delegating some of the processing away from the host control computer to local hardware potentially offers several advantages to UMC. If target machines run the handlers it frees the host from this time consuming activity, thus allowing more hardware to be incorporated within a particular machine. The target processors need not be resident within the host machine and by using a network they can be positioned physically close to the hardware devices which they control. This reduces cabling requirements, simplifies installation and can thus reduce the overall control system cost.

Work on implementing UMC distributed control began by developing an implementation methodology which identifies the importance of keeping task and handler processes to a single, standard form for use in both distributed and non-distributed systems. With this as a pre-requisite, extra interface processes have been specified which enable the task and handler processes to communicate across the network. 'Pseudo handlers' will run on the host processor, communicating 'upwards' with the tasks and 'downwards' with the network. 'Target tasks' will run on the target processors, communicating 'upwards' with the network and 'downwards' with the axis and port handlers.

3.3 Creation of Systems Configuration Tools

A suite of tools is currently being created which will assist in the design, evaluation and communication of the physical and logical machine. This software is being written around an open version of the proprietary robot modelling package "GRASP" and takes the form of a set of graphical configuration and evaluation tools.

In addition to the existing GRASP menu options, a number of new menu options have been provided which allow the machine designer to successively construct a working environment from modular building blocks. The building blocks themselves consist of one, two and three degree of freedom axis groups, where any degree of freedom can be either prismatic or revolute. Each degree of freedom has an associated set of editable kinematic parameters consisting of home position, maximum and minimum positions, maximum acceleration and maximum velocity, and can be oriented relative to any object in the workspace. The menu options allow the designer to exercise any individual axis group according to the associated parameter sets and to interactively edit and refine individual parameters. When the designer is satisfied with a particular group it can be stored to an on- line library of previously created groups, then retrieved and duplicated as required.

Current work is addressing the problems associated with synchronisation of axis groups and how the kinematic information is transferred between the modelling environment and the physical machine. The tools will also provide a means of communicating design ideas between the system designer and the customer.

4 STEPS TOWARDS EXPLOITATION

The first documented version of the UMC software system was delivered to Quin Systems in January 1990. A second version of the software is envisaged within the remaining period of the grant. This will incorporate

many of the new features described in Section 3 above and will require some work to bring the various branches of the project together. New features will include facilities to allow dynamic modification of machine structure and use of rotary axes.In addition to the existing handler types, a new multi-axis handler will be provided for the control of closely coupled axis groups. The diagnostic utilities to provide monitoring and information extraction will also be improved and enhanced.

The commercial utilisation of the UMC architecture is being forwarded on two fronts. Firstly a one year HSM-LINK contract employing two RA's is now exploiting the architecture by using it to control a gantry robot and conveyor system. The mechanical system has been developed by Cambridge Consultants Ltd - one of the industrial partners who required a more versatile control system to replace the dedicated controller currently in use. The other industrial partners are Quin Systems who are providing motion control elements and Syntel Microsystems who provide high speed digital I/O controllers and processor systems.It is hoped that a further two year contract will be entered into, with other industrial collaborators, to further exploit the architecture and use it in conjunction with ongoing projects in the HSM-LINK scheme.

The second avenue towards exploitation of UMC is concerned with crane control. A BRITE project is looking at new ways of controlling cranes. LOT's involvement in this was originally concerned with network communications only but there is now a strong possibility that the UMC architecture will be chosen as the overall control platform.

5 PUBLICATIONS (OVER THE GRANT PERIOD)

5.1 Conference Papers/Presentations

(1) "Machine control with advanced architectures" P.R.Moore, R.H.Weston, R.Harrison, A.H.Booth and M.Jackson - IASTED Int. Symp. on Mini & Microcomputers & their Applications, Zurich, June 89.

(2) "Advanced concepts in machine design through the adoption of mechatronics technology in modular machines" P.R.Moore, M.R.Jackson, R.H.Weston, R.Harrison and A.H.Booth- Mechatronics '89 Conf., Lancaster Uni., Sept.89.

(3) "The use of distributed programmable actuators for flexible assembly" R.Harrison, J.Pu, R.H.Weston and P.R.Moore – l0th Int. Conf. on Assembly Automation, Tokyo, Oct 20-23 1989.

(4) "A machine control shell for next generation manufacturing machines" R.H.Weston, R.Harrison, P.R.Moore and A.H.Booth - 28th Matador Conf., CIM FMS and Robotics Session, UMIST, Apr.90.

(5) "The role of programmable automation" R.H.Weston - chair address at the IMechE Seminar on "Programmable Modular Automation", Birmingham, April 1990.

(6) "New concepts in programmable automation" R.H.Weston - Proc. IMechE Seminar on "Control in Process Industries", Solihull, May 1990.

(7) "Modular Production Systems" G.Rogers and R.H.Weston - Proc. Int. Conf. on "Mechatronics- Designing Intelligent Machines" Camb., Sept.90.

(8) "Open architectures: a requirement of modern highly flexible manufacture" R.H.Weston - Proc. Mechatronics Res. Con£. SERC/IMechE, St Albans, Sept.90.

(9) "An emulation system for machine design and control" X.Yan, K.Case and R.H.Weston - Proc. 11th Int. Con£. on Assembly Automation, SME, Detroit, USA. Nov 1990.

(10) "An open control architecture for assembly automation" P.R.Moore, R.H.Weston, A.H.Booth and R.Harrison - Proc. 11th Int. Con£. on Assembly Automation, SME, Detroit, USA. Nov 1990.

5.2 Publications in Academic Journals

(1) "Universal machine control system primitives for modular distributed manipulator systems" R.H.Weston, R.Harrison, A.H.Booth and P.R.Moore - Special Issue on Robotics. Int. Journal Prodn. Research, Feb.89.

(2) "A new approach to machine control" R.H.Weston, R.Harrison, A.H.Booth and P.R.Moore - CAE Journal, Feb.89.

(3) "A new concept in machine control" R.H.Weston, R.Harrison, A.H.Booth and P.R.Moore - Computer Integ. Manu£. Sys. May 1989.

5.3 PhD Theses

(1) "New concepts for machine control systems" R.Harrison - PhD thesis, near completion.

5.4 Contributions to Books

(1) "Software design of distributed single-axis motion controllers for industrial applications" R.H.Weston, J.Pu, R.Harrison and P.R.Moore - Microprocessing and Microprogramming, Vol 27, North Holland, 1989, pp53-60.

5.5 Publications in Preparation

(1) "Architecture/Software design for machine control" J.Pu, R.Harrison, R.H.Weston and P.R.Moore - submitted for publication to Journal of Advanced Manu£. 1990.

(2) "Fieldbus for manufacturing users" P.R.Moore and N.Armstrong - currently being written for publication.

(3) "The logical and geometric modelling of a universal machine control reference architecture" R.Doyle and K.Case - submitted to Eurotech Direct '91 run by the IMechE.