Productivity Management of Flexible Manufacturing Systems Using Advanced Parallel Computer Architecture

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ABSTRACT: *This paper outlines the aspects of architectural design of an advanced parallel computer system applicable to flexible manufacturing systems (FMS). The proposed architecture is based on an advanced parallel computer network utlising combinations of star multiring-multibus configuration. Incorporating parallel processing network in FMS architecture fulfils the productivity management requirements as well as improving speed, accuracy, reliability, performance of the system and quality of products. Fault Tolerance, flexibility and self-reconfiguribility of the overall system is further improved by incorporating artificial intelligence and expert system in the body of the database management system.*

Keywords: Parallel processing, flexible manufacturing, engineering management, system architecture.

INTRODUCTION

In the increasing competitive world of advanced flexible manufacturing, online process control requirements are becoming ever more demanding in terms of fast processing power and high accuracy. The present computing power of many existing automation control systems does not satisfy these highly desirable engineering parameters.

To fulfil this requirement, one common approach is to implement a faster microprocessor, or for some applications a faster microcontroller. In order to satisfy this condition, system designers either have adopted a microarchitecture technology as a design tool that includes super-scaling and super-pipelining features, or have increased the clock frequency.

Alternatively, use of a parallel processing system could equally serve the same purpose and consequently, parallel processing systems with a wide range of architectures are being developed and implemented in many areas of manufacturing. In the light of these requirements, the parallel processing architecture described in this paper has been formulated. In the proposed architecture, as described in this paper, parallel processing is in fact implemented via a dual approach involving parallelism within the microarchitecture of the microprocessor itself, and also via the architectural design of the overall system. The former implements a miniature architecture whereas the latter implements a master-slave multi-bus architecture within the high performance computer architecture.

In order to further increase the processing power of any parallel processing system, within the hardware and software design limitations one could increase the number of the processing elements of such a system. Nevertheless, as the number of processors in any parallel processing system increases, undoubtedly the complexity of the system both from hardware as well as software point of view would increase. This in turn would enhance the possibility of both transient and permanent failures and pose serious reliability problems. One solution is to build redundant communication paths and provide spare units and introduce dynamic reconfiguration capability into network design. The performance and fault-tolerance of the system can further be improved if a distributed knowledge-based system is incorporated within the database management of the system architecture. Hence the system would be capable of fault recovery, instead of permanent processor failures continually causing system failures. [1, 2]

Applications of Parallel processing system in FMS

Advanced Flexible Manufacturing Systems (AFMSs) in general can be defined as fast and reliable computer-controlled configurations of a group of machines having tool handling capabilities served by automated materials handling systems. These systems can be reconfigured to manufacture a wide variety of parts and can be used in discrete batch production systems such as those used in automotive, aerospace and tool industries [3]. To even further improve the performance and efficiency of such delicate operations, the system designers of

AFMS can incorporate some degree of parallelism in conjunction with distributed operating system as well as multitasking and multiuser facility within the overall architecture of the system. Some industrial applications in military and space programs can not tolerate any down time due to malfunctioning of the parallel processing system. To overcome this problem and increase the fault tolerance of the system one would incorporate redundant units that could be replaced upon existence of the fault which can be detected through self-testing carried out by the applications of neural networks. [4]

Architectural design of the proposed system

Automation of physical production processes on the shopfloor is a key component of the computer integrated manufacturing strategy related to parallel processing system design for improving productivity.

The use of automation and multi-industrial robots is desirable in areas such as arc welding, Integrated Circuit (IC) manufacturing and Printed Circuit Board (PCB) assembly industries. Due to the need for continued improvement and prevention of increase in labour costs on one hand and lack of available qualified expert manpower on the other hand, inevitably there is strong incentive to improve engineering parameters. This include, improvements on quality, reliability, accuracy and performance of automated manufacturing systems using a parallel processing system in conjunction with a multi robot facility. [5, 6]

The proposed architecture in this paper is based on the multi-bus, star-multi-ring parallel processing system architecture. In this organisation which utilises the principle of master-slave arrangement, the star node acts as a master processor and the satellite computers attached to the ring would form the slave processors.

In the proposed configuration the first level is the master processor operating at 650 Mhz, clock frequency, 32-bit microprocessor with two caches for data and code. This processor uses the principle of super-scaling and pipelining microarchitecture in order to implement the internal parallel processing approach for fast data transfer and data processing. Its addressing capability is minimum of 4 Gigabytes and the processor incorporates up to 4 million transistors in its design. All the necessary semiconductor memories, including RAM & EAPROM are included to satisfy design requirements. The slave processor can also be of 32-bit in nature but can be operated at the lower clock frequency if need arises. The overall system is then connected to the required peripherals that include printer, colour display, keyboard, floppy disk unit cassette unit and plotter scanner if needed.

Failure to use multi-ring, multi-bus in contrast to single-ring, single-bus would result in significant down time due to the existence of a fault in the system highway. In most production environments down time due to single machine tool malfunction or communication failure could result in catastrophic failure. In our proposed architecture failure of any unit or path would reduce the performance of the overall architecture but the system is not subject to total failure [6].

Within the level 2, one of the slave processors performs as cell control computer and controls the PLC. The PLC has a central role and it is linked with all stations (NC machine, robot, conveyor) via parallel digital inputs/outputs and linked with the cell controller via RS 232 serial communication link. The designed FMS includes CNC Lathe, milling centre, and robots. If the driving capability of the overall system permits it can be further interfaced to additional automated sub-units. The FMS control system receives manufacturing instructions and necessary information via the Manufacturing Message Specification (MMS) variable access services. The MMS defines building blocks for generation of an abstract of a manufacturing device. It also specifies services which facilitate work with these building blocks. The individual subsidiary units including NC, PLC are tasked and supervised by the supervisory management program of the FMS control system via the MMS and AI applications. This involves a protocol stack conversion between the NC system and the FMS control system. Thus the control systems have access to a file server which is responsible for the central data organisation.

5. OPERATION OF THE IMPLEMENTED ARCHITECTURE

One of the main applications of the parallel processing system is to increase the computational power of the system compared to the uniprocessor system. To achieve this, the implemented configuration is outlined. In this architecture the bidirectional nature of the direct communication links between the master processor and slave processors and consequently the subsidiary functional units of the overall system allows receiving and transmitting of information in a real time environment. In addition, due to the multiuser and multitasking nature of the hardware and software of the master and slave processors fast and reliable access to all subsidiary units can take place.

The operation of the implemented architecture can best be explained in terms of dividing the main manufacturing task into independent sub-tasks and loading them into the main memory of the master processor. The master processor then allocates each sub-task into the memory buffer of each slave processor. From this point onwards each subsidiary unit functions independently and the result of each sub-task is transferred to the master processor via slave processor. Upon completion of each sub-task subsidiary units send an interrupt

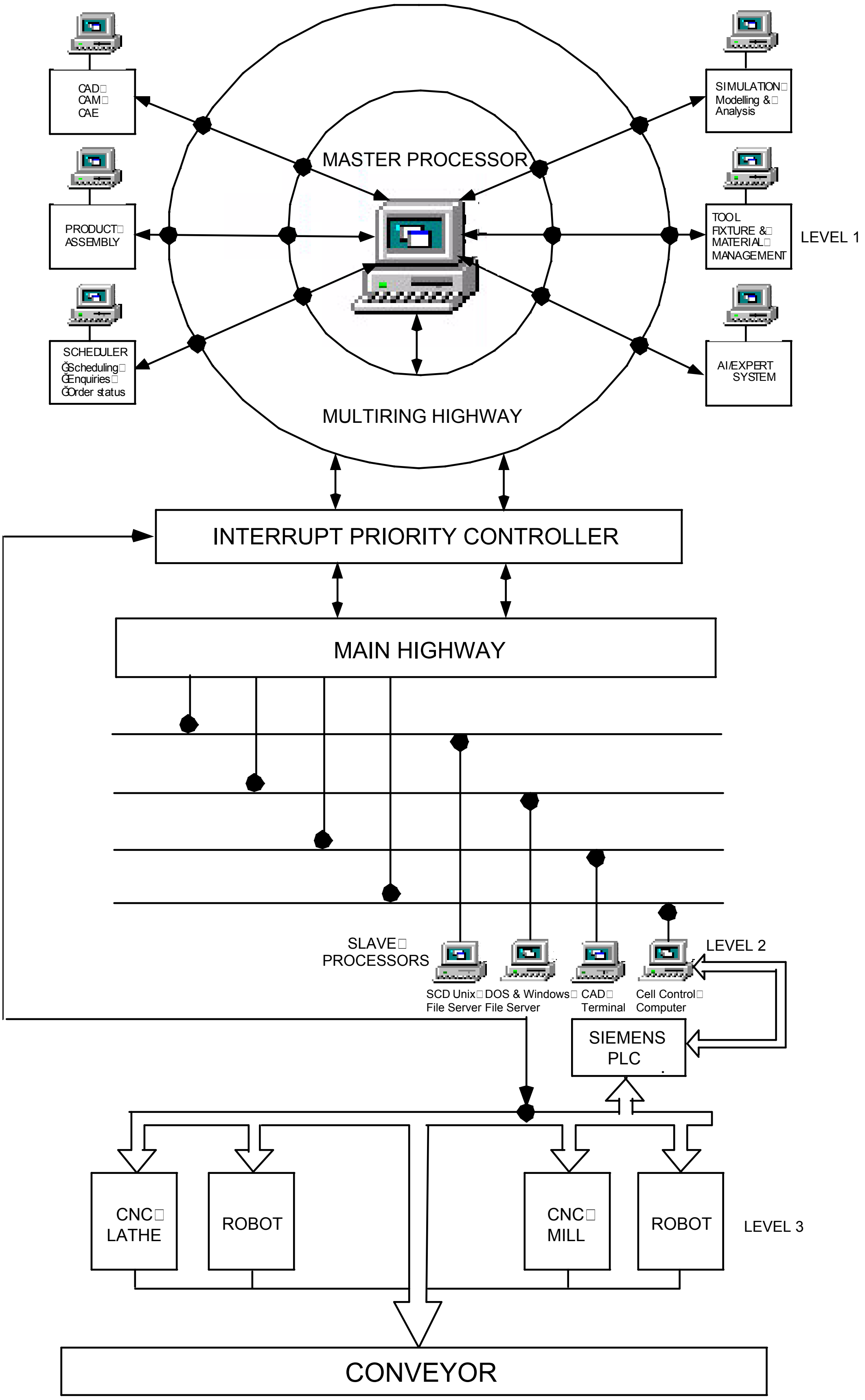

Figure 1: Multi ring multi bus parallel computer architecture for an advanced FMS configuration

request signal to the slave processor and that is forwarded to the master processor for allocation of a new sub-task for processing purpose. This process of allocating sub-tasks will continue until the task is completed. Upon existence of simultaneous interrupt and their generation by the subsidiary units an interrupt priority controller will allocate priority to the slave processors and they receive service in time.

Within the FMS while subsidiary units are performing their tasks, master processor can perform other functions and responsibilities. These include:

- CAD/CAM (design, drafting, NC tool path)
- Product Assembly (feasibility check for product)
- Schedular (scheduling, enquires, order status.)
- Simulation (modeling & analysis)
- Tool fixture & material management (availability and status check).

During this period the main function of the slave processors include but not limited to :

- SCD Unix (file server, DOS and Windows),
- File server, CAD terminal and cell controller which mainly involves the PLC controller.

For a given task, depending on the machine status, the PLC has to make decision based on the information provided by the master processor on how to start and co-ordinate the whole system in a correct sequence of operation and feed back information relating to the status of the whole system for future reference to the master processor.

CONCLUSIONS

Advanced microprocessors and microcontrollers are playing a dominant role in the development of many new design methodologies and strategies for modern industrial applications. This contribution is very evident in the area of Flexible Manufacturing Systems. The architecture put forward in this paper, for parallel processing control of a multiple-robot system, provides for improvements in production efficiencies within manufacturing engineering environments. Among the most important features of the proposed configuration are operational speed increases arising from parallel processing capabilities, improved accuracy, enhanced system automation, greater system flexibility and cost reductions which all falls into an efficient engineering management framework. In order to further improve the system performance, knowledge-based system approaches can also be incorporated within the master processor. This option will enhance the system's capabilities in relation to self testing diagnostics, and system self reconfigurability.

The proposed system also benefits from ease of implementing modifications and additions to the system with minimum disruption, due to the ring-type architectural configuration.

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