Artificial Intelligence Applications and Innovations

Edited by
Max Bramer and Vladan Devedzic

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Foreword

The papers in this volume comprise the refereed proceedings of the First International Conference on Artificial Intelligence Applications and Innovations (AIAI-2004), which formed part of the 18th World Computer Congress of IFIP, the International Federation for Information Processing (WCC-2004), in Toulouse, France in August 2004.

The conference is organised by the IFIP Technical Committee on Artificial Intelligence (Technical Committee 12) and its Working Group 12.5 (Artificial Intelligence Applications). Further information about both can be found on the website at http://www.ifiptc12.org.

A very promising sign of the growing importance of Artificial Intelligence techniques in practical applications is the large number of submissions received this time - more than twice the number for the Artificial Intelligence stream of the last World Computer Congress two years ago. All papers were reviewed by at least three members of the Programme Committee. The best 40 were selected for the conference and are included in this volume. The international nature of IFIP is amply reflected in the large number of countries represented here.

The conference also featured an invited talk by Eunika Mercier-Laurent and a Symposium on Professional Practice in Artificial Intelligence, which ran alongside the refereed papers.

I should like to thank the joint conference chairs, Professor John Debenham and Dr. Eunika Mercier-Laurent and my co-program chair Dr. Vladan

Devedzic for all their efforts in organising the conference and the members of our programme committee for reviewing an unexpectedly large number of papers to a tight deadline. I should also like to thank my wife Dawn for her help in editing this volume of proceedings.

This is the first in a new series of conferences dedicated to real-world applications of AI around the world. The wide range and importance of these applications is clearly indicated by the papers in this volume. Both are likely to increase still further as time goes by and we intend to reflect these developments in our future conferences.

Max Bramer
Chair, IFIP Technical Committee on Artificial Intelligence

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ARTIFICIAL INTELLIGENCE SYSTEMS IN MICROMECHANICS

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Abstract: Some of the artificial intelligence (AI) methods could be used to improve the automation system performance in manufacturing processes. However, the implementation of these AI methods in the industry is rather slow, because of the high cost of the experiments with the conventional manufacturing and AI systems. To lower the experiment cost in this field, we have developed a special micromechanical equipment, similar to conventional mechanical equipment, but of much smaller size and therefore of lower cost. This equipment could be used for evaluation of different AI methods in an easy and inexpensive way. The proved methods could be transferred to the industry through appropriate scaling. In this paper we describe the prototypes of low cost microequipment for manufacturing processes and some AI method implementations to increase its precision, like computer vision systems based on neural networks for microdevice assembly, and genetic algorithms for microequipment characterization and microequipment precision increase.

Key words: artificial intelligence, micromechanics, computer vision, genetic algorithms

1. INTRODUCTION

The development of AI technologies opens an opportunity to use them not only for conventional applications (expert systems, intelligent data bases [1], technical diagnostics [2,3] etc.), but also for total automation of mechanical manufacturing. Such AI methods as adaptive critic design [4,5], adaptive fuzzy Petri networks [6,7], neural network based computer vision systems [8-12], etc. could be used to solve the automation problems. To check this opportunity up, it is necessary to create an experimental factory with fully automated manufacturing processes. This is a very difficult and expensive task.

2. MICROEQUIPMENT TECHNOLOGY

To make a very small mechanical microequipment, a new technology was proposed [13,14]. This technology is based on micromachine tools and microassembly devices, which can be produced as sequential generations of microequipment. Each generation should include equipment (machine-tools, manipulators, assembly devices, measuring instruments, etc.) sufficient for manufacturing an identical equipment set of smaller size. Each subsequent equipment generation could be produced by the preceding one. The equipment size of each subsequent generation is smaller than the overall size of preceding generation.

The first-generation microequipment can be produced by conventional large-scale equipment. Using microequipment of this first generation, a second microequipment generation having smaller overall sizes can be produced.

We call this approach to mechanical microdevices manufacturing MicroEquipment Technology (MET) [15].

The proposed MET technology has many advantages:

(1) The equipment miniaturization leads to decreasing the occupied space as well as energy consumption, and, therefore, the cost of the products.

(2) The labor costs are bound to decrease due to the reduction of maintenance costs and a higher level of automation expected in MET.

(3) Miniaturization of equipment by MET results in a decrease of its cost. This is a consequence of the fact that microequipment itself becomes the object of MET. The realization of universal microequipment that is capable of extended reproduction of itself will allow the manufacture of low-cost microequipment in a few reproductive acts because of the lower consumption of' materials, energy, labor, and space in MET. Thus the miniaturization of equipment opens the way to a drastic decrease in the unit cost of individual processing.

At a lower unit cost of individual micromachining, the most natural way to achieve high throughput is to parallelize the processes of individual machining by concurrent use of a great quantity of microequipment of the same kind. Exploitation of that great number of microsized machine-tools is only feasible with their automatic operation and a highly automated control of the microfactory as a whole. We expect that many useful and proved concepts, ideas and techniques of automation can be borrowed from mechanical engineering. They vary from the principles of factory automation

(FMS and CAM) to the ideas of unified containers and clamping devices and techniques of numerical control. However automation of micromanufacturing has peculiarities that will require the special methods of artificial intelligence.

3. AI BASED CONTROL SYSTEM FOR MICROMECHANICAL FACTORY

Let us consider a general hierarchical structure of the automatic control system for a micromechanical factory. The lowest (first) level of the system controls the micromechanical equipment (the micro machine-tools and assembly manipulators), provides the simplest microequipment diagnostics and the final measurement and testing of production. The second level of the control system controls the devices that transport workpieces, tools, parts, and the whole equipment items; coordinates the operation of the lowest level devices; provides the intermediate quality inspection of production and the more advanced diagnostics of equipment condition. The third control level contains the system for the automatic choice of process modes and routes for parts machining. The top (fourth) level of the control system performs detecting of non-standard and alarm situations and decision making, including communication with the operator.

We proceed from the assumption that no more than one operator will manage the microfactory. It means that almost all the problems arising at any control level during the production process should be solved automatically and that operator must solve only a few problems, that are too complex or unusual to be solved automatically.

Since any production process is affected by various disturbances, the control system should be an adaptive one. Moreover, it should be self-learning, because it is impossible to foresee all kinds of disturbances in advance. AI that is able to construct the self-learning algorithms and to minimize the participation of operator, seem to be especially useful for this task. AI includes different methods for creating autonomous control systems. The neural classifiers will be particularly useful at the lowest level of the control system. They could be used for the selection of treatment modes, checking of cutting tool conditions, control of the assembly processes, etc. They allow to make the control system more flexible. The system will automatically compensate for small deviations of production conditions, such as the change of cutting tool shape or external environment parameters, variations in the structure of workpiece materials, etc. AI will permit to design self-learning classifiers and should provide the opportunity to exclude the participation of human operator at this level of control.

At the second control level, the AI system should detect all deviations from the normal production process and make decisions about how to modify the process to compensate for the deviation. The compensation should be made by tuning the parameters of the lower level control systems. The examples of such deviations are the deviations from the production schedule, failures in some devices, off-standard production, etc. At this level the AI system should contain the structures in which the interrelations of production process constituents are represented. As in the previous case, it is desirable to have the algorithms working without the supervisor.

The third control level is connected basically with the change of nomenclature or volume of the production manufactured by the factory. It is convenient to develop such a system so that the set-up costs for a new production or the costs to change the production volume should be minimal. The self-learning AI structures formed at the lowest level could provide the basis for such changes of set-up by selection of the process parameters, the choice of equipment configuration for machining and assembly, etc. At the third control level the AI structures should detect the similarity of new products with the products which were manufactured in the past. On the basis of this similarity, the proposals about the manufacturing schedule, process modes, routing, etc. will be automatically formed. Then they will be checked up by the usual computational methods of computer aided manufacturing (CAM). The results of the check, as well as the subsequent information about the efficiency of decisions made at this level, may be used for improving the AI system.

The most complicated AI structures should be applied at the top control level. This AI system level must have the ability to reveal the recent unusual features in the production process, to make the evaluation of possible influence of these new features on the production process, and to make decisions for changing the control system parameters at the various hierarchical levels or for calling for the operator's help. At this level, the control system should contain the intelligence knowledge base, which can be created using the results of the operation of the lower level control systems and the expert knowledge. At the beginning, the expert knowledge of macromechanics may be used.

At present many methods of AI are successfully used in the industry [16,17]. They could be used also for micromechanics. But the problems of fully automated microfactory creation can not be investigated experimentally in conventional industry because of the high cost of the experiments. Here we propose to develop low cost micromechanical test bed to solve these problems.

The prototypes of the first generation microequipment are designed and examined in the Laboratory of Micromechanics and Mechatronics, CCADET, UNAM. The prototypes use adaptive algorithms of the lowest level. At present more sophisticated algorithms based on neural networks and genetic algorithms are being developed. Below we describe our experiments in the area of such algorithms development and applications.

4. DEVELOPMENT OF MICROEQUIPMENT PROTOTYPES AND ADAPTIVE ALGORITHMS

4.1 Micromachine Tools

The developed prototype of the first generation micromachine tool is shown in Fig. 1. We have been exploiting this prototype for approximately four years for experimental work and student training.

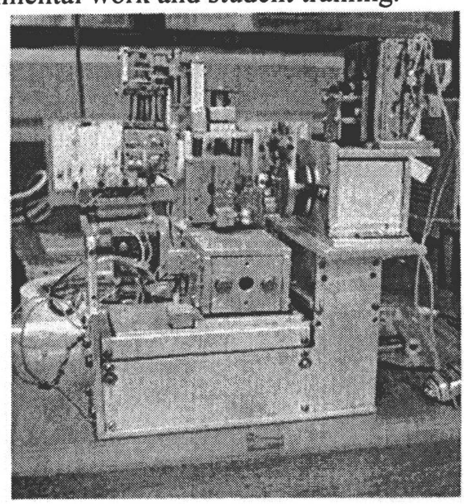

Figure 1. The developed second prototype of the first generation of micromachine tool.

This prototype of the micromachine tool has the size 130×160×85 mm^3 and is controlled by a PC. The axes *X* and *Z* have 20 mm of displacement and the *Y*-axis has 35 mm of displacement; all have the same configuration. The resolution is 1.87 μm per motor step.

4.2 Micromanipulators

At present, in the Laboratory of Micromechanics and Mechatronics, CCADET, UNAM the principles, designs and methods of manufacture of micromachine tools and micromanipulators corresponding to the first