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Research at the MEC

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SUMMARY
This article focuses on research at the MEC, giving three examples of areas of concerted activities at the Centre: intelligent manufacturing, concurrent engineering and rapid manufacturing.

KEYWORDS: Manufacturing technology; Automation; Control; Artificial intelligence

1. INTRODUCTION

The award-winning Manufacturing Engineering Centre (MEC) forms part of Cardiff University, which dates back to 1883 and is one of Britain's major universities. The 70-strong Centre has an international reputation for its leading-edge research in advanced manufacturing and information technology spanning a broad spectrum of subjects.

The work of the MEC has received overwhelming endorsement from sponsors and supporters in the private and public sectors. Since 1996, the Centre has secured over £20M in grants and contracts and has attracted more than 200 industrial partners. For its many achievements, the MEC has been recognised as a Centre of Expertise by the Welsh Development Agency and has received the DTI's First Prize for University/lndustry Partnership and the Queen's Anniversary Prize for Higher and Further Education.

2. INTELLIGENT MANUFACTURING

Work in this area has been ongoing since the inception of the Centre almost ten years ago. It covers research on Quality Systems and on Process Modelling and Control Systems. This work has been widely reported in learned journals and books, examples of which are listed in the References Section.

Intelligent quality systems

This research has received support from the EPSRC, the DTI, the EC and industry. It has involved nine research staff, teaching company associates and Ph.D. students at the Centre in addition to academic staff and industrial collaborators. The Centre has tackled difficult quality problems presented by five companies from different industries in the UK, Belgium, Finland and Germany involving automotive, home appliances, textile, wood and steel production.

The Centre has developed algorithms and systems based on neural networks and other intelligent pattern recognition techniques for high-speed inspection of a diverse range of products including combustion engine valve stem seals, microwave oven doors, steel sheets, veneer boards and fabric. In addition to generating new techniques (for example, see references [1–8]), the work has produced real practical systems for industry. The original systems are still operating successfully and have been replicated in the companies for whom they were developed. They have also attracted the interest of potential users from France, Italy, Japan and the USA.

Another major part of the work has been concerned with systems for effective quality monitoring and feedback. The Centre has focused on systems using expert statistical process control (SPC) techniques. A product is XPC which is an intelligent knowledge-based SPC system that employs a combination of expert-system techniques and neural networks for effective process monitoring and control. XPC has been proven in the real-time control of a rubber injection moulding process where, using its intelligent facilities, it has shown itself able to detect signs of incipient faults and feedback this information in a timely manner to ensure the integrity of products.

The results of this research have been published in a book[9] and in several journal papers.[10–16] Paper [12] was awarded the Institution of Mechanical Engineers' Sir Joseph Whitworth Prize for Manufacturing Engineering.

Using the research results obtained, one of the industrial partners (Federal Mogul Sealing Systems) has achieved some £900K in additional profits. This has encouraged other companies to form partnerships with the Centre. These include Mitutoyo and IBS who have established 'generic partnerships' by endowing substantial facilities at the Centre for use in a wide range of quality-related projects (Figure 1).

Intelligent process modelling and control systems

This research has received substantial funding from the EPSRC, the EC and industry. The Centre's partners operate in a number of industrial sectors in the UK and Europe including computer manufacture, telecommunication technology, pharmaceuticals, transport, and energy and petroleum production.

The thrust has been to develop novel intelligent systems techniques based upon fuzzy logic, neural networks and

Fig. 1. The Mitutoyo Metrology Centre at the MEC.

genetic algorithms for the effective modelling and control of non-linear processes and complex machines. This work has successfully addressed a diverse range of problems: control of a high-speed metal forming system; modelling and identification of faults in computer hard-disk drive systems; modelling and control of petroleum distillation columns; modelling and control of antibiotic production systems; control of hydraulic actuation systems; control of alignment of fibre optic couplings.

The Centre's work has been adopted profitably by industry. For example, IBM, which has incorporated a neural-network-based fault identification system developed at the MEC in their hard-disk drive manufacturing plant, has been able to identify faults more reliably than with human operators. Using the Centre's evolutionary fuzzy logic controller, Hewlett-Packard has been able to produce fibre optic devices for telecommunication systems more speedily and with better performance than previously achievable.

Generic knowledge arising from this research area includes novel types of recurrent and self-organising neural networks, genetic algorithms for small chromosome populations and fuzzy logic backward reasoning methods.[17–33] References [21] and [33] are monographs that both had to be reprinted immediately after first publication due to high demand. Reference [21] on neural control is now in its fourth printing without needing revision. In a rapidly moving field such as neural computing, the lasting nature of the work is a mark of considerable achievement.

3. CONCURRENT ENGINEERING

Research in this area has also been long established at the Centre, originating from an interest in design as well as the intelligent manufacturing research described above. This work has received substantial support from the EPSRC, the EC, the Higher Education Funding Council for Wales, the Welsh Assembly and industry. It has to date involved thirty-two research staff, Ph.D. students and visiting researchers at the Centre.

The focus of the work is the effective use and management of information to reduce the time-to-market for new products, thereby improving industrial competitiveness. This research has addressed the problems of assisting the designer through the provision of advanced manufacturing-related information and of supporting the manufacturing engineer with information derived from the design stage. The Centre's work has also covered the extraction or 'mining' of useful information from large manufacturing databases, the organisation of virtual teams of designers located at different sites and the management of engineering changes in such a concurrent environment. Recently, the Centre has been devoting a large amount of effort to Internet-based multimedia systems for supporting users of complex products. In particular, work has been conducted on methods of developing electronic product manuals concurrently with the design of the product.

Notable collaborators in this area are Daimler-Chrysler, SAP, Siemens, Welsh Water and Allied Steel and Wire. As two of the Centre's 'generic research partners', Siemens and SAP (the producer of R/3, the market-leading enterprise information management software) have established substantial facilities at the Centre to support its work (Figure 2). Amongst the multinational partners recently attracted to the Centre are Aerospatiale, Nokia and Schneider who have joined new initiatives to obtain EC Framework 5 funding for further research on intelligent product support.

So far, results have included: a new approach to concurrent engineering that facilitates simultaneous product and process design, methods for structuring and re-using manufacturing information, new machine learning and data mining algorithms and a new methodology for creating and maintaining product support systems using integrated product data and knowledge-based and hypermedia techniques.[34–44]

The output of the intelligent product manual research has already been successfully applied in industry as part of the Centre's technology transfer programme. Other results being used industrially include an incremental inductive learning algorithm which is being incorporated in a commercial data mining package produced by MIT, a company based in Aachen. The algorithm has also been adopted in nuclear fusion research at General Atomics in San Diego.

4. RAPID MANUFACTURING

This research is one of the Centre's newer areas. It began at the Centre four years ago and has experienced a rapid expansion with substantial funding from the EPSRC, the EC, the Welsh Assembly and industry. To date, twenty-five research staff, Ph.D. students and visiting researchers have

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Fig. 2. The Right-Honourable Peter Haines MP, Welsh Office Minister, opens the Siemens Automation and Drives Laboratory at the MEC.

been engaged in the research. State-of-the-art facilities totalling more than £6M in value have been installed at the Centre to support its work (Figures 3–6).

The work, which has links to the concurrent engineering research described above, addresses the *compression of product development time scales using rapid prototyping technology*. Both virtual and physical prototyping are employed. The physical prototyping research has a strong practical bias and underpins the Centre's technology transfer activities in this area.

The research topics covered have included: control of virtual humans on a prototype production line, simulation of robotic and human prehension, orientation of parts in stereolithography (SLA), product design for SLA, characteristics of selective laser sintering (SLS), prediction of SLS build time, and rapid tooling techniques.

This work has involved partners from non-engineering disciplines (for example, the School of Psychology at Cardiff University and the Department of Neuroscience at the University of Paris) as well as the largest number and widest range of industrial collaborators. The latter have included technology suppliers (for instance, Silicon Graphics, Parametric Technology, Tecnomatix, 3D Systems, DTM, Stratagem and DMG), large users (such as Land Rover and BOC) and numerous SMEs (for example, Iota Sigma, Atlantic Plastics, GX and Methods Centreline).

The following are examples of practical results derived from the research at the Centre and used to assist its

Fig. 3. HRH Prince Philip visits MEC's Rapid Prototyping Laboratory.

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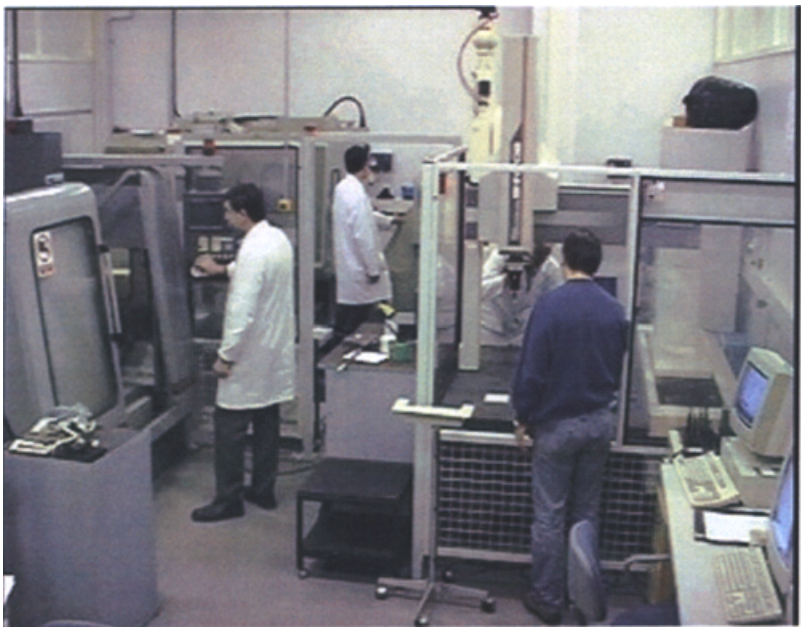

Fig. 4. MEC's Computer-lntegrated Manufacturing Laboratory.

Fig. 5. CAD Laboratory at the MEC.

partners: techniques for providing kinesthetic feedback to humans operating in a virtual world, methods of improving the efficiency of the SLA process, a detailed understanding of the capabilities of SLS, software for SLS build time and cost prediction, methods of finishing Rapid Steel parts, and hybrid techniques for rapidly producing plastic injection tooling.

Further information on this area of the Centre's work is given in its publications, including references [45–51], of which Paper [48] won the Thomas Stephen Group Prize and Paper [49], the Sir Joseph Whitworth Prize, from the Institution of Mechanical Engineers.

5. CONCLUSION

This paper has summarised three main areas of research at the MEC. It can be seen that the Centre has invested sustained research efforts in many projects relevant to different user communities. The information given on the achievements of the MEC strengthens its Queen's Anniversary Prize citation that, "using its expertise in manufacturing engineering, the Centre has built up an exceptional programme of support for firms providing first-class research and practical technology transfer."

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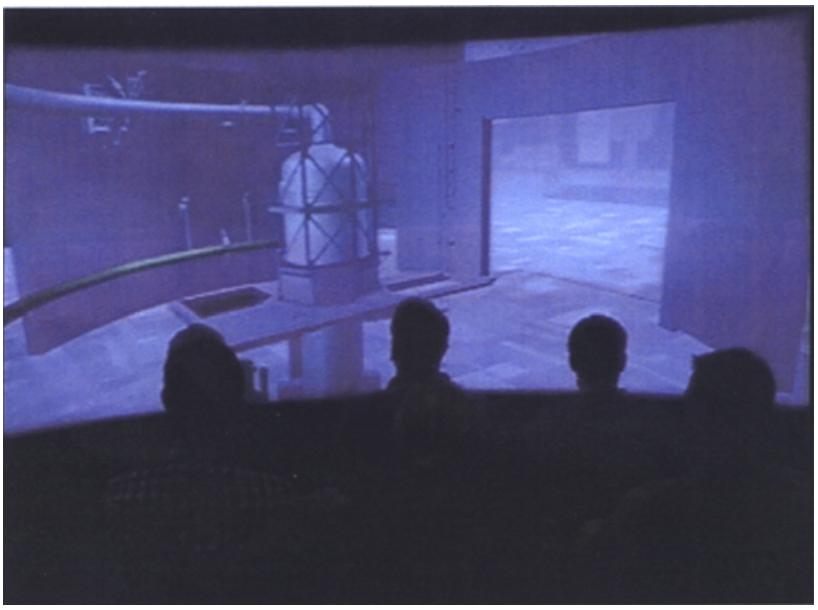

Fig. 6. MEC's Virtual Reality Theatre.

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