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# BRIDGING THE GAP BETWEEN INDUSTRIAL AND SCIENTIFIC COMMUNITIES FOR THE NEXT GENERATION MANUFACTURING SYSTEMS

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Abstract: The paper will provide an overview of the main scope, objectives and future actions of the worldwide IMS Network of Excellence (NoE). The main aim of the IMS-NoE is to create the proper environment to group academic and industrial communities for developing co-operation links, for co-ordinating current and future research, for facilitating knowledge transfer and dissemination of project results and for assessing the technological development and expertise in Europe in the key areas of design, engineering and control of manufacturing systems in the extended enterprise. *Copyright ã 2002 IFAC*

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## 1. INTRODUCTION

Intelligent developments in the field of manufacturing systems are at the core of many European business activities. Accordingly, intelligent manufacturing systems have a great potential to increase the competitiveness of today's Enterprise Networks and make the manufacturing and the provision of goods and/or services more user-friendly, ubiquitous as well as reducing the related costs.

As various parts of the enabling infrastructure for intelligent manufacturing systems are developed by different providers, there is a danger of ending up with a number of different implementations that are incompatible and which effectively prevent interoperability of manufacturing systems within future enterprise environments. It is therefore paramount to work towards a harmonized development that will safeguard interoperability and will benefit enterprises in selecting and designing adequate approaches for future (intelligent) manufacturing infrastructures (Filos and Banahan, 2001).

The IMS-Network of Excellence (IMS-NoE, 2001), funded within the IST program, will work towards these goals by facilitating the discussion between a number of actual and upcoming developments and perspectives - such as the digitalization of the product as well as of the factory, the role and health of humans in future production environments, sustainability of products and processes - and by supporting the development of a consensus and common approach among them. In parallel, IMS-NoE will also raise awareness and provide insight for researchers and practitioners involved in the development and provision of tomorrow's manufacturing systems.

The IMS-NoE aims at providing a well-coordinated and effective support infrastructure throughout Europe, and through collaborations with other non-EU Networks also at IMS inter-regional level, in order to share and exchange the latest researches and developments in the *key areas of design, engineering and control of manufacturing systems in the extended enterprise.*

Specifically, the main medium-term goals are:

- to stimulate new project proposals in the field of IMS, and by this way to strengthen the European involvement in the world-wide IMS community;
- to provide a stimulating and high-quality forum for discussion, exchange of ideas, planning for collaboration and debates about trends, research and further developments of IMS concepts;
- to provide a *Web-based Benchmarking Service* for the research and industrial community;
- to provide a *Technology Observatory* to elaborate and update at regular intervals *Technology Roadmaps* and *Expertise Maps* within the Network's scope at European level;
- to anticipate the EU's scientific and technological needs in order to help the EU to react rapidly to new scientific and technological developments.

At this time the IMS-NoE can count on the support of 71 European partners (30 universities, 22 industrial companies and consultancies and 19 technology transfer centers).

But which are the main reasons for a new Research Network? Why such a scope is being addressed? What about possible involvement and contributions from the research community, and in particular from scientific associations and federations as for example IFAC?

This paper aims firstly at providing a vision of the main industrial needs research community will have to solve out in the next years. Secondly, it will propose a comprehensive analysis of the role of the IMS-NoE in filling the gap between industry and academia, practitioners and researchers in a very large, but indeed highly integrated, domain as the CIME (Computer Integrated Manufacturing Engineering) area. Finally, some argumentation about possible contributions on the Network's activities coming out from IFAC TC on Advanced Manufacturing Technology will be pointed out.

## 2. VISIONARY MANUFACTURING CHALLENGES

The pervasive diffusion of information and communication technologies within industrial endeavors is producing a profound and radical upset of the manufacturing scenario. Some common technological drivers, such as *network interconnectivity* between distant nodes and consolidation of *e-processes* in carrying out complex task in lieu of human decision-making, are spreading out not only in large multinational companies but also in small medium-sized factories.

It is evident how also the scientific community, traditionally looking farther than the day-by-day involved industrial world, wonders about possible future scenarios. In this sense, more surveys carried out concurrently in the last years - among which we cite "*Information Technology for Manufacturing: a Research Agenda*" (National Academy of Science, 1995) and "*Visionary Manufacturing Challenges for 2020*" (Committee on Visionary Manufacturing Challenges, 1998) - converge in assessing a common vision of the main key factors which will heavily influence the next years' industrial policies:

- the competitive climate, further exasperated by a higher accessibility to information, will require a even *more rapid reactivity* by all production forces;
- consumers' needs will be even more unforeseeable since their habit to request *customized products* in reduced volumes will be more and more prominent;
- customers do not request only physical goods, but rather ask for the possibility to count on related *services during the whole product life-cycle*;
- the *environment protection* will become fundamental, since the ecosystem will be more and more unstable;
- the *geographical distribution* of the production resources will become a critical factor.

### *2.1 Manufacturing challenges*

Within the study conducted by the *National Research Council's Board on Manufacturing and Engineering Design,* six main production challenges for the research community, to be followed in the next 20 years, have been pointed out.

1. *Achieve concurrency in all operations* - the goal is to make conceptual, design and production activities to be temporally concurrent in order to reduce the *time-to-market*, boast up innovation and improve quality. Companies, during their engineering and production phases, should also consider the supporting activities covering all the product life-cycle.
2. *Integration of human and technological resources* - producers will have to sustain a high competitive pressure and operate huge efforts in

customizing their products. Both individual and teams will have to consider time and technology as challenges to productivity.

3. *From information to knowledge bases* - Manufacturing sector already heavily depends on *Information Technology*. This dependency is destined to increase in the future. Producers are more distributed all around the world in order to answer effectively to consumer demand. This globalization phenomenon implies a decentralization of the human work force which requires a more rapid, accurate and high quality communication. Communication must be transparent to languages and cultural differences. Thus, the main requirement is to get and store immediately information, transform it into a common knowledge base and make this knowledge available to possible users, either humans or machines, in an instant way and where necessary, in a familiar language and form.

4. *Development of manufacturing enterprises rapidly in response to changing needs and opportunities* - this concept means reconfiguration of manufacturing companies in response to changes in the demand and opportunities offered by the external market. Reconfiguration can involve multiple organizations, a single organization or a single plant or production plant of a single organization. Companies will have to be able to plan, create and manage simultaneously new products and their relative processes, operating within a virtual network of companies able to reconfigure themselves in a rapid fashion in order to respond to the continuous external stimuli and be easily adaptable to the variation of technologies, markets and competitive contexts.

5. *Reduce production waste and product environmental impact to "near zero"* - one of the main objectives of manufacturing companies will be the development of competitive products and processes, which will be not environmentally harmful, by making use of recycled material and reducing at its minimum level any kind of waste, in terms of energy, materials or use of human resources. In the future, companies, which will be committed with these environmental issues, will be able to gain a very remarkable competitive advantage.

6. *Develop innovative manufacturing processes and products on decreasing dimensional scale* - Significant advantages will be possible by designing and processing products at smaller and smaller scales, ultimately at molecular and atomic levels.

## 3. SCOPE AND STRUCTURE OF THE IMS - NETWORK OF EXCELLENCE

The main goal of the IMS-NoE is to create the proper environment to group academic and industrial communities for developing co-operation links, for coordinating current and future research, for facilitating knowledge transfer and dissemination of project results and for assessing the technological development and expertise in Europe in the key areas of design, engineering and control of manufacturing systems in the extended enterprise.
Through the establishment of six Special Interest Groups (SIG), the IMS-NoE intends to provide some scientific but also pragmatic answers to the main manufacturing challenges outlined in the previous section.
Here follows a brief summary of the scope of each SIG.

*SIG 1 : Engineering of Manufacturing Systems in the Extended Enterprise* - This SIG deals with methodologies and tools to support the design and re-engineering of intelligent manufacturing systems.
More and more it is required to do the design and re-engineering of these systems in an intra/inter-enterprise context, to meet the requirements for timeliness, quality and product variety. The current state of ICT provides opportunities to more rapidly set up inter-enterprise manufacturing systems, but methodological guidance on how to do this exactly is seriously lacking. The manufacturing challenges will be leading, not the information technology which could address them. Which traditional manufacturing “laws” still have to be respected and which rules can be challenged, given the new ICT opportunities? Which hurdles can be distinguished in a transition path away from the status quo in practice? Which are the organizational and ICT tools which can enable companies to operate in a concurrent fashion?
The SIG incorporates leading research institutes with the capability to formulate long-term perspectives on next generation manufacturing, but also software vendors which face the day to day challenges of the industrial customers. The confrontation between these two perspectives will be encouraged to maximize the chance of a result which is both challenging and realistic.

*SIG 2: Manufacturing Scheduling and Control in the Extended Enterprise* - The shortening of product life cycles and time to market leads necessarily to the integration of the company business and technological processes and to the agility and reconfigurability of these processes themselves. With regards to the manufacturing facilities and resources, highly reactive and fault-tolerant scheduling and control systems are needed, while keeping the requirements of the right cost, dependability and productivity parameters. Moreover, the natural shift towards decentralized systems encourages the development of intelligent architectures based on autonomy and cooperation of the production facilities.

In that way, the two main objectives/challenges of SIG2 are:

- from a scientific point of view, to work on formalizing but also developing and investigating novel scheduling and control approaches for managing complexity, changes and disturbances appearing in the Extended Enterprises;
- from an industrial point of view, to work on demonstrating the added value of these approaches in relation to the conventional ones, in order to facilitate their migration to the industrial world.

*SIG 3: The Healthy Human in Intelligent Manufacturing* - It has been demonstrated that a motivated and healthy workforce contributes significantly to innovation and productivity. Therefore, new manufacturing enterprises should not only have healthy working conditions, but also a stimulating working environment. In the past, often, knowledge intensive evaluations that could indicate whether technological changes imply hazardous activities or tasks were too expensive to be part of the improvement and/or innovation processes. This situation is rapidly changing due to new ICT possibilities of applying knowledge. In the foreseeable future, this will allow manufacturers to improve health and motivation of the workforce to contribute to quality improvement, productivity increase, better services and lower costs. This SIG focuses on improvement of the human performance by testing human behavior in an early stage of the manufacturing development.

*SIG 4: Benchmarking and Performance Measures* - Ongoing developments in scheduling and control of shop-floor systems are addressing increasingly complex problems - e.g. providing on-line control, reaction to disturbances, and adaptation to changes on the shop floor. This makes it very hard to assess and compare achievements. Therefore, developers have difficulties communicating and cooperating. SIG 4 aims to improve this situation. SIG 4 will focus on establishing benchmarks on which research results can be compared. These benchmarks will be made available through web technology. Emulations of shop-floor systems and their control systems will be brought together to execute performance tests. The tests will reflect the new challenges. To this end, suitable performance criteria will be elaborated. Moreover, these tests will address all relevant aspects, including ensuring the quality of the scheduling and control software itself, the deployment effort in a shop floor and the productivity of the shop floor itself.

*SIG 5: Sustainable Products and Processes* - The main objective of the interest group is to create a meeting place and environment for academia and industry within the area of "*sustainable products and processes*", to discuss and exchange knowledge and experiences, make scenarios for future developments, and establish contacts as basis for new research projects.

Important topics for discussion and areas for research activities are:

- Models for product development and manufacturing systems focusing on (and including) environmental and ecology aspects and requirements. How to make environmental products to meet less use of resources and optimal recycling ?
- Life cycle analysis of different value chains to minimize use of materials, energy and waste.
- Design and manufacturing for disassembling, recycling and refurbishment.
- Promotion and development projects for improved image of sustainable products and manufacturing systems.
- Development of indicators and measures for sustainable and environmental products and processes. The indicators should be designed for different purposes – to compare environmental figures between products, verify requirements from public authorities and continuous improvement.
- Handling life-cycle and environmental issues in extended enterprises and distributed systems.
- Needs for tools and methodology to industry and authorities on local and national level to formulate strategies for sustainability, waste and national legislation.

*SIG 6: Collaborative Engineering of Virtual Products* - Shortening "Time-To-Market" forces enterprises to speed up their development processes. Enterprises tend to react with two main activities. One is to extend the use of tools for virtual engineering, increasing the effects of simultaneous engineering. A common goal of virtual engineering is the use of a virtual product model. Using the virtual product for simulation and evaluation reduces the need for real prototypes, simplifies the evaluation of alternative solutions resulting in shorter development times and increased product quality. The second is to reduce the development portfolio, solely concentrating on the enterprise's core competencies. In order not to reduce the product portfolio, enterprises are forced to establish co-operations with other companies. Enterprise needs for co-operation conflict with the market competition. In literature this kind of conflict is named as co-opetition. The scope of this SIG covers both aspects mentioned.

## 4. PROVIDING A BRIDGE BETWEEN INDUSTRY AND RESEARCH TRHOUGH BENCHMARKING ACTIVITY

For development of IMS there is a need for a complete set of technologies and (basic) methods applicable for the various problems of the whole field. To this end, it is essential to consider how research can be coordinated and enhanced to provide the enabling technologies and categorize them according to their applicability to concrete problems of the diverse sectors of manufacturing.

Besides, for a successful introduction of novel technologies in intelligent systems for manufacturing industry it is essential to:

a) gain understanding of the industrial requirements in the scientific community so that solutions consider those conditions;
b) promote and disseminate approaches and solutions among potential industrial users in a form that can be understood and intuitively linked to industrial problems;
c) heighten trust in the applicability and strengths of the new solutions.

For these reasons, the Network intends to provide a clear and objective platform for validating and assessing the capabilities of new technological and scientific paradigms in order to ascertain their potential role in enhancing the productivity and competitiveness of modern manufacturing enterprises.

This is mainly a critical issue in the scheduling and control area, which is considered one of the most commercially important topics in the manufacturing area and a popular research domain in various academic fields, including industrial engineering, operations research, artificial intelligence, holonic and multi-agent systems.

From the industrial side, the adoption of highly reactive and efficient scheduling and control systems strongly affects the level of productivity and utilization of a manufacturing enterprise, particularly under the pressure of shortened product cycles, reduced batch sizes and a ampler variety of items to be produced.

From the research side, there has been a considerable amount of work done in the area of manufacturing systems control. The work has focused mainly on getting away from traditional centralized forms of controls moving to more decentralized forms, involving multiple decision makers which can be arranged in various architectural forms. However, a number of questions follow from the research that has been conducted so far in this fundamental area. Of primary importance is the assessment of objective and clear methods for determining which is the best control architecture for a given manufacturing problem.

It is evident that without giving a clear answer to this fundamental question, the technology gap between research and industrial application would dramatically widen.

How to solve this dichotomy? Through the design and development of realistic and industrially relevant test-cases. These test-cases would address specifically the evaluation and stress of the performance of scheduling and control systems based on new technological paradigms.

As a result, one of the main objective and distinctive roles of the Network is to provide researchers and industrial engineers with a collection of manufacturing test beds, spanning from job-shop systems to flow lines and assembly shops. One of the major features of this benchmarking service, which makes it different from other analogous projects, is its main goal to provide users with an interactive environment simulating the physical system and a variety of manufacturing scenarios through the use of Web-based simulation.

The service would be targeted to both industrial and scientific communities.

*Industrial users* would exploit benchmark test cases for evaluating the real capabilities of different approaches to scheduling and control solutions onto their own industrial plants. Thus, production engineers would have the unique chance:

- *to test, evaluate, and compare different solutions to manufacturing scheduling and control onto their emulated plants*, thus reducing risks and costs of direct experimentation on their real physical plants to a great extent;
- *to use the service as a medium for communicating specific industrial needs to the research community and to solution vendors* as well, thus increasing the chance of finding a suitable answer to their problems.

*The research community* would benefit from such a service since these test beds would make possible:

- *a time-saving and objective evaluation of scheduling and control systems*: the design of a good simulation test bed is often time-consuming and subjected to critics, since either it encompasses a very narrow manufacturing problem or it is considered purposely designed for getting biased and not objective performance results; in this sense, a benchmarking service would effectively overcome all these problems by enabling a researcher to “pick”, from a given selection of cases already engineered for a specific production domain, the sample system to use for his/her experimental purposes;
- *an open environment for triggering mutual comparison and discussion*: researchers would have the possibility to evaluate their scheduling proposals on a variety of cases, compare their

performance with those provided by alternative solutions and discuss the quality of scheduling results in an open forum.

Finally, *solution vendors* would be able to demonstrate the relative virtues of their products against common benchmarks as well, stimulating competition and promoting advanced products this way.
Figure 1 sums up the kind of support the benchmarking service could provide to the industrial and scientific communities.

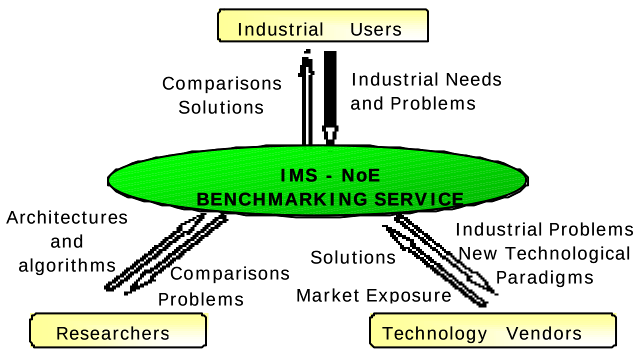


Fig. 1 - Relationships between the IMS NoE Benchmarking Service and the users.

## 5 . POSSIBLE CONTRIBUTIONS FROM SCIENTIFIC ASSOCIATIONS AND FEDERATIONS

The IMS-NoE aims to be the main and most qualified European competence center in the manufacturing area. It will fully exploit the “virtuous circle” coming out from a well balanced co-operation between academia and industry, the former bringing into the Network new paradigms and solutions, the latter providing requirements, cases, best practices and experience on-the-field.
With this respect, IMS-NoE has already established or contacted for future co-operation activities the following Scientific Federations or Associations:

- IFAC Technical Committees on Advanced Manufacturing Technology (MIT-TC), on Social Impact of Automation (IEN-TC), IFAC TC on Mechatronic Systems.
- IFIP WG 5.7 Working Group on Computer-Aided Management of International Federation for Information Processing.
- IFIP WG 5.7 Special Interest Groups on Performance Measurement and on Advanced Techniques in Production Planning & Control.
- CIRP (International Institution for Production Engineering Research).

In particular, a strong collaboration is expected with the IFAC MIT-TC on joint activities and scientific events. There is in fact a common view between the IMS-NoE initiative and the MIT-TC on the way to address next years' challenges. As declared in the 2000-2001 Annual Report (IFAC MIT-TC, 2001), "the MIT-TC will continue to promote the main paradigms, techniques and technologies emerging from industrial organizational needs in order to improve the flexibility, the integration and the adaptability of automated manufacturing systems and processes. Attention will be specially drawn to the automatic control aspects and to the automation engineering aspects of these Advanced Manufacturing Processes in order to test their scientific foundations, i.e. the existing concepts, theories, models, methods, methodologies, languages and tools which could be applied or the new ones which should be developed…..The next generation of manufacturing systems, as addressed by the world-IMS industry-led research and development initiative, will have to support all facets of this globally distributed "extended/virtual enterprise" as addressed by various paradigms".

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