With today’s growing demand on system productivity, availability and safety, product quality, customer satisfaction and the decrease of profit margins, the importance of the maintenance function has increased [1,2]. Indeed the maintenance function plays a critical role in a company’s ability to compete on the basis of cost, quality and delivery performance (maintenance synchronised with production requirements) [3]. For example, studies over the last 20 years have indicated that around Europe, the indirect cost of maintenance is equivalent to between 4% and 8% of total sales turnover (similar amount as for the direct cost). Thus, in the countries where modern maintenance practices have yet to be well adopted by industry, the potential savings from modern maintenance are massive. These modern and efficient maintenances imply to identify, at least, the root-cause of component failures, reduce the failures of production systems, eliminate costly unscheduled shutdown maintenances, and to improve productivity as well as quality. To support this role, the maintenance concept undergone through several major developments to lead to proactive considerations which require changes in transforming traditional “fail and fix” maintenance practices to “predict and prevent” e-maintenance methodology [4] (potential impact on service to customer, product quality, cost reduction...). The advantage of the latter is that maintenance is performed only when a certain level of equipment deterioration occurs rather than after a specified period of time or usage (from current mean-time-between failure (MTBF) practices to mean-time-between-degradation (MTBD) technologies). E-maintenance is a sub-concept of e-manufacturing and e-business for supporting next generation manufacturing practices (NGMS).

Therefore, e-maintenance is defined at the “Intelligent Maintenance Centre”¹ as “the ability to monitor plant floor assets, link the production and maintenance operations systems, collect feedbacks from remote customer sites, and integrate it upper level enterprise applications.” A more general definition is that “maintenance management concept whereby assets are monitored and managed over the Internet.” Indeed Internet regarded as a new technology, have led for some companies to replace conventional reactive strategy by proactive versus aggressive strategies [5]. It is a revolutionary change rather than evolutionary advance.

In that way, e-maintenance is integrating the principles already implemented by tele-maintenance which are added the web-service and collaboration principles [6]. Collaboration allows not only to share and exchange information but also knowledge and (e)-intelligence (new services, new processing), and this not only between units but also between units, departments, experts, processes, companies... By means of collaborative environment, pertinent knowledge and intelligence are available and usable (through e-channel) to the right place, at the right time for developing best maintenance decisions all along the product life cycle (design, manufacturing, use, end of life...). The distance between actors is now measurable in “network intelligence power” rather than in thousand of miles [7]. Thus with the use of Internet, web-enabled and wireless communication technology, e-maintenance is transforming manufacturing companies to a service business to support their customers anywhere and anytime.

Some companies (such as General Motors, Canon, Rockwell, etc.) have investigated e-maintenance since several years ago [8] and have now already adopted it with significant impact on business process changes. Some e-maintenance platforms² exist where the resulting e-maintenance infrastructure versus e-maintenance system replaces the conventional hierarchical structure by a heterarchical or intelligent one as advocated by the Intelligent Manufacturing Systems (IMS)³ worldwide initiative [9]. The infrastructure is adding “intelligence” to components through Infotronics technologies [4] such as Watchdog Agent, D2B, etc. It entails several networks for supporting not only the exchanges between the Enterprise and its external relationships (CRM, etc.) but also real-time communications between devices, computers, etc. at different enterprise levels (ERP, MES).

Collaboration, Web-services, e-Intelligence, Infotronics... materialise key concepts leading to classify e-maintenance as

¹ http://www.imscenter.net/
² ENIGMA (http://www.enigma.com); CASIP (http://www.predict.fr); ICAS-AME (http://www.en1.endiva.net/3eti/); Remote Data Sentinel; INTER-MOR; INID; IPDSS; WSDF; MRPOS; etc.
an emerging field which has to face still a lot of challenges\textsuperscript{4} to well define its scientific foundations and industrial benefits. Indeed positive impacts of e-maintenance on productivity, sustainability, quality, etc. have to be demonstrated to justify investments in this emerging field. Thus future common industrial/academic working/research directions address, but are not limited to:

- Proposal of a e-maintenance framework formalising most of the concepts, theories, models, methodologies, methods and tools required for promoting e-maintenance as a discipline of science and engineering (i.e. a work led by the guest editors is in progress and will be published soon)
- Development of new “intelligent devices” such as MEMS, PDA, smart tags able to support monitoring, diagnosis in remote way for assessing component performances (i.e. IP project DYNAMITE and SMMART).
- Development of new techniques for wireless communication to support specific real-time constraints between e-maintenance devices and systems.
- Modelling and deployment of new services (processes) such as e-monitoring, e-diagnosis, e-prognosis, e-logistics, etc. required from “intelligent devices” information for helping maintenance decision making according to system expected performances.
- Extension of the e-maintenance services over all the Product Life Cycle (to track the product from birth to death) (i.e. IMS Project PROMISE).
- Developing theories and tools for describing, quantifying and optimising the behaviour of the interactions of the system-maintenance-economy model (MME) and then developing maintenance decision support system (MDSS) for cost-effective decisions enhancing company’s profitability and competitiveness continuously (cost-effectiveness models).
- Modelling of interoperability requirements between all the e-maintenance services (and software) and definition of ontologies formalizing the e-maintenance service semantics (i.e. project PROTEUS, NOE-INTEROP, MIMOSA initiative, IEC6224).
- Development of new Infotronics-based e-maintenance system (intelligent maintenance system) able to make functioning as a whole the distributed intelligent devices, the services, the maintenance software such as CMMS, etc. It consist, for example, in proposing new protocols for collaboration and negotiation, DAI techniques, maintenance workflow, etc. but also proof tools to verify the properties of the global functioning from each distributed items (i.e. proof-oriented fault system engineering).
- Development of new e-maintenance standards (for sensors, for wireless communication, for Interoperability, for safety, etc.) (i.e. IEEE 802.11x, IEEE 802.15, EN457:1992-ISO7731….) for perpetuating e-maintenance infrastructure, etc.

Papers included in this special issue are contributing to some of previous items. This special issue on e-maintenance is mainly the result of the activities of the SIG2 (Special Interest Group 2 on “Manufacturing Scheduling and Control in the Extended Enterprise”) of the European IMS-NOE\textsuperscript{5} (IST-2001-65001) and more precisely the activities of the e-maintenance working group. The special issue is based, on the one hand, on papers developed by SIG2 members for IMS-FORUM2004 which took place in Como, Italy, 17–19 May 2004, and on the other hand, on papers coming from other research or industry teams that are very active in the e-maintenance domain.

The 10 selected papers are classified, and briefly summarised, within the following topics:

- New e-maintenance services
  - Lee et al. introduced intelligent prediction tools for prediction of a particular product’s performance, ultimately enable proactive maintenance to prevent machine from breakdowns.
  - Péres and Noyes presented, for the application area of isolated systems in which the part supplying is made difficult, e-logistics development based on freeform technologies making spare parts manufacturing on request and in a short time.
  - Simeu-Abazi et al. proposed a new monitoring system able of absorbing internal degradation of any variables and ensuring the continuity of the service.
  - Emmanouilidis et al. investigated the development of a flexible software solution for condition monitoring, novelty identification and machinery diagnostics, which can easily be customised to a wide range of monitoring scenarios. Its main constituents are a number of independent software modules, such as the Fault and Symptom Tree, the Fuzzy Classification module, the Novelty Detection and the Neural Network Diagnostics sub-systems.
  - Palluat et al. investigate a new method for developing a neuro-fuzzy monitoring system supporting a diagnosis aid system combining neural network learning capabilities and natural language formalism.

- Integration versus interoperability for e-maintenance services
  - Based on the results of the PROTEUS project, Bangemann et al. present the architecture and the basic concepts of an integration platform, which constitutes the framework of systems implementing the tasks dedicated to remote maintenance, as well as other applications, for large and medium scale industrial installation. The approach is useful for executing any maintenance strategy by implementing the relevant means for controlling workflow between several system components as well as the component’s integration itself.

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\textsuperscript{5} http://www.ims-noe.org/.
Intelligent maintenance infrastructure versus system

- Garcia et al. propose an intelligent system for predictive maintenance called SIMAP. It is a software application addressed to the diagnosis in real-time of industrial processes. It takes into account the information coming in real-time from different sensors and other information sources and tries to detect possible anomalies in the normal behaviour expected of the industrial components.

- Han and Yang investigated a new e-maintenance system which enables manufacturing operations to achieve near-zero-downtime performance on a sharable, quick and convenient platform through integrating the existing advanced technologies with distributed sources. This e-maintenance system is structured with a maintenance centre and local maintenance.

Interaction between system/maintenance/economy/performance for decision making

- Macchi and Garetti develop a benchmark study in complex production systems materialising information requirements for e-maintenance strategic planning to properly size the maintenance logistics support. A benchmark study is performed in order to analyse how the selection of the maintenance policy may change when information is collected with regard to the production system as a whole instead of its separate equipments.

- Moore and Starr investigate a strategy called cost-based criticality (CBC). CBC weights each incident flagged by condition monitoring alarms with up-to-date cost information and risk factors, allowing an optimised prioritisation of maintenance activities. Thus CBC combines information about technical state or machine health, cost of maintenance activities or loss of production, and non-technical risk factors such as customer information.

Finally the special issue Guest Editors thanks the Editors M. Wortmann and M. Szirbick (for special issues) for providing Computers in Industry as a forum and the editorial staff of the journal as well as the reviewers (mainly Dr. E. Levrat) and the authors for their efforts.

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