MAINTENANCE AND SUPPORT

FR005

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MAINTENANCE AND SUPPORT	**FR005**
Robotics	FR001
Clean Manufacturing	FR002
High Precision Manufacturing	FR003
Zero Defect Manufacturing	FR004

Roadmap

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STATE OF THE ART

01 Optimized & Predictive Maintenance

- Condition-based maintenance is available for many applications. However, predictive maintenance is only available in special cases (e.g. where there is a high number of similar systems) and remaining useful life (RUL) estimation is a very difficult task even under laboratory conditions.
- Maintenance planning models and concepts are available. While models within probabilistic modeling and machine learning are available, they are not connected.

02 Data Analytics and Prediction

- Operating data is collected in most production environments.
- Data is mostly only used for statistics and not for forecasts, missing approaches for multivalent data analysis.
- Machine and process data are often only analyzed in the case of a failure.
- Behavioral models of production systems are missing and/or not employed in the operating phase.
- Advanced software tools for predictive maintenance in production are missing.

03 Networked IT Infrastructure

- Different software systems are used for data processing (condition monitoring (CM) and RUL estimation, enterprise resource planning (ERP), production planning, maintenance planning), but interlinkage is not yet a reality.
- Distributed large-scale data processing solutions are available (e.g. Apache Spark).
- Global web-based networks are available.

04 Condition Monitoring Systems

- Instrumentation and data acquisition are available for many applications, but are cost intensive.
- Limited reliability of sensory and DA systems.
- Direct measurement of relevant parameters is often not possible.
- Monitoring of all relevant spots is not possible (costs, technical reasons, accessibility).
- There is no combination of condition and process monitoring.
- CM systems are often “stand alone” systems which are not easily integrated with computerized maintenance management system (CMMS)/ERP systems.

05 VR/AR*-based Human-Machine Interaction for Improved Maintenance

- Video-based remote support solutions are available for maintenance.
- A range of AR headsets are available, but only very few are suited for industrial environments.
- Only simple interfaces and instructions are available on AR headsets due to technical limitations.
- The first application is in logistics (picking) and maintenance will be the next stage for application.

* VR: virtual reality | AR: augumented reality

GAP

Optimized & Predictive Maintenance

- Insufficient RUL model quality and estimation uncertainties.
- Limited maturity of big data infrastructure for predictive maintenance (central, decentral).
- Data mining solutions, prediction algorithms and self-learning solutions.
- Missing deterministic cause-effect failure models for many machine components.
- High uncertainty of RUL estimations.
- Commercialized CMMS solutions that update the maintenance plans based on predictive models of the remaining useful life.
- Predictive maintenance of small batch components and special purpose machines is not available in practice.

Data Analytics and Prediction

Although big data solutions are available today their application to production scenarios is limited. This is due to:

- The complex procedures required to transfer data from specialized data acquisition systems into general-purpose data analysis solutions.
- The high diversity of production systems that require model-based approaches to cope with the resulting complexity in data acquisition and analysis.
- Many manufacturing companies also do not own or cannot afford the required IT infrastructure and software systems to collect and process operating data on a large scale.
- Furthermore, the provisioning, installation and operation of such systems tends to be too complex for small companies, which also hinders their adoption.

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- Limited acceptance of web-based data networks (e.g. because of doubts about data security).

Condition Monitoring Systems

- Cost-intensive data acquisition systems.
- Complete physical instrumentation of systems is not possible (accessibility, costs).
- The necessary information about condition is only available for discrete spots (sensor position).
- Limited reliability of electronic components (sensory, embedded DA).
- Multivalent data usage (e.g. for maintenance AND process control) is not a reality yet.
- Better integration of CM systems e.g. in CMMS/ERP systems is required, not only physically, but also logically.

VR/AR-based Human-Machine Interaction for Improved Maintenance

- Limited suitability of existing AR headsets for industrial use especially considering the environment. In addition they lack good screen resolution and have low compute capability and high response times.
- Precise tracking is required to enable applications. Most applied camera-based tracking systems require good conditions and need compute power.
- Integration in IT infrastructure of applications, especially security aspects of often sensitive data.
- Natural hands-free interaction is needed for most cases in which the actual job requires manual work.
- Usability of AR (user interface, interaction and hardware).

CHALLENGE TO FILL THE GAP

Optimized & Predictive Maintenance

- General improvement of RUL estimation and prognostics are needed.
- Combine signal processing/artificial intelligence/machine learning methods with probabilistic methods. Combine probabilistic modeling and machine learning applied in maintenance planning (more fusion of model-driven and data-driven methods).
- Planning of maintenance activities that are more integrated dynamically into the production activities.
- KPIs applied for integrated planning between maintenance and manufacturing to achieve “integrated planning” also in a formalized mathematical sense.
- Networking of similar systems to increase the information base needed (global/within a company/within a plant).

Data Analytics and Prediction

- Development of flexible data storage systems that are easily adaptable to different production systems and scenarios.
- The collected data should be linked to digital models of the corresponding production systems, components and sensors to provide a self-describing knowledge base for different data mining tasks.
- A combination of model-based and linked-data approaches can help to reduce the number and complexity of interfaces for data access as well as supporting the long-term evolution of data structures if components of a production system change over time.
- Industrial acceptance of cooperative, cross-company data networks.
- Long-term maintenance of flexible IT infrastructures (e.g. after modifications of observed production systems).
- Instrumentation solutions for structured long-term data storage.
- Algorithms to analyze huge amounts of data: transformation of big data to smart data.
- Approaches of multivalent data analysis using extended databases.
- Reliability and maintainability of IT infrastructure (hardware and software).
- Methods to evaluate economic benefits.

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Condition Monitoring Systems

- Cost reduction of sensor and CM systems (low-cost instrumentation).
- Instrumentation solutions for long-term data acquisition with high reliability.
- Maintainability of IT infrastructure (hardware and software).
- Holistic CM with a limited number of sensors, e.g. using virtual sensory systems.
- Wireless DA solutions.
- Instrumentation strategies for multivalent data usage (use and combine data from different sources for different goals).
- Physical and logical integration of CM systems in networked systems needed.

VR/AR-based Human-Machine Interaction for Improved Maintenance

- Advancement of AR hardware solutions e.g. AR headsets (resolution, response times, compute capability, interaction devices).
- Establish robust tracking solutions that work under industrial conditions (will probably require sensor fusion).
- Develop new and intuitive user interfaces and interaction methods that do not disturb the work.
- Develop generalized interfaces for secure access to a company’s IT infrastructure to acquire the necessary data (including a robust data connection).

RESEARCH PRIORITIES

Optimized & Predictive Maintenance

Holistic and scalable strategies for predictive maintenance to handle the uncertainties in the RUL estimation of assets for valuable decision support.

- Development of methods to improve RUL estimation in general.
- Development of methods to connect/combine different approaches for RUL estimation/ prognosis to get the best representation of RUL uncertainty.
- Development of methods to formulate RUL estimation uncertainty and definition of belonging KPIs.
- Development of solutions for integration/combination of RUL predictive models of the physical asset and prediction of maintenance resources supporting the maintenance planning function.
- Dynamic root cause analysis in maintenance.
- Development of data-oriented (cooperational) business models.
- Development of legal frameworks for data-driven businesses in maintenance.

Data Analytics and Prediction

Development of novel approaches and solutions for the transformation of big data to smart data and multivalent data usage.

- To extract value-added information as a prerequisite to increase the availability and productivity of complex production systems.
- To "learn" correct functionality of machines as a prerequisite to predict and forecast the prospective behaviour of components, machines and production systems.
- To extract hidden information regarding maintenance from extended datastores (interlinked production-related software systems).

Networked IT Infrastructure

Scalable IT systems for predictive maintenance have to be developed to realize a virtual representation of complex production systems and factories. The IT infrastructure has to be flexible and adaptable regarding different production scenarios. Key questions which have to be answered:

- How can all machines provide data?
- How will production-related data be managed?
- Development of methods to increase IT security and customer confidence.

Condition Monitoring Systems

- Development of novel solutions for low-cost, virtual and reliable sensory for holistic data acquisition in production systems.
- Development of low-cost and easy-to-install CM solutions.
- Development of highly reliable CM solutions.
- Development of monitoring and maintenance strategies for CM solutions to increase reliability.
- Development of virtual sensor solutions to enhance output of a limited number of physical sensors.
- Better integration of CM systems in industrial networks is required, not only physically, but also logically both to have an overall approach for maintenance (e.g., planning) and for analyzing the data.

VR/AR-based Human-Machine Interaction for Improved Maintenance

- Develop systems for providing context-based information to support and integrate humans in complex production environments.
- Develop an intuitive, easy to use and easy to accept AR-support system with high-quality user experience.
- Research focusing on three research areas: tracking system for position determination in regard to point of interest; data interface; ways to display information and to interact with it.
- Enable faster and better maintenance through multimodal interfaces for obtaining relevant data without obstructing actual work.

FUTURE TRENDS

Optimized & Predictive Maintenance

- Just-in-time supply chains need higher reliability, and plannable maintenance will become more relevant for higher reliability and cost effectiveness in production.
- Maintenance planning capabilities in computerized maintenance management systems (CMMS) with more analytic functions.

Data Analytics and Prediction

- Transparency in production will be a basic prerequisite to increase the availability and productivity of complex production systems.
- Big data solutions will be a key factor for efficient production systems of the future (transformation of big data to smart data).
- Task-dependent time constants will become more relevant for monitoring and optimization (from real-time to long-term) of production systems.

Networked IT Infrastructure

- Global interlinkage of assets can improve self- and cross-learning.
- Interlinkage of different production-related software systems to realize extended datastores for advanced data analysis.
- Using key-value-stores to store large amounts of operating data.

Condition Monitoring Systems

- Condition-based and predictive maintenance will become more important within trends like CPS and I4.0.
- Sensor integration and asset instrumentation will be enhanced in general.
- Monitoring of all value- and function-relevant components.
- CM systems will be just an integrated sub-part of networked systems.

VR/AR-based Human-Machine Interaction for Improved Maintenance

- To minimize costs and downtime, remote support solutions are needed to assist local crews.
- A higher degree of automation and production intelligence requires workers to have a broader and deeper knowledge of production systems. They could be supported on-site by AR solutions bound to knowledge bases and the required information.
- Industry is using more and more AR solutions (with AR headsets, mobile phones, tablets and projectors) to support manual work and deliver context-sensitive information.

Project Partners

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Norwegian University of
Science and Technology

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