rijksuniversiteit groningen

ACADEMIC ROADMAP SMART INDUSTRIES

Academic focus of researchers in the University of Groningen
Research institutes ENTEG and SOM

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The University of Groningen is a university with a global outlook, deeply rooted in Groningen, City of Talent. The university stimulates interdisciplinary research, and places emphasis on its interaction with society and industry. A unique trait of the University of Groningen is the close relationship between its faculties for natural sciences, social sciences and engineering. It is the only university in the Netherlands where engineering research takes place in a comprehensive environment, thus resulting in a unique integration of fundamental and engineering sciences.

The aims of the University of Groningen *academic roadmap for smart industries* are to develop new fundamental knowledge, to create a conceptual foundation for current smart industry initiatives, and to train and inspire students in a variety of Master programs. It presents themes of on-going and future research on smart industries—as jointly formulated by the Research institute SOM (Faculty of Economics and Business) and the Engineering and Technology institute Groningen (ENTEG, Faculty of Mathematics and Natural Sciences). Our collaboration in this area enables a close relation to the newest developments in business studies at one hand, and the newest developments in natural sciences on the other hand. In addition, the roadmap provides opportunities to collaborate with other research groups in, for example, social science and computer science to further strengthen the smart industry profile. The presented roadmap offers ample opportunities for joint academic and industrial research efforts aiming for stimulating industrial settlement and thereby increasing employment opportunities.

The roadmap includes several research topics, which are grouped in four research themes:

1. Business Innovation. Technological innovations go hand in hand with changes in business models and may impact the viability of new business eco-systems. In this theme, we take a systems perspective in identifying new business models and—together with industry partners—developing a strategic blueprint for smart industries.

2. Advanced Production Processes. Advanced production processes are robust, self-regulatory and controlled in real-time. In this theme, we focus on the development, optimization and implementation of advanced production technologies and manufacturing processes with an emphasis on mechanical engineering. Industrial robotics play an important role in advanced production processes. Moreover, 3D printing is considered as it results in a paradigm shift—where computer controlled tools and processes are used to transform digital designs directly into physical products.

3. Agile demand-driven manufacturing. Technological innovations enable increased customization using efficient manufacturing processes that can easily adapt to changing volumes and variety of products. In this theme, we develop new methods and techniques to efficiently produce a wide range of products. Moreover, we explore possibilities to decrease the time required for effective product and process design. Finally, we study the changing role of the workforce.

4. Embedded intelligence. Innovative products, services and production processes provide and require large quantities of data. In this theme, the management of those data is the main topic of research. There is a focus on the design and application of cyber-physics and The Internet of Things in the light of pertaining technological and business challenges.

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THEME 1: Business innovation

Business model innovation

Breakthrough technological innovations often require organizational redesign and rethinking of a company's strategic value. Revenues from existing markets can deteriorate, whereas new market opportunities arise. Our current research to sustainable product innovation shows that product and service innovation go hand in hand with innovations in business models. The knowledge gained in this research line can be translated to—and expanded with—new business models arising from intelligent products and production processes. A key part of newly emerging business models is the choice with what other parties a firm should cooperate in order to develop and market products and services based on newly developed knowledge.

Blueprint for the future

Technological innovation often requires new business services. As a result, supply chains will change and new business ecosystems may emerge. One of our current lines of research is directed to modelling those business ecosystems and determining their economic viability. In prior research projects, we developed such models for new energy systems and proposed a strategic blueprint for a phased infrastructure development for LNG as a transport fuel. It is our ambition to develop similar models and a strategic blueprint for the transition towards smart industries—describing the necessary technological and business innovations.

Serious gaming

Creating, realizing and using simulation-based serious games enables further optimization and augmentation of the use of human capital. For example, (1) the employability of workers can be improved given their capabilities in process execution, improvement, and innovation; and (2) the adaptive capacity of companies in the area of business process management and design can be increased. On-going research projects include the use of simulation-based serious games in the context of employability (SPRINT@Work) and worker individual skills in business process improvement (WorkXperience). We strive to expand our research in this area towards the context of smart industries.

Collaboration with SMEs

Smart industry initiatives take place in complex chains of larger and smaller firms. A transition towards smart industries is typically initiated and championed by a leading—and large—firm in the chain. Involvement of SMEs upstream and downstream in the supply chain is crucial for the success of such initiatives, but remains a challenge. Our prior research in the field of organizational behavior has resulted in fundamental theory on coordination that well-apply to the challenge set out above.

THEME 2: Advanced Production Processes

Physics-based modeling / model-based engineering

Physics-based modeling, or model-based engineering, concerns the formulation of a generic dynamical modeling framework that facilitates the design of complex systems, such as mechatronic systems, robotic systems or cyber-physical systems. In collaboration with other institutes of the Faculty of Mathematics and Natural Sciences, we develop power- and energy-based frameworks. It is our ambition to handle the modeling, design and control of complex physical systems in an industrial environment.

Industrial robotics in production processes

Industrial robotics in production processes concerns all design aspect of robotic systems that are specific for industrial applications. These range from designing the control of low-level manipulators to the supervisory control for a complete robotic system and even the coordinated control of multiple robotic systems. Recent examples of this type of research are provided by our contribution to the robot development for the inspection of ballast water tanks in ships, and the contribution to multi-agent *robotics for industrial applications in the SmartBot consortium, http://www.smartbot.eu/en/. We aim at extending these results to improve the functionality, flexibility and robustness of industrial production lines.*

3D printing/rapid prototyping

3D printing creates a paradigm shift in manufacturing—where computer controlled tools and processes are used to transform digital designs directly into physical products. It stimulates product modularity as highly specialized components can be printed at the spot. Consequently, the whole supply chain is affected, for example by a reduced need for storage and transportation. We study potential supply chain changes and their effects on traditional distribution strategies. Moreover, we research and utilize cutting-edge 3D printing technologies with metallic powders with the aim to develop first-time-right specialized mechanical parts. Polymers are used to rapidly create prototypes used in mechanical design research.

Enabling technologies and functional materials

Integral to the development of advanced production processes, we investigate innovative processes for efficient and high-quality manufacturing of current and new materials or products. Towards this endeavor, we focus on the development of manufacturing processes for advanced thin films and coatings, for innovative graphene-based materials and products, and for biomaterials-based products. The latter is aimed towards improving sustainable processes by enabling easy materials recycling, reuse and re-manufacturing. As part of enabling technologies at the interface on micro-nano level, we also investigate the fluctuation induced electromagnetic forces between bodies at sub-micrometer proximity which are increasingly important for device applications, such as, the micro/nano actuation systems used in very-high-density storage systems. We strive to use the newly developed knowledge for developing novel bonding technologies to assemble durable stiff materials (e.g. SiC, ITO etc.).

Advanced production technology

Advanced production technology is a broad research field that deals with the development, optimization and implementation of advanced production technologies and manufacturing processes with an emphasis on mechanical and materials engineering. A recent example of our research is the development of a breakthrough Physical Vapor Deposition (PVD) technology for depositing novel anti-corrosion coatings. For the chemical industry, our research focuses on novel catalytic chemistry and reactor concepts for catalytic processes with a strong emphasis on the conversion of renewable feedstock to energy, liquid transportation fuels and bio-based chemicals.

Towards a sustainable and optimal factory

Economic and resource sustainability relies on an optimal implementation of the entire range of technologies and enablers in the flexible manufacturing system, including embedded sensors, local controllers and predictive maintenance systems. We design and evaluate novel condition-based maintenance policies and include inventory decisions for spare parts and tools. Moreover, we study frameworks and tools that guarantee optimality under tight resource constraints, while at the same time coping with the dynamics of the processes and with highly unpredictable demand. Recent research results have opened up possibilities to study complex industrial processes with help of distributed (and easier to implement) solutions to the overall optimal control problem.

THEME 3: Agile demand-driven manufacturing.

Design and control of smart industry

Cost-effective and sustainable creation and realization of highly customized products and services throughout the entire supply chain is key in smart industry initiatives. In designing smart production process, due attention should be given to the concepts of flow and responsiveness. To address this issue, we formulated an integrated product line design problem that involves a firm's product variety, lead *time, inventory, and pricing decisions in a dynamic environment with various customers' preferences. During the production phase, real-time product and resource information (e.g., product routing, specifications, status) should be used to further improve the design and control of the processes. We aim to develop new methods and techniques based on Lean and Quick Response Manufacturing theories, as well as network theory to support organizations in addressing new or changing customer requirements without incurring high additional costs.*

Reconfigurable, adaptive and evolving factories

Highly flexible manufacturing tools, processes and systems enable the realization of more personalized products in much smaller batches. This requires novel industrial processes—including automation that can be reconfigured and adapted to individual needs. Towards this endeavor, we focus on developing a framework for reconfigurable, adaptive and robust automation and aim at various levels of system abstraction.

Product and process platforms

While product lifecycles are short, many new products are derived from existing ones. The common components between new and existing products can be properly maintained in so-called product platforms, which enable the re-use of tools, norms, computational models, data, quality procedures, et cetera. Accordingly, a product platform approach facilitates a quick response to demand changes while avoiding duplication of effort. The same line of reasoning also applies to manufacturing processes: a process platform is a generic manufacturing process description which holds for many products.

Workforce agility

The flexibility, complexity and technological innovations associated with demand-driven manufacturing pose serious challenges on (future) employees. More research is needed to define future employee skills, methods to divide skills among employees (level and division of cross-training), the use of temporary versus permanent employees, and the real-time assignment of employees to specific tasks. Human capital forms an important source of resilience. We study the role of creativity of individual workers therein as well as (leadership) mechanisms to facilitate the necessary collaboration within and between teams.

Simulation for process innovation

Simulation models are regularly used to design and evaluate innovative planning and control policies, to support process innovations and to assess the return of investing in such novel processes. We have experience in developing various types of simulation models (e.g., discrete and continuous) for a wide range of industrial applications. Currently, each process innovation often requires a new model and dedicated study. We increasingly observe a need for more adaptive simulation models that closely mimic a real-world manufacturing system and its relations with other stakeholders in the supply chain and enable frequent evaluation of envisaged future states of that system in relation to its customers and suppliers.

Remanufacturing

Remanufacturing is the most extensive form of product recovery, where a used product is returned to new-like conditions and original performance with an equal warranty as its newly manufactured equivalent. Our current research in this area has focused on 1) organizational conditions enabling or blocking remanufacturing, 2) optimal strategies for hybrid manufacturing / remanufacturing systems, and 3) assessing the ecological performance of remanufactured products with LCA. We aim to extend this line of research by determining how product data can be gathered, stored and used to design and manage remanufacturing processes (including reverse logistics) and to develop products for remanufacturing (e.g., a product that can be remanufactured more efficiently and multiple times). Moreover, an enhanced focus on remanufacturing can result in new supply chain roles and actors that focus on facilitating the supply of re-usable product components.

THEME 4: Embedded Intelligence

Internet of things

The Internet-of-Things is related to the design of robust and reliable interconnected systems via the Internet. The systems can be sensor systems, actuator systems, control systems and monitoring systems. The Internet of Things transforms physical objects into autonomous subjects. Apart from huge societal and ethical issues about responsibility, autonomy, privacy and other values, there are enormous technical opportunities and challenges. The opportunities of lightless manufacturing, of combined manufacturing and logistics, of new services (e.g. transportation, recreation, education, distribution, retail, health care support) and sustainability (energy and material savings) are huge. However, there is still a plethora of technical challenges, such as the reliability of wireless connections, data distribution and the robustness of robot software. These technical challenges translate in to business challenges and opportunities as new services for reliability, fail safe systems solutions, new perspectives for waste recovery and treatment, customized services around physical products and visual analytics.

Cyber-physical systems and cyber-security

Cyber-physical systems combine physical devices (actuators, sensors, plant, etc.) with communication and computational units. The interaction occurs via data networks. Cyber-security deals with the problem of guaranteeing the information exchanged over the network to be secure and reliable. New industrial systems are generally rather complex, i.e., the increased complexity of such systems is currently under investigation. It is our ambition to handle many different types of communication constraints and protocols.

Human-centered manufacturing

As part of social sustainability of smart industry, we are studying ways to enhance the role and potential of knowledge-workers in future factories. At the core of these endeavors is the utilization of big data generated and collected in the factory environment, which must be processed and analyzed into valuable information for the knowledge-workers and other stakeholders at all levels. In this regards, our research on cognitive science and human factors, such as, detailed cognitive models, can be readily applied to design an optimal environment for effective human performance in future factories.

Data management

Operating at the edge of technological knowledge, manufacturing and quality engineers are always searching for sources of variation that should be controlled to produce within tight tolerance and quality constraints. An essential resource for this work is data. Data management is to be developed towards maturity in the same way as physical assets are. Current data management suffers from several weaknesses. First, there is a need for a seamless integration of CAE systems with CAM systems, including engineering change management. Second, integration of feedback and manufacturing data to product design is required. Third, manufacturing data should be integrated with machine parameter settings and measurements to effectively implement condition-based maintenance strategies. All these integrations require semantic harmonization, as well as syntactical and technical standards. Moreover, sensor data need to be filtered and interpreted before they can contribute in a useful way to quality control and continuous improvement in manufacturing.

Participation of researchers in the different institutes (in alphabetical order)

Name	**Faculty**	**Institute/Department**
Prof. dr. M. Aiello	FMNS	JBI
Prof. dr. P. Avgeriou	FMNS	JBI
Dr. G.R. Blake	FMNS	ZIAM
Dr. J.A.C. Bokhorst	FEB	Operations
Dr. P. Buijs	FEB	Operations
Prof. dr. ir. M. Cao	FMNS	ENTEG
Prof. dr. M.K. Camlibel	FMNS	JBI
Dr. F. Cnossen	FMNS	ALICE
Prof. dr. C. De Persis	FMNS	ENTEG
Prof. dr. J.T.M. De Hosson	FMNS	ZIAM
Prof. dr. W.A. Dolfsma	FEB	I&O
Dr. P.J.M.D. Essens	FEB	HRM & OB
Prof. dr. H.J. Heeres	FMNS	ENTEG
Prof. dr. B. Jayawardhana	FMNS	ENTEG
Drs. B. de Jonge	FEB	Operations
Prof. dr. ir. B.J. Kooi	FMNS	ZIAM
Dr. M.J. Land	FEB	Operations
Prof. dr. G. Palasantzas	FMNS	ZIAM
Prof. dr. Y. Pei	FMNS	ENTEG
Dr. K. Peters	FEB	Operations
Prof. dr. F. Picchioni	FMNS	ENTEG
Dr. J. Riezebos	FEB	Operations
Dr. F.A. Rink	FEB	HRM & OB
Prof. dr. ir. J.M.A. Scherpen	FMNS	ENTEG
Prof. dr. L.R.B. Schomaker	FMNS	ALICE
Prof. dr. J.I. Stoker.	FEB	HRM & OB
Dr. N.B. Szirbik	FEB	Operations
Prof. dr. N.A. Taatgen	FMNS	ALICE
Dr. P. Tesi	FMNS	ENTEG
Prof. dr. R.H. Teunter	FEB	Operations
Prof. dr. D.P. van Donk	FEB	Operations
Prof. dr. G.S. van der Vegt	FEB	HRM & OB
Dr. M.K. van Vugt	FMNS	ALICE
Dr. J. Veldman	FEB	Operations
Prof. dr. I.F.A. Vis	FEB	Operations
Prof. dr. J.C. Wortmann	FEB	Operations
Dr. M.A. Wiering	FMNS	ALICE
Dr. D.J. van der Zee	FEB	Operations
Dr. X. Zhu	FEB	Operations

Abbreviations:

- FEB: Faculty of Economics and Business
- FMNS: Faculty of Mathematics and Natural Sciences
- ALICE: Artificial Intelligence Center
- ENTEG: Engineering and Technology institute Groningen
- HRM & OB: Human Resource Management & Organizational Behaviour
- I&O: Innovation & Organization
- JBI: Johann Bernoulli Institute of Mathematics and Computer Sciences
- ZIAM: Zernike Institute for Advanced Materials

Webpages of the research institutes ENTEG and SOM

- http://www.rug.nl/research/enteg/
- http://www.rug.nl/research/research-feb/

Relation to education

The roadmap is relevant for a number of degree programs of the University of Groningen. The most relevant are:

- Industrial Engineering and Management
- Supply Chain Management
- Technology and Operations Management
- Computer Science

Other degree programs of interest are: Applied Mathematics, Applied Physics, Artificial Intelligence, Business Administration, Chemical Engineering, Human Resource Management, Operations Research