Research programs

Data Science is an interdisciplinary field that uses a variety of techniques to create value based on extracting knowledge and insights from available data. The successful and responsible application of these methods highly depends on a good understanding of the application domain, taking into account ethics, business models, and human behavior. The Data Science Center Eindhoven (DSC/e) therefore runs several research programs on various application domains of Data Science at Eindhoven University of Technology. Each program is focused on a specific application area where Data Science is heavily used. This brochure contains a concise description per research program, explaining the program, scope, vision, research interests, the key staff involved, and the main fields of expertise.
data science

- algorithms
- data mining
- machine learning
- process mining
- predictive analytics
- distributed systems
- databases
- statistics
- privacy, security, law & ethics
- behavioral/social science
- business models & marketing
- visualization & visual analytics

T. Shaped People
The Data Science Center Eindhoven

What is Data Science?
Data Science is an interdisciplinary field that uses a variety of techniques to create value based on extracting knowledge and insights from available data. Data Science is applied everywhere: in business, health, industry, finance, government, education, and also scientific research. Data scientists use state of the art approaches from statistics, data/process mining, machine learning, visualization, algorithms, databases, security, privacy, and distributed computing. The successful and responsible application of these methods highly depends on a good understanding of the application domain, taking into account ethics, business models, and human behavior. Data Science can be used to identify patterns and regularities in huge data streams, combine various data sources and answer questions at a scale previously not possible. Questions that could not be answered in the past can now be answered immediately and at any point in time. Therefore, Data Science is becoming an integral part of most types of engineering and scientific research.

Data Science Center Eindhoven - DSC/e
The Data Science Center Eindhoven is TU/e’s response to these challenges and possibilities. By bringing top scientists and students from over thirty research groups from different TU/e departments together on specific topics, we can tackle the most complex scientific and societal challenges. The DSC/e has a simple, threefold mission: (1) providing an interface between TU/e’s Data Science researchers and external parties, (2) supporting scientists in creating new initiatives and acquiring funding, and (3) providing a meeting place for Data Science enthusiasts inside and outside TU/e.

DSC/e Research Programs
Part of DSC/e’s mission is to bring researchers together in research programs. Each program is focused on a specific application area where Data Science is heavily used: customer journey, health analytics, internet of things, quantified self and smart manufacturing and maintenance. Typically several disciplines are involved. The set of research programs is not fixed. New programs are created when new and important challenges emerge. Each research program describes its main challenges and collaborations in a flyer. This information is collected in this brochure. We hope that this will help you to find the right Data Science expertise within DSC/e. Feel free to contact us via dsce@tue.nl.

Enjoy reading!

Prof.dr.ir. Wil van der Aalst
Scientific Director DSC/e
DSC/e research programs

What is a research program?
The DSC/e consists of over thirty research groups, each of which is working on their own topic and/or technique, across six involved departments. This wide distribution of research efforts creates many opportunities for new collaborations. By setting up research programs the DSC/e aims to connect these efforts to initiate and align joint research. The research programs are centered around key topics where there is a strong researcher base, with a high impact in research and society.

Each research program is focused on a specific application domain. The program is led by a professor who is internationally renowned in this specific domain. In each research program researchers from several DSC/e groups (usually three to five) from different departments join forces to collaborate and advance the research in this domain. Furthermore, members from the university’s research support network join to connect researchers to upcoming calls. This core team meets once a month, and organizes larger meetings around this topic.

Current research programs
Currently we have five research programs running:
Within the Internet of Things (IoT) research program, we research how IoT networks can be autonomous, sustainable, and self-orchestrated ecosystems. These networks can be used for example in industrial settings, where manufacturing and maintenance processes are continuously and coherently optimized. Another example is given by the Health Analytics research program, where data from several sources is combined to transform health services by analyzing, processing and acting on health data. As of recently, data can also come from personal devices. The Quantified Self research program aims at using Data Science to provide personalized and context-aware suggestions to improve people’s vitality and wellbeing. Both research programs are therefore considering different phases in the health continuum. Data Science techniques are also applied in the context of customer journeys where customer interaction with businesses is analyzed to support both the customer and the business in making better decisions.

Each research program provides a meeting place for researchers and industry to get together and have discussions, workshops or research meetings. The goal is to let novel ideas emerge and collaborations between researchers and external parties to be started or strengthened. It is also important for researchers to be aware of the current industrial challenges, and for industry to be aware of the state of the art of research. Existing external contacts can easily be shared to further increase external collaboration. Research programs also contribute to the Data Science Lecture series and annual summit by suggesting interesting speakers on their topic. These interactions of course also connect existing networks and enable external parties to find their way within the DSC/e.

I hope that each reader, whether from academia, industry, or government can find a link with at least one research program. In any case, feel free to contact us, or one of the researchers directly, in case you would like to know more.

Enjoy reading!

[Signature]

dr.ir. Joos Buijs
Research program manager DSC/e
Customers interact with an organization and its products and services in various ways: online shopping, after-sales, added services, social media, complaints, actual product usage (internet of things), upgrades, etc. Linking the various touch-points between these forms of interaction is vital for understanding and improving the overall customer journey. We analyze this challenging multidisciplinary problem from several complementary research perspectives: predictive analytics, process mining, human computer interaction, user psychology, marketing and innovation.
Scope

Customers interact with an organization and its products and services in various ways: online shopping, after-sales, added services, social media, complaints, actual product usage (internet of things), upgrades, etc. To understand and to improve the overall customer journey, it is vital to link the various touch-points. This is an extremely challenging multidisciplinary problem that we analyze from several complementary research perspectives: **predictive analytics, data mining, process mining, human computer interaction, user psychology, marketing, and innovation.**

During the interaction with an organization, customers leave many traces of their behavior. The interpretation of these traces and the extraction of actionable knowledge requires expertise on data collection and statistical techniques. Actionable knowledge is linked to understanding customers in the way that they behave, collect information and decide. A vast amount of data makes this possible. Data analytics ought to be employed to understand the user population, the organization’s outputs and the interaction between them. It is time to find streams of knowledge in a sea of data!

Vision

To understand and improve the customer journey through informed and responsible analytics.

Research challenges

a) **Gaining actionable and trustable insights**
   By using the data and user theories, actionable and trustable insights should be gained. The output is to be provided in the form of user-interpretable and trustworthy models.

b) **Modeling evolving customer behavior, and customer behavior under (co-)evolving circumstances**
   Customer behavior changes. It is important to recognize such changes, and to understand how behavior changes under evolving circumstances.

c) **Enriching data mining**
   Consumer psychology and marketing insights should enrich the data mining and process mining approaches.

d) **Understanding when and why segments of customers deviate from the common path**
   Recognizing that groups of customers behave differently, for instance through process mining and exceptional model mining.

e) **Analyzing life-long customer journeys**
   Customer journeys are not always local and short, but often part of a longer journey. This requires a different analysis approach to cope with the longer time-scale.

f) **Creating real-time predictive and prescriptive models**
   Real-time predictive models are necessary to quickly react to actions when managing sales processes and customer experience processes. Prescriptive models are necessary to guide the standard process.

g) **User-centric evaluation of the customer journey**
   Triangulation of behavioural and user experience data to understand why and how interventions work (or not).
Informed and responsible analytics
to understand and improve the customer journey

Project examples

**NWO RATE-Analytics Rabobank, Achmea, TiU/JADS**
We develop foundations and techniques for next generation big data analytics, combining predictive analytics, modern statistics, and visual analytics. This unique combination will lead to breakthroughs in data-driven banking and insurance, facilitating the development of more reliable, transparent, and responsible analytics solutions and products.

**MiCuB BrandLoyalty**

Real-time mining of customer behavior to increase the effectiveness of loyalty programs and predict bottlenecks. The evolution of customer behavior models over time is mined together with the streams of resources during the promotion period.

Supporting energy saving decisions **NWO-PhD**
Helping users save energy by supporting them through personalized saving recommendations using their implementation likelihood and energy saving ability.

Sales process engineering at Philips Lighting
Analyzing customer journeys using process mining techniques to propose improvements based on bottleneck detection and a comparison of the actual execution with the formal process. The most valuable activities per attribute are also analyzed.

**KYC-Analytics Rabobank**
Applying deep learning, NLP, and pattern mining.

Scientific staff involved

**Core team**

Prof. Mykola Pechenizkiy (RP leader)  
Predictive analytics

Dr. Michel van der Borgh  
Data-driven sales process engineering

Dr. Wouter Duivesteijn  
Data mining

Dr. Marwan Hassani  
Customer journey real-time process mining

Prof. Chris Snijders  
Human-data interaction

Dr. Martijn Willemse  
User psychology / user-centric evaluation

Ir. Joost Gabriels / Drs. Masja Kempen  
Project Development Officers

**Selection of other staff involved**

Dr. Sarah Gelper  
Quantitative marketing research

Prof. Uzay Kaymak  
Business intelligence

Prof. Fred Langerak  
Product development & management

Dr. Massimiliano de leoni  
Customer journey process mining

Dr. Vlado Menkovski  
Deep learning

Dr. Nevin Mutlu  
Retail operations

Prof. Ed Nijssen  
Technology marketing

Prof. Bettina Speckmann  
Geo-spatial algorithms and visualization

Prof. Jack van Wijk  
Visual analytics

**External cooperation**

Phils Data Science for health flagship (DDVP Stream)  
Process mining, model adaptation, coaching models, recommenders, user experience

Adversitement and StudyPortals STW CAPA  
Context-awareness and concept drift handling

Interpolis  
Developing prevention recommendations for clients using a smart combination of recommender systems algorithms and user psychology

We also collaborate with Tilburg University in the Jheronimus Academy of Data Science (JADS).
Health analytics is transforming health services owing to the advent of digitization and new information collection systems (e.g. patient portals, IoT, cloud computing, big data, and wearables), so that health innovation is driven by analyzing, processing and acting on health data.
Scope

Information technology, IoT, cloud computing, big data and data analytics have a large impact on the health services. While advances in medical knowledge result in better diagnosis and more and better treatment solutions, patient-centricity, self-care, integrated care delivery and shared decision making are appearing as new trends. The way health services are delivered is being revolutionized by sharing and integrating large volumes of health data. Health analytics is the key element of this revolution, allowing to merge, analyze and process all health related data to gain more actionable insight, understanding and knowledge at individual and population level. This provides the basis for modern innovation and value addition in evidence-based medicine.

We have 3 main focus themes:

- **Decision support for better health**
  Data analysis, computerized modeling, clinical decision support, personalized models

- **Visual health analytics**
  Visualization, visual analytics, medical image analysis, decision support based on image analysis

- **Healthcare process and environment innovation**
  Process mining, environmental factors, organizational aspects, privacy

Vision

In the future, the availability of large volumes of health data is an important asset for health organizations. Data, controlled by the citizens, are collected ubiquitously throughout the care continuum, connected seamlessly and interpreted within the right context. Data are used to improve health solutions and to advance medical knowledge, leading to better outcomes while increasing efficiency. For instance, data are continuously used to analyze and improve workflows and medical guidelines, thereby providing stronger evidence for best practice solutions. For this purpose, health analytics enables personalized care delivery throughout the care continuum. Using personalized health records citizens are empowered to control their own health better, such that the collected data is of service to the individuals and to the society at large.

Research challenges

**Data handling**

**a) Collect and integrate health data (at the broad scale)**

How can we collect, integrate and harmonize data to create consistent models across organizations, regions and nations, taking into account semantic interoperability aspects?

**b) Collect and examine health data to examine the interaction between the environment and persons**

Environment has a large influence on peoples’ health. How can we use environment data (e.g. indoor and outdoor climate data) to improve health solutions?

**c) Techniques and algorithms for federated or distributed data analysis**

Can we run all data analysis methods fast and accurate in a federate way, when data can not be pooled in one location?

**Personal healthcare**

**d) Develop data-driven decision-support models**

How can data-driven and consistent multi-scale decision-support models be developed to support both individuals and health professionals in the whole care continuum?

**e) Develop data analytics solutions to optimize and personalize care workflows**

Can we analyze the effectiveness of clinical protocols and clinical pathways to suggest individualized treatment paths?

**f) Personalized decision support models**

How can we create data driven models that allow personalization of recommendations and treatments?

**Models**

**g) Developing and improving techniques for process analytics in healthcare**

How can we improve process modeling under different sources of personalized heterogeneity and how do we estimate the influences of the risk factors?

**h) Integrate data analytics into continuous medical improvements for value based healthcare**

How to facilitate the deployment of the models in practice? Can those models continuously learn and adapt to increase their prediction quality?
Project examples

**BrainBridge program, Philips, TU/e and Zhejiang University**
Clinical Pathway Analysis - Develop tools to analyze and study the performance of clinical pathways and clinical workflows.
Cardiovascular Risk Assessment - Develop an intelligent system for long-term cardiovascular risk assessment and prediction.

**Creating healthy environments in hospitals, Meander Medical Centre Amersfoort and Jeroen Bosch Hospital in ’s-Hertogenbosch**
Collecting and analyzing indoor climate data to understand the interaction between the environment and staff’s performance and patients’ safety.

**Creating healthy lighting environments in offices, Philips and Deloitte**
Collecting and analyzing light data to understand the interaction between light and staff performance while taken in consideration energy savings.

**Philips Data Science for health flagship, Philips, Catharina hospital, TU/e**
A joint initiative by Philips, Catharina hospital and TU/e.
Continuous personal health - Develop data-driven, predictive solutions for the whole care continuum.
Optimizing Healthcare Workflows stream - develop process analytics techniques and interactive visualizations to analyse and improve process performance.

**Gamebus, EIT Digital and MUMC+ Maastricht**
Valorization focused project to stimulate physical, cognitive and social healthy behavior across communities and generations of people.

Scientific staff involved

**Core team**

- **Prof. Uzay Kaymak** (RP leader)
  - Business process analytics for healthcare
- **Dr. Joos Buijs**
  - Process mining in healthcare
- **Prof. Edwin van den Heuvel**
  - Longitudinal health studies
- **Prof. Helianthe Kort**
  - Health in the built environment
- **Prof. Natal van Riel**
  - Computational biology
- **Dr. Anna Wilbik**
  - Linguistic summarization
- **Chris Knighting**
  - Project development officer

**Selection of other staff involved**

- **Dr. Elizabeth O’Neill**
  - Ethics
- **Prof. Mykola Pechenizkiy**
  - Data mining, predictive analytics
- **Dr. Bert Sadowski**
  - Users and business models
- **Prof. Bettina Speckmann**
  - Applied geometric algorithms
- **Dr. Pieter Van Gorp**
  - Digital health promotion
- **Dr. Mitko Veta**
  - Biomedical image analysis
- **Dr. Michel Westenberg**
  - Data visualization and visual analytics in life sciences and healthcare

External cooperation

Within the Research Program we work actively together with companies like Philips, Rabobank, Adverstainment, StudyPortals, Achmea, and Interpolis. We also collaborate with Tilburg University in the Jheronimus Academy of Data Science (JADS).
Everything is being interconnected. Data bigger than ever are to be generated and transferred. Innovative algorithms are being devised to make connections and sense out of seemingly uncorrelated information. DSC/e sets to give to Internet of Things what nature gave to life on our planet, evolution. We strive for a global autonomous sustainable and self-orchestrated ecosystem of everything.
Scope

Connectivity is, already now, possible between virtually anything. Internet of things relies on a multitude of technologies to help anything communicate and share its own data. However, it is the local computational intelligence that will allow smarter things generate more valuable and actionable data. At the intersection of artificial intelligence, network science and internet of things, DSC/e strives to build things able to autonomously create their own code of conduct, self-organize and interact with their environment.

Our belief:
**A global sustainable IoT consumes the data it produces**

Our drivers:
- **Connect anything anywhere anytime**
  dependable networks, network science, swarm intelligence, self-organization, security
- **Sense everything, act selectively**
  Computational intelligence, data analytics, machine learning, pattern recognition, self-awareness
- **Actionable data is business**
  Business models and strategies, standardization, intellectual property

Vision

Autonomous evolution, self-orchestration and global interconnection of everything are features of real ecosystems. An ecosystem of IoT devices is capable of self-organizing in clusters, competing for resources with each other, gaining new capabilities and devising new strategies to boost their own survivability. In such a system, analyzing data is the key to achieving awareness of the local environment and detecting internal and external threats. The interaction of such an ecosystem with the human society, business models and applications will define a dynamic set of rules of operation.

The realization of IoT systems at scale is a daunting task, involving the digitization of sensing, actuation, and control. Future IoT systems won’t be driven by the deterministic mechanisms of today. They will be sustained by all sorts of intelligent processes, both inside the devices and among them. Things will have the ability to seamlessly interplay but also to survive external perturbations, minimize their digital footprint, self-diagnose, and generally operate based on predictions.

Research challenges

The roadmap of this vision relies on several paths, currently at different maturity levels.

**Business Modeling**
- Redesign data intensive applications and business models and strategies with IoT and Data Science
- Valorization and intellectual property strategies despite recent explosion of industry standards

**Deployment**
- Digitize physical world via innovative sensors and data pre-processing and dissemination methods
- Design future-proof autonomous and dependable networks ready to deal with massive scale and traffic, complexity and security challenges

**Making Sense**
- Build data mining methods and tools for semantic interoperability of IoT systems and for (near-)real-time complex events detection and correlation
- Design methods for automated detection of emergent patterns in data streams

**Control Loops**
- Translate patterns in data to learned and preferred actions via online machine learning, prediction, and control
- Design dependable control loops to provide end-to-end performance predictability and guarantees

**IoT Ecology**
- Architect global self-evolving IoT systems to attain swarming, competing and behavior emergence characteristics

**Risk management**
- Develop methods to manage risk in distributed and interconnected IoT systems, including threat analysis, threat propagation, and strategic response
- Design security measures and procedures that effectively represent risk and provide immediate security advice to customers and network managers
Project examples

**Inter-IoT EU Horizon 2020**
IoT interoperability and data mining to enable any-to-any standard-agnostic communication.

**ACCUS EU Artemis**
Cooperative control in smart cities breaks silos and allows for dependable survivable networks of devices.

**DEMANES EU Artemis**
Monitoring and operation in industrial IoT systems fuels the future logistics with high value actionable data.

**SCOTT EU Horizon 2020 ECSEL**
Secure ConNected Trustable Things to realize dependable data dissemination and control.

**ProHeal EU ITEA**
Automated self-protection and self-healing software solutions towards a fully autonomous evolving IoT.

**Facilities & Datasets**

We maintain an experimental open IoT facility, that allows the deployment of applications, cloud-assisted event and data logging and correlation, IoT data mining, dataset generation and analysis.

**External cooperation**

Within the Research Program we work actively together with companies like Philips Healthcare, Philips Lighting, NXP, FEI, Genexis, ASML, and TomTom.

**Scientific staff involved**

**Core team**
- **Dr. George Exarchakos (RP leader)**
  Dependable communications
- **Dr. Luca Alldi**
  Risk quantification
- **Dr. Vlado Menkovski**
  Machine learning
- **Dr. Tanir Ozcelebi**
  Smart spaces
- **Ir. Jan Haagh**
  Business developer

**Selection of other staff involved**
- **Ir. Mariëlle Aarts**
  Light & health, data & lighting applications, process modelling, verification
- **Prof. Lin-Lin Chen**
  Learning user behavior and preference, augmenting human senses
- **Dr. Rajendra Dangol**
  LED lighting & applications, Subjective preferences from data collection and analysis
- **Dr. Mathias Funk**
  Adaptive data design in a systems context
- **Dr. Madeleine Gibescu**
  Balancing smart grids, power system optimization, DC grid technologies, local markets
- **Dr. Marwan Hassani**
  Stream data mining
- **Dr. Jun Hu**
  Social computing
- **Prof. Johan Lukkien**
  Embedded real-time systems, architectures protocols
- **Dr. Phuong Nguyen**
  Active distribution networks, micro-grids, multi-agent system, data analytics, deep learning
- **Dr. Ksenia Podoyintsyna**
  Data-driven business models and ecosystems
- **Prof. Alexander Rosemann**
  Human centered lighting, lighting applications, smart lighting
- **Dr. Bert Sadowski**
  Economic value of IoT systems, digital markets, business modeling, regulation
- **Prof. Tom van Woensel**
  Freight transport, city logistics, e-commerce, omnichannel logistics, retail operations
Quantified Self
Human Vitality & Technology

Modern, health and sports related, ICT systems have the ability to acquire considerable amounts of real-time data from the human body on a 24/7 basis using technology that recently has become available and affordable. These personalized and context-aware technologies can help to provide new opportunities to improve people’s vitality, prevention, and sports performance. More research is needed and possible because a multi-perspective approach brings new interesting questions.

DSC/e
www.tue.nl/DSCe/RP/QS
Scope

In the Quantified Self research program we research the role of personalized and context-aware technologies that help to:
• better understand relations between people’s vitality and their behavioral patterns in daily life (including but not restricted to sports);
• better understand relations between actual (sports) achievements and activity patterns before, during and after being physically active;
• better understand the contextual motives shaping active behavior, conditioned as this is by routines shaped by our social peer group and our physical everyday living environment.

This will not only provide new opportunities to improve people’s vitality, prevention, and sports performance but it will also enable early detection and slow down the impact of possible injuries and onset of (chronic) diseases. This can give people adequate information to gain control over their (potential) disorder and manage their personal health state with much greater effectiveness than previously and at a fraction of the cost of traditional, curative intramural care.

For researchers, policy makers, health professionals, planners and designers these personalized and context-aware technologies deliver real time, individual and big data on correlations between an active lifestyle and health outcomes contextualized for lifestyle groups and living environments. This provides invaluable information to understand these correlations, to develop intervention strategies and to monitor and evaluate their effectiveness to contribute to a more healthy and sustainable society, countering the nowadays health epidemics of our consumer society: obesity, burn-outs and dementia to mention a few.

Vision

The ambition is to establish, together with partners, a Vitality Academy. In this Virtual Research Centre wide ranges of active life style, recreational sports- and vitality related data are collected to:
• Acquire on a 24/7 basis for groups of people requiring/appreciating this;
• Analyze using state-of-the-art data analytics;
• Integrate into a standardized framework;
• Use to design personalized support for sporters, coaches/trainers as well as for researchers, health professionals and designers active in the above fields.

Research challenges

• The acquisition of activity related data from individual people in “everyday life” related to their health and wellbeing.
• The analysis of this data and translation into scientific models that provide insight in the underlying patterns.
• Develop concepts and models establishing the correlations between psychological, social and physical motives and conditions shaping an active lifestyle as well their impact on health outcomes, both physically and mentally
• The design and validation, in context, based upon these models, of new propositions that will improve the health and wellbeing of these people.
Project examples

**Marathon Eindhoven** (partner since 2013)
Analyzing and supporting the behavior before, during and after the event especially for (starting) recreational runners.

**Inspirun**
Personalized coaching for recreational runners based upon individual activity data.

**Nano4Sports, Interreg V**
Use sensor technology to develop smart innovative solutions for better, safer and lifelong sports experiences for all.

**User-Generated Data for Urban planning**
Analyzing physical activity related wearable data for monitoring and intervention in urban areas.

**Bouncers**
The use of social media techniques to analyze and improve physical activity patterns in social groups.

**Philips-TU/e Flagship on Data Science**
Within the flagship the project ‘Data-Driven Value Propositions; Systems supporting customers and coaches’ addresses quantified self in a sports setting.

**Mine Your Own Body** *Philips*
Psychological effects of the quantified self.

Scientific staff involved

The research program quantified self is also known as the research roadmap human vitality & technology.

**Core team**

**Prof. Aarnout Brombacher** (RP leader)  
*Vitality & recreational sport, IoT, preventive health care*

**Prof. Wijnand IJsselsteijn**  
*Cognition and affect in human technology interaction*

**Prof. Steven Vos**  
*Designerly solutions for vital people*

**Prof. Pieter van Wesemael**  
*Urban planning and design for healthy cities*

**Marijke van Beurden**  
*Program director human vitality & technology*

**Selection of other staff involved**

*Scientific staff from 5 departments and more than 13 research groups are involved.*

**Prof. Caroline Hummels**  
*Design and theory for transformative qualities*

**Prof. Jan de Jonge**  
*Work psychology in human performance management*

**Prof. Evangelia Demerouti**  
*Organizational behavior & human decision processes*

**Prof. Masi Mohammadi**  
*Empathic environment*

Labs

**Genneper Parken (GP) ‘Sports & Vitality district’**: promote physical activity by an interactive route for individual sporting through the GP greenbelt combining park design, intelligent probes and ICT technologies.

**Fieldlab Op Noord: Interactive running and walking path**: the use of led-technology for monitoring and coaching of recreational sports participants in the fieldlab Op Noord in the Eckart area Eindhoven.

**Smartness, Society, Stories**: continuing our work with the New Institute and Gemeente Eindhoven in the neighbourhoods of Woenselse Heide and Temple from 2016, we will explore existing community connectivity, neighbourhood tensions, and role of governance. The project questions how and where smart city initiatives are addressing the role of people, society, and needs in the city.

External cooperation

Knowledge institutions: Fontys Hogeschool, University of Utrecht and Utrecht Academic Medical center.

Platform Gezond Ontwerp (“Healthy design”), city governments, Cluster Sports & Technology, several fieldlabs, and local football clubs.

Contact

Please join our community and feel free to contact us for more information: vitality@tue.nl.
Smart Manufacturing & Maintenance

Exploit the full potential of your data to boost manufacturing and maintenance!

The new industrial revolution is driven by the data collected via new-generation information and sensor technologies. This enables the optimization of a factory or a service-logistics network as a whole, instead of sub-optimizing business units and processes separately.

DSC/e
www.tue.nl/DSCe/RP/SMM
Scope

The new industrial revolution (Industry 4.0) is driven by new generation information and sensor technologies such as cloud computing, big data and data analytics, robotics and additive manufacturing. These technologies create the internet of things (IoT) in which objects (products, machines, factories, warehouses, customers) are all connected. The increased availability of massive amounts of sensor and manufacturing data that can be shared among the whole supply chain will enable integrated planning in industry to improve manufacturing and maintenance processes and to develop innovative products and services.

Vision

The digitizing industry bears the promise to improve and integrate manufacturing and maintenance planning, thus facilitating the optimization of a factory as a whole, instead of sub-optimizing business units and processes separately. Integrated planning will lead to higher and more flexible production capacity, more efficient maintenance, more reliable production lead times, and lower stock levels. To make this promise come true, the current way of making separate plans for manufacturing and maintenance based on ad-hoc collected data must change.

Research Program

Smart Manufacturing & Maintenance

Research challenges

a) Development of data-collection and data-aggregation techniques to parameterize production, estimation, prediction and maintenance models.

b) Implementation of advanced prediction and estimation techniques (e.g. failures, wear out, demand).

c) Investigate simulation-based optimization techniques.

d) Creation of data-driven integrated prediction and optimization models.

e) Development of a data-driven decision-making framework at operational and tactical level to support integrated production planning and predictive maintenance.

f) Analysis of the value of integrated planning for the whole factory.

Project examples

Daisy4Offshore, TKI WoZ
To develop new algorithms for early failure detection to support maintenance of offshore wind turbines.

Dynamerge, NWO
Develop new models for emergency service logistics, dynamic planning at operational level, and network design with companies such as Philips, Brandweer Amsterdam, CWI.

MANTIS, EU ECSEL
Develop a predictive maintenance platform for smart manufacturing, fleet management, energy production and healthcare.

Philips Data Science for health flagship
A joint initiative by Philips and TU/e to create new methods and tools for the smart maintenance of healthcare imaging systems.

ProSeLo Next, TKI Dinalog
Creating new predictive maintenance approaches, service business models, and control towers with Marel, Océ, ASML, and Vanderlande.
**Success stories**

**ASML**
A software tool is developed for tactical and operational planning of spare parts that go through engineering changes. The tool uses data from multiple sources within ASML to improve the quality of the planning, which leads to less emergencies, and a reduction of the total workload for the planners.

**Marel Stork**
A sensor system has been developed to continuously monitor the condition of the chain of an overhead conveyor system in a poultry processing plant. This system is capable to accurately monitor and predict the chain length over time, enabling engineers to perform the right maintenance at the right point in time.

**Nexperia**
Advanced optimization algorithms have been developed to automate and improve the weekly scheduling of hundreds of production batches on assembly lines in Nexperia’s semi-conductor plants. Substantial capacity gain is shown to be feasible.

**NXP**
26 gigabytes of production data is translated into valuable information for maintenance managers and engineers. Based on a fluid-flow simulator, a software tool has been developed. Overall equipment efficiency has increased since implementation of the software.

**Philips Data Science for health flagship**
A data-driven approach was developed for the prediction of the useful remaining lifetime of critical components. This approach was implemented into a tool permitting the characterization of the criticality of a predictive alarm and facilitating proactive maintenance.

**Scientific staff involved**

**Core team**
- **Prof. Geert-Jan van Houtum** (RP leader)
  - Smart maintenance
- **Prof. Ivo Adan**
  - Smart manufacturing
- **Dr. Alp Akçay**
  - Simulation-based optimization
- **Dr. Alessandro Di Bucchianico**
  - Statistical process control, reliability theory, maintenance
- **Dr. Mike Holenderski**
  - Machine learning
- **Dr. Stella Kapodistria**
  - Data-Driven stochastic processes and optimization
- **Dr. Ingrid Vliegen**
  - Project development officer

**Selection of other staff involved**
- **Dr. Rob Basten**
  - Predictive maintenance, spare parts supply
- **Dr. Joos Buijs**
  - Process mining, process modeling, process analysis
- **Dr. Remco Dijkman**
  - Process optimization, data-driven logistics
- **Dr. Rik Eshuis**
  - Data-driven process management
- **Dr. Simme Douwe Flapper**
  - Maintenance, re-manufacturing
- **Dr. Tugce Martagan**
  - Stochastic modeling and optimization, manufacturing systems
- **Prof. Mykola Pechenizkiy**
  - Predictive analytics, evolving data streams, handling concept drift, complex networks
- **Dr. Sasha Pogromskiy**
  - Manufacturing networks, control systems
- **Dr. Paulo Serra**
  - Bayesian statistics, time series analysis, recursive estimation
- **Dr. Irene Vanderfeesten**
  - Workflow management, business process modelling, human aspects of information systems

**Software**
ProM: An open source and extensible framework for process mining techniques, used to analyze processes and detect deviations. For more information see [www.promtools.org](http://www.promtools.org).