New Software Engineering Challenges in the Digital Transformation era

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TU Kaiserslautern &
Fraunhofer IESE &
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Agenda

• Fraunhofer Applied Research Organization
• Mega-Trend „Digital Transformation“
• Examples
  • Today
  • Future
• Opportunities
• Challenges (Systems & Processes)
• Takeaways
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Fraunhofer-Gesellschaft, the largest organization for applied research & technology transfer in Europe

Applied Research for Economy and Society

About 27,000 employees

70 institutes and research institutions

2 billion €
1.7 billion €

Research Volume
Contracted Research

About 30% of base funding from federal and state government
Above 70% of industry contracts and publicly funded research projects

Trusted Partner of German/European Industry for Innovation since 1949
Fraunhofer Institute for Experimental Software Engineering

- Founded in 1996
- Scaleable software & systems engineering with quality guarantees to support digital transformation
- Applied in automotive/mobility, industry 4.0, health, energy, etc.
- Over 200 (FTE) employees

Leading German/European Institute for Software & Systems Engineering
IESE Core Focus – Software-Intensive Systems (Digital Transformation)

- Software enables innovation and growth
  Example: Industry 4.0

- In the area of software, networking is increasing, smart ecosystems are evolving, and system complexity is growing
  Example: Internet of Things

- Quality assurance is crucial
  Example: Managing trust

Smart Ecosystems are the „Systems of the Future“
IESE Core Competencies

IESE provides „Scaleable SE approaches“
IESE Top Industry Customers in 2016

Heterogeneous set of industrial customers (region, size, sector)
Fraunhofer has become a world-wide acting Research Organization
Science Alliance Kaiserslautern
(Leading German Competence Center in Digital Transformation)

- 2 Universities
- 10 Research Institutes in IT and Engineering, including
  - Max Planck (CS)
  - 3 x Fraunhofer (CS, Math, Physics)
  - German Center for AI
- App. 35 High-Tech Companies
- Leading National Research Centers in
  - Industry 4.0 („Smart Factory“)
  - Agriculture („Commercial Vehicle Alliance“)
  - Energy („Fraunhofer Service Center: Cross Energy Management“)
  - Health („Fraunhofer Service Center: eHealth“)

App. 1000 scientists in Software;
Equal Strengths in Engineering & Information Technology
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Mega-Trend „Digital Transformation“

- Digital technologies enter all areas of business, private and public life (iPhone is main access device)
- Key enablers are
  - Omni-present ad-hoc communication technologies (with internet as backbone)
  - Micro-sensors to capture masses of data
- Key synergizing characteristics are
  - Interconnected things (physical, digital, human)
    - Buzzword: Internet of things (IoT)
  - Value generation via (big) data analytics

Smarter & New Products and Services via networking of all „things“ (IoT) and smart data usage!
Digital Transformation – Evolution vs. Revolution?

Evolution represents normal innovation (competitive advantage); revolution enables new revenues & jobs!
Smart Ecosystems
Same Trend across Domains

Digital Transformation affects all sectors of industry and society – all of us!!
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Digitalization: A Driver in Private Life

We all use it: Uber, Streaming services to produce our own music, apps!
Digitalization as Driver for Business Life: Integration Enables Innovation!

... in Information Systems as well as in Embedded Systems

Wide-spread usage in logistics, traffic management, smart farming, driver assistance systems, etc.!
The Fourth Industrial Revolution

- Industry 4.0 is more than automation:
  - Individual products at the cost of mass products
  - Massive integration of data into technical systems of systems
  - Self-organisation and reorganisation
  - Self-optimisation: Autonomy
  - Self-diagnostics: Safety!

Industry 4.0 is about run-time adaptive production – enabling the production of individual products at the cost of mass-production.

Too many industry 4.0 solutions are truly only industry 3.0!
Individual Products; Batch Size = 1

- The product configures the production line, which is assembled from interoperable production cells
  - Research: Smartfactory @ DFKI/Kaiserslautern
  - Practice: BoschRexroth, Wittenstein

Germany is investing heavily in digitalized production (Industry 4.0)
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Future Examples (More of the same!)

- Cross energy management systems
  - Fraunhofer leads large consortium on „Cross-Energy-Management“
- Mobility management systems
  - Intelligent guidance systems (fully connected)
- Automated Driving
  - To guide in boaring & critical systems
- Integrated health systems (hospital, doctor‘s office, home)
  - Telemonitoring, tele-medicine, …

Systems of ecosystems (smart traffic management & smart working at home create synergies)!
Examples of new „revolutionary“ Business Models

Definition: Integration of physical & digital worlds with the objective to enable new intelligent products and services by applying interconnection along the value chain and use of big data. The focus is the true needs of the customer!

Examples:

1. Taxi company „Uber“ - owns no cars
2. Predictive Maintenance of investment goods (e.g., Daimler Trucks, John Deere) to avoid down times
3. Siemens’ „On-Time-Arrival-Contract“ for ICE-train connection between Madrid and Barcelona
4. SME selling welding machines will change to selling „High Quality Welding lines per m²“ in the future
5. SME selling Plastic foiles for food industries will change to include „Digital memories“ regarding all ingredient and processes.
6. Shopping and health services provision in rural areas (e.g., Digital Villages)
7. Longer self-determined life at home (e.g., Ambient Assisted Living)
8. Earlier return to a normal life after critical surgeries (e.g., Telemonitoring)
9. Automated Driving (e.g., Agriculture, public transport in cities)

The digital train is rolling! More and more revenues will result from such services – often based on intelligent products!
Our Main Theme in 2015 – Smart Rural Areas

Smart networking between mobility, logistics, energy, health, communication, safety and security “only” for cities?

This project is currently being replicated in many states in Germany, USA & Australia!
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Opportunities

• (Continued automation ➔ Stay / become competitive)

• Commercial opportunities
  • Establish new streams of revenues and jobs
    ➔ could function as spinoff enabler
    ➔ Software = machine; data = fuel!

• Societal opportunities
  • Partial solution to the lack of highly qualified personnel
    • Guidance via virtual & augmented reality (glasses)
  • Cost reduction of public infrastructures
    • Health, energy, education, …

Opportunities affect entire society!
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Challenges

• Business

• Business models that generate value?
• Challenge for SMEs (Rapid Innovation Labs)
Prototyping New Business Models in IESE’s Rapid Innovation Labs to reduce Risks for SMEs

Rapid Innovation Lab enables “creativity” to find revolutionary business models, and reduces “risk” by evaluating them rapidly before major invest!
Challenges

• Business
  • Business models that generate value?
  • Challenge for SMEs (← Rapid Innovation Labs)

• Technical (products & processes)
  • (Software) Engineering of complex, open, and hybrid (embedded & information systems) ← model-based dev/simulation
  • Run-time adaptivity ← run-time safety certificates & safety cages
  • agile development for critical systems ← guidelines
  • Runtime data analytics ← pre-filtered (GQM) analysis
  • Comprehensive trust ← safety & security & data privacy
Smart Ecosystems

Key Technical Challenges for Software & System Engineering (products & processes)

- Complexity (→ model based system dev)
- Lifecycle Management (e.g., Agile for critical systems)
- Inter-Disciplinary
- Uncertainty (Runtime safety certificates)
- Big Data (including RT analytics)
- Guaranteed Qualities
- Safety
- Security
- Data Privacy

Developing Smart Ecosystems requires solid engineering approaches!
Complex Systems: Front-Loading ➔ MB-SE (Simulation)

This enables early evaluation of X-ilities – to avoid project catastrophies!

[source: CESAR Book, Springer]
Model-based System Architecture Design and Analysis

Integrated Systems Architecture and Failure Modeling

This enables cross-model consistency checking!
Addressing Uncertainty/Runtime adaptivity: Conditional Safety Certificates

This enables RT safety checks in the case of run-time adaptation!
Agile Development for Critical Systems

• Objective
  • Not about „agile“ vs. „process based“
  • About „what is the proper degree of agility for my type of project“?

• Approach
  • Identify objectives of project
  • Customize your project (agility, documentation, …)
    • Guidelines (e.g., length of sprint, min. documentation)
  • Deal with exceptions explicitly
  • Evaluate risks wrt. Project objectives (quality, rework)
  • Convince developers via evidence (not just case studies!!!)

• Practice
  • Many „nominal agile approaches“ (fake!)
  • Many „true agile approaches“ (customizations)

The proper degree of agility depends on project goals and characteristics!
Runtime Data Analytics

- Objectives
  - Use of historical data in order to devise predictive models for new projects
  - Use of actual project data in order to perform RT calibration (exceptions)

- This requires 2 classes of data analytics
  - Off-line data mining (old)
  - On-line (Real-time) data analytics (new)

- Challenges
  - Off-line: Volume & heterogeneity of data
  - On-Line: Pre-filtering

- Pre-Filtering:
  - GQM to select relevant data
  - TR-capable analysis procedures

The new opportunity and challenge is RT data analytics!
Comprehensive Cyber Security

- Security, Safety & Data Privacy are closely related in smart ecosystems
  - Security in open interconnected systems may affect safety
  - Critical smart ecosystems still have to be certified
  - Safety is easily quantifiable; this is not true for security!

- Approaches
  - Include security into safety trees
  - Surround critical security areas in your system with firewalls
    (IESE example: safety cages)

- Data Privacy / Ownership has increasing impact on trust (see data usage control)
Challenges

• Business
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• Social, ethical, legal, trust…
  • Dealing with acceptance, ethical decision making of automated systems, responsibility, data privacy (⇐ data usage control), …

Challenges are multi-dimensional and serious, but can be addressed!
Trust: IND²UCE
Data Privacy Framework

- The IND²UCE Framework (INtegrated Distributed Data Usage Control Enforcement) provides all necessary components for implementing data usage control.
- Static access control & encryption are insufficient in smart ecosystems!
- Context-sensitive data usage policies support appropriate compromise between new business models and data privacy needs (e.g., data can only be used in a specific building, data must be deleted after 1 week, data can only be copied 3 times)
- Graphical selection of policies by end-user creates trust!
- The framework has been implemented in several environments and can be evaluated in the IESE Data Usage Control Lab

The Induce approach addresses „data privacy“ in the appropriate way for smart ecosystems!
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TAKEAWAYS

• **Smart Ecosystems** are typical future systems in the digital transformation era
• **Opportunities outweigh challenges/risks by far**
  • Opportunities: competitiveness, new revenues and jobs through new business models, overcoming demographic and geographical challenges
  • Challenges: finding the right business models, proper engineering, addressing also economic, social, ethical and legal aspects
• **Education, Research and Practice need to recognize the disruptive changes through Digital Transformation**
• **Governments need to take a comprehensive approach**
  • Communication infrastructure everywhere (government)
  • Education addressing new challenges (government)
• **Fraunhofer IESE offers cooperation across Europe & beyond**
  • **Rapid Innovation Labs** (to identify proper business models and validate them rapidly)
  • **Engineering support** (complex and adaptive critical software systems)

The Future of Software & Systems Engineering will be exciting & challenging!
Thank You!

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