Intelligent Behavior and Simulated Reality for Industrie 4-0

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• Motto
  – „Computer with Eyes, Ears, and Common Sense“

• Overview
  – Germany’s leading research center for innovative software technologies (since 1988)
  – One of the world’s most important “Centers of Excellence”
  – Today 5 locations in Germany
    • Saarbrücken, Bremen, Kaiserslautern, Berlin, Osnabrück
  – 14 research areas, 6 living labs
  – Close to 500 researchers (~850 with students)
  – Budget of over 42M€ per year (2015)
  – More than 60 spin-offs
DFKI is a Joint Venture (PPP) of:

- Saarland
- Rhineland-Palatinate
- Bremen
- SAP
- HARTING
- JOHN DEERE
- Intel
- Google
- VSE
- Nuance
- software AG
- EMPOLIS
- Microsoft
- Deutscher Post
- BMG
- VOLKSWAGEN
- Airbus
- Claas
- Fraunhofer
- Universität des Saarlandes
- Universität Bremen
- Technische Universität Kaiserslautern
- Deutsche Messe AG
The Management Structure of DFKI

Top Management

Prof. Wolfgang Wahlster (Chair)
Dr. Walter Olthoff

Site Manager Bremen
Prof. Frank Kirchner

Site Manager Kaiserslautern
Prof. Andreas Dengel

Site Manager Saarbrücken
Prof. Philipp Slusallek

Management

Spokesman DFKI Berlin
Prof. Hans Uszkoreit

Spokesman DFKI Osnabrück
Prof. Joachim Hertzberg

Spokesman DFKI St. Wendel
Prof. Antonio Krüger
Computer with Eyes, Ears and Common Sense

- Language Understanding
- Augmented Reality
- Knowledge Management
- Men-Machine Interaction
- Robotics & Agents
- Image Understanding
- 3D-Graphics & Visualization
- Security/Verification

Intelligent Software Systems
DFKI: Research Area ASR: Agents and Simulated Reality

ASR = Graphics + AI + HPC + Security
Flexible Production Control
Using Multiagent Systems

Verification and Secure Systems
(BSI-certified Evaluation Center)

Physically-Based Image Synthese

Reconstruction of Cultural Heritage

Scientific Visualisation

GIS and Geo Visualization

Future City Planning and Management

Large 3D Models and Environments

Large Visualization Systems

Intelligent Human Simulation in Production

Web-based 3D Application (XML3D)

Distributed Visualization on the Internet

ASR Research Topics
Flexible Production Control Using Multiagent Systems
Intelligent Human Simulation, e.g. in Production Environments
ASR Technology Toolbox

Applications
- Future Internet
- Industrie 4.0
- Customer-specific Development
- Intelligent Building Management
- Life Sciences, etc.

Requirements

Technology Toolbox
- Motion-synthesis
- Virtual Reality
- Asset Server
- Middleware
- 3D-Web
- (Formal) SW-Validation
- Security
- Display-systems
- HPC/HPG-Compiler
- etc.

Concepts & Methods

Research
- Secure Systems
- Multiagent Systems
- Simulated Reality
- Visual Computing
- High Performance Computing
“Future-Project” Industrie 4.0 of German Chancellor Dr. Merkel

500 M€ for 3 Years
National Program:
250 M€ Funding each from
Ministry for Research and
Ministry for Economics

Evolution from
Embedded Systems
to Cyber-Physical
Systems

Internet of Things

Intelligent Environments/Smart Spaces
Digital City

Cyber-Physical Systems
Smart Factory, Smart Grid

Networked Embedded Systems
Intelligent Street Crossing

Embedded Systems
Airbag

National Roadmap
Embedded Systems
Agenda
Cyber-Physical Systems
Intelligent Environments based on the Internet of Things and Services

1) Central Computer
   - 1 Computer
   - Many Users

2) PC, Notebook
   - 1 Computer
   - 1 User

3) Smart Phone
   - 1 Computer
   - 1 User

4) Embedded Computers

5) Intelligent Environments

90% of all computers are embedded

Smart Factory

Many Computers, 1 User
From Industrie 1.0 to Industrie 4.0: The 4th Industrial Revolution

1. Industrial Revolution through introduction of mechanical production facilities powered by water and steam
   - **First Mechanical Loom**
   - 1784
   - End of 18th Century

2. Industrial Revolution through introduction of mass production based on the division of labour power by electrical energy
   - **Start of 20th Century**

3. Industrial Revolution through introduction of electronics and IT for a further automization of production
   - **Start of 70ies**

4. Industrial Revolution based on Cyber-Physical Production Systems
   - **today**

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**Industrie 1.0**

**Industrie 2.0**

**Industrie 3.0**

**Industrie 4.0**

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Degree of Complexity
Socio-Economic Drivers of Industrie 4.0

- Lack of Skilled Workforce
- Aging Society Later Retirement
- Volatile Markets and Cost Reduction Pressure
- Dynamic Value Chain Networks
- Shorter Product Lifecycles
- Increasing Product Variability
- Resource-Efficient and Clean Urban Production
- Batch Size 1, Mass Customization Low-volume High-mixture Factories

Batch Size 1, Mass Customization Low-volume High-mixture Factories
Mercedes-Benz swaps robots for people on its assembly lines

Car makers switch to smaller and safer robots working alongside humans for greater flexibility

Bucking modern manufacturing trends, Mercedes-Benz has been forced to trade in some of its assembly line robots for more capable humans.

The robots cannot handle the pace of change and the complexity of the key customisation options available for the company’s S-Class saloon at the 101-year-old Sindelfingen plant, which produces 400,000 vehicles a year from 1,500 tons of steel a day.
The German Future Project: Industrie 4.0

• Industrial production is the backbone of Germany’s economic performance:
  – Jobs direct: 7.7 Million, indirect: 7.1 Million, every second job
  – More than als 158 € Billion trade surplus from export of industrial products
  – (Export : machine tool industry, automotive industry)

• Disruptive Paradigm Shift in Production based on the Future Internet
  1. M2M and All-IP Factories are shifting from central MES to decentralized item-level production control
  2. The embedded digital product memory tells the machines, which production services are needed for a particular emerging product.
  3. Green & urban production via cyber-physical production systems
  4. Apps for software-defined products and smart product services

Germany is preparing the 4th Industrial Revolution based on the Internet of Things, Cyber-physical Production Systems, and the Internet of Services in Real industry.
Convergence of IT and Automation

- Increasing degree of automation in production environments
- Enterprise IT systems converge with automation technology

Source: IoT Analytics
Convergence of IT and Automation

Today
- 5-layer architecture

Future
- Cyber-physical system (CPS) based automation

Source: IoT Analytics
Need for New Development and Control Models

- CPS break up the monolithic functional automation hierarchy into virtualized distributed networked nodes
- Clash between hierarchical control in 5-layer architecture and (at least partial) autonomy of components in CPS

→ Need for approaches and tools to reconcile gap
→ Support for maintaining control in CPS
The Retrofitting of Legacy Factories with an Additional Layer of Cyber-Physical Systems

- **Raspberry PI 1**
  - CPS as an Active Product Memory for the Emerging Product

- **WLAN Router**

- **Classical SPS**

- **Gadgeteer with Sensors for Acceleration, Shock, Humidity and Temperature**

- **Raspberry PI 2**
  - CPS for Processing Sensor Data from the Additional Sensor Web
INVERSIV: Control & Automation for Versatile Production Environments

- Intelligent Simulated Reality
  - Bringing together the Physical and Cyber Environments
  - For planning, simulation, control, monitoring, support, ...
INVERSIV: Components

HAVLE: Functional Verification via Hybrid Automata

Semantic Data Analysis with Stream Processing

Visualization & Interaction 
Web- & Ressource Oriented Arch.

Automation Control & Sensor Data via Sequential Function Charts

Modelling Intelligent Behavior using multiagent models

FiVES Plugin

Human Motion Synthesis & Planning via MoCap & Machine Learning

FiVES

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FiVES

FiVES: Realtime Synchronization

- Scalable Realtime Synchronization Framework
  - Generic Entity-Component-Attribute data model
  - Allows for easy adaption to a wide range of use-cases
  - Slim server core with plugin system to add new runtime logic
Human Factor in Production Environments

Task-oriented, autonomous, highly-intelligent Characters

Semi-intelligent Characters

User-controlled Characters

Interactive changes to the 3D world

Automatic planning and synthesis of animation

Semantically annotated 3D model

Interactive Simulation of Production Scenarios

Interactive Simulation of Production Scenarios
Interact: Motion Synthesis for Production Planning (EU)

- Machine learning of statistical motion models from Motion Capture data
- Language description of human task (semi-formal syntax)
- Human behavior generation and visualization (with Daimler)
- Based on semantically parameterized Motion Graphs
- Use of semantically annotated 3D model of the production line
- Extension to physical-based 3D models
Automatic Motion Synthesis from Motion-Capture Data

Video
(MotionSyn-GlobalOpt-OneStep-34sec.mp4)
<html>
<body> ...
<xml3d id = "world1" style = "width: 1000px; height: 500px;"> ...
<group id = "shape_d1" shader = "#s_d1"
    ondblclick = "triggerMenu(event); capture_record(event)"
    > ...
<mesh type = "triangles" id = "m_mesh" >
    <data> <float3 name= "position"> 1.0 0.0 1.0 1.0 0.0 1.0 0.0 1.0 0.0 1.0 0.0 1.0 0.0 1.0 0.0 1.0 </float3> ...
</mesh> </group></xml3d> ....
</body> </html>
Industrie 4.0 @ DFKI

• Application- & Systems-Oriented Research
  – Agents and Simulated Reality
  – Robotic Innovation Center
  – Intelligent User Interfaces, plus many more

• Many Projects with Industry
  – DFKI Smart Factory & Power4Production
    • 2x Competence Centers for Industrie 4.0
  – SmartFIT: Bosch, BMW, Miele, ...
  – HySociaTea: Hybrid Social Teams
  – Inversiv: Real-Time Monitoring & Control
  – Interact: Daimler & Electrolux
  – HybrIT: Applications at VW, Airbus, KUKA

• International Networks in Industry and Research
Industrie 4.0 & Future Internet

- **FIWARE: EU-PPP for the Future Internet**
  - Creation of standardized set of generic services: Enablers
    - IoT, (Big) Data Management, Apps, Security, Cloud, Networks, ...
    - Advanced Web-based User Interfaces: XML3D & Services
  - Plus extensions for domain-specific services
    - Manufacturing, Media/Content, Health, Food, Energy, ...
  - Everything is Open Source, managed by FIWARE Foundation

- **Example: Manufacturing Enablers (FITMAN)**
  - 3D Web Viewer: Visualizing and Interacting with factories and products
  - Planning and Interacting with Human Avatars
FITMAN: Manufacturing Enablers

Video
(FITMAN007.mov)
Conclusions

• **Industrie-4.0**
  - Enabling completely new approaches to production
  - Quickly transforming the industry in German (& EU)
  - Completely rethinking the IT landscape in factories (all-IP)
  - Strong interest by small, medium, and large industries
  - Security and privacy are key factor for Industry-4.0

• **DFKI: Agents and Simulated Reality**
  - Using Graphics, AI, HPC & IT-Security in common platform
  - Major focus on Industrie-4.0
  - Comprehensive, systems-oriented research