SIEMENS

Siemens Corporate Technology | November 12, 2014

Autonomous Systems Revolution

Münchner Kreis

Autonomous Systems will boost flexible automation

Changing needs in industrial manufacturing

The production environment significantly changed in recent years

- Mass production migrated from Europe, North America and Japan to South-east Asia

Flexibility requirements for in factory automation are constantly increasing

- Shorter product life cycles and small batch production
- Frequent variation of production volume

Classical automation is very limited when handling variability

- Explicit programming of variants costly
- Re-engineering of hardware to handle variations
- High cost and limited availability of human operators

Autonomous systems are key to master the flexibility challenge

Automation today: Explicitly programmed variants and human intelligence for flexibility

Source: Daimler

Automation tomorrow: Autonomous machines handle variations without human intervention

Source: Les Echos

Truly flexible automation is still an open issue

Compared to human workers, automation is very limited when it comes to flexibility

Source: etz

Source: Mercedes

Automation → **Flexibility**

Today automation pays off for mass production and long product life cycles only

Limiting factor: Cost for production line (re-)engineering in case of product or volume changes

Today human labor is the only way to achieve high flexibility

Limiting factor: Cost and **availability of skilled work force**

The table is set for the upcoming "Autonomous Systems Revolution"

SIEMENS

SW Trends

- AI mature for real-world applications
- Big data
- Internet of things
- Cloud-enabled Robotics, Cyberworld
- Plug & Play

HW Trends

- Sensors everywhere
- Highly integrated mechatronics: Soft-Robotics, exoskeletons, novel end-effectors
- On-demand components through additive manufacturing

The Autonomous Systems Revolution

Customer Demands

- **Manufacturing:** Increasing demand for flexibility, Self-organizing / optimizing plants, man-robot-cooperation
- **Logistics**: Full automation, flexibility
- **Transportation:** Highly automated driving
- **Healthcare / Home:** Automation, assistance

Market

- **IT players stepping in:** Google
- **Logistics:** Amazon (KIVA), DHL
- **New players:** Start-ups e.g. Rethink Rob.
- **Traditional players diversifying:** KUKA, ABB, …

Socio-economic Trends

Extending automation towards human-like capabilities is general trend, regional main motivations vary

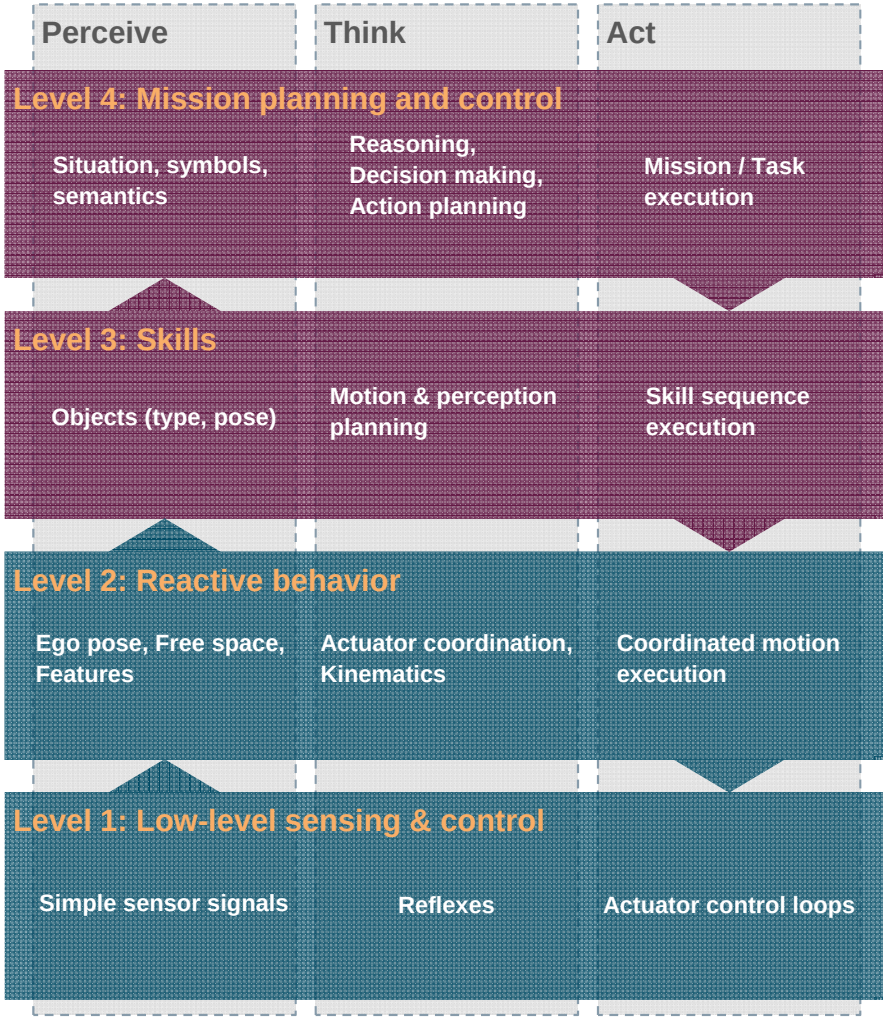
- Maintain competitive advantage
- Reclaim manufacturing
- Demographic change

Autonomous systems feature higher-level cognition

Elements of a definition of the term “Autonomous System”

Autonomous Systems

- Machines[1] able to implement and execute **high-level task** specifications **without detailed programming**
- Machines performing non-trivial (physical) tasks, **coping with changing situations**
- Machines that perceive the environment, make decisions, orchestrate and apply powerful skills to **achieve specified goals**
- Machines that implement control loops on **multiple levels of abstraction**
- Machines closely **interacting and collaborating** with other agents (humans / machines)



1) Here the term “machines” also refers to large, potentially distributed groups of machines e.g. complete plants

Autonomous Systems know what they are doing

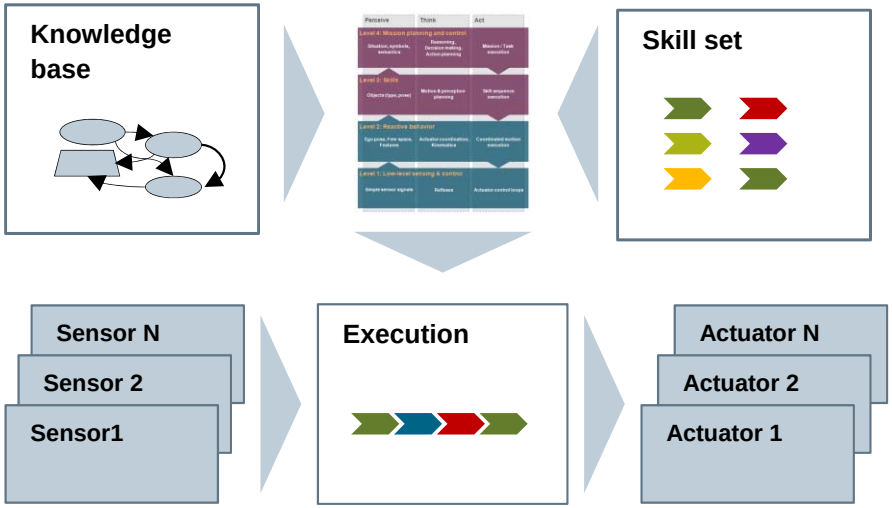
The essential difference between automated and autonomous systems

Automated System

- Automatically executes an **engineered sequence** of actions (potentially with variants)
- Does not understand the consequences of its actions
- Cannot change the sequence

Autonomous System

- Has an **explicit model / understanding** of what it is doing
- Can reason about effects and consequences of its actions
- Can dynamically modify the course of action to respond to environmental changes



Autonomous systems will pave the way to the fully SW-defined factory

SIEMENS

Objective: Minimize plant engineering efforts in case of changing products or production volumes

Pathways towards fully flexible automation

SW-defined production processes

- Available today: Additive manufacturing, CNC machines, SMT placement, laser cutters, …

Photo: RedEye

Photo: Juraform

Self-organizing factory architecture and work flows

- Will be provided by “Industrie 4.0”

Photo: Siemens

Teams of autonomous, collaborative robots and human workers

- Handling of parts and material
- Assembly and quality control
- Operation and maintenance of production machinery

Photo: the Japan news

SW-defined factories will likely change the economics of manufacturing

Autonomous systems will change manufacturing

Conclusions

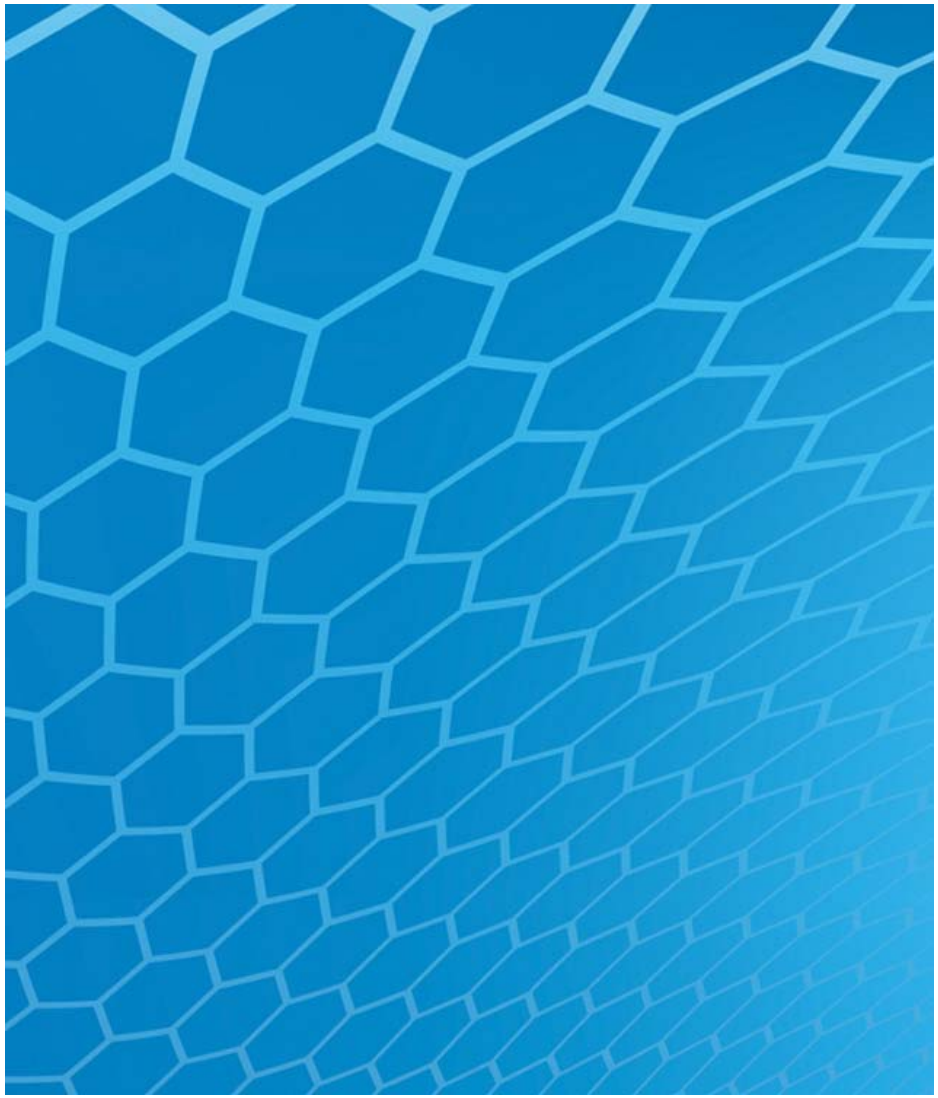
- Requirements for production automation are changing fast
- Strong demand for more flexibility in developed countries to stay globally competitive
- Autonomous systems technology is maturing rapidly, first applications already appearing on the market

Source: BBC

- Autonomous systems will enable disruptive changes in automation engineering and impact current manufacturing economics
- Autonomous systems will change the way we interact with technology in our daily life and on the job

Source: Siemens/LAPP

Thank you for your attention



Dr. Kurt D. Bettenhausen
Head of Technology Field
Automation & Control
Siemens Corporate Technology

Siemens Corporation
755 College Road East
08540 Princeton, NJ
USA

E-mail:
kurt.bettenhausen@siemens.com

www.siemens.com