INDUSTRIAL AUTOMATION
- PAST, PRESENT, FUTURE

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http://www.lsr.ei.tum.de/gspresentations.html
PUC 2008

User: PUC  PW: Santiago

Plenary Presentation IECON, Nagoya, Japan
Areas Requiring Modern Automation

- Production
- Transportation, Distribution
- Logistics
- Traffic: Air, Ground, Marine
- Products
- Services
- Intellectual Processes
- . . . . . .
INDUSTRIAL AUTOMATION
- PAST, PRESENT, FUTURE

TOPICS

• MILESTONES AND ACHIEVEMENTS OF IA

• INDUSTRIAL INFORMATION TECHNOLOGY AND AUTOMATION

• NEXT-GENERATION CHALLENGES

• CONCLUDING REMARKS
INDUSTRIAL AUTOMATION
- PAST, PRESENT, FUTURE

• MILESTONES AND ACHIEVEMENTS OF IA
  “We can’t understand the future without knowing the past”

• INDUSTRIAL INFORMATION TECHNOLOGY AND AUTOMATION

• NEXT-GENERATION CHALLENGES

• CONCLUDING REMARKS
19th Century: First Automatic Machines

“Lap” (Steam) Engine, James Watt, 1788: continuous control operation

Power Loom with Bartlett Let-off Mechanism: discontinuous control operation
1950: Era of Instrumentation

**Instrumentation Designs**
- Electromechanical
- Pneumatic, Hydraulic
- DC-Amplifier

**Automation Tasks**
- Single Control Loops
- Monitoring and Recording
- Simple Signal Processing

**Hardwired Control Functions**
- Analog Signal, PID
- Relay Logic, Binary

**Automated Processes**
- Steel and Automobile Industry
- Chemical Processing
- Power Generation
1960: Beginning of Modern Industrial Automation

First Digital **Computers** for Real-Time Industrial Applications (IBM)

First Industrial **Robots** (Unimate, GM)
A Remarkable Milestone

**AUTOMATION**

The Advent of the Automatic Factory

JOHN DIEBOLD

D. VAN NOSTRAND COMPANY, INC.
PRINCETON, NEW JERSEY
TORONTO   NEW YORK   LONDON

1952

**Automation:**
“Key Enabling Factor”

- Comprehensive View of IA, Discussing Technological as well as Related Business and Social Issues
- Objectives and Directions still Remain Major Driving Forces and Challenges of Current Developments
A Remarkable Milestone

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1980: Multi-Microcomputer Based DCS, PLC, SCADA, ...

**Systems**
- Decentralized Architecture
- Standard and Customized Integrated Electronic HW
- Industrial Robots

**Automation Tasks**
- Multivariable Control
- Sequential Control
- Coordination, Optimization
- Fault Detection

**Flexible Control Software**
- CFC and SFC Algorithms
- Configurable HMI
- Serial Bus Communication

**Automated Factories**
- Large-Scale Industrial Plants
- Manufacturing, Production
- Transportation, Distribution
# List of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>DCS</td>
<td>Distributed Control System</td>
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<tr>
<td>PLC</td>
<td>Programmable Logic Control</td>
</tr>
<tr>
<td>HMI</td>
<td>Human Machine Interface</td>
</tr>
<tr>
<td>SCADA</td>
<td>Supervisory Control and Data Acquisition</td>
</tr>
<tr>
<td>SFC</td>
<td>Sequential Function Chart Control</td>
</tr>
<tr>
<td>CFC</td>
<td>Connectionist Fuzzy Classifier</td>
</tr>
<tr>
<td>CNC</td>
<td>Computer Numerical Control Machine</td>
</tr>
<tr>
<td>EDI</td>
<td>Electronic Data Interchange</td>
</tr>
<tr>
<td>OPC</td>
<td>Open Interface over PC-based Software by means of</td>
</tr>
<tr>
<td>OLE</td>
<td>Object Linking and Embedding</td>
</tr>
<tr>
<td>PCR</td>
<td>Polymerase Chain Reaction</td>
</tr>
<tr>
<td>CE</td>
<td>Cost Effectiveness Analysis</td>
</tr>
<tr>
<td>CACSD</td>
<td>Computer Aided Control System Design</td>
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<tr>
<td>RFID</td>
<td>Radio Frequency IDentification</td>
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</table>
1990: Beginning of Information Age in IA

“From *Signal*-orientation to *Information*-orientation”

**Industrial Automation Technology** establishes a

**Plant-wide, Real-time Digital Nervous System**
Industrial Efficiency, Productivity and Safety Closely Linked to Advances in IA

- Processing Industries (Continuous)
  DCS, Motion Control

- Hybrid Industries (Continuous/Batch) + Discrete
  DCS + PLC, Motion Control

- Manufacturing Industries (Discrete)
  PLC, CNC, Motion Control

IA Solutions Developed by System Integrators
Growth of Productivity in Steel Production

Stahlproduktion und Beschäftigung in Deutschland

**Volume**
Rohstahlherzeugung
(in Mio t)

1960: 34,1
1970: 45,0
1980: 43,8
1990: 46,4
2000: 44,5
2005: 46,4

**Staff**
Beschäftigte *
(in 1,000)

1960: 417
1970: 374
1980: 288
1990: 175
2000: 103
2005: 92

**Productivity**
Produktivität
(Tonnen Rohstahl je Beschäftiger)

1960: 82
1970: 120
1980: 152
1990: 220
2000: 452
2005: 490

* am Jahresende in der Stahlindustrie, einschl. örtlich verbundene Betriebe

SZ-Grafik: Baka; Quelle: WV Stahl
Major Contributions of IA in the Recent Past

- Computers, Interfaces and Related Components for Safe, Real-Time, Closed-Loop Operations in a great Variety of Harsh Industrial Environments

- Novel HW- and SW-Systems for Advanced Control and Color CRT-HMI Technology

- Robot Technology as Means of Flexible Automation
Major Contributions of IA (cont’d)

- Conceptual, Methodological, Theoretical Foundations for Analysis and Design of Sophisticated Automation Functions

- Modelling and Simulation Techniques and SW-Tools for CAD/CAE-Approaches in Automation
INDUSTRIAL AUTOMATION
- PAST, PRESENT, FUTURE

• MILESTONES AND ACHIEVEMENTS OF IA

• INDUSTRIAL INFORMATION TECHNOLOGY AND AUTOMATION

• NEXT-GENERATION CHALLENGES

• CONCLUDING REMARKS
Industrial Information Technology and Automation

- General Trends and Driving Forces
- Vertical and Horizontal Integration by IT
- Open Automation System Platforms
- Impact of Innovative Technology
- New Requirements to IA from Plant-floor
Global Market Volume for IA Equipment

**Total:** 150 Billion Euro  
(excluding mechanics)
Changes in IA Scope, Examples

Enterprise Technology Solution, Yokogawa
Changes in IA Scope (cont’d)

Industrial IT, ABB

Totally Integrated Automation, Siemens
FROM IA TO INDUSTRIAL IT AND AUTOMATION

- **Familiar Topics**: Automation, Control, Sensors, …

- **New Buzzwords and Topics**:
  - ERP: Enterprise Resource Planning
  - MES: Manufacturing Execution
  - PAM: Plant Asset Management
  - LCM: Life Cycle Management
  - Supply Chain Management
  - Logistics & Services
  - E-Commerce
  - ……
PC and Web-Based Operations

Enterprise-Wide Digital Nervous System

BUSINESS
@
THE SPEED
OF THOUGHT

SUCCEEDING IN THE
DIGITAL ECONOMY

BILL GATES
WITH COLLINS HEMINGWAY

A Time Warner Company

1999
FROM IA TO INDUSTRIAL IT AND AUTOMATION

Enterprise-Wide Information Flow
Enterprise-Wide Information Logistics

Industrial Information Technology and Automation

„... with the Goal to Integrate Automation Systems in Real-time from Pursuit of Orders via Traditional or E-Commerce Methods right through Production and Delivery of Finished Products“
Industrial Information Technology and Automation

- General Trends and Driving Forces
- **Vertical and Horizontal Integration by IT**
- Open Automation System Platforms
- Impact of Innovative Technology
- New Requirements to IA from Plant-floor
Information Management links Automation, Enterprise, Suppliers and Customers
Vertical Integration of Enterprise by IT

Transparency of all Business Processes, e.g. by Means of Open Standardized Communication
Vertical and **Horizontal** Integration by IT

**Interconnection of the Various Digital Nervous Systems**
Industrial Information Technology and Automation

- General Trends and Driving Forces
- Vertical and Horizontal Integration by IT
- Open Automation System Platforms
- Impact of Innovative Technology
- New Requirements to IIA from Plant-floor
From Proprietary Systems to Open Automation System Platforms

Cost Reduction in DCS by Use of Standards

• Official Standards, e.g.
  Ø IEC 1131-3 PLC Programming Language
  Ø IEEE 802.3 Ethernet

• Consortium-Developed Standards, e.g.
  Ø Profibus PA
  Ø Foundation Fieldbus

• De Facto Standards, e.g.
  Ø Microsoft Windows CE
  Ø Java Sun Microsystems
Open Platform Automation Systems

Cost Reduction by Commercial-off-the-Shelf HW and SW

COTS-Hardware
- PC, Laptop, Notebook
- Mobile Phone
- Internet
- Ethernet
- ....

COTS-Software
- Microsoft Windows
- Web Browsers
- ....
Open Systems Approach in IA

**Essential Industrial Requirements**

- Real-time Capability
- 24 hrs Availability
- Robustness
- Safety, Security
- EMC
- .....
Open Platform Control Systems (OCS)

• **Present** Controls Market
  - PLC: 56%
  - CNC: 20%
  - DCS: 14%
  - Custom: 10%
  - Other: 4%

• **Future** Controls Market
  - OCS: 62%
  - PLC: 18%
  - CNC: 11%
  - DCS: 5%
  - Other: 4%
OCS Approach in IA

Benefits for Users
- Reducing Initial and Maintenance Cost
- Increased Performance by Advances in Technology
- Ability to Integrate Special Purpose Products
- ....

Drawbacks for Users
- Develop System Specifications
- Select and Evaluate Products
- Responsibility for Integration and Trouble-shooting
- ....

Unsolved Problems for Users and Suppliers
- Incompatibility of Technology Cycles in IA and IT Investments: 10 years to 1 year
Mid-term and Long-term Trends

- From Proprietary to Interoperable and Interchangable Systems, Sensors and Actuators, Plug&Play

- DCS, PLC, .... may become “Throw-Away-Items“?

- DCS, MES, … Automation Services via Internet from Remote Service Provider?

- ...
Future Role of IA Companies

IA Equipment Supplier

IA-HW and SW System Integrator

IA/IT Solution and Service Provider: 
Total Life Cycle Management
Industrial Information Technology and Automation

- General Trends and Driving Forces
- Vertical and Horizontal Integration by IT
- Open Automation System Platforms
- Impact of Other Innovative Technology
- New Requirements to IA from Plant-floor
Sensors for Complex Physical and Chemical Quantities

Monitoring and Control in Process Industries:
Foods, Pharmaceuticals, ….

E-nose CYRANOSE
• 32 Polymer Composite Sensor Elements
• PCA Analysis
Embedded Sensors / Actuator Systems

“Intelligent“ Components Through Embedded Sensors and Sensor Data Fusion/Integration

- Fault Detection
- Predictive Maintenance
- Asset Management

Remote Robotics Subsea Equipment
MEMS Technology, e.g. Laboratory on Chip (LOC)

Real-time Multiplex Product Analysis on a Micro Chip

Multiplex PCR and CE Analysis on a Chip;

ornl, Laser Spectroscopy and Microinstrumentation Group
Digital Imaging and Advanced Image Analysis

Advanced Process Control and Optimization

Ø Polymer Reaction
Ø Steel Continuous Casters
Ø Semiconductor Material Production
Ø Recycling
Ø .......

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Short-haul Wireless Communication Technologies

Ø Reconfiguration of Production Line without Extensive Rewiring
Ø Communication from and to Sensors / Actuators
Location-based Services and Supply Chain Control

In/Outdoor Tracking and Tracing of Object and Person Location

- GPS-/Galileo Satellites
- VHF-Telemeter Data
- Mobile Station
- Reference Station
- Container-Terminal
- RFID Tag/Reader
- Straddle Carrier
Intelligent Appliance Silicon Chip Technology

Totally Distributed Architectures Through Networking

Plant Domain

Enterprise Domain

I/O-Devices

Internet

HMI, CAE Maintenance, E-services
Built-for-Purpose IT Devices

Control / Automation Systems Assembled out of BFPs

Wireless Technologies

WLan, Bluetooth, ZigBee, etc

PalmTop as Embedded Logic Controller
Scalable Supercomputer Technology

- Distributed Parallel Processing
- Terabytes of High-speed Memory
- Penta/Tera-flops of Performance

Potential applications in IA, e.g.

- Decision-making in Closed-Loop Automated, High-Quality Demand-Based Production
- Advanced SPC/SPQ including Data-Mining Techniques
Industrial Information Technology and Automation

- General Trends and Driving Forces
- Vertical and Horizontal Integration by IT
- Open Automation System Platforms
- Impact of Innovative Technology
- New Requirements to IA from Plant-floor
Requirements from the Plant-floor

- Deregulation, Regulatory or Economical Constraints
- Trimming of Primary Buffers
  - Operate Process Closer to Capacity and Stability Limits
  - Operation Closer to Constraints, without Violation
- Novel Manufacturing and Processing Techniques, e.g. in
  - Biotechnological Operations
  - Discrete Parts Manufacturing: “Digital Factory”
  - Microelectronics Manufacturing
Biotechnology Plant

Flexible Automation: Management of Equipment, Product Recipes; Integral Control of Production and Cleaning of Equipment

Reactor Line in a Multi-Product, Multi-Stream Batch Process
Demand-based Pull-type Discrete Manufacturing

From Scheduled to Demand-based Flow Techniques

- Close Coupling between MES and IA System
- Short Cycle Production Feedback
- Flexible Material Handling and Assembly by Intelligent Robots

- Improvements in Quality and Deliverability
- Reduced Lead Time
- Reduced Inventory
- Customized Products
- ....

Assembly of Model Mix with Thousands of Options on a Single Production Line
Electronic Chip Manufacturing in Mega Fabs

Reduce Contamination by Minimizing Retention Time of Operators in Facility through Higher Degree of Automation

- Sophisticated Automated Wafer and Material Handling Systems
- Real-time Equipment and Run-to-run Supervisory Control
Automation of Container Terminals/Yards

Increase Productivity by Automation

Applications

• Sophisticated Automated Container Handling Systems:
  • Automated Guided Vehicles (AGV), Stacking Cranes (AST)
• Advanced Management and Navigation Software

Source: Gottwald GmbH, Düsseldorf
Rotterdam Terminal
INDUSTRIAL AUTOMATION - PAST, PRESENT, FUTURE

• MILESTONES AND ACHIEVEMENTS OF IA

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• CONCLUDING REMARKS
Selected Examples of Emerging Processing and Manufacturing Technologies

• Microreactors in Chemical Process Engineering

• Genomics: Systems for High-Throughput Screening, Synthesis and Sequencing

• Automatic Design and Manufacturing of Robotic Lifeforms
Scalable and Just-in-Time Production with Desk-top Microreactor Systems

Automated Production Line
Microreactor Chips and Networks

CombiChem Microreaction Network Based on FlowFETs

FlowFET Structure incl. Sensors / Actuators

Controlled Operation
NEXT-GENERATION CHALLENGES

- Microreactors in Chemical Process Engineering
- Genomics: Systems for High-Throughput Screening, Synthesis and Sequencing
- Automatic Design and Manufacturing of Robotic Lifeforms
High-throughput Screening and Synthesis

Cope with Combinatorial Complexity through Parallel Operations and Sophisticated IA Approaches Including Data Mining Techniques

Dispenser: 50 nl to 5 μl

Automation Robots for Preparation of Screening

Compound Retrieval and Weighing VIDEO
How Automation Made Decyphering the Human Genome Possible

[3] The sequencing laboratory at the Whitehead Institute [above] in Cambridge, Mass., uses a number of automation advances. For instance, the Q-bot [above, right] picks thousands of bacterial colonies from agar-coated plates and places them in wells filled with liquid growth media. DNA purification [right] has also been automated by a process invented at Whitehead.

PHOTOGRAPHS: STEPHEN ROSE/WARDROPE AGENCY INC.
NEXT-GENERATION CHALLENGES

- Microreactors in Chemical Process Engineering
- Genomics: Systems for High-Throughput Screening, Synthesis and Sequencing
- Automatic Design and Manufacturing of Robotic Lifeforms
Artificial Evolutionary Design Process Connectes to Rapid Prototyping Machine

Example: **Automation of Cognitive Mental Processes**

**The Golem Project:** “Create a walking creature out of ......“
http://golem03.cs-i.brandeis.edu/index.html
Notable Aspects of this Research

• Evolutionary Design in Virtual World:
  Ø Dynamic Process Based on Feedback Control
  Ø Simultaneous Information and Physical Processing

• Integration of Virtual Design and Rapid Prototyping Shows Features of Autonomy, Self-Organization and Artificial Life

• Possible Expansions of Approach
  Ø Coupling of Performance Evaluation in Real World with Evolutionary Design Process
  Ø Behaviour Optimization via Performance Feedback Loop

Prototype Model for a Novel Paradigm of Automated Design and Manufacturing ?
Concluding Remarks

Overall Challenges of IA at the Beginning of 21st Century

• Optimization of Technological Operations on Plant-floor
• Energy Efficiency, Conserv. of Resources = Green-Tech
• Optimization of Entire Business Performance by Strenthening of the Enterprise-wide Digital Nervous System
• Mastering Growing Complexity

Incorporation of Technologies from IT & Telecommunications and Innovations in Industrial Electronics, Robotics etc.

• Open wide Avenues for Novel IA Solutions & Applications
• Define a New Role of IA as “IA / IT Solution and Service Provider“ for Complex Industrial Activities and Operations
Future of "Automation and Control"
"Automation and Control" in der Zukunft

The Siemens View

Service

Production

Logistik

Forschung

Research
Concluding Remarks, cont’d

Discussion underscores activities at major universities with respect to creation of a novel academic discipline

**Services Science, Management, and Engineering - SSME**

This presentation did not focus *novel theoretical and methodological aspects* going along with the sketched technological evolution from

*IA to IT T&A.*

Sample areas are listed on the next page
Examples of Related Theoretical and Methodological Research

- System Theory of Automation
- SW Infrastructure for IIT&Automation
- Safety, Security, Diagnosis
- Modelling, Simulation and Control of
  - Discrete Event Systems
  - Hybrid (discrete-continuous) Systems
- Reconfigurable Controls
- Multi-Agent-based & Cognitive Controls
- Networked Controls
- Cooperation of Humans, Machines, Robots
- System Biology, Biomedical Systems
INDUSTRIAL AUTOMATION - PAST, PRESENT, FUTURE

Résumé

“Digital Industries, Economies and Societies of the 21st Century will Heavily Depend on Continuous Progress in Industrial IT and Automation”
The End