Industrial robots
by Marius Fink and Christoph Kriehn
index

- Introduction and start-up video
- Definition of industrial robots
  - Comparison to known robot-definitions
  - Critical view at industrial robots: Just tools or autonomous machines?
- History
- Today’s use
  - Branches
  - An important example: car industry in Germany
    - Advantages in the use of robots
    - Some statistics
    - Social aspects
- Overview: different types of industrial robots
  - Types of end effectors
- Programming robots
  - Online programming
  - Offline programming
- Conclusion
- Discussion and questions
Part one >> Definitions
define: industrial robots / robotics

- “[…] automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes.” - ScienceDaily LLC, referenced on Wikipedia.org

comparison to known robot-definitions

- Automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes

---

Industrial robots

Robot-definition by Ph.D. Zhang

- A robot is an artificial, intelligent, autonomous system with a physical electro-mechanical platform.
- It is a combined device with enough perception, manipulation capability or mobility to implement typical tasks.

References: ScienceDaily LLC | Ph.D.Zhang, Houxiang, TAMS Hamburg
Mostly they repeat just pre-defined manipulations.

They often have sensors (e.g. cameras) to handle tasks (or parts of tasks) on their own.

They work unattendedly.

They remind of human behaviour (arm movement).
Part two >> History
First robotic patents in 1954 (granted in 1961) by George Devol

Hydraulic actuators were used to move arms

Movement was programmed in joint coordinates

1962 Unimate was the first industrial robot working, spot welding and extracting die castings at General Motors (GM)

Victor Scheinman invented the Stanford arm in 1969 at Stanford University
Unimation bought Scheinmans designs and developed in collaboration with GM a Programmable Universal Machine for Assembly (PUMA)

1971: Europe's first welding transfer line with robots

1973: KUKA Robotics built their first robot called FAMULUS
1974: Scheinman designed a robotic arm using feedback from touch and pressure sensors, which is controlled by a minicomputer

1977: ASEA (European robot company) introduced two robots that used microcomputer controller for programming and operation

1979: OTC Japan introduced the first generation of dedicated arc-welding robots

1981: Takeo Kanade invents the first robotic arm that has motors installed directly in the joints
1984: Height of the (industrial) robot boom

1988: Motoman ERC control system is able to control up to 12 axes

1994: Motoman ERC 21 axes, synchronize 2 robots

1998: XRC controller 27 axes, synchronize 3 to 4 robots

1999: first internet remote diagnosis for robots developed by KUKA
2002: KUKA robot starring James Bond "Die Another Day"

Part three >> Today’s use
Typical applications of industrial robots include:
- welding, painting,
- ironing, assembly,
- pick and place,
- palletizing,
- product inspection and testing,

all accomplished with high endurance, speed, and precision.
An important example: Car industry in Germany

- Development of robots within the car industry
- Advantages in the use of robots
- Social aspects
car manufacturing before robots

- Assembly line by Henry Ford
  - Optimized for one unit
  - Minor flexibility
  - Many manual activities
  - E.g. welding at fixed positions with manual spot-welding
  - Rising standards relating to human workplace and flexibility, quality and costs of cars
- Assembly line should support
  - Labor
  - Various car types
1950-1990

- Standards were
  - 60kg payload
  - electromechanic actuator
- SCARA (Selective Compliance Assembly Robot Arm) used at subcontractor areas
- New tasks were plating, assembly-welding
- 1980: ca. 1200 industrial robots in Germany
- Forecast: about 33-50% of the workers will become unemployed because of robots
- - Costs and technical feasibility
- + Automotive welding and assembly lines
1990-2000

- Mid 90s the controlling and programming was switched from hardware-programming to programming with an interface on a PC
- Increasing complexity caused by different robots working within the same station
- 2000: Half of installed robots in Germany are working at a car manufactory
advantages in the use of robots

- Cost minimizing
- Automated Production
- Quality
- Speed
social aspects

- Qualified workers are needed to supervise robots
- Dangerous work is done by robots $\rightarrow$ no humans get hurt
- More cars built
  - $\rightarrow$ New jobs for final inspection and testing
- Robots took jobs
  - $\rightarrow$ Risk of high unemployment
Part four >> Types of robots
Overview: types of robots

Articulated robots

Cartesian robots (Linear robots)

SCARA robots
Selective Compliant Articulated Robot Arm

Video: articulated 6-axes robot

http://www.youtube.com/watch?v=TMqoNk9ShXw
Video: SCARA robot

http://www.youtube.com/watch?v=8E6aqN4r_Y1Q
Video: cartesian/linear robot

http://www.youtube.com/watch?v=MCsqlwyjxl4
Overview: types of end effectors

- **Tools**
  - Welding
  - Painting
  - Grinding
  - (Laser-) Cutting

- **Grippers**
  - Impactive
  - Ingressive
    - Intrusive
    - Non-Intrusive
  - Astrictive
    - Vacuum suction
    - Magneto adhesion
    - Electro adhesion
  - Contingutive
    - Thermal
    - Chemical
Overview: types of end effectors

- **Tools**
  - Welding
  - Painting
  - Grinding
  - (Laser-) Cutting

- **Grippers**
  - Impactive
  - Ingressive
    - Intrusive
    - Non-Intrusive
  - Astrictive
    - Vacuum suction
    - Magneto adhesion
    - Electro adhesion
  - Contingutive
    - Thermal
    - Chemical

Video: KUKA Roboter GmbH © 2009

http://www.youtube.com/watch?v=1-J_EzKm_70
Overview: types of end effectors

Tools
- Welding
- Painting
- Grinding
- (Laser-) Cutting

Grippers
- Impactive
- Ingressive
  - Intrusive
  - Non-Intrusive
- Astrictive
  - Vacuum suction
  - Magneto adhesion
  - Electro adhesion
- Contingutive
  - Thermal
  - Chemical

Video: © 2009 ABB Ltd Robotic Industries

http://www.youtube.com/watch?v=O3mG_7VeYfQ
Overview: types of end effectors

- Tools
  - Welding
  - Painting
  - Grinding
  - (Laser-) Cutting

- Grippers
  - Impactive
  - Ingressive
    - Intrusive
    - Non-Intrusive
  - Astrictive
    - Vacuum suction
    - Magneto adhesion
    - Electro adhesion
  - Contingutive
    - Thermal
    - Chemical
Overview: types of end effectors

- Tools
  - Welding
  - Painting
  - Grinding
  - (Laser-) Cutting

- Grippers
  - Impactive
  - Ingressive
    - Intrusive
    - Non-Intrusive
  - Astrictive
    - Vacuum suction
    - Magneto adhesion
    - Electro adhesion
  - Contingutive
    - Thermal
    - Chemical

http://www.youtube.com/watch?v=6-qKZJxCWKY

Overview: types of end effectors

Impactive prehension  
... means gripping things with pressure

- most frequently used grippers
- normally between 2 and 4 fingers, moving simultaneously
- great variety of technical realizations

Typical examples
- tongs
- clamps

Typical manipulated material
- rigid (inelastic), graspable objects

Tools
- Welding
- Painting
- Grinding
- (Laser-) Cutting

Grippers
- Impactive
- Ingressive
  - Intrusive
  - Non-Intrusive
- Astrictive
  - Vacuum suction
  - Magneto adhesion
  - Electro adhesion
- Contingutitive
  - Thermal adhesion
  - Chemical adhesion

Overview: types of end effectors

Ingressive prehension

... means gripping things with mechanical stress

- Intrusive: prehension needs penetration through handled material
- Allows the object to be held without the need of maintain an applied force.

**Tools**
- Welding
- Painting
- Grinding
- (Laser-) Cutting

**Grippers**
- Impactive
- Ingressive
  - Intrusive
  - Non-Intrusive
- Astrictive
  - Vacuum suction
  - Magneto adhesion
  - Electro adhesion
- Contingutive
  - Thermal adhesion
  - Chemical adhesion

**Typical examples**
- pins, needles and hackles (small and precise needles)
- hooks and loops

**Typical manipulated material**
- soft materials like foam or fibrous components
- textiles
- carbon and glass fiber

Overview: types of end effectors

Astrictive prehension

... means gripping things with physical help

- holding force without the application of pressure
- needs continuous energy supply

Typical examples
- vacuum suction cups
- electromagnet
- (electrostatic field)

Typical manipulated material
- non-porous, rigid material
- ferrous objects
- (microcomponents)

Tools
- Welding
- Painting
- Grinding
- (Laser-) Cutting

Grippers
- Impactive
- Ingressive
  - Intrusive
  - Non-Intrusive
- Astrictive
  - Vacuum suction
  - Magneto adhesion
  - Electro adhesion
- Contingutive
  - Thermal adhesion
  - Chemical adhesion

Overview: types of end effectors

Contingutive prehension
... means gripping things with chemical help

- thermal (ice-bridge): small droplets of water between gripping head and object get frozen by liquid carbon
- chemical (adhesive): objects stick to gripping head with the help of glues

Typical examples
- freezing, melting
- adhesives (glues)

Typical manipulated material
- textiles, carbon, glass fiber

Tools
- Welding
- Painting
- Grinding
- (Laser-) Cutting

Grippers
- Impactive
- Ingressive
  - Intrusive
  - Non-Intrusive
- Astrictive
  - Vacuum suction
  - Magneto adhesion
  - Electro adhesion
- Contingutive
  - Thermal adhesion
  - Chemical adhesion

Part five >> Programming robots
programming robots

- Robots are typically programmed via
  - Laptop or desktop,
  - Internal network or Internet
- After installing the program, the PC is disconnected from the robot, that now runs on the installed program
- But most of the time a computer permanently “supervises” the robot and gives additional storage
- Modern robot control systems have a complex programming environment with integrated tools to adopt modules like external sensors (such as cameras or a turning moment measuring system)
- Programmable to adjust outside influences (like recognition of different objects)
two ways of programming robots

Online-Programming:
- Programming at or with the robot
- Methods:
  - Teach pendant
  - Playback
  - Manual programmed

Offline-Programming:
- Programming does not require the robot so that no working time gets lost
- Methods:
  - Textual programming
  - CAD programming
  - Macro programming
  - Acoustic programming
online-programming methods

- Teach pendant
  - handheld control and programming unit
    - P2P (Point-to-Point)
    - CP (Continuous Path)
- Playback or Lead-by-the-nose
  - Path given by human
- Manual programmed
  - Via button and switch (out of date)
offline-programming methods

- Textual programming - comparable to high programming languages
- CAD programming - based on engineering drawings and simulation
  - Verification possible:
    - Components attitude in space
    - Movement of components and tools
    - Are working points reachable?
    - Time needed for movement
    - Collision with environment?
    - Checking for alternatives
- Macro programming - shortened code of frequently recurring motions
- Acoustic programming - natural language used to program the robot
## Online-/offline-programming

<table>
<thead>
<tr>
<th>Online</th>
<th>Offline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not abstract – working with the robot (teach it)</td>
<td>Abstract</td>
</tr>
<tr>
<td>Working with in the “real” environment</td>
<td>Not time-consuming</td>
</tr>
<tr>
<td>Intuitive</td>
<td>Easy changeable</td>
</tr>
<tr>
<td></td>
<td>Without the robot</td>
</tr>
<tr>
<td></td>
<td>Look “inside” the robot</td>
</tr>
</tbody>
</table>
Final part >> Conclusion/Discussion

☐ Questions?

☐ Comments?