Robotizing of small lot production

Challenges and opportunities

1. Structural changes brings challenges for industry

2. Special obstacles for SME

3. Vision: Semi automation with robots

4. Benefitting from specific skills of robot and human
   1. Robotic assembly
   2. Robot Human Interaction
   3. Robotic disassembly
   4. Robotic grinding

5. Summary
Structural change in Luxembourg

From steel production via finance services to knowledge society
National manufacturing corporations

Luxembourgish manufacturing companies & selection of our project partners
Challenges to manufacturing enterprises

- Market requires more *individualized* products at reduced price
- Nbr. of *variants* increases
  - => smaller batches
  - => Enhanced *flexibility* of machines, of operators, of processes
- Reduced lead time (faster time-to-delivery)
- Quality expectations remain high or even increase
- Ageing employees
- Novel technologies needed
Especially SMEs face significant challenges

- Limited inhouse R&D capabilities available => cooperation w/ universities
- Customized products => small lot / low volume production
- Limited skills for maintenance for “high tech” automation accessible => no over-engineered level of automation
- Fast response to customer demands is mandatory => versatile automation

Summarizing:

Full robotic automation may not be the answer for small lot production
Vision of the future: Semi-automation

Robotic automation as enabler

Sources: Uni Luxembourg, http://checomm.biz, Miele AG
Complementary skills of human and robots

**Strength of robots:**
- Integrated process control
- Repetitive accuracy
- Fatigue-proof
- Handling of heavy or sharp-edged parts
- ...

**Weaknesses of robots:**
- Simple tasks
- Low flexibility
- Low decision power
- ...

**Weaknesses of human:**
- Low repeatability
- Variability of positioning
- Limited force/ lifting capability
- Exhaustion
- ...

**Strength of human:**
- High availability
- Complex tasks, self adaptive
- Handling of filigree parts
- Accurate and fast positioning
- ...

Sources: http://alliancecomm.biz, Miele AG
Would you work alongside with an industrial robot?

Survey during EU project “fourbythree”

I wouldn't like but I would accept 6%

I wouldn't accept 6%

Fenceless HRC

I wouldn't mind 88%

HRC: Human Robot collaboration

http://fourbythree.eu/
Area of action for this vision / Robotic research topics

- **Assembly:**
  - Manipulation of filigree parts
  - Detect contact
  - Compliant, flexible components
  - Position inaccuracy
  - Handle Heavy modules
  - Consider unknown geometry
  - Partial automation
  - Safe interaction robot / worker
Example 1: Robotic assembly of Product

a) Detect discrete contact states

- Robotic assembly
- „Peg-in-hole problem“
- Use of robot internal force and torque sensor signals
- Detect contact state

Robot Control
Internal force, torque and pose signals

Method
Contact state recognition

Expectation Maximization
Gaussian Mixed Models

\[ p(x_k | c_i; \theta) = \sum_{q=1}^{M} \omega_q N_q(x_k | \mu_q, \Sigma_q) \]
Example 1: Robotic assembly of Product

b) Search Algorithm

- Self adaptive control for not precisely located parts

- Requirements:
  - Simple implementation
  - Large Position Uncertainty
  - High Success Rate
  - Reduced Assembly Time

- Results:
  - Localization Success Rate
    92.5% (74/80) rigid peg
    90.0% (72/80) compliant peg

As reference: other literature (only rigid parts.):
- Particle Filtering resulted in LSR of 73.75% (59/80).
- Shape Recognition resulted in LSR of 66.25% (53/80).
Example 1: Robotic assembly of Product

c) Industrial Application

- Camshaft Cap Assembly
- Multiple peg-in-hole
- Archimedean spiral search
- Accommodates targeted variation
Example 1 – b : Robotic assembly of Product

c) Industrial Application

- Manipulating of compliant parts
- Assembly of O-rings
- Automation of manual process
Example 2: HRC Human - Robot - collaboration

Safe working environment
Human Robot Cooperation for assembly

- Target: semi-automated assembly
- Human and robot interact in same working zone
- Safe detection of human required
- Dynamic environment => fast and real-time path planners are needed

Source: University of Luxembourg
Example 2: HRC Human - Robot – collaboration (continued)

Collision avoidance - static

- 3D time-of-flight (T.o.F.) camera detects obstacles
- Path planning algorithm computes detour of obstacles

Initial planning
- Peg-in-hole process

3D-Time-of-flight sensor
- Scene information

Result
- Safe path applied by the robot

Flexible assembly – considering unknown, un programmed obstacles

Static environment

Published in R. Ahmad, P. Plapper:
Safe and Automated Assembly Process using Vision assisted Robot Manipulator,
Example 2: HRC Human - Robot – collaboration (continued)

Collision avoidance- dynamic

- Robot & worker interact in the same area
- Optical 3D detection of moving obstacles
- Collision avoidance
- Intelligent decision
- Fast real time re-routing of robot path
- Dynamic distribution of labor content
Example 3: HRC Human - Robot – collaboration

Disassembly

- Circular flow economy
- Partial automation
- Robot & worker share disassembly tasks
- No automatic decision about distribution of disassembly tasks available
- Planning tool for disassembly required
- Worker requests specific tasks as assistance from robot
- Distribution of labor content
Example 3: HRC Human - Robot – collaboration

**Disassembly**

- **Disassembly planner**
- **Controller**
- **GUI-Interface**
- **Assistance**
- **Environment**

**Goal-based (Assistant-)Agent**

- Initial state
- Current state
- Disassembly status of product
- Robot commands
- Errors
- Actuators
- Sensors

- Input
- Syncs
- Defines
- Proposes
- Defines
- Action

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P. Plapper
Example 4: Robotic grinding

Path-tracking of 3 dimensional freeform surfaces

Tracking of internal and external freeform surfaces

Adaptive Force/Position Control

Integrated force & torque sensors

Tactile Perception

Anticipation based on Experience

Decision Making

Adaptation

Biomimetic Translation

Sources:
www.toeff-magazin.ch
www.fotolia.de
Summary

Robotizing of small lot production

- Challenges due structural change
- Complementary skills of human and robots
- Examples:
  - Robotic assembly of rigid and compliant parts
  - Robot and human interact in same work space
  - Disassembly assistance by robots
  - 3D free form grinding