Thrust 3 – R6
Final Meeting Stuttgart, 7-8 May 2009
Robot task generation based on product/process data

(1) Automatic generation of robot programs

How can a robot be programmed in an efficient way with fast changeover and different work pieces?

(2) Sensor based world model reconstruction

Calibration methods to support (1) and (2)

Supporting tools for fast deployment and programming

Testbeds at partners and implementation of results at Demonstrations
Approaches

- **Model based** task generation of robot instructions (work processes)
- **Sensor based** active exploration and reconstruction of unmodelled objects

Challenges

- **Calibration issues**
- **Data formats** and **interfaces**
- **Automatic execution and workflow**
Supporting tools for programming

- CAM functionality for spraying
- Feature based object registration
- Semi-automatic path planning and programming
- Deployment wizard: off-line → on-line

How can the operator get support to be more efficient in flexible production?
Semi-Automatic path planning and programming

- Semi-Automatic path planning
  - Automatic recognition of weld joint
  - Creates a path for the robot
  - Manual / operator interaction via defined wizards

SMErobot welding cell

RSL statements

Programming algorithms
Interface

- Connect seams
- Test seams
- ...
- Horizontal seam
- Vertical seam

- Connect seams
- Speed up welding
- Correct orientation
AutoPosition, external axis

- **AutoPositioner**: calculates the pose of the gun (robot) and positioner
  - Wire orientation; Base normal; Wall normal; Off
- **Process specific parameters**
  - Template to define specific data, for example wire orientation
- **Part calibration**
  - Least square; 6-point; 9-point
Feature based object registration

**Programming support:**
Sensor independency
- Robot (Touch up)
- Teach Wand
- Distance Sensor

Approximating the object with a convex hull built from some points on the object surface

Interactive modelling of non-convex objects

Example of object with specific features (edges, surfaces, angles)
CAM functionality for spraying

- **Workflow:**
  - User defines contour (sketch editor, robot and 6D mouse)
  - Parameters for the spraying process
  - Automatic calculation and generation of program
  - Operator starts the program
Guide the user through configuration of devices, calibration of tools and work object, and integrated GUI:s

Integration of off-line and on-line programming to support fast robot task deployment
GUI example of calibration SIM ↔ REAL

Step by step guidance to calibrate a WorkObject
Calibration methods to support programming

- Object registration and placement
- Tool and cell calibration
- Mapping data and 3D modelling
- Data formats, protocol and interfaces

*How can I tell the robot where the work piece is, dimensions of the tool and what the work piece look like?*
Work-piece pose algorithms for computing placement based on general sensor model/touch-data points

Point-cloud obtained during touch sensing (manual guidance)

- Different point-cloud from same regions but new workpiece and new touching
- Matching to estimated data (no CAD)

Results can be used for work object calibration of complex workpieces, allowing simple fixtures
Test bed quick calibration (example)

Global calibration, Stereo vision
- Calibration points in camera world (one time)
- Work objects to be calibrated (many times)

Typical accuracy: ±20 mm
Sensor based active exploration of unmodelled objects / world model

- Definition of a Region of Interest (RoI)
- Multisensory exploration of work piece geometry within RoI
- Next-Best View based on:
  - Current occupancy state
  - Sensor model
- Consideration of occlusion
- Model-free approach (no CAD data required)
Sensor based model acquisition

- DLR testbed with 3DModeller
- Data protocol developed and tested at KUKA and REIS
- Complete workflow tested at wood working scenario
- Software components developed to support the integrated workflow:
  - model generation
  - visual feedback
  - texture acquisition and mapping
  - data transfer protocol
3D-Modelling of Work Pieces use case at Reis

- Sensor: 3D-Modeller
- Work Piece: Wooden Block with milled structure
- Wooden work piece scanned using Texture 3D-Modeller acquisition
- Top and bottom side are scanned separately
- Global registration method delivers complete surface model
Model based task generation based on product / process data

- Service Oriented Architecture at Lund test-bed to demonstrate automatic programming
- Services Oriented Architecture based on
  - Manager (coordination / orchestration)
  - Robot Studio
  - Rinas Weld
  - WorkPiece (CAD)
  - Software components to define services and data protocol
- Results:
  - Work flow automatic; manual intervention possible
  - Full system workflow verified!
SOA implementation demonstrates automatic programming

- Define intent: Robot station, CAD, process data
- Get services for the task
- Provide the information to the planner
- Generate program
- Upload to the robot
- Run and execute

### Task Workflow Execution

<table>
<thead>
<tr>
<th>Service</th>
<th>Operation</th>
<th>Done</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workpiece</td>
<td>Fetch workpiece geometry</td>
<td>✓</td>
</tr>
<tr>
<td>RinasWeld</td>
<td>Store workpiece geometry</td>
<td>✓</td>
</tr>
<tr>
<td>RobotStudio</td>
<td>Load station</td>
<td></td>
</tr>
<tr>
<td>RobotStudio</td>
<td>Get station equipment</td>
<td></td>
</tr>
<tr>
<td>RobotStudio</td>
<td>Get station calibration data</td>
<td></td>
</tr>
<tr>
<td>RinasWeld</td>
<td>Set calibration</td>
<td></td>
</tr>
<tr>
<td>RinasWeld</td>
<td>Set process data</td>
<td></td>
</tr>
<tr>
<td>RinasWeld</td>
<td>Create weld lines</td>
<td></td>
</tr>
<tr>
<td>RinasWeld</td>
<td>Select weld lines</td>
<td></td>
</tr>
<tr>
<td>RinasWeld</td>
<td>Set weld lines</td>
<td></td>
</tr>
<tr>
<td>RinasWeld</td>
<td>Start planning</td>
<td></td>
</tr>
<tr>
<td>RinasWeld</td>
<td>Planning is finished</td>
<td></td>
</tr>
<tr>
<td>RobotStudio</td>
<td>Get generated task</td>
<td></td>
</tr>
<tr>
<td>RobotStudio</td>
<td>Deploy task</td>
<td></td>
</tr>
</tbody>
</table>
Calibration method and components to support automatic programming

• Simplified calibration support through RobotStudio
  – Tool data for tool (weld gun), work object data
  – Interface to support any needed interaction
  – Maintains calibration status

• Fine calibration using triangulation laser sensor
  – Speed up search routines
  – Sw implementated to support automatic calibration

• Tests verify technology
  – RinasWeld automatically produces fine calibration programs
  – Measurements verified and operational on work pieces
    • Work piece distance: 350 mm nominal
    • Orientation to surface: +/-45 degrees (to be confirmed)
WEB interface screen dumps – SOA (examples)
WEB interface screen dumps – SOA (example)
Automatic programming in seconds
Conclusions – task programming

✓ Automatic programming developed, validated and verified

✓ Reconstruction and generation of world model developed and complete workflow validated and verified

✓ Calibration techniques and methods developed to support task programming

✓ Supporting tools and methods developed to speed up operator work in programming and deployment of programs

✓ Results verified: fast task generation, quicker execution with integrated calibration, support for flexible production with changing products
Automatic task programming achieved!

Tested and verified!
Thank You!