YuMi come and play with me!
A Collaborative Robot for piecing together a Tangram Puzzle
ROBOTICS – Institute for Robotics and Mechatronics

- R&D partner with know-how in the scientific & engineering foundations of robotics and mechatronics
- R&D at the interface between university-level basic research, applied research and advanced robotic system’s integration
- R&D and consultancy for robot- and functional safety
- Robot system’s safety certification
- Research Focuses:
  - Robot Mechanisms and Mechatronic Systems
  - Robot Systems
  - Cognitive Robotics
  - Robot Safety
Project Motivation

Current Standard Industrial Robotics:
- Robots perform clearly specified, pre-defined, repetitive motions in constrained environment
- No or very limited abilities to perceive the environment and adapt to it
- Operated behind safety fences
- High investment costs
- Financial benefits only for large batch sizes

Collaborative Robotics:
- Combine strengths of robots (endurance, precision, etc.) and humans (perceptual and cognitive abilities, etc.)
Why collaborative?

„The action of working with someone to produce or create something“

- 4 type of collaborative features
  - Safety-rated monitored stop
  - Hand-guiding
  - Speed and separation monitoring
  - **Power and force limiting**
Challenges

- Machine perception
- Sensitive redundant kinematic manipulation
- Dynamic adaptive task planning
- Human robot interaction and information exchange
- Human state evaluation
- Safety standards
Levels of H-R Interaction

<table>
<thead>
<tr>
<th>Category</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Umbrella Term</td>
<td>encapsulation</td>
<td>H-R co-existence</td>
<td>static H-R collaboration</td>
<td>dynamic H-R collaboration</td>
<td>static / dynamic</td>
<td>static / dynamic</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>R-R collaboration</td>
<td>H-R-R collaboration</td>
</tr>
<tr>
<td>Interaction-Level</td>
<td>interaction-free operation</td>
<td>safety stop</td>
<td>static collaboration</td>
<td>dynamic collaboration</td>
<td>static / dynamic</td>
<td>static / dynamic</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>collaboration</td>
<td>collaboration</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temporal Dependence</td>
<td>independent</td>
<td>interrupt</td>
<td>sequential</td>
<td>simultaneous</td>
<td>sequential/ simultaneous</td>
<td>sequential/ Simultaneous</td>
</tr>
<tr>
<td>Spatial Dependence</td>
<td>separated</td>
<td>separated</td>
<td>shared</td>
<td>shared</td>
<td>shared</td>
<td>Shared</td>
</tr>
<tr>
<td>Human-Robot Contact</td>
<td>none</td>
<td>rudimentary</td>
<td>pronounced</td>
<td>comprehensive</td>
<td>n.a.</td>
<td>pronounced / comprehensive</td>
</tr>
</tbody>
</table>

One set of use cases had to be defined -> Solving a Tangram puzzle
Inherently safe
- Eliminated pinch points
- Speed limited motors
- Lightweight and padded 7 DoF dual arms
- Effective payload with the standard gripper around 250 gram
- Reconfigurable gripper modules (servo, vision, compressed air)
Video
Technical Details

FLOWCHART Diagram: Movement and Process

- START: Waiting for shape decision → Waiting for confirmation → Load solution & schedule order → Waiting for GO instruction
- Move into detecting position: Is the exposure time sufficient?→ Change it
- Scan the image area to locate the parts: Move into detecting position → Is the next piece there?→ Move into gripping position → Try to grip
- Is there something between the fingers?→ Yes → Move into detecting position → Was it the last piece?→ Yes → Move into standby position & send ready
- Drop error message → Acknowledge and consider the next piece
- Is it there?→ Yes → Move over the target area
- Scan the image area to locate the parts → Move into the target location
- Collision → STOP
- Key press → Continue
Drawbacks

- Too short, only 5 pieces
- Hardware restrictions (vision)
- Human wasn’t so precise
- They accidentally moved away pieces, resulted (robot) finger braking
- Player must know the behavior of the program
(a) The located puzzle pieces with the pattern and their object frames

(b) Mismatch of the pieces
Conclusions, Extensions

- Features in future (speech recognition, advance learning, etc.)
- In industry small part assembly, pick and place operation
- Rehabilitation purposes
- Entertainment
- (Human factor study: part of a program was used for this purpose)
Human factor study
**Results**

<table>
<thead>
<tr>
<th>Method</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>One hand – 5 vision jobs</td>
<td>78 s</td>
</tr>
<tr>
<td>Two hand – 5 vision jobs</td>
<td>64 s</td>
</tr>
<tr>
<td>One hand – 1 vision job</td>
<td>59 s</td>
</tr>
<tr>
<td>Two hand – 1 vision job</td>
<td>42 s</td>
</tr>
</tbody>
</table>