Safety and Mobile Manipulation

Experiences from the VALERI project

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Safety and Mobile Manipulation
Experiences from the VALERI Project

1. The VALERI project
2. Applying safety standards to VALERI
   - Application specification
   - Intended Use
   - Hazard Identification
   - Novel VALERI safety technologies
   - Verification of power and force limits
3. Outlook/discussion

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The VALERI Project
The VALERI Project

Assisting human workers with a mobile manipulator in aerospace production tasks

Sealant Application

start inspection task

Inspection
Applying safety standards to VALERI

Robotic hardware
Initial configuration compliant with general health and safety requirements

Torque sensing in joints (collision detection and interaction)

Laser scanner (proximity detection)
Applying safety standards to VALERI

Define the application

Sealant Application

© Airbus DS

Inspection

© Profactor

Autonomous navigation

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Applying safety standards to VALERI

Event-driven process chains model the process
Define the role of operator and the intended use

<table>
<thead>
<tr>
<th>Life Cycle/Task</th>
<th>Intended use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commissioning</td>
<td>Haptic feedback for task definition, creating a map and platform navigation via game pad, testing</td>
</tr>
<tr>
<td>Maintenance</td>
<td>During maintenance the operator can test all robot functions (see Commissioning).</td>
</tr>
<tr>
<td>Task definition</td>
<td>In this operational phase, a user has the opportunity to teach-in a new station via haptic feedback. In this case, the user will use the haptic interfaces of the tactile skin and the force feedback in the manipulator to guide the system. Physical contact with the robot is necessary.</td>
</tr>
<tr>
<td>Job submission</td>
<td>During this phase, there is no intended physical contact with the robot. Commands are input via the GUI on a computer or a touch panel</td>
</tr>
<tr>
<td>Autonomous platform movement</td>
<td>No intended contact with the robot. The platform operates completely autonomous.</td>
</tr>
<tr>
<td>Sealant application</td>
<td>No intended physical contact with the robot. The platform and manipulator operate completely autonomous. Operator has opportunity to pause/interrupt robot operation, if necessary.</td>
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<td>Inspection</td>
<td>No intended physical contact with the robot. The platform and manipulator operate completely autonomous. Operator has opportunity to pause/interrupt robot operation, if necessary.</td>
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</table>
Applying safety standards to VALERI

Identify hazard sources for each task

*A gray box covering a component denotes that the component is inactive and not in motion during that particular case.*
Novel safety technologies in VALERI

Two special cases considered in VALERI

1. Platform motion during process (sealant, inspection)
2. Tool safeguarding during process (sealant, inspection)
Novel safety technologies in VALERI

Tactile sensors on OmniRob base (contact detection and interaction)

Tactile bumper ring around the lower part of the OmniRob base (collision detection)

Sealant tool

Sealant Inspection Camera (not pictured)

Localization Camera (not pictured)

Tactile sensors on LWR base (contact detection)

Torque sensing in joints (collision detection and interaction)

2 1/2D workspace monitoring system on pan-tilt unit (Tool Safeguarding)

Column with 2 DOF (workspace extension)

Tactile sensors on column (contact detection and interaction)

Tactile sensor on OmniRob base (contact detection and interaction)

Laser scanner (proximity detection)
Novel safety technologies in VALERI

Safeguarding method:
Speed and separation monitoring
(Laser scanners)

Safeguarding method:
Power and force limiting
(Tactile sensors)

Operators can get as close to robot as necessary. Robot motion will only stop due to contact with human.
Novel safety technologies in VALERI

4 tactile transducers, geometrically adapted to the robot’s geometry
Novel safety technologies in VALERI

- **Integrated sensor electronics**
- **Integrated safety contacts** (monitor proper mounting of tactile transducers)
- **Magnetic Fastening Systems** (allows quick and easy removal of tactile transducers for maintenance or exchange)

back side of a tactile transducer

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Novel safety technologies in VALERI

- Modular bumper solution
- Compatible with the ITEM Profile 8 series
- Quick and easy replacement of damaged sensor elements
Max allowable forces

- 400 N clamping force (DIN 1525)
- 125 N clamping force, 250 N dynamic collision force (upcoming ISO TS 15066)
Max allowable forces
- 400 N clamping force (DIN 1525)
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Novel safety technologies in VALERI

Optical workspace monitoring system for tool safeguarding

→ Speed and separation monitoring

Set-up
• 3 grayscale (NIR/VIS) cameras for redundant stereo
• 1 Time-of-Flight camera with NIR illumination in the center
Novel safety technologies in VALERI

- Combining 3D point clouds from stereo-camera and ToF-camera using extrinsic parameters and distance calibration.

3D point clouds from ToF camera (left), stereo-camera (middle) and fused point cloud (right).
Novel safety technologies in VALERI
Systematic approach to safety
- Define the application
- Define user roles and intended use
- Identify hazards
- Mitigate hazards
- Verify (when using power and force limiting)
Validation of Advanced, Collaborative Robotics for Industrial Applications

- Research and Development Partners
  - Fraunhofer IFF, Germany (Coordinator)
  - Profactor GmbH, Austria
  - PRODINTEC, Spain

- Industrial Partners
  - KUKA, Germany
  - Airbus DS, Spain
  - IDPSA, Spain
  - FACC, Austria

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