VALERI - A COLLABORATIVE MOBILE MANIPULATOR FOR AEROSPACE PRODUCTION

CLAWAR 2016, London, UK
Fraunhofer IFF · Robotersysteme
1. The VALERI project
2. Applying safety standards to VALERI
   - Application specification
   - Intended Use
   - Hazard Identification
3. Novel VALERI safety technologies
   - Verification of power and force limits
4. Outlook/discussion
The VALERI Project
The VALERI Project

Assisting human workers with a mobile manipulator in aerospace production tasks

Sealant Application

Inspection
Robotic hardware
Initial configuration compliant with general health and safety requirements
Applying safety standards to VALERI

Define the application

Sealant Application

© Airbus DS

Inspection

© Profactor

Autonomous navigation

London, 12-09-2016
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><strong>Commissioning</strong></td>
<td>Haptic feedback for task definition, creating a map and platform navigation via game pad, testing</td>
</tr>
<tr>
<td><strong>Maintenance</strong></td>
<td>During maintenance the operator can test all robot functions (see Commissioning).</td>
</tr>
<tr>
<td><strong>Task definition</strong></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><strong>Job submission</strong></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><strong>Autonomous platform movement</strong></td>
<td>No intended contact with the robot. The platform operates completely autonomous.</td>
</tr>
<tr>
<td><strong>Sealant application</strong></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>
</tr>
<tr>
<td><strong>Inspection</strong></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>
</tr>
</tbody>
</table>
Defining form of co-work for each step of process:

1. **Start here**
   - **Shared workspace?**
     - **yes**
     - **Simultaneous co-work?**
       - **yes**
         - **Physical contact?**
           - **yes**
             - **Collaboration**
           - **no**
             - **Parallel Cooperation**
       - **no**
         - **Sequential Cooperation**
     - **no**
       - **Coexistence**

References:
Identify hazard sources for each task

Conflicting standards:

- EN 1525 – “Safety of industrial trucks – driverless trucks and their systems”:
  - 400 N force limit
- ISO 10218 and ISO/TS 15066:
  - 150 N force limit
Identify hazard sources for each task

<table>
<thead>
<tr>
<th>Task Information</th>
<th>Hazard Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Life Cycle</td>
<td>Hazard Class</td>
</tr>
<tr>
<td>Productive operation</td>
<td>Specific mechanical hazards</td>
</tr>
<tr>
<td>Process Name</td>
<td>Hazard Type</td>
</tr>
<tr>
<td>Sealant application</td>
<td>Clamping / crushing (2.1)</td>
</tr>
<tr>
<td>Task Group No.</td>
<td>Collision velocity</td>
</tr>
<tr>
<td>N/A</td>
<td>0.25m/s</td>
</tr>
<tr>
<td>Form of HRC</td>
<td>Effective robot mass</td>
</tr>
<tr>
<td>Parallel Cooperation</td>
<td>14kg (approx.)</td>
</tr>
<tr>
<td>Involved Components</td>
<td>Contour</td>
</tr>
<tr>
<td>manipulator, tool and linear axis</td>
<td>Rigid edge</td>
</tr>
</tbody>
</table>

Task Illustration

Crushing of human body parts by robot structure when moving the manipulator and/or the linear axis. Contact with moving object of rigid structure.
Applying safety standards to VALERI

Choose safeguarding method

Forms of Co-Work

- Coexistence
- Sequential Cooperation
- Parallel Cooperation
- Collaboration

Hand-guided robot?

no
- Power & Force Limiting

yes
- Hand-Guiding

Safeguarding Modes

- Separating Guards*
- Safety-rated Monitored Stop
- Speed & Separation Monitoring
- Power & Force Limiting

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 sensor on OmniRob base (contact detection and interaction)
- Tactile bumper ring around the lower part of the OmniRob base (collision detection)
- Tactile sensors on LWR base (contact detection)
- Tactile sensors on column (contact detection and interaction)
- 2 ½D workspace monitoring system on pan-tilt unit (Tool Safeguarding)
- Column with 2 DOF (workspace extension)
- Torque sensing in joints (collision detection and interaction)
- Laser scanner (proximity detection)
- Sealant tool
- Sealant Inspection Camera (not pictured)
- Localization Camera (not pictured)
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
Max allowable forces

- 400 N clamping force (DIN 1525)
- 125 N clamping force, 250 N dynamic collision force (ISO TS 15066)
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

This project has received funding from the European Union’s Seventh Framework Programme for research, technological development and demonstration under grant agreement no 314774
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