SiLA Rapid Integration

Pick & place labware transportation with benchtop and mobile robots
Lab robot use cases and how to address them - Introduction

4th bioSASH (BioLAGO – SiLA 2/AnIML Serial Hackathon), Konstanz, Germany

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PhD Student, Takeda
Working Group Lead, SiLA Robotics

State of the art lab robotics and their limitations

The lab robotics landscape - Present

Color code
- Established product
- Fresh on the market
- Emerging/under development

SiLA Rapid Integration

Liquid handling

- **Use Case**
  - Parallel pipetting
  - Flexible pipetting
- **Technologies**
  - Gantry-type liquid handler robots
    - Tecan
    - Beckman Coulter
    - Hamilton
    - Opentron
  - Robots handling hand-held pipettes
    - Andrew+
    - Research

Sample transportation

- **Use Case**
  - Pick and place
  - Standard objects
  - Physical device interactions
- **Technologies**
  - Benchtop robots
    - PreciseFlex
    - xArm
    - Denso Cobotta
    - UR
  - Mobile manipulators (floor)
    - Kevin
    - Biosero
    - Astech Projects
    - United Robotics Group
    - Gearu
    - Omron, Stäubli, Kuka
  - Mobile manipulators (bench/track)
    - Formulatrix ROVER
  - Drones (Research)

SiLA Rapid Integration

Sample transportation robots

Stationary robot arms

uFactory

PreciseFlex ®

Mobile manipulators

KEVIN, Fraunhofer IPA

OMRON – Biosero

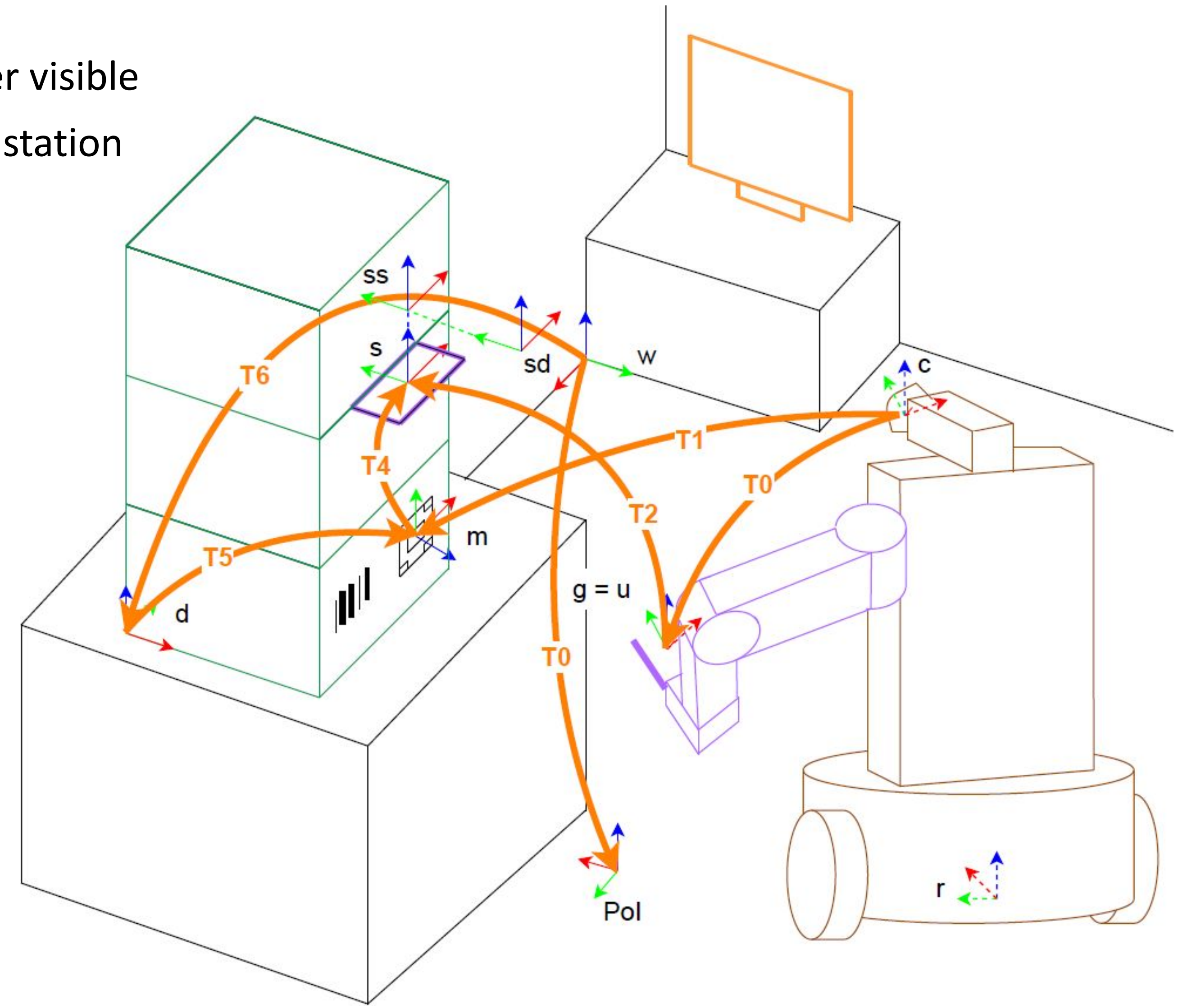
KUKA – University of Liverpool

UniteLabs – Astech Projects

Coordinate frames and robot positions

Teaching of vision-based robots [15]

- Manually drive the robot to station, make sure marker visible
- Base's location on the map is stored as the PoI of the station
- Camera-to-marker transformation is stored (T1)
- Manually move the arm to the site position (s)
- The marker-to-nest transformation is stored (T4)



The SiLA Robotics Working Group

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Organization

- Domain-specific working group
- Reports back to the core WG
- Open group
- Bi-weekly meetings

Mission

- Combine existing established technologies in a comprehensive framework
- SiLA as the central element of the tech stack
- Unify, scale-up and extend functionality
- Incorporate new concepts
- Facilitate exchange in the lab robotics community

Vision

- Foster the SiLA-based plug & play integration of lab robots
- Unify the communication standard
- Provide vendor-independent solutions

Milestones

- SiLA-ROS interface
  - BioSASH 3
- Unify feature definitions
  - Structure to incorporate present and future lab robot capabilities
  - Identify candidates as standard definitions for specific capabilities

Hierarchical levels of laboratory processes

Process		Lab examples			
Level nr	**Level name**	**Examples, liquid handler**	**Examples, robot arm**	**Examples, mobile robot**	**Examples, conveyor**
7	Service	microscale services			
6	Procedure (Experiment / assay)	microscale chromatography workflow			
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4	Subtask	aspirate	get labware, put labware		
3	Motion sequence	approach site with pipettor arm	approach site	navigate to target	-
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Unified feature definitions - Levels

<table>
<tr><th colspan="2">Process</th><th colspan="3" rowspan="2">SiLA implementation</th></tr>
<tr><th>Level nr</th><th>Level name</th></tr>
<tr><td>7</td><td>Service</td><td>Fraunhofer Kevin</td><td>UniteLabs MoMa</td><td>LAPP RARs / Unified SiLA Robotics feature definitions</td></tr>
<tr><td>6</td><td>Procedure
(Experiment / assay)</td><td></td><td></td><td></td></tr>
<tr><td>5</td><td>Task</td><td>Primary SiLA Commands</td><td>Primary SiLA commands</td><td>Outcome-oriented</td></tr>
<tr><td>4</td><td>Subtask</td><td>Some SiLA commands reach down</td><td rowspan="2">Additional SiLA commands
For debugging and custom implementations</td><td rowspan="2">Low-level</td></tr>
<tr><td>3</td><td>Motion sequence</td><td rowspan="3">Robot level</td></tr>
<tr><td>2</td><td>Motion primitive</td><td rowspan="2">Robot level</td><td></td></tr>
<tr><td>1</td><td>Actuator primitive</td><td></td></tr>
</table>

Unified feature definitions – Structure (1)

Outcome-oriented (high-level) features

- cleaning
  - CleaningController-v0_0.sila.xml
  - SprayController-v0_0.sila.xml
  - WipeController-v0_0.sila.xml
- devicemanipulation
  - BayController-v0_0.sila.xml
  - HatchController-v0_0.sila.xml
  - UIController-v0_0.sila.xml
- humaninteraction
  - SpeechSerevice-v0_0.sila.xml

- labwaremanipulation
  - CapController-v0_0.sila.xml
  - ClampController-v0_0.sila.xml
  - ConnectorController-v0_0.sila.xml
  - LabelController-v0_0.sila.xml
  - LabwareTransferController-v1_0.sila.xml
  - LidController-v0_0.sila.xml
  - LidFlipController-v0_0.sila.xml
  - PackagingController-v0_0.sila.xml
  - SlideInController-v0_0.sila.xml
  - TransportationController-v0_0.sila.xml
  - TrolleyController-v0_0.sila.xml
  - TubeHandlingController-v0_0.sila.xml

- perception
  - BarcodeProvider-v0_0.sila.xml
  - LiquidLevelProvider-v0_0.sila.xml
  - ObjectDetectionProvider-v0_0.sila.xml
  - PhotoProvider-v0_0.sila.xml
  - PresenceProvider-v0_0.sila.xml
  - ShapeProvider-v0_0.sila.xml
- samplemanipulation
  - PipetteController-v0_0.sila.xml
  - PourController-v0_0.sila.xml
  - ShakeController-v0_0.sila.xml
  - StirController-v0_0.sila.xml
  - VortexController-v0_0.sila.xml

Unified feature definitions – Structure (2)

Low-level features

- lowlevel
  - ArmController-v0_0.sila.xml
  - BaseController-v0_0.sila.xml
  - GripperController-v0_0.sila.xml
- maintenance
  - BatteryController-v0_0.sila.xml
  - ConfigurationController-v0_0.sila.xml
  - InitializationService-v0_0.sila.xml
  - MapService-v0_0.sila.xml
  - PositionService-v0_0.sila.xml
  - ProgramController-v1_0.sila.xml
  - StatusProvider-v0_0.sila.xml
  - TeachingService-v0_0.sila.xml
  - ValidationService-v0_0.sila.xml

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Milestones

- SiLA-ROS interface
  - Hackathons
- Unify feature definitions
  - Structure to incorporate present and future lab robot capabilities
  - Identify candidates as standard definitions for specific capabilities
- Reference implementations
  - TIAGo □ Panna

Reference implementations - TIAGo

Panna Zsoldos, summer intern

- Take part in the SiLA Robotics Working Group's effort to unify the feature definitions
  - See later
- Apply the reference SiLA-ROS bridge implementation to TIAGo's framework
- Implement the basic marker-based pick-and-place sample transportation
- Prepare TIAGo for a PoC on LAPP

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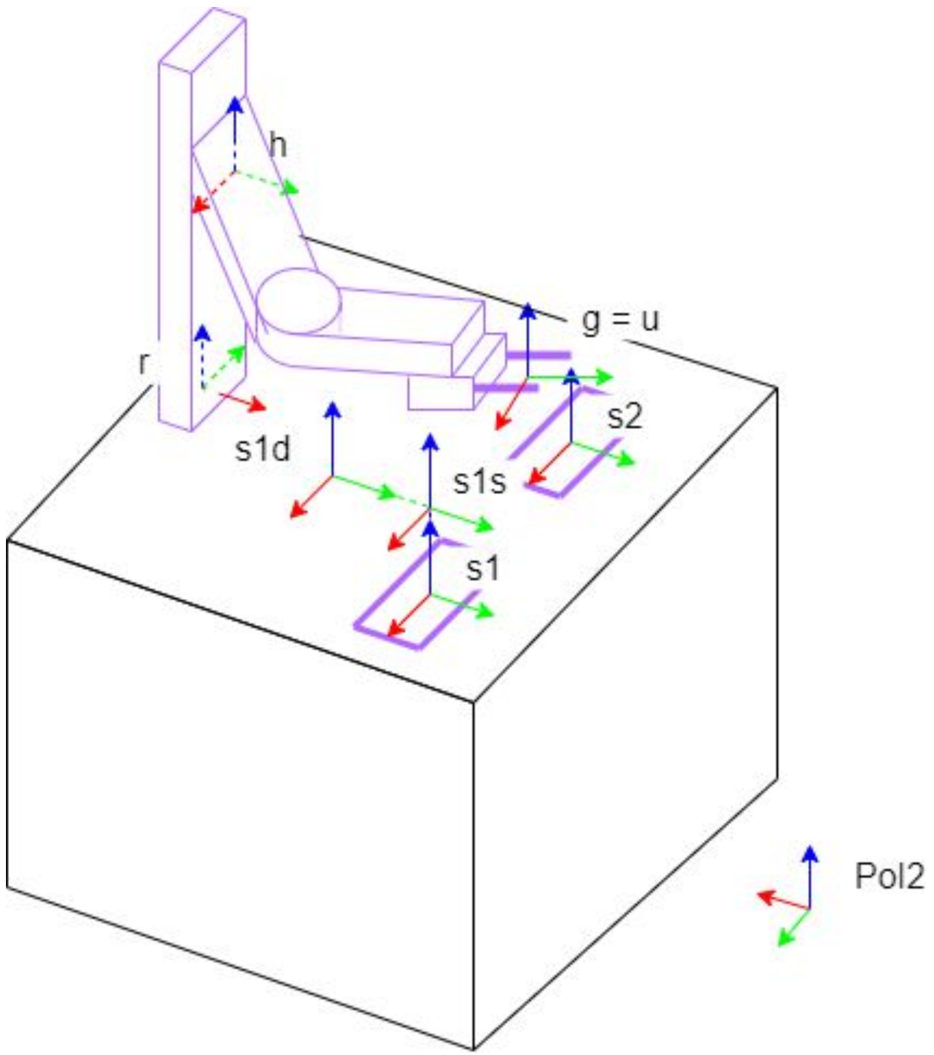
  - **4th BioSASH Hackathon**

Reference implementations – The hackathon working group

SiLA Rapid Integration

Goals

- Reference implementation of the **labware transfer** feature for different benchtop robot arms
  - Based on the LabwareTransferController feature definition
- Implement an exemplary labware transfer action, where the robot picks a plate from one device and places it in another device
  - Passive dummy devices with **fixed** site (aka nest) **positions**



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- Incorporate new concepts (LAPP)
  - Digital twin
  - Robotic action templates
  - Labware library

The Laboratory Automation Plug & Play (LAPP) framework

Motivation

SiLA Rapid Integration

The three pillars of plug & play lab robotics

Communication

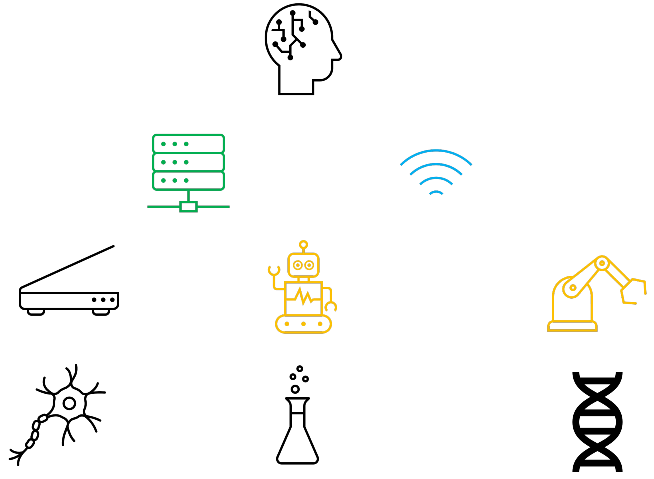
- Standardized interoperability for lab devices
- Peer-to-peer communication between:
    - LIMS/Scheduler
    - Lab equipment: Liquid handlers, analytics
- **Standardization in Laboratory Automation (SiLA)**

Digital Twin

- Information layer for the various components of the system
- Enables plug & play setup
- Laboratory Automation Plug & Play (LAPP)

Robot level

- Advanced robot implementations
- Robot Operating System (ROS)



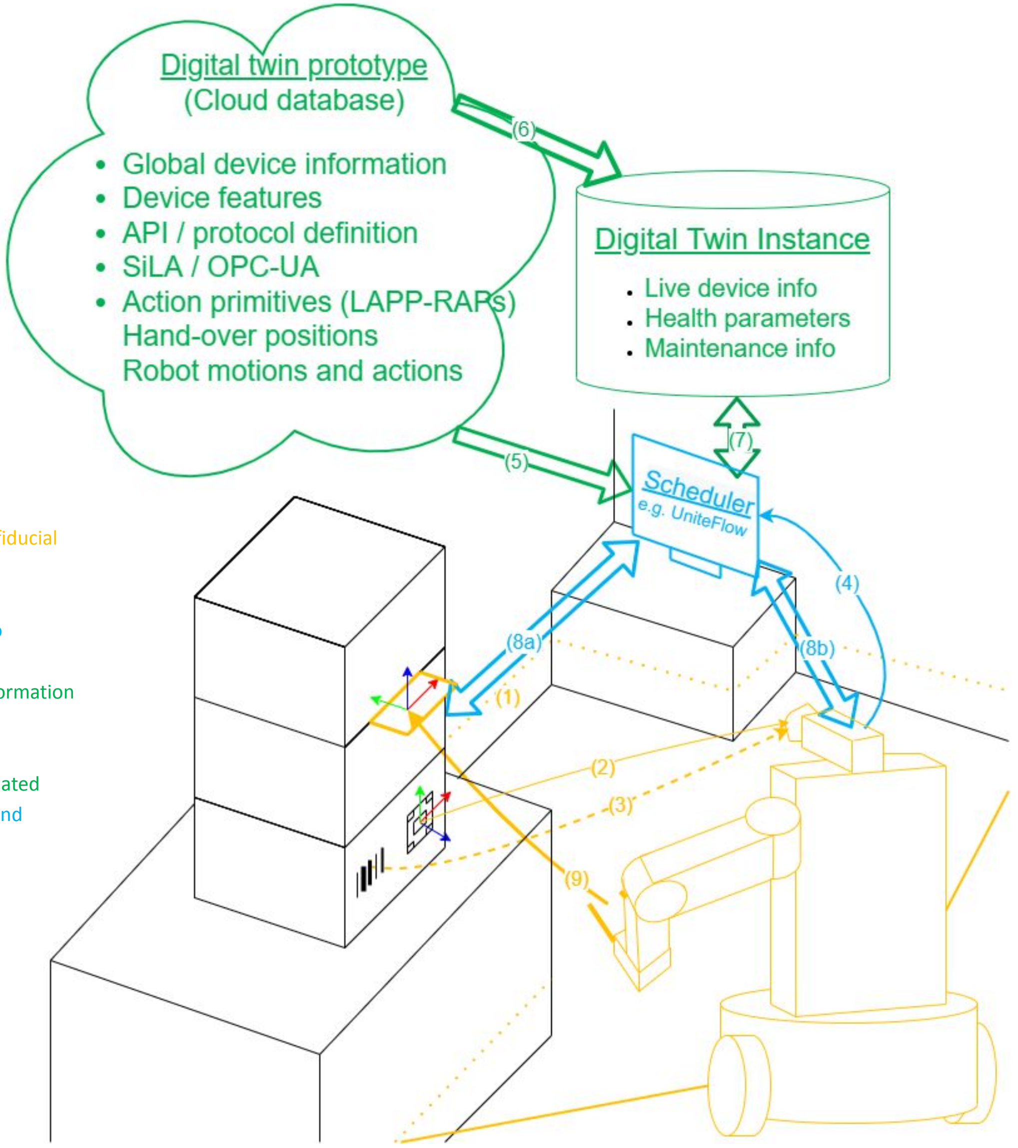
The Laboratory Automation Plug & Play (LAPP) framework

Why:
To enable a fully autonomous setup sequence for:
- Navigation
- Motion planning
- Device interactions

What:
A comprehensive all-round integration framework for manipulator robots in the lab

How:
- Combine existing building blocks
  - SLAM, Fiducial markers, kinematics, vision
- Add semantic and ontological layer:
  - The digital twin
- Provide a systematic approach:
  - Distinguish the components and layers of the system
  - Outline a reference architecture model

(1) SLAM
(2) Pose detection with fiducial marker
(3) Reading the barcode
(4) Upload barcode ID to scheduler
(5) Download device information from the database
(6) Initiate digital twin
(7) Keep digital twin updated
(8) Control the devices and robots
(9) Device operation



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Hierarchical levels of workflow representation and control architecture

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<tr><td>7</td><td>Service</td><td colspan="2">Service protocol</td><td colspan="2">Lab management (LIMS, LES)</td></tr>
<tr><td>6</td><td>Procedure
(Experiment / assay)</td><td colspan="2">Experiment design language
Laboratory process language</td><td colspan="2">Automation Scheduler (E.g. GBG, niceLabs, PharmaMV)</td></tr>
<tr><td>5</td><td>Task</td><td>High-level liquid handling script</td><td rowspan="2">Modular robot program</td><td rowspan="3">EVO PC</td><td rowspan="3">Robot controller PC</td></tr>
<tr><td>4</td><td>Subtask</td><td rowspan="2">Low-level liquid handling script</td></tr>
<tr><td>3</td><td>Motion sequence</td><td rowspan="2">Low-level robot program</td></tr>
<tr><td>2</td><td>Motion primitive</td><td rowspan="2">Device firmware</td><td rowspan="2">Embedded controller</td><td rowspan="2">Robot controller</td></tr>
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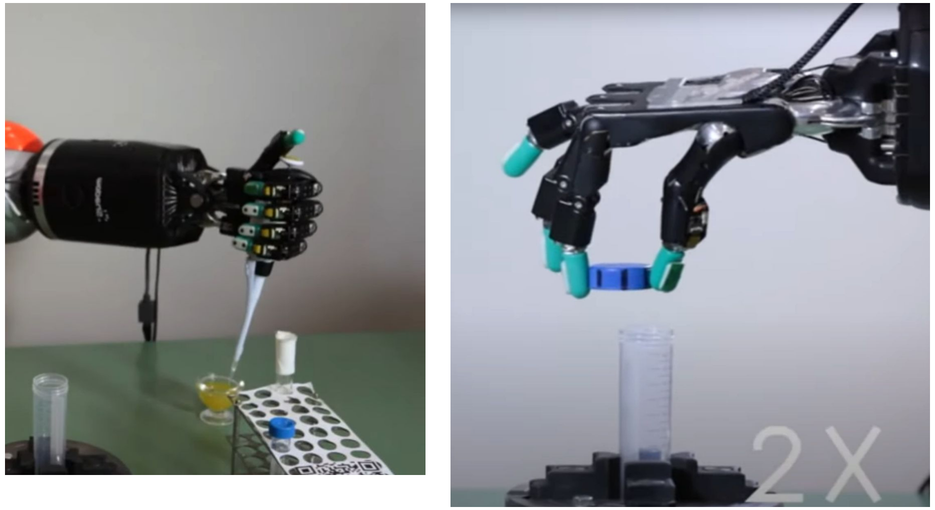
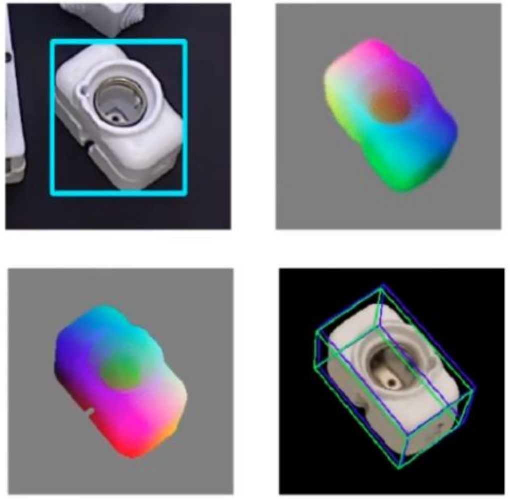
  - Labware library
  - Advanced robotic technologies: Perception, manipulation, Human-machine collaboration

Position representation for stationary robots with the LAPP DT

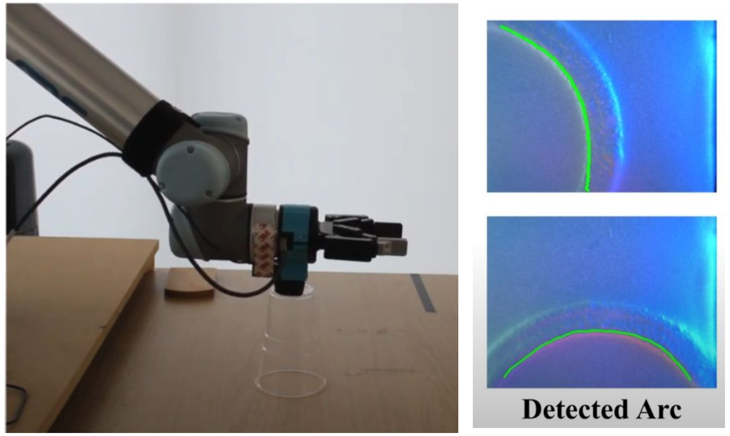
SiLA Rapid Integration



Shadow Robot



V4R, ACIN, TU Wien



Jiang et al.

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  - Advanced robotic technologies: Perception, manipulation, Human-machine collaboration
- Bi-weekly meetings on-going
  - Discussions: workflow representations, labware ontologies, etc.
  - Contact adam.wolf@sila-standard.org to join