Towards Robotic Laboratory Automation Plug & Play: The "LAPP" Framework

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Introduction: Problem statement

Drug development is becoming more and more complex, which calls for advanced technical solutions, especially in terms of automation and system integration[1]. Supportive laboratory robots are enabling the connection of stand-alone equipment by the means of labware transportation and other types of physical interactions. The ultimate flexibility can be achieved by mobile manipulators (MoMa's). These platforms, however, represent a high degree of complexity in terms of control architecture and interoperability. Integrating them reliably still requires the dedicated work of specialists.

Overview

As a part of our reference architecture model, we present:

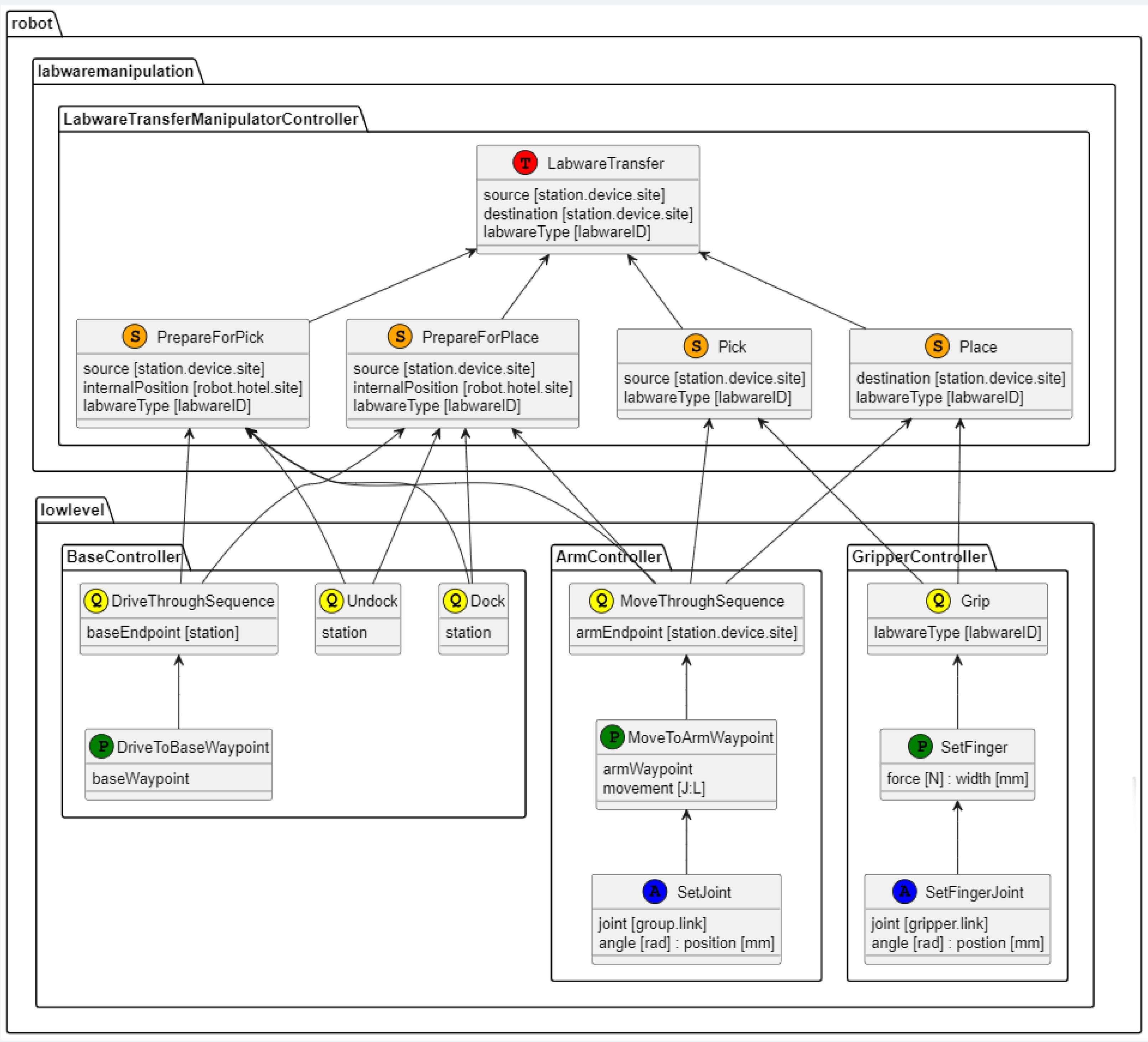
- A hierarchical decomposition of the workflows, focusing on robot-related activities
- The corresponding layers of the control pyramid
- An information representation framework, which is needed to enable a teaching-free robot integration

Finally, we present an outlook on future lab robot capabilities.

Methods: The reference architecture model (LAPP-RAM)

Hierarchical decomposition of laboratory workflows[2]

In order to automate such a complex process, as a laboratory assay, a multi-level breakdown into mutually exclusive sub-activities is required[2]. Our framework characterizes high-level (outcome-oriented) and low-level (hardware-specific) activities. Lab robots implement labware transfer in the form of motion sequences.

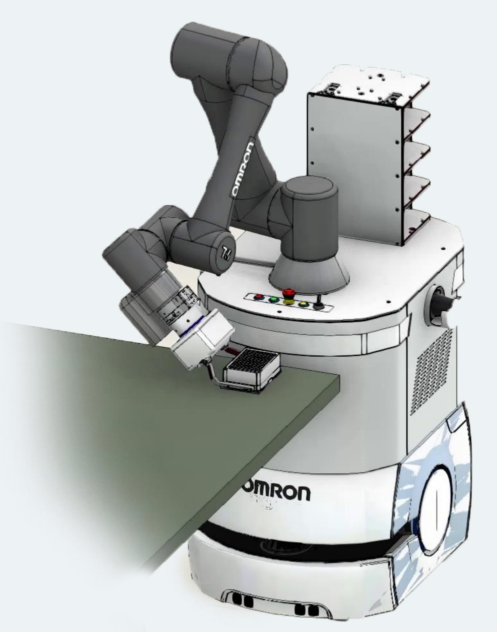


< **Fig. (A)**: Hierarchical decomposition of the labware transfer task.

- Namespaces represent activity categories
- Arrows represent composition
- Parameters of each activity are listed in the body
- Data type of each activity are shown in square brackets

(See table for color legend and description)

Level name	Description
Service	The entirety of the laboratory's capabilities
Procedure	An experiment or assay
Task	An elemental, device-level action item
Subtask	An intermediary layer that represent parts of a task. Accomplish minor landmarks
Motion sequence	The robot performs a sequence of motions. E.g., in order to approach a handover site
Motion primitive	An elemental motion of a robot or other mechanism
Actuator primitive	An output excerpted by a certain actuator. E.g., robot joint or pump



^ **Fig. (B)**: Mobile manipulator (MoMa) for sample transportation. © EngRoTec – Solutions

Position representations for mobile robots with the LAPP DT

Storing robot (base- and arm-) positions in the context of lab entities enables a teaching-free lab robot setup.

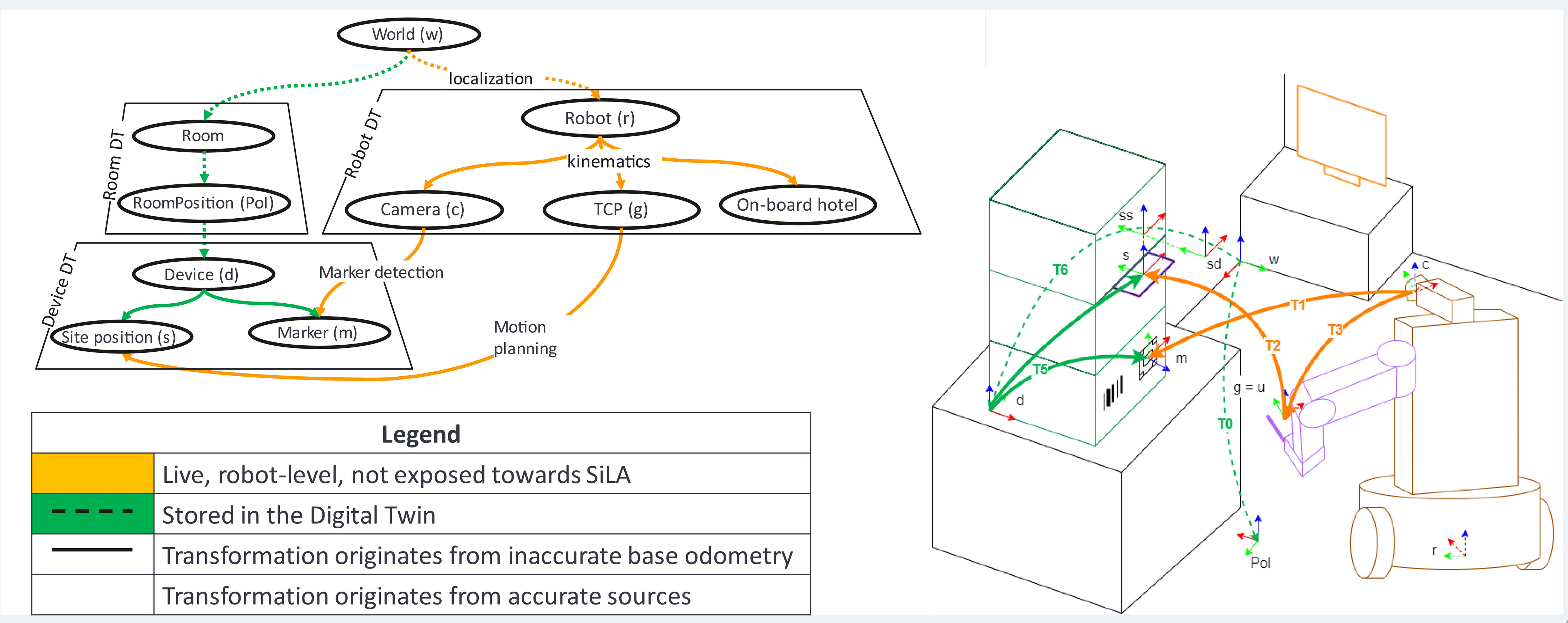


Fig. (C): Hierarchical position representation in the LAPP Digital Twin ontology

Results: Proof-of-concept studies

Implementing the control architecture and the ontologies

The different levels of granularity are reflected in a multi-layer control architecture, where a scheduler triggers high-level activities on the devices, which execute them in a hardware-specific way, interacting with the physical world.

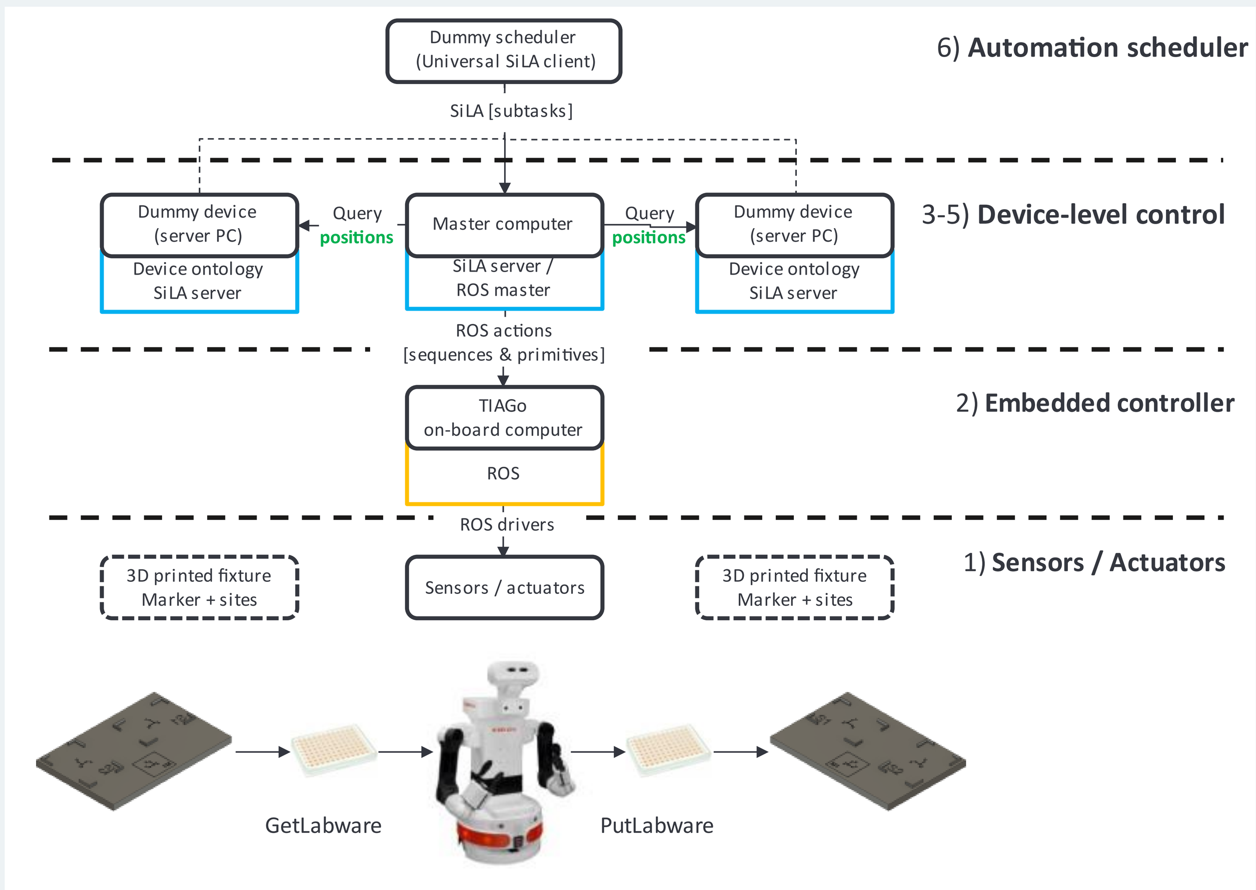


Fig. (D): Exemplary (PoC) implementation of the proposed architecture. The Robot Operating System (ROS) was used as a robotic middleware, and the Standardization in Laboratory Automation (SiLA) protocol for high-level communication. A device ontology implements the LAPP-DT for storing positions.

Level name	Layers of the control architecture
Service	**Lab management:** LIMS/ELN
Procedure	**Automation scheduler**: Laboratory Execution System (LES)
Task	**Device-level control:** Dedicated PC
Subtask	
Motion sequence	
Motion primitive	**Embedded controller:** Microcontroller or Programmable Logic Controller (PLC)
Actuator primitive	

Tab. (A): Layers of the control architecture, mapped against the levels of the workflow decomposition.

Next Steps

Advanced manipulation and human-robot collaboration

Enhancing lab robots' capabilities (e.g., to enable skilled manipulation) is possible via advanced cognition and perception. Human-in-the loop approaches, such as telemanipulation open up additional application areas[3,4].

Fig. (E): A VR headset is used to control the movements of a mobile manipulator to implement simple object manipulation. The virtual cockpit is shown on the right, featuring stereo and side views and a live robot model.

References:

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