

# TraceBot

Traceable robotic handling of sterile medical products



**Maike Neumann, BioLAGO e.V.**  
Project coordinator TraceBot



Horizon 2020

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Connecting

Pharmaceutical

Knowledge

# TraceBot context

- Considering a process still done manually
- Showcase robotic capability in manipulation, verification and traceability
- Bring agile production concept into laboratory domain
- Address domain specific challenges



# Project state

Healthcare & industrial robotics (ES)



Cluster in medical domain (DE)

Robotic sensing (AT)



Healthcare robotics (FR)



Task-based reasoning (DE)

Robotic integrator (UK)



Use case & regulation (DE)

## TRACEBOT

- Perception
- Learning
- Dexterity
- Tracing & Verifying
- Control
- Reasoning

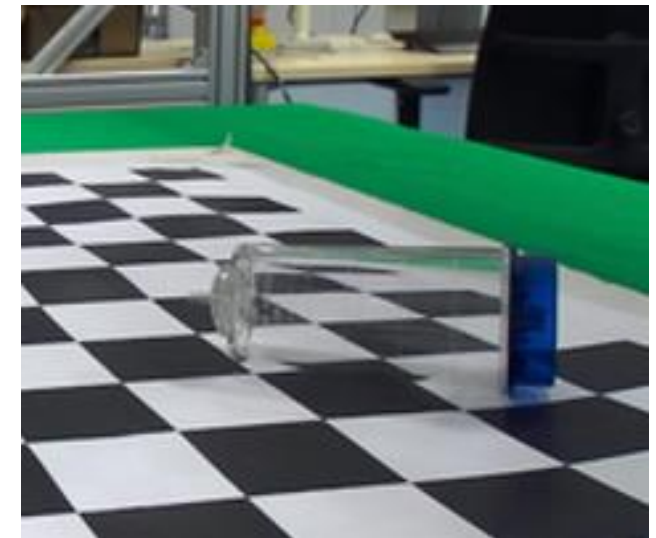
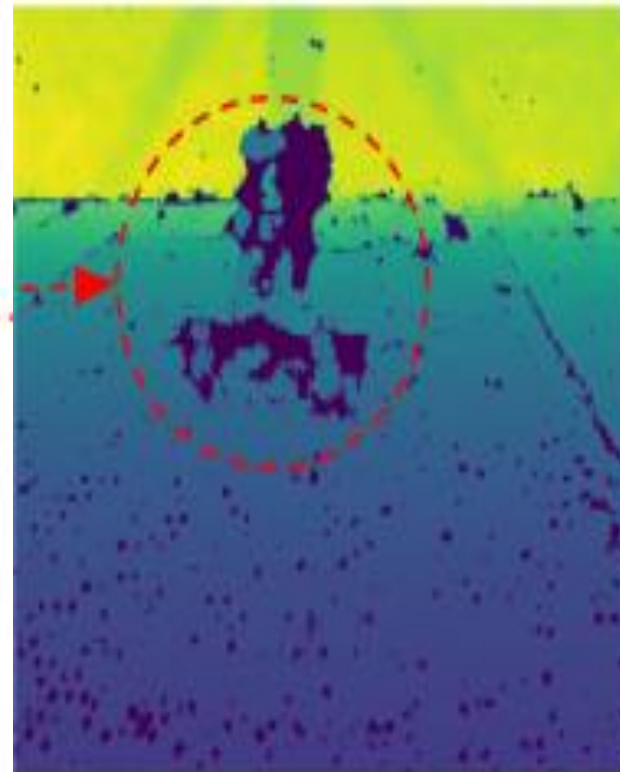
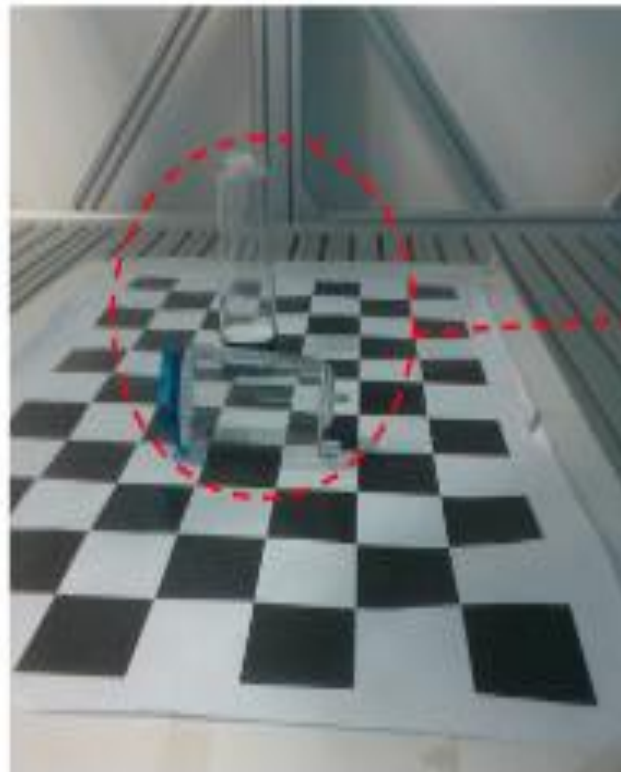
# TraceBot highlights - Perception

TRACEBOT



- Perception
- Learning
- Dexterity
- Tracing & Verifying
- Control
- Reasoning

How to perceive the pharmaceutical items?



# TraceBot highlights - Perception

RGB Image

GT/GDRN Pose

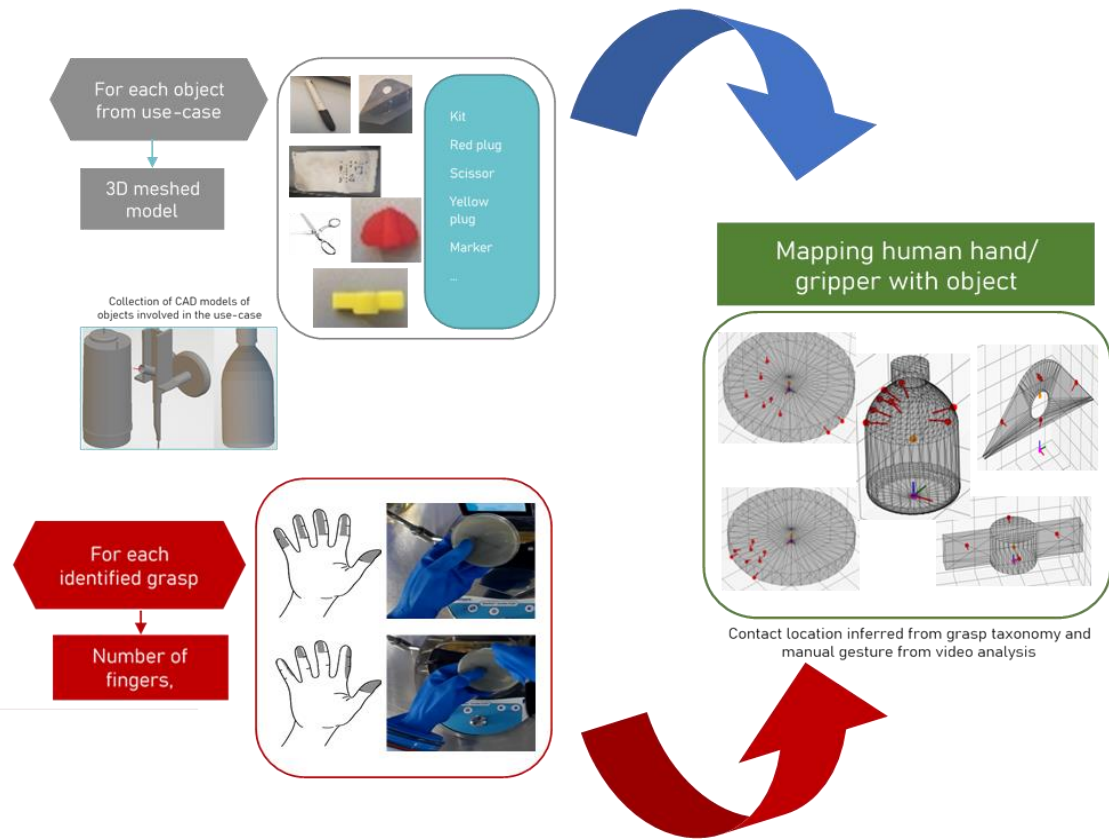
GT/ Ours. Pose



# TraceBot highlights - Dexterous manipulation

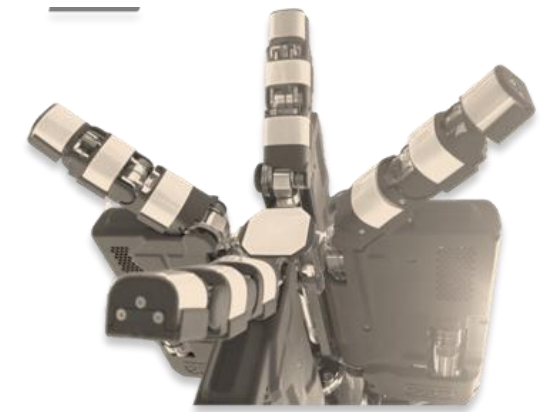
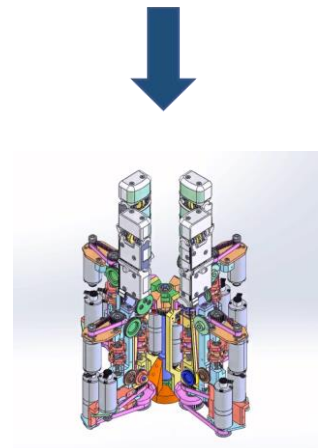
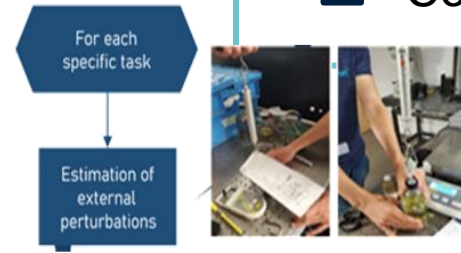


## How to manipulate the pharmaceutical items?



### TRACEBOT

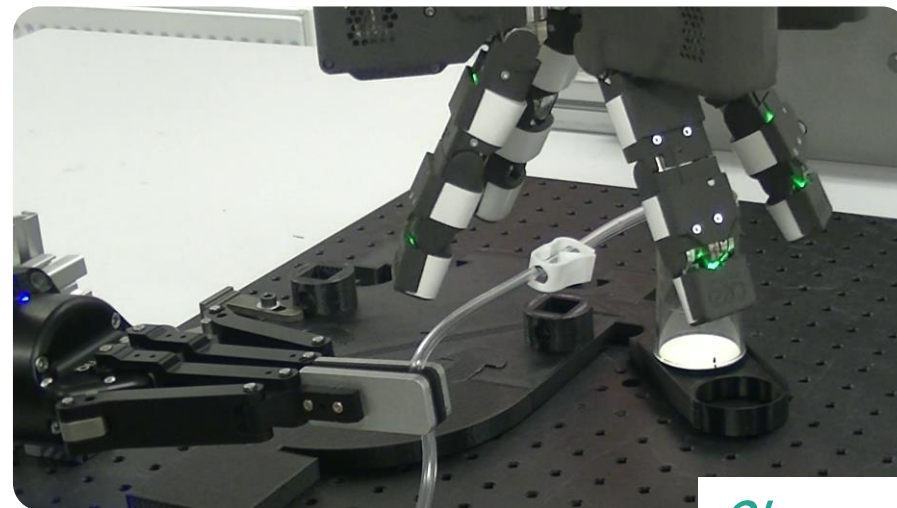
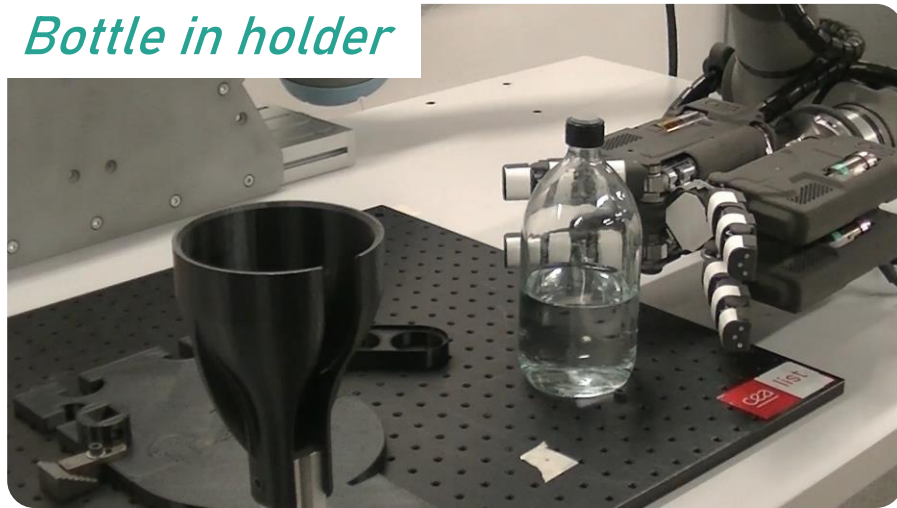
<input type="checkbox"/> Perception	<input type="checkbox"/> Learning
<input checked="" type="checkbox"/> Dexterity	<input type="checkbox"/> Tracing & Verifying
<input type="checkbox"/> Control	<input type="checkbox"/> Reasoning



# TraceBot highlights - Dexterous manipulation

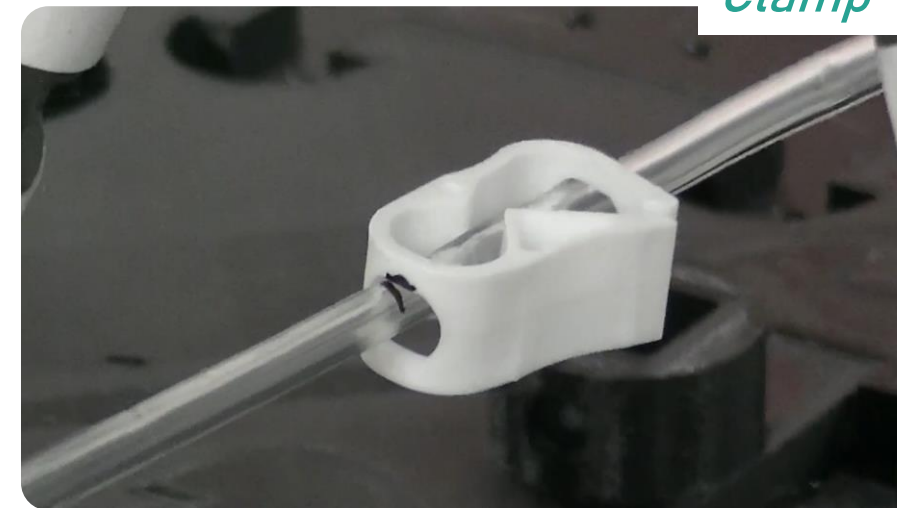
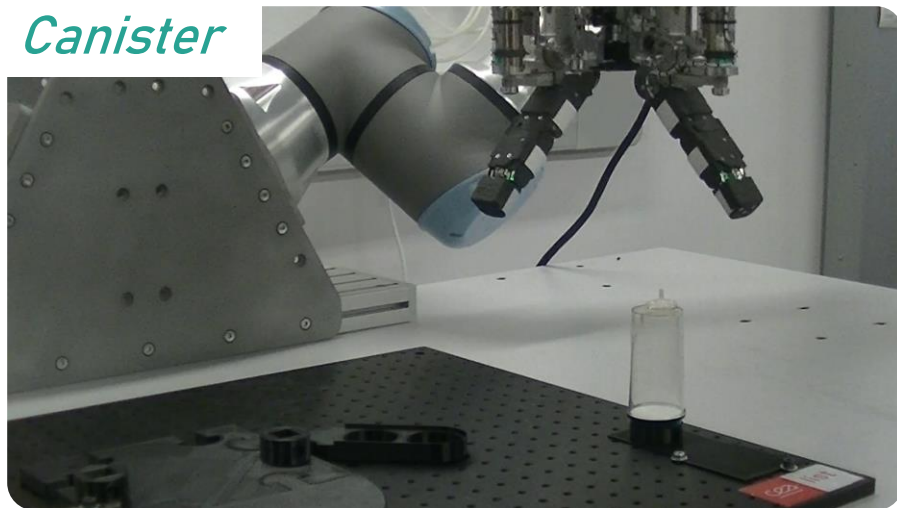


*Bottle in holder*

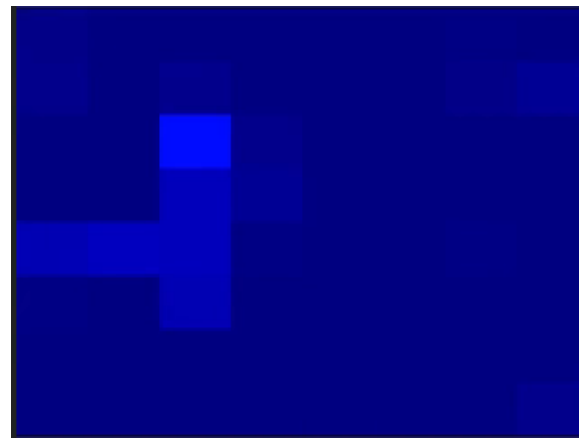
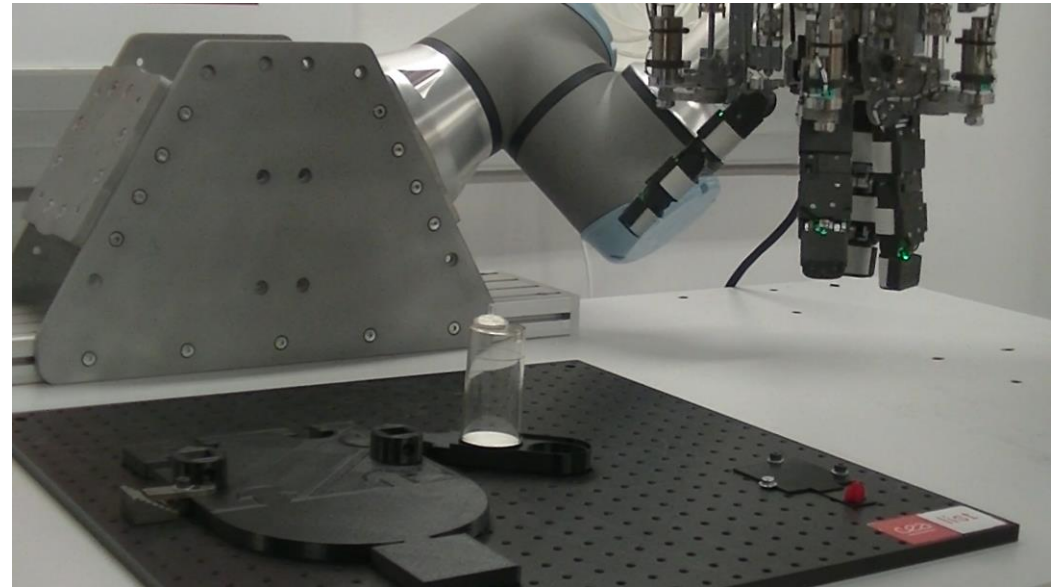
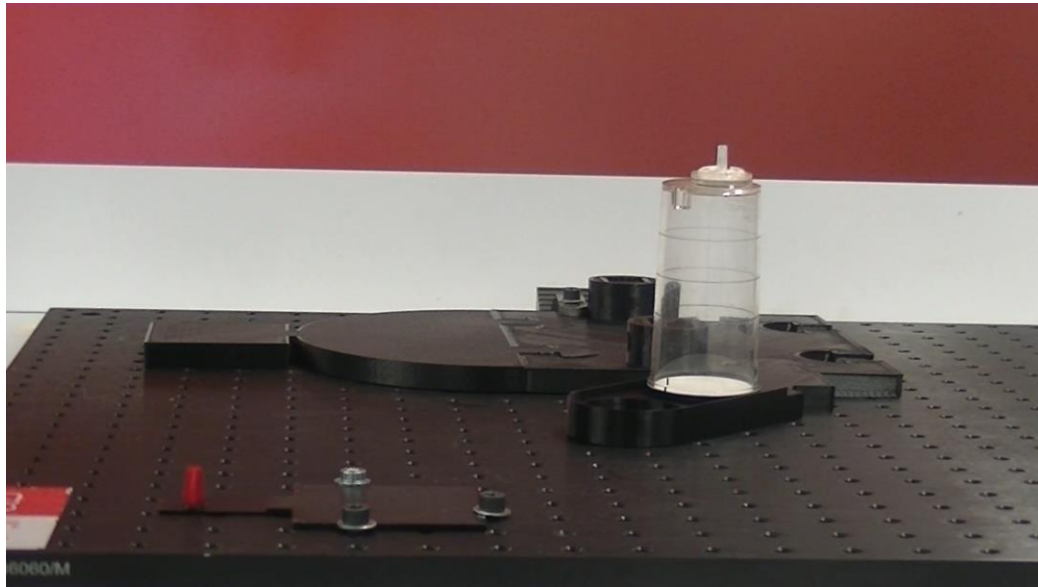


*Clamp*

*Canister*



# TraceBot highlights - Dexterous manipulation



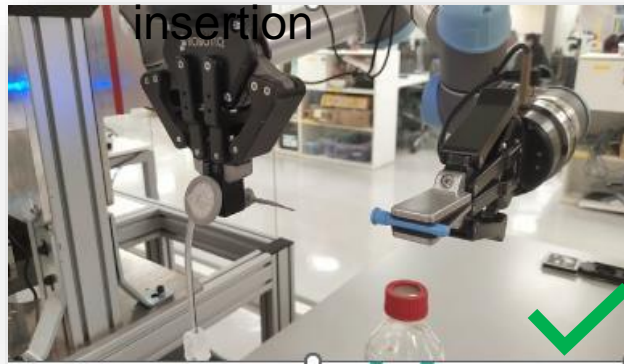


# TraceBot highlights - Robot Control

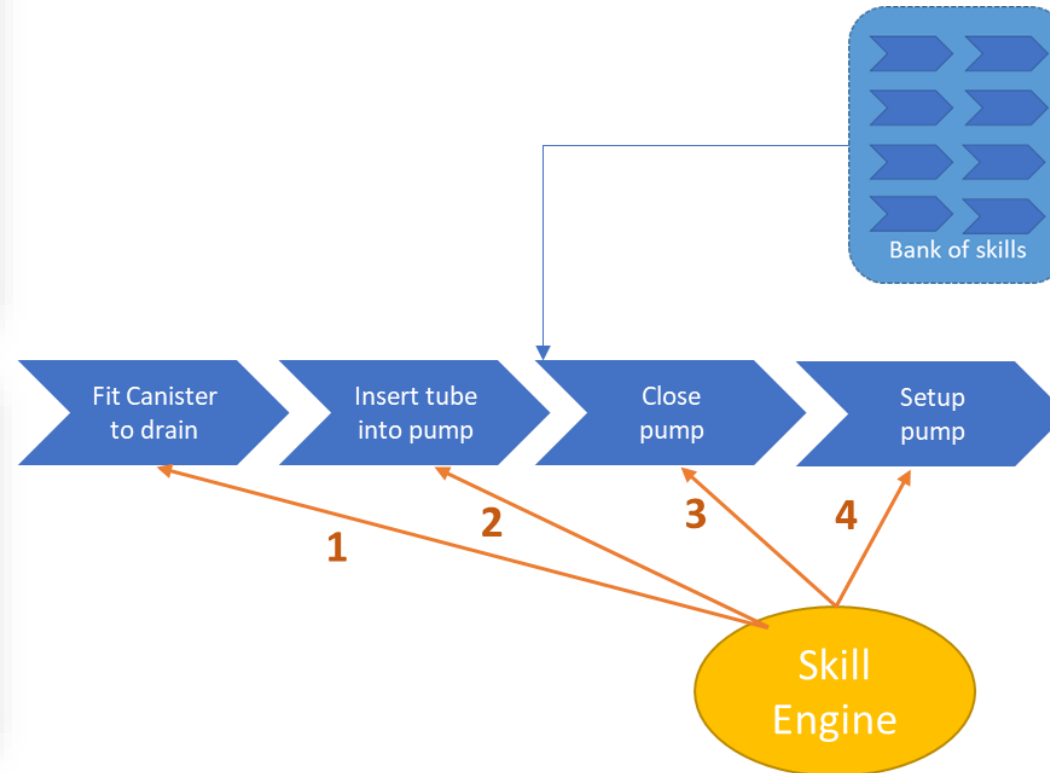
How to control the robot - System control through skill framework (and ROS)



Canister



Needle manipulation



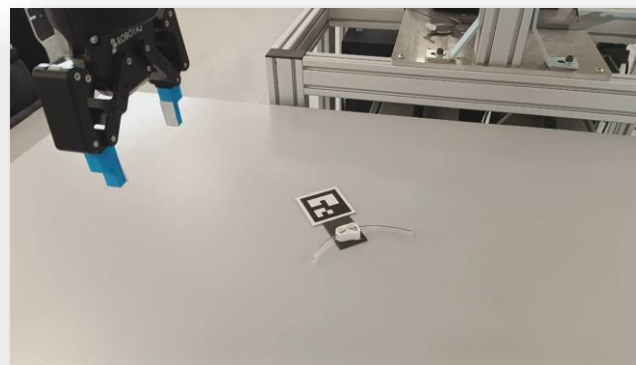
## TRACEBOT

- Perception
- Dexterity
- Control
- Learning
- Tracing & Verifying
- Reasoning

# TraceBot highlights - Robot Control



Canister insertion



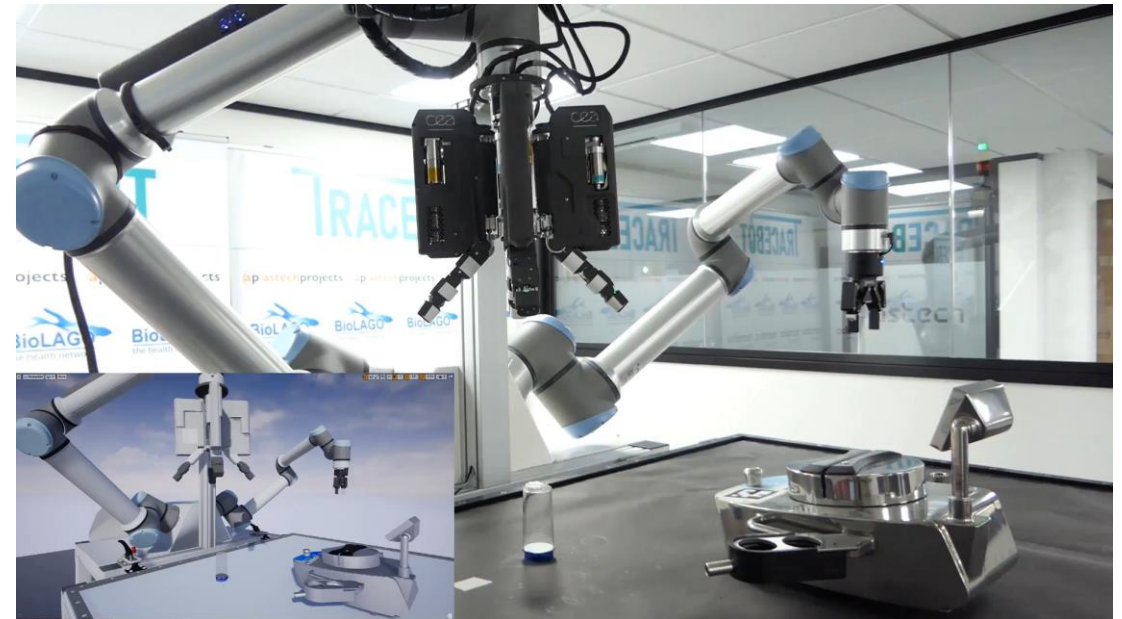
Clamp manipulation



Needle manipulation

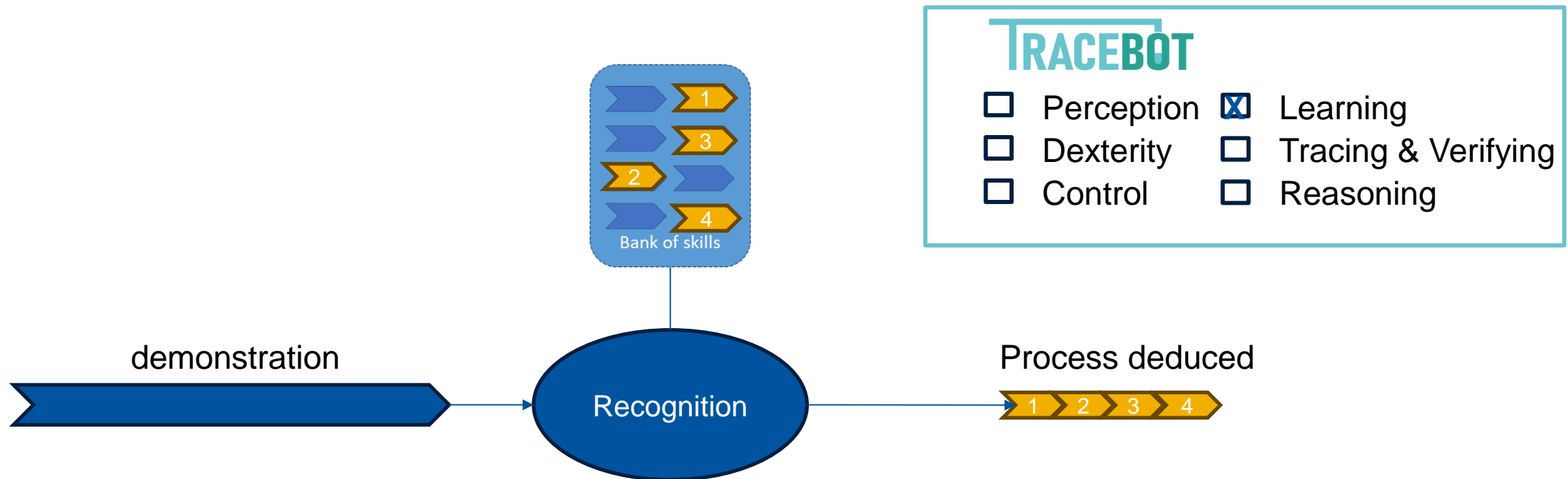


# TraceBot highlights - Robot Control



# TraceBot highlights - Learning

## How to teach new behavior - Process demonstration & recognition



# TraceBot highlights - Learning

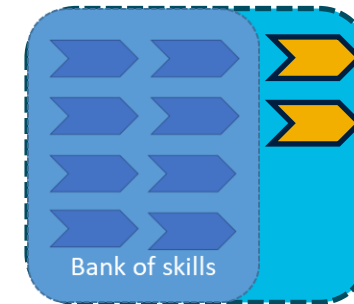
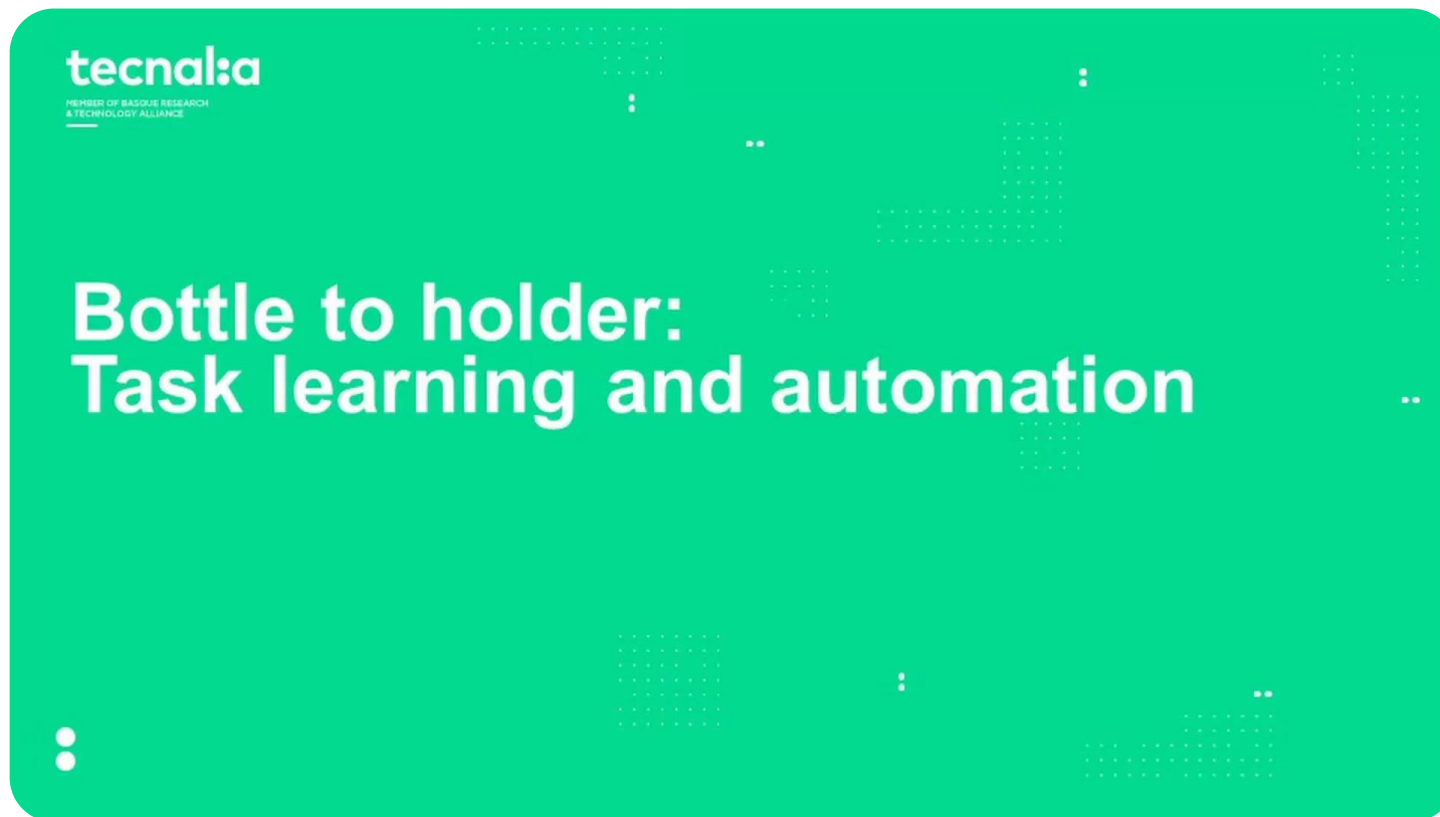


Robot camera view

To start programming, the user only needs to perform the task with the robot.

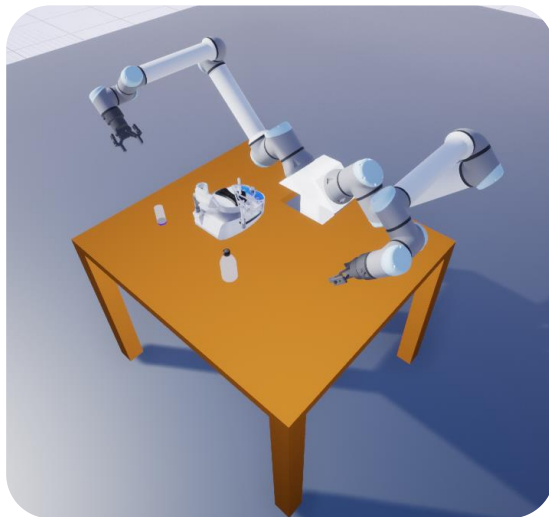
# TraceBot highlights - Learning

How to teach new behavior - Specific motion learning through (teleoperated) demonstration

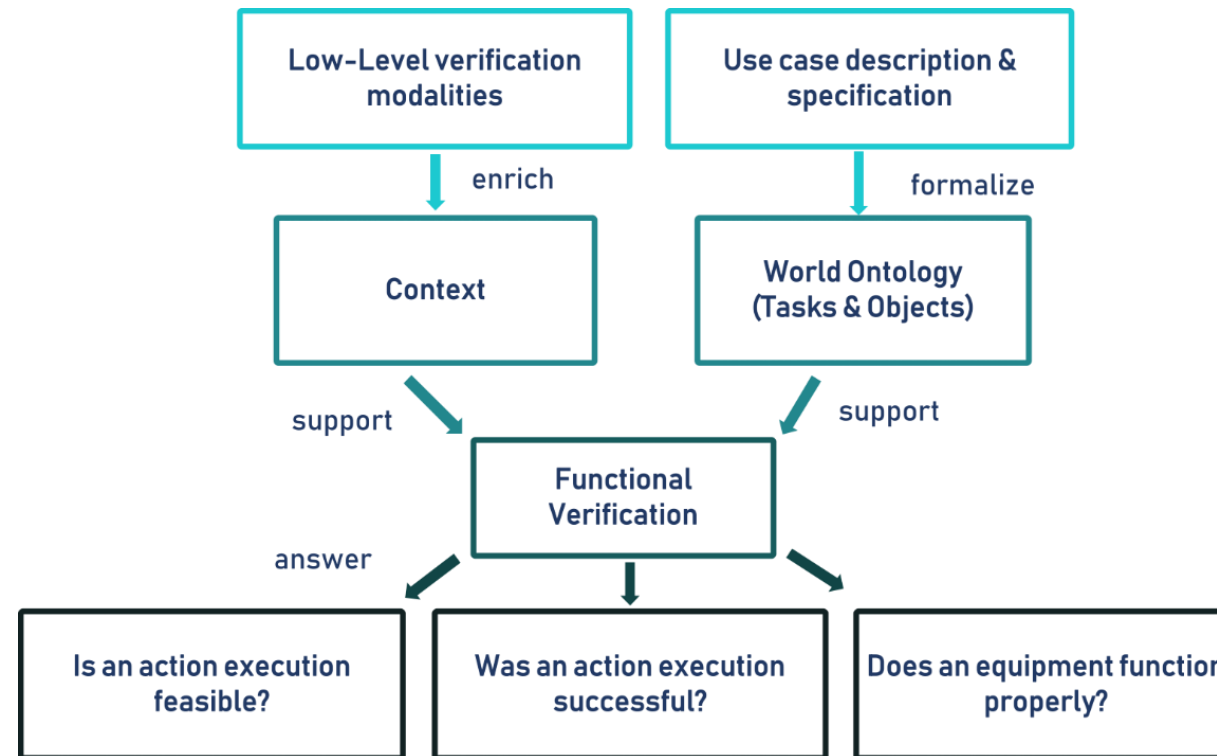


# TraceBot highlights - Reasoning

How to understand and control what is going on?



Traceable Semantic Twin – Digital Twin

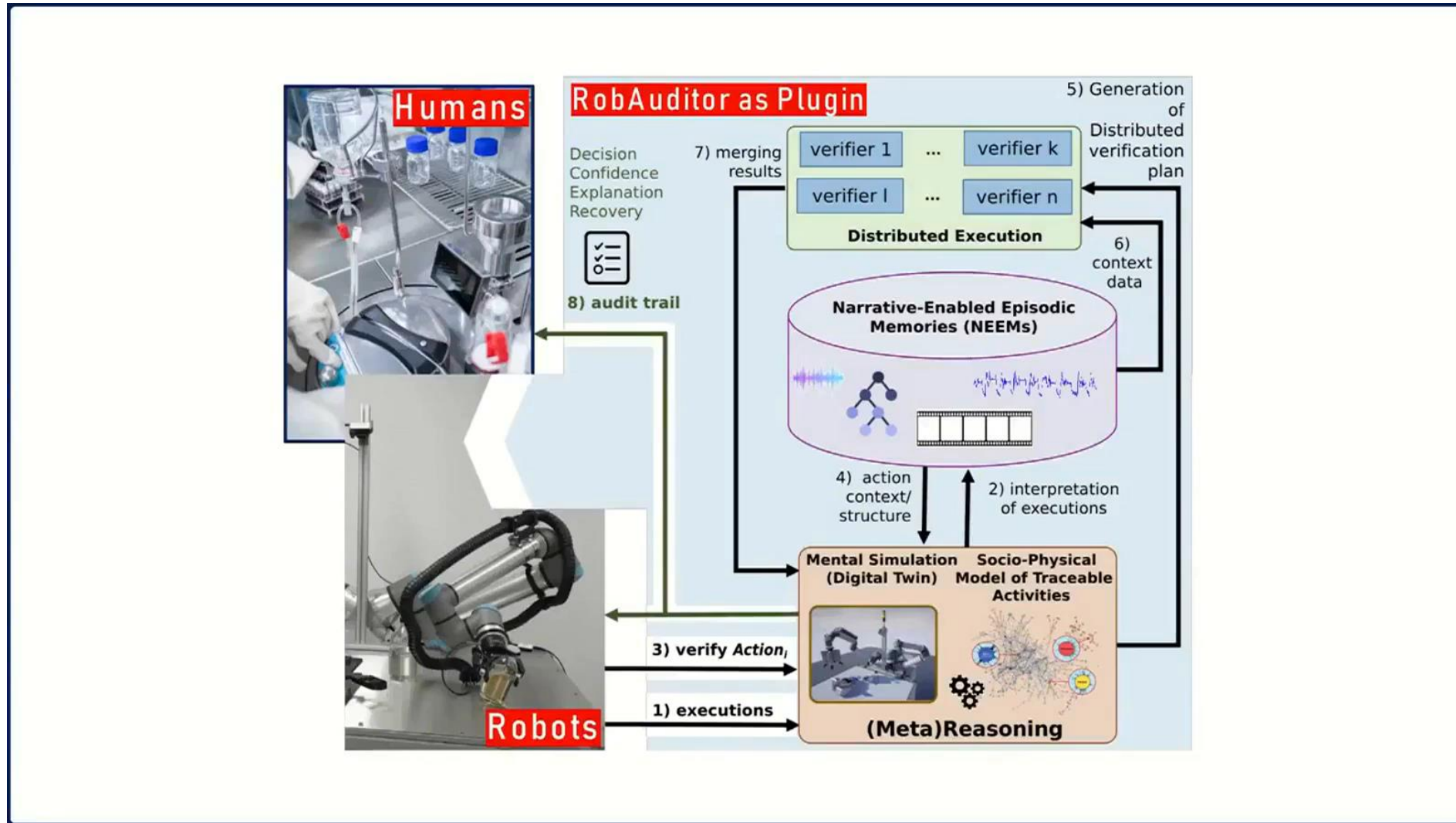


Functional verification

**TRACEBOT**

- Perception
- Dexterity
- Control
- Learning
- Tracing & Verifying
- Reasoning

# TraceBot highlights – Reasoning for verification





# TraceBot highlights – Reasoning for verification

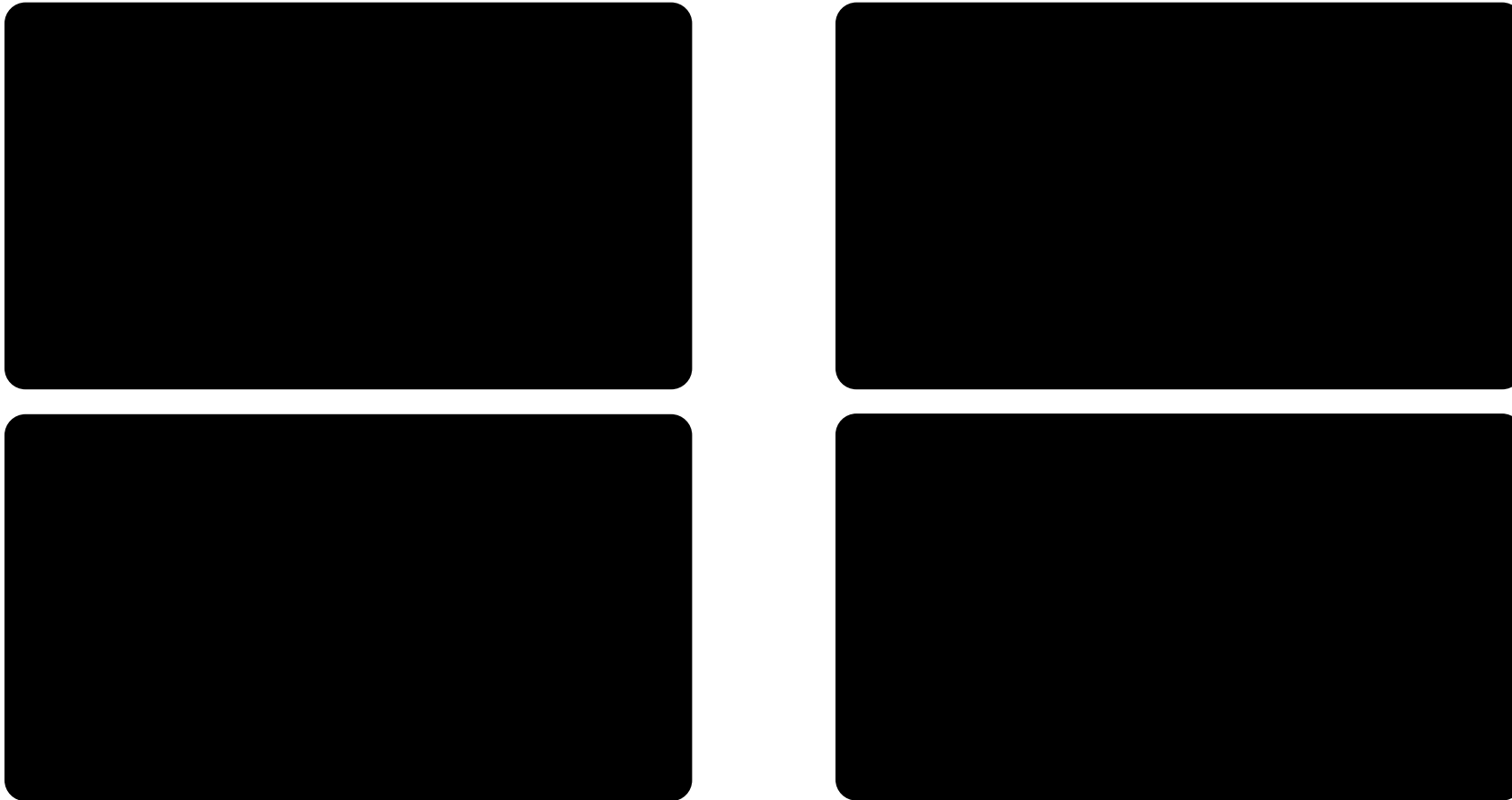


Illustration of the verifiers

# TraceBot highlights – Reasoning for verification

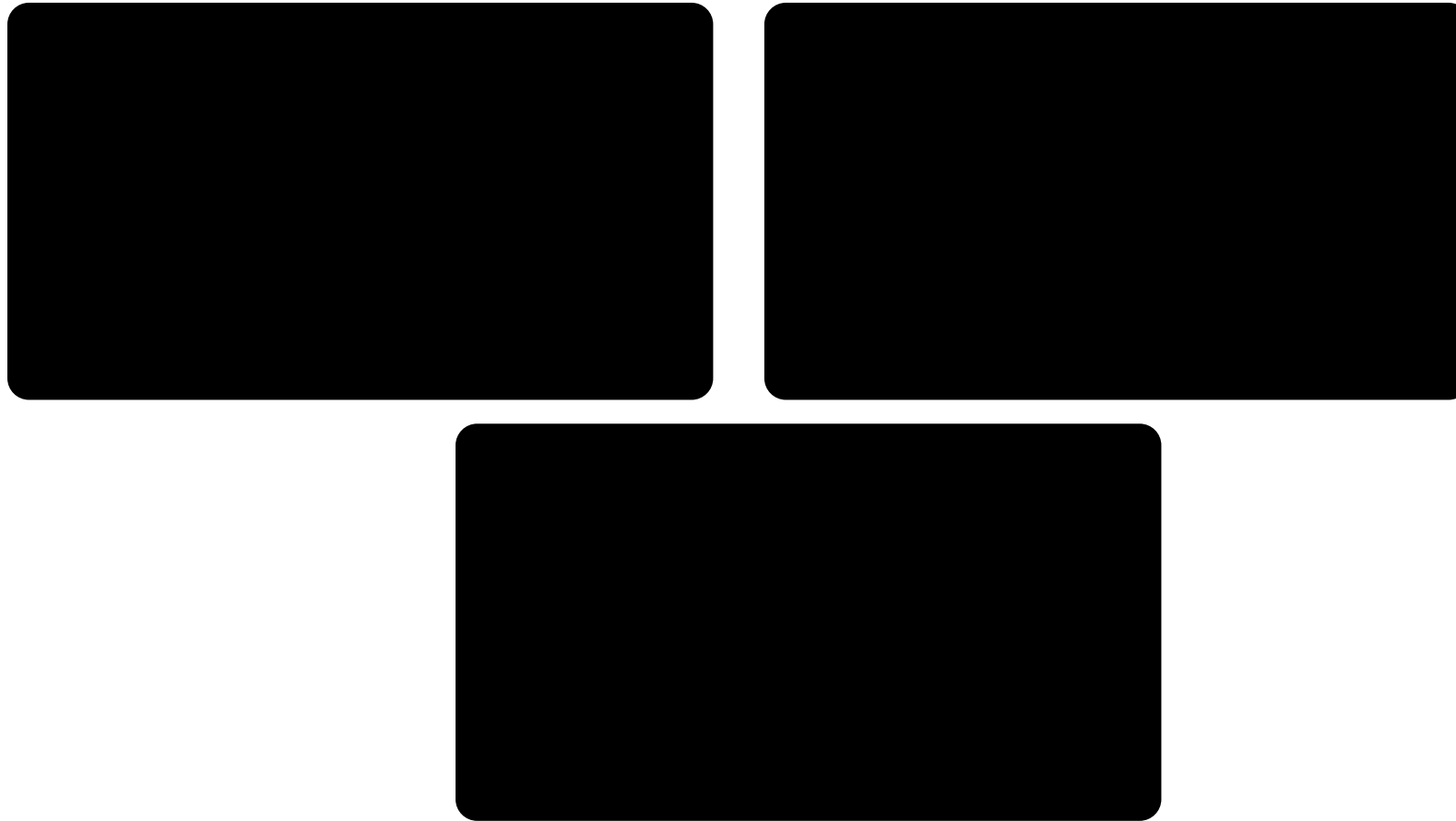


Illustration of the verifiers

# TraceBot highlights - Reasoning

How to understand and control what is going on - Audit Trail with verification and traces

▼ 1. Detect Canister

Goal sent 11.09 / Received by the tracer at 11.09  
Result sent 12.24 / Received by the tracer at 12.24  
• Sequence metadata

▼ 1.1 Locate Canister

Goal sent 11.09 / Received by the tracer at 11.1  
Result sent 11.12 / Received by the tracer at 11.14  
Object to locate: Canister

▶  1.2 Verify Canister Pose

▼ 2. Grab Canister

Goal sent 12.32 / Received by the tracer at 12.32  
Result sent 24.84 / Received by the tracer at 24.87  
• Sequence metadata

▼ 2.1 Lookup Canister Grasp Info

▼ goal  
Goal sent 15.78 / Received by the tracer at 15.78

```
{
  "placeholder_goal": "CANISTER_GRAPS_INFO"
}
```

• result

Summary

Action Tree

TRACEBOT							
End-User Auto-Generated Audit Trail							
<b>Episode</b> : Inserting Canister Into Draintray							
<b>Duration</b> : 24.10.2023, 18:54:33 - 24.10.2023, 18:54:54							
<b>Status</b> : Failed / --[Successful]-- / Interrupted / Pending							
<b>Confidence</b> : 92.38%							
Action Designator	Executive Module	Participants	Execution Time(s)	Status	Confidence Level	Verbal Explanation	Non-verbal Explanation
Filling Insertion Into Draintray	Manipulation; Perception; Reasoning; Planning	Robot Module: TROBOT; Human: User@Bremen; TROBOT; Human: User@Bremen; TROBOT; Human: User@Bremen	24.10.2023, 18:54:33 - 24.10.2023, 18:54:54	Successful	92.38%	All constitutive sub-actions were successful	Yet to be resolved
1. Parking Arms	Manipulation	Robot Module: TROBOT; Human: User@Bremen; TROBOT; Human: User@Bremen	24.10.2023, 18:54:33 - 24.10.2023, 18:54:34	Successful	98.07%	Yet to be resolved	
2. Traceable Locating	Perception; Reasoning	Robot Module: TROBOT; Human: User@Bremen; TROBOT; Human: User@Bremen	24.10.2023, 18:54:34 - 24.10.2023, 18:54:38	Successful	99.98%	All constitutive sub-actions were successful	
				<b>Semantics</b>		<b>Verification</b>	
E.1. Verifying Pose	Reasoning	Robot Module: TROBOT; Human: User@Bremen; TROBOT; Human: User@Bremen	24.10.2023, 18:54:34 - 24.10.2023, 18:54:36	Successful	99.98%	Yet to be resolved	Yet to be resolved
3. Traceable Parking Up	Manipulation; Planning; Reasoning	Robot Module: TROBOT; Human: User@Bremen; TROBOT; Human: User@Bremen	24.10.2023, 18:54:36 - 24.10.2023, 18:54:40	Successful	99.94%	All constitutive sub-actions were successful	Yet to be resolved
G.1. Planning Grasp	Reasoning; Planning	Robot Module: TROBOT; Human: User@Bremen; TROBOT; Human: User@Bremen	24.10.2023, 18:54:38 - 24.10.2023, 18:54:38	Successful	99.54%	Yet to be resolved	Yet to be resolved
4. Traceable Locating	Perception; Reasoning	Robot Module: TROBOT; Human: User@Bremen; TROBOT; Human: User@Bremen	24.10.2023, 18:54:40 - 24.10.2023, 18:54:43	Successful	100.0%	All constitutive sub-actions were successful	
E.1. Verifying Pose	Reasoning	Robot Module: TROBOT; Human: User@Bremen; TROBOT; Human: User@Bremen	24.10.2023, 18:54:40 - 24.10.2023, 18:54:43	Successful	100.0%	Yet to be resolved	Yet to be resolved
5. Traceable Inserting	Manipulation; Planning; Reasoning	Robot Module: TROBOT; Human: User@Bremen; TROBOT; Human: User@Bremen	24.10.2023, 18:54:43 - 24.10.2023, 18:54:51	Successful	94.93%	All constitutive sub-actions were successful	
G.1. Planning Inversion	Reasoning; Planning	Robot Module: TROBOT; Human: User@Bremen; TROBOT; Human: User@Bremen	24.10.2023, 18:54:43 - 24.10.2023, 18:54:45	Successful	98.22%	Yet to be resolved	Yet to be resolved
5.2. Inserting	Manipulation	Robot Module: TROBOT; Human: User@Bremen; TROBOT; Human: User@Bremen	24.10.2023, 18:54:45 - 24.10.2023, 18:54:46	Successful	99.75%	Yet to be resolved	
G.3. Orienting	Manipulation	Robot Module: TROBOT; Human: User@Bremen; TROBOT; Human: User@Bremen	24.10.2023, 18:54:46 - 24.10.2023, 18:54:47	Successful	99.01%	Yet to be resolved	Yet to be resolved
5.4. Releasing	Manipulation	Robot Module: TROBOT; Human: User@Bremen; TROBOT; Human: User@Bremen	24.10.2023, 18:54:47 - 24.10.2023, 18:54:47	Successful	98.35%	Yet to be resolved	

# Conclusions

## Several progresses towards sterility testing automation

Dexterity, perception, robot control, tracing & verification, reasoning

Programming interface, programming by demonstration, integration

Combining several steps into unique demonstration

Conducting acceptance test to check progress

## Concepts applicable to other processes

Looking for more use cases to confirm technique validity

## Pending / challenging steps

Small object manipulation

Deformable consumable management

Object affordances management



# Thank you

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