Robot Control and Plan Execution for Automated Experiments in Industrial Laboratory

Master Thesis in Artificial Intelligence and Robotics

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Outline

- Introduction of AIPlan4EU project
- Problem summary
- Software and Tools
- Laboratory and Devices
- Robot configuration
- How to avoid collision
- How the robot grasps the pouch
- Overview of robot movements
- Actions and Fluents implemented
- Plan implementation
- Video showing complete experiements

MOTIVATIONS AND OBJECTIVES

- AIPlan4EU aims to bring the most advanced AI planning technology to companies
- *"Use-cases"* drive the design of AI planning systems
- For this thesis, use-case consists of the executive procedure for the analysis of the laundry detergent pouch, performed by a robotic arm, in a dedicated *P&G* laboratory
- Furthermore, to lay the foundations for an AI planning framework that leverages on the "human-in-the-loop" concept
- To accomplish this, all robot components and devices in the laboratory have been connected between them and designed AI plans

Problem overview

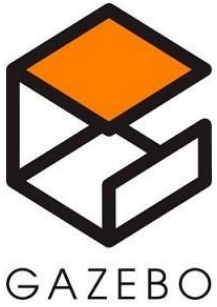
The executive procedure for the analysis of the laundry detergent pouch consists in:

- Detect the pouch position
- Grasp the pouch
- Execute the weight test
- Execute the tightness test
- Trash the pouch

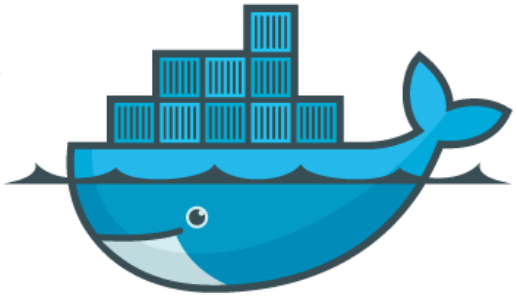
We want to **REPEAT** this procedure ***for each*** pouch in the drawer and ***for every*** available drawer.

Software and Tools

A collection of software libraries and tools that aim to build robot applications



3D robotics simulator that consent to create realistic and dynamic simulations of robots in a work environment

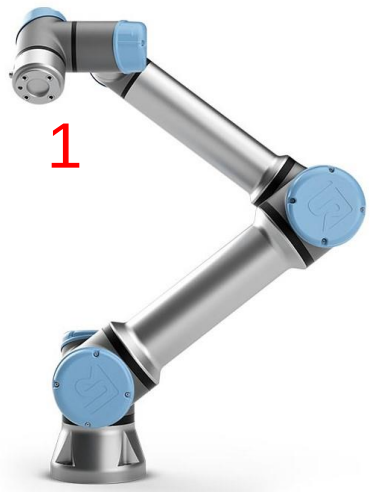


A state-of-the-art containerization technology that guarantees portability, autonomy, accelerates and simplifies application development

A robotic manipulation platform that incorporates the latest advances in motion planning, manipulation, 3D perception, kinematics, control and navigation

One of the most famous object detection tools based on CNN due to its speed and accuracy

Laboratory and Devices



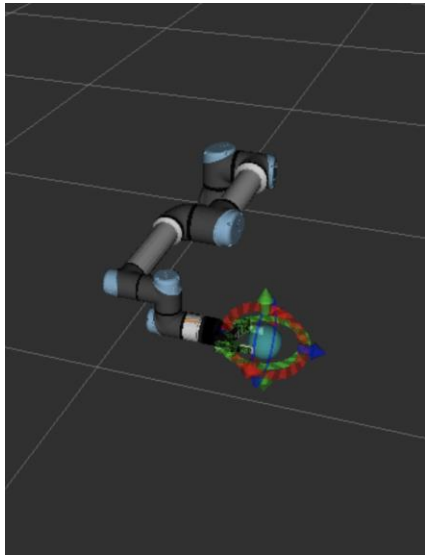
Robot configuartion

URDF - Unified Robotic Description Format

XML format to describe the complex interconnected structure of the robot (link in connected in Parent-Child relationship)

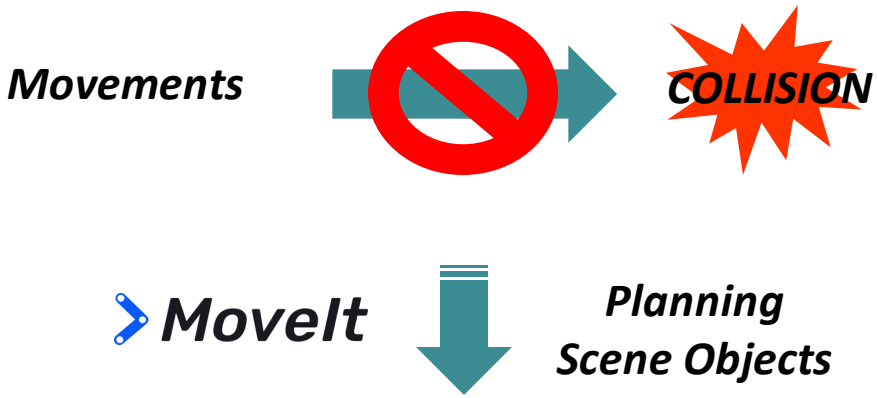
New MoveIt configuration

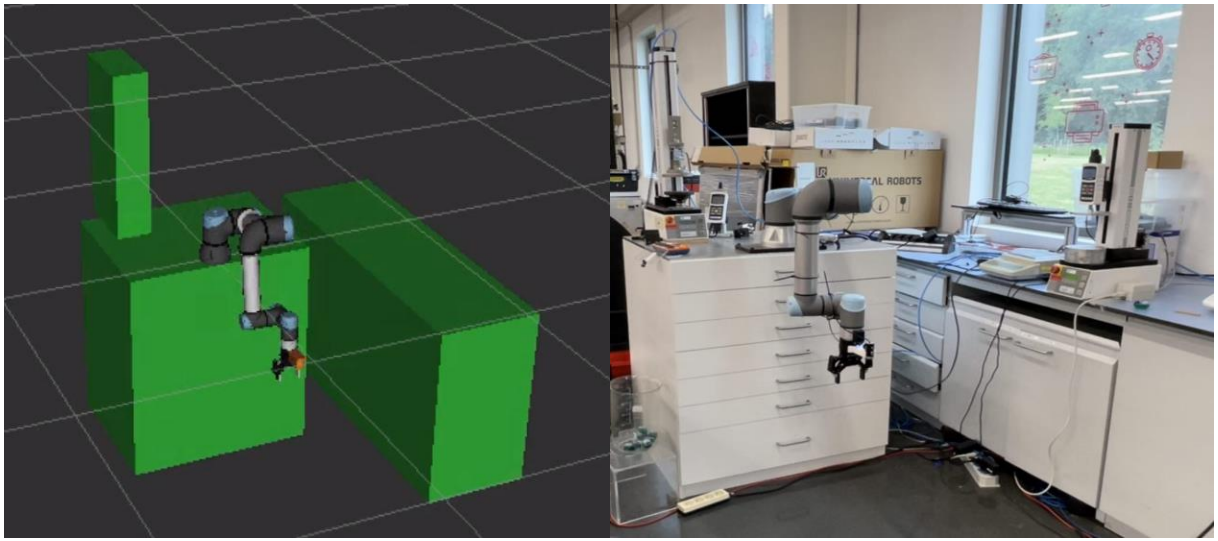
Inverse Kinematics solution



MoveIt

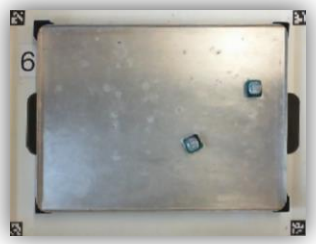
Collision avoidance





Grasping Pouch

OpenCV



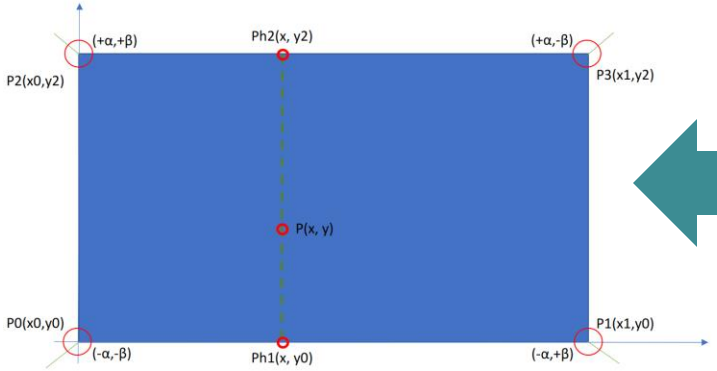
YOLOv5

$(x, y)_I$

$(x, y, z)_R$

Depends on current drawer

Interpolation over gripper orientation....



....important for grasping pouches near drawer without hitting it!

RPY

(x, y, z, rx, ry, rz)

MoveIt

Note! If the robot fails to grasp the pouch, it enters in Recovery Pouch Mode until he grasp it

Actions & Fluents

- **GOTO** → performs movements of the robot for reaching various joint states or pose goals that are reachable in the environment (home position "*vision2*", scale, mark10, bin, etc.)
- **BOX** → performs lots of complex movements of the robot for opening or closing a certain drawer

MoveIt

- **MOVEGRIPPER** → this action is useful for controlling and sending commands to the gripper (activation, reset, open or close gripper, set the speed or force movement)

ROS industrial

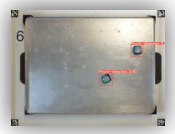
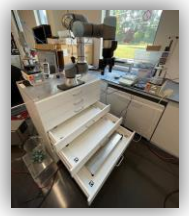
- **PERCEPT** → this action performs the perception of the pouches obtaining as output their position (x, y) and also the number recognition of any opened drawer

YOLOv5

- **SCALE – TIGHTNESS - STRENGTH** → this actions performs the interaction with the instruments for carrying out the corresponding test

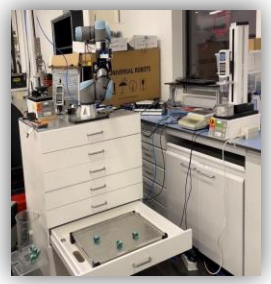
Actions & Fluents

- **PRESENTPOUCH** → returns *true* if at least one pouch has been detected, *false* otherwise
- **SWITCHDRAWER** → returns *true* if at least one drawer is available to be open, *false* otherwise
- **SENSEPOUCH** → returns *true* if the pouch has been grasped, *false* otherwise
- **SENSEOPENBOX** → returns *true* if all the ArUco markers has been detected and the drawer number has been perceived, *false* otherwise
- **SENSEARRUCO** → returns *true* if the number of ArUco markers detected is equal to 0 or 4, *false* otherwise
- **SENSE{SCALE – TIGHTNESS – STRENGTH}** → returns *true* if the value perceived during the test exceeds a threshold, *false* otherwise

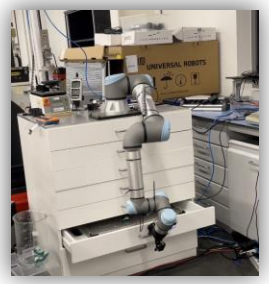

Robot movements overview

BOX open
GOTO vision2



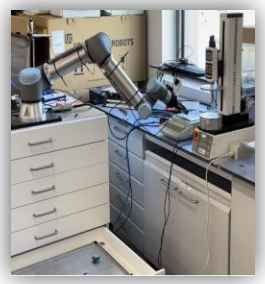
GOTO vision2
PERCEPT pouch

BOX open
GOTO vision2



GOTO pouch
MOVEGRIPPER close

GOTO bin
MOVEGRPPER open



GOTO scale
GOTO mark10

GOTO mark10_out
GOTO mark10_in

GOTO mark10
GOTO mark10_in

Plan Implementation

Petri Net Plans (PNP) → formalism for high level description of plans
Plan Execution Interface (PLEXI) → frameworks for implementation of actions/predicates

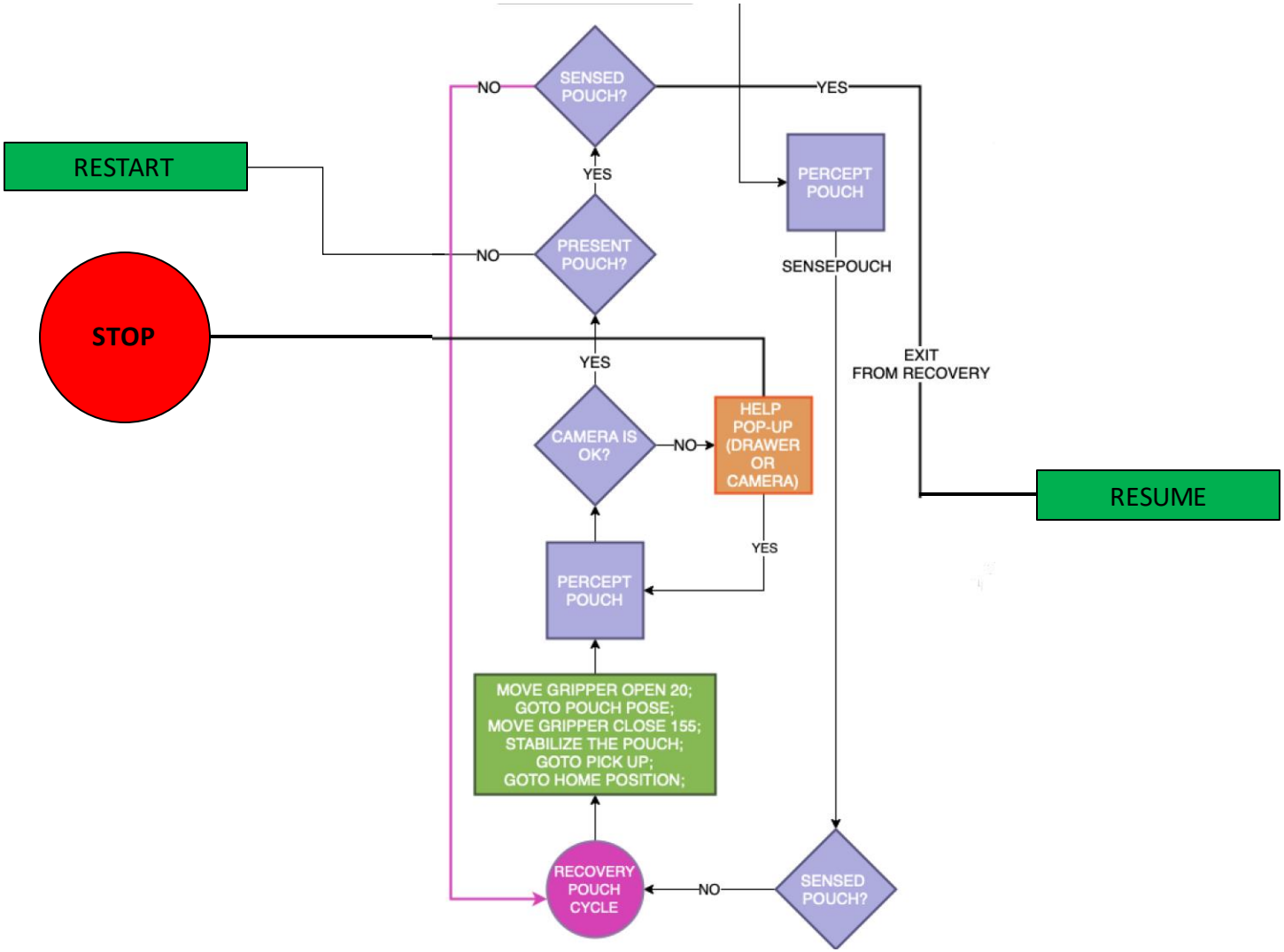
```
< presentpouch? say_PresentPouch :
   (not presentpouch)? say_NoPresentPouch;
    movegripper_o; box_close; goto_vision2;
    GOTO_LABEL_DRAWER
>;
movegripper_20;
goto_pouch_pose;
movegripper_155;
wait_1;
goto_pickup;
goto_vision2;
percept_pouch;
< sensepouch? say_SensedPouch :
   (not sensepouch)? say_HelpRequestMissPouch;
    finalpglabrecovery >;
scale_reset;
goto_scale_up;
```

Very complex!!!

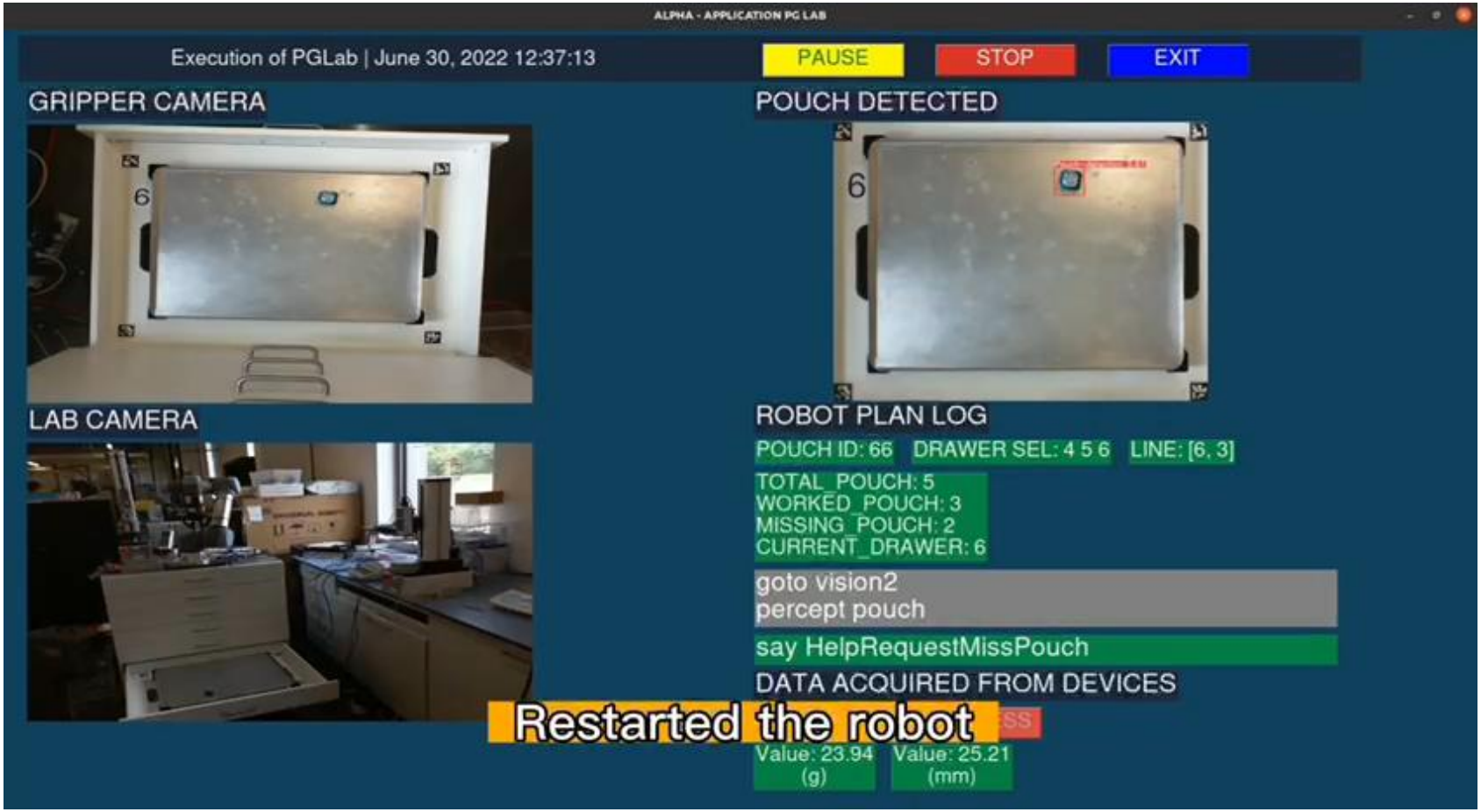
Short sample of the *NOMINAL* plan… from which a recovery procedure resume its execution if any action fails

This plan implementation will allow future theses to use a plan generation system that will use the same actions/fluents implemented

Recovery procedure flow



Enjoy the video ☺



Thanks for watching!!!