WS#42: Advancing AI-Powered Robotic Cognition, Deliberation and Learning for Real-World Applications

“Advancing the physical intelligence and performance of robots towards human-like objects manipulation”

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CERTH/ITI, MANiBOT project coordinator

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MANiBOT Vision

Future service robots that are capable to manipulate **diverse** and **not necessarily well-known** objects

- …**efficiently**, in a **human-like** manner

To achieve this, MANiBOT tries to advance

- **Individual technologies** for robot perception, cognition and bi-manual manipulation
- Their **coupling**

Main goal

MANiBOT focuses on **bi-manual mobile manipulation robots** that can operate in **challenging, real-world, possibly human-populated** environments

Aim: To enable robots perform a **wide variety of manipulation tasks** even with diverse objects

- that may have varying **sizes**, **shapes**, **weights**, and **materials**
- including those that exceed the robot's **payload** capacity

MANiBOT objectives

1. To develop a **novel technological framework** for **robust, resilient, intrinsically safe and efficient** robotic systems **with advanced physical capabilities** for addressing a wide range of bi-manual manipulation tasks with human-like characteristics and performance
2. To develop **advanced, real-time, adaptive and context-aware multi-modal perception** capabilities, including tactile and proximity sensing coupled with robot vision
3. To develop a **novel suite of manipulation primitives** to allow the effective transfer and placing of diverse objects
4. To develop **advanced cognition and HRI capabilities** to enable the robotic system to fuse and orchestrate in a dynamic context-aware manner its core enabling technologies within **adaptive multi-level cycles**
5. To develop fit-for-purpose **tactile and proximity sensing cognitive mechatronics**

Indicative application areas/ MANiBOT use cases

✓Focus on real-world tasks that are performed daily by millions of humans throughout the world

Super market shelve restocking

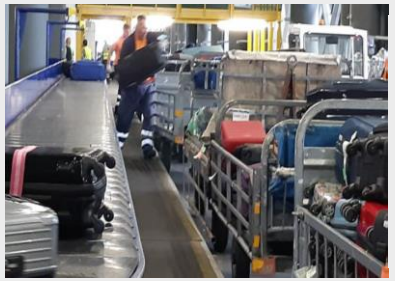
Single item manipulation

Goal: Restock single items located into a packaging box, placing them in very tight places with their label shown to the humans

Boxes of items manipulation

Goal: Restock full EU pallets with mixed Stock Keeping Units into shelves, placing them in very tight places

Airport baggage handling



Loading objects from conveyor belt to cart

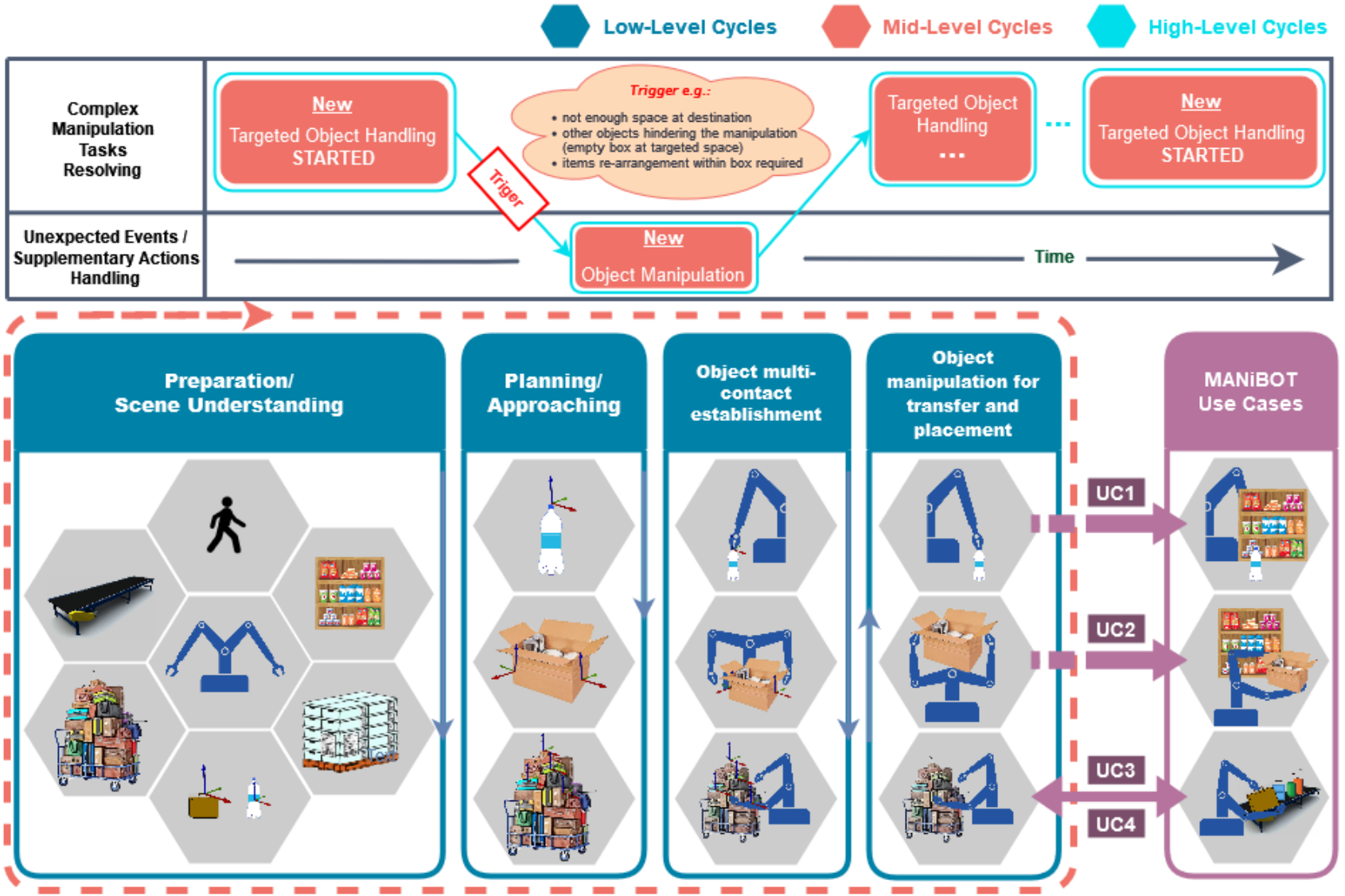
Goal: Load baggage in the correct cart based on the flight indicated on their tag in less or equal time than the current human performance

Loading objects from cart to conveyor belt

Goal: Handle diverse bag items in a safe manner using the robot's transfer belt as a bridge between the conveyor belt and the upper level of stacked baggage

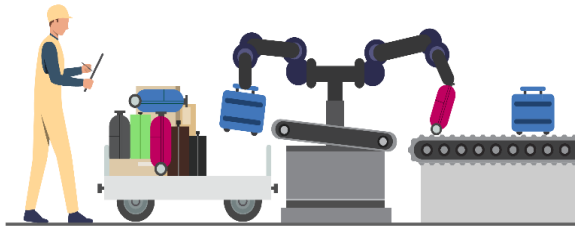
Functional architecture

- **Low level** steps
  - Scene understanding
  - Planning/Approaching
  - Object multi-contact establishment
  - Object manipulation
- **Mid-level**
  - Collections of low-level cycles
  - Can achieve the manipulation of a single object
- **High-level**
  - Collections of mid-level cycles
  - Formulate the robot's capability to handle more complex tasks

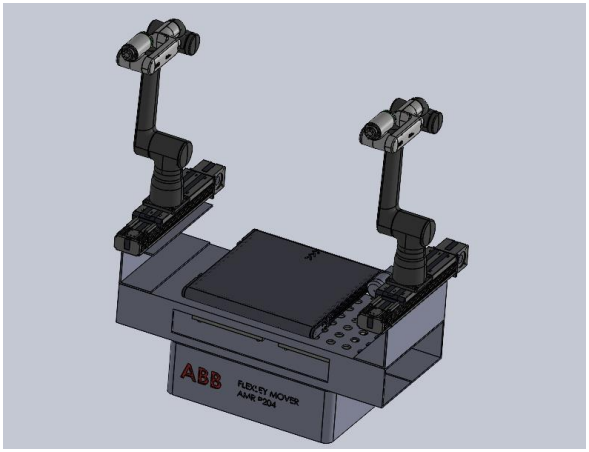


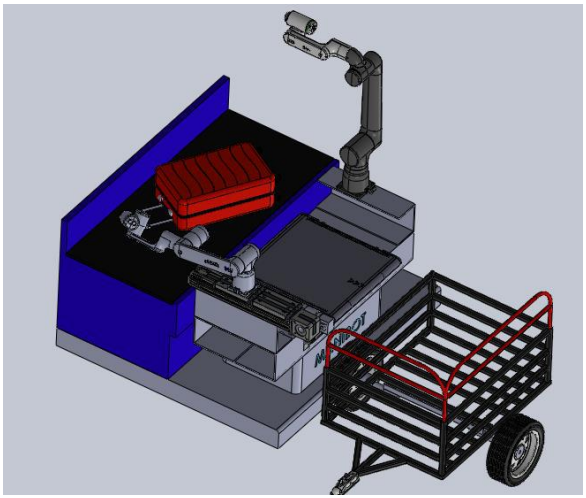
MANiBOT robot design and novel mechatronics

MANiBOT robot concept in application scenarios



MANiBOT robot design





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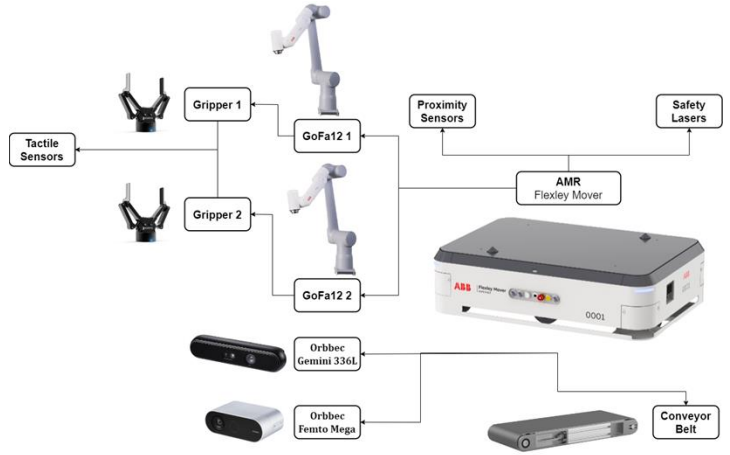
HW components and novel mechatronics



Optical fibre tactile sensor

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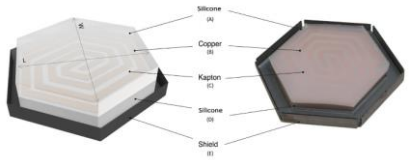
Proximity/capacity sensor

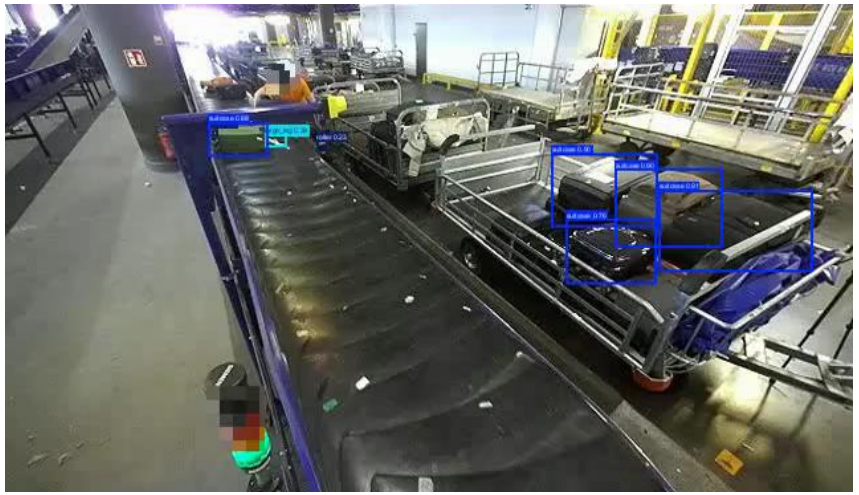


Scuola Superiore San'Anna

Enabling technologies: Adaptive robot perception

Adaptive robot perception for object recognition and dynamic environment sensing

- ✓ Vision-based perception:
  - ✓ 2D object and object sub-part detection
  - ✓ Category-level 6DOF object estimation
  - ✓ Manipulation affordances extraction
  - ✓ Object structural relations understanding
- ✓ Proximity sensor-based human detection
- ✓ Contact force/pose estimation using tactile sensors
- ✓ High-level adaptive sensing dynamically orchestrating sensor modules



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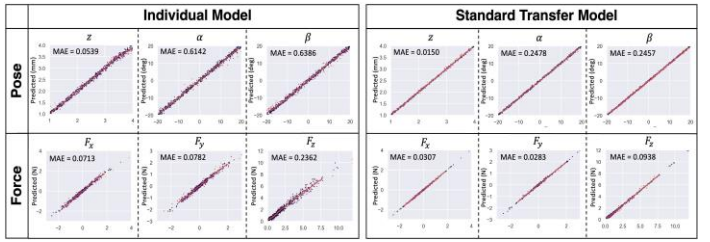

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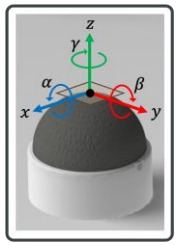


Enabling technologies: Navigation, control, bimanual manipulation and cognition

Manipulation primitives, bimanual control and navigation

- ✓ Human-aware navigation
- ✓ Coordinated non-prehensile manipulation in both unimanual and bimanual primitives such as push, pull, rotate
- ✓ Compliant methods for the reaching of the initial contact points and methods for connecting the consecutive execution of different primitives
- ✓ Hierarchical optimization methods to execute the various primitives under kinematic constraints

Aristotle University of Thessaloniki

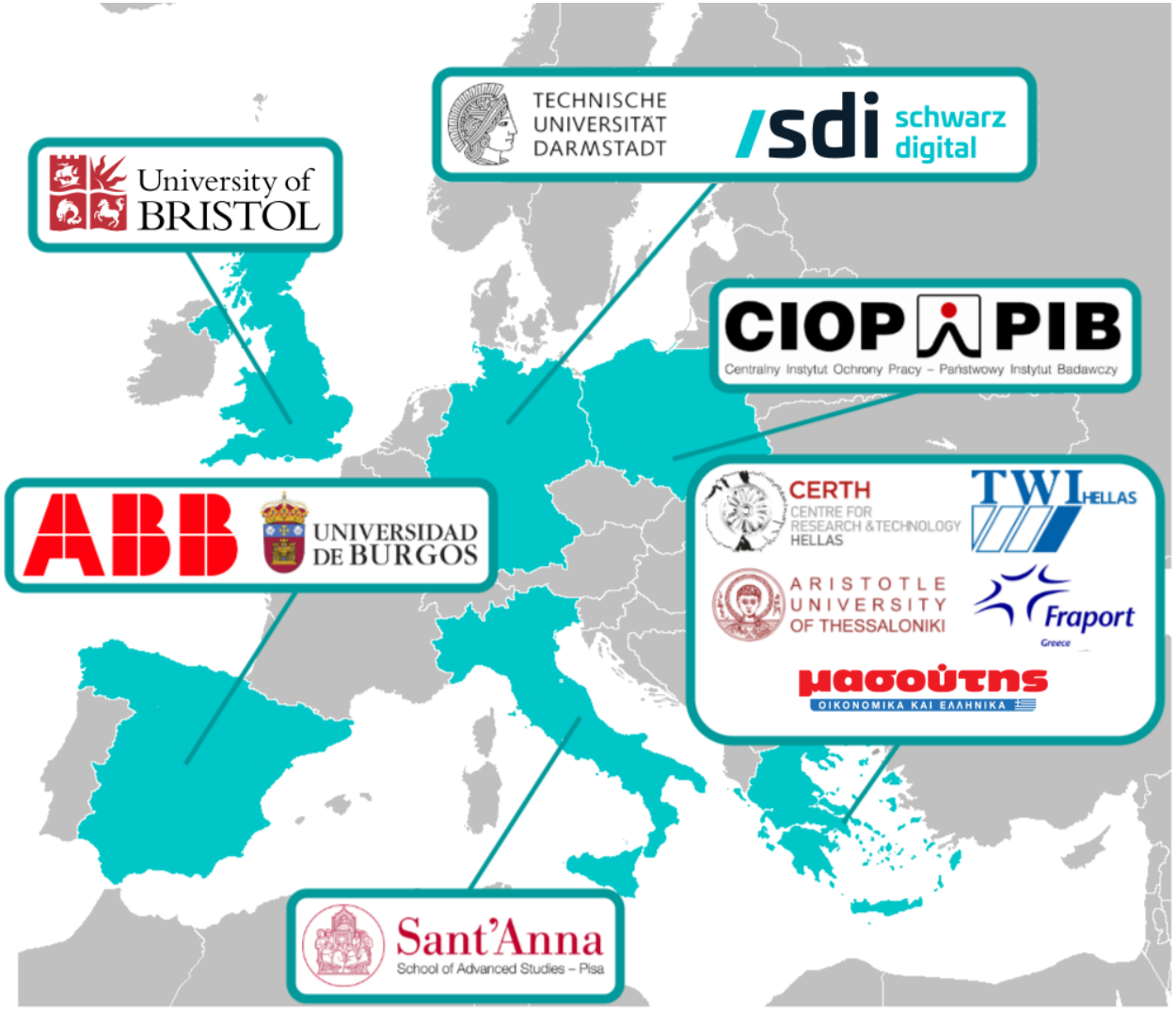
Technical University of Darmstadt

Airport Baggage Handling Automation

Robot cognition and HRI

- ✓ Semantic scene-graph representations for task planning
- ✓ Task graph learning approach from human demonstrations
- ✓ Affordance extraction from human demonstrations
- ✓ Language-driven affordance extraction
- ✓ User friendly HRI

MANiBOT consortium



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1 SME
3 End-users

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for your attention

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