Cobots: Robots That Work With People

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What Are Cobots

Collaborative robots: robots designed to assist humans in completing tasks, or to work simultaneously with human in the same workspace

- Improve work performance and quality of humans by matching machine strengths with human soft skills
- Reduce or aid jobs that are otherwise "dirty, dangerous or dull"
- Make robot "less technical and more intuitive" to everyone

(a) (b) (c) (d)

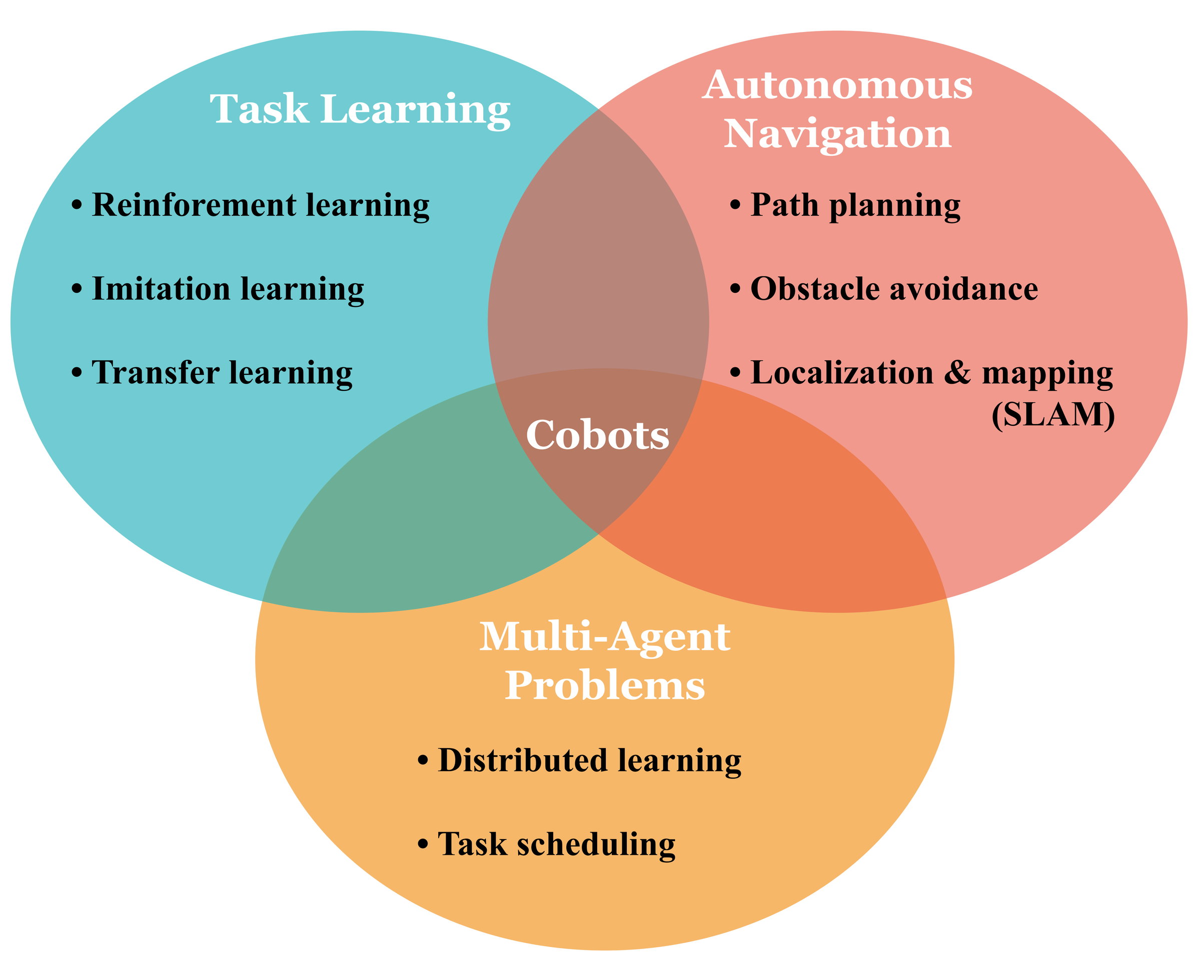
Figure: Application of Cobots in different industries

- Manufacturing assistive welding, assembling, material handling, product inspection, picking, packing and palletizing items
- Agriculture target spraying, harvesting, branch pruning, automatic sensors and report
- Healthcare and servicing rehabilitation helper, sterilization, cleaning and infection testing

Table: Traditional robots deployed in the industries vs collaborative robots

Features	Traditional Robots	Collaborative Robots
Workspaces	Isolated	Shared (human-in-the-loop)
Controls	Tele-op (remote control), or hard programming	Soft automation by Human Robot Interaction (HRI)
Tasks	Repeatable tasks, rarely changed	Frequent task changes

Challenges and Opportunities



Cooperative Object Transport Case Study

Two KUKA YouBot's coordinate with each other to lift, carry and drop the payload onto the target conveyor

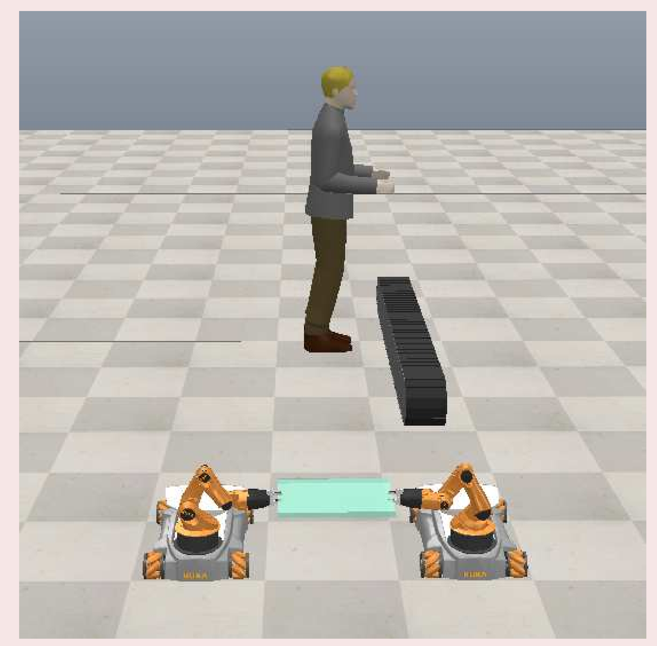
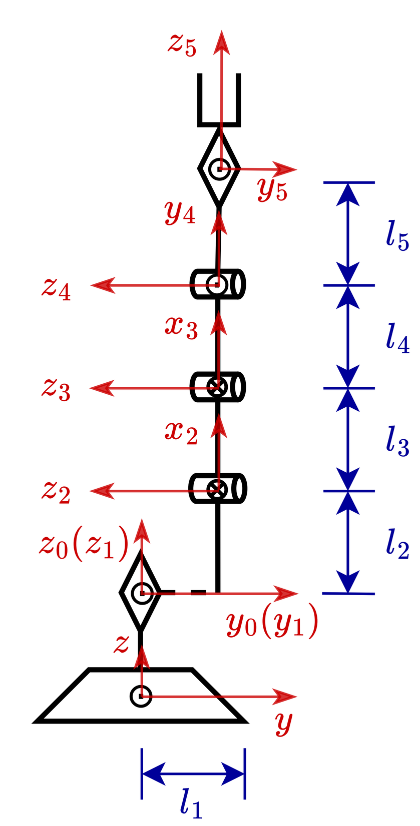


Figure: A sheet of glass as heavy delicate object

Figure: KUKA YouBot

Synchronized Manipulator Control

1. Dynamical analysis
   Rigid body analysis of the manipulator link kinematics
2. D-H parameters
   A method of describing kinematic chains, commonly used in computer-based solving methods
3. Jacobian matrix
   Describes motion differentials with respect to joint command



$$J(\boldsymbol{\theta}) = \frac{\partial \boldsymbol{f}}{\partial \theta}$$

4. Iterative inverse kinematics (IIK)
   Adaptively adjust joint command iteratively over time to match target pose

$$\Delta\boldsymbol{\theta} = J^T(JJ^T + \lambda^2 I)^{-1}\boldsymbol{e}_q$$
$$\boldsymbol{e}_q \equiv \boldsymbol{q}^{\text{ref}} - \boldsymbol{q}$$

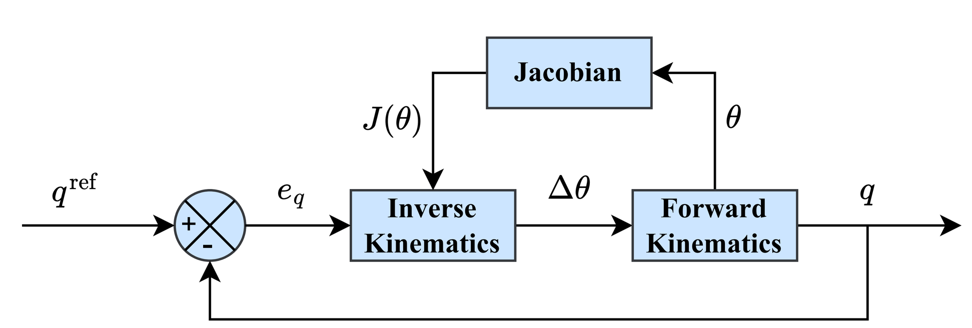


Figure: Simplified Block diagram of IIK control method

Coordinated Autonomous Navigation

- Leader-follower formation
  - Arbitrarily select leader and follower robot
  - Follower keeps a fixed perpendicular distance and the same orientation as leader
- Payload-focused path planning
  - Leader robot makes sure the payload navigates to the goal

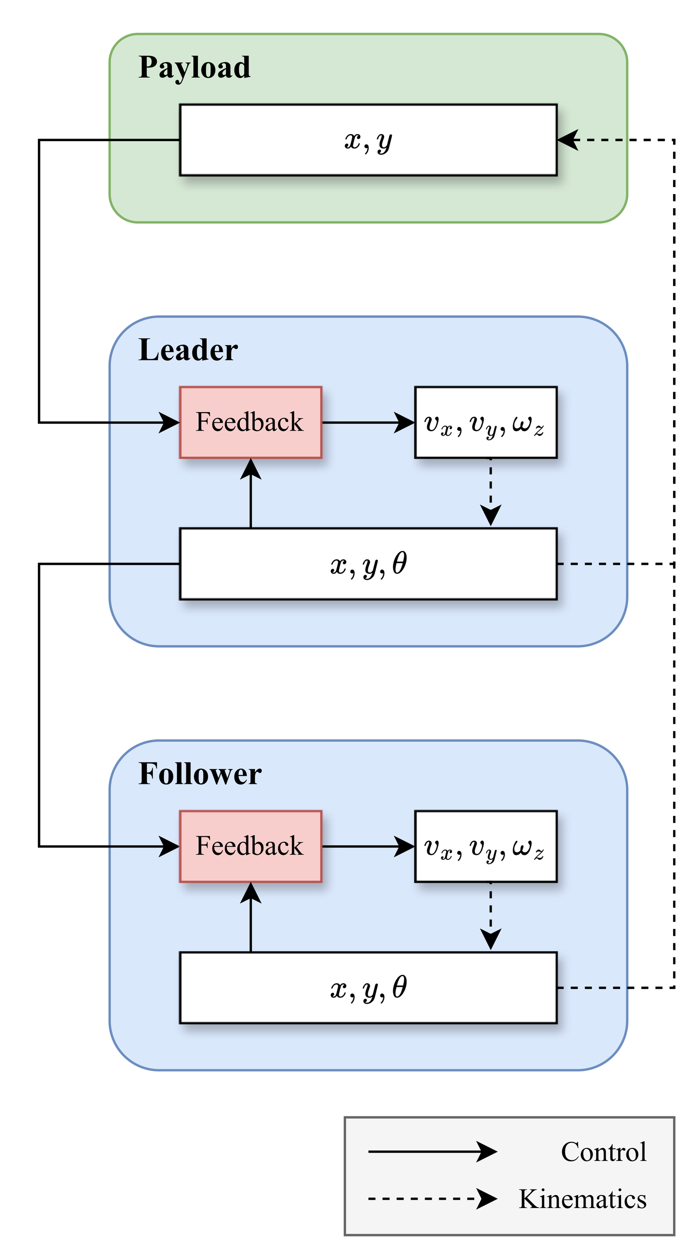


Figure: Twin robot object transport navigation scheme

Automation and Simulation

Transportation task is automated with 5-stage finite-state-machine method

Simulation uses CoppeliaSim simulation software and Python programming language

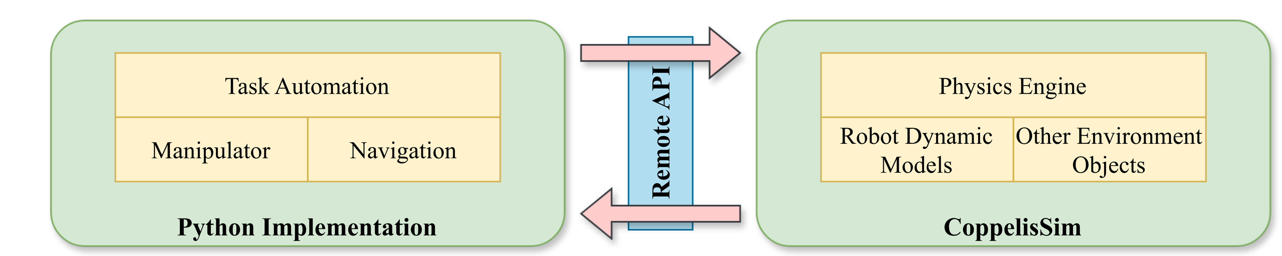


Figure: Software architecture of simulation

Results

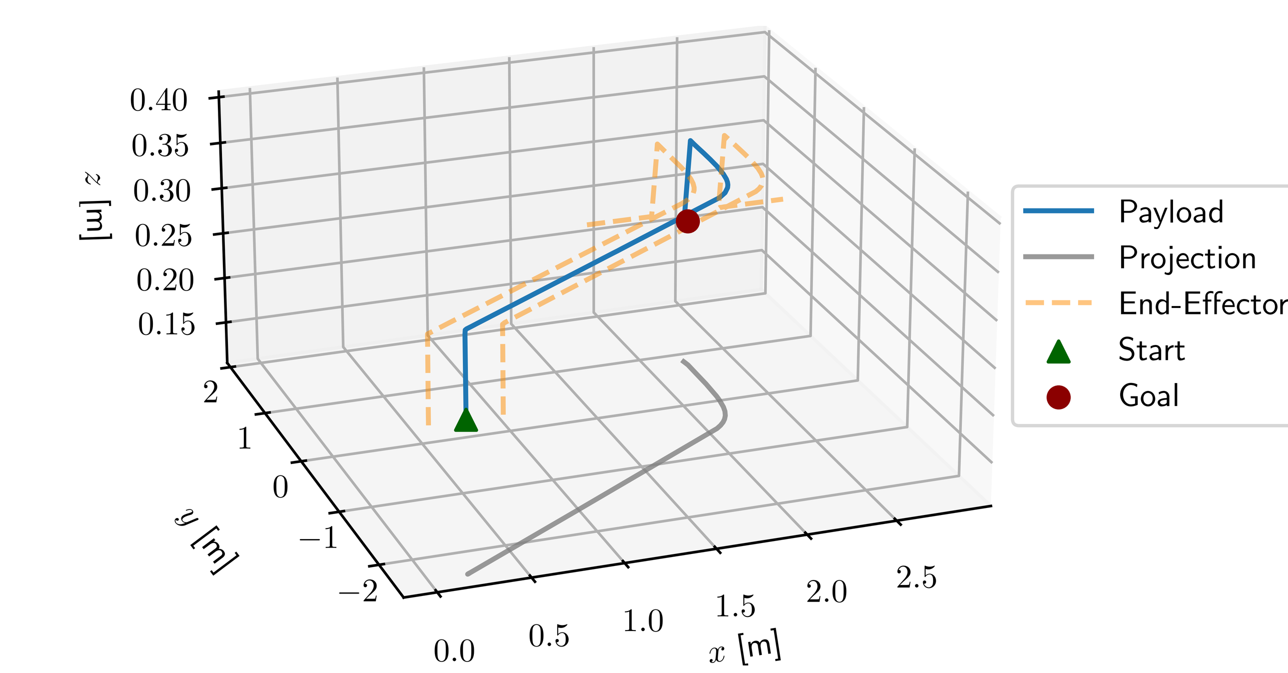


Figure: Trajectory of the payload from start to end position

Future Work

Feedback from CAT

- Implement intercommunication to simulate industrial scenarios
- Integrate sensor vision for navigation
- Consider communication latency and cutoff handling for safety purpose
- Implement more robust balancing control with sensors

Improve Human-Robot Interaction

- Implement human-aware path planning
- Extend application to arbitrary start and end point in the environment
- Design and attach user-friendly control interface

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