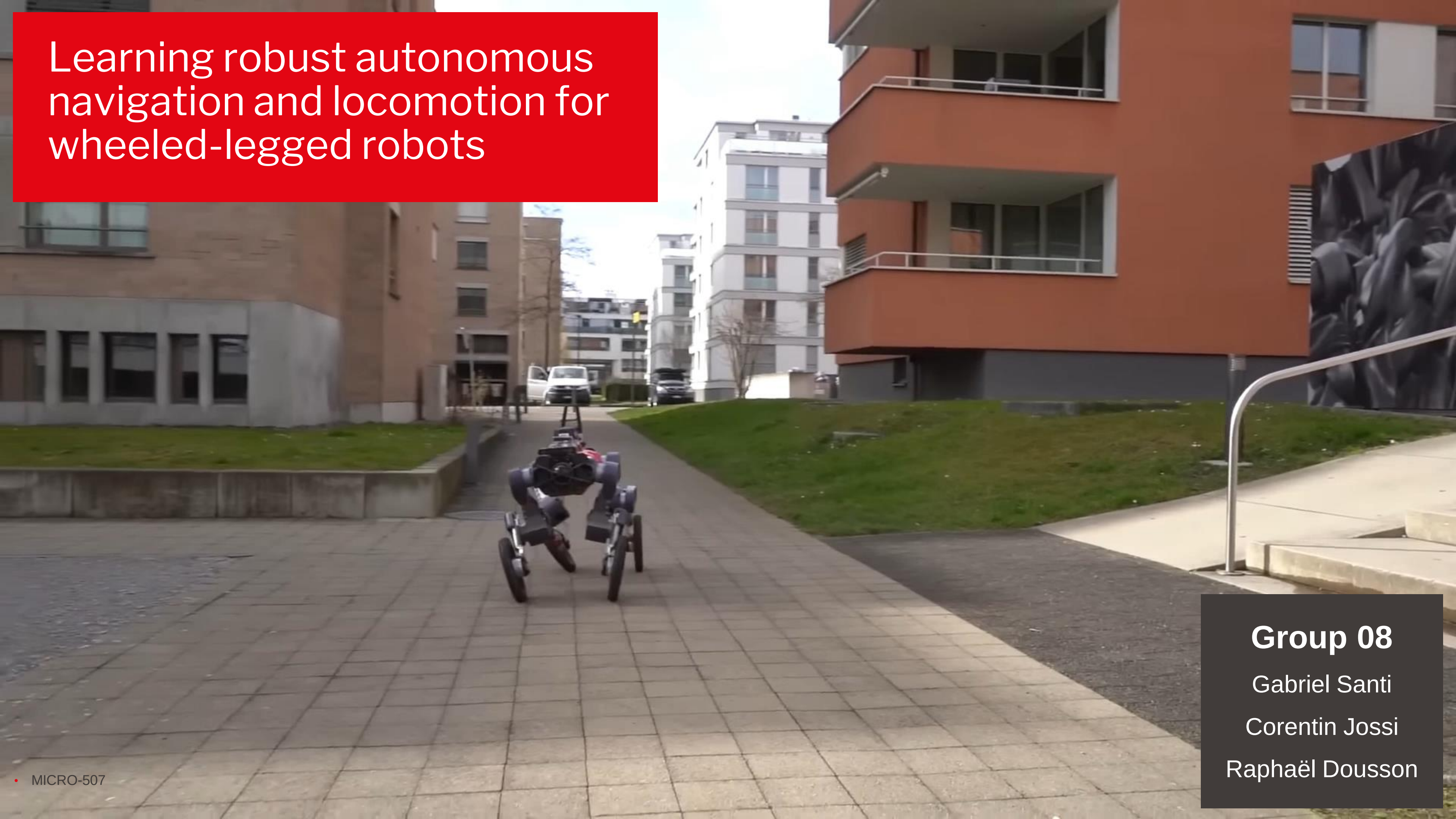

Learning robust autonomous navigation and locomotion for wheeled-legged robots

Group 08

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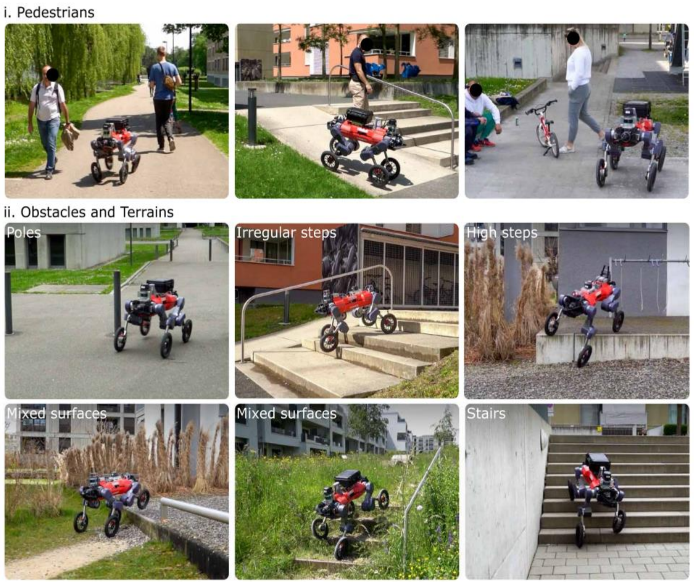
Content

- Overview
- Technical details
- Controllers
- Results
- Citations
- Pros and cons
- Exam questions

Overview
Motivation and Challenges

- **Motivation**
  - Efficient last-mile delivery in urban areas
  - Fast and efficient on flat ground and able to overcome obstacles like stairs
- **Challenges**
  - Static and dynamic obstacles avoidance
  - Fully integrated navigation and locomotion
  - Adaptive gait selection and locomotion control over various terrains (stairs, grass, slopes)
  - Cannot be inspired by nature



Technical details

The robot

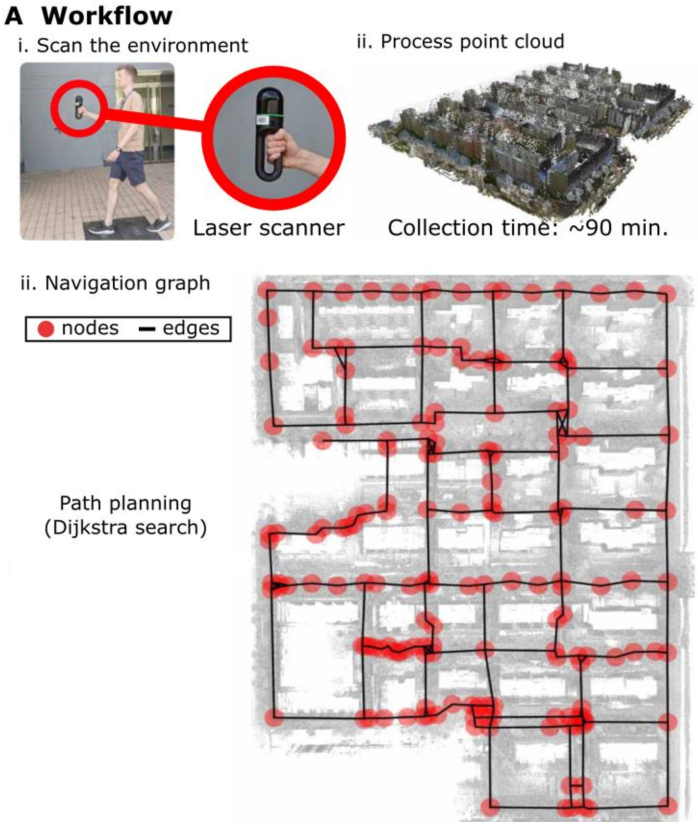
- **Wheeled-Legged Quadruped Robot (ANYmal)**
- **Sensors**
  - 3 LIDARs: Terrain mapping and Localization
  - Stereo Camera: Dynamic obstacles detection
  - GPS: Unused
  - IMU and Joint encoders
- **Control**
  - Joint position control: PD
  - Wheels velocity control: PD

https://newatlas.com/robotics/swiss-mile-transformer-robot/

Technical details

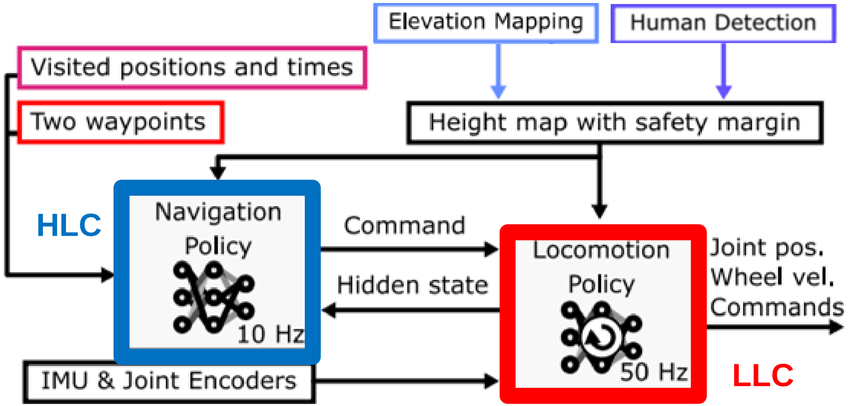
Localization and path planning

- **Environment previously scanned with laser scanner**
  - Create mesh of the city from point cloud
  - Create navigation graph
- **Dijkstra algorithm on navigation map to choose path**
- **LIDAR sensors to localize inside mesh**
  - More robust than GPS
  - Still problems with long corridors as stereo camera cannot see far away



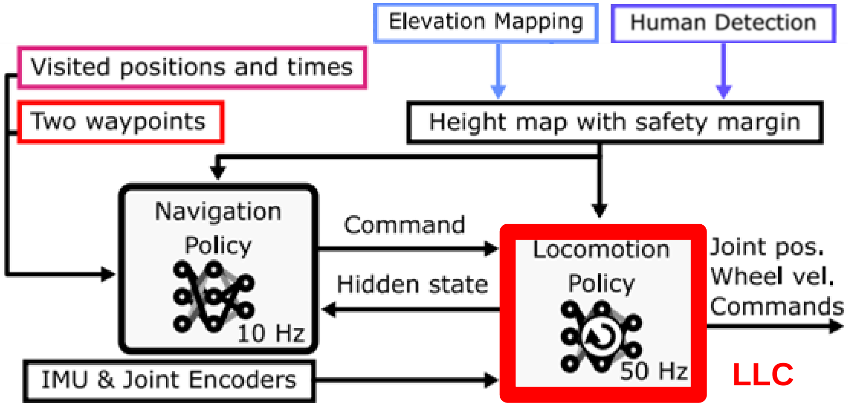
Locomotion control

- **Two controllers**
  - High-Level Controller (HLC)
  - Low-Level Controller (LLC)
  - Both neural networks trained with model-free reinforcement learning
  - Trained sequentially, starting from the LLC



Low-Level Controller (LLC)

- **Output**
  - Velocity tracking
  - Gait choice
  - Mode transition(walking/driving)
- **Neural network trained in two steps**
  - **Teacher policy**
    - Follows random velocities on rough terrains
    - Privileged information (Robot's motion, terrain properties, noiseless exteroceptive measurements)
  - **Student policy**
    - Noisy measurments (IMU, joint states, height, …)
    - Learning from the teacher
  - Reward: velocity tracking

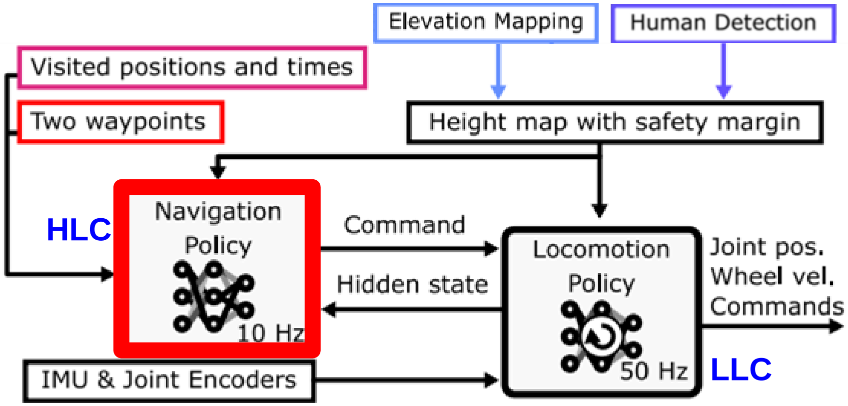


EPFL

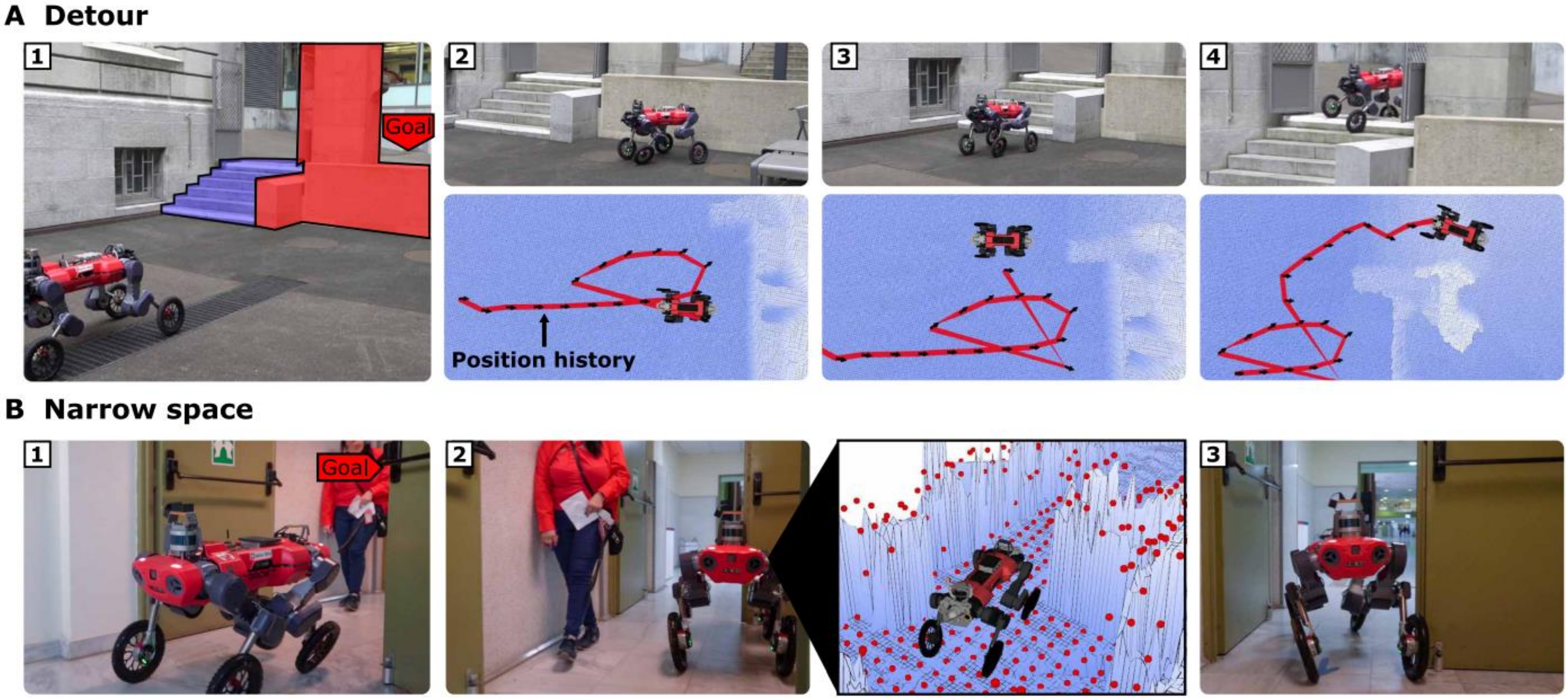
Mobility-aware navigation controller

Mobility-aware navigation controller (HLC)

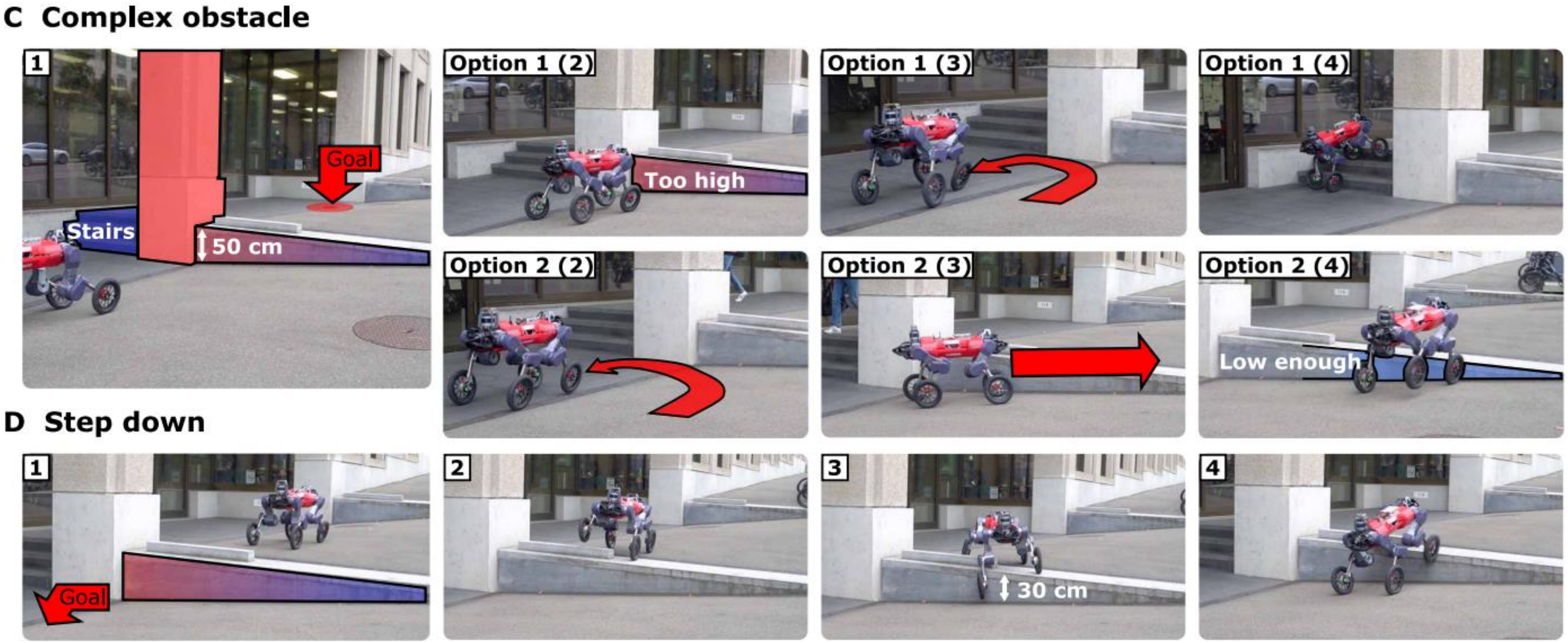
- Computes velocity targets at high frequency
- Bounded action space (hard constraints on output)
- Rewards:
  - Smallest distance to waypoint
  - Bonus on exploration



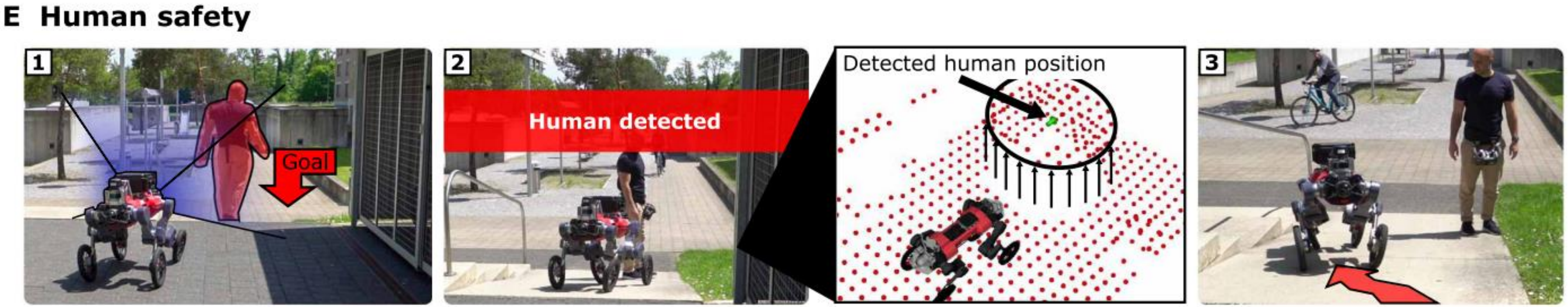
Results: Obstacles



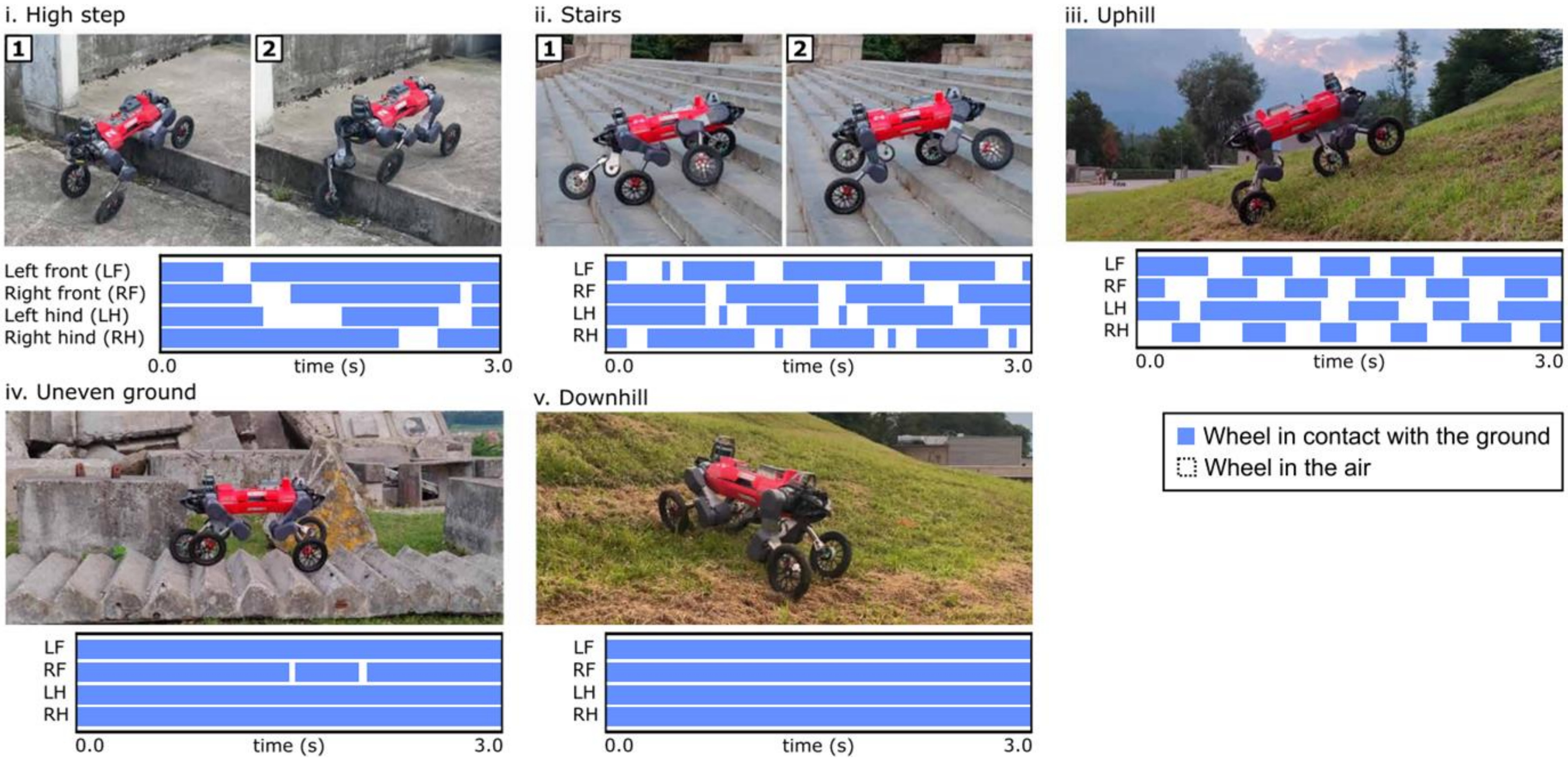
Results Obstacles



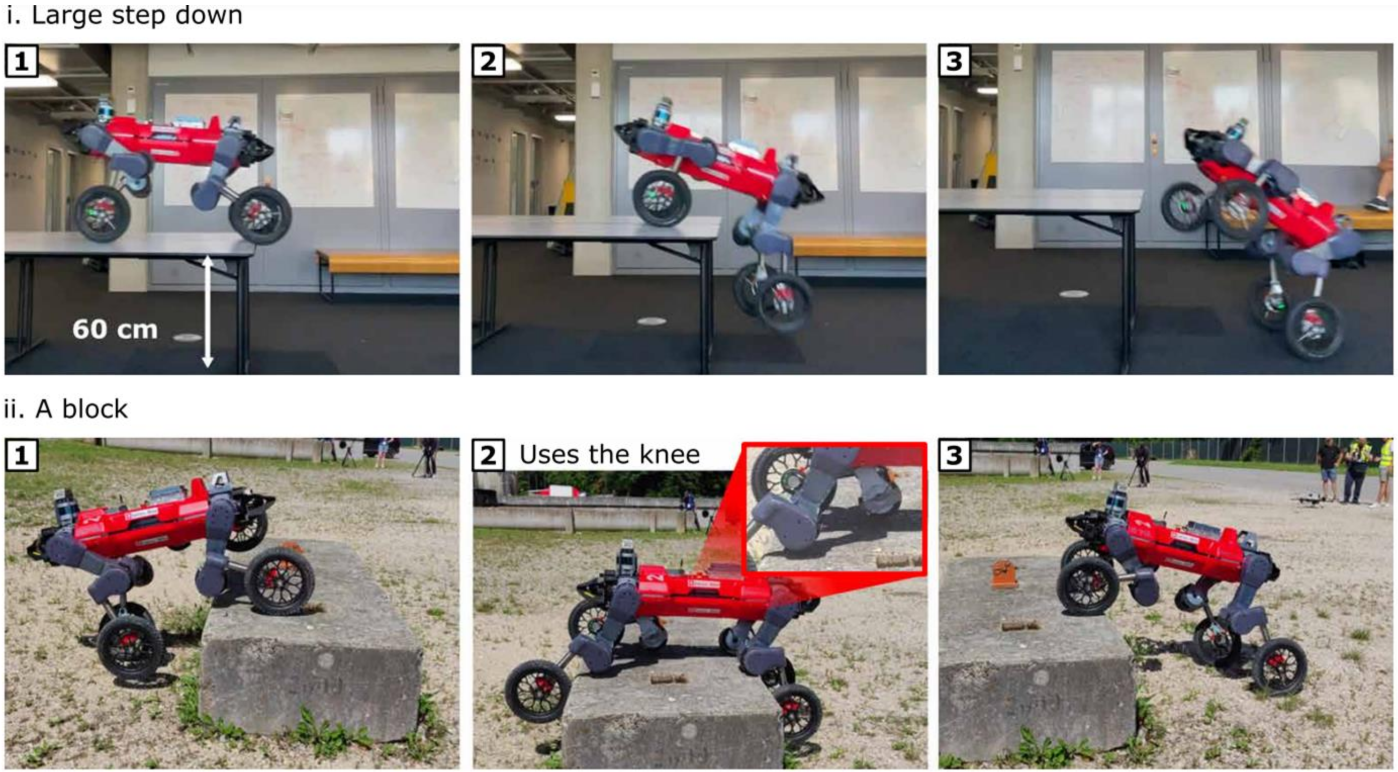
Results Obstacles



Results
Gaits on different terrains



Results
Extreme obstacles



Results
Comparison with Legged robot

	Wheeled-legged	Legged
Average speed	1.68 m/s	0.55 m/s
COT Cost of transport	0.17	0.34

$$COT_{\mathrm{mech}} = \sum_{\text{all joints}} [\tau\dot{\theta}]^{+} / (mg|v_{xy}^{b}|)$$

Joint torque

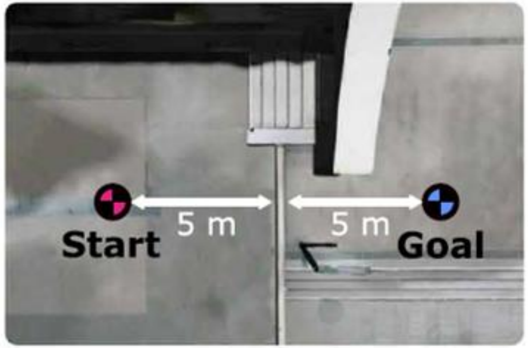
Joint speed

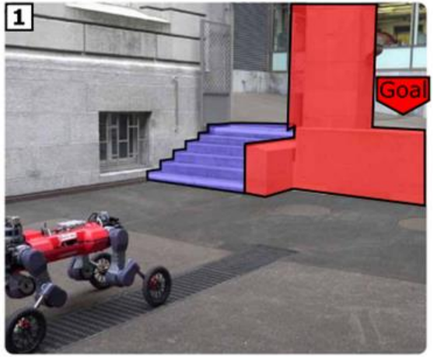
total weigth

robots horizontal speed

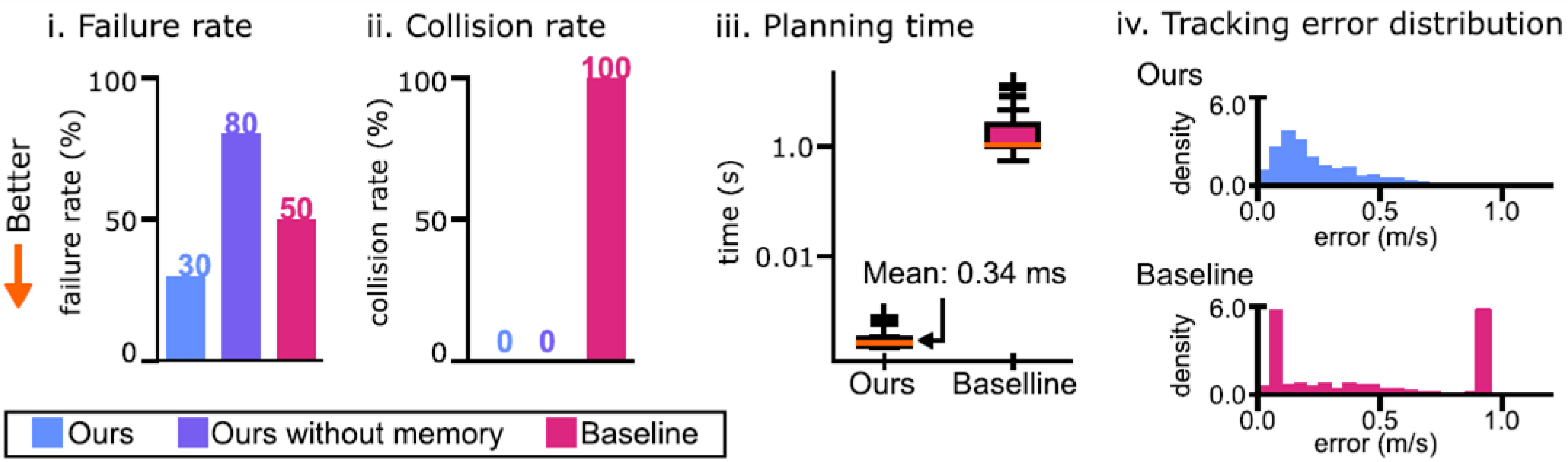
Results
Comparison with baselines

- Controllers:
  - Controller
  - Controller without memory
  - Baseline (legged)
- 10 experiments / controller





Results
Comparison with baselines



Cited by

Cited by 12 articles:

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- Google DeepMind, USA
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- University of British Columbia, Canada
- Neuromeka, Korea
- Georgia Institute of Technology, USA
- Hong Kong University of Science and Technology
- Institute of Artificial Intelligence (TeleAI), China Telecom
- Shanghai University, China

Pros & Cons

Pros	Cons
▪ Speed on flat terrain AND agility on stairs ▪ Successful testing on real hardware	▪ Number of actuators

Possible exam questions

Question 1: What challenges do a wheeled-legged robots face in urban navigation and how does the hybrid locomotion controller in this article address these challenges?

Answer: Wheeled-legged robots must handle varied terrains and obstacles like stairs, uneven surfaces and dynamic obstacles in urban environments.
It uses model-free reinforcement learning to adapt gaits and transitions between walking and driving modes. This ensures a robust navigation across complex terrains and efficient operation at high speeds.

Question 2: Describe the hierarchical reinforcement learning framework used in this article for navigation and its role in autonomous urban missions.

Answer: The HRL framework includes a high-level controller for navigation and a low-level controller for locomotion, both trained through reinforcement learning.
The high-level controller computes velocity targets, while the low-level controller executes joint position and wheel velocity commands. This HRL system enables the robot to efficiently navigate and adapt to obstacles autonomously over kilometer-scale urban missions.


B. Narrow space