DYNAMOGRADE

LA FORCE DE LA MARCHE

WATCH YOUR STEPS

Torque controlled locomotion in unknown environments

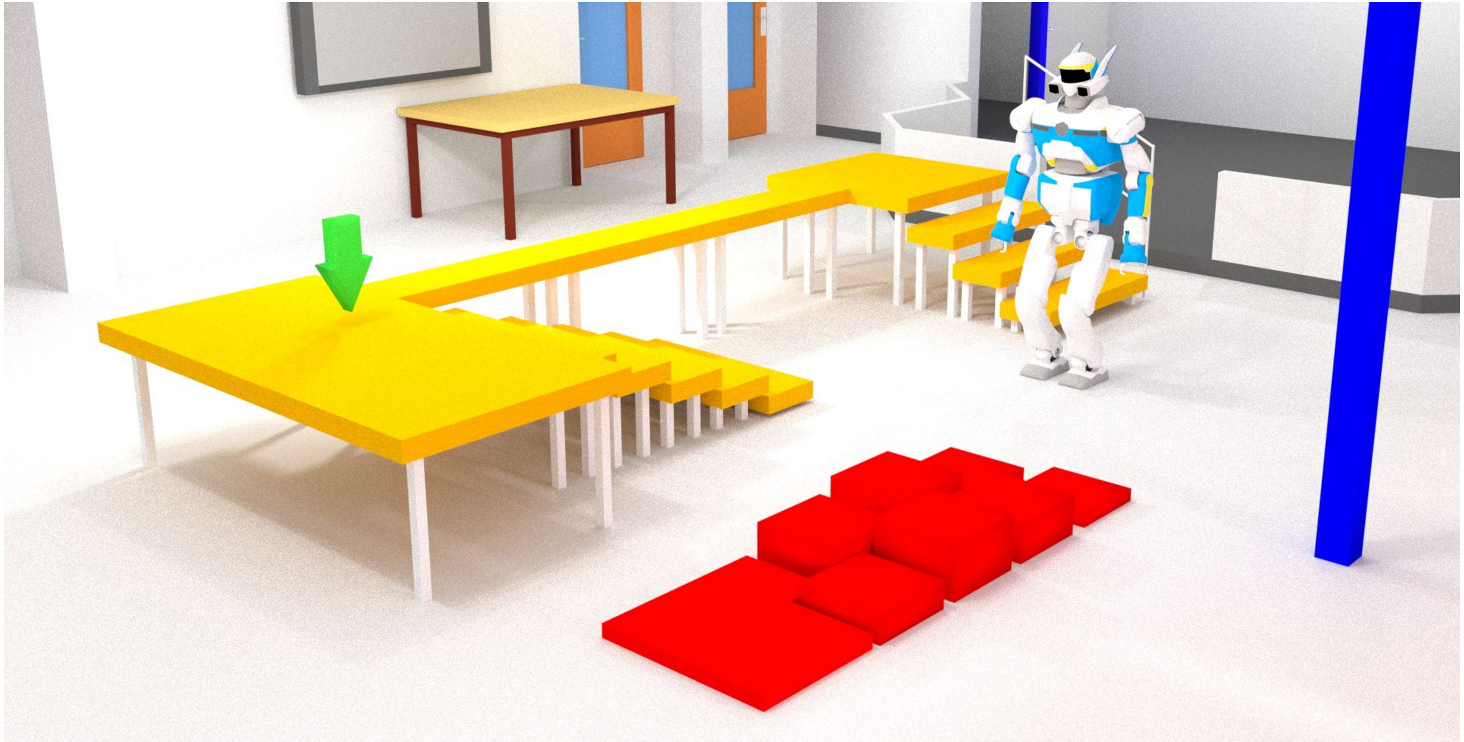
Pierre Fernbach, Maximilien Naveau | JNRH 2023

TOWARD

High level inputs
(eg. root position or joystick input)

→

Whole body motion, dynamically consistent and collision free



High level inputs
(eg. root position or joystick input)

Whole body motion, dynamically consistent and collision free

Perception

Contact Planner

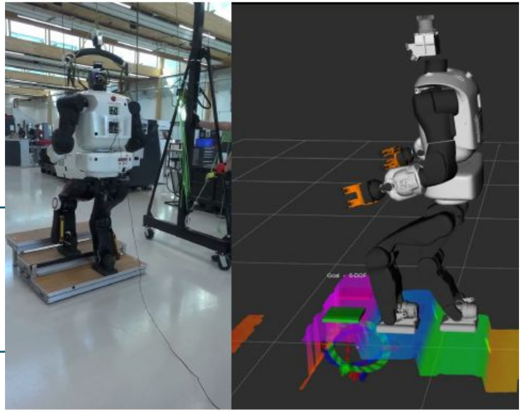
Centroidal Predictive Controller

Inverse Dynamics

Estimator

Estimated Point cloud

LiDAR



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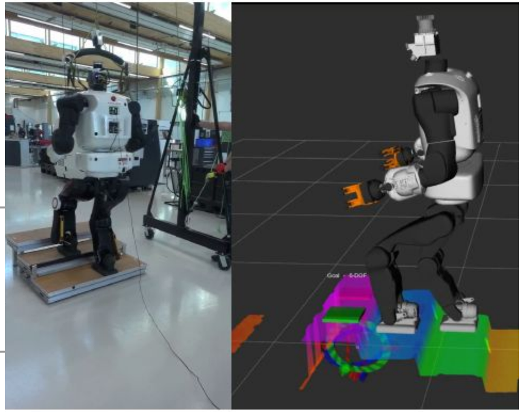
τ_a



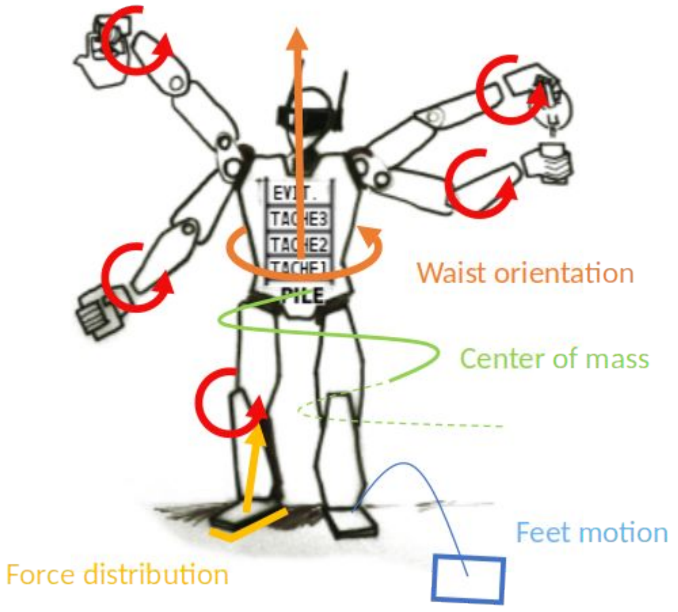
Estimator

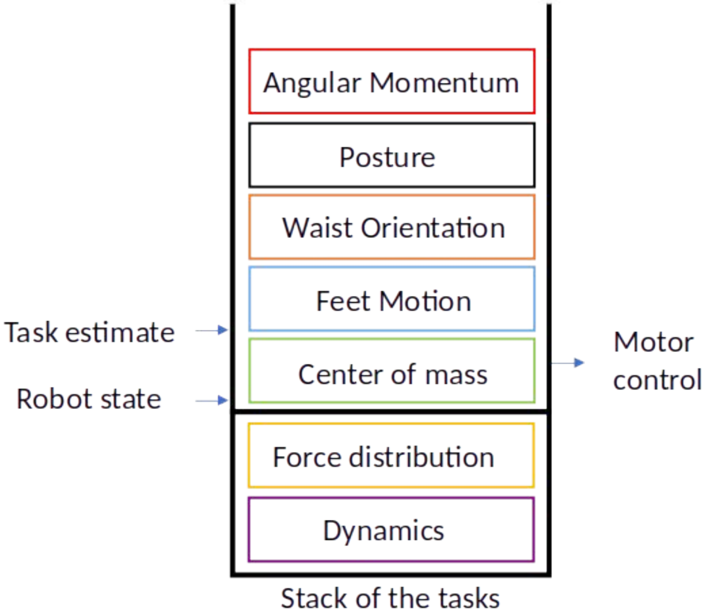
Estimated Point cloud

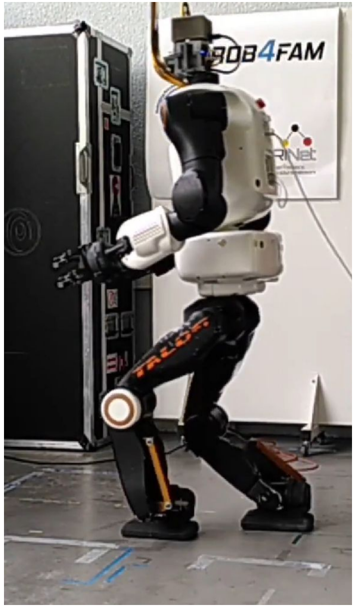
LiDAR

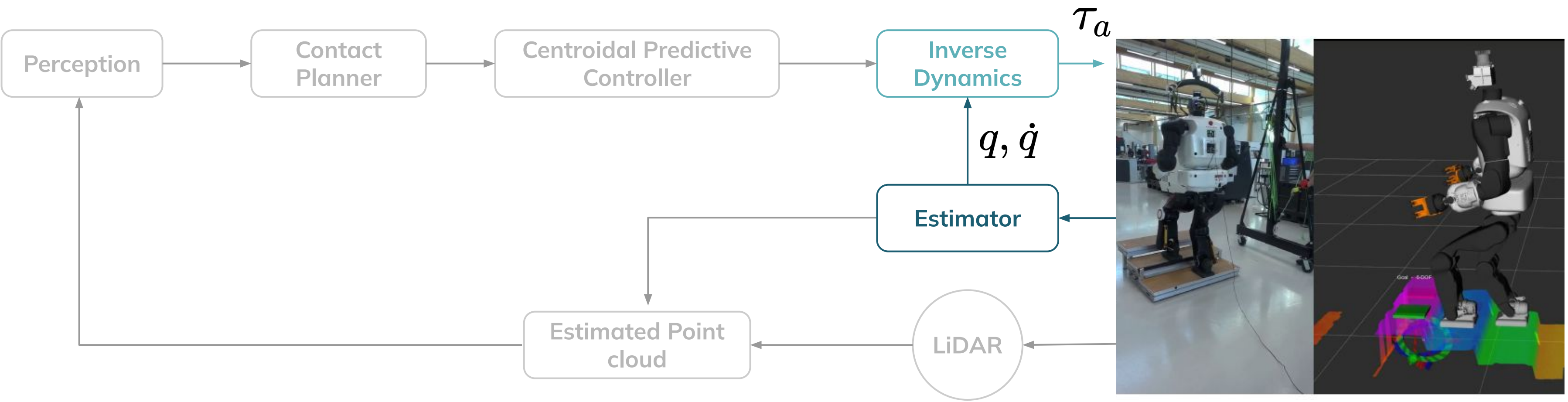
Task Space Inverse Dynamics

Hierarchical QP solving for joints torque with respect to rigid body dynamics, friction cone constraints and a weighted set of tasks.



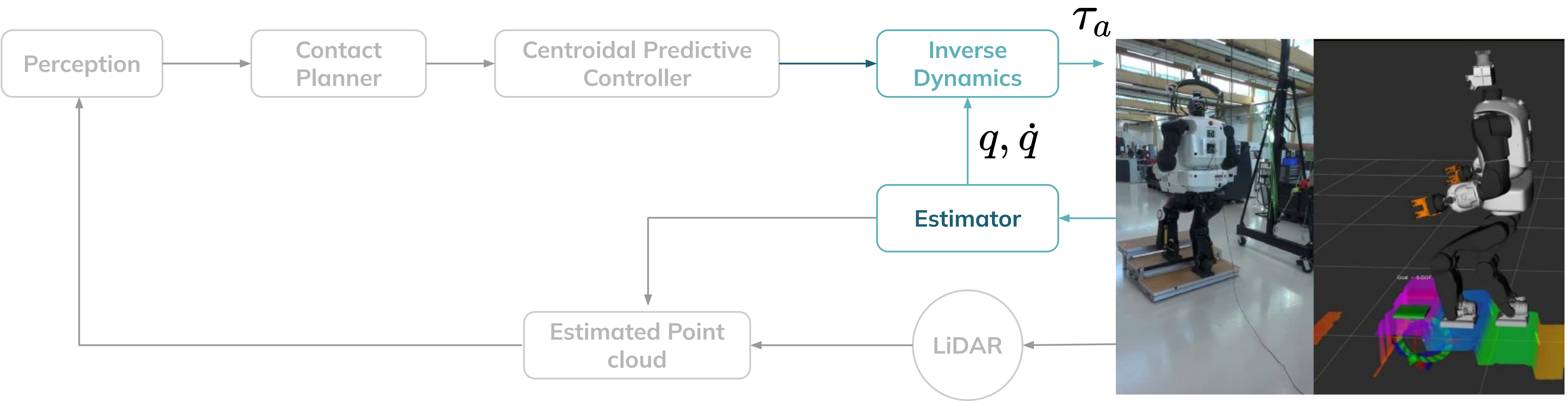






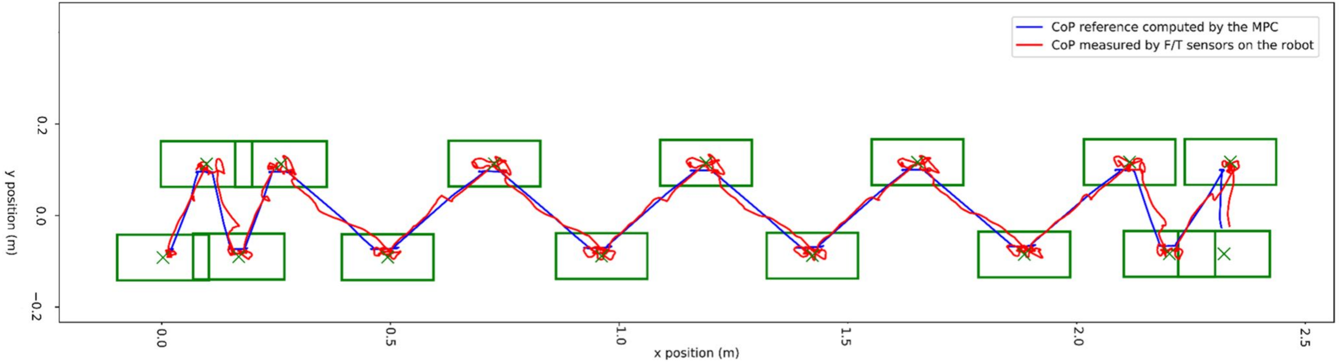
Estimator:

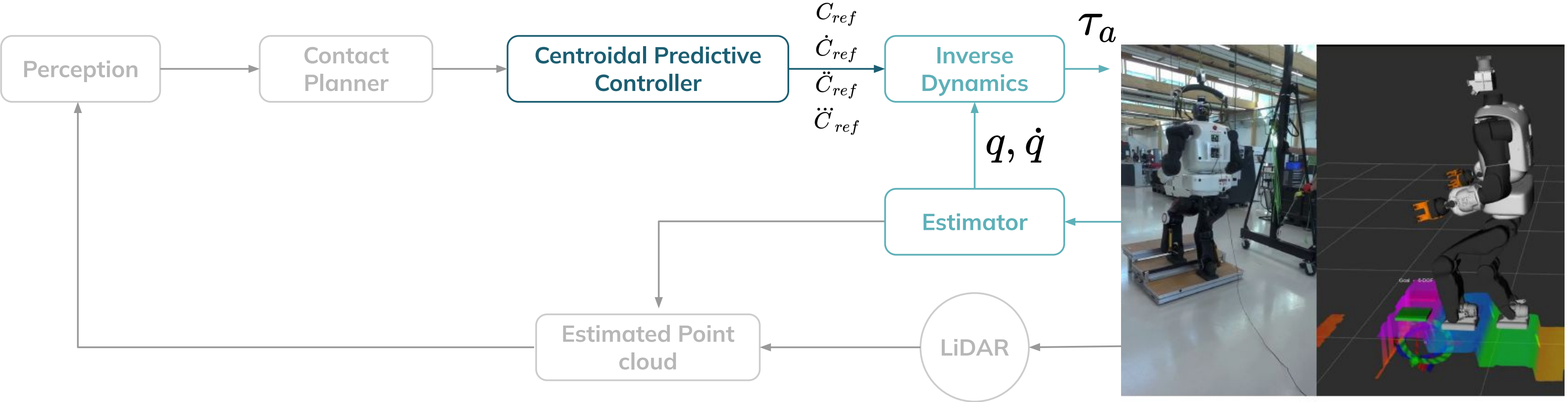
EKF with IMU and Kinematics odometry
Hip flexibility compensation



Task references:

Contact position
Feet trajectories
Center of mass trajectory

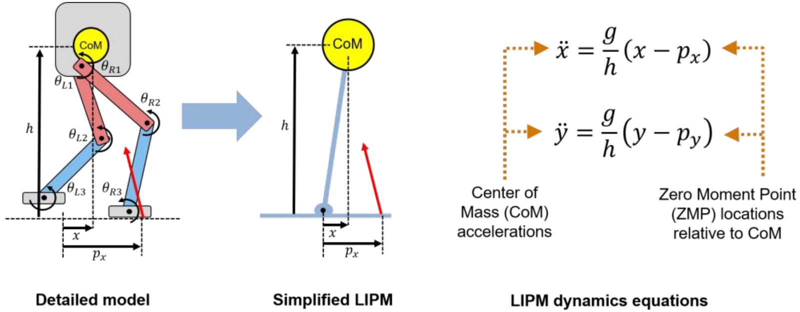




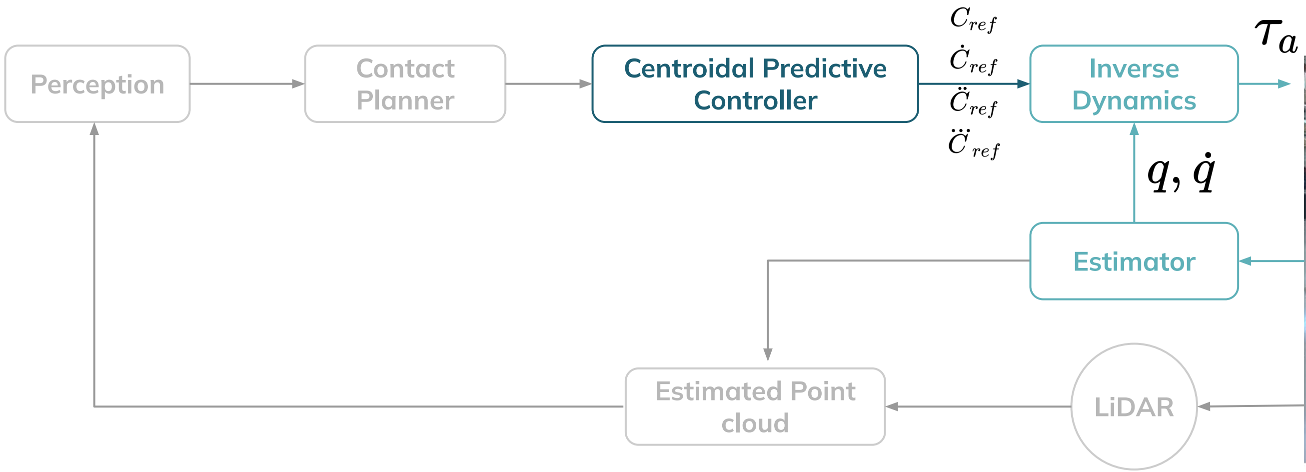
Centroidal Predictive Controller

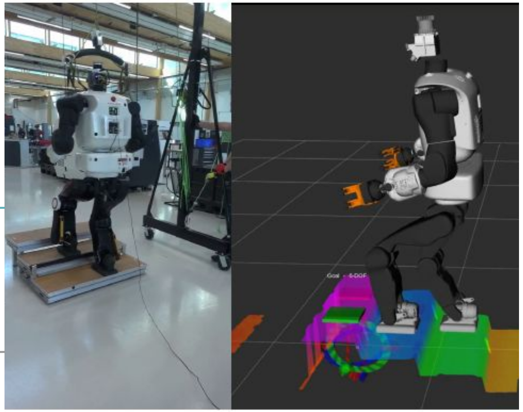
MPC based on Linear Inverted Pendulum Model

Formulation of Kajita 2003[1]



[1] S. Kajita et al., "Biped walking pattern generation by using preview control of zero-moment point," 2003 IEEE International Conference on Robotics and Automation



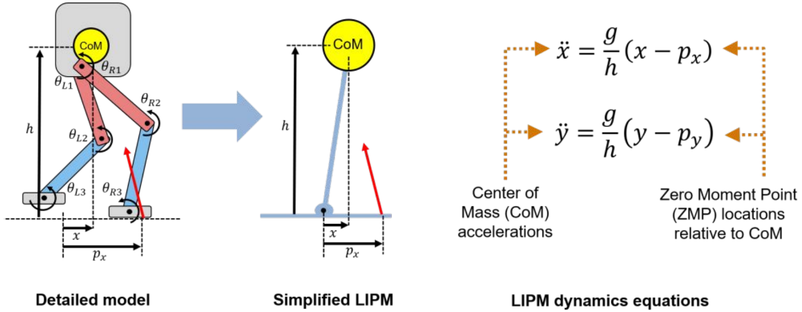


Centroidal Predictive Controller

MPC based on Linear Inverted Pendulum Model Formulation of Kajita 2003[1]

Optimize center of mass jerk over time horizon:

- Minimize center of mass jerk
- Track center of pressure references (computed from a contact sequence)



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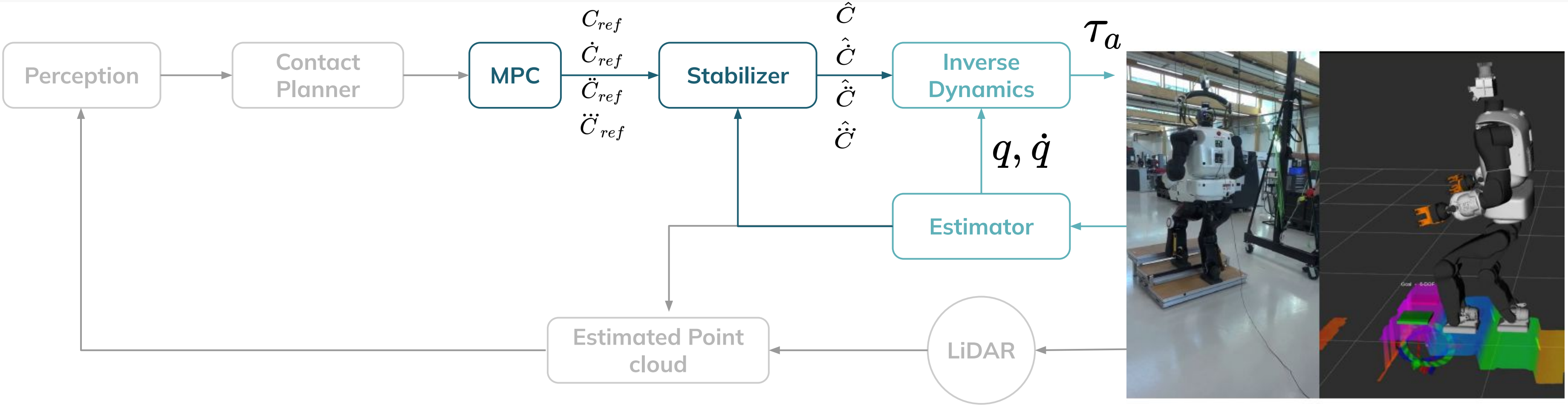
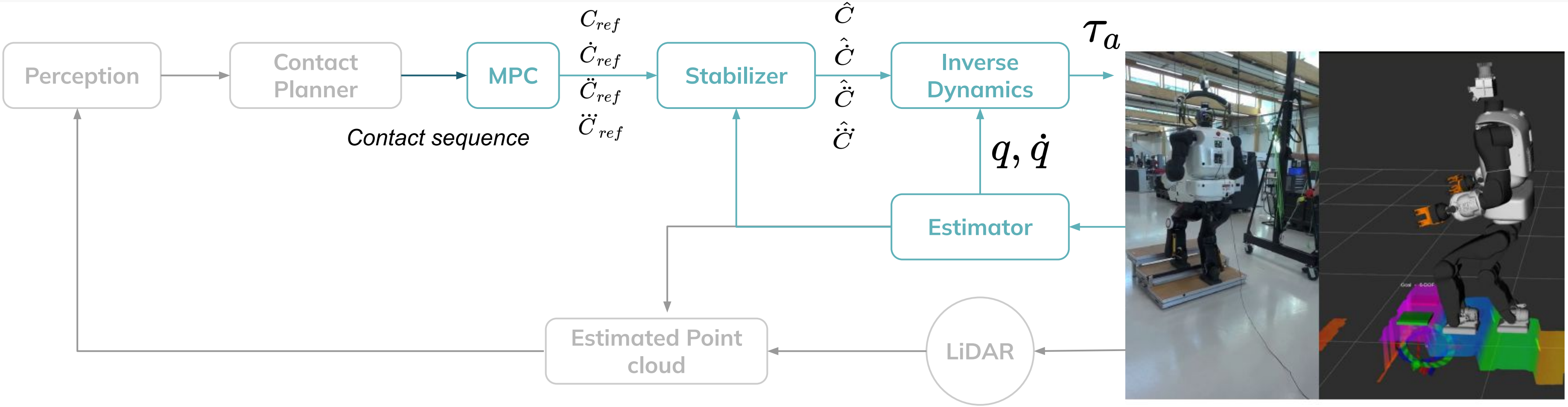


Stabilizer

Capture Point control using natural dynamics of LIP[2]

[2] J. Englsberger, C. Ott, M. A. Roa, A. Albu-Schäffer and G. Hirzinger, "Bipedal walking control based on Capture Point dynamics," 2011 IEEE/RSJ International Conference on Intelligent Robots and Systems


Perception
Contact Planner
MPC
Contact sequence
C_{ref}
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$\dddot{C}_{ref}$
Stabilizer
$\hat{C}$
$\dot{\hat{C}}$
$\ddot{\hat{C}}$
$\dddot{\hat{C}}$
Inverse Dynamics
τ_a
$q, \dot{q}$
Estimator
Estimated Point cloud
LiDAR

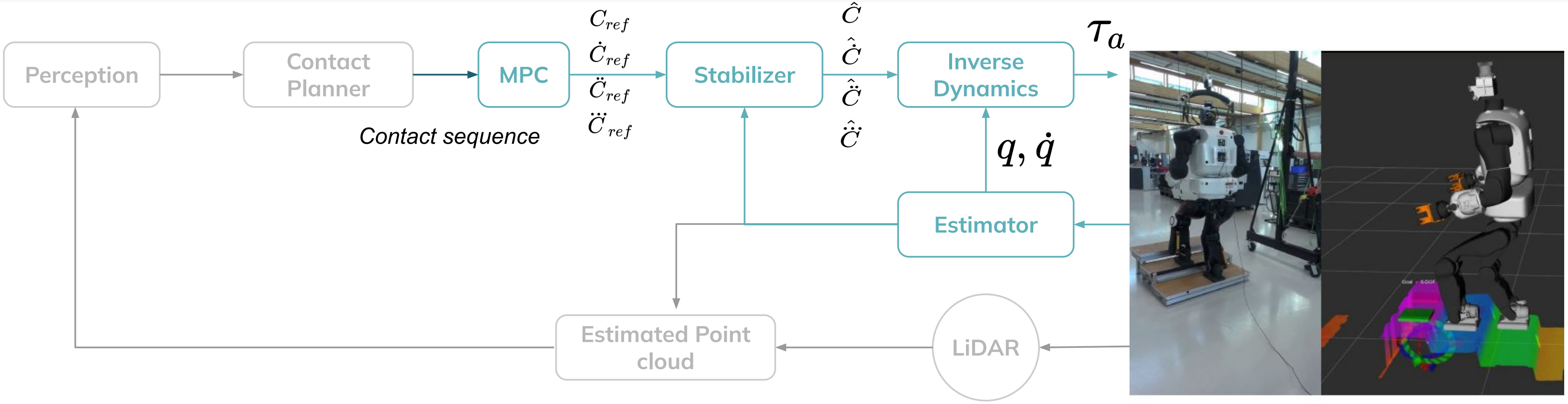
Walk with predefined footsteps:

30cm steps, 1.4 seconds per steps

Walk with predefined footsteps:

30cm steps, 1.4 seconds per steps

20cm steps, 0.9 seconds per steps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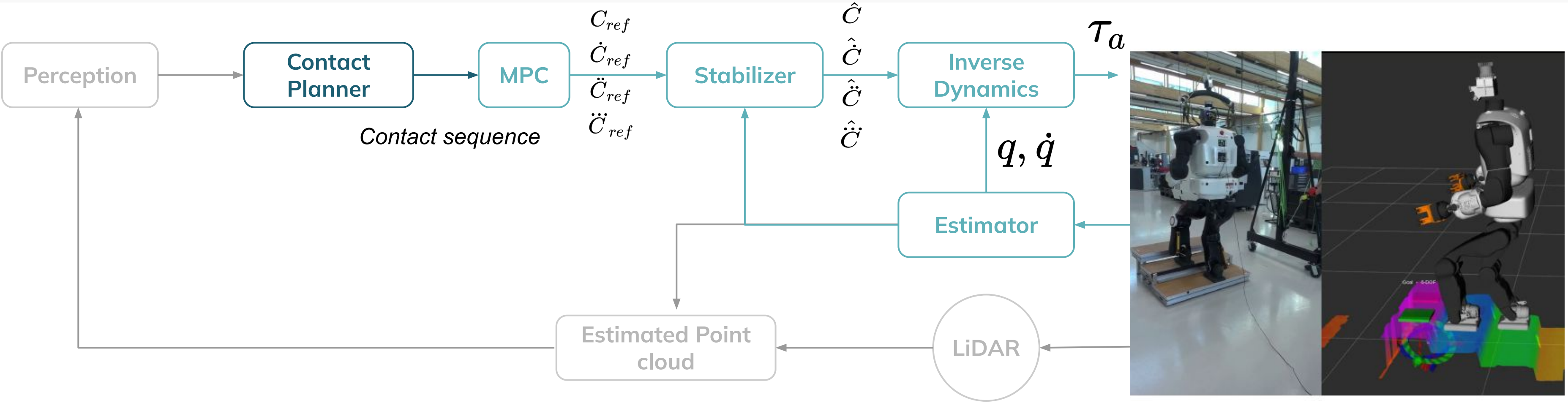


Contact Planner: SL1M[3]

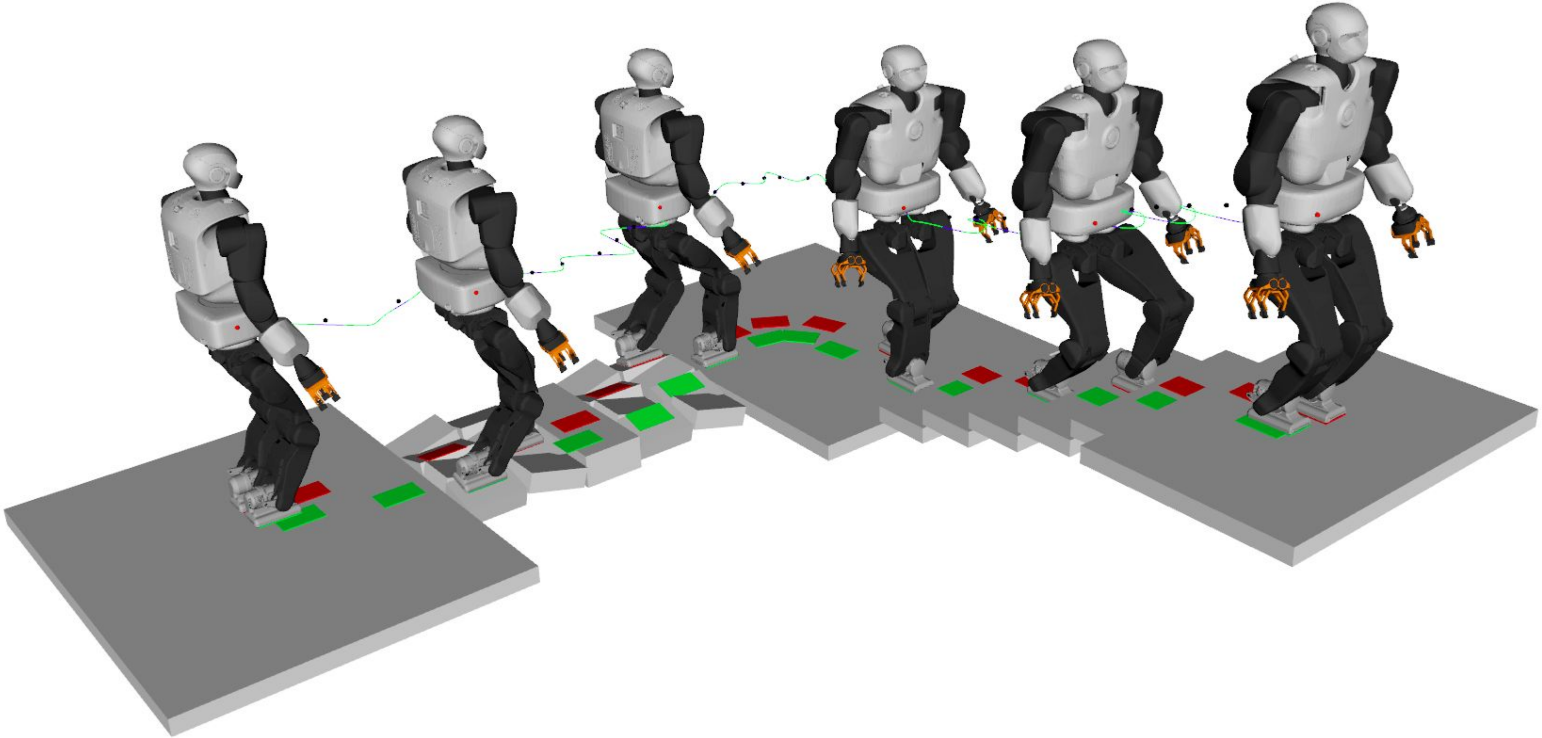
Optimization-based method

Work on non-coplanar surfaces

Feasibility constraints considering kinematic limits and equilibrium

[3] S. Tonneau, D. Song, P. Fernbach, N. Mansard, M. Taïx and A. Del Prete, "SL1M: Sparse L1-norm Minimization for contact planning on uneven terrain," 2020 IEEE International Conference on Robotics and Automation (ICRA)

Contact Planner: SL1M[3]



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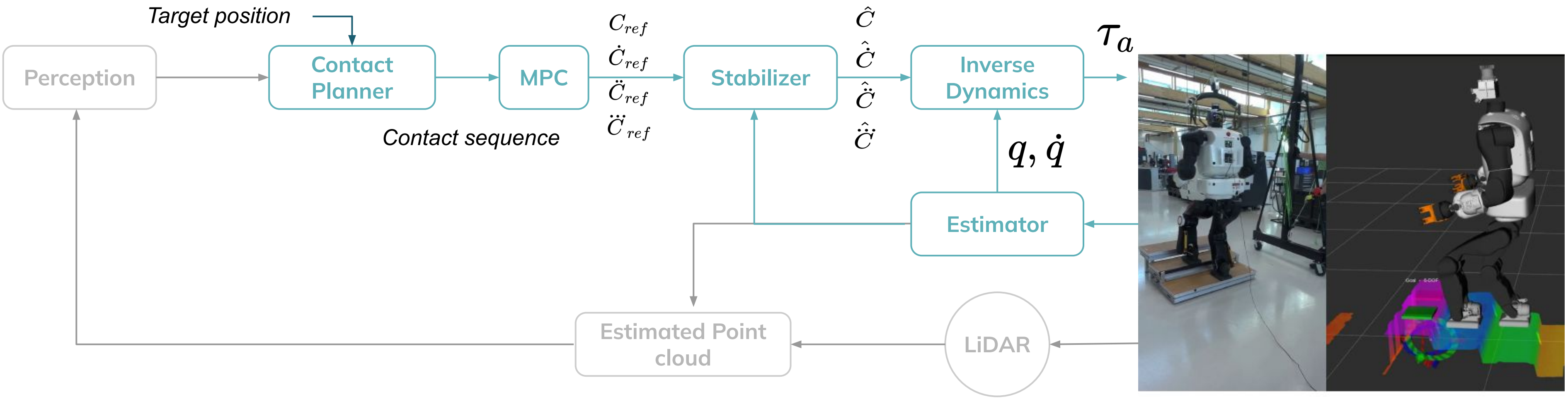
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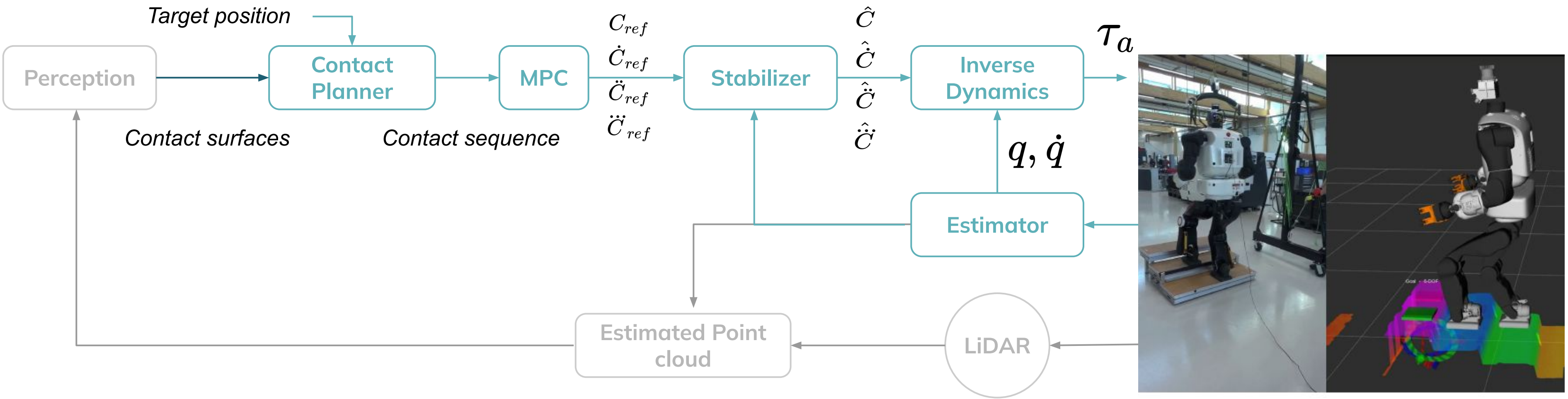
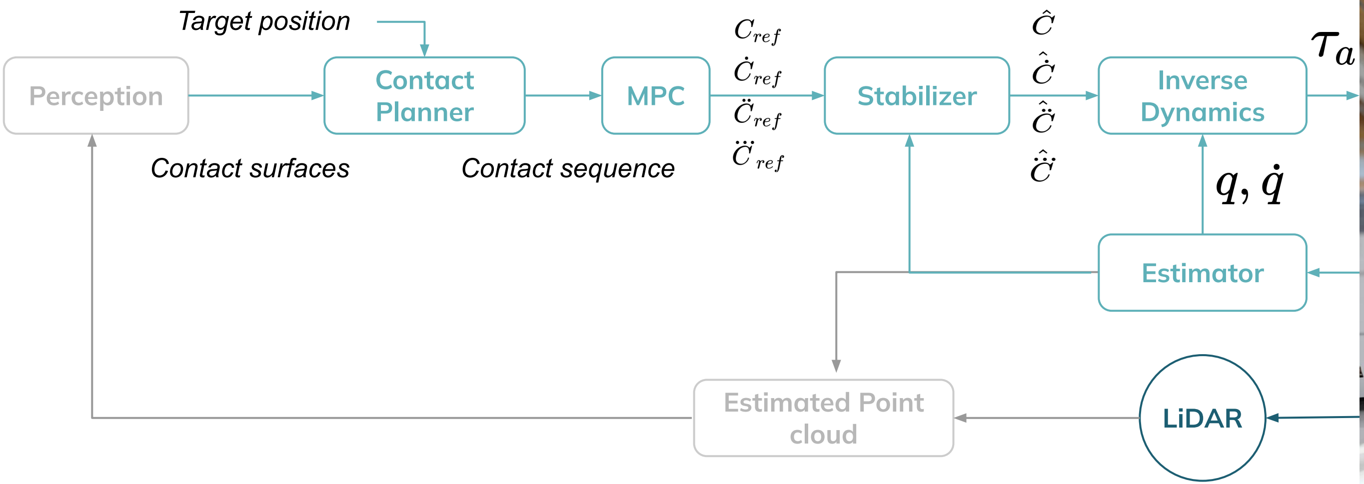
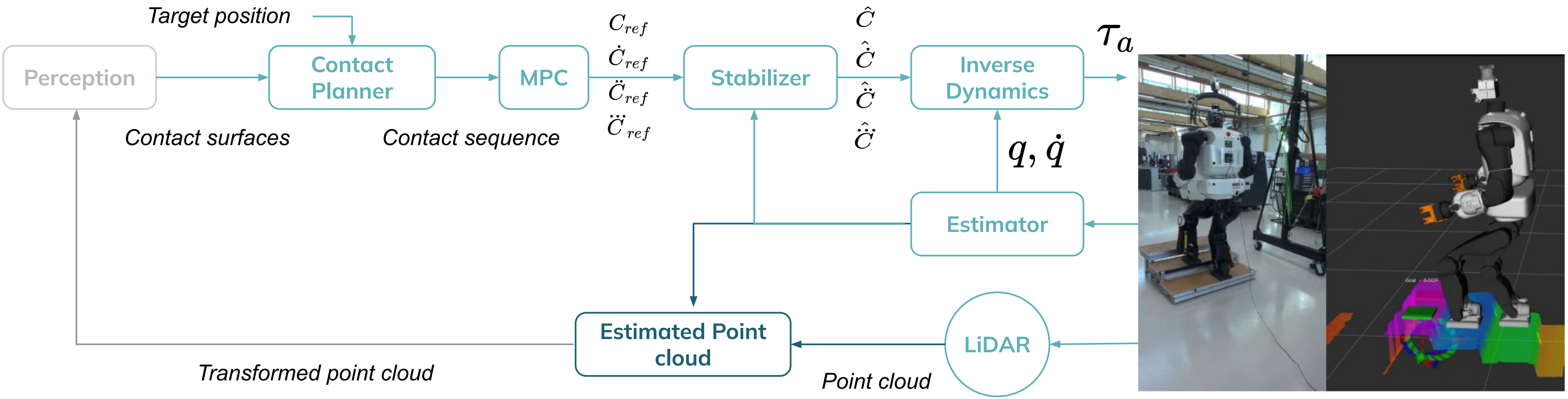


Contact surfaces:

- Defines the locations where the center of the feet can create a contact
- Convex polygons
- Non overlapping



Realsense L515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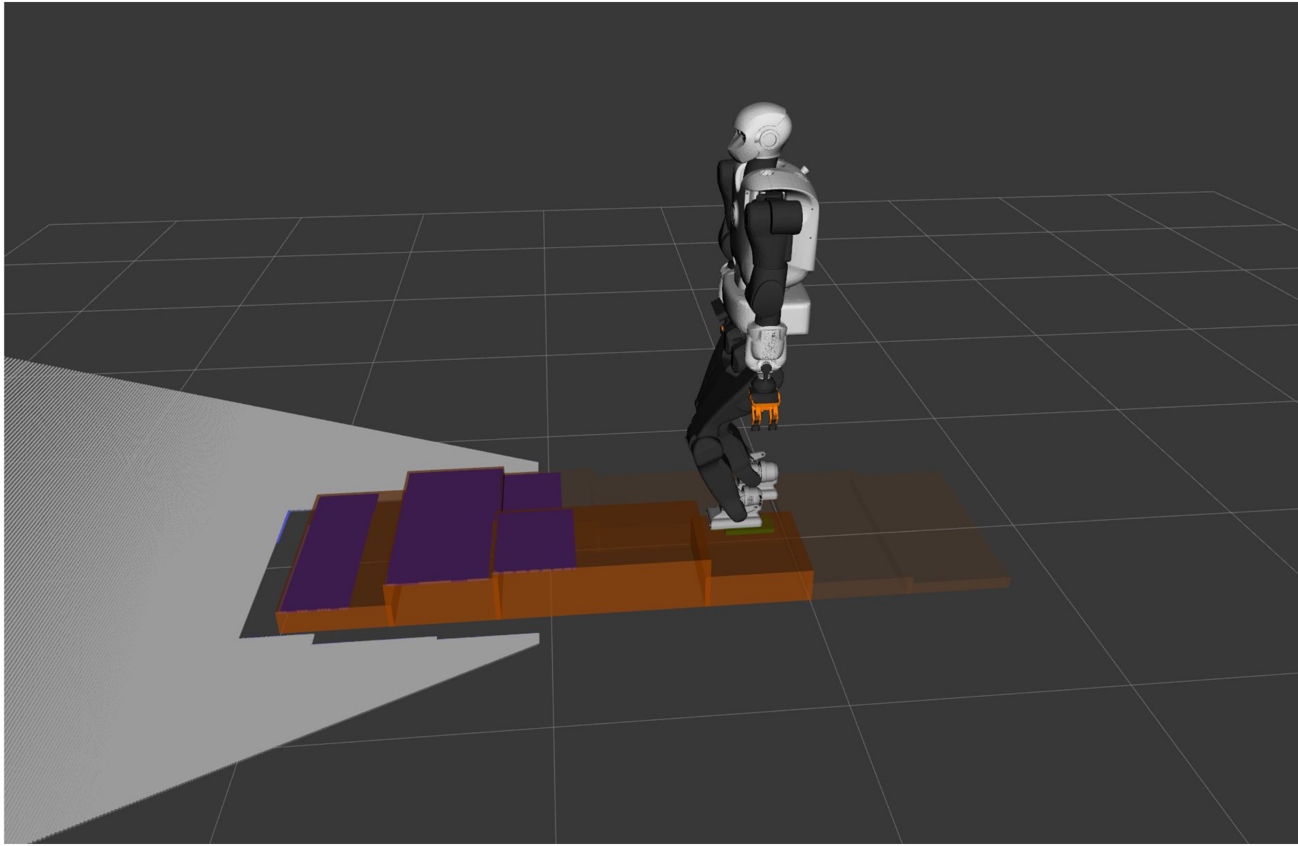
LiDAR
Transformed point cloud
Point cloud

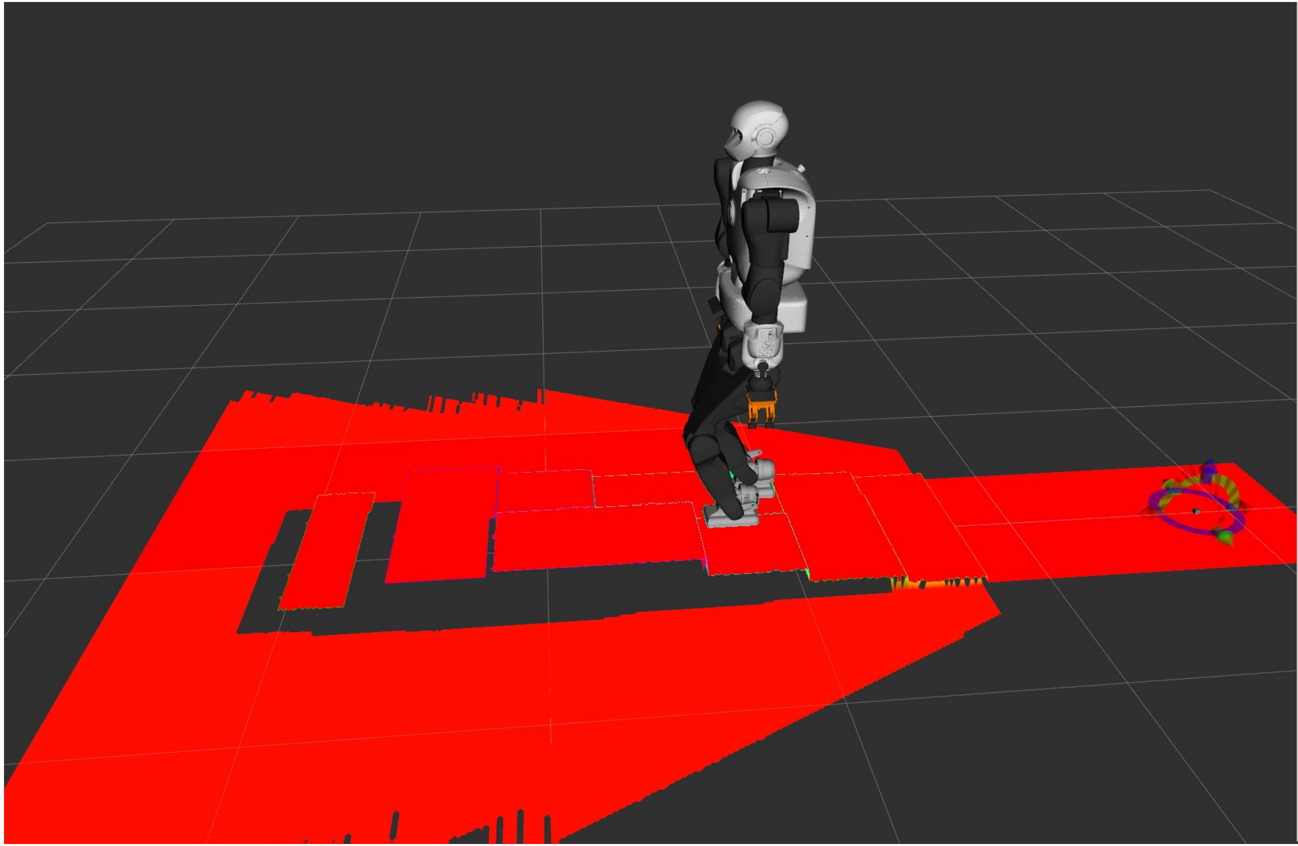
Point cloud from LIDAR

No perception of the close surrounding of the robot



Elevation map construction

Build and update an elevation map from the LIDAR point cloud during the motion

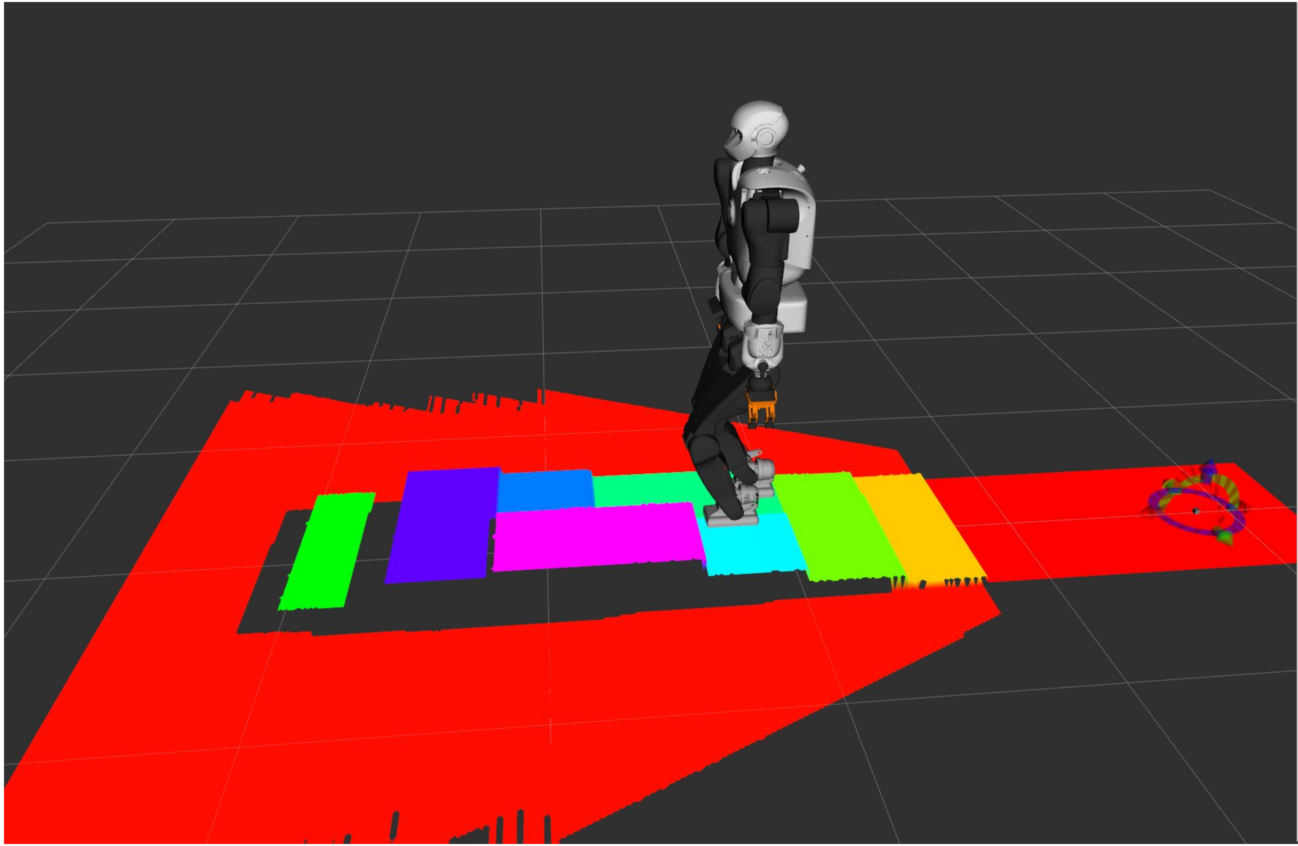


Elevation map construction

Build and update an elevation map from the LIDAR point cloud during the motion

Plane segmentation

Based on RANSAC method



Elevation map construction

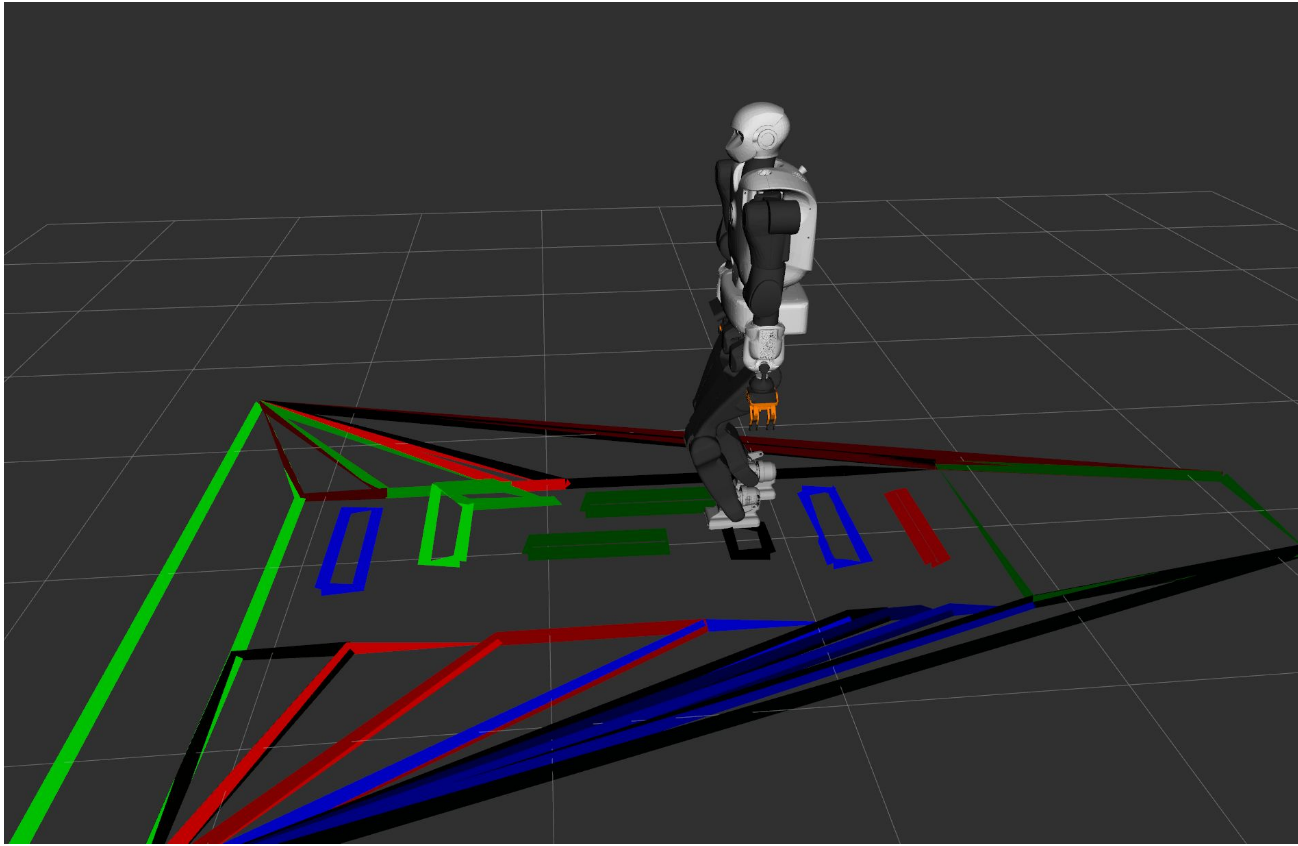
Build and update an elevation map from the LIDAR point cloud during the motion

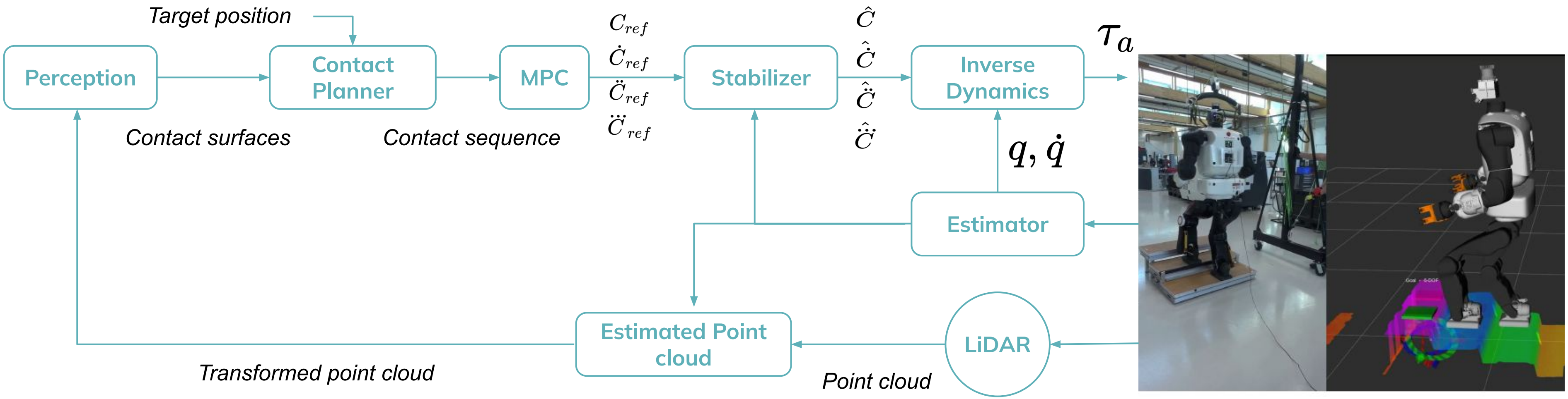
Plane segmentation

Based on RANSAC method

Surface processing

Convexify surfaces
Reduce number of vertices
Reduce with feet size margin
Remove overlapping

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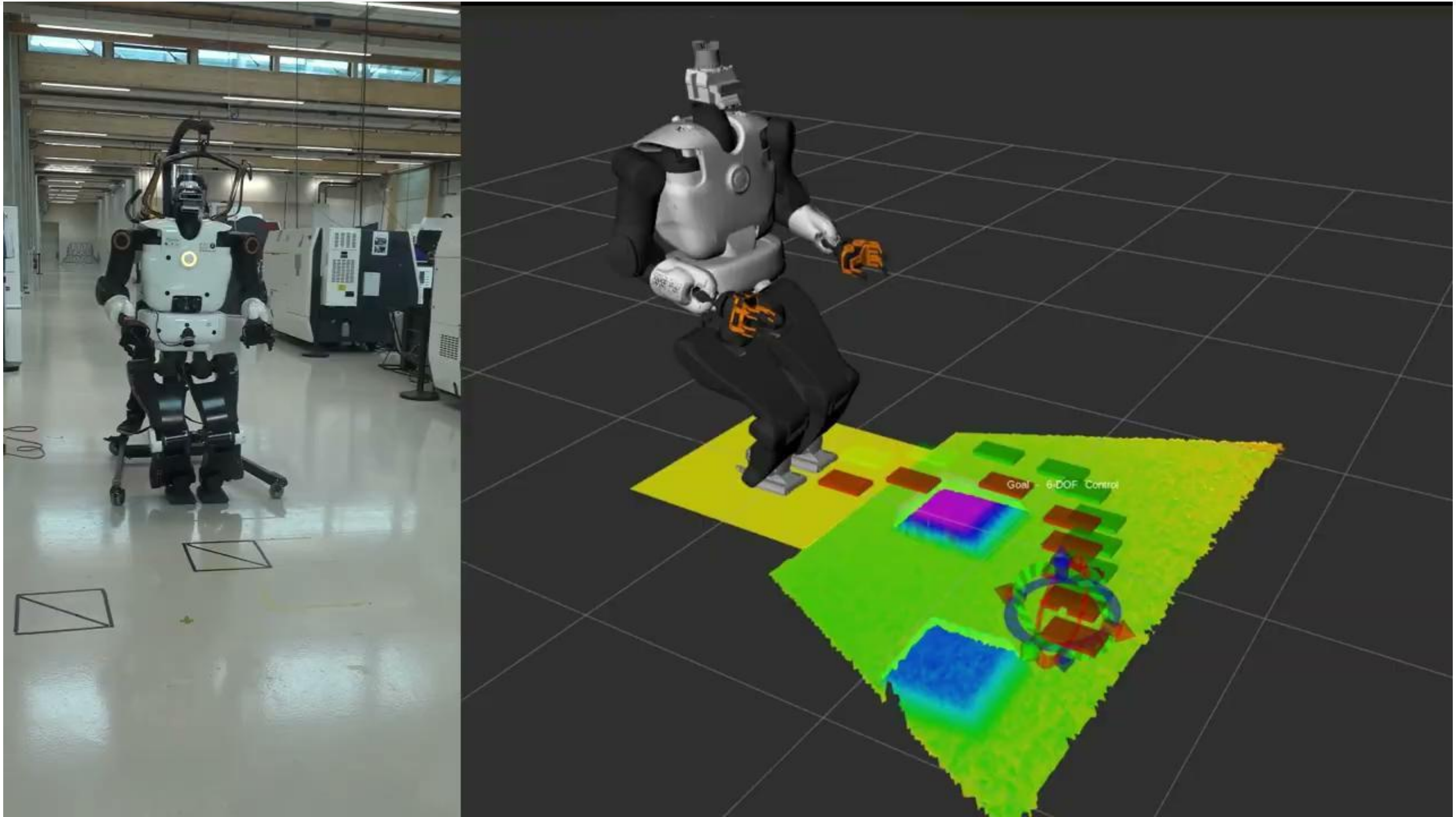
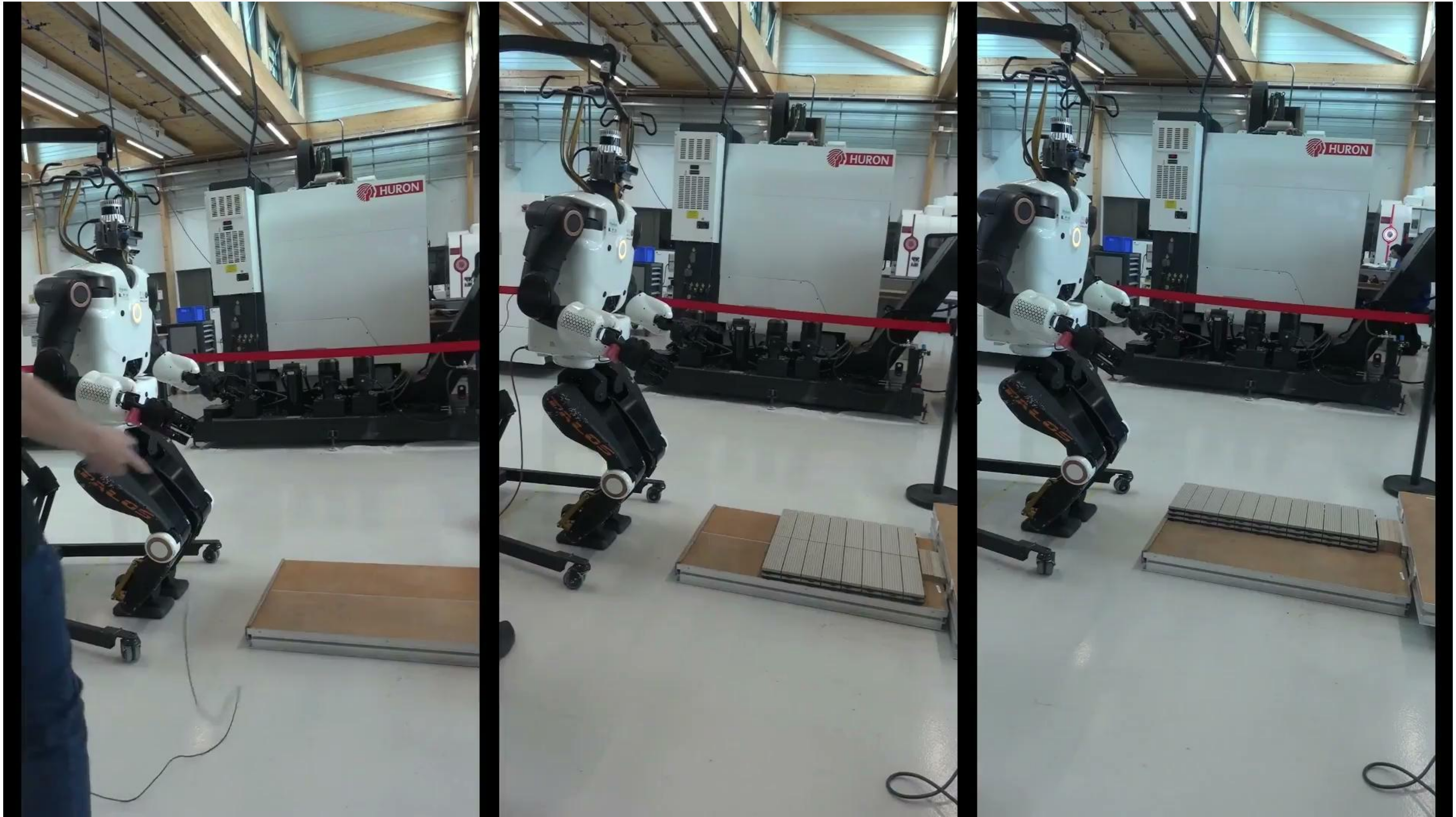

Goal - 6-DOF Control


HURON
HURON
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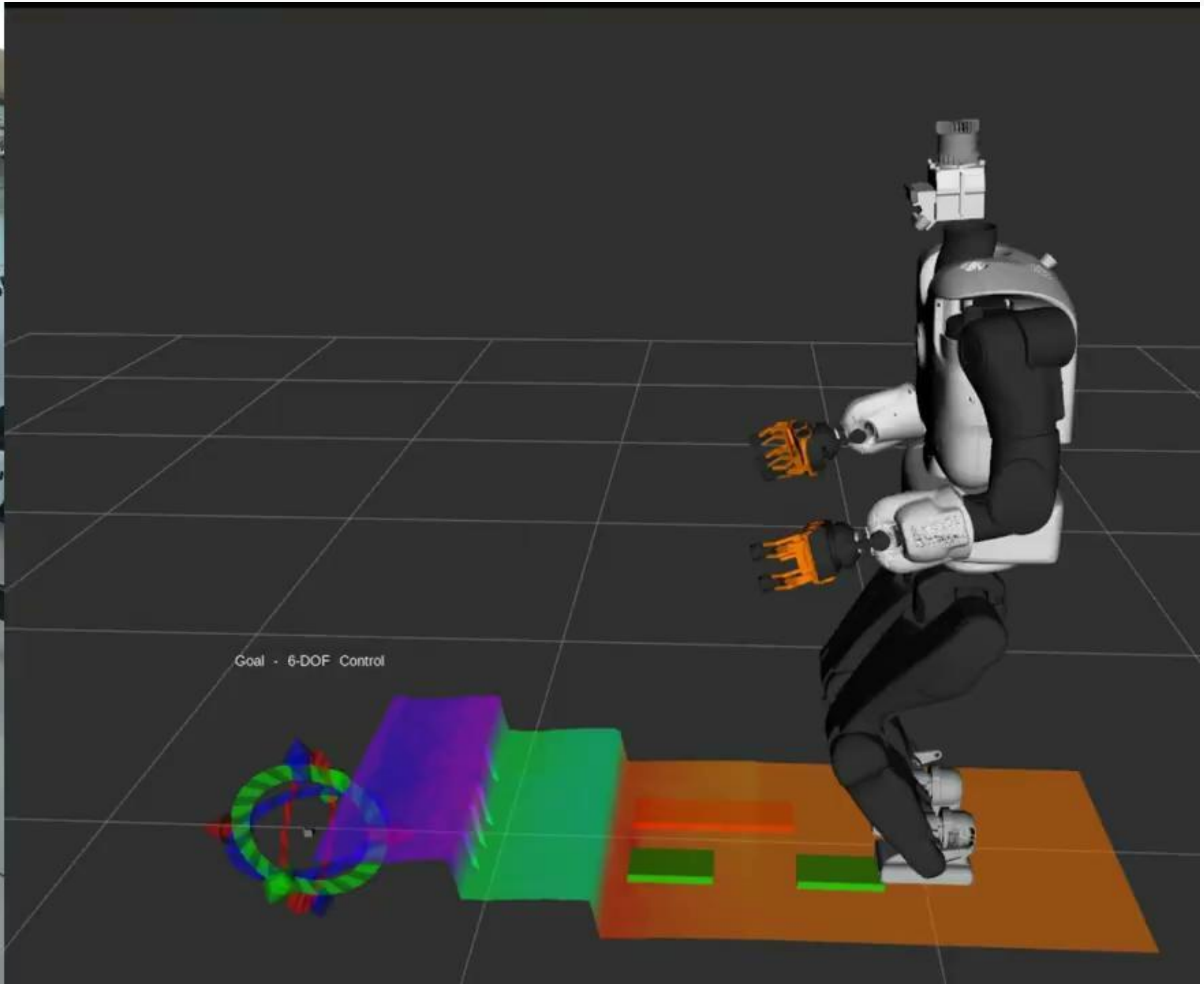
TALOS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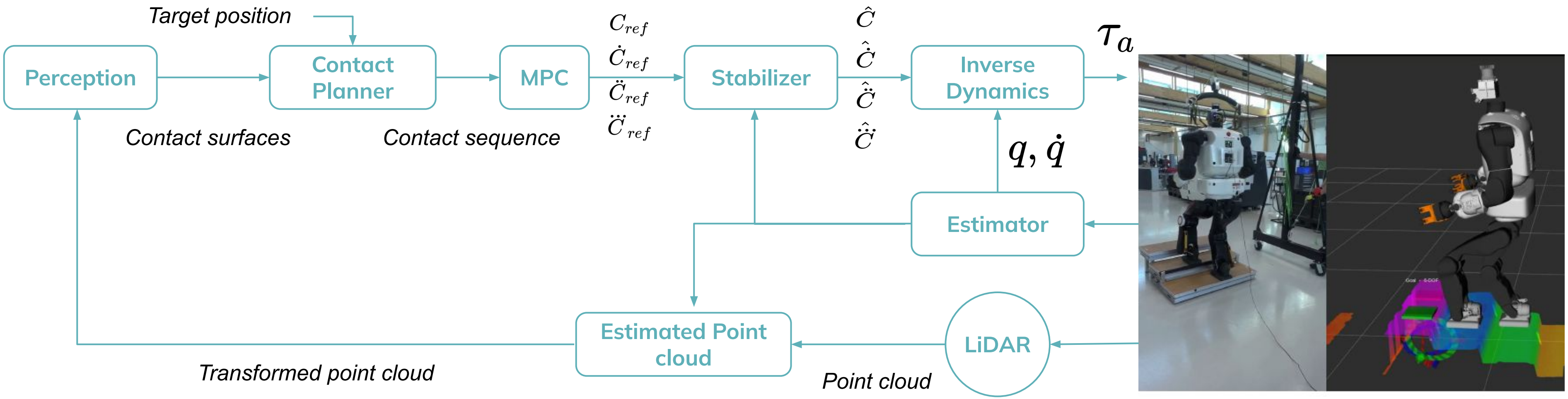
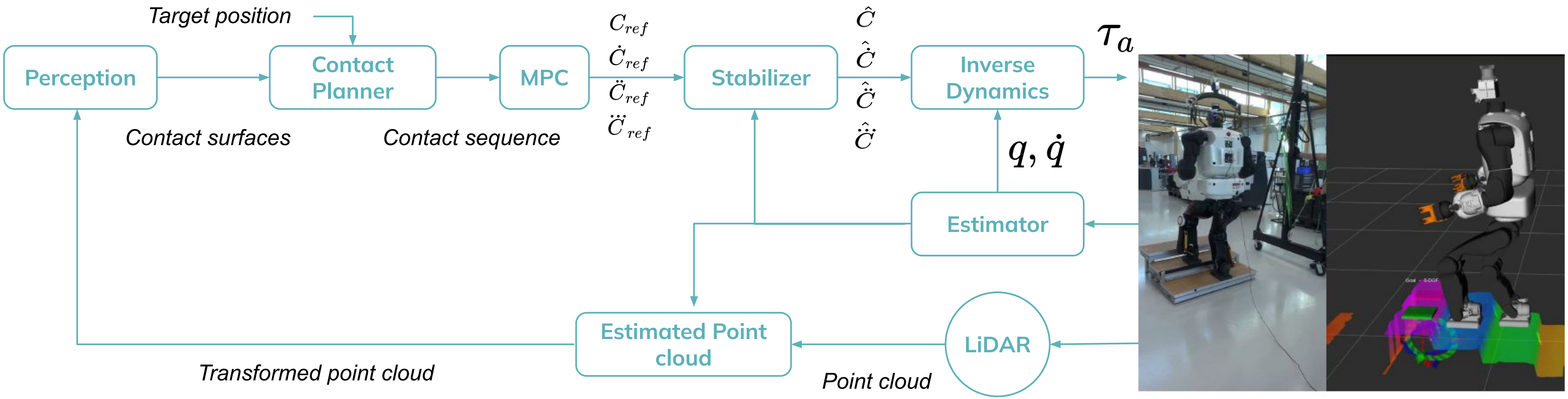


Conclusion:

- Implementation of an architecture for locomotion in unknown environments
- Able to replan online
- Fully integrated with ROS
- Run fully onboard



Conclusion:

- Implementation of an architecture for locomotion in unknown environments
- Able to replan online
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- Run fully onboard

Future work:

- Robustify the perception block
- Improve floating base estimation with visual odometry
- Fusion of head and waist sensors
- Global path planning

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Thank you

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