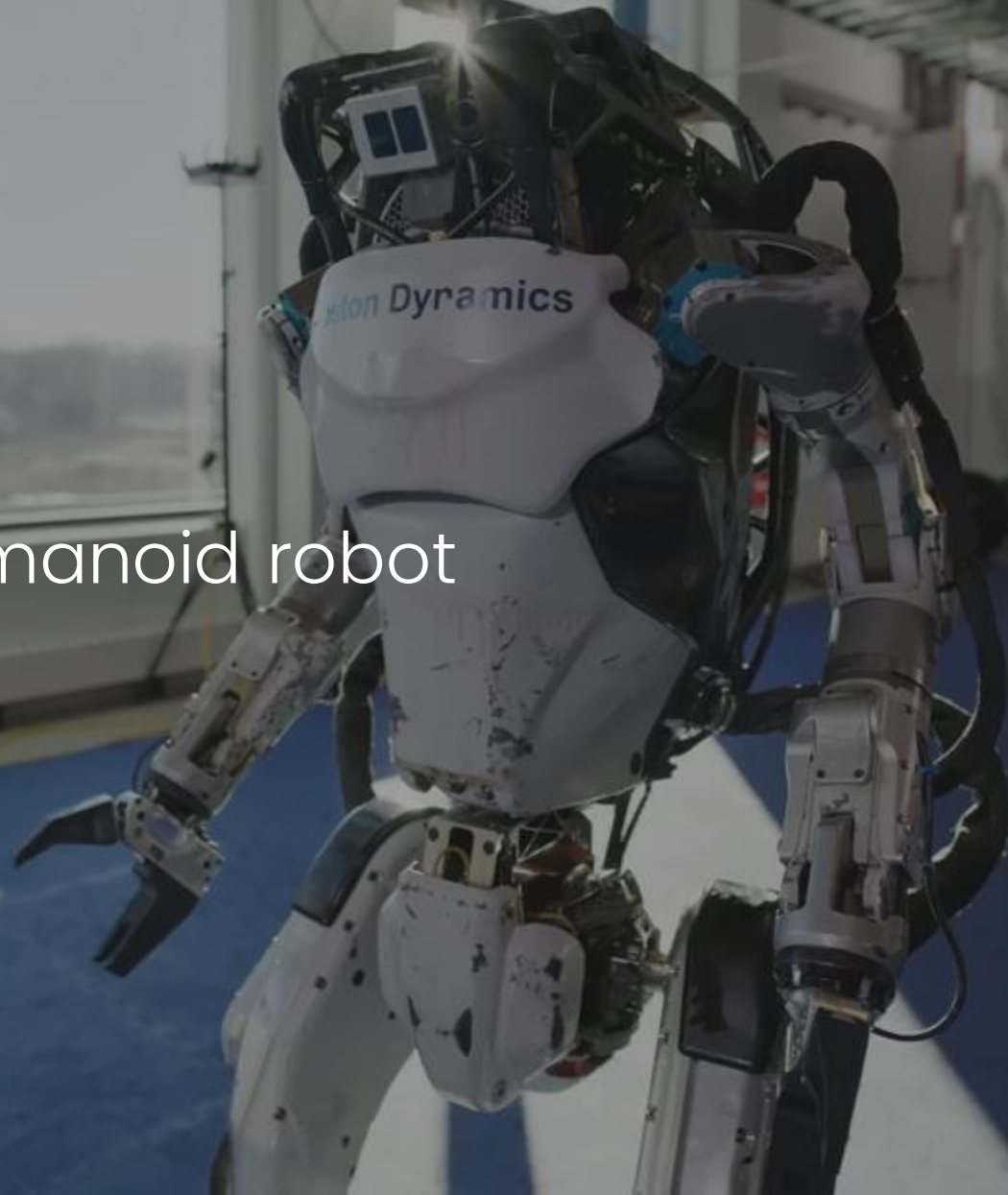


Atlas

A one-of-a-kind humanoid robot



Boston Dynamics History

Google acquired company
2013

MIT spin-off to
Boston Dynamics
company
1992

SoftBank acquired
company
2017

Boston Dynamics acquires
Kinema Systems
2019

To optimize 3D vision for its robots

Associate to French Shark Robotics for COVID
decontamination robot
2020

The Spot robot is deployed by the Ukrainian
government in Chernobyl to measure radiation levels.

Hyundai Motor takes 80%
stake in Boston Dynamics
2021

Boston Dynamics **Spot**

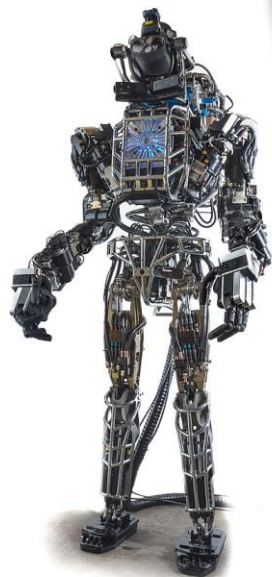
an agile mobile robot that navigates terrain with unprecedented mobility, allowing you to automate routine inspection tasks and data capture safely, accurately, and frequently.

Boston Dynamics **Stretch**

a flexible autonomous mobile robot that automates case handling tasks for more efficient warehouse operations.

Boston Dynamics – Research

Atlas history



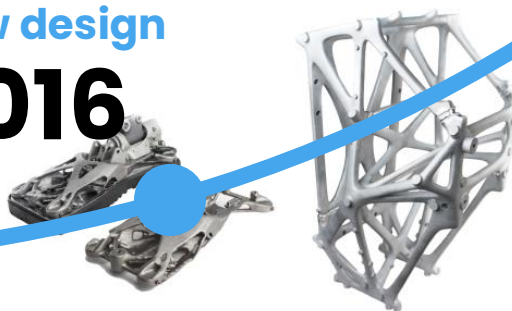
Atlas project
launch

2013

Tests, Pros/cons

New design

2016



Backflip

2021

Cobot

2022

Increase mobility

2022

Dance

2022

Soft n hardware
optimised

2022



Boston Dynamics – Research

Atlas features

89

kg weight thanks to
3D printed steal parts



2,5

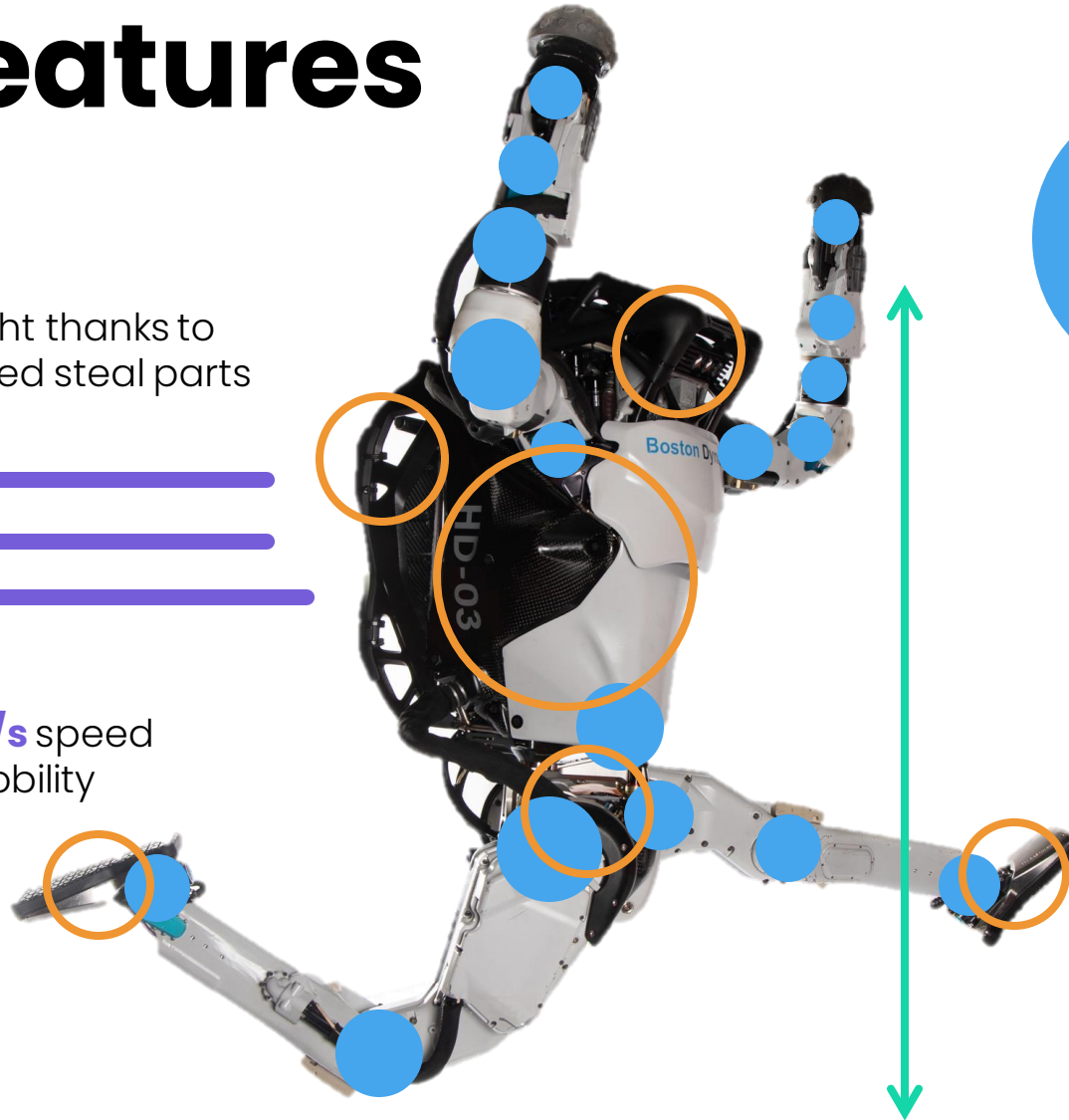
m/s speed
mobility

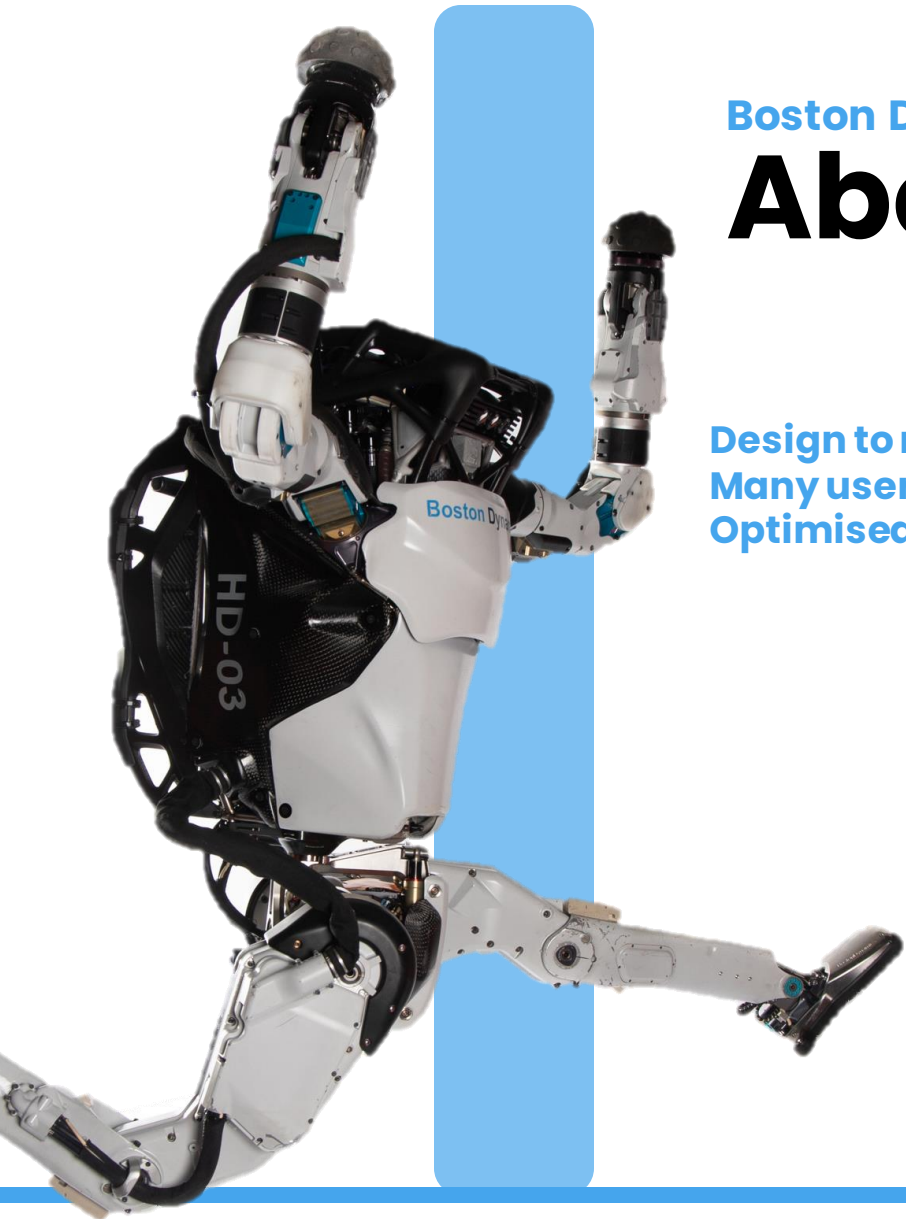
28

hydraulic joints
for impressive
feats of mobility.

1,5

meter height





Boston Dynamics – Research

Above all competition

Design to manufacturing
Many user experience thanks to Spot
Optimised Software and Hardware

No user experience but
quick design tanks to Tesla
motors technologies

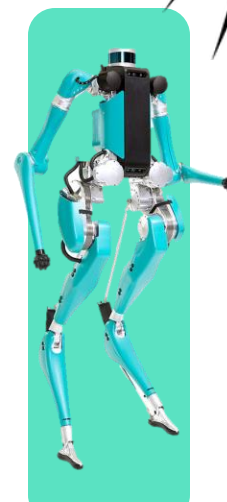
Few user experience but
define use cases

Agility
Robotics

Laboratory tests
LAAS CNRS

PAL
ROBOTICS

Manufacturing
only



1992

2004

2015

2021



Boston Dynamics – Research – The paper

Humanoid Path Planning over Rough Terrain using Traversability Assessment

Humanoid Path Planning over Rough Terrain using Traversability Assessment

Stephen McCrory^{1,2}, Bhavyanh Mishra^{1,2}, Jaehoon An^{1,4}, Robert Griffin^{1,2},
Jerry Pratt^{1,2,3} and Hakkı Erhan Sevil²

Abstract—We present a planning framework designed for humanoid navigation over challenging terrain. This framework is designed to plan a traversable, smooth, and collision-free path using a 2.5D height map. The planner is composed of two stages. The first stage consists of an A* planner which reasons about traversability using terrain features. A novel cost function is presented which encodes the bipedal gait directly into the graph structure, enabling natural paths that are robust to small gaps in traversability. The second stage is an optimization framework which smooths the path while further improving traversability. The planner is tested on a variety of terrain in simulation and is combined with a footstep planner and balance controller to create an integrated navigation framework, which is demonstrated on a DRC Boston Dynamics Atlas robot.

I. INTRODUCTION

Legged robots have increasingly become capable of robust locomotion and navigating over unstructured terrain. A major advantage of legged locomotion is an ability to traverse terrain which contains obstacles, gaps or other challenges intractable to wheeled or tracked platforms. For many real-world applications of legged platforms, it is a requirement that such terrain can be navigated with a high degree of autonomy. Path planning for legged robots requires reasoning about the platform's capabilities and can be difficult to deploy when combined with practical limitations such as sensor noise. While there has been significant work towards this goal, finding a robust and operational solution to humanoid path planning remains an open problem.

This paper presents a navigation path planner designed to enable humanoid locomotion over rough terrain and is intended to be used as a heuristic for a lower-level footstep planner. We build on the approach of many existing planners and perform a sample-based graph search which includes a traversability cost model [1]–[3]. The main contribution of our formulation is setting up the planner to use these traversability costs in a way that reflects the bipedal gait. Additionally, we include checks to prevent cutting corners, maintain a safe distance from obstacles and find reliable routes for ascending and descending terrain.

¹Author is with the Institute of Human and Machine Cognition (IHMC), 40 S Alameda St, Pensacola, FL 32502, USA, author@ihmc.org
²Author is with the University of West Florida (UWF), 1000 University Pkwy, Pensacola, FL 32514, USA, author@uwf.edu
³Author is with Bluebird Robotics, Inc., 11 Galloway Green E, Pensacola, FL 32502, USA, author@bluebirdrobotics.com
⁴Author is with Pusan National University, Busan, South Korea, author@pu.ac.kr
⁵This work was supported through ONR Grant No. N00014-19-1-2023 and NASA Grant No. 80NSSC20M0197.

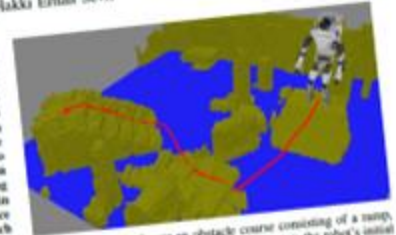


Fig. 1: Path planned over an obstacle course consisting of a ramp, cinder blocks, and a staircase. A 2.5D height map, the robot's initial configuration and an open-loop specified goal is given to the planner as input.

Our approach first performs an A* search over a 2.5D height map by sampling terrain in the vicinity of each node to measure traversability. This initial path is then optimized using gradient descent in order to smooth the path while further improving its quality. We select A* for a few reasons, the first being that our cost functions are sample-based and preclude the use of a closed-form solver. The second is for the practical reason that the A* planning process lends itself to logging and visualization more than randomized or probabilistic graph-search approaches. The planner is tested extensively using real sensor data on a variety of terrain containing stairs, stepping stones, ramps, cinder blocks and large obstacles (Fig. 1). We also share results from testing on a DRC Atlas robot by integrating with an existing balance controller and footstep planner.

II. RELATED WORK

In developing more capable path planners, work has been done to create heuristic cost models for terrain traversability. Metrics such as local terrain slope, roughness and curvature are commonly used [4]. During planning, these metrics can be used in combination with a geometric model of the robot to predict the likelihood that a node contains secure footholds [5]. If sufficiently accurate sensing is available terrain can

Technical data

Trajectory planning



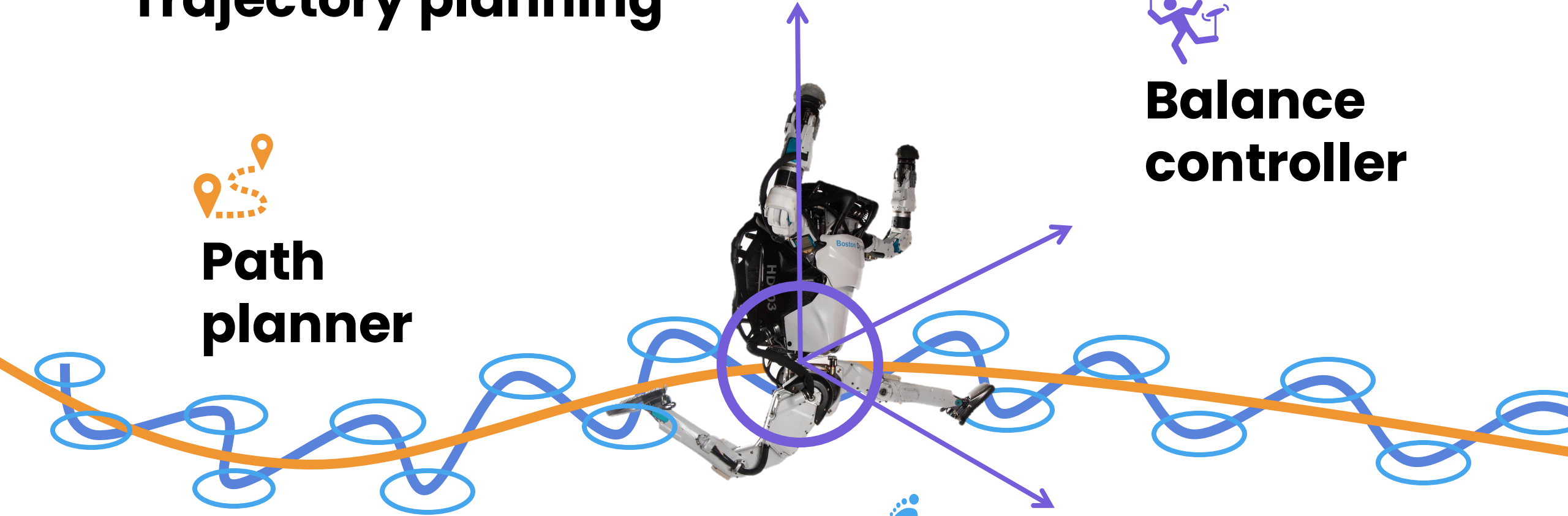
**Path
planner**



**Balance
controller**

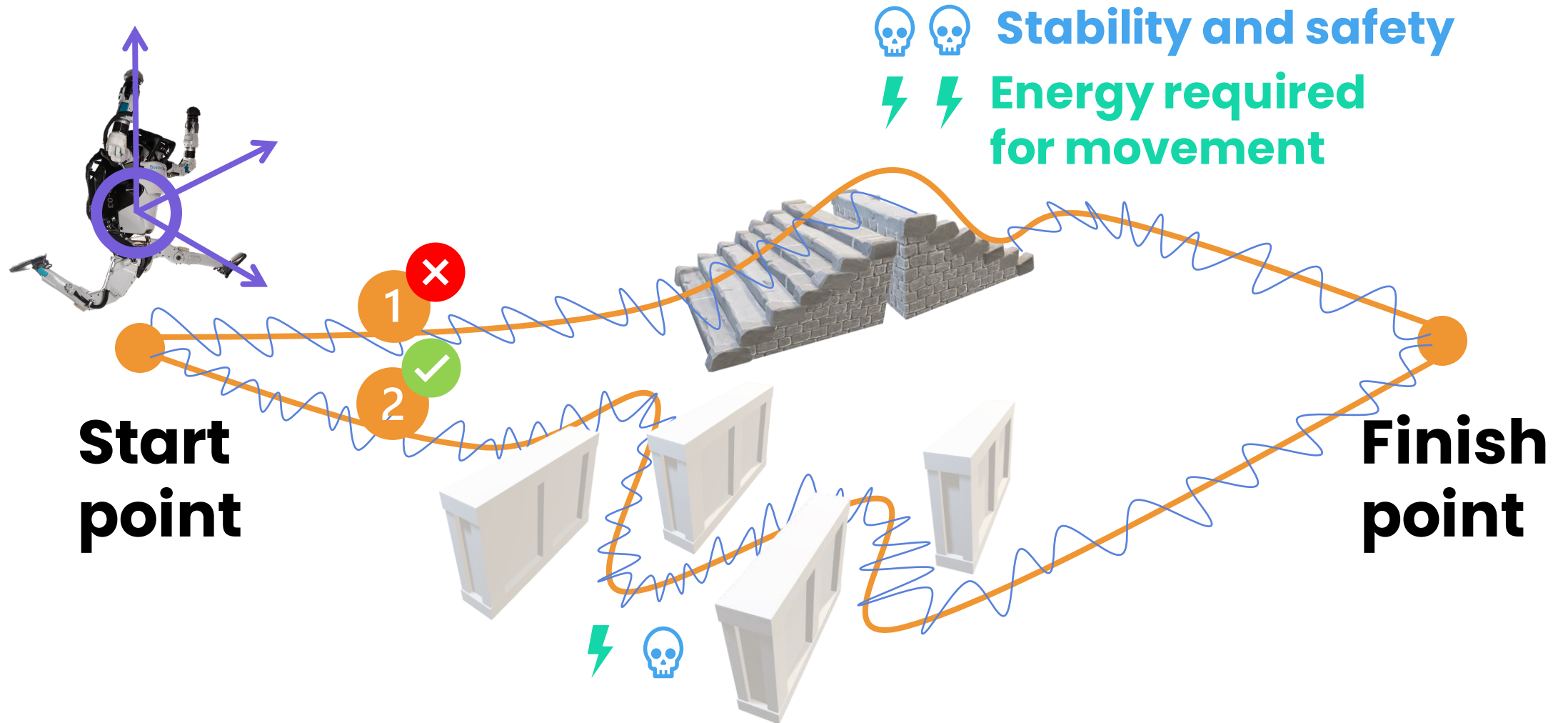


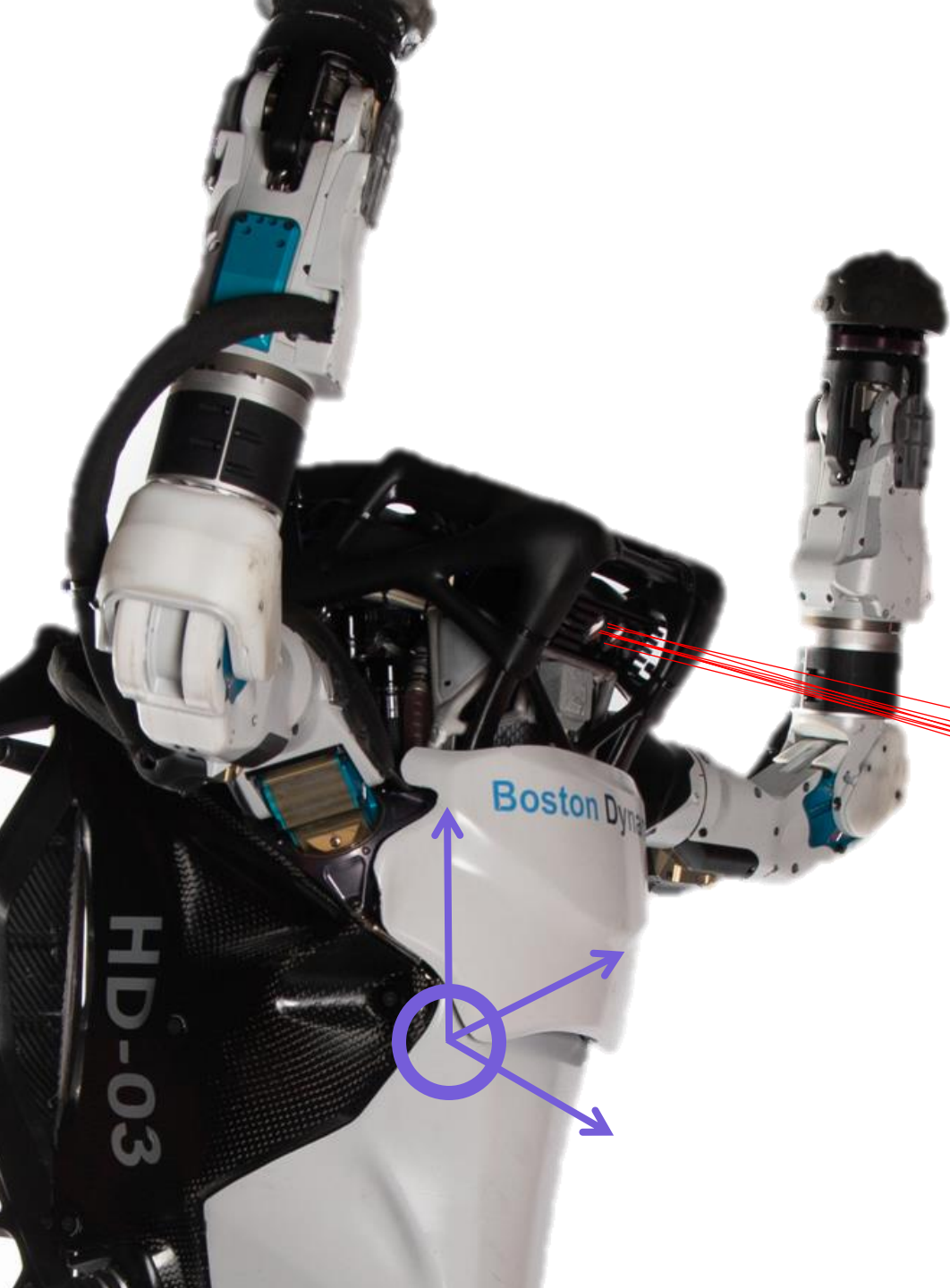
Step planner



Technical data

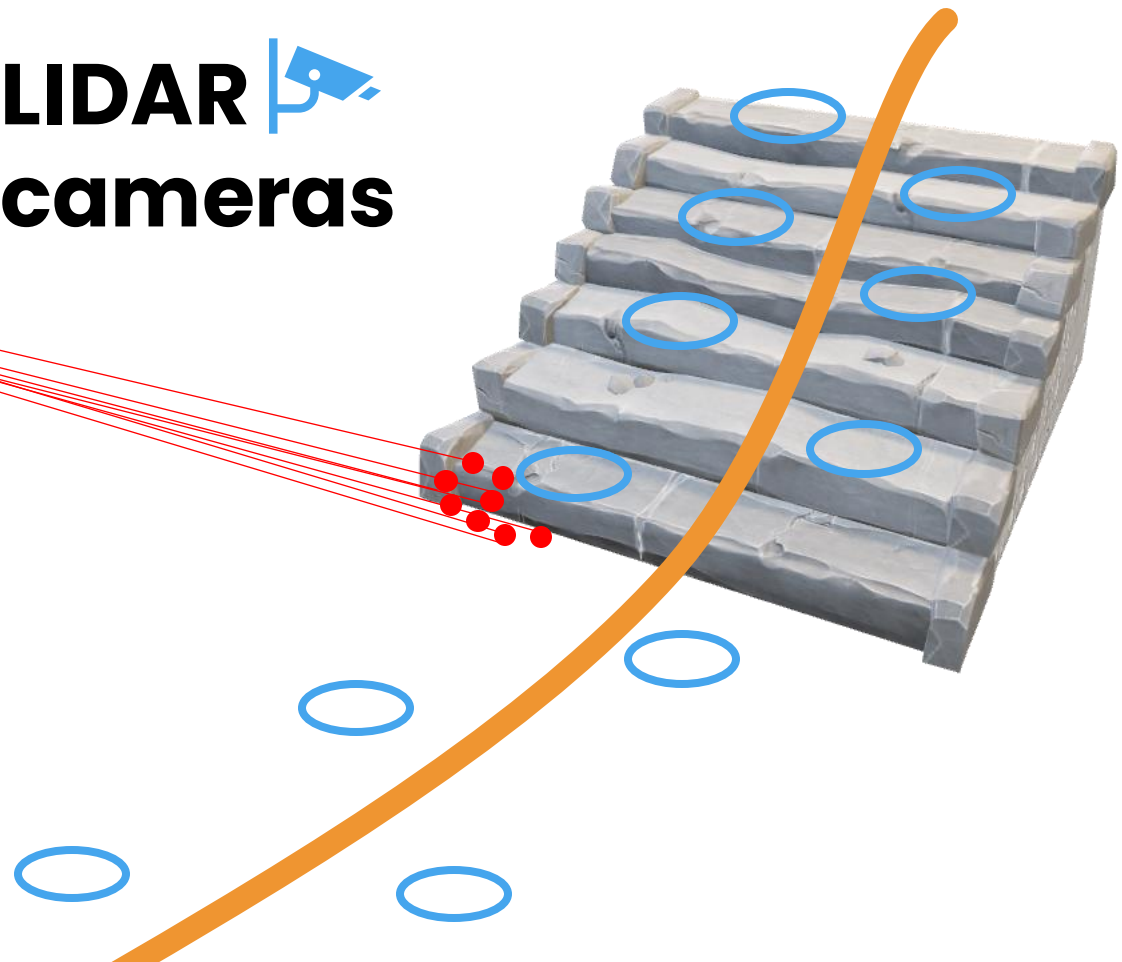
Optimal trajectory





LIDAR 
cameras

Technical data
Step planner



Technical data

Papers pictures

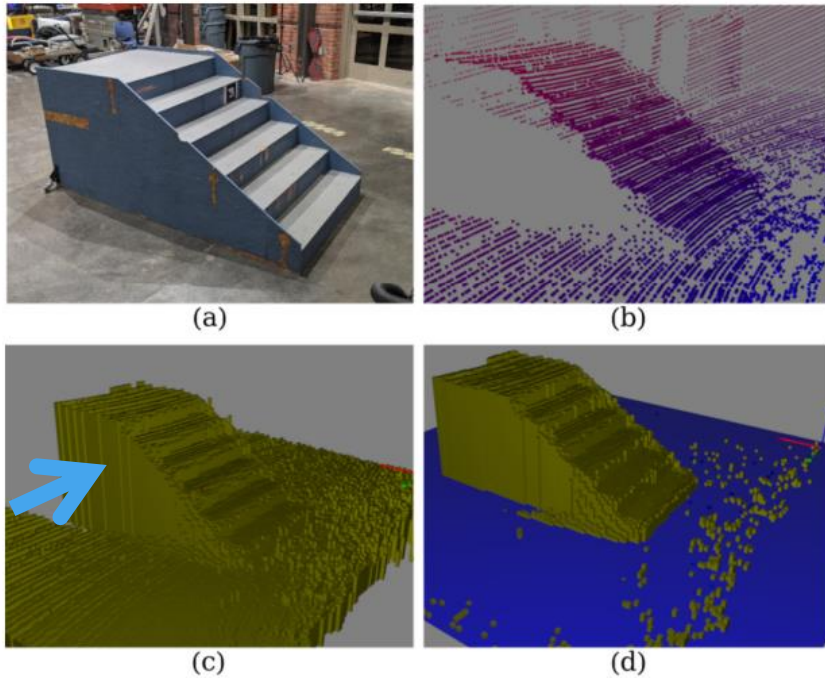


Fig. 5: The height map is built using point clouds from an Ouster OS0-128 LIDAR. Points within the height map's domain are then assigned a cell, merged with previous data, then filtered to estimate the ground plan and remove outliers.

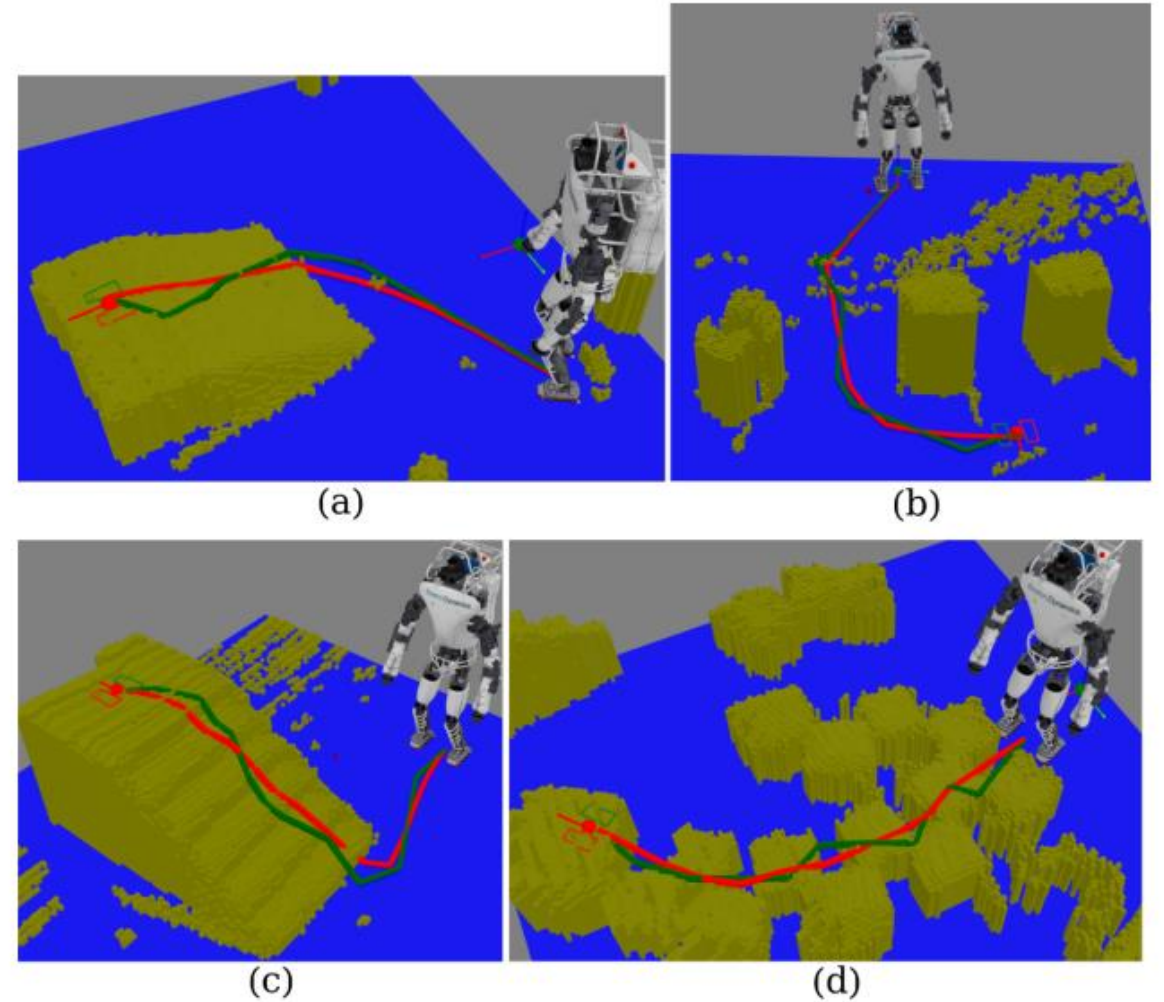


Fig. 6: Simulation results for various rough terrains using real sensor data. The green path shows the initial path generated by A* and the red is the optimized path.

Technical data

Problems



**variety of
challenging
terrains**



**"dead end"
problems**



**Time for
impossible
directions**

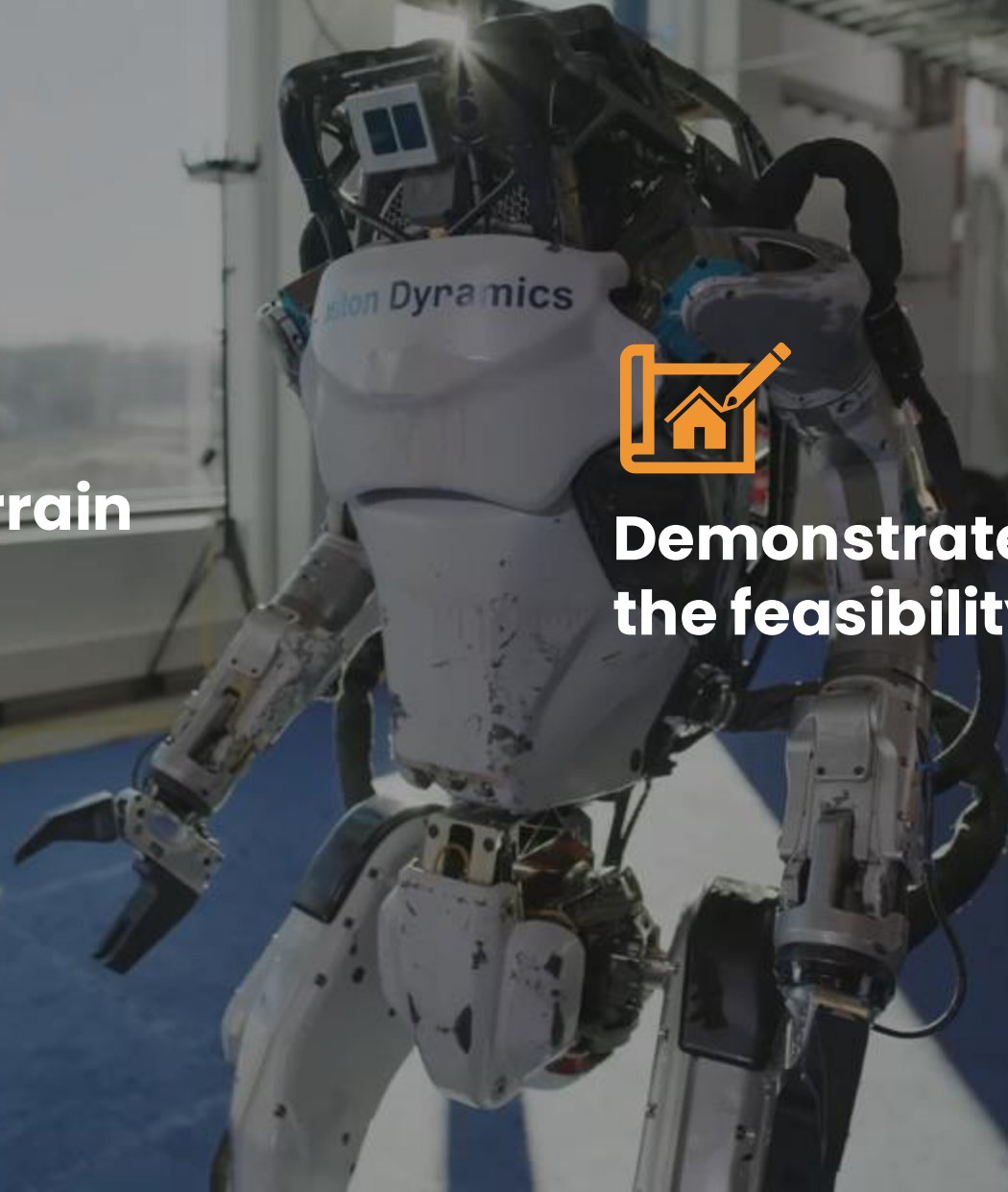
Conclusion



**Difficult terrain
robotic
navigation**



**Demonstrate
the feasibility**



A white and black humanoid robot, likely a Boston Dynamics Atlas, is shown in a factory or research facility. The robot is standing on a blue carpeted floor, and its torso features the "Boston Dynamics" logo. The background shows industrial equipment, large windows, and a blue carpeted floor.

Boston Dynamics – Research

Some technical informations

Short 2 min video

A humanoid robot, identified by the 'Tesla Dynamics' logo on its chest, stands in a large industrial facility with high ceilings and large windows. The robot is white and black, with visible mechanical joints and wiring. The background shows industrial equipment and a blue carpeted floor. Overlaid on the left side of the image is the text 'Thank you for listening.' in blue and 'Do you have any questions?' in white.

Thank you for listening.

Do you have any questions?