COMP0130: Robotic Vision and Navigation

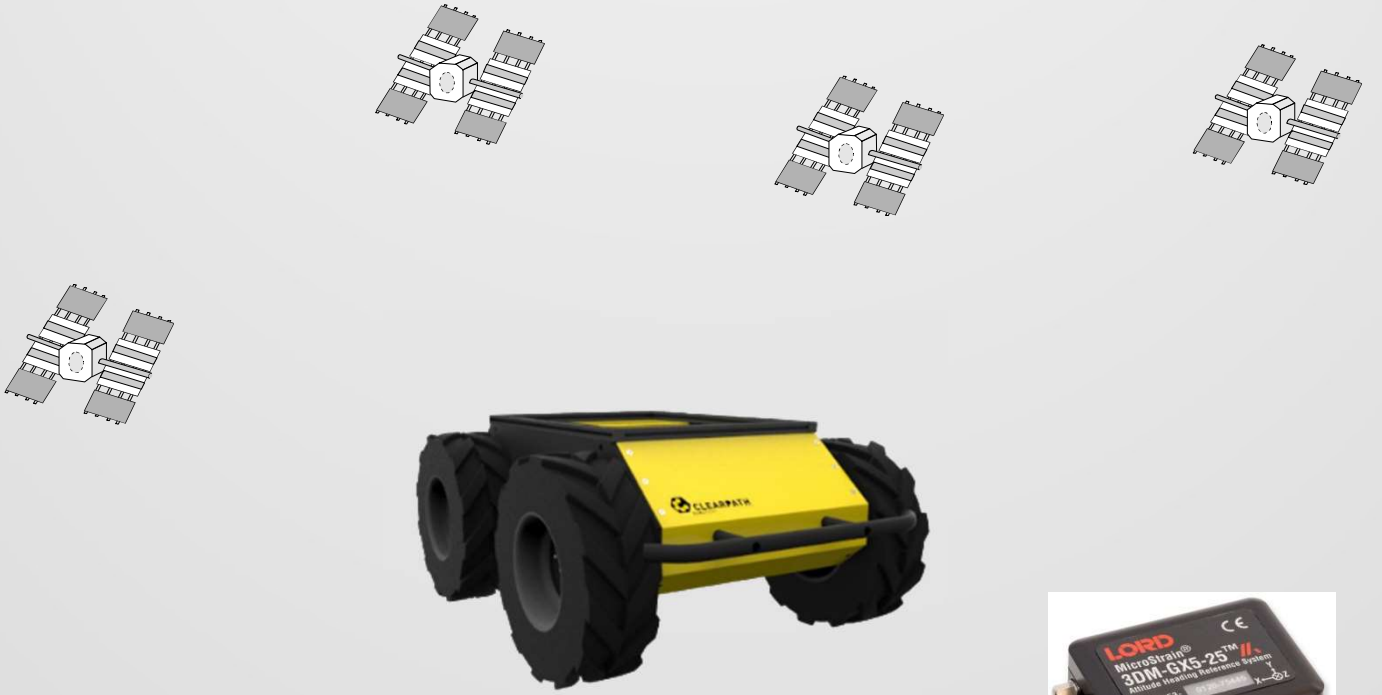
Lecture 05A: Motivation and Basic Concepts of Localization, Odometry, Mapping and SLAM

Simon Julier

Structure

- Motivate the problem
- Types of Map
- Characteristics of Landmarks
- The relationship between localization, mapping, odometry and SLAM

The Story So Far…



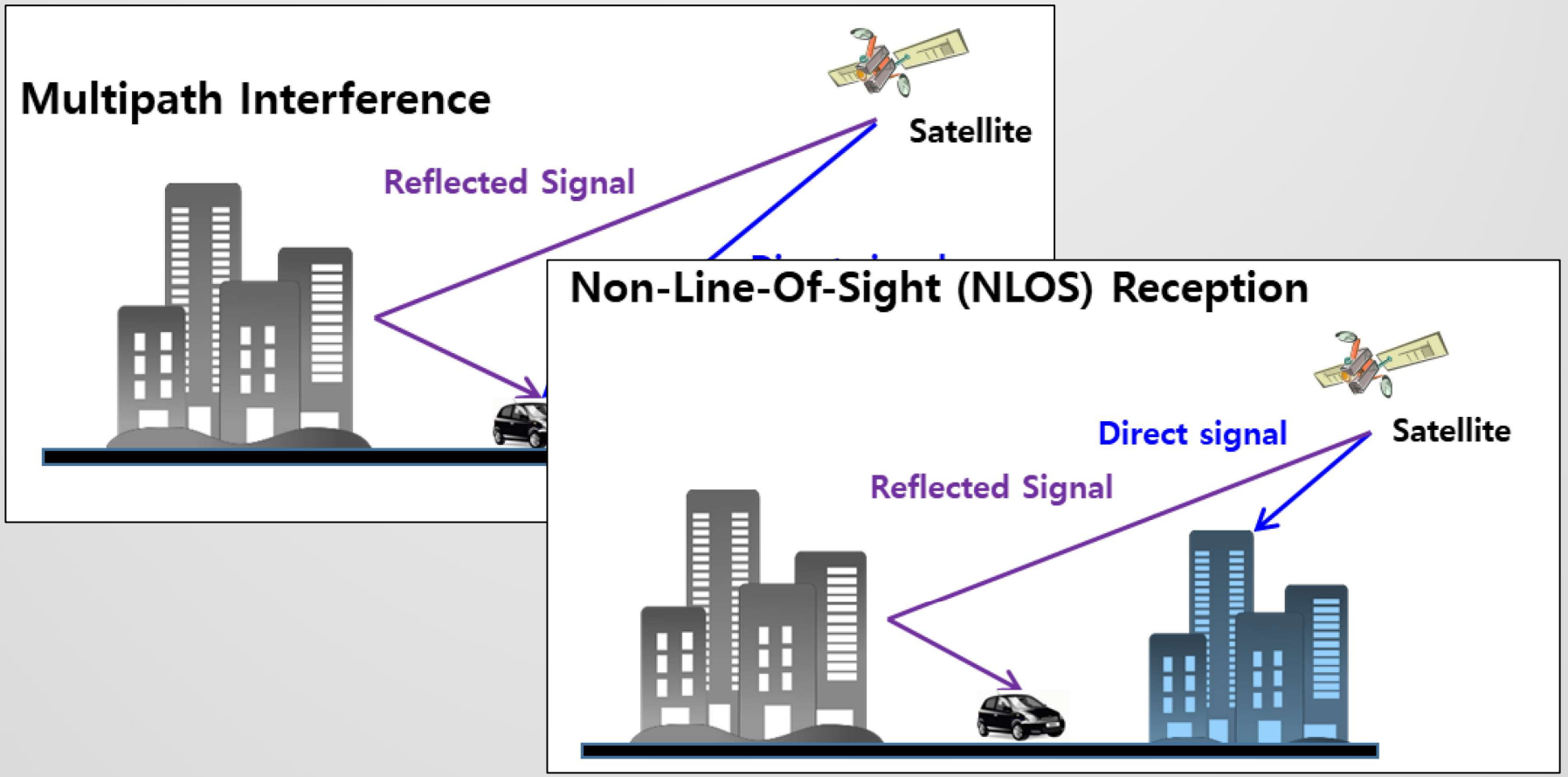
Clearpath Husky robot, Microstrain LORDS AHRS

Examples of Robots

Naïo Technologies DINO vegetable weeding robot

C-Enduro (University of Exeter)

Effects of Environment on GNSS



Effect of Multi-Path on GPS

From "Improved GPS sensor model for mobile robots in urban terrain"

Why Model the Environment?

- It can be used to predict where localization is bad
- It can be used to improve localization
- It informs collision avoidance, path planning and manipulation

- As a result, we can use platforms in more places and do more things

DARPA Grand Challenge Robots

Oculus Quest and the Real World

How Do We Model the Environment?

- There are many representations of how we can model the environment
- These depend upon what we want to use the model for
- There are two basic kinds:
  - Occupancy grids
  - Sparse point clouds (main focus of this module)

Occupancy Grids

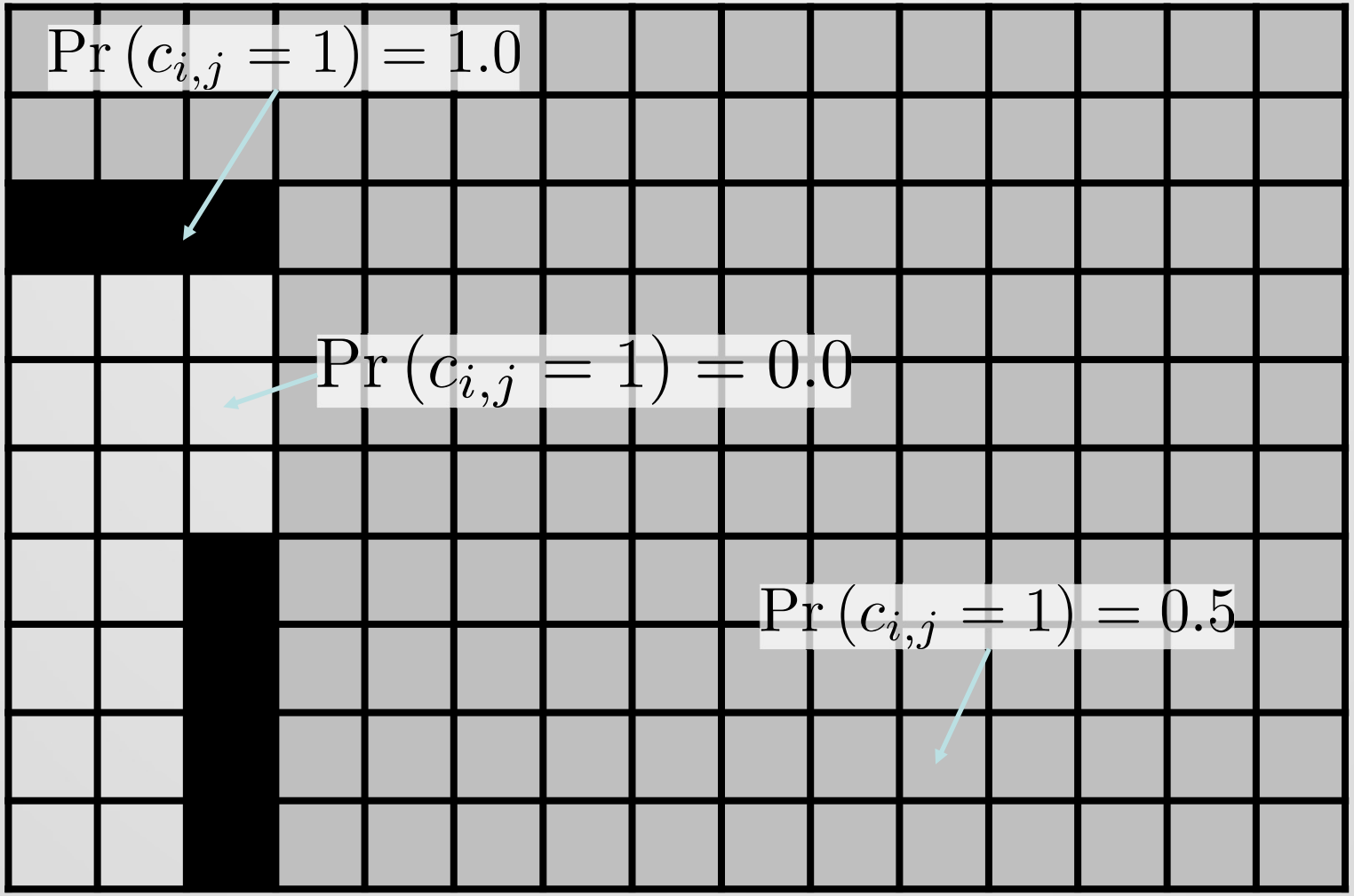
- The world is decomposed into a set of regularly-shaped volumes
- Each volume is assigned a label:

$$c_{i,j} = \begin{cases} 0 & \text{cell is free} \\ 1 & \text{cell is occupied} \end{cases}$$

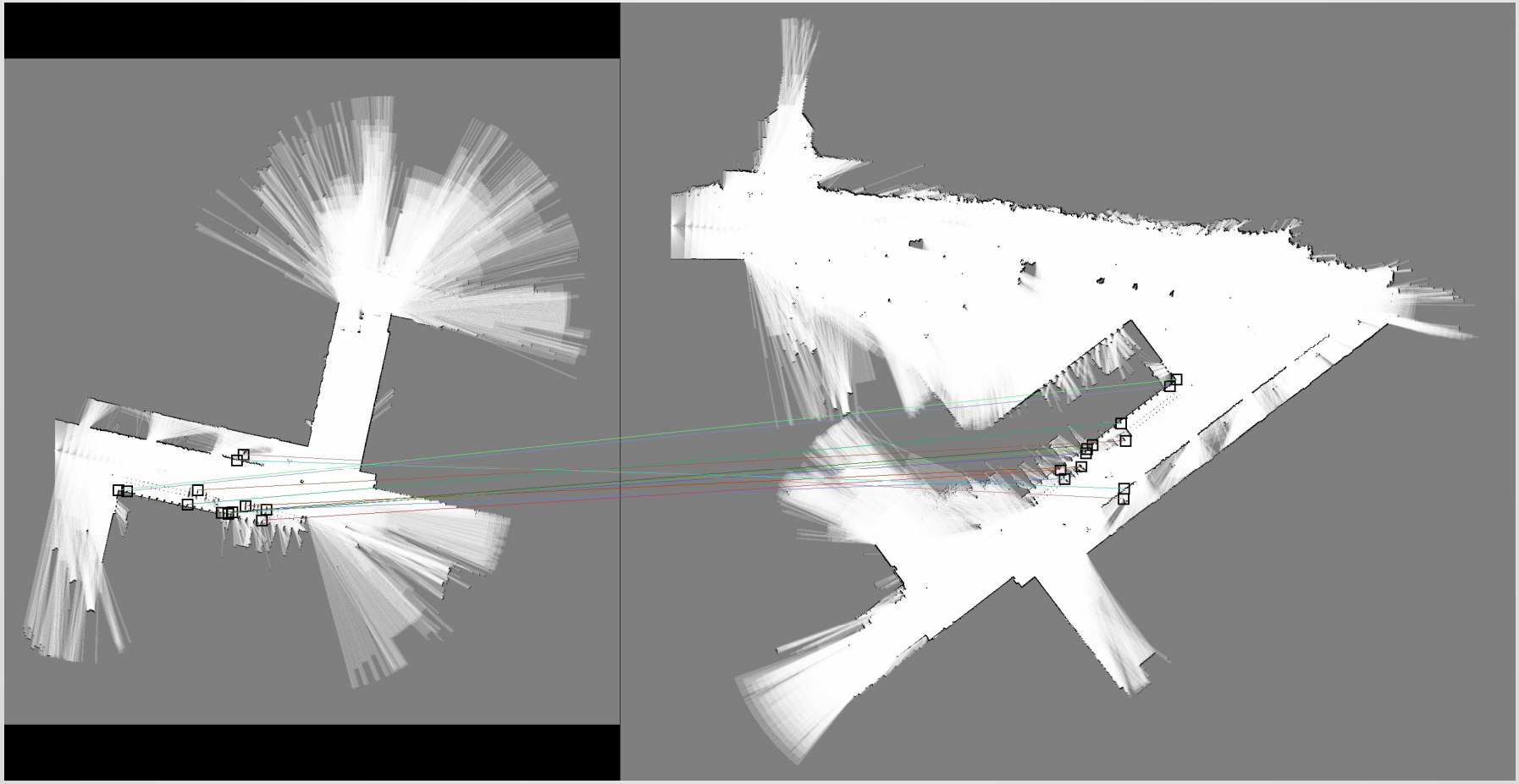
- The occupancy grid, stores for each cell

$$\Pr\left(c_{i,j} = 1\right)$$

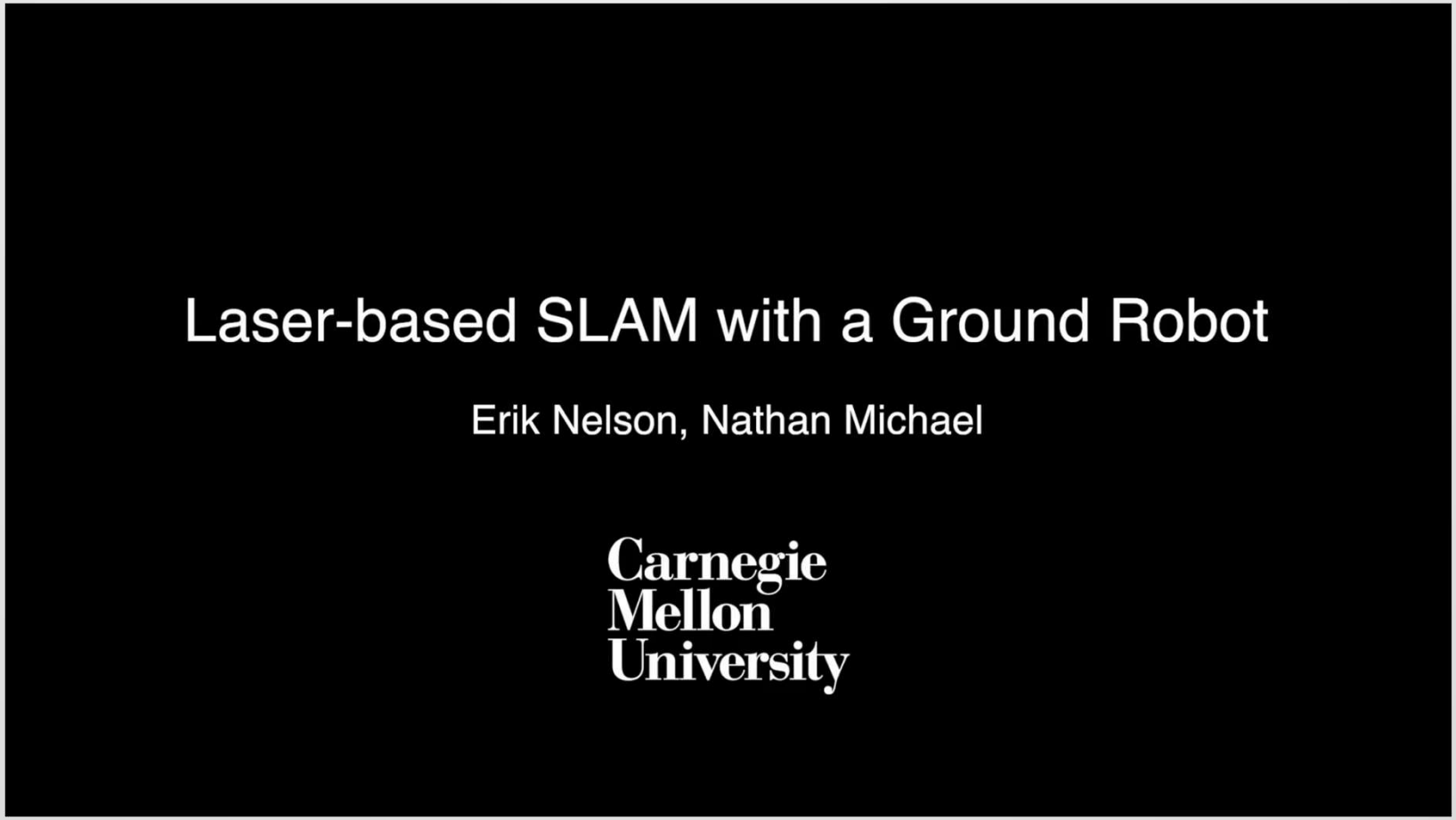
Occupancy Grid Map



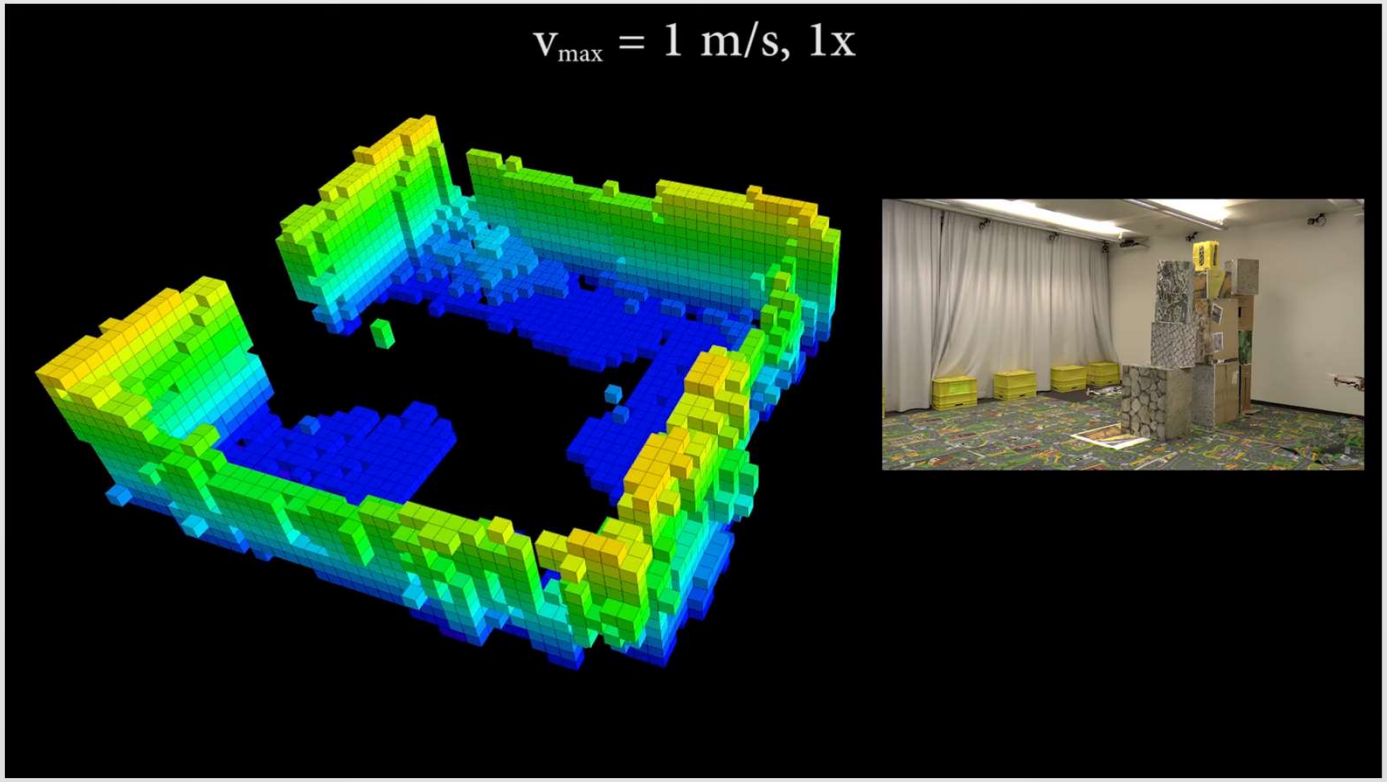
Probabilistic Occupancy Grids



SLAM and Indoor Spaces

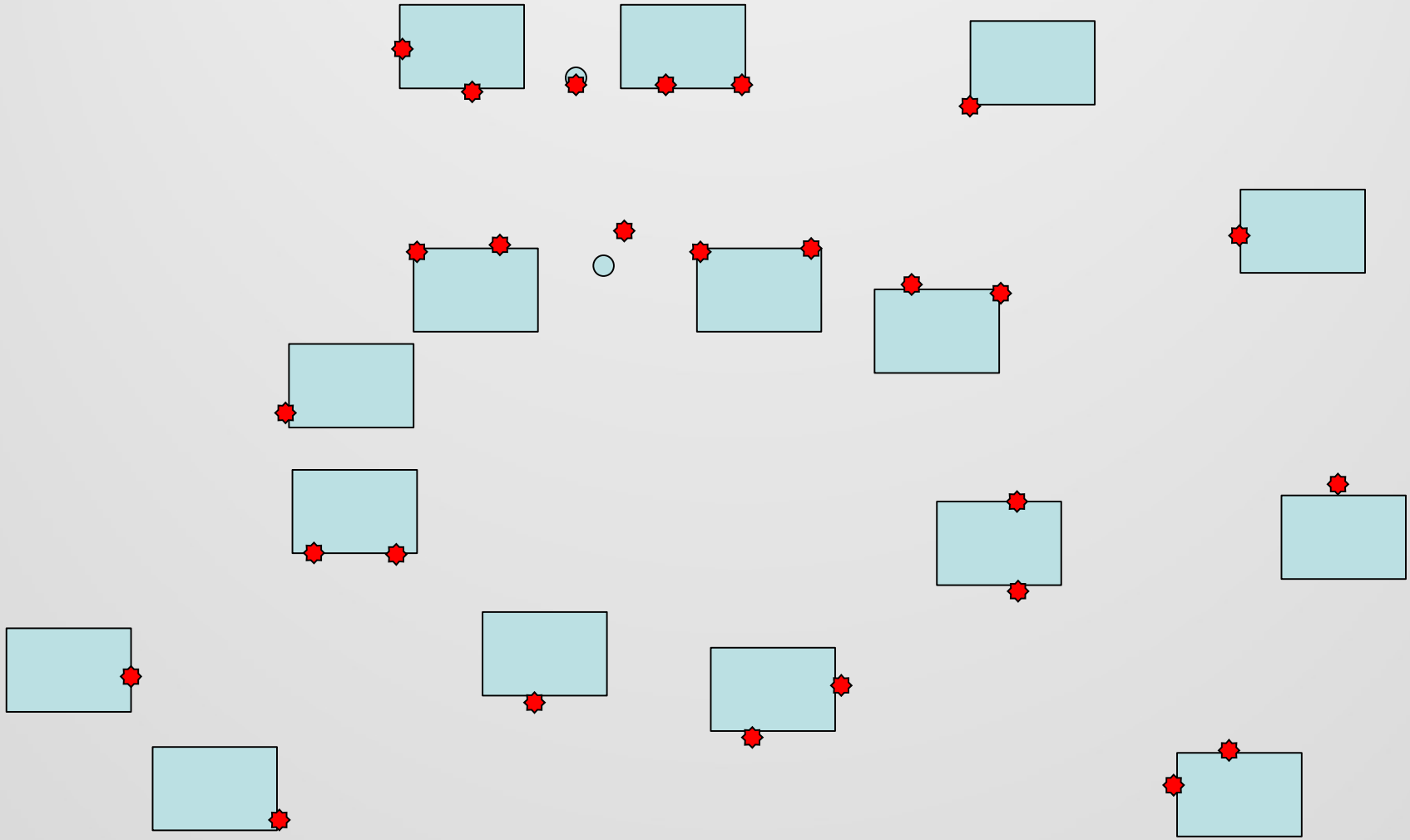


3D Occupancy Grids



Pointclouds and Occupancy Volumes

Environment with Landmarks



Sparse Point Clouds and Computer Vision

Characteristics of Landmarks

- They must be detectable by the sensing systems and feature detection algorithms
- They must be separable from one another
- When observing them, spatial information can be obtained

- These can be most easily appreciated with computer vision

Characteristics of Landmarks

- They must be detectable by the sensing systems and feature detection algorithms
- *They must be distinct from one another*
- *When observing them, spatial information can be obtained*

Landmarks are Artificially Placed Targets

- The easiest case is when the targets are artificial
- They have some distinctive properties about them which makes them easy to detect
- They can provide additional information (e.g., numerical ID) through a coded target

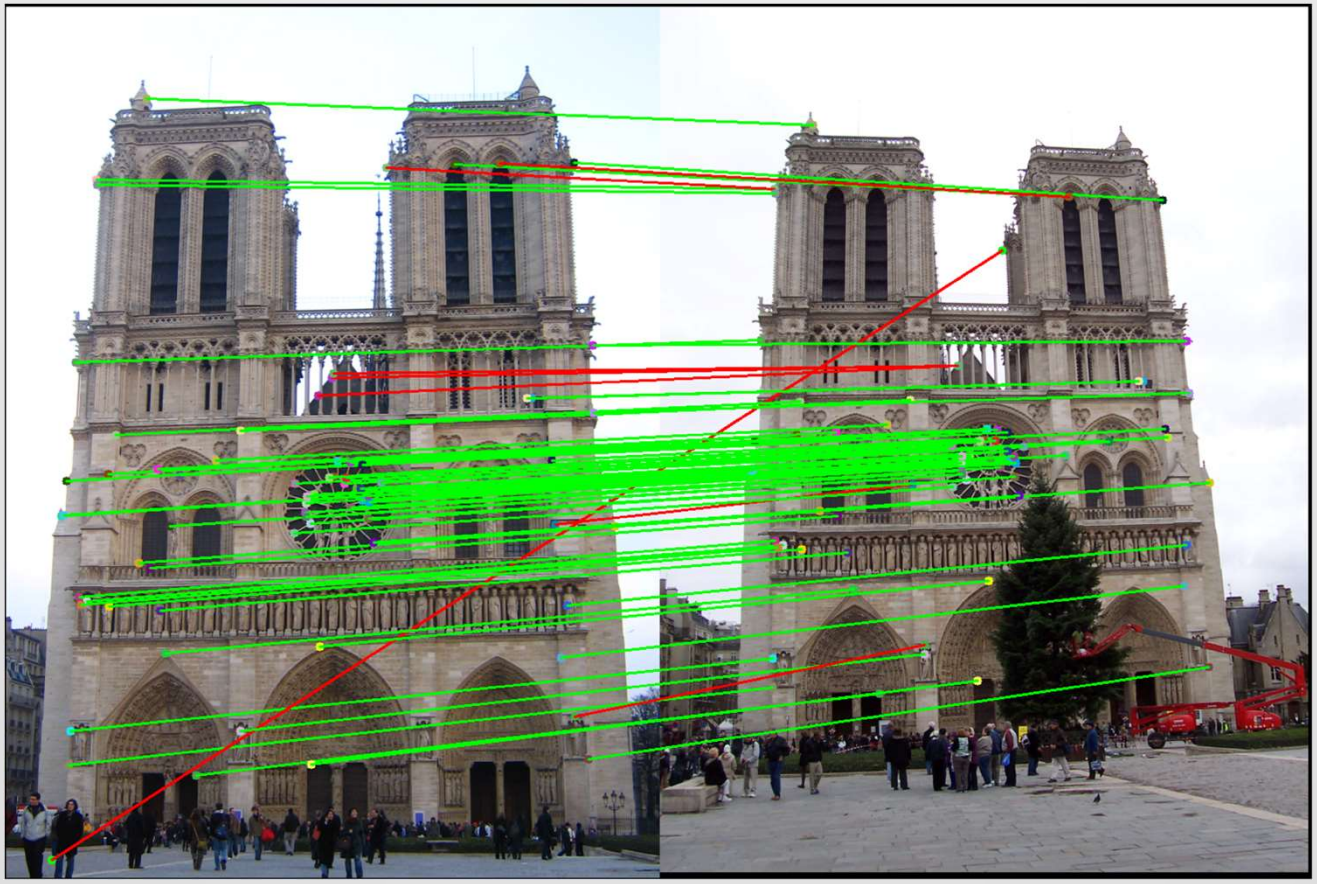
Film and TV Production

Ceiling-Mounted Markers

Ceiling-Mounted Markers

Installing Artificial Markers

Naturally Occurring Features



From https://www.cc.gatech.edu/~hays/compvision/proj2/

ORB-SLAM2


ORB-SLAM
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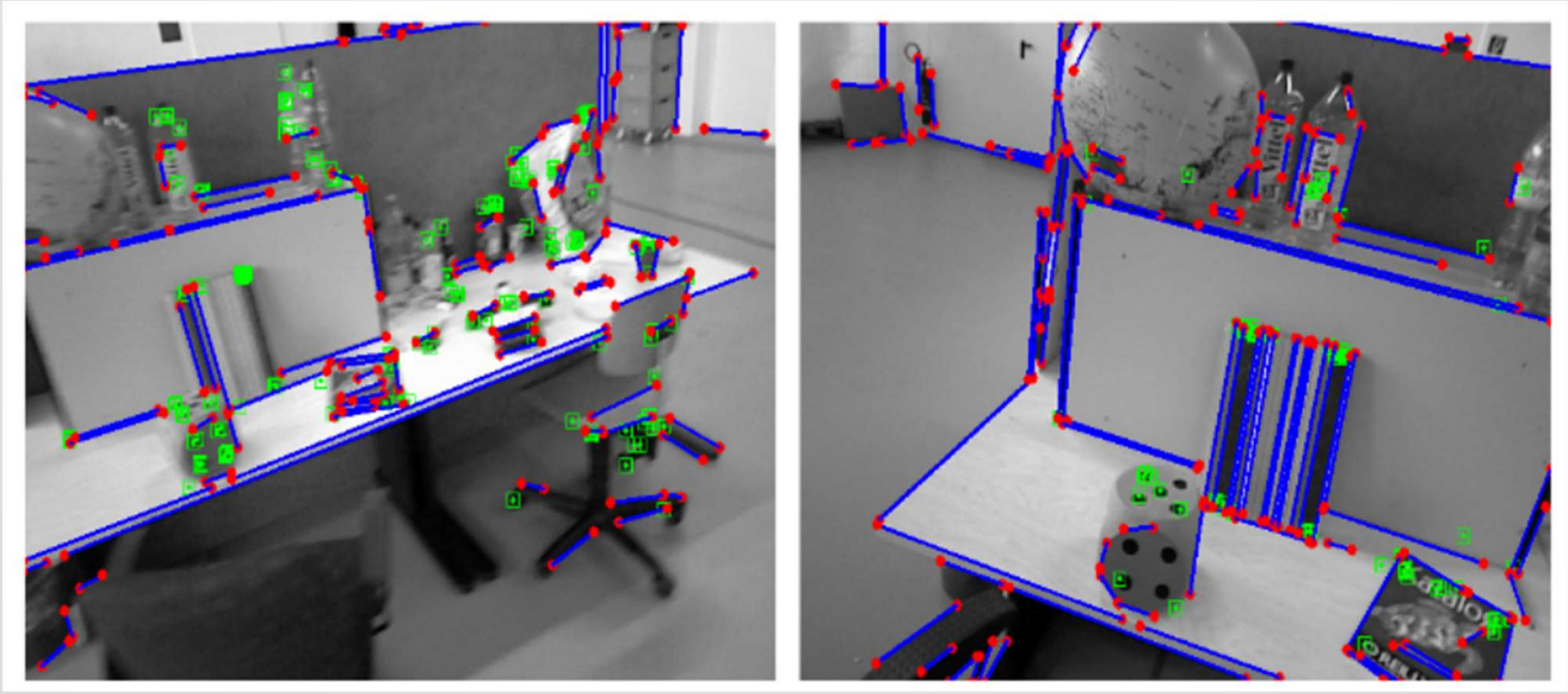
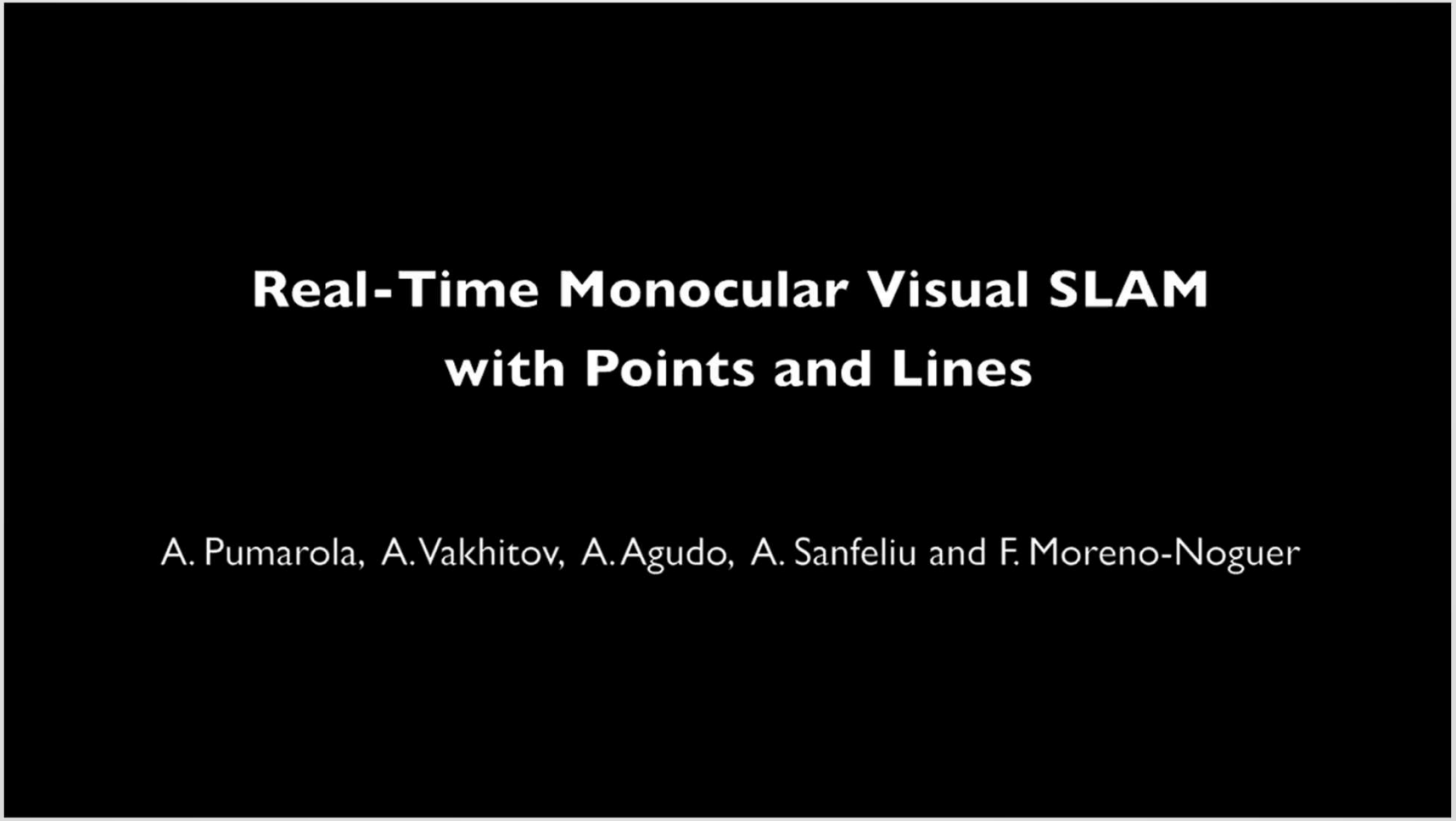
Zaragoza

Points and Edges



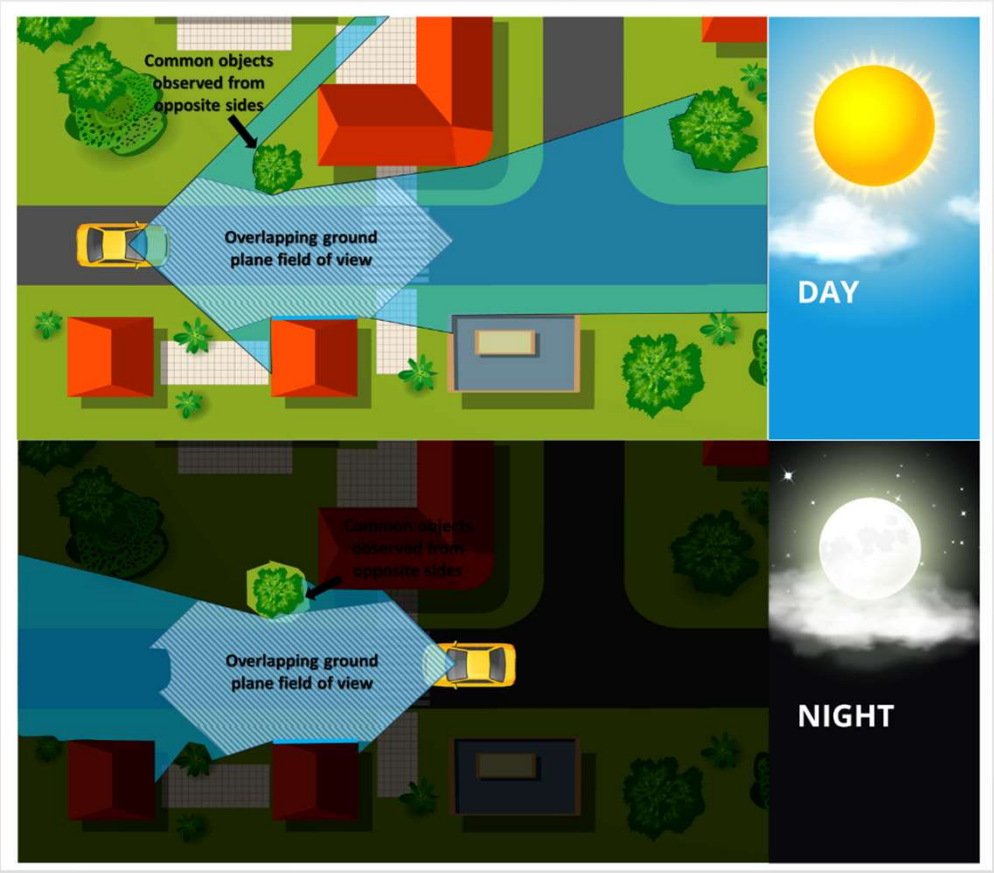
PL-SLAM: Real-Time Monocular Visual SLAM with Points and Lines,
Pumarola et al, 2017

Points and Edges



From PL-SLAM: Real-Time Monocular Visual SLAM with Points and Lines

Robust Feature Recognition



"LoST? Appearance-Invariant Place Recognition for Opposite Viewpoints using Visual Semantics", Garg et al., RSS 2018

Robust Semantic Matching

"LoST? Appearance-Invariant Place Recognition for Opposite Viewpoints using Visual Semantics", Garg et al., RSS 2018

Characteristics of Landmarks

- *They must be detectable by the sensing systems and feature detection algorithms*
- They must be distinct from one another
- *When observing them, spatial information can be obtained*

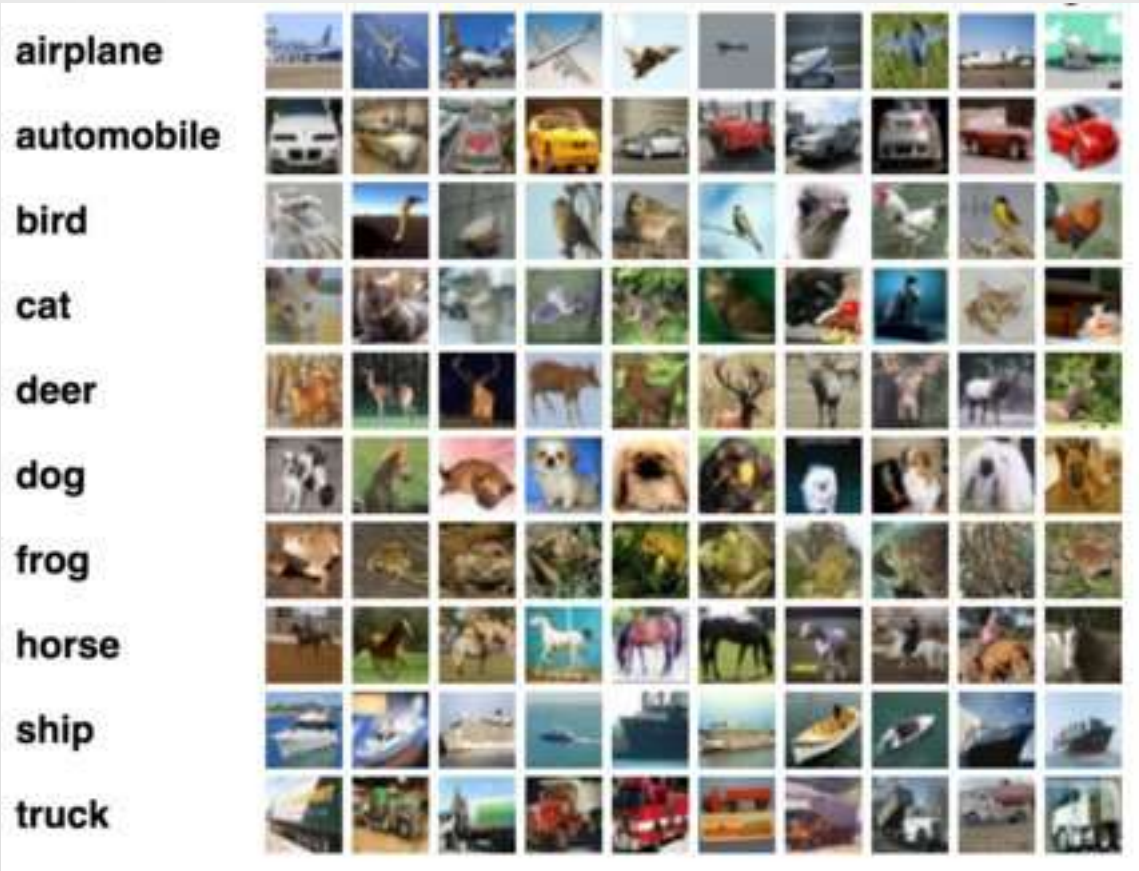
Distinct Landmarks

Non-Distinct Landmarks

Characteristics of Landmarks

- *They must be detectable by the sensing systems and feature detection algorithms*
- *They must be distinct from one another*
- When observing them, spatial information can be obtained

Image Labelling Detection, no Localization



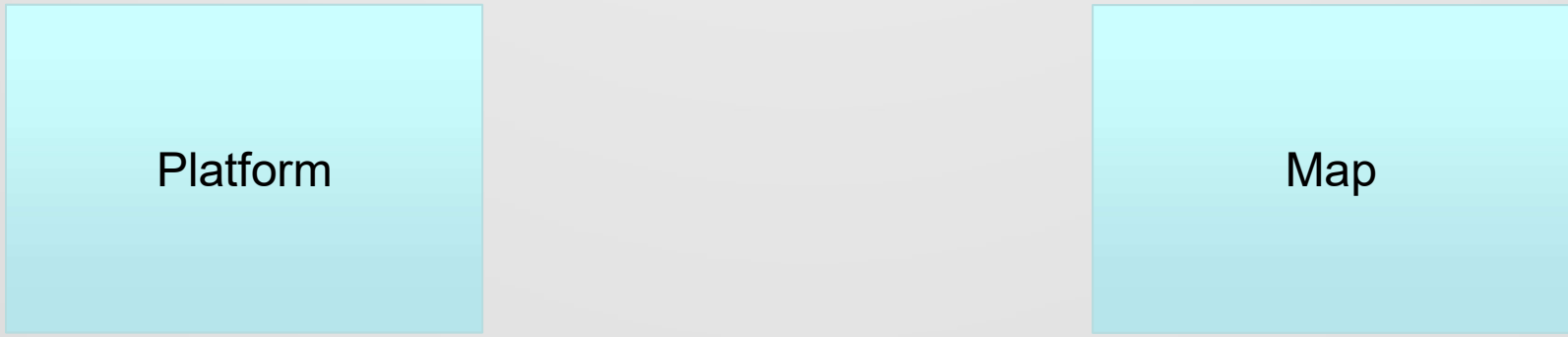
From Achieving 90% accuracy in Object Recognition Task on CIFAR-10 Dataset with Keras: Convolutional Neural Networks

Laser Scanners

- These use active projectors to broadcast structured light in some way and record both the angle and range

- They are very widely used in self driving cars, user interaction devices (Kinect, HoloLens, MagicLeap, LeapMotion), and increasingly mobile phones

Localization, Mapping, Odometry and SLAM



Localization

The platform uses the map to localise

Localization in Cities Using Street View

From [“MAV Urban Localization from Google Street View Data”]

Mapping

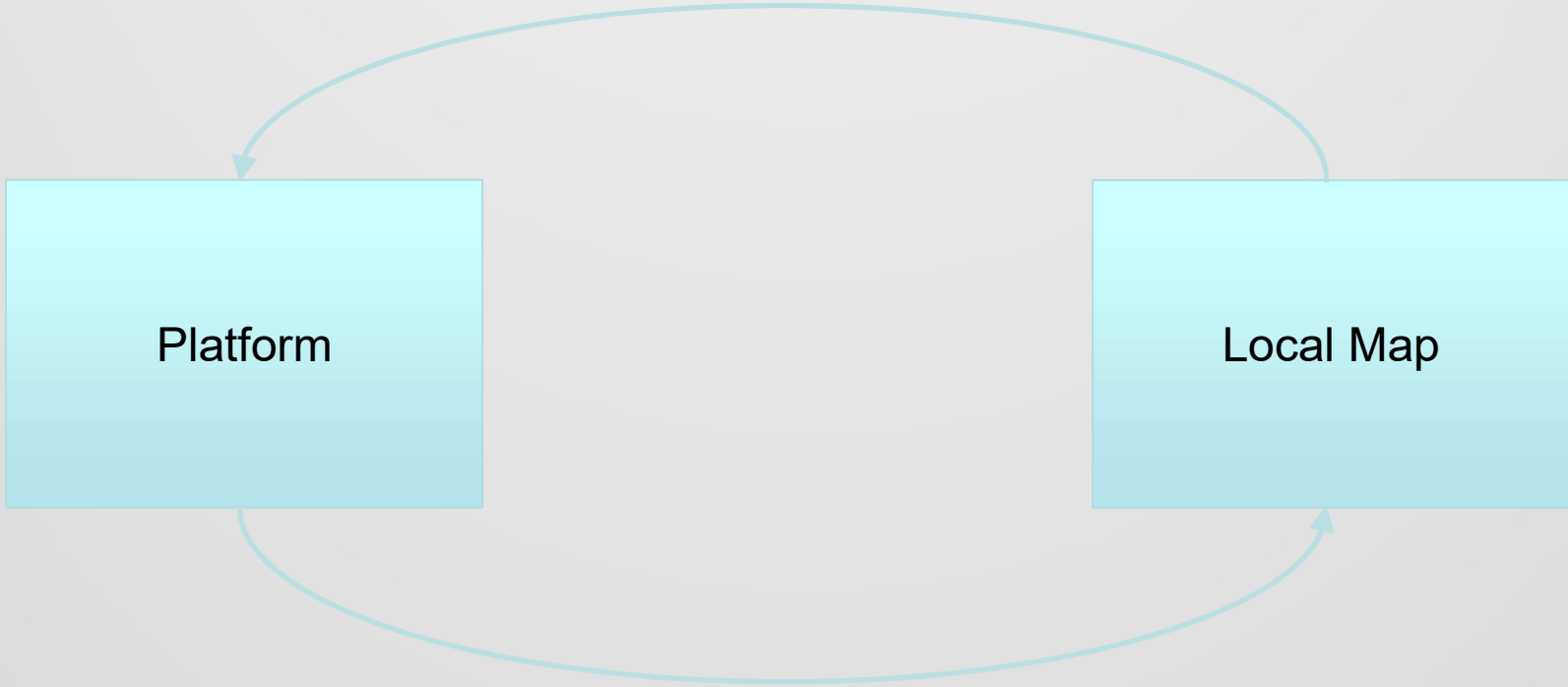
The platform position is used to build the map

High Precision Mobile Scanning

Leica Absolute Tracker AT60, Leica T-Scan and use case from Hexagon MI

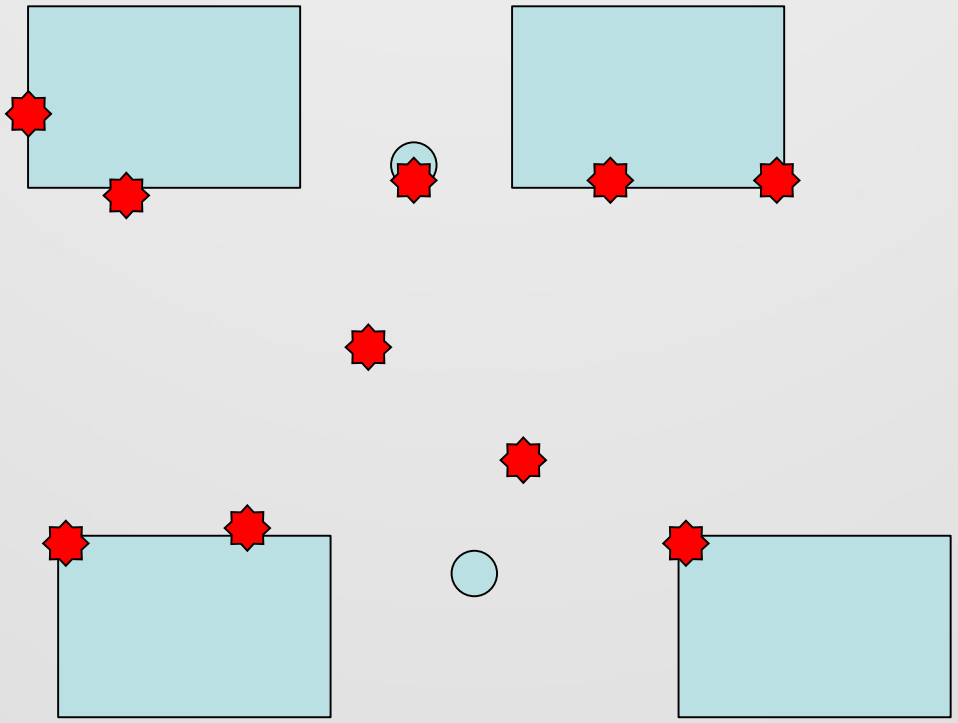
Odometry

The platform uses the local map to localise



The local map uses the platform to build itself

Illustrating Odometry



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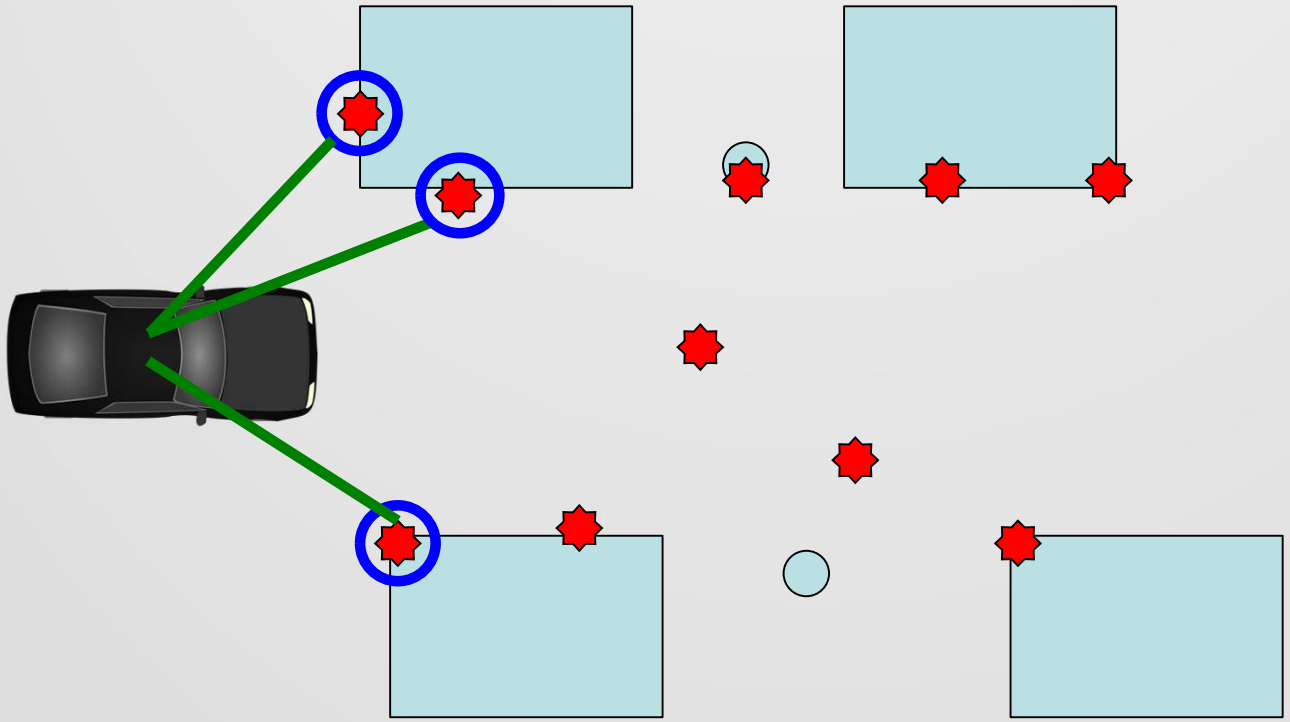

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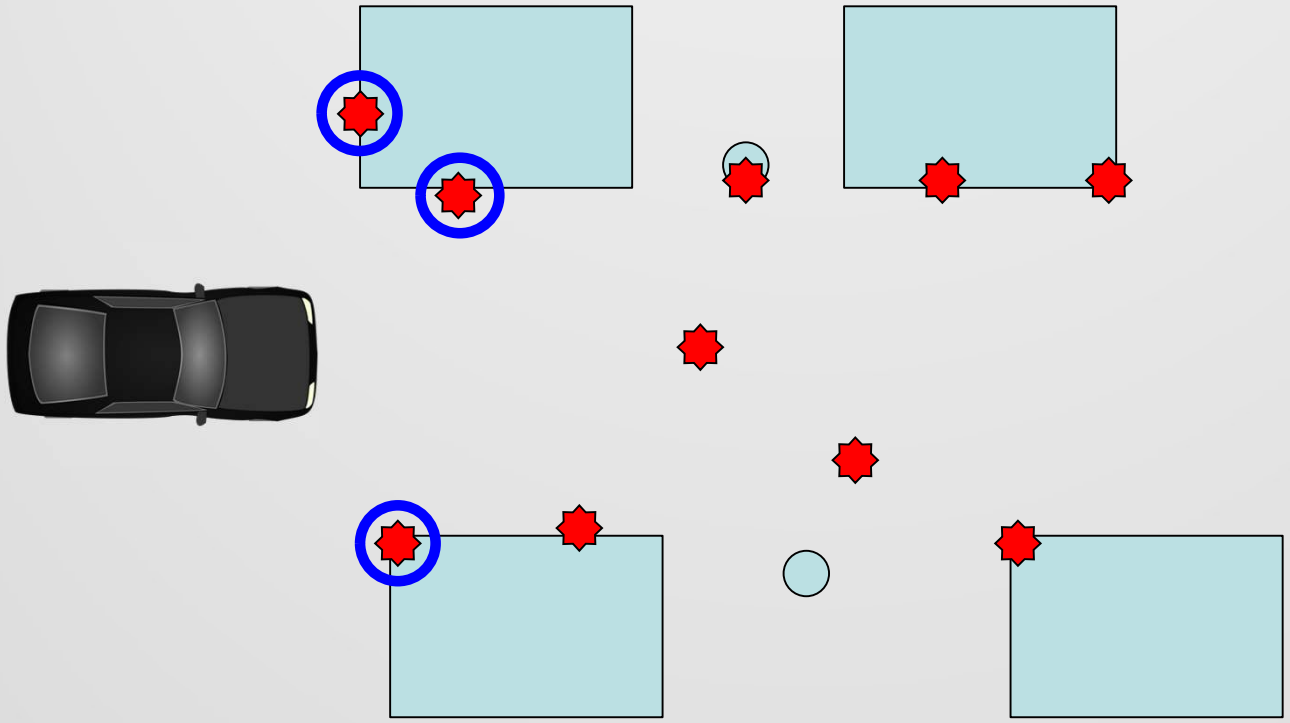

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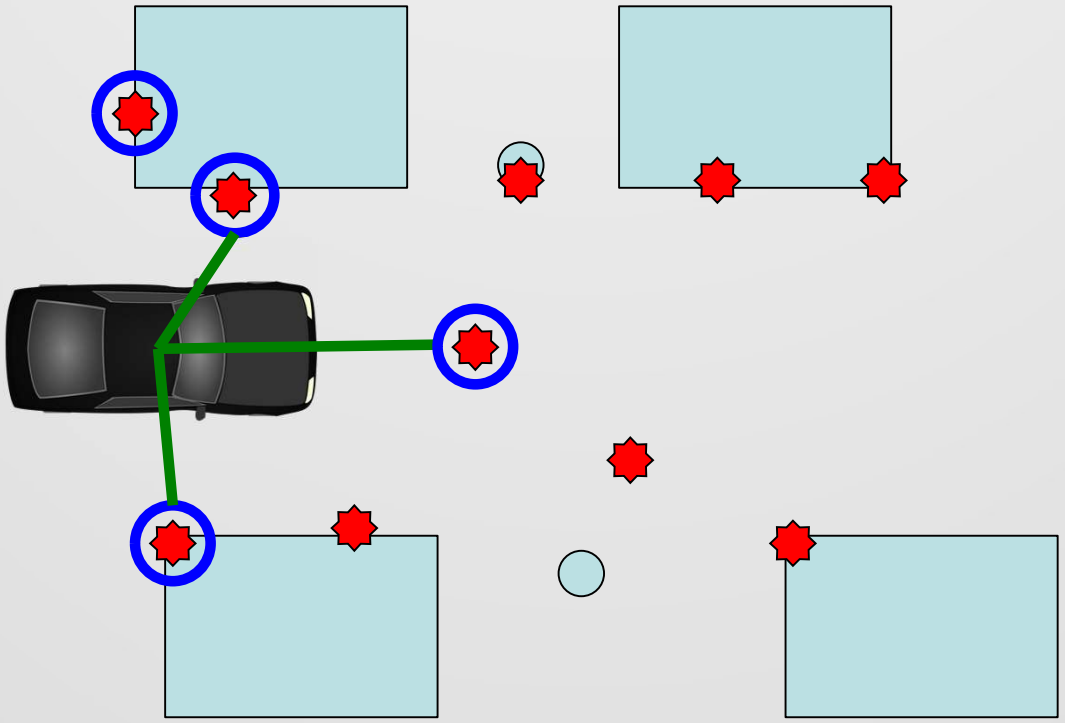

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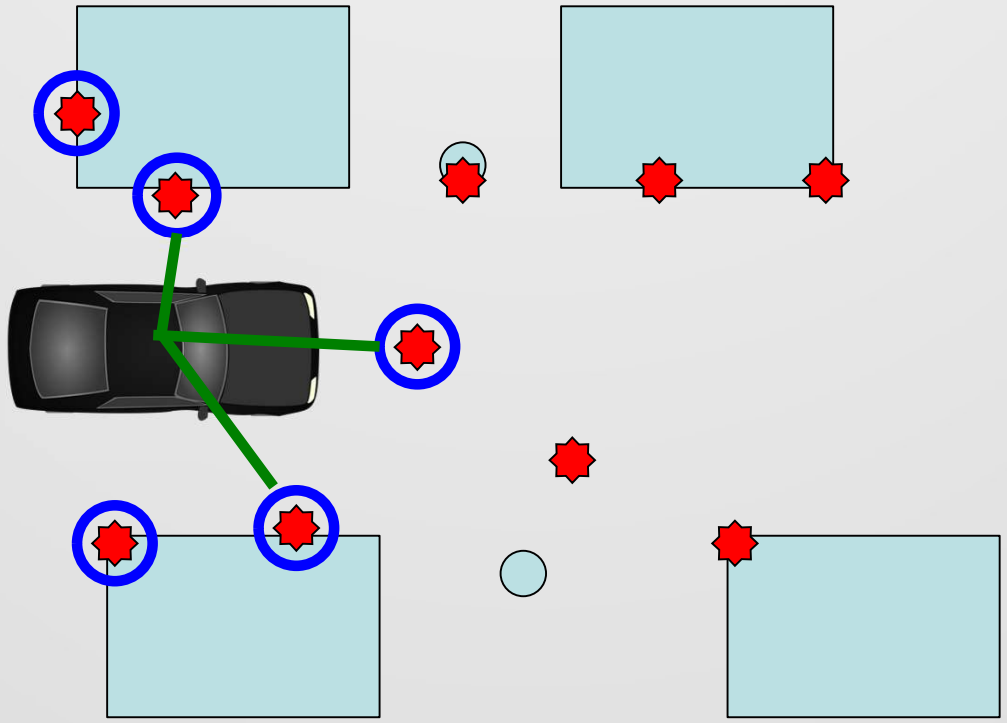
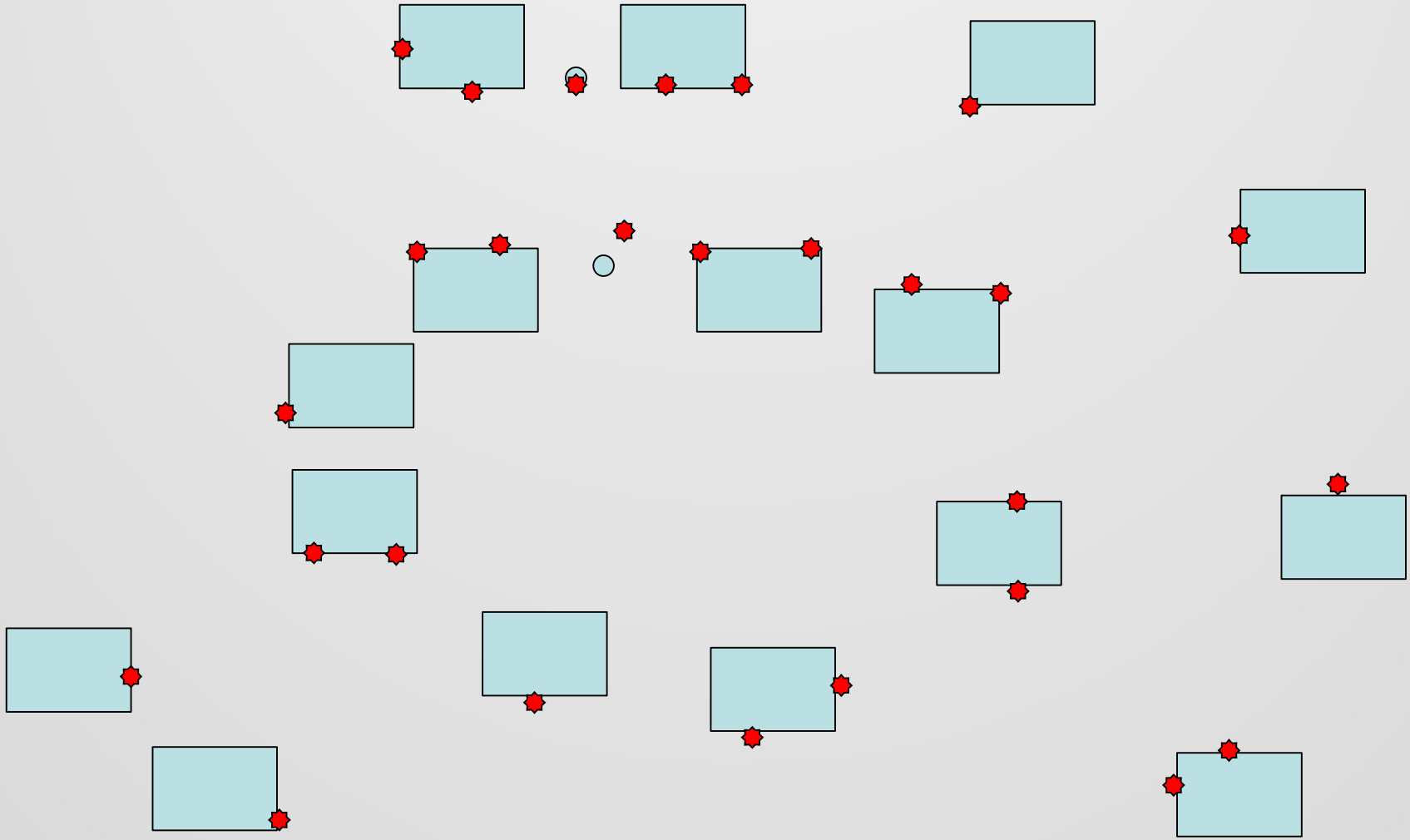


High-Level View of Odometry



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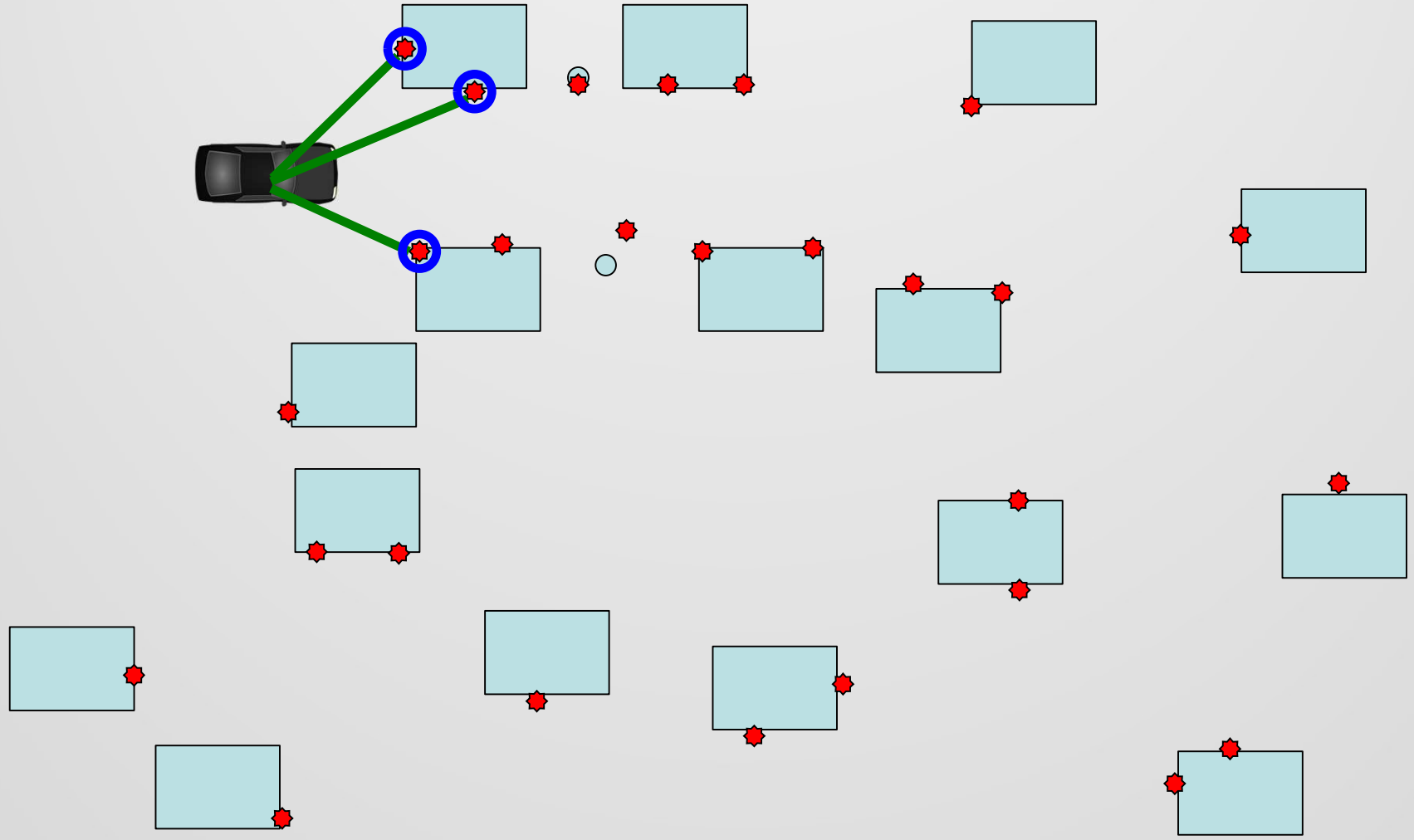

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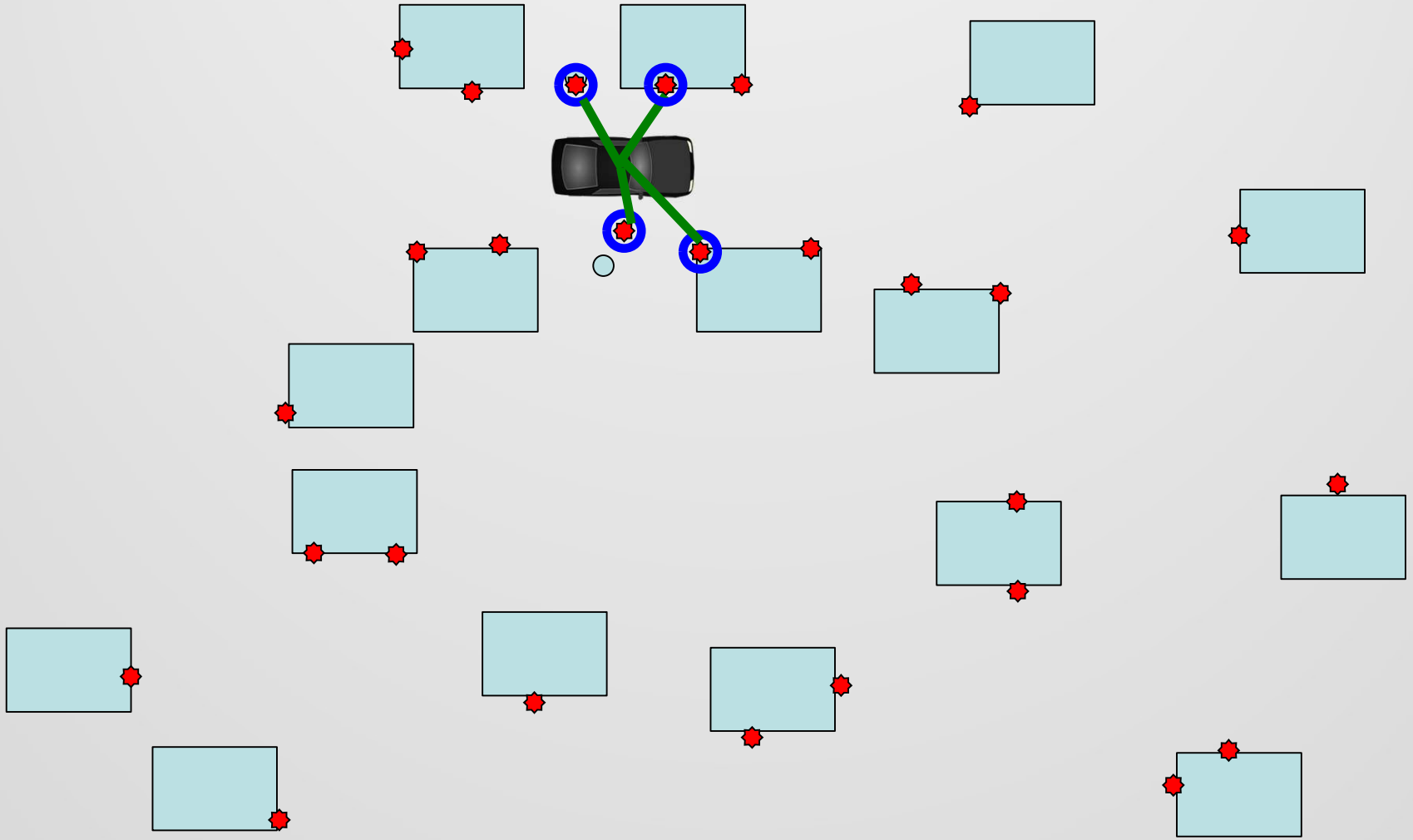

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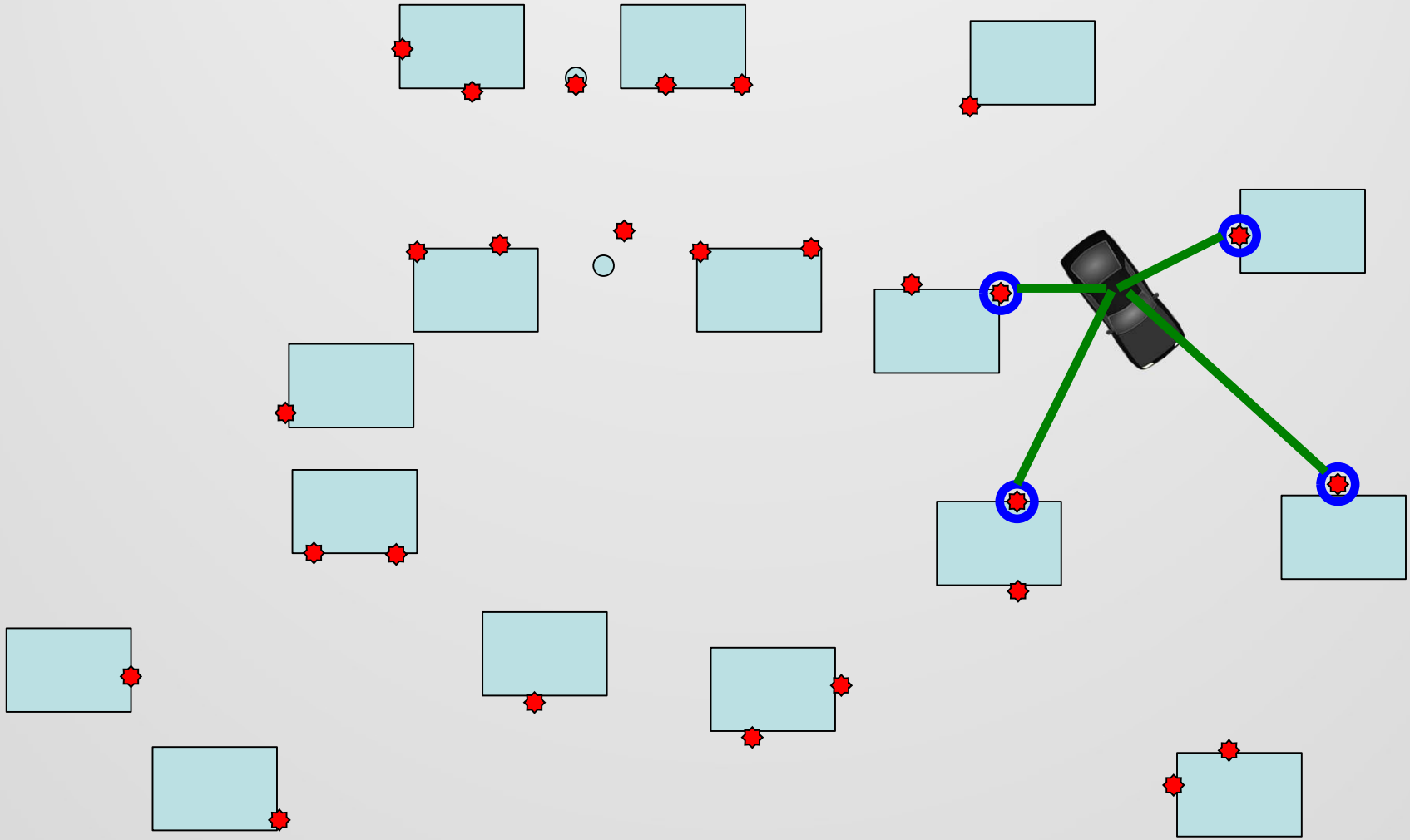

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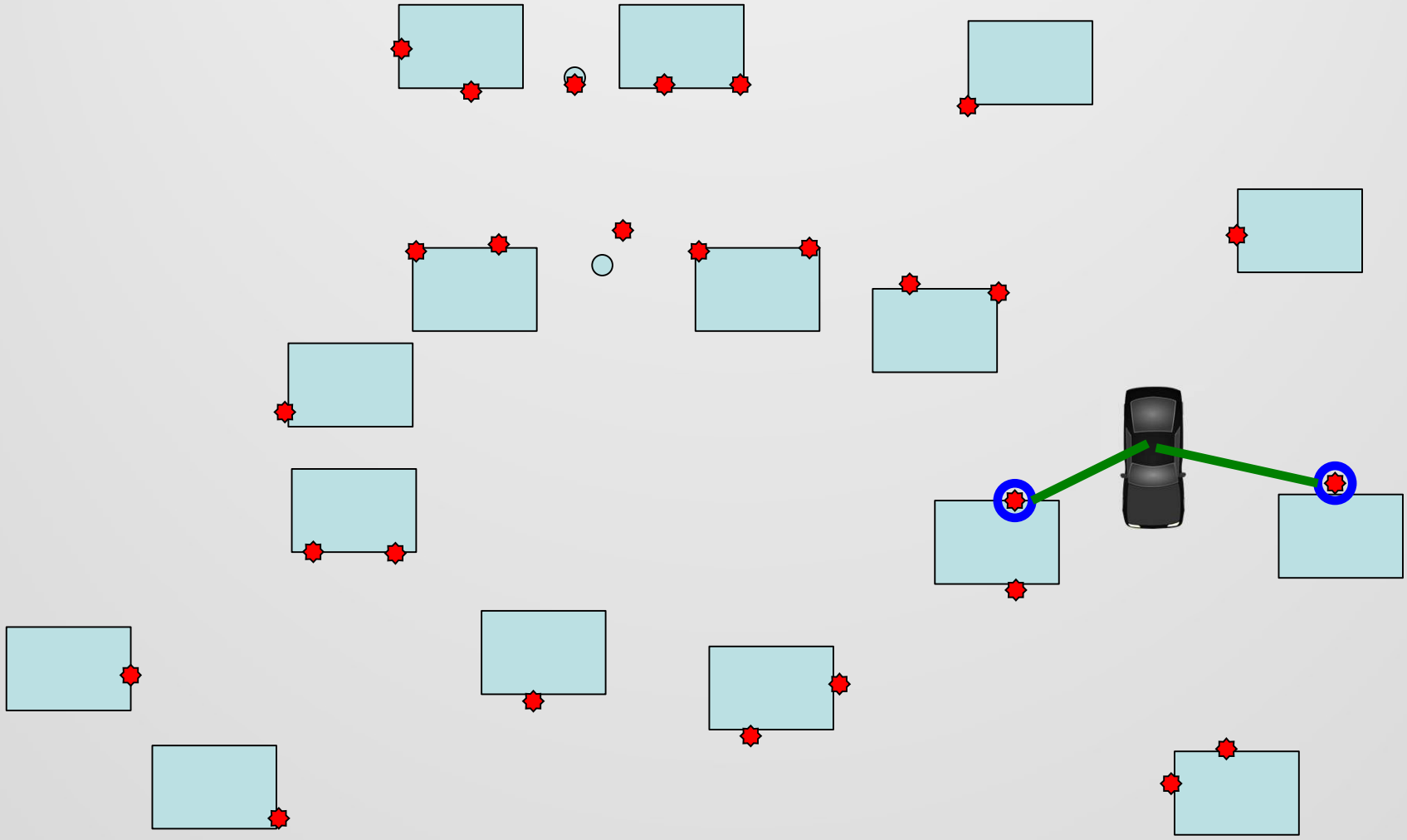

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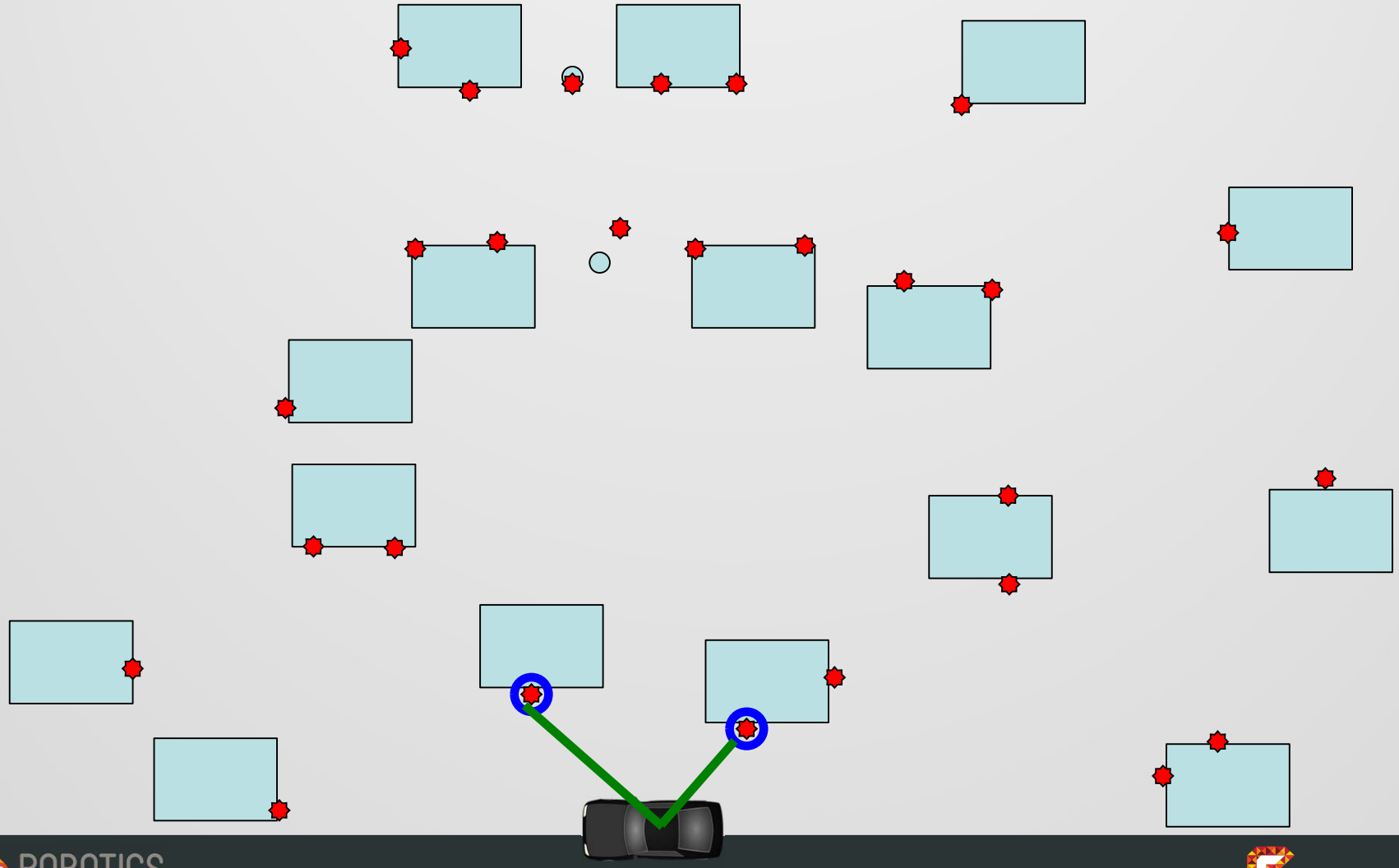

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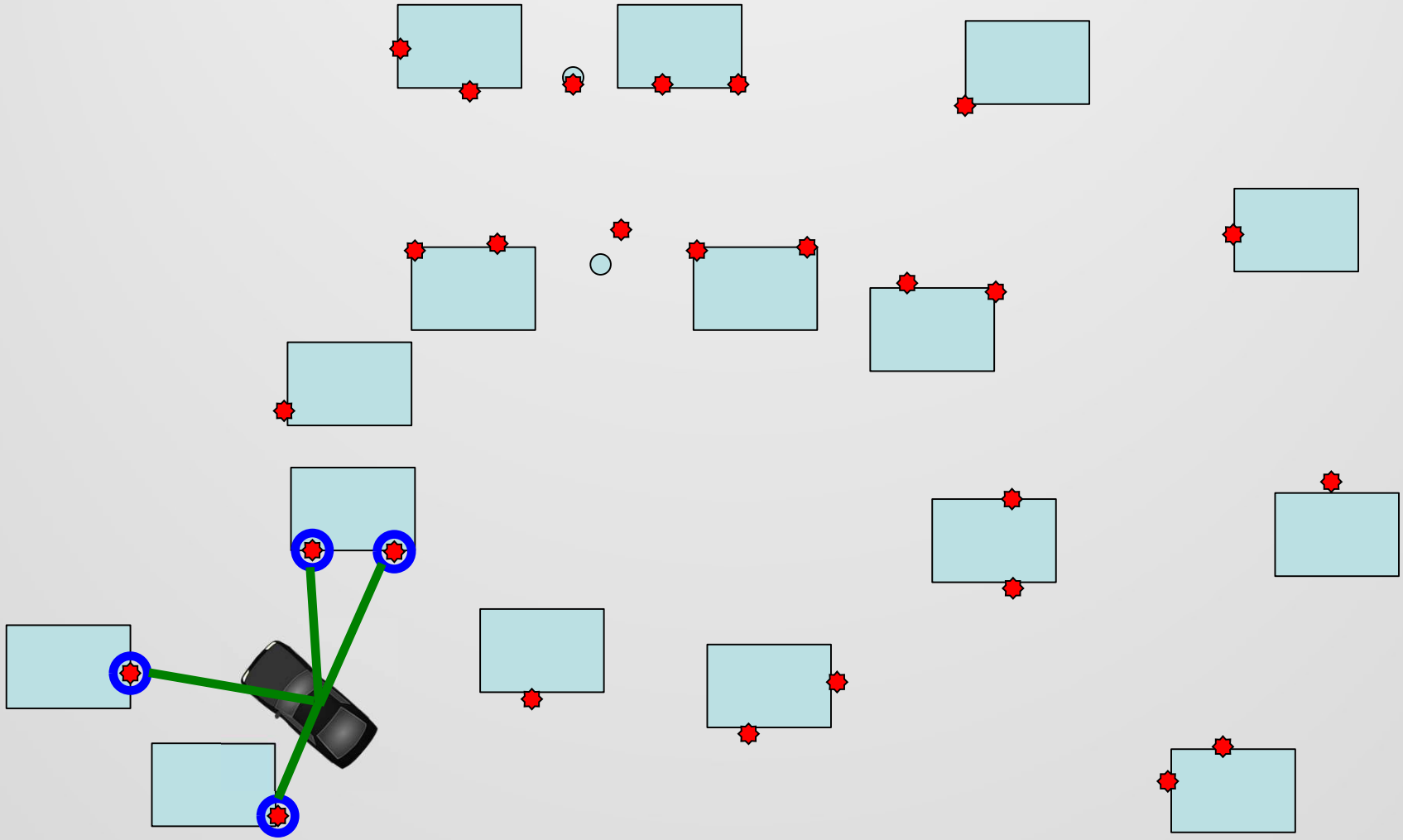
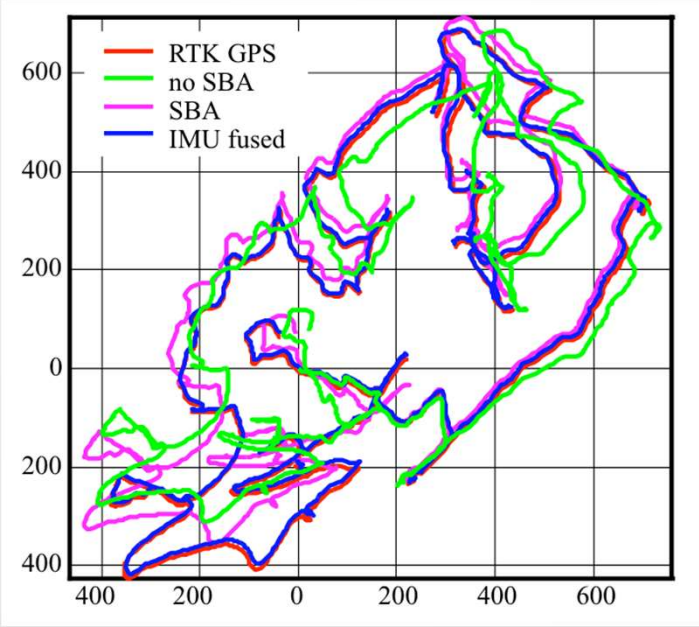


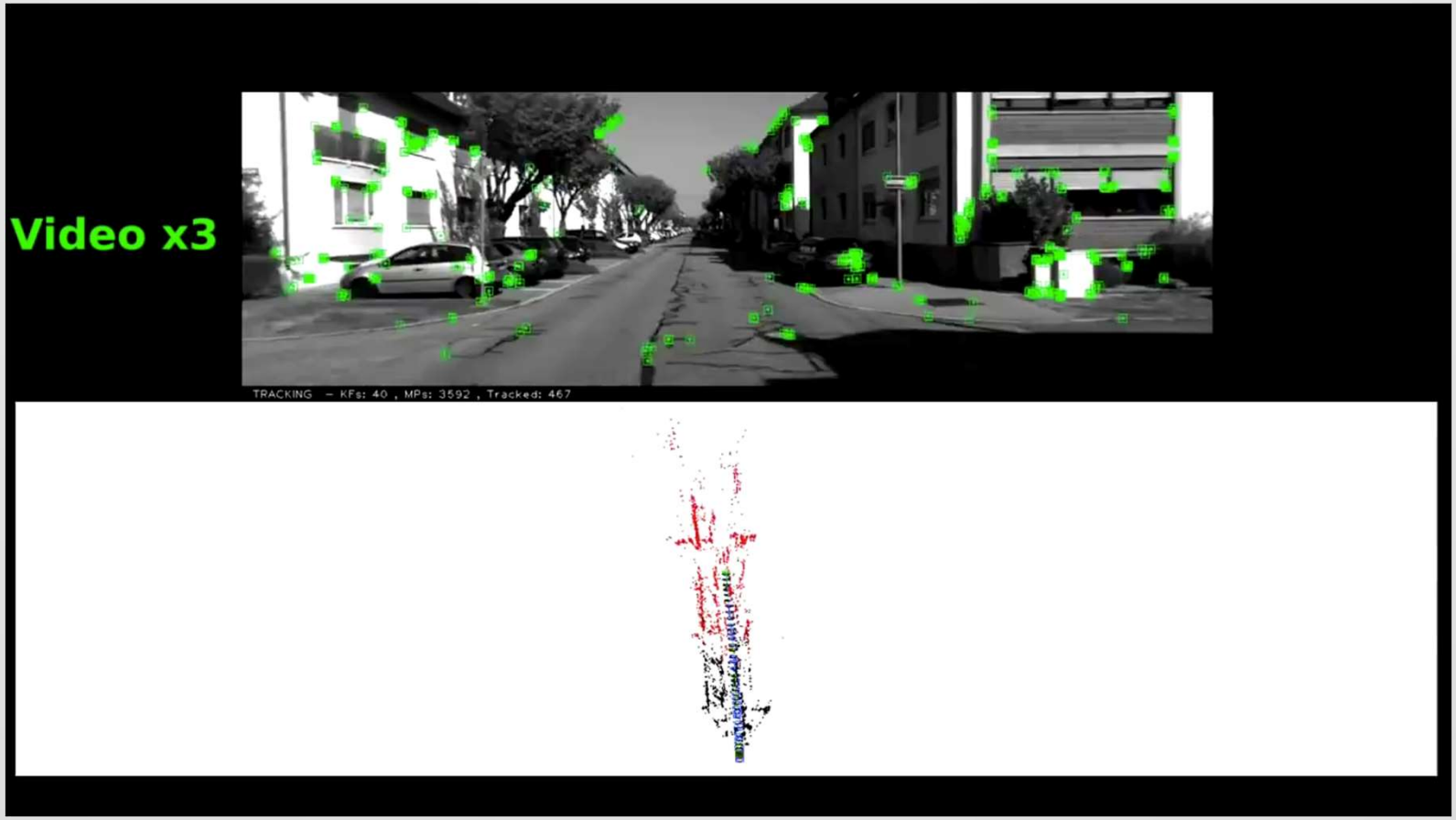
Visual Odometry Can be Highly Effective



		RMS error in XYZ
Little Bit	VO No SBA	97.41 (1.0%)
	VO SBA	45.74 (0.49%)
	VO No SBA + IMU	7.83 (0.08%)
	VO SBA + IMU	4.09 (0.04%)

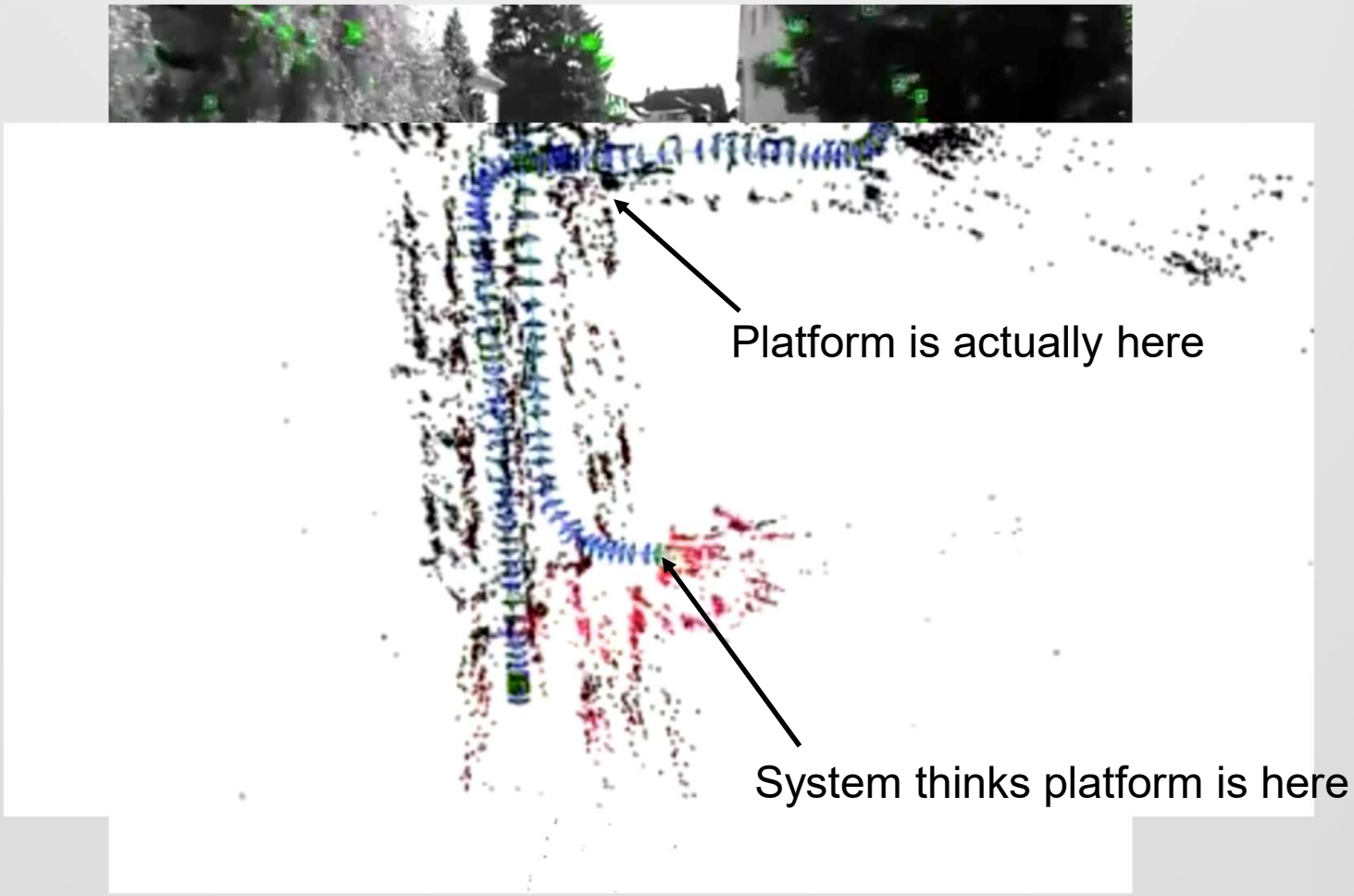
Rough Terrain Visual Odometry, M. Agrawal, K. Konolige, 2007

ORB-SLAM Running as Visual Odometry



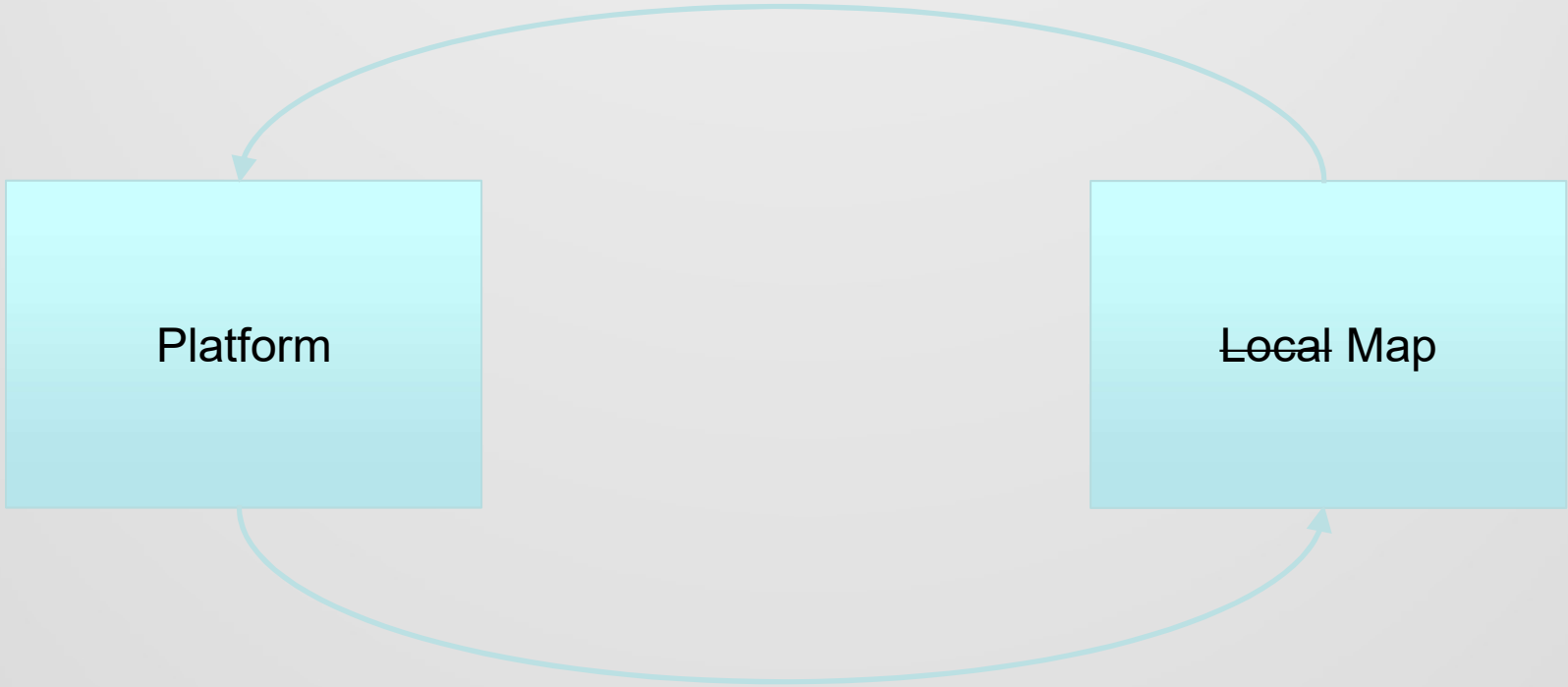
From https://www.youtube.com/watch?v=8DISRmsO2YQ
(00:15-00:59.4 seconds)

Drift in ORB-SLAM



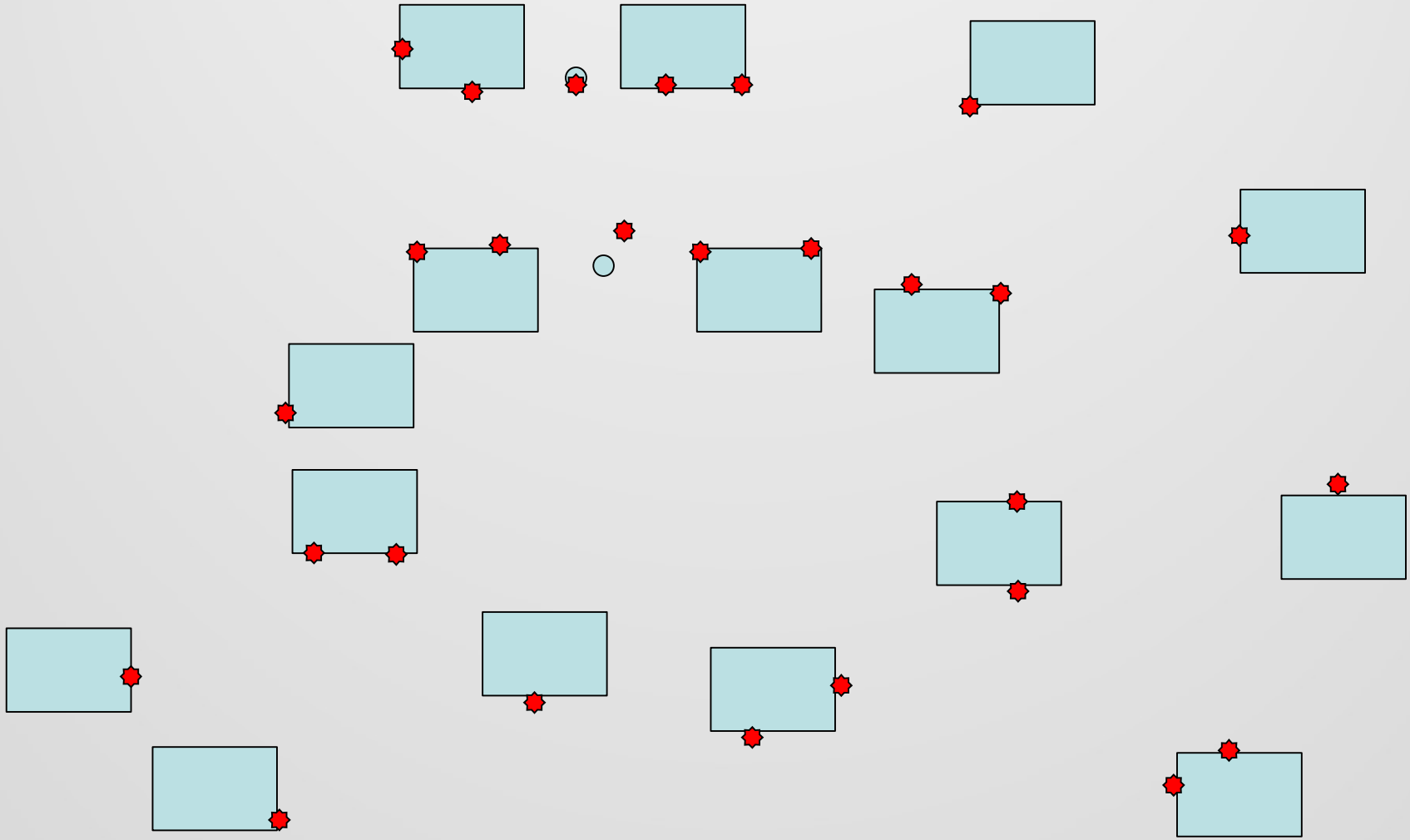
SLAM

The platform uses the ~~local~~ map to localise



The ~~local~~ map uses the platform to build itself

High-Level View of Self-Mapping (SLAM)



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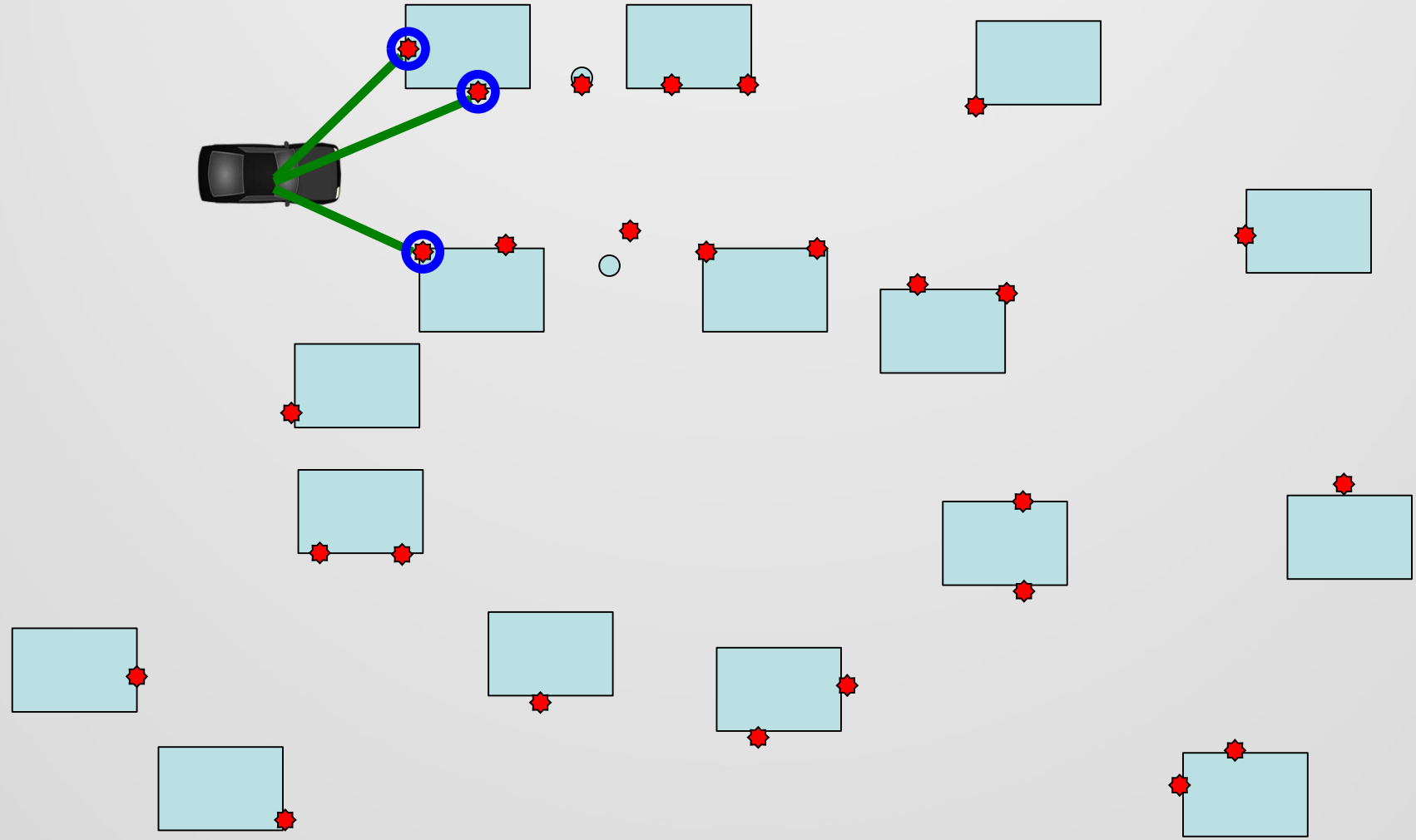

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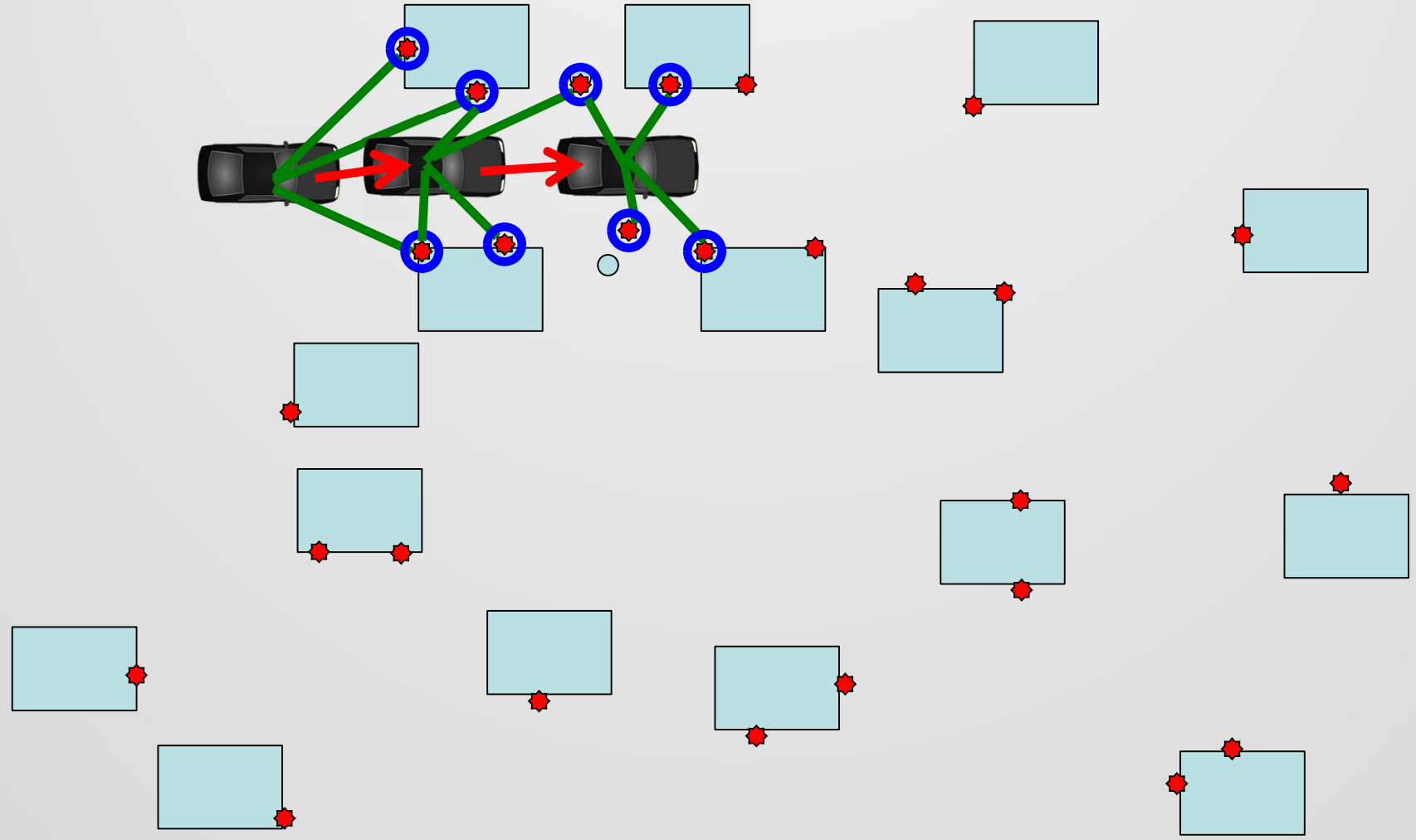

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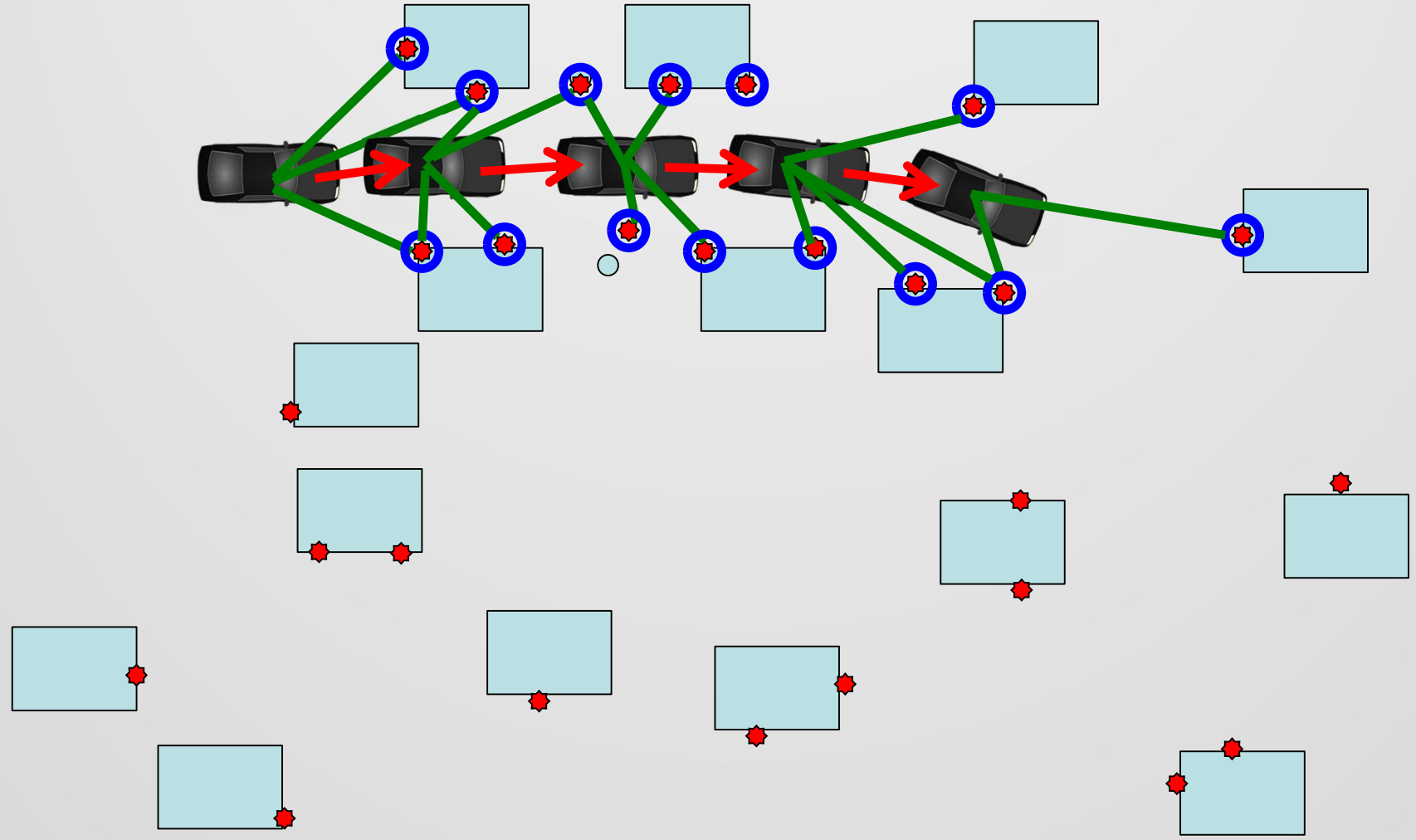

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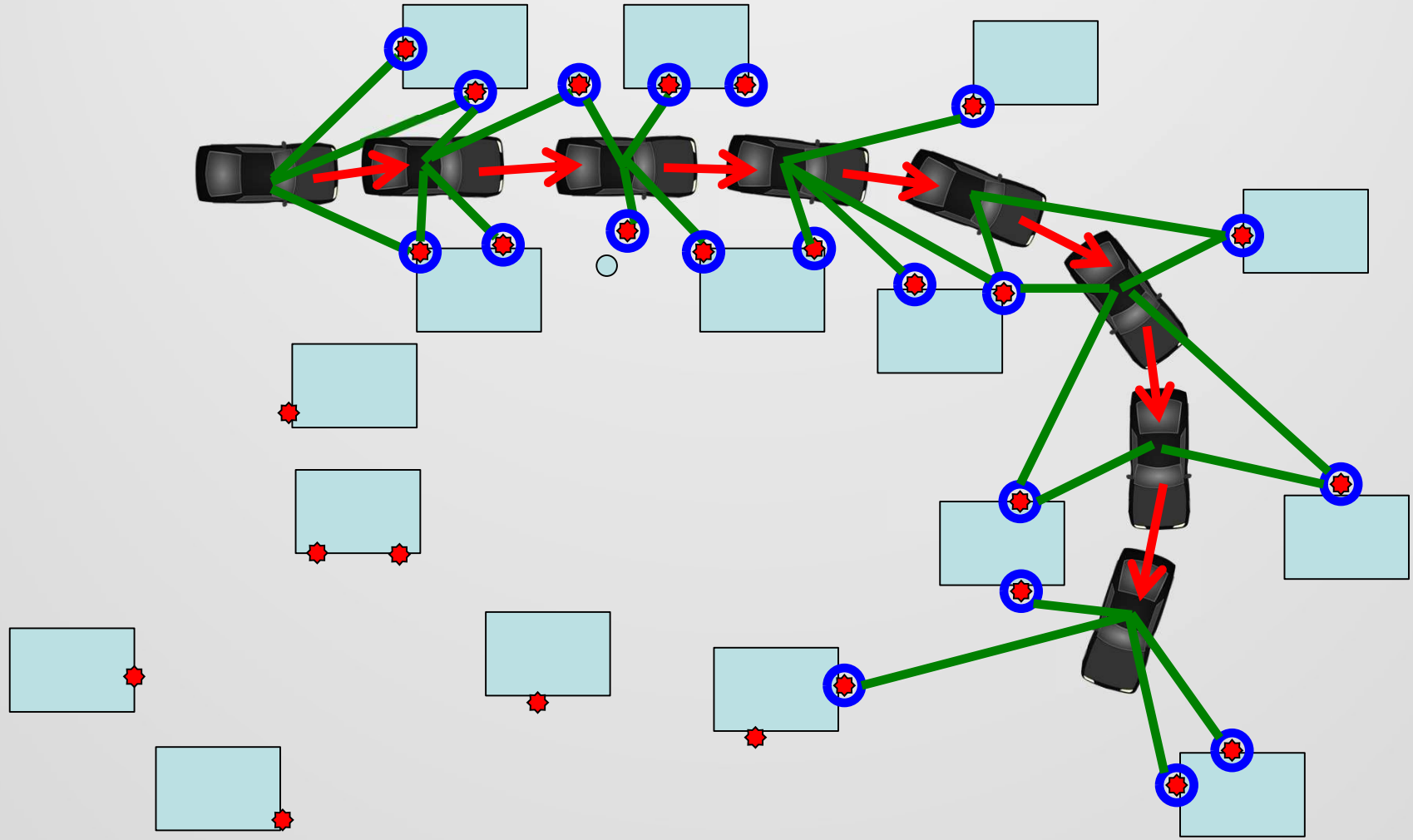

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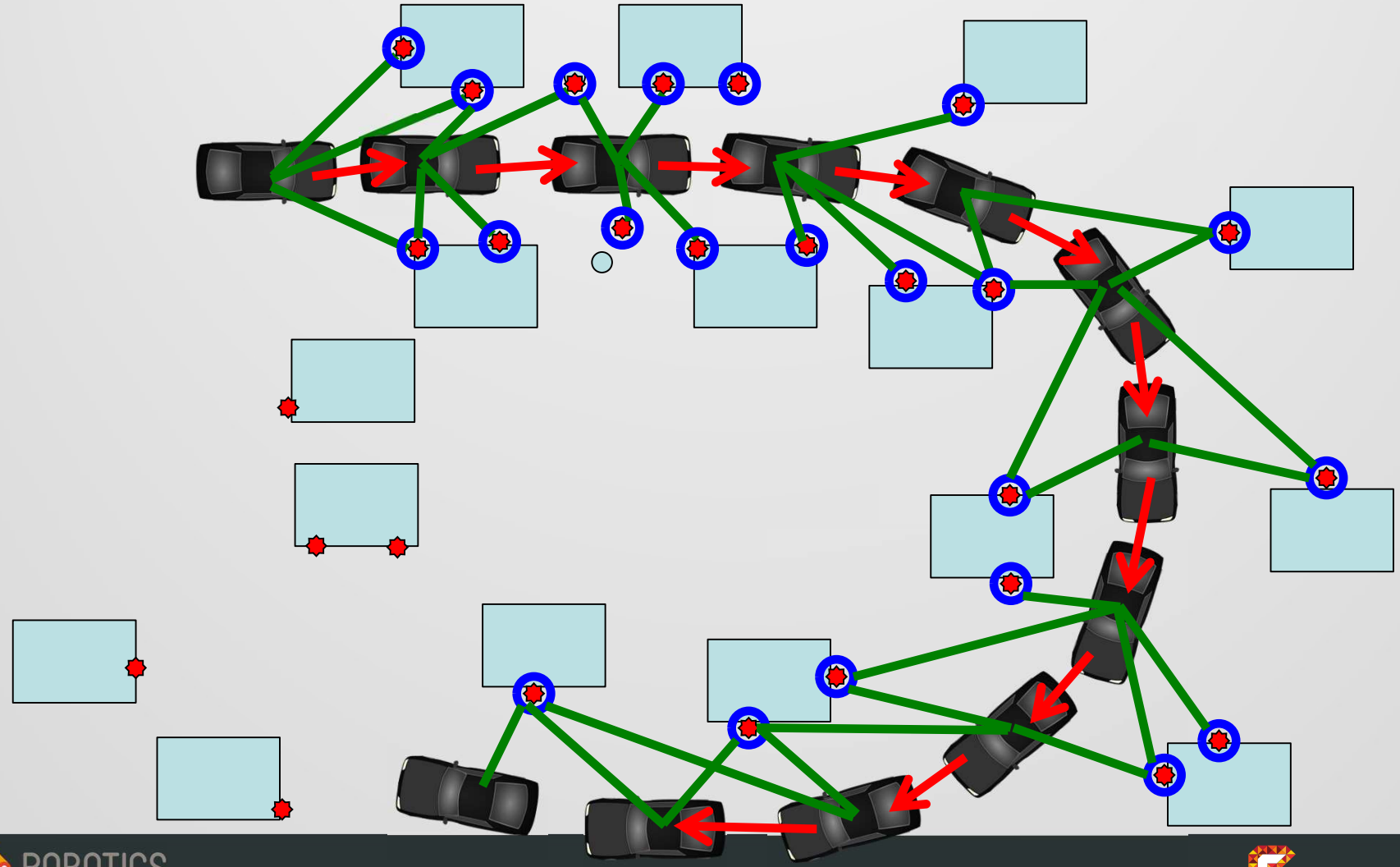

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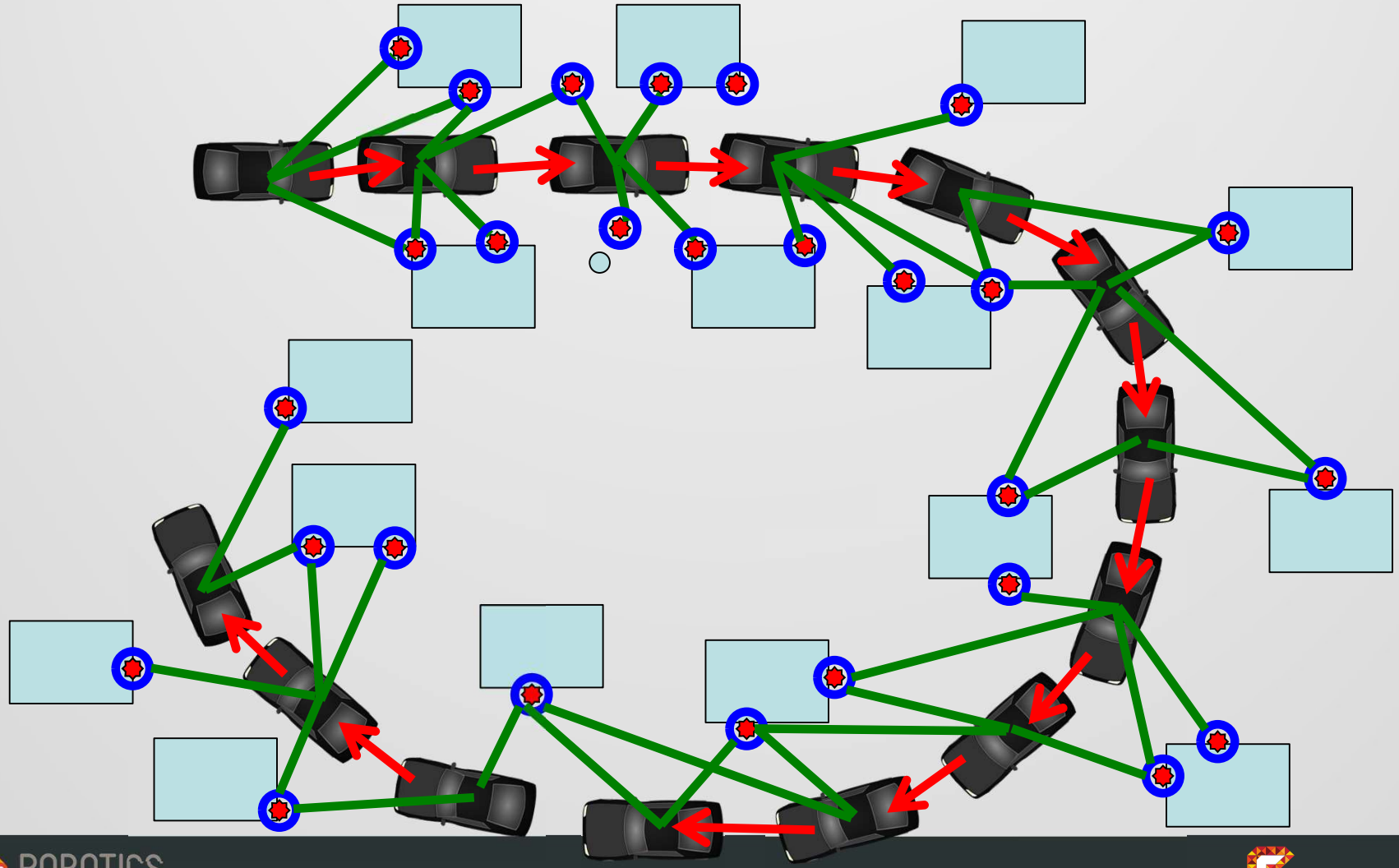

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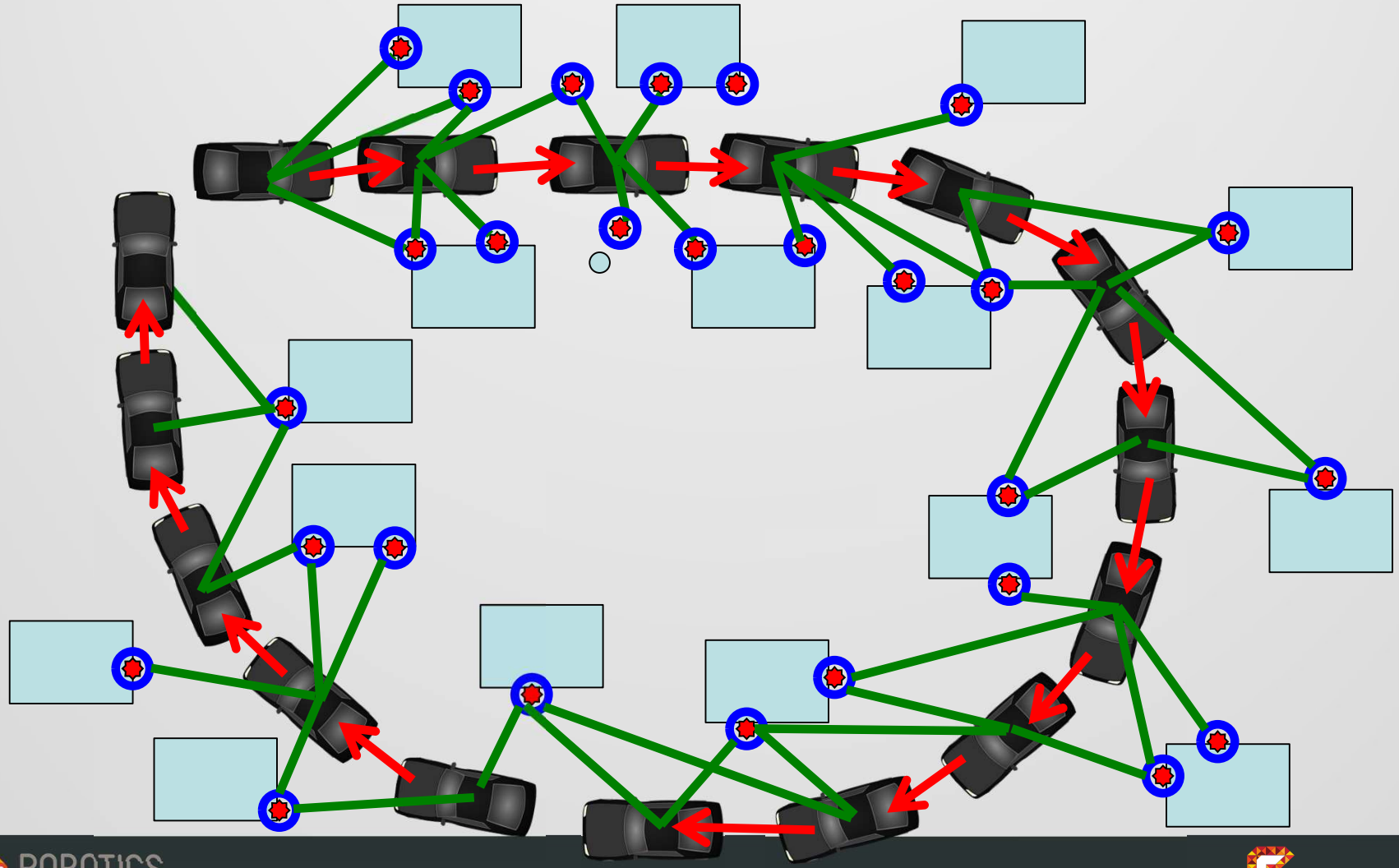

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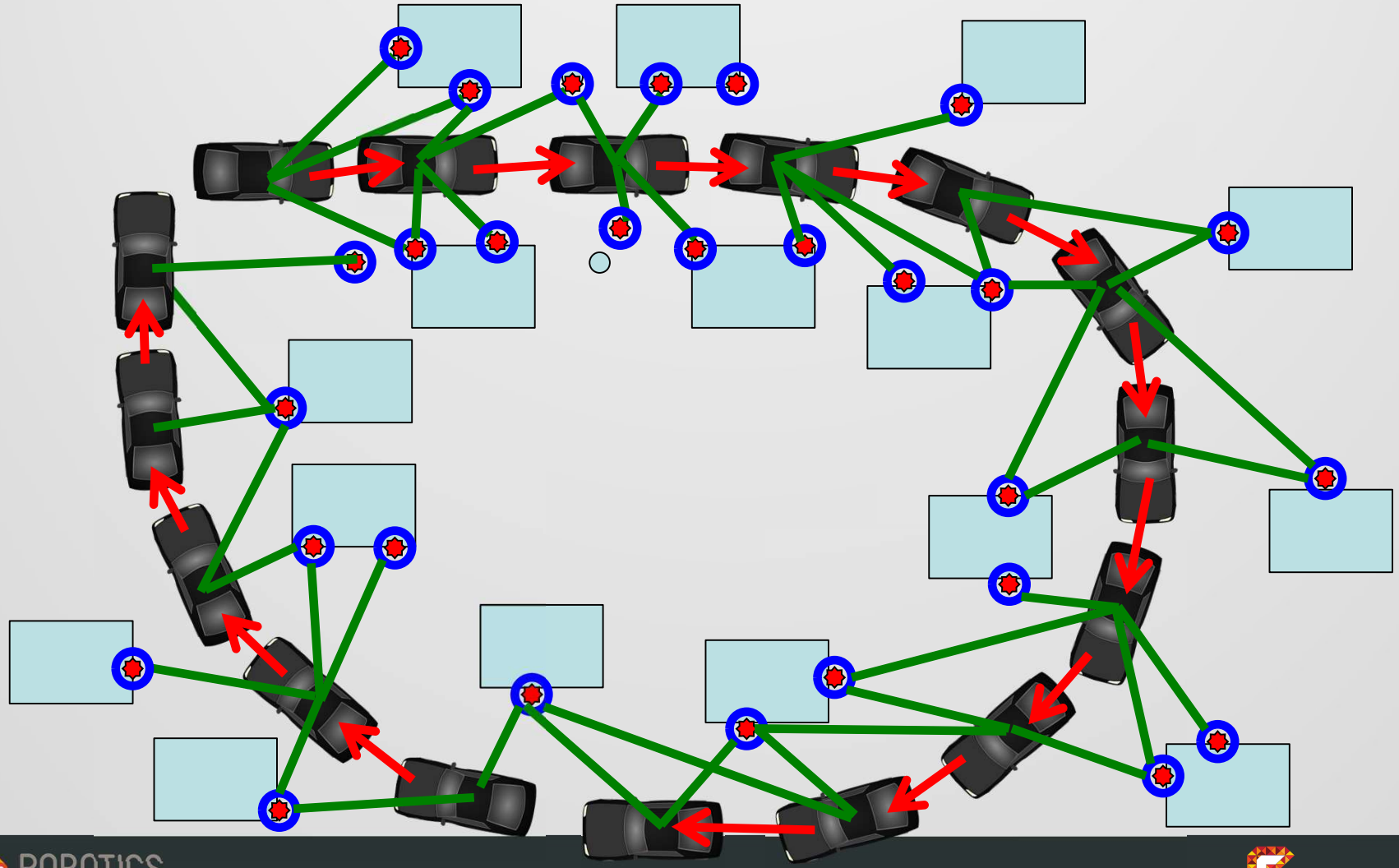
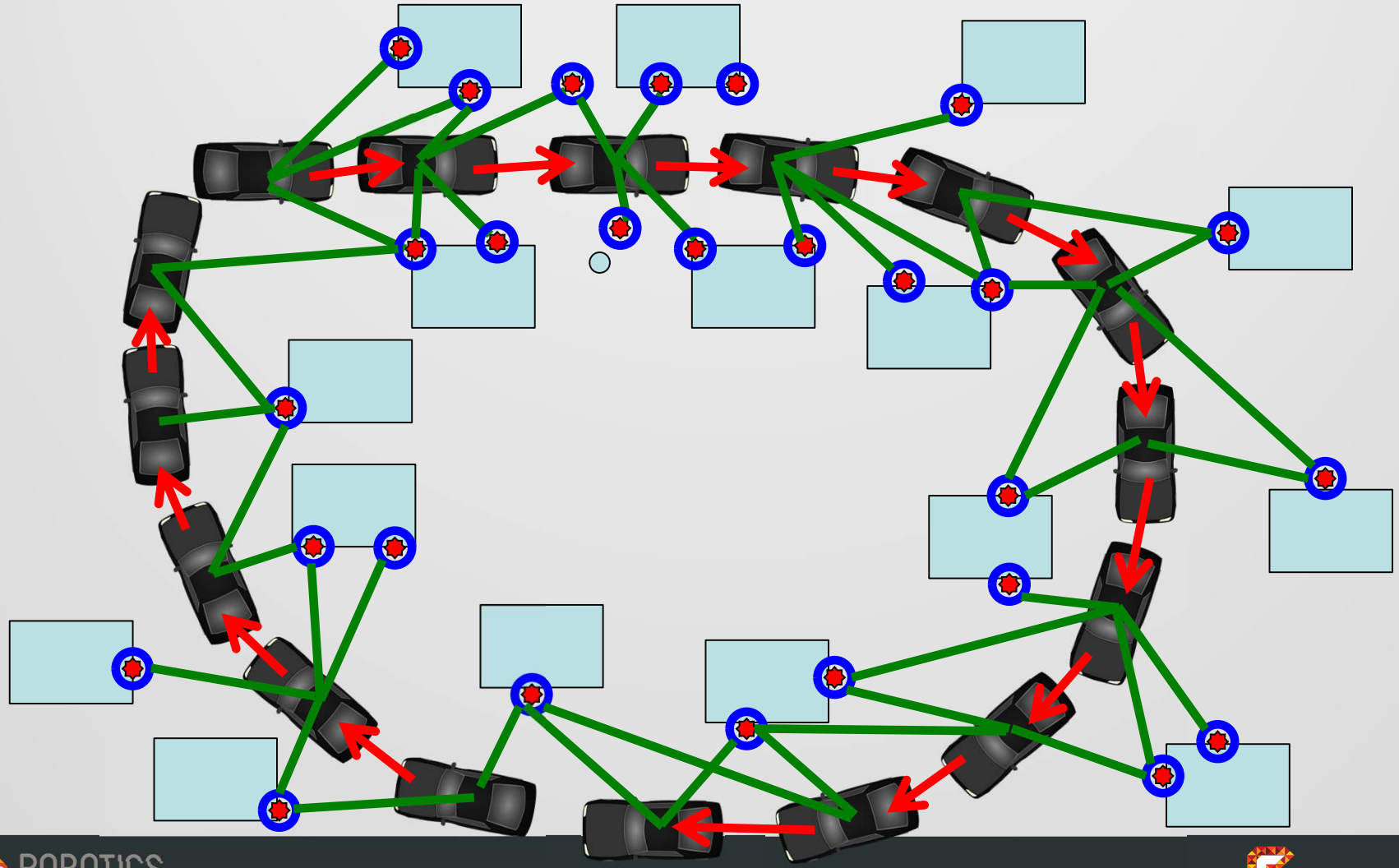
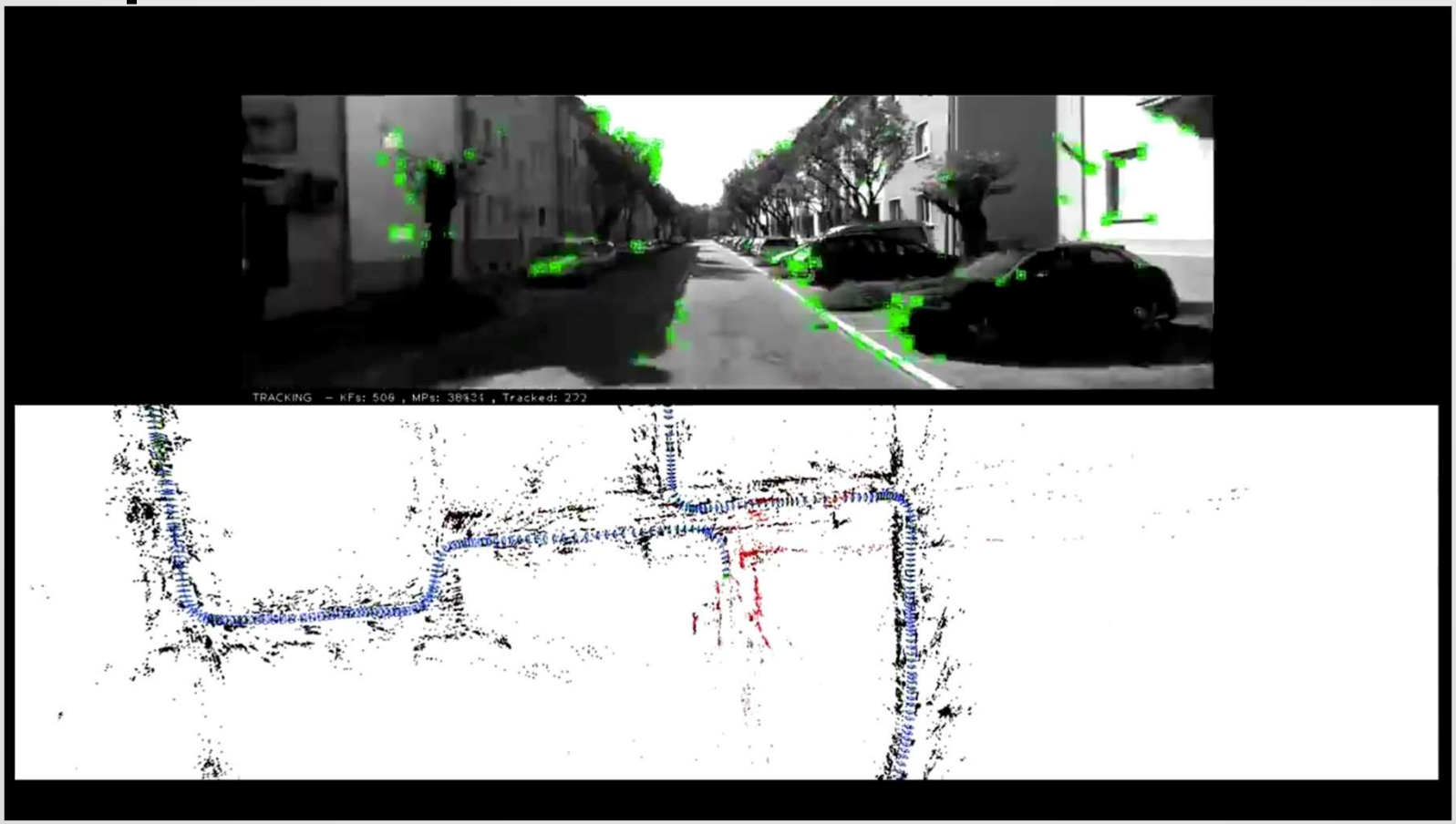


SLAM and Loop Closing



Loop Closure in ORB-SLAM on KITTI



From https://www.youtube.com/watch?v=8DISRmsO2YQ
(00:57.5-00:62.5 seconds)

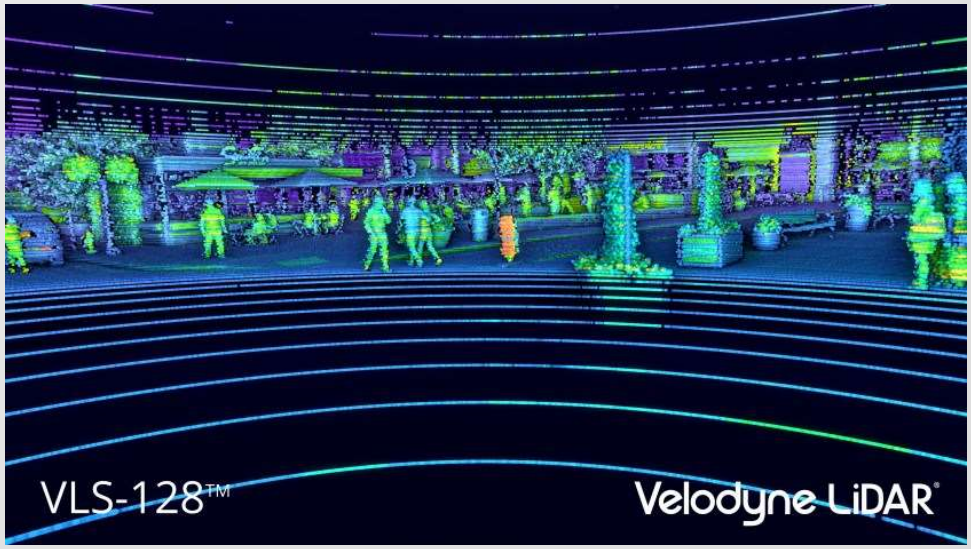
Where Next?

- For the next few weeks we will look at the core underlying algorithms needed to create SLAM
- These are mathematically some of the most challenging problems people have had to face
- Workable solutions now exist, which is changing the face of robotics and mixed reality
- And so we are going to start with ….

Extra Material

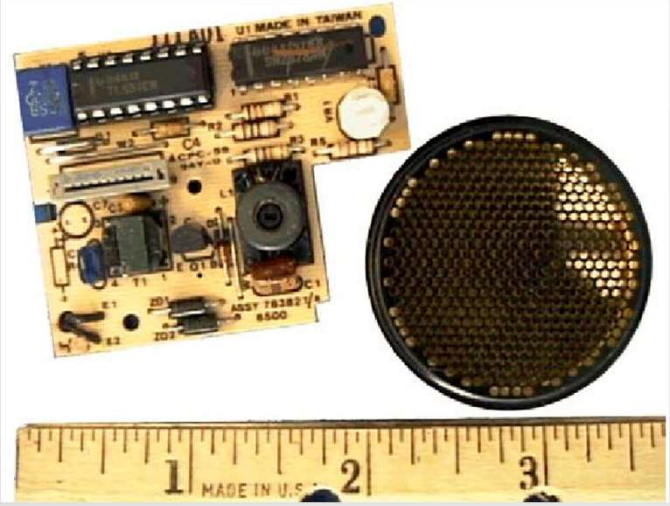
- Other sensing modalities are used with SLAM
- Lidar and sonar outlined below

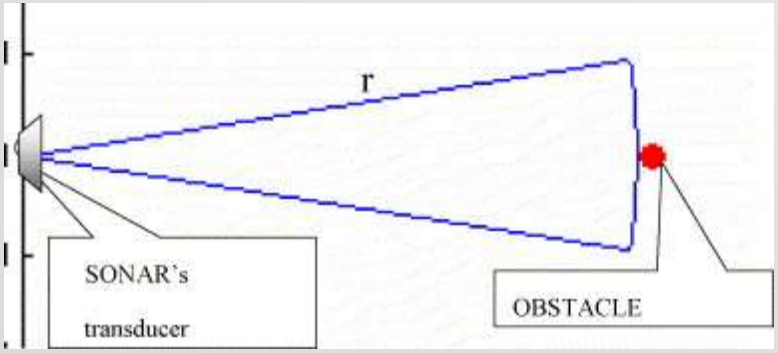
Velodyne 128



From [Velodyne Lidar Showcases Groundbreaking Technology for Security and Safety Applications at the Unmanned Security Expo]

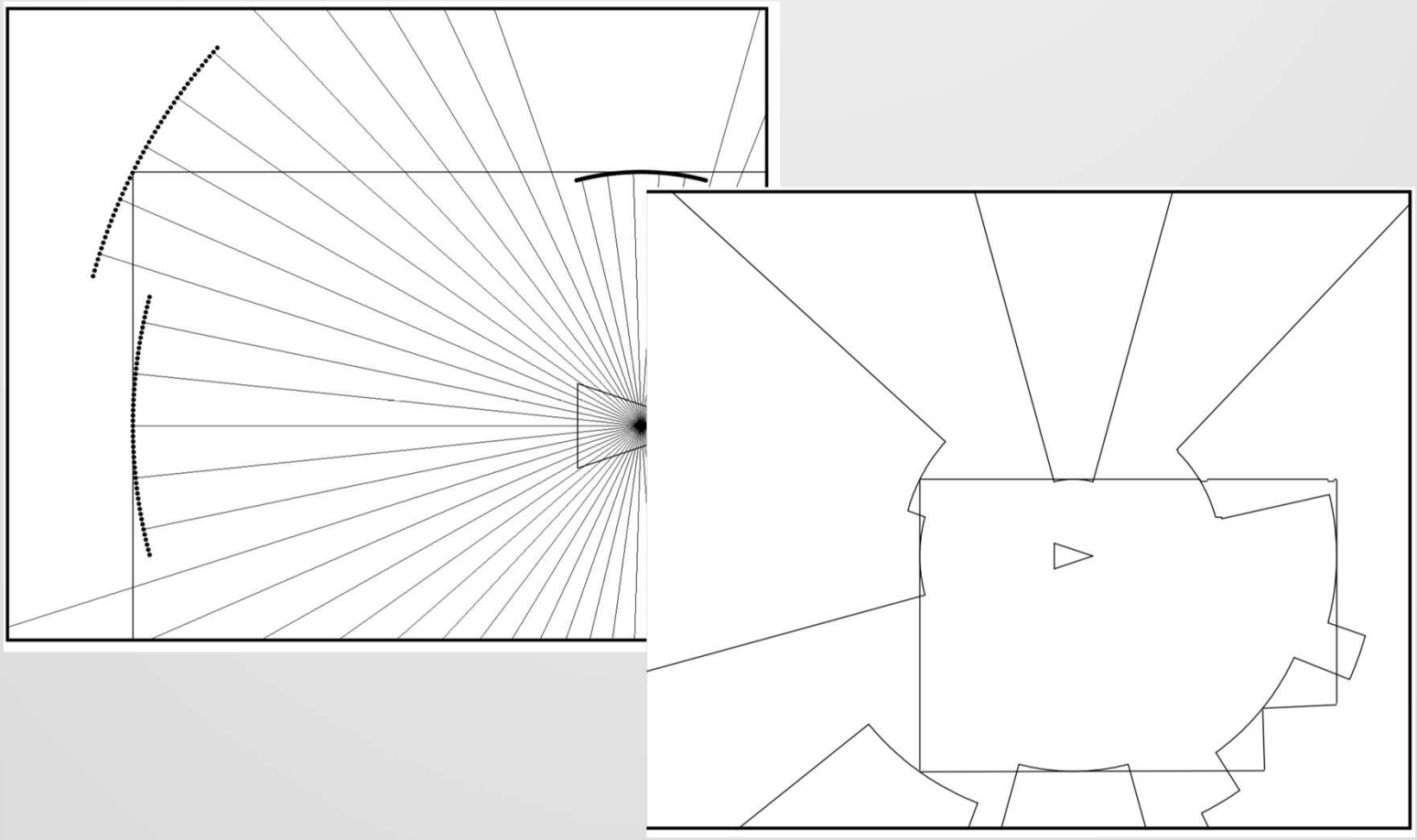
Sonar





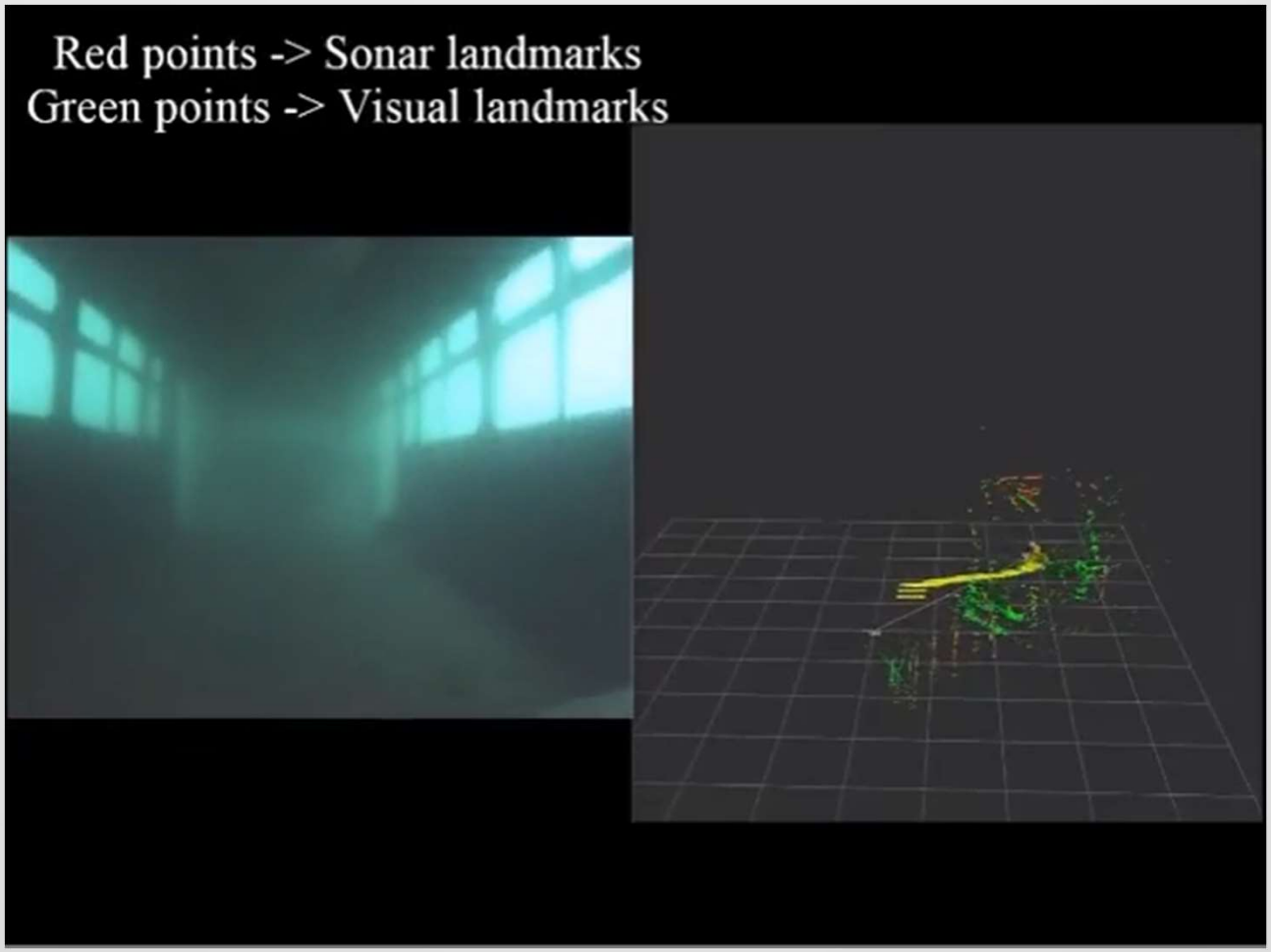
From: Incorporating Spatial Representations at Multiple Levels of Abstraction in a Replicated Multilayered Architecture for Robot Control, Calibration and interface of a polaroid ultrasonic sensor for mobile robots,

Features in Sonar-Based SLAM



From Directed Sonar Sensing for Mobile Robot Navigation

Visual Inertial SLAM



From Sonar Visual Inertial SLAM of Underwater Structures