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Implementation of a path following controller on Unmanned Ground Vehicle

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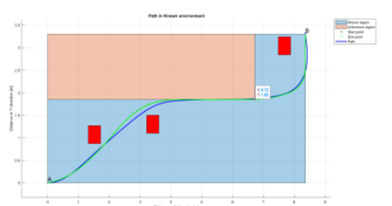

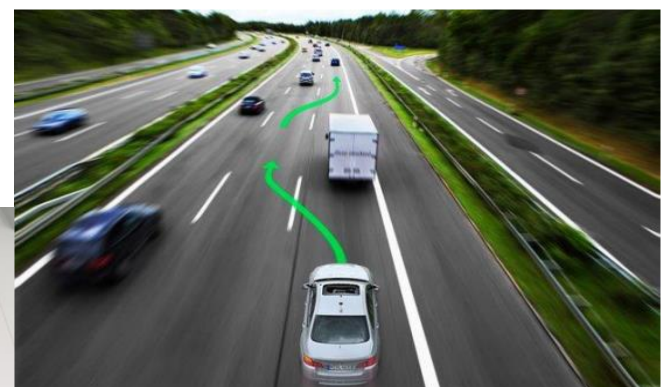

[1]https://towardsdatascience.com/planning-the-path-for-a-self-driving-car-on-a-highway-7134fddd8707

Contents

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Objective

- Continuation of NTP, Literature of UGV /Latex/MPC/Matlab-Acado/DI model.
- Implement a path following controller on UGV having obstacle and prohibited region in the path.
- Taking obstacle into account-Problem become Non-convex.
- Designing a safe path while considering vehicle dynamic for feasible path.
- Created environment> Path fitting as per planner>NMPC formulation, and finally in the calibrated environment impledmented the path controller on our Hamster to get the desired result.

Introduction

-Hamster robot is a robotic research platform focused on autonomy.
-Piece of mechanized equipment.

Military

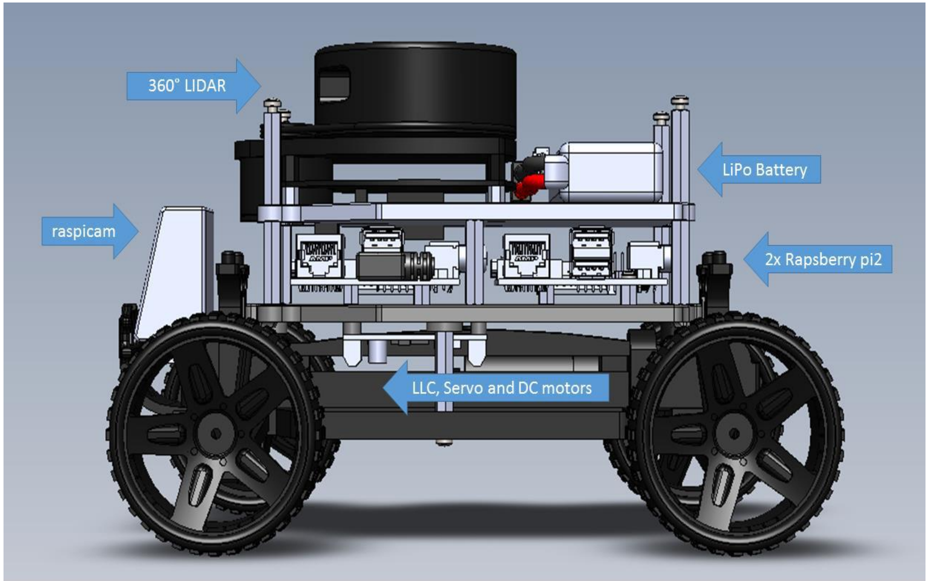
Cleaner

Surveillance

Warehouse

Ref:[3,4,5]

Hamster specification by cogniteam



Components

-360° LIDAR
-LiPo Battery
-DC motors
-Rapsberry pi2
-Raspicam
-Wheels

Parameters

-Speed: $0.1 \leq u \leq 1.2$ m/s
-Steering angle: -0.245 rad ≤ 0.245 rad ($-14°$ to $14°$)
-Car dimension- 24 cm x 19 cm x 15 cm

[2]https://www.hit.ac.il/.upload/HamsterDeveloperManual-REV4_v1.pdf

Mathematical formulation of car model

Kinematic four wheels vehicle → Lumped into Bicycle model

$$\begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{\psi} \end{bmatrix} = \begin{bmatrix} v\cos(\psi+\beta) \\ v\sin(\psi+\beta) \\ v\tan(\delta)/L \end{bmatrix} \begin{matrix} \text{x-position} \\ \text{y-position} \\ \text{heading angle} \end{matrix}$$

Inputs:
- Velocity v
- Steering angle δ

Other parameters:
- Vehicle Length L
- Slip angle β

Nonlinear dynamic system

↓

Nonlinear MPC was used to solve the problem

[7] NTP

Components used on the top of Hamster

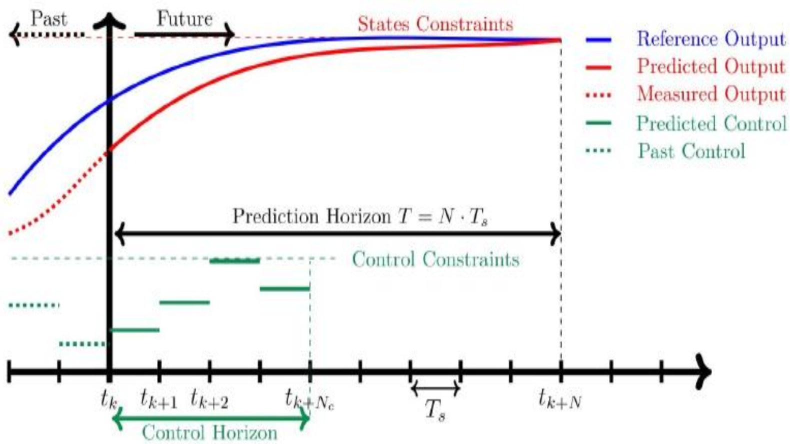
Point marker

Hamster

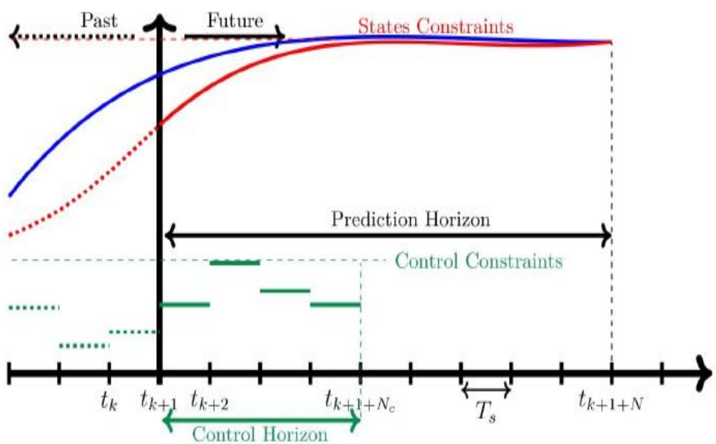
WPS antenna

Charger

Model Predictive Controller



(a) At time t_k

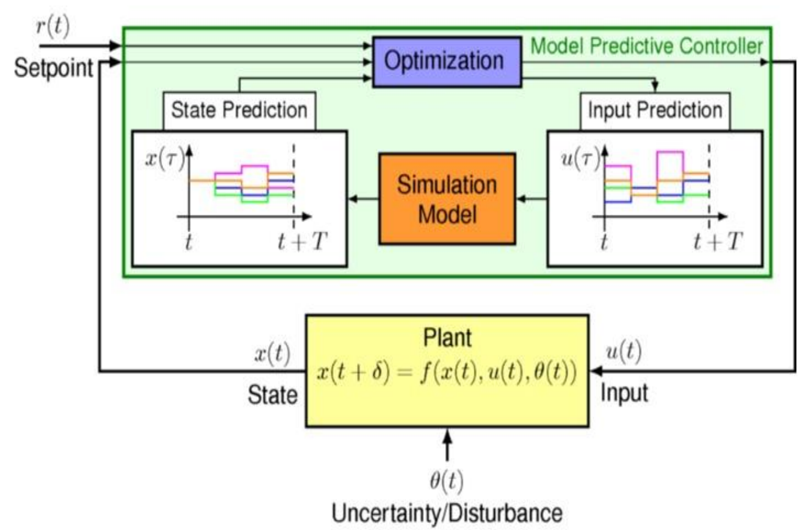


(b) At time t_{k+1}

-Optimization-based control, which follows the repetitive decision-making process.

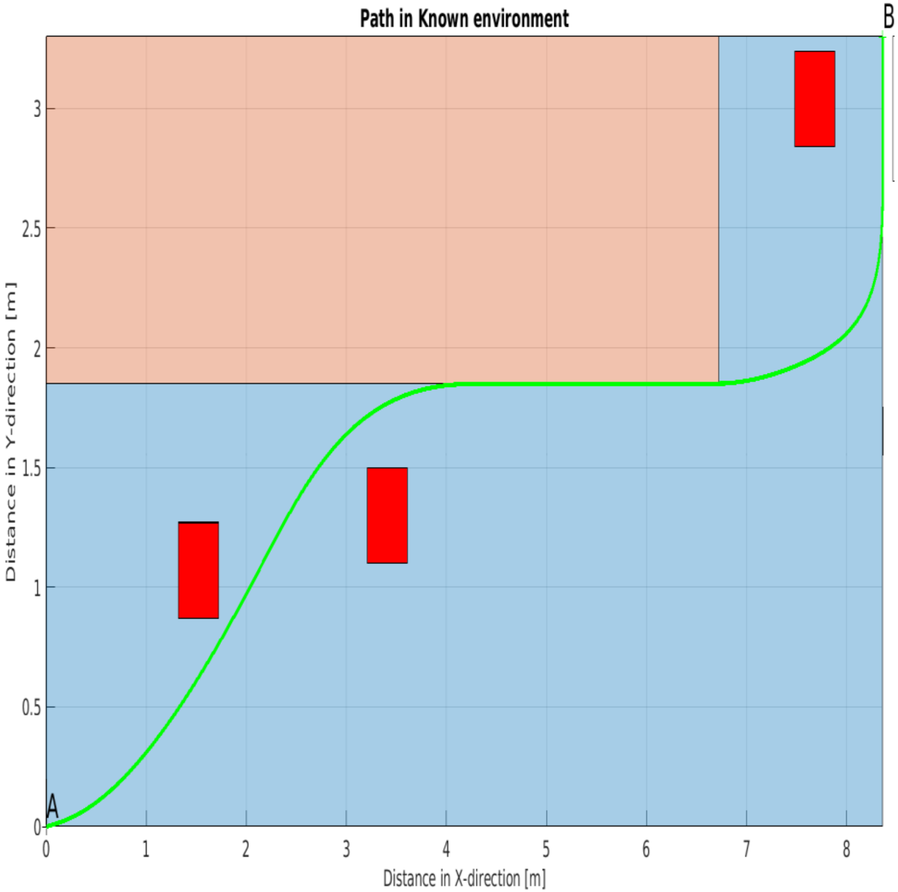
-Adjusts inputs until prediction reaches desired output.

-Sample time: 0.1s
-Prediction Horizon Np:50
-Control Horizon Nc: 2



[7] NTP

Path generated by the Planner

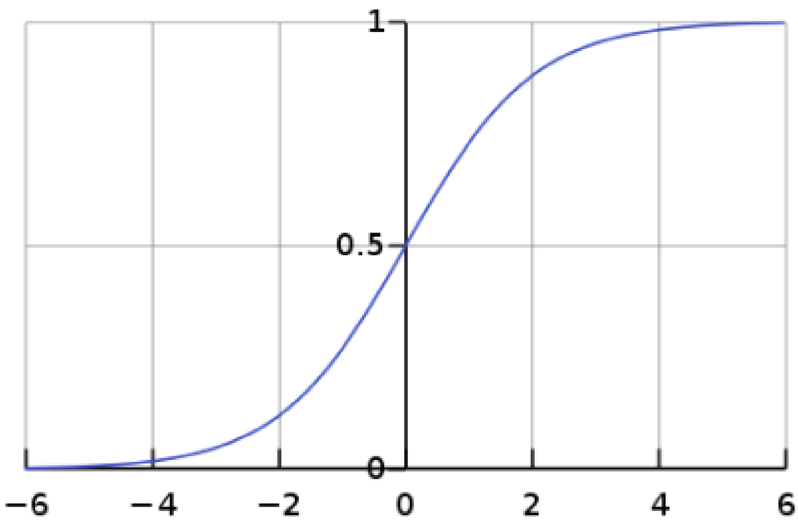


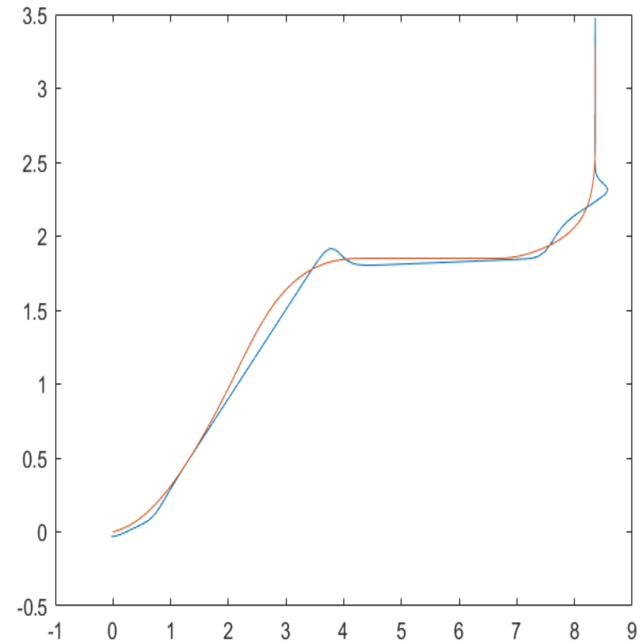
Simulation Environment	
Parameters	Value
Distance in X-direction	8.36 m
Distance in Y-direction	3.3 m
Initial position	[0,0]
Final position	[8.36,3.3]
Area of prohibited region	6.72x1.45 m^2
Position of obstacle 1	[1.52,1.03]
Position of obstacle 2	[3.41,1.3]
Position of obstacle 3	[7.68,3.04]
Safe margin	0.20m

Generated Path from offline-planner in simulated environment

Path fitting

$$S(x) = \frac{1}{1+e^{-x}} = \frac{e^x}{e^x+1}$$

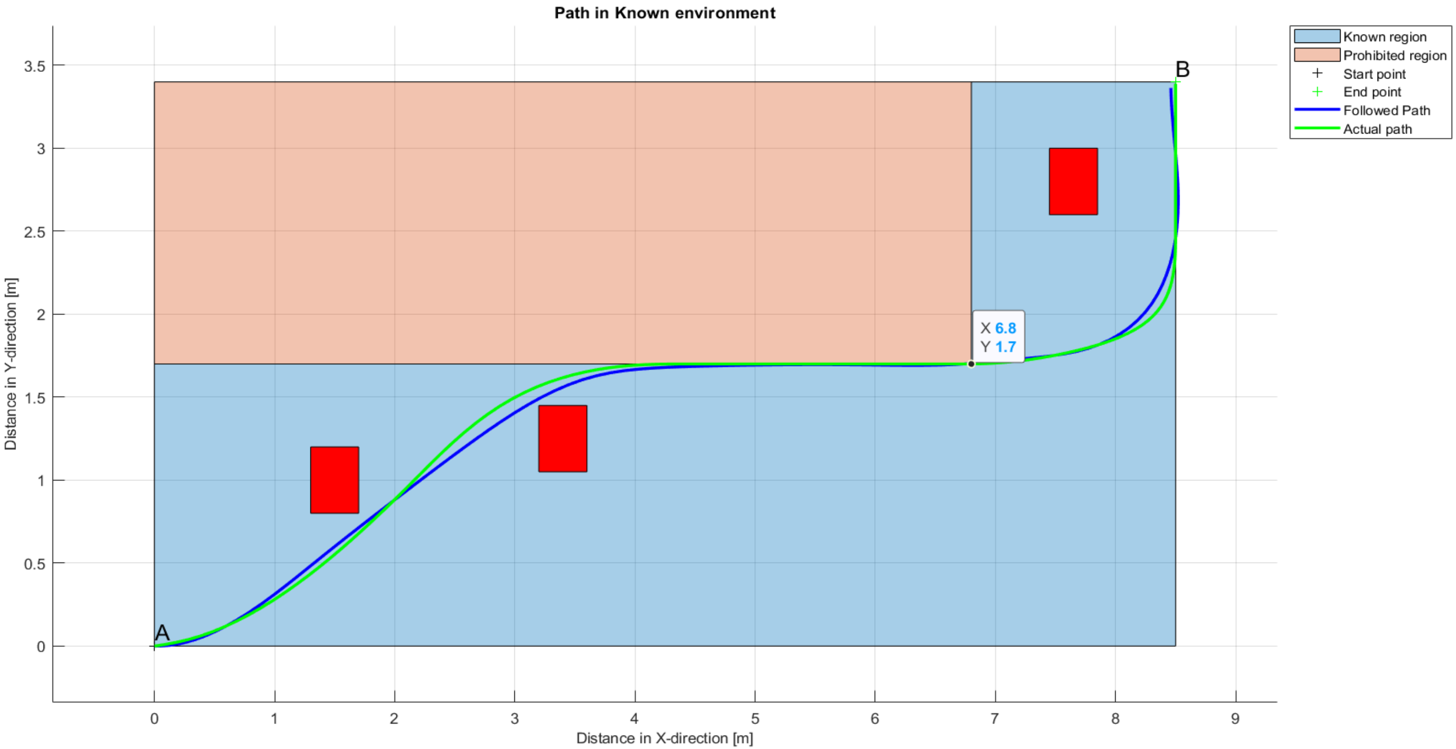


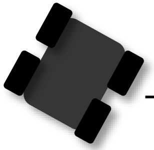


https://en.wikipedia.org/wiki/Sigmoid_function

Use of poly-fit and sigmoid function to get the the fitted path

Path fitting and driving

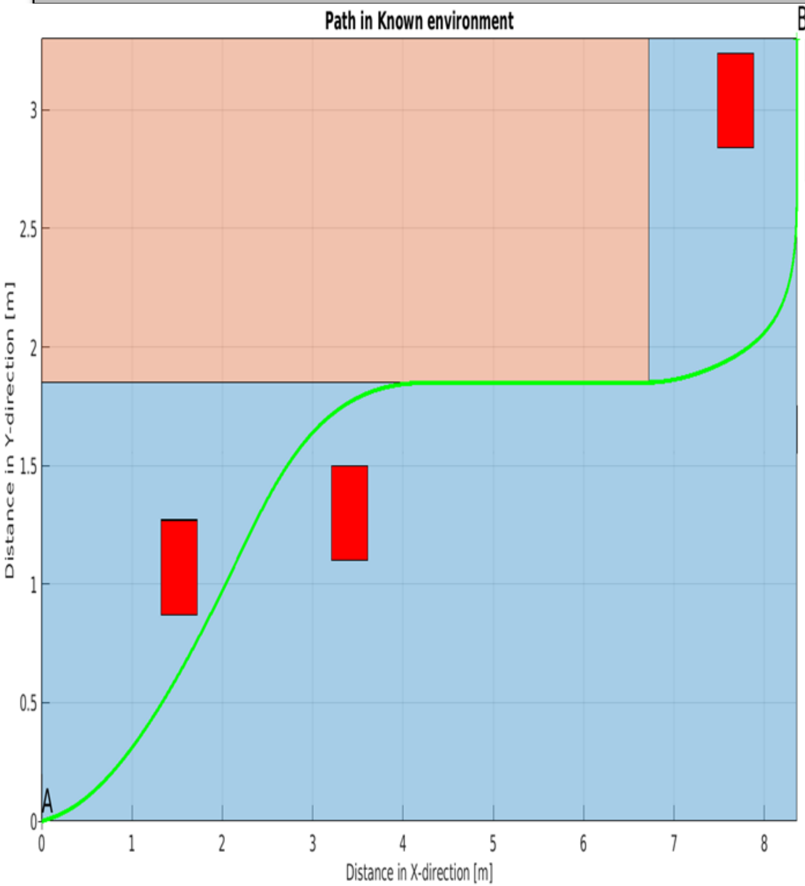


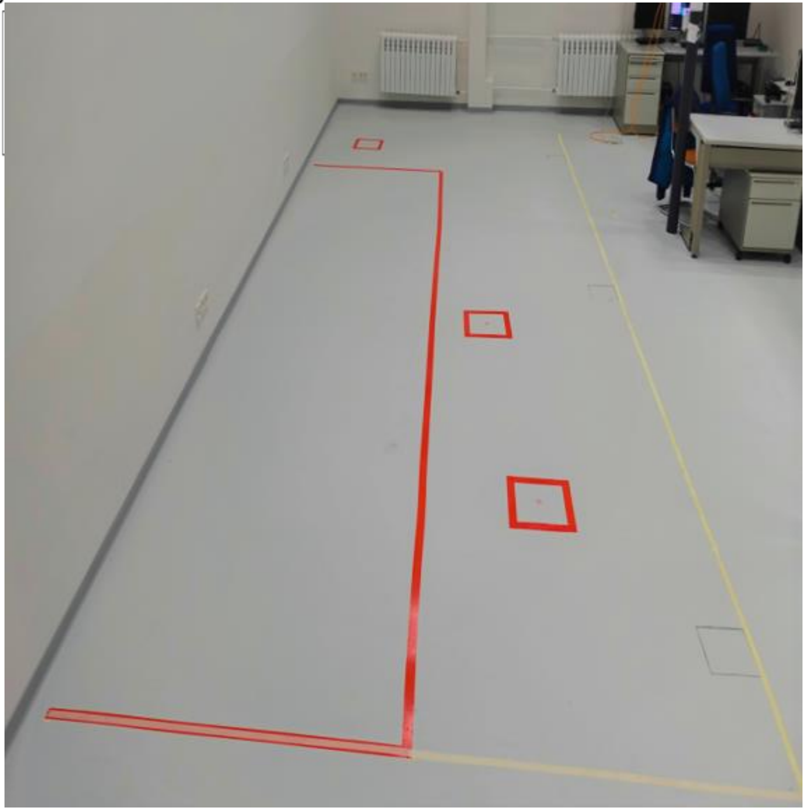


Hamster

Fitted path in simulated environment using ACADO toolkit for solving NMPC

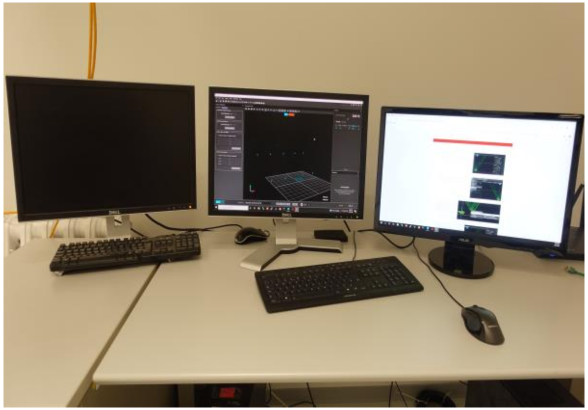
Experimental setup for Unmanned Ground Vehicle

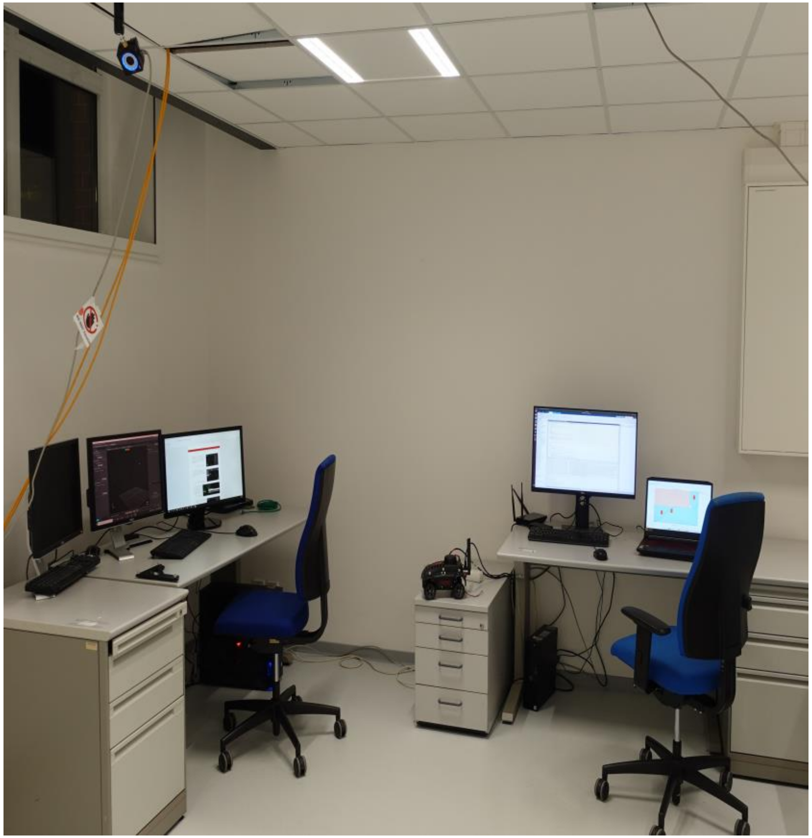




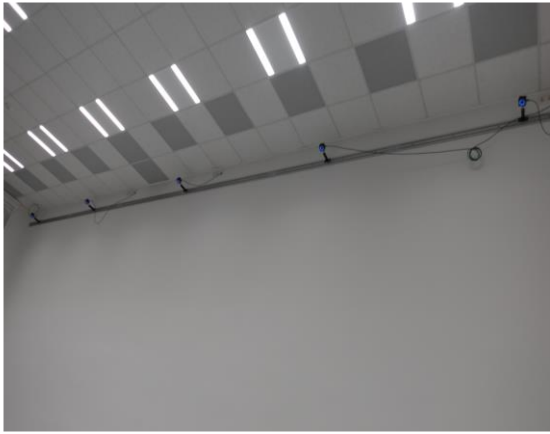
Global environment setup as per the provided data

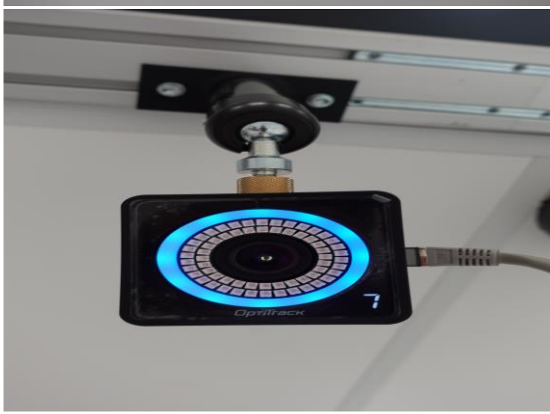
Ground station

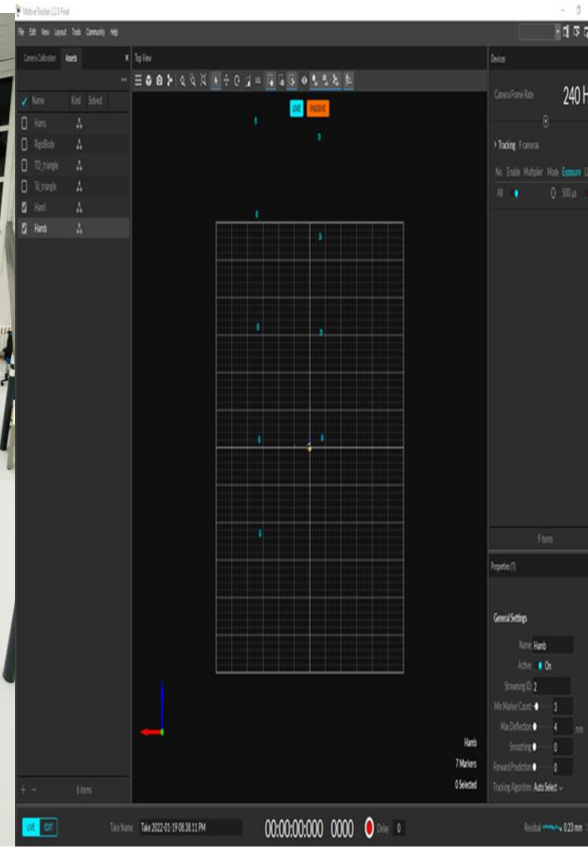




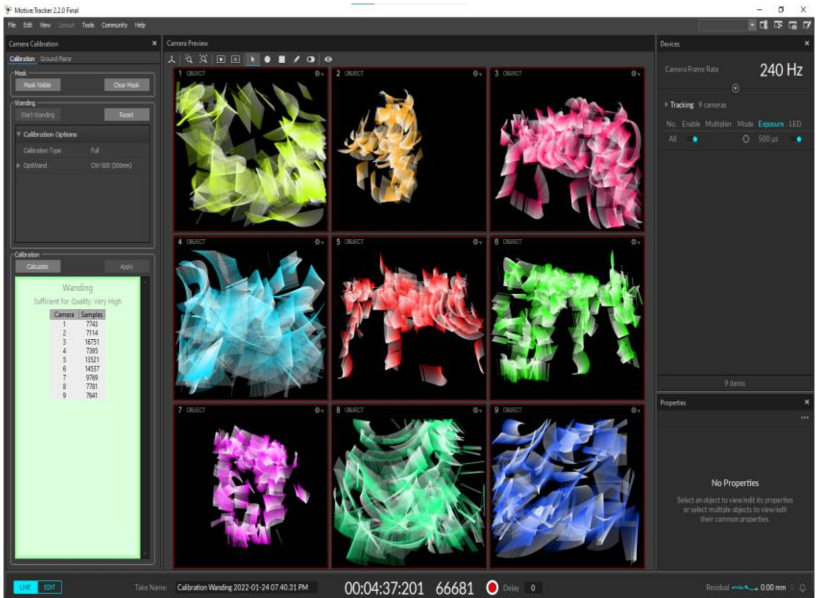
Camera system







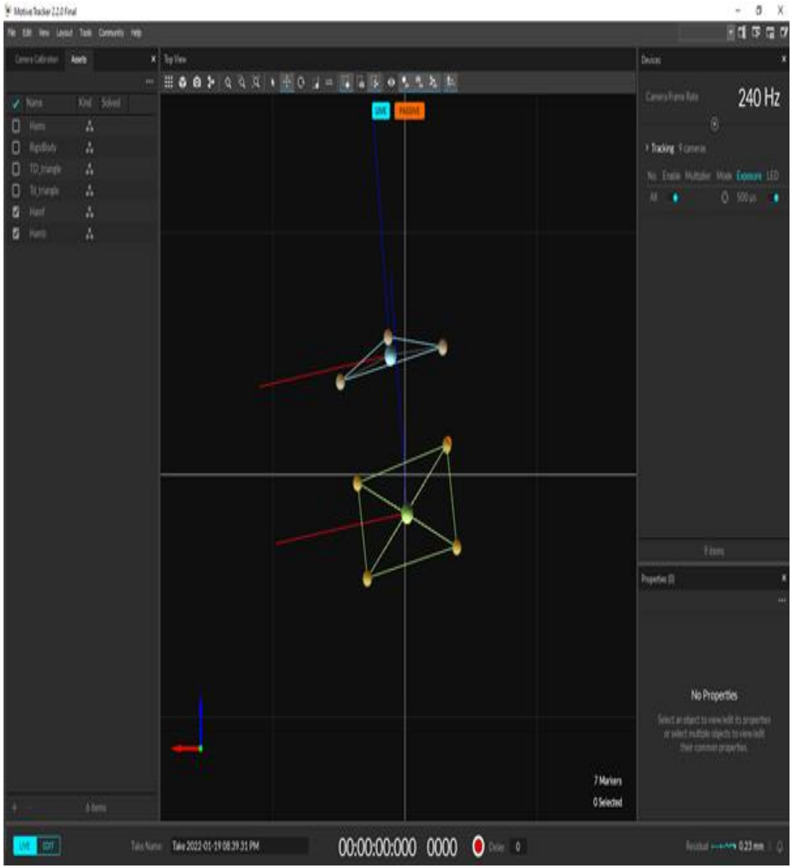
Camera calibration -OptiTrack



Camera calibration process

- Put USB Open motive
- Go to View>Camera calibration Panel > Star wanding
- Use Calibration wand(CW_500) and Calibration Ground square(CS-200)
- calculate and Apply

Rigid Body in Motive



Process to create rigid body

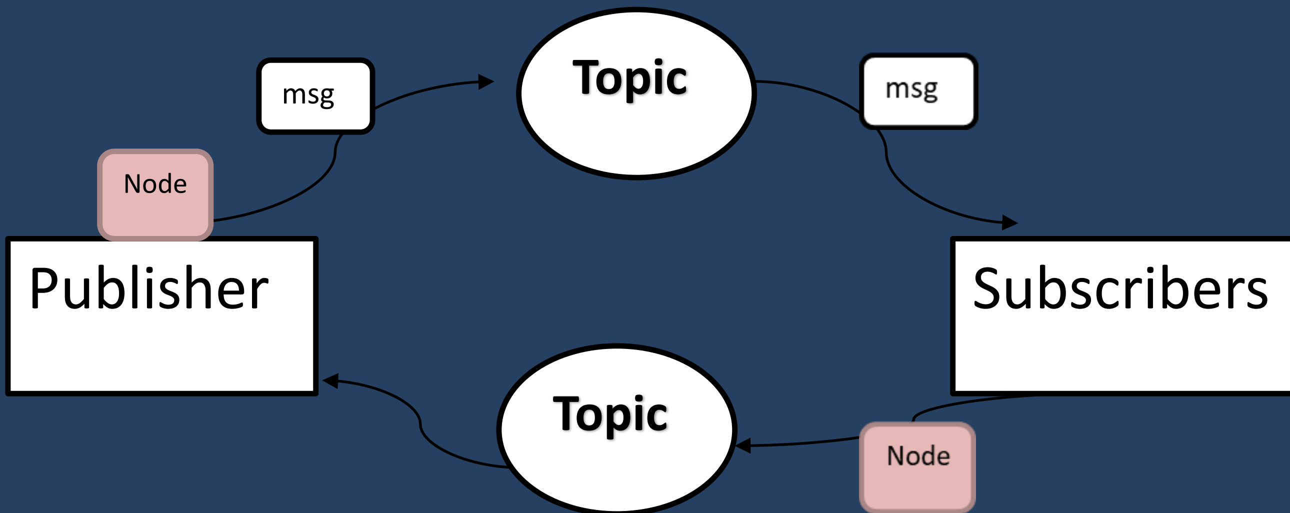
- Put USB > Open motive software
- Select calibration file.
- Put Hamster and select markers.
- View>Asset panel> desired body

ROS Architecture

-Open source robotics middleware.

-Hamster is a smart ROS based UGV.

-Linux and ROS pre-installed.



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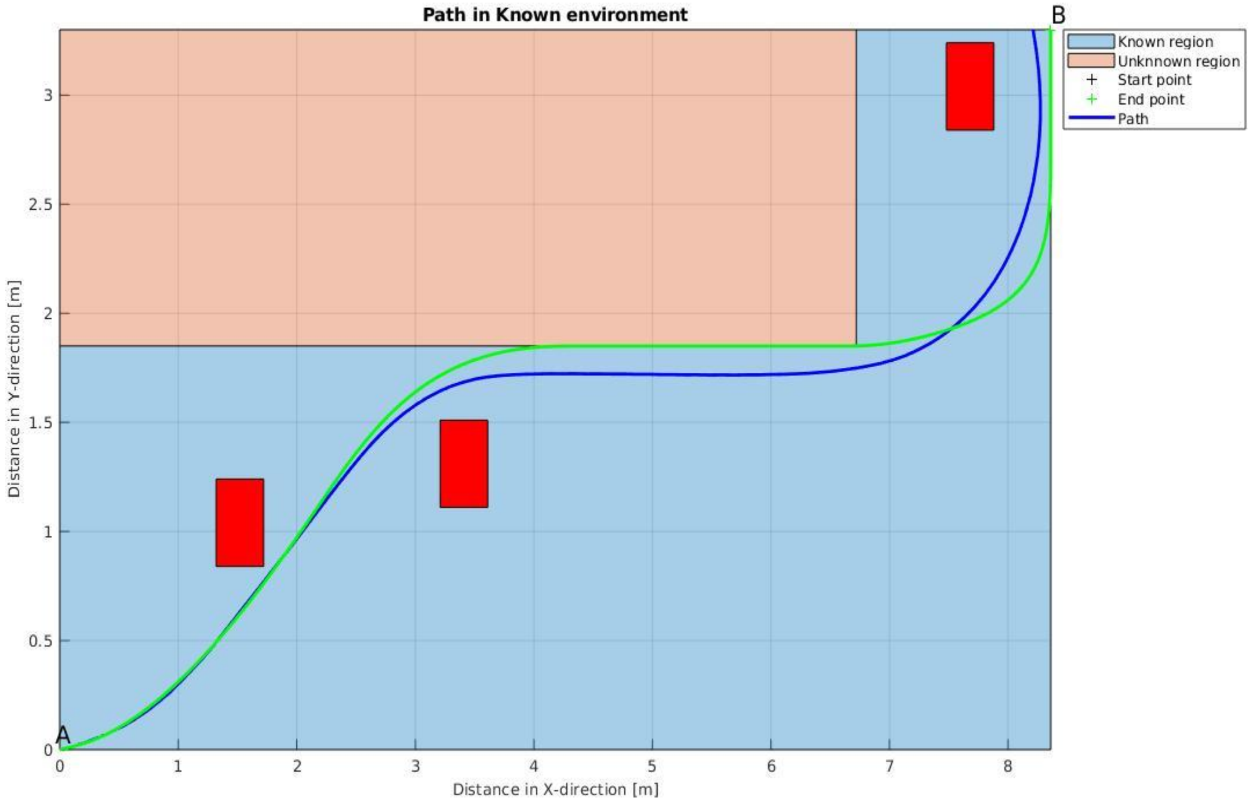
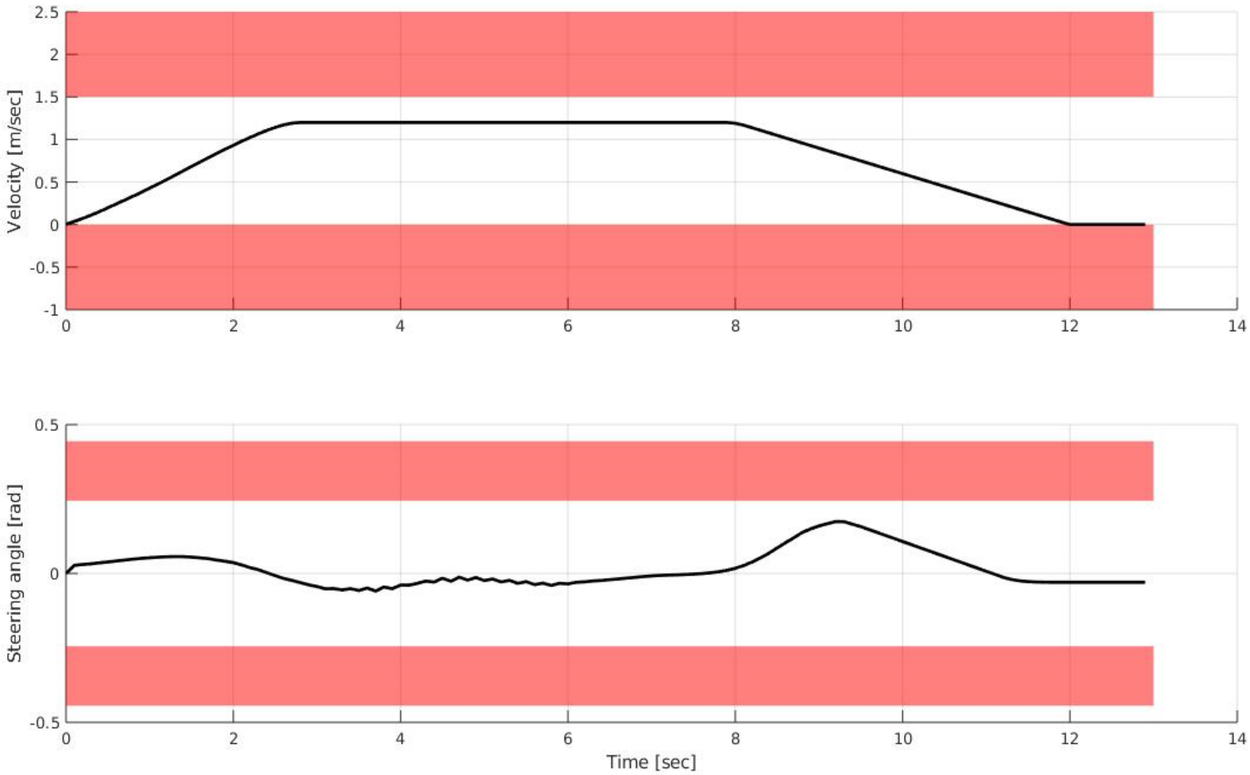
Path of Hamster in actual environment



Error in y :15 cm, Error in x: 6cm- approx: 5%

Change in Velocity and Steering w.r.t time



[1] Planning the path for a Self-Driving Car on a Highway, https://towardsdatascience.com/planning-the-path-for-a-self-driving-car-on-a-highway-7134fddd8707
[2]Hamster model by Cogniteam, https://www.hit.ac.il/.upload/HamsterDeveloperManual-REV4_v1.pdf
[3] A UGV robot is patrolling the streets during the lockdown website. https://www.inceptivemind.com/ tunis-ugv-robot-p-guard-patrolling-streets-lockdown/12805/. Accessed: 2020-04-20.
[4] Themanufacturer Jonny Williamson. How is slam software powering the next-generation of autonomous industrial robots ?, 2013 https://www.themanufacturer.com/articles/slam-software-powering-nextgeneration- autonomous-industrial-robots/.
[5] Rheinmetall AG. Rheinmetall Mission Master. https://www.rheinmetall-defence.com/en/rheinmetall_defence/public_relations/themen_im_fokus/ugv/index. php, 2016