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Simulation of mobile robot navigation in vineyard row in Matlab

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Research background

In field of autonomous mobile robotics, the quality of control is a crucial aspect. A properly designed control algorithm can increase precision of carried task and also reduce energy consumption of a robot. Simulations provide a fast way to optimize controllers in comparison to experiments with real hardware. Mobile robots can perform various agricultural work activities and tasks completely independently without intervention and can relieve and protect people from monotonous and often dangerous to human health agricultural work. Therefore, our goal was to create a simulation model of a mobile robot motion in a vineyard row including robot dynamics for evaluating motion consumption by commonly used control algorithms. The task was to navigate the robot through the middle of the vineyard row section by measuring distances from trellises on both sides of the robot. The designed algorithm for navigating the robot through the centre of the vineyard row and optimized controllers will be in following stages implemented in a real robot and tested in a real scenario.

Navigation algorithm

Inputs to the controller represent measured distances from a vineyard wall on each side of the robot. The basic equation for robot position error is $\boldsymbol{e = d_R - d_L}$ where d_R is distance from the right vineyard row wall and d_L is distance from the left vineyard row wall, m. Because we want not only the position error to be minimized, but also the robot orientation error, we used a similar technique to one presented by [1] to calculate desired robot orientation angle θ_d where T is sample time and Δs is distance travelled during T.

$$\theta_d = arctan\left(\frac{-e}{\Delta s}\right) = arctan\left(\frac{-e}{v_R T}\right)$$

Final quantity entering the controller is robot orientation angle error θ_e is calculated from $\boldsymbol{\theta_e = \theta_d - \theta_R}$ where θ_R is actual measured robot orientation angle, rad. Optional input to a controller is velocity error e_v. Similar to θ_e it can be calculated as difference between desired velocity and actual robot speed. More demonstrative representation of this algorithm is in Fig. 1.

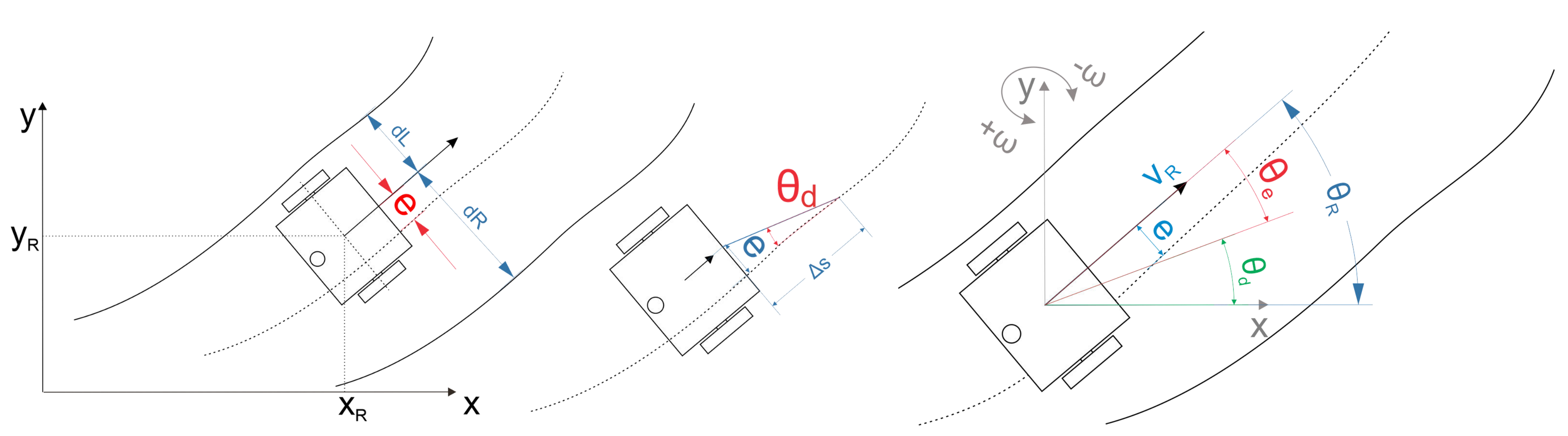

Fig. 1. Calculation principle of navigation algorithm

Simulation model

The simulation model was created and evaluated in *Matlab & Simulink* software. A simplified simulation flowchart of the Simulink model is shown in Fig. 2 with highlighted quantities calculated in each block. The model consists of following elements:

- Mobile robot mathematical model
- Sensor and environment simulation
- Navigation algorithm and controller blocks
- Consumption calculation
- Display blocks

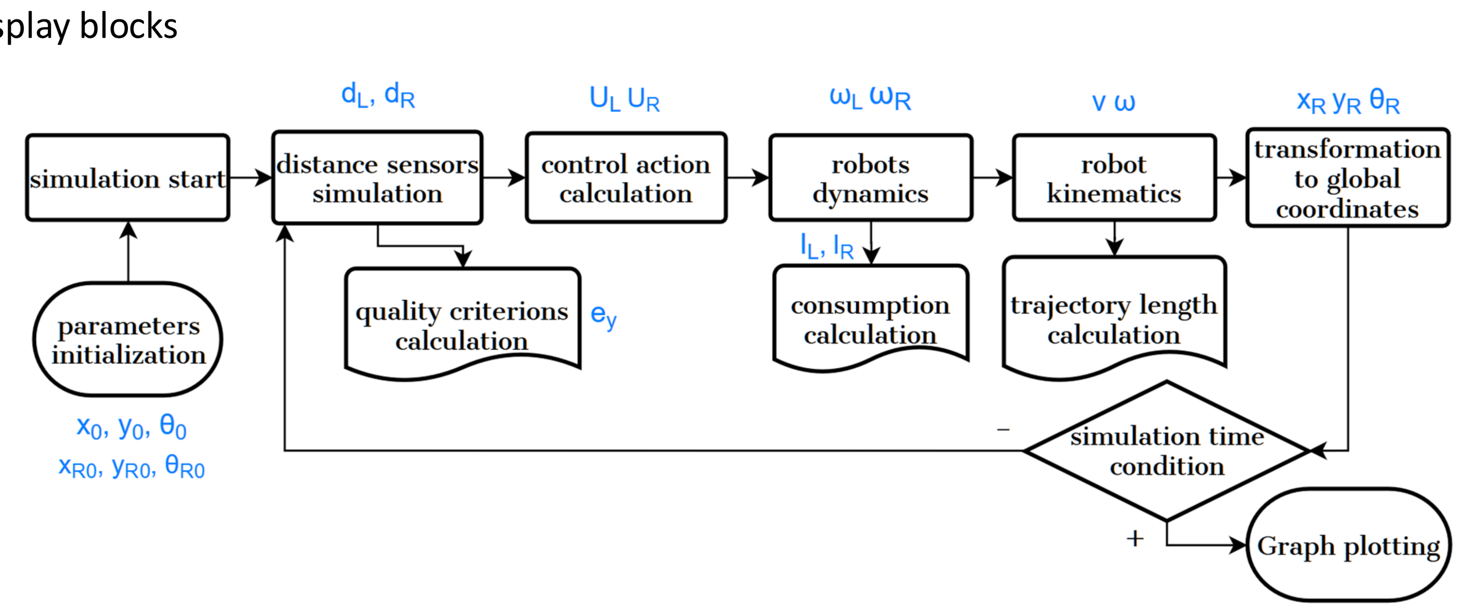

Fig. 2. Simulation flowchart

For a distance sensor simulation, we used results from our previous work [2] where we compared 3 different distance sensors for the use of measuring distance in vineyard row in motion and determined sensor with best overall performance. A testing track design, distance sensor characteristics and their placement on the robot was done in the Matlab *Driving Scenario Designer toolbox*. Simulation of the sensor during simulation on the testing track without and with applied filtering is shown in Fig. 3. The toolbox has a feature *Bird's-Eye Scope* which enables to watch robot motion and sensor performance from bird's-eye view during simulation runs, as is shown in Fig. 4. This gives us more clear view on controller behaviour than just graphs with variables time courses.

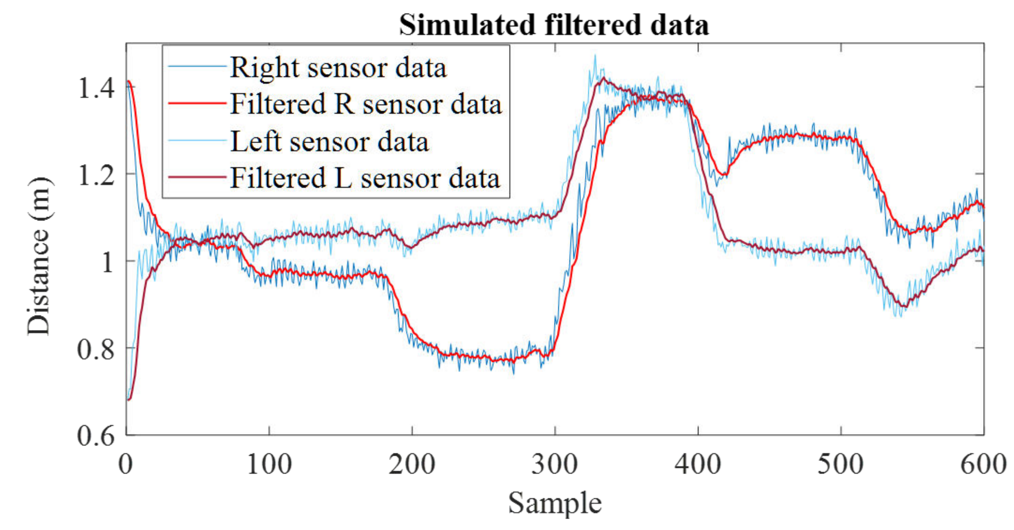

Fig. 3. Sensor and filter simulation

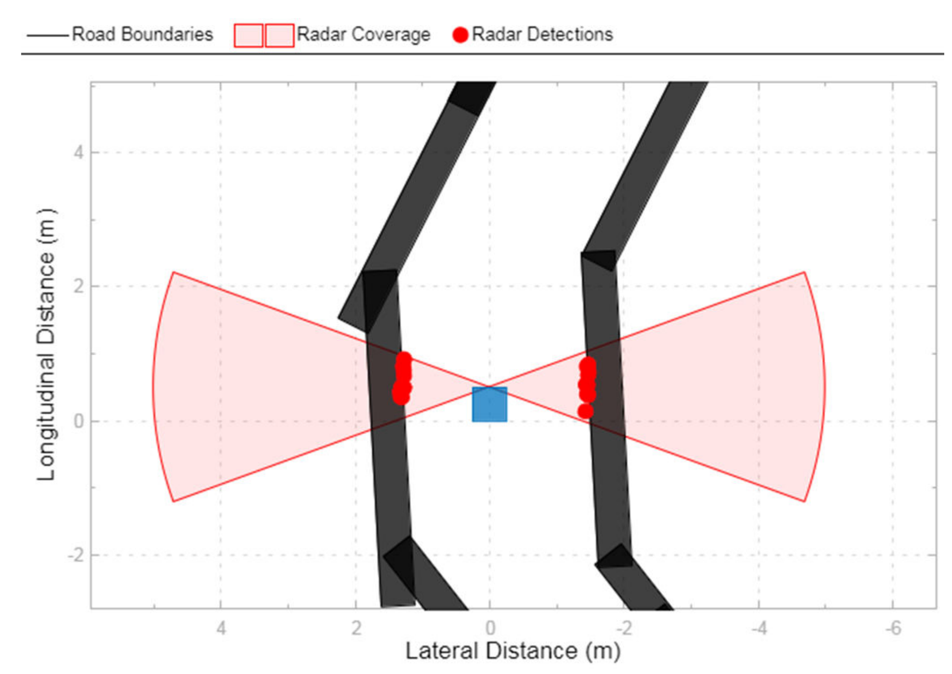

Fig. 4. Simulation in Bird's-Eye Scope

Four our purpose of verification of the algorithm we set sampling period to T=0.1 s to simulate the numerical controller's behaviour more realistically and the desired speed of the robot v_R was for all simulations constant. Fig. 6 shows robot trajectories with various tested control algorithms on designed test track. As can be seen, the proposed navigation algorithm provides appropriate quantity to the controller for accomplishing the task.

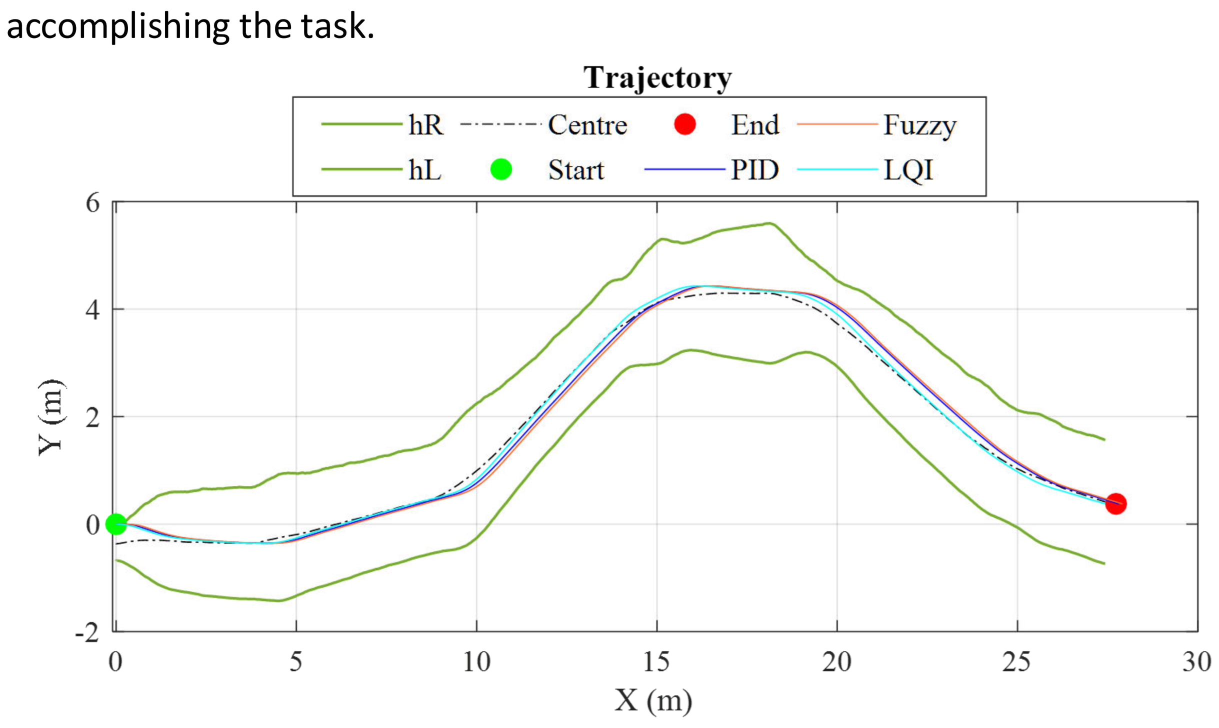

Fig. 5. Robot trajectories travelled using different control algorithms

Conclusion

The presented results of our work brought a framework for simulating mobile robots navigation in a vineyard row with aim to test and optimize various control algorithms. With small modifications the simulation model can be used for simulation of other ground navigation tasks not only in agriculture. The features of used Matlab toolboxes can even simulate complex robots used in [3,4] or algorithms [5] and optimize their performance.

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