
Control synthesis for flexibly manufacturing cells in Matlab/Simulink/Stateflow environment

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Intermediate Project – Embedded Robotics
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Project purpose was to build couple of models of manufacturing cells, using different types of control: Time and Event-Driven. Project should combine those different types of control and make simulations work like a real plant. 3 types of plants were planned to be built. Project resulted in two of them finished.

1. Introduction

The goal of the project was to build models of event and time driven cells. Environment used in it was to be special tool of Matlab Simulink called StateFlow. It is an Environment used for modelling and simulating combinational and sequential decision logic which are based on state machines and Flow Charts. It allows to combine graphical and tabular representations. It uses representations such as: state transition diagrams, flow charts, state transition tables, and truth tables, to model how the system reacts to events, time-based conditions, and external input signals.

Stateflow can be used to design logic for supervisory control, task scheduling, and fault management applications. Stateflow includes state machine animation and static and run-time checks for testing design consistency and completeness before implementation.

Project is supposed to prepare background for his master thesis.

Originally Project was to build following models:

- a. Model of two mobile robots sharing part of their tracks.

Model was to contain models of 2 robots moving on circular tracks. Models should mirror such parameters as velocity, acceleration, position and control of those values. Additionally there should be added a controller that coordinates movement of robots and to have shared resources at its disposal.

- b. Model and control system for Multiple Mobile Robot System (MMRS)

Model construction included designing robots pathways in Matlab, robots dynamics and control. It bases on a state transition graph which describes possible states and events of the system and helps which of them are safe. System should be designed the way that it avoids collisions and deadlocks. This Model was also supplied with animation showing its work.

- c. Model of plant using FMS Controller for a flexible manufacturing cell consisting of one transport robot and 5 machines. Machines should be executing concurrently couple of pipeline processes.

This part of the project should have develop controller supplying safety control and a simulator of a plant. Unfortunately this part wasn't managed to be finished.

2. Description of designed models

a. Model of mobile robots sharing part of the track.

This model was built with minimal use of other environments than StateFlow. All of the robot movement was modelled in it. Traditional kinematic equations were used to model movement of robot. Geneneral view of model in simuling can be seen on figure 1:

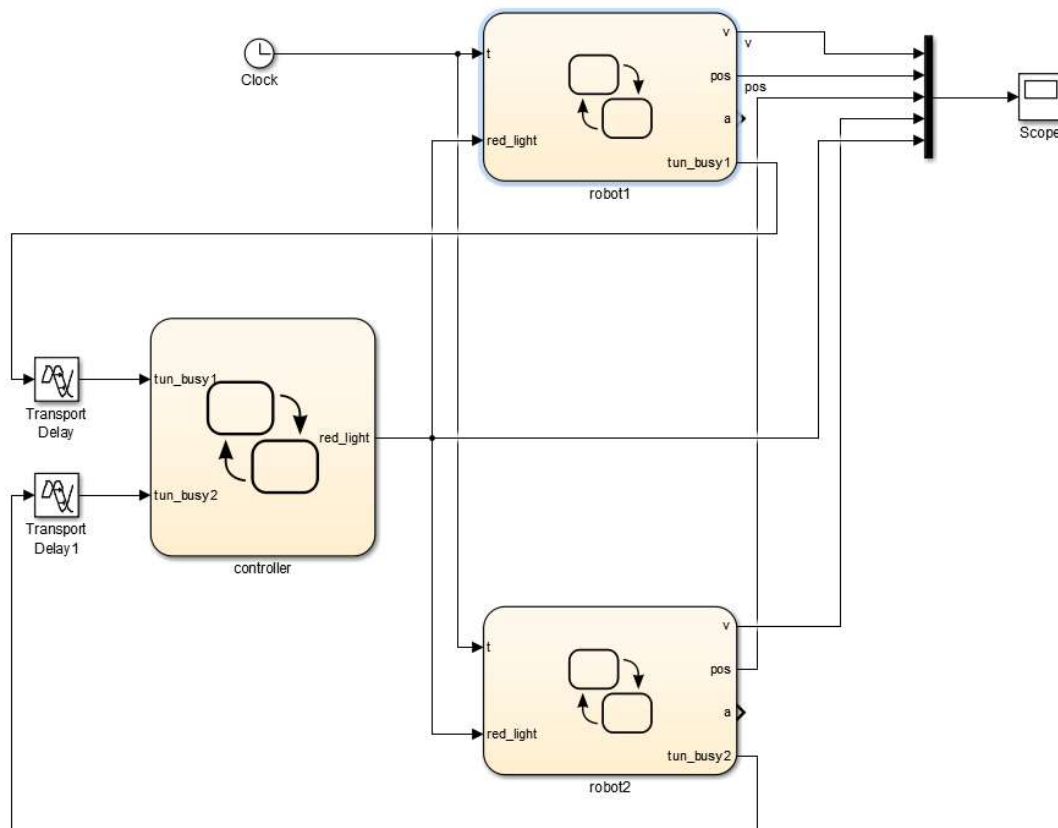


Figure 1

Model consists of a controller which decides which robot is allowed to enter the shared track. The properties of robot's movement can be seen with Scope tool. Robots are fully represented in StateFlow charts. Double click on the chart shows what's inside the chart. The view is shown on Figure 2.

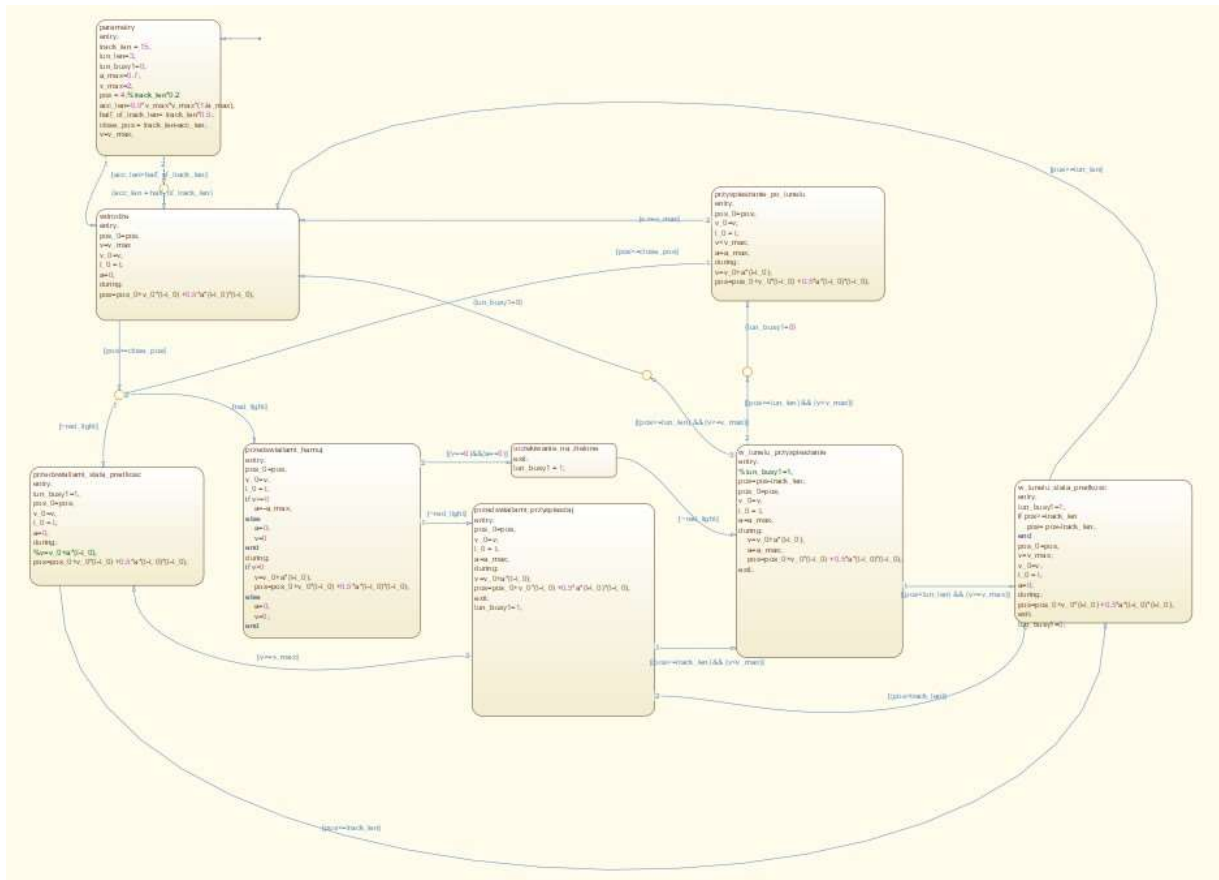


Figure 2

Each block represents one of the states that robot is currently in. States differ in velocity, acceleration, position on track, proximity of check points. Kienematics of the robot is modelled in Matlab code In each of the blocks individually for the state.

Run of the program results in chart represented on Figure 3. The blue and purpule lines represents position of the robot on circular track in time. Yellow and red one represents their velocities and thick green shows when controller gives one of the robots permission to enter the shared track. All parameters (track length, maximal velocity, acceleration, length of shared track) of movement can be changed to get freedom of any test one can imagine in this situation. Shared track always begins in part of the track marked by 0. Before entering it robots ask controller if they are allowed to enter it. Depending on the answer they accelerate or stop.

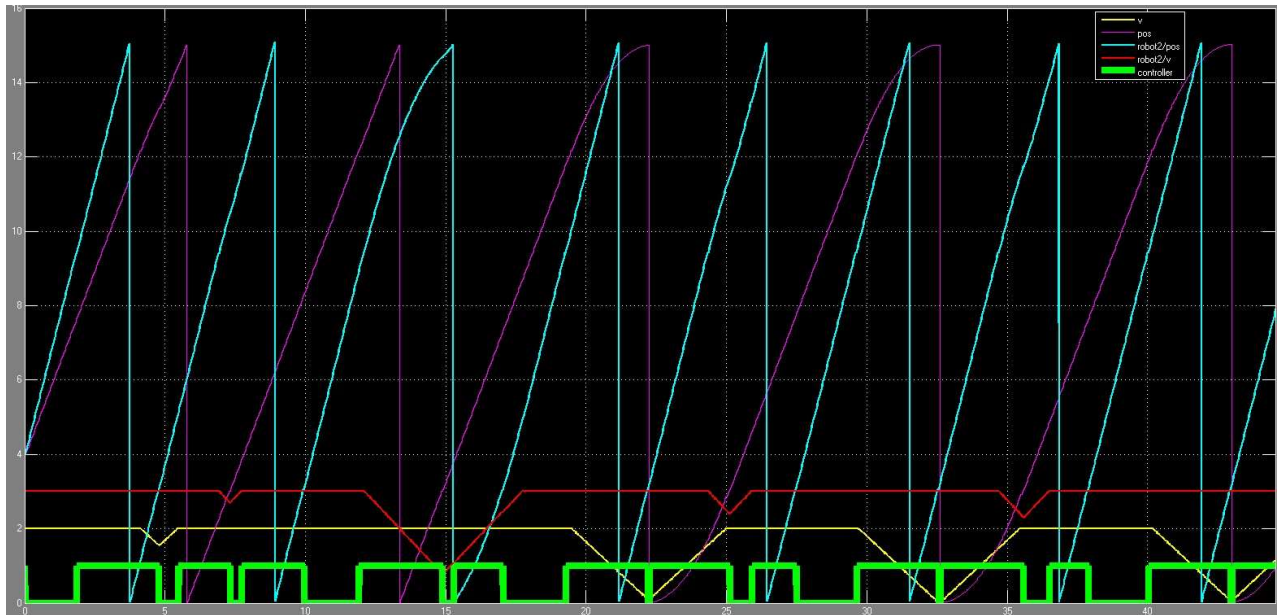


Figure 3

b. Model and control system for Multiple Mobile Robot System

This model was to represent Two robots moving on predefined tracks that cross. Track were divided into sectors. If sectors were too close to each other robots couldn't enter them at the same time. Model was built on the basis of the article [3]. Routes are presented on figure 4.

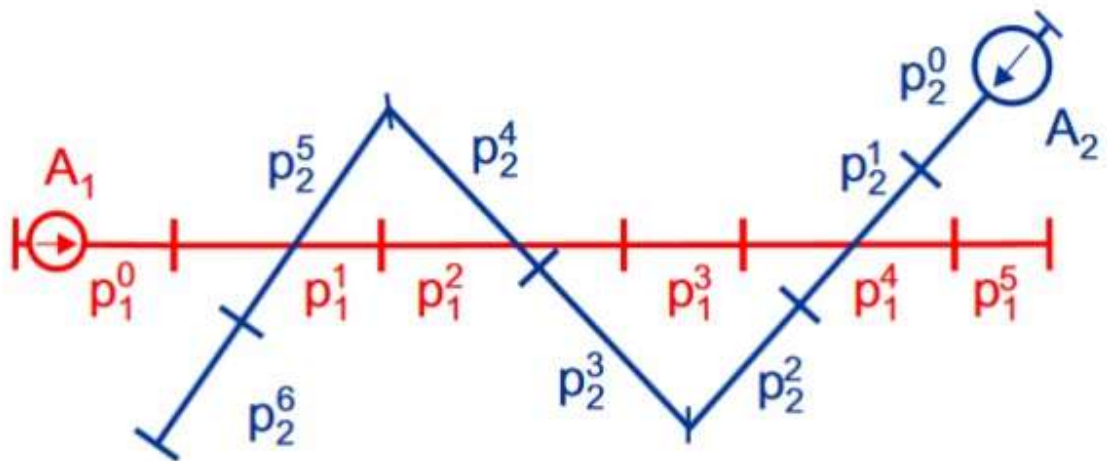


Figure 4

Based on the routes table of allowed states was created. Rows and columns represent sectors of track and the table shows allowed states of whole system. Table is presented as table 1

	1	2	3	4	5	6
1	1	1	1	1	1	1
2	1	1	1	1	0	1
3	1	1	1	1	1	1
4	1	0	0	1	1	1
5	1	0	0	1	1	1
6	1	0	0	1	1	1
7	1	1	1	1	1	1

Table 1

Based on this theoretical knowledge, there was build a model in Simulink, visible on figure 5.

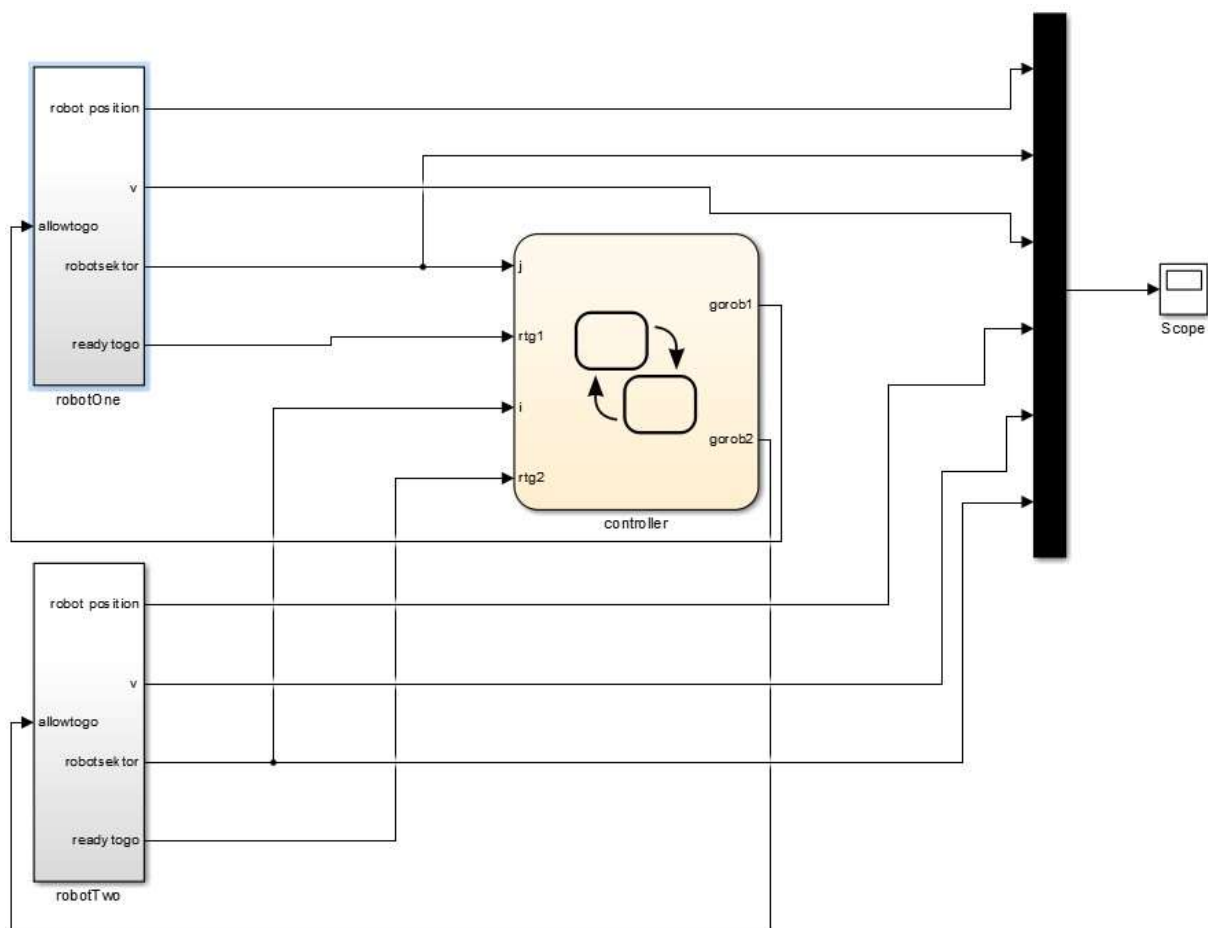


Figure 5

Model contains 3 Stateflow charts: a controller and two robots. The controller supplies the logic, considering states table, and prioritize robots. The whole system uses more complicated tools than in the first model. StateFlow chart of the robot looks much clearer and is divided in 2 subcharts (figure 6). Upper one has contact in controller, sends its willingness to go to next sector and receives permissions from it. The lower decides the acceleration of the robot. Later it is integrated to obtain velocity and position. Block uses some Matlab functions. For example one of them checks if robot reached place where it should stop decelerating if it doesn't have the permission to enter the next state.

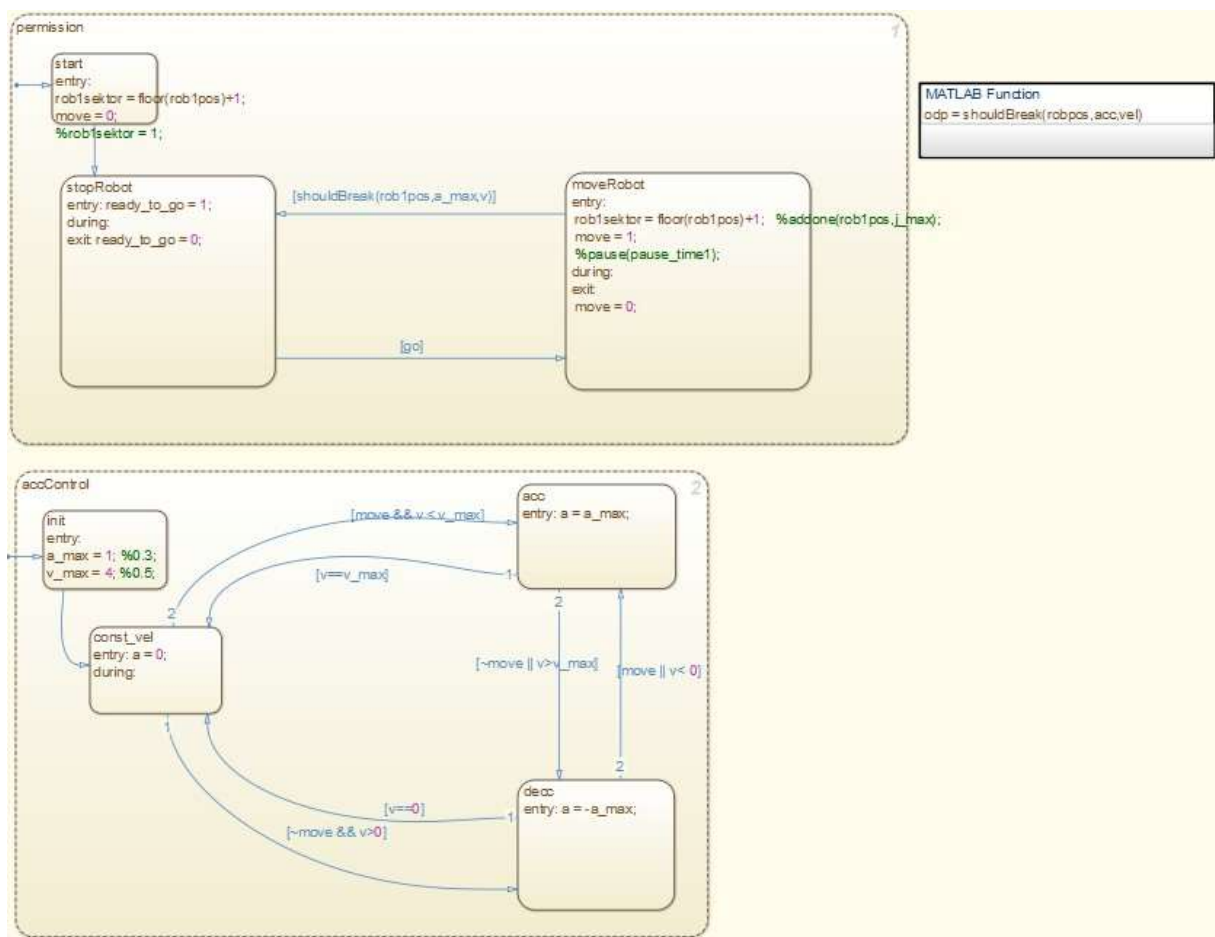


Figure 6

Positions, here understood as distance from the beginning of the track, are sent to Workspace and properly calculated to coordinates to enable the animation. Symbol of the robot is viewed on predefined track on Matlab figure. The animation shows movement of robots and how they stop in the sectors to let go one another. Screenshot of the animation window is shown on figure 7. Animation was created in separate .m file in Matlab.

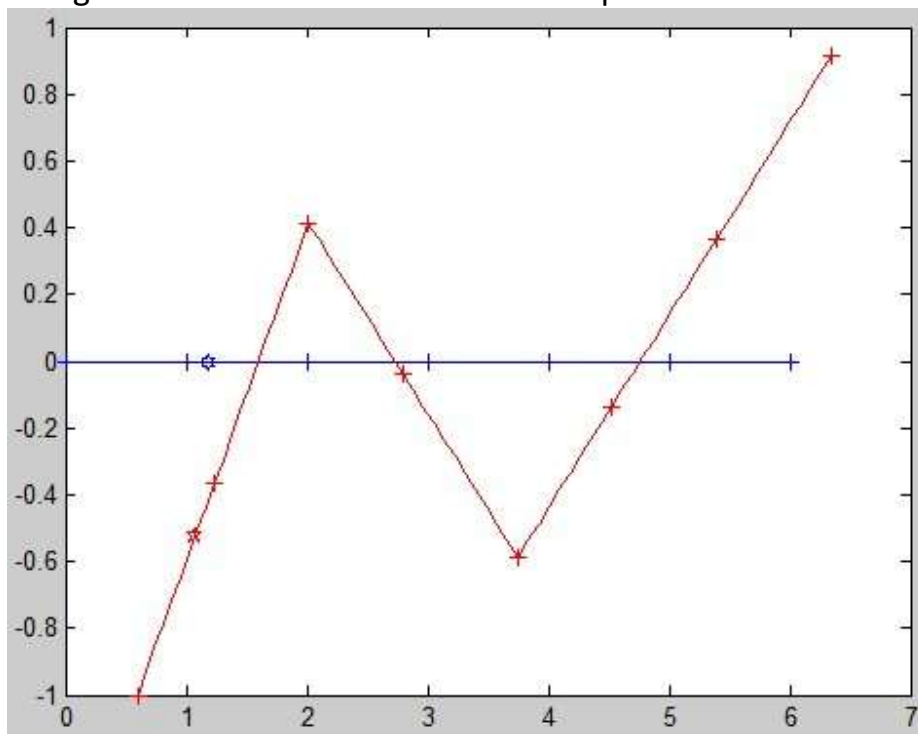


Figure 7

3. Conclusions

Two prospering models from described in the task description were build. Although the third one is not finished the main goal of the project – getting acknowledged with Stateflow environment and preparing basis to create even more complex models for master thesis purposes – were accomplished.

4. References

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3. E. Roszkowska, “Provably Correct Closed-Loop Control for Multiple Mobile Robot Systems”, Proceedings - IEEE International Conference on Robotics and Automation 2005:2810 - 2815 · May 2005
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