Assignment: FastSLAM

Start Assignment

Due No Due Date **Points** 30 **Submitting** a file upload **Attempts** 0
Allowed Attempts 1 **Available** until Jan 29 at 11:59pm

Assignment Overview

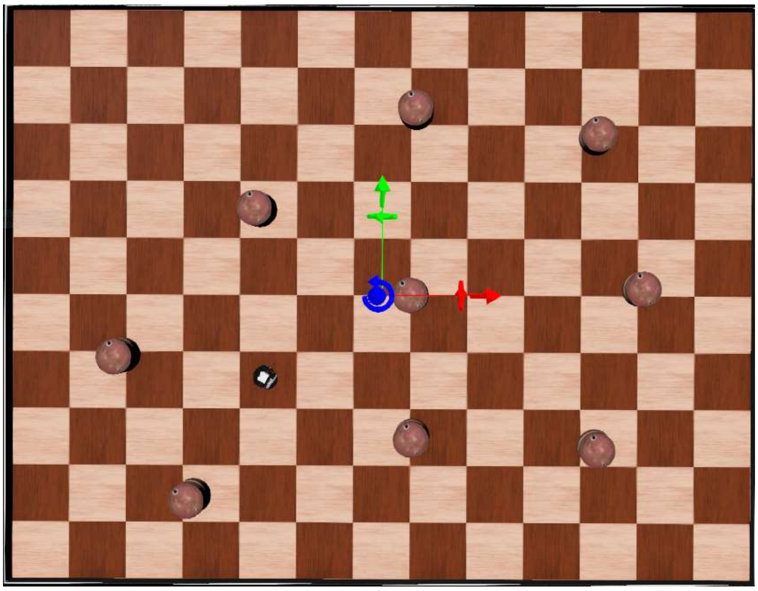
In this assignment, you need to complete the FastSLAM algorithm in Webots. Similarly to the particle filter exercise, you are provided with a code framework with blanks that you have to fill out.

Here, we consider the landmark-based version of FastSLAM. The robot can sense the landmarks within its proximity whereby the measurements consist of the (noisy) $\langle x, y \rangle$ distances between the robot and the landmarks. You can further assume known correspondences, i.e., the robot knows what measurement belongs to what landmark.

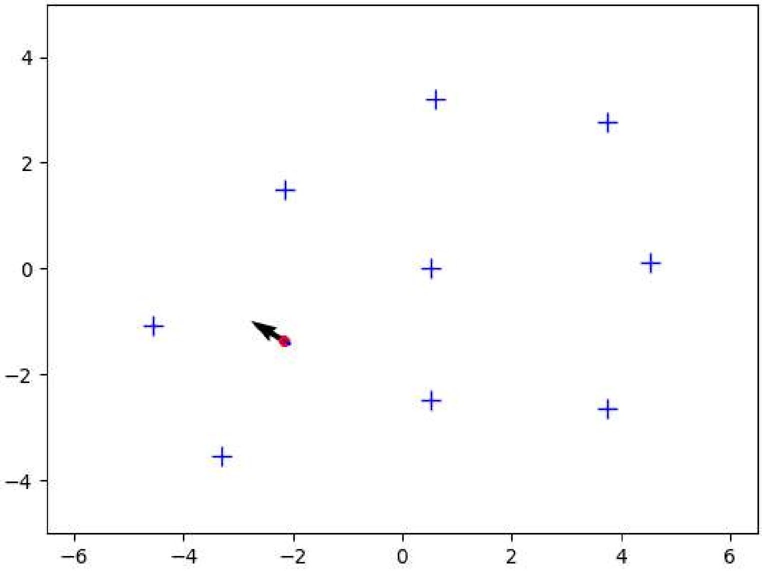
For this assignment, you can choose whether you would like to submit your answer by yourself or as part of a group.

Framework

Please download [fast_slam.zip (https://utn.instructure.com/courses/111/files/1196?wrap=1)](https://utn.instructure.com/courses/111/files/1196?wrap=1) (https://utn.instructure.com/courses/111/files/1196/download?download_frd=1) (or [fast_slam_2022a.zip (https://utn.instructure.com/courses/111/files/1197?wrap=1)](https://utn.instructure.com/courses/111/files/1197?wrap=1) (https://utn.instructure.com/courses/111/files/1197/download?download_frd=1)) and open worlds\fast_slam.wbt in the simulator. You should see an environment as shown below:



Similar to the previous assignment, you can control the robot with the arrow keys. After moving the robot, you should see the following plot:



The black arrow shows the robot pose obtained from the particle with the highest weight. The red dots show the particle, here all particles are initialized with the ground truth robot pose. The blue crosses mark the ground truth landmark positions.

Next, look at slam_controller.py. The main function is almost identical to the one used in the particle filter. However, there are differences in how the particles, measurements, and odometry are modeled. Each particle is a python dictionary where the entries 'x', 'y', and 'theta' represent the pose hypothesis, 'weight' is the importance weight, and 'landmarks' stores a dictionary of the landmark estimates of that particle. The keys in that dictionary are numerical landmark ids $1, \ldots, M$ where M is the number of landmarks in the environment. Each landmark is again a dictionary where 'mu' is the mean of the landmark position estimate and 'sigma' the covariance matrix, represented as numpy arrays. Further, the entry 'observed' is a boolean flag that indicates whether the landmark has been observed at least once.

The measurements are a dictionary with the entries 'id', 'x', and 'y'. The 'id' is a list of landmark ids that were observed at the current time step, 'x' and 'y' are lists of the corresponding distances relative to the robot.

To complete the algorithm, you need to implement the resample_particles() and eval_sensor_model() functions, as explained below.

Implement particle resampling (5 points)

The resample_particles() method should use the universal stochastic sampling algorithm similar to the standard particle filter. However, you will need to adapt your code to the new particle representation. Further, you have to make sure that when you sample a new particle from the old set you actually create a copy of that particle. Use python's copy.deepcopy() function for that purpose.

Implement the sensor model (25 points)

Next, implement the correction step of the FastSLAM algorithm in the eval_sensor_model() method, i.e., lines 4-18 in the algorithm outline on the previous page. There are a few things to notice. First, the landmark measurements are distances relative to the robot, and the landmark poses estimated by the Kalman Filters are in world coordinates. There is no linear transformation that could map between the two spaces. Thus, to be able to apply the KF correction, it is first necessary to convert the raw measured distances d_t into global landmark positions. That means that the measurement $z_{i,t}$ as in line 6 of the algorithm should be computed as $z_{i,t} = d_{i,t} + x_t^{[k]}$, where you omit the robot orientation in $x_t^{[k]}$. With that, the matrix C_t is simply the two-dimensional identity matrix.

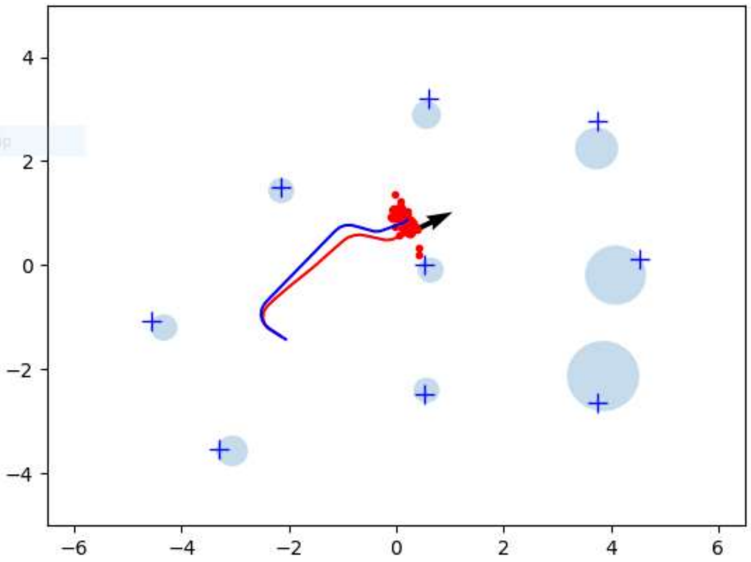
Assume further that the measurement noise is independent on the x and y axes with unit variance, i.e., R_t is also an identity matrix.

Notice also that not all landmarks are observed at each time step. When a landmark is observed for the first time, you will need to initialize the mean and covariance of that landmark. You can use $z_{i,t}$ for the mean and R_t for the covariance initialization. After initialization, set the 'observed' entry of the landmark to True.

Finally, do not forget to compute new particle weights by evaluating a two-dimensional Gaussian at $z_{i,t}$, using $\hat{z}$ as mean and Q as covariance (line 12). Further do not forget to normalize the particle weights.

Expected results

If implemented correctly, the code should produce an output similar to the one below:



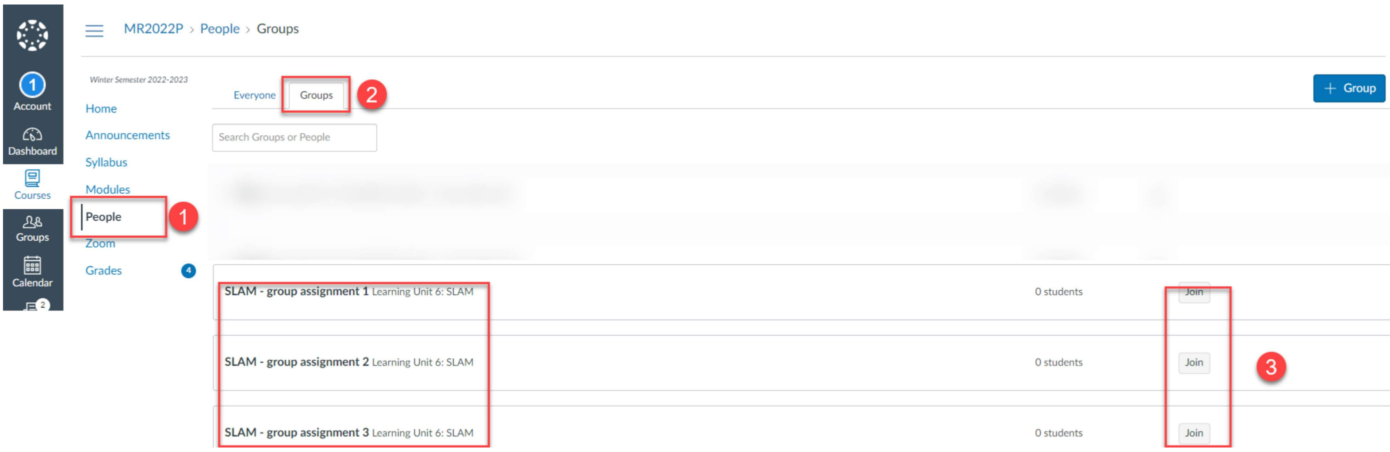
The blue line represents the ground truth trajectory of the robot. The red line shows the trajectory of the particle with the highest weight. The blue circles represent the estimated positions of the landmarks (of the highest-weight particle), where the circle size is proportional to the covariance of the estimate. Since the particle weights are recomputed in each time step, the plot can jitter from step to step.

Guidelines

For this assignment, you can choose whether you would like to submit your answer by yourself or as part of a group (every group member receives the same grade).

Please submit the modified controller file as slam_controller_your_name.py (or _your_group_name.py), the deadline is Sunday, Jan 29, 23:59 CET.

- If you would like to submit by yourself, just submit the assignment as usual by clicking on the button "submit assignment".
- If you would like to submit as a group, find your group members (group maximum is 4 people) and then all of you need to join the same group under the group set "Learning Unit 6: SLAM". Click on "People" in the navigation bar, then "Group" and then look for the groups labeled "SLAM - group assignment". One of you needs to submit your answer by clicking on the "submit assignment" button but all of you will receive the same mark. Please include the names of your group members in your submission.



Should you experience any technical problems, please click on "Help" and "Report a problem" on the left-hand navigation bar. The StaRs-Team will then be in touch with you shortly.

Technical Support

For technical support please get in contact with [stars@utn.de (mailto:stars@utn.de)](mailto:stars@utn.de).

For questions regarding the Webots simulator and the assignment please contact Dr. Michael Krawez.

Need help using Canvas Discussions? If so, please review the following page: **[Canvas Resources for Students - Discussions (https://design.instructure.com/courses/178/pages/discussions?module_item_id=676)](https://design.instructure.com/courses/178/pages/discussions?module_item_id=676)**.

Module 6 Rubric

Criteria	Ratings		Pts
Resampling implementation	**5 to >0.0 pts** **Full Marks**	**0 pts** **No Marks**	5 pts
Correction step implementation	**25 to >0.0 pts** **Full Marks**	**0 pts** **No Marks**	25 pts
			Total Points: 30