NA 568 Mobile Robotics: Methods & Algorithms Winter 2020 – PS3

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This problem set counts 10% of your course grade. You are encouraged to talk at the conceptual level with other students, but you must complete all work individually and may not share any non-trivial code or solution steps. See the syllabus for the full collaboration policy.

Submission Instructions

Your assignment must be received by 11:55 pm on Sunday, February 23. You are to upload your assignment directly to the Gradescope website as two attachments:

1. A `.tar.gz` or `.zip` file *containing a directory* named after your uniqname with the structure shown below.

   ```
   alincoln_ps3.zip:
   alincoln_ps3/
   alincoln_ps3/alincoln_ps3.pdf
   alincoln_ps3/run.m
   alincoln_ps3/occupancy_grid_map_CSM.m
   alincoln_ps3/occupancy_grid_map_continuous_CSM.m
   alincoln_ps3/semantic_grid_map_S_CSM.m
   alincoln_ps3/semantic_grid_map_continuous_S_CSM.m
   alincoln_ps3/utils/.
   ```

2. A PDF with the written portion of your write-up. Scanned versions of hand-written documents, converted to PDFs, are perfectly acceptable. No other formats (e.g., .doc) are acceptable. Your PDF file should adhere to the following naming convention: `alincoln_ps3.pdf`.

Homework received after 11:55 pm is considered late and will be penalized as per the course policy. The ultimate timestamp authority is the one assigned to your upload by Gradescope. No exceptions to this policy will be made.

Discrete and Continuous Counting Sensor Model

In this assignment, you will be implementing both discrete and continuous counting sensor models for occupancy grid maps and semantic grid maps. We will evaluate the 2D mapping algorithm using the `Intel dataset` [1] in `data/`. We've provided the visualization tools for you. After completing each task, you can test your code by running the command `run(task_num, true)` to visualize your map.

Task 1: Counting Sensor Model (20 points)

A. (20 pts) Implement a 2D counting sensor model for occupancy grid mapping in `occupancy_grid_map_CSM.m`. Visualize your map with `grid_size = 0.135 m` and its associated variance map. Include the figures in your pdf.

Task 2: Continuous Counting Sensor Model (30 points)

From the lecture, we know that if we have the concentration parameter $\alpha_j = (\alpha_j^1, \alpha_j^2)$, where α_j^1 represents the free-space class and α_j^2 represents the occupied class, we can have our continuous counting sensor model updated by the following equations:

$$\alpha_j^k := \alpha_0^k + \sum_{i=1}^{N} k(x_j, x_i) y_i^k \tag{1}$$

$$\mathbb{E}(\theta_j^k) = \frac{\alpha_j^k}{\sum_{k=1}^{K} \alpha_j^k} \quad \text{and} \quad \mathbb{V}(\theta_j^k) = \frac{\left(\frac{\alpha_j^k}{\sum_{k=1}^{K} \alpha_j^k}\right)\left(1 - \frac{\alpha_j^k}{\sum_{k=1}^{K} \alpha_j^k}\right)}{\sum_{k=1}^{K} \alpha_j^k + 1} \tag{2}$$

In this assignment, we choose the sparse kernel for $k(x_*, x_i)$. That is:

$$k(x_*, x_i) = \begin{cases} \sigma_0 \left[\frac{1}{3}(2 + \cos(2\pi \frac{d}{l}))(1 - \frac{d}{l}) + \frac{1}{2\pi} \sin(2\pi \frac{d}{l})\right], & \text{if } d < l \\ 0, & \text{if } d \geq l \end{cases}, \tag{3}$$

where hyperparameters are $\sigma_0 = 0.1$ and $l = 0.2$, and the distance metric is the usual Euclidean norm, i.e., $d = \|x_* - x_i\|$.

A. (15 pts) Implement a 2D continuous counting sensor model in `occupancy_grid_map_continuous_CSM.m`. Visualize your map with `grid_size = 0.135 m` and plot its associated variance map. Include the figures in your pdf.

B. (10 pts) Generate the map and the variance map using `grid_size = [0.135, 0.270, 0.5]`. Study the effects of varying the map resolution on the map inference. Provide a conclusion after discussing the results and clearly explain your reasons behind your conclusion. Include all figures (6 plots in total) in your pdf with appropriate captions.

C. (5 pts) Compare the continuous CSM to discrete CSM. What's the difference? What is the advantage of continuous CSM?

[1] http://www2.informatik.uni-freiburg.de/ stachnis/datasets.html

Task 3: Semantic Counting Sensor Model (20 points)

Now we have some noisy semantically labeled measurements of the Intel dataset, as shown in Figure 1. The measurements are classified into six different categories: *north rooms, west rooms, east rooms, south rooms, middle rooms, and hallways.*

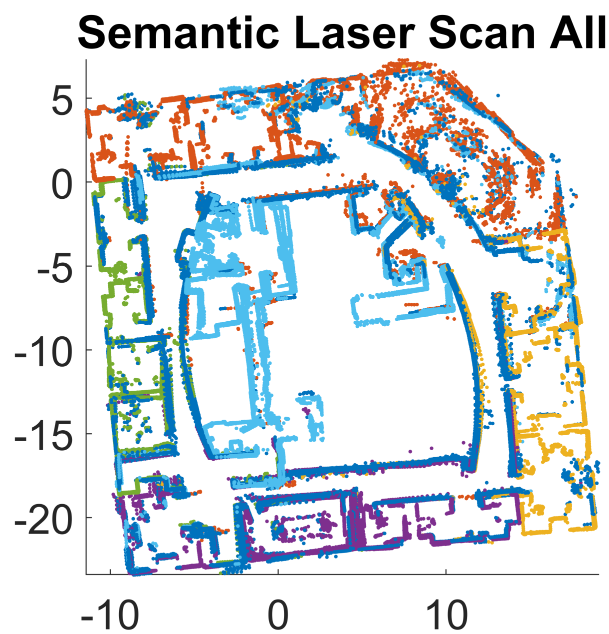

Figure 1: Semantic point cloud measurements; the Intel dataset.

A. (20 pts) Implement a semantic counting sensor model in `semantic_grid_map_S_CSM.m`. Visualize your map with `grid_size = 0.135 m` and visualize the variance of the class with highest probabilities at each grid. Include those two plots in your pdf.

Task 4: Countinuous Semantic Counting Sensor Model (30 points)

A. (15 pts) Implement a continuous semantic counting sensor model in `semantic_grid_map_continous_S_CSM.m` using the kernel defined in **Task 2**. Visualize your map and variance of the class with highest probabilities at each grid. Include those two plots in your pdf.

B. (10 pts) Generate the map and the variance map using `grid_size = [0.135, 0.270, 0.5]`. Study the effects of varying the map resolution on the map inference. Provide a conclusion after discussing the results and clearly explain your reasons behind your conclusion. Include all figures (6 plots in total) in your pdf with appropriate captions.

C. (5 pts + 10 Extra credits) Compare the continuous S-CSM to discrete S-CSM. What's the difference? What is the advantage of continuous S-CSM? Provide a discussion on which mapping algorithm(s) should be implemented on the robot and why.