

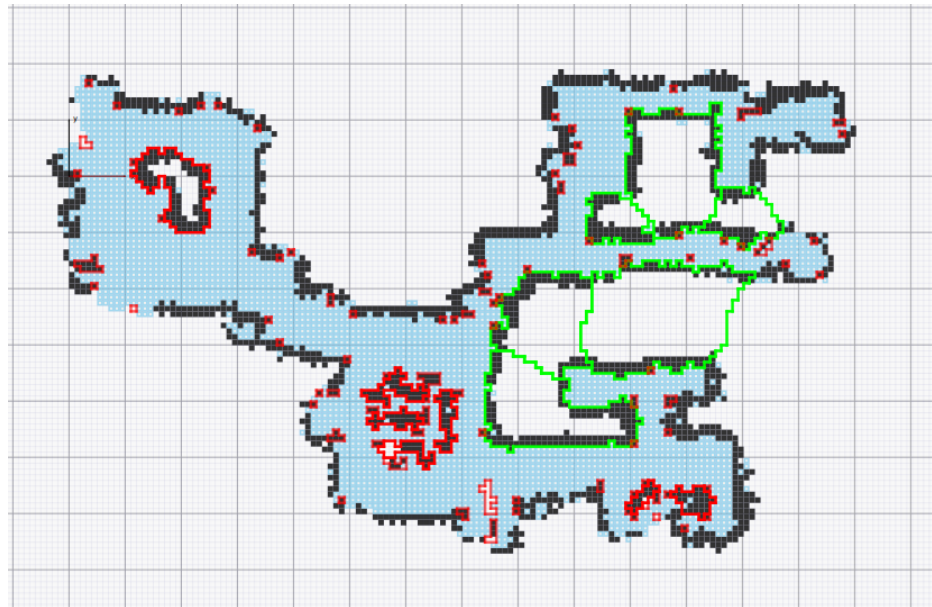
Wall/Clutter Classification

Fengyu Zhou

Supervised by: Andreas Kolling

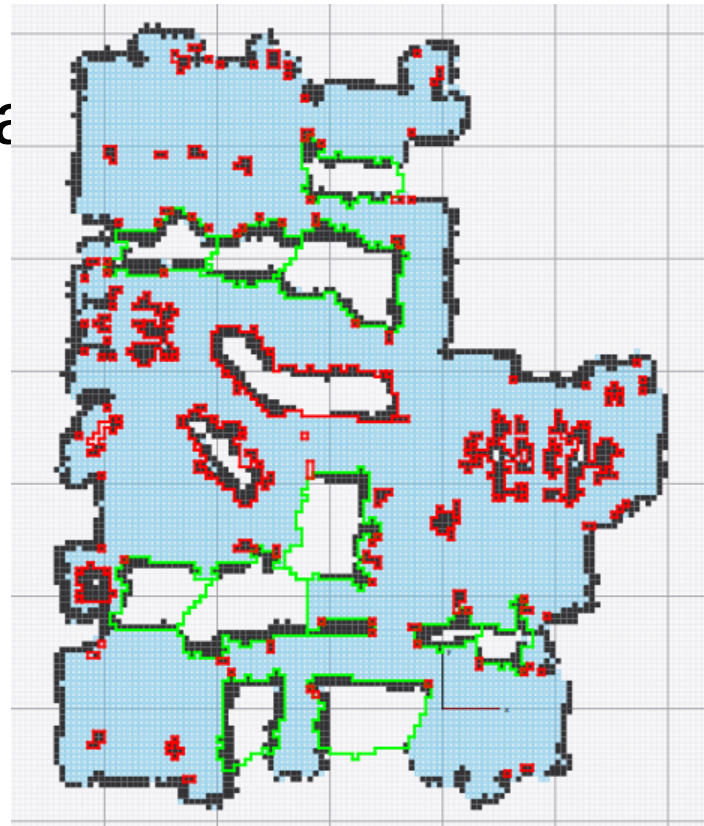
Wall/Clutter Classification

- Goal
 - Determine if a region is part of the wall or clutter
 - Wall: Boundary of a room
 - Clutter: Anything else (like a table, chair, carpet, etc.)



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Wall/Clutter Classification

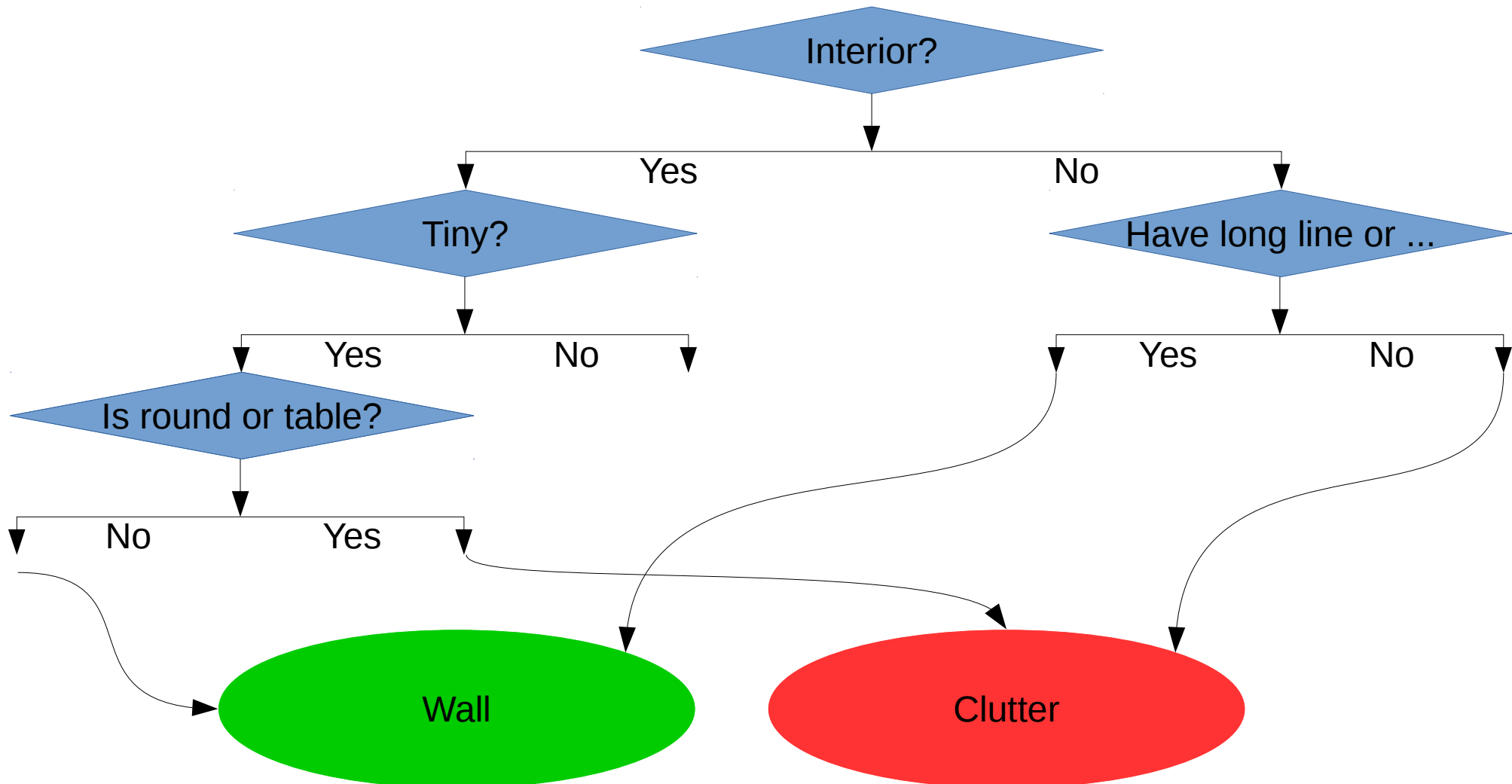
- Motivation
 - Can present the navigation map in a clearer way
 - Better classification performance can help the room segmentation
 - Give the robot a better understanding of the room in potential functions in the future.

Wall/Clutter Classification

- Existing work
 - An intuitive framework for classification
 - Can characterize some main features that distinguish wall from clutter

Wall/Clutter Classification

- Existing work



Wall/Clutter Classification

- Outline
 - Manually label the dataset (~500 maps, 4000 regions)
 - Gather features from regions
 - Apply classification models to training dataset
 - Use 5-folder cross validation to select the optimal parameters
 - We use 3 models: SVM with rbf kernel, Decision tree, XGBoost
 - Test on testing dataset

Wall/Clutter Classification

- Statistics

id	Feature	id	Feature
0	area	12	is_free
1	xmin	13	is_interior
2	xmax	14	compactness
3	ymin	15	long_line_length
4	ymax	16	n_long_lines
5	centroid_x	17	n_free_pixels
6	centroid_y	18	n_unexplored_pixels
7	majorAxisLength	19	n_neighbors
8	minorAxisLength	20	ratio_of_simplification
9	orientation	21	n_doors
10	eccentricity	22	total_door_length
11	solidity		

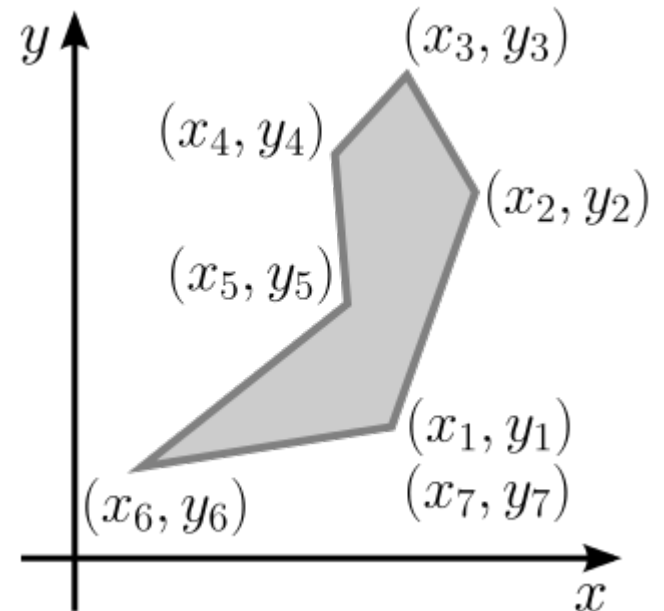
Statistics

- Moments

- $I_x = \int_S y^2 dA$

- $I_y = \int_S x^2 dA$

- $I_{xy} = \int_S xy dA$



Statistics

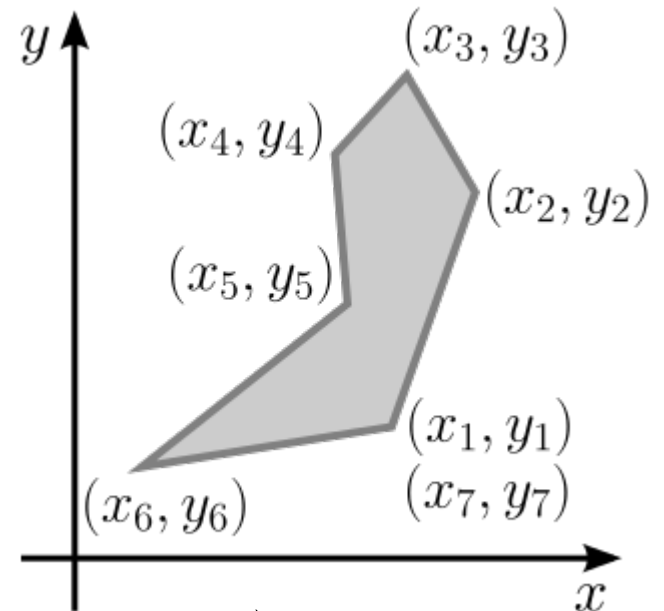
- Moments

- $I_x = \frac{1}{12} \sum_{i=1}^n (y_i^2 + y_i y_{i+1} + y_{i+1}^2) (x_i y_{i+1} - x_{i+1} y_i)$

- $I_y = \frac{1}{12} \sum_{i=1}^n (x_i^2 + x_i x_{i+1} + x_{i+1}^2) (x_i y_{i+1} - x_{i+1} y_i)$

- $I_{xy} = \frac{1}{12} \sum_{i=1}^n (x_i^2 + x_i x_{i+1} + x_{i+1}^2 + y_i^2 + y_i y_{i+1} + y_{i+1}^2) (x_i y_{i+1} - x_{i+1} y_i)$

- $\begin{bmatrix} I_x & I_{xy} \\ I_{xy} & I_y \end{bmatrix}$



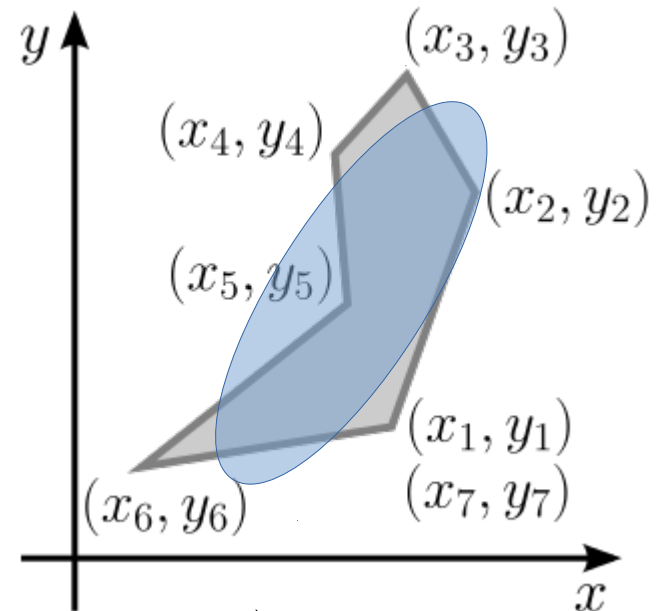
Statistics

- Moments

- $$- I_x = \frac{1}{12} \sum_{i=1}^n (y_i^2 + y_i y_{i+1} + y_{i+1}^2) (x_i y_{i+1} - x_{i+1} y_i)$$

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Statistics

- Moments

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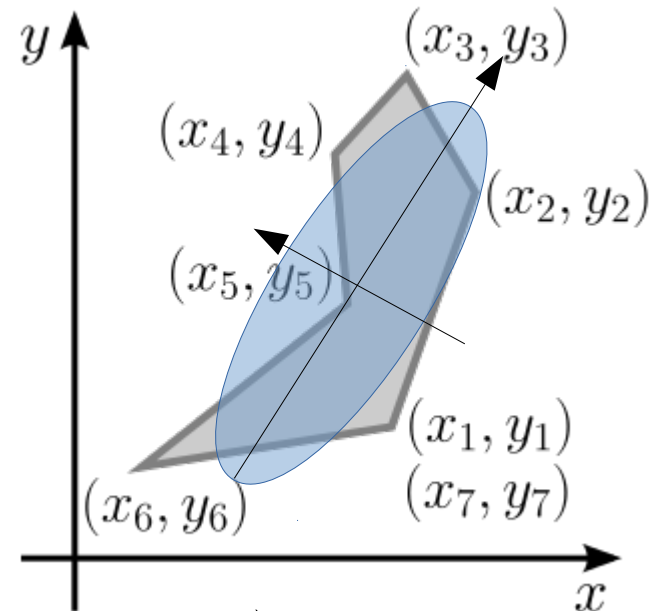
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- Eccentricity

- $\sqrt{a^2 - b^2} / a$

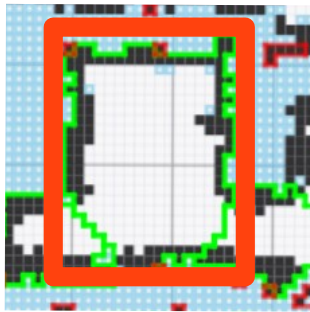
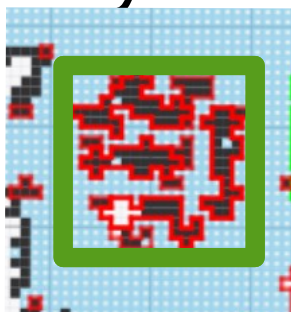
- Orientation



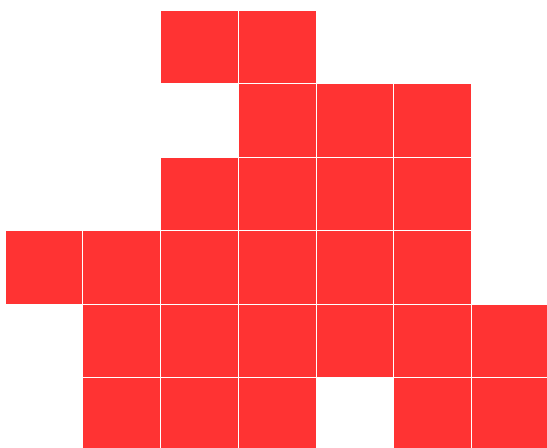
Statistics

- Solidity

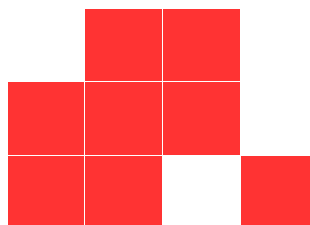
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- Compactness



Erode →

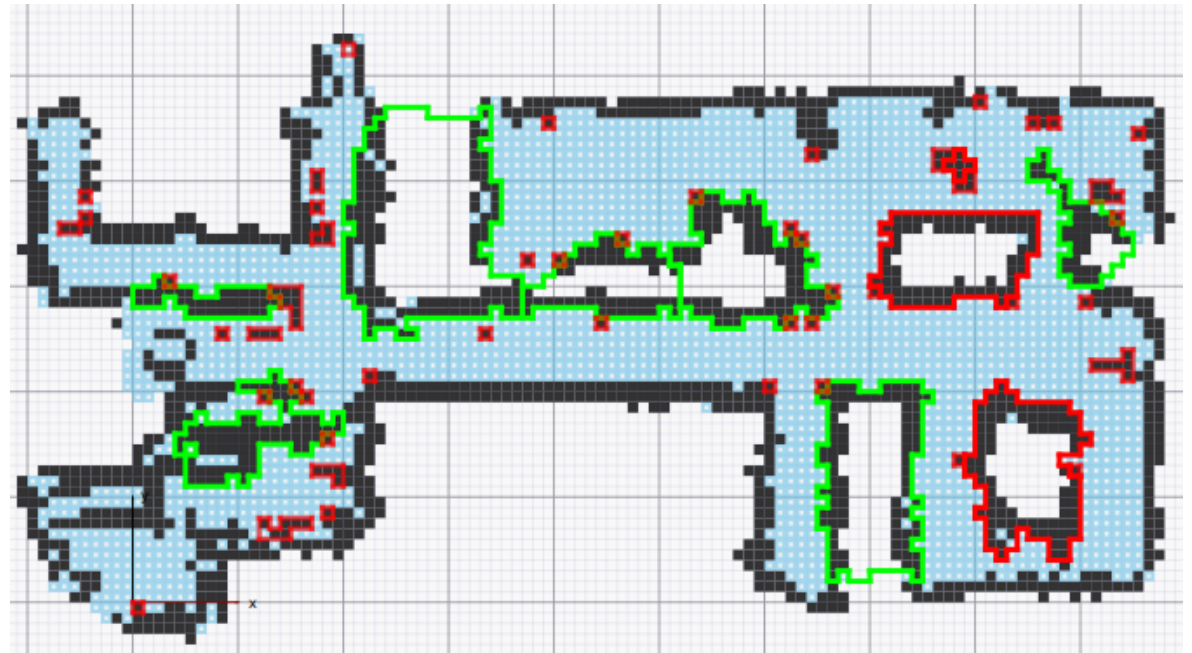


Erode →



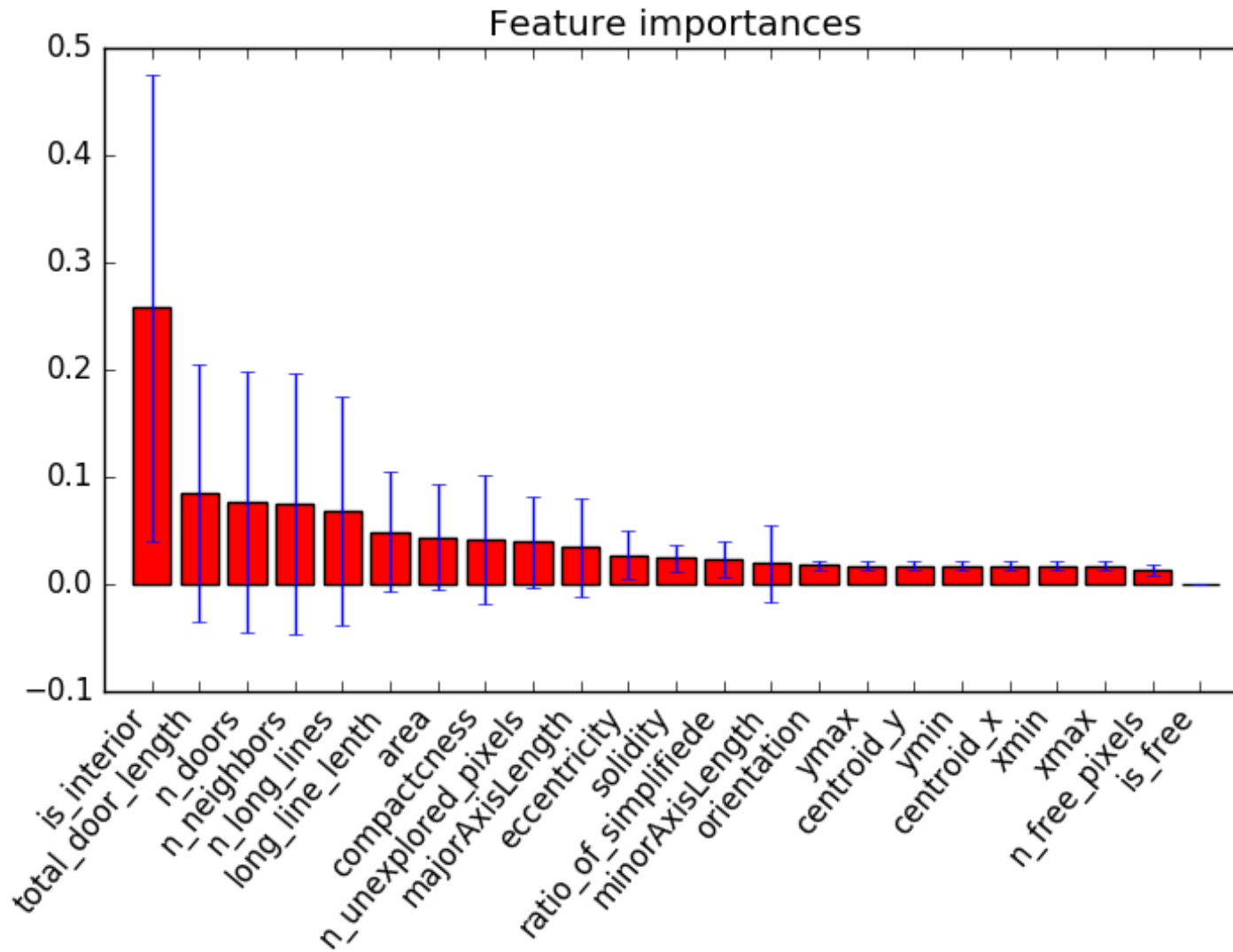
Statistics

- Context information
 - Number of neighbors
 - Interior or Background connected
 - Total length of doors
 - Number of doors



Wall/Clutter Classification

- Feature Importance



Wall/Clutter Classification

- Classifiers

- SVM

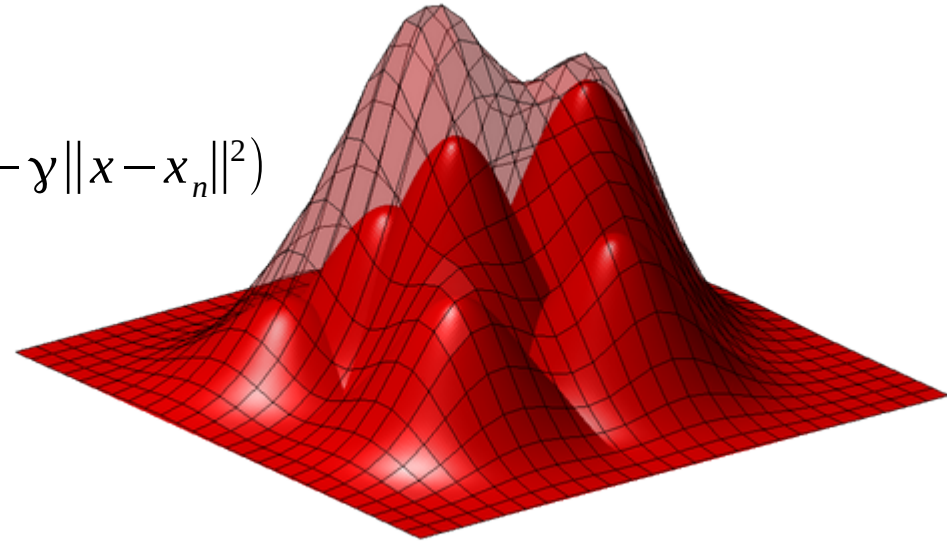
- Hypotheses: $h(x) = \sum_{n=1}^N w_n \exp(-\gamma \|x - x_n\|^2)$
 - Cost for misclassification

- Decision Tree

- Max depth: 3~4 levels

- XGBoost

- Ensemble multiple trees
 - A large parameter hyperspace
 - Only tune 3 parameters here
 - γ : regularization coefficient (for the size of tree)
 - η : shrinkage step length
 - d : max depth for regression tree



Wall/Clutter Classification

- Error Rate (Cross Validation Error)

Case id	# Training/# Testing	Intuitive Classifier	SVM	Decision Tree	XGBoost
1	3301/890	10.22%	10% (8.91%)	7.42% (10.66%)	7.79% (7.64%)
2	3547/644	13.82%	12.73% (8.43%)	11.80% (9.44%)	12.88% (7.58%)
3	3511/680	13.38%	11.76% (8.69%)	11.03% (9.40%)	10.14% (7.32%)

Wall/Clutter Classification

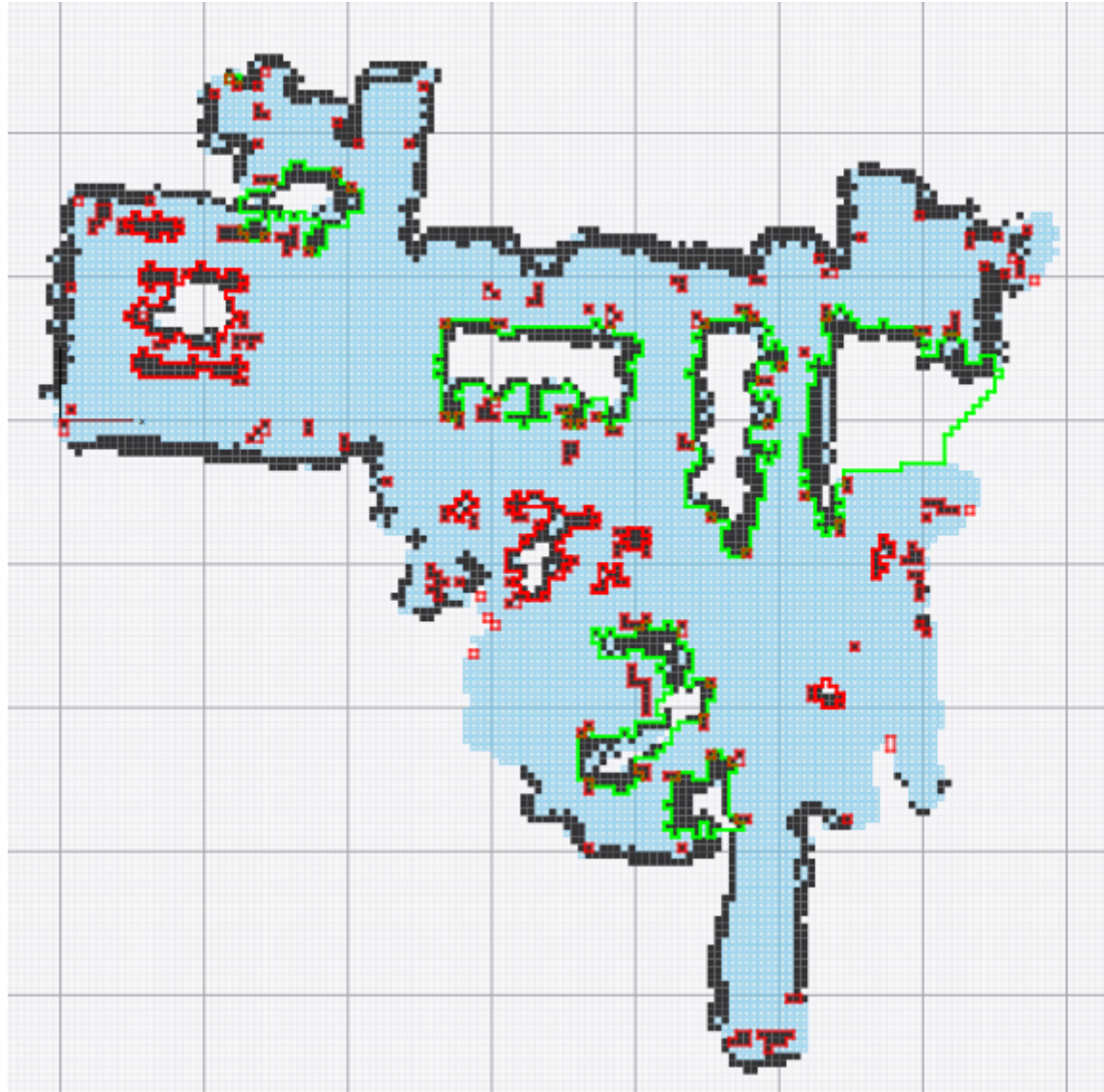
- Facts
 - Intuitive Classifier

Type of Region	Total	Correct	Wrong	Wall or Clutter	Correct	Wrong
Interior	316	290 (91.8%)	26 (8.2%)	Wall: 5	4 (80.0%)	1 (20.0%)
				Clutter: 311	286 (92.0%)	25 (8.0%)
BG connected	364	299 (82.1%)	65 (17.9%)	Wall: 297	279 (93.9%)	18 (6.1%)
				Clutter: 67	20 (30.0%)	47 (70.0%)

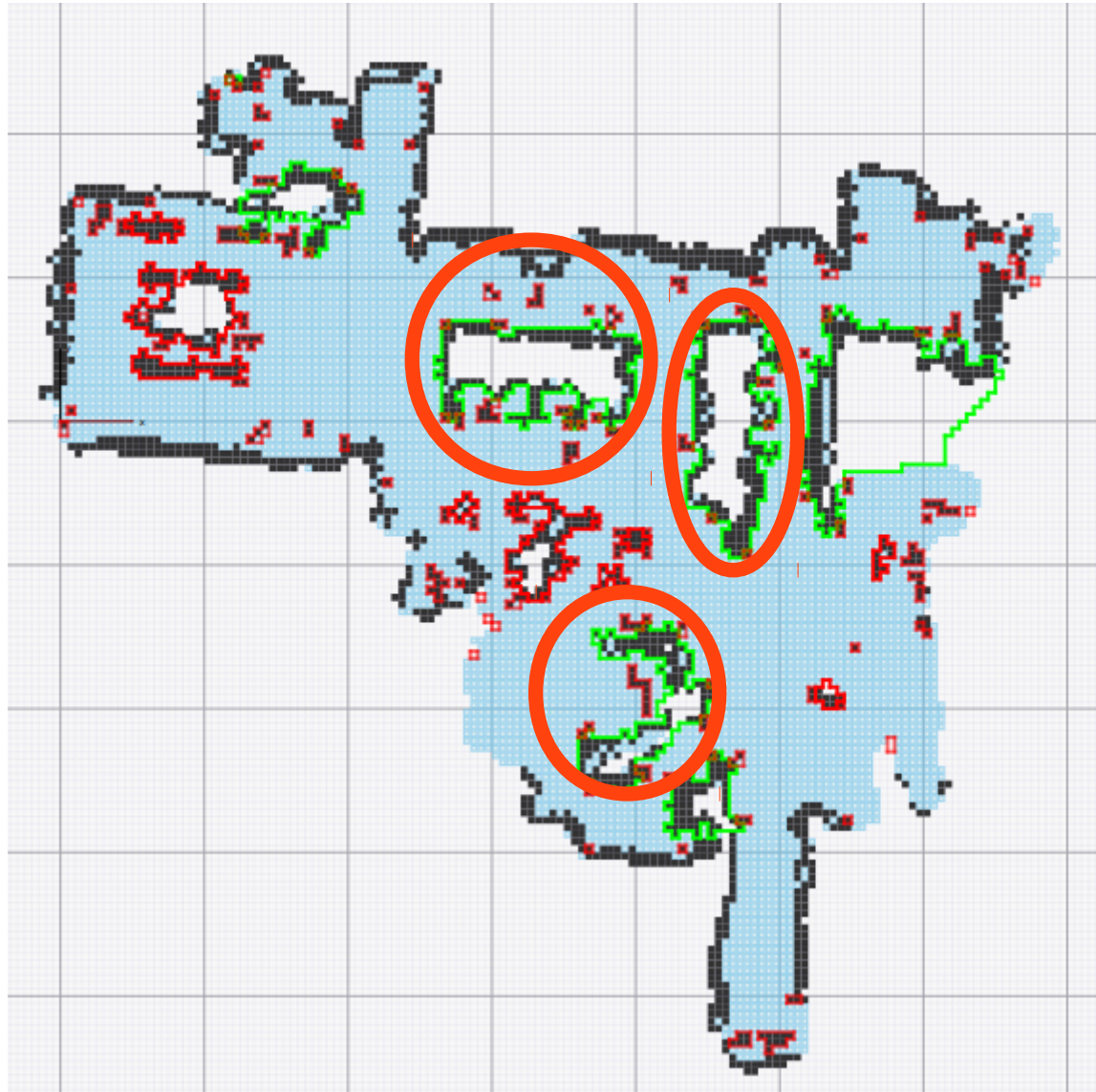
- XGBoost

Type of Region	Total	Correct	Wrong	Wall or Clutter	Correct	Wrong
Interior	316	296 (93.7%)	20 (6.3%)	Wall: 5	3 (60.0%)	2 (40.0%)
				Clutter: 311	293 (94.2%)	18 (5.8%)
BG connected	364	315 (86.5%)	49 (13.5%)	Wall: 297	289 (97.3%)	8 (2.7%)
				Clutter: 67	26 (38.8%)	41 (61.2%)

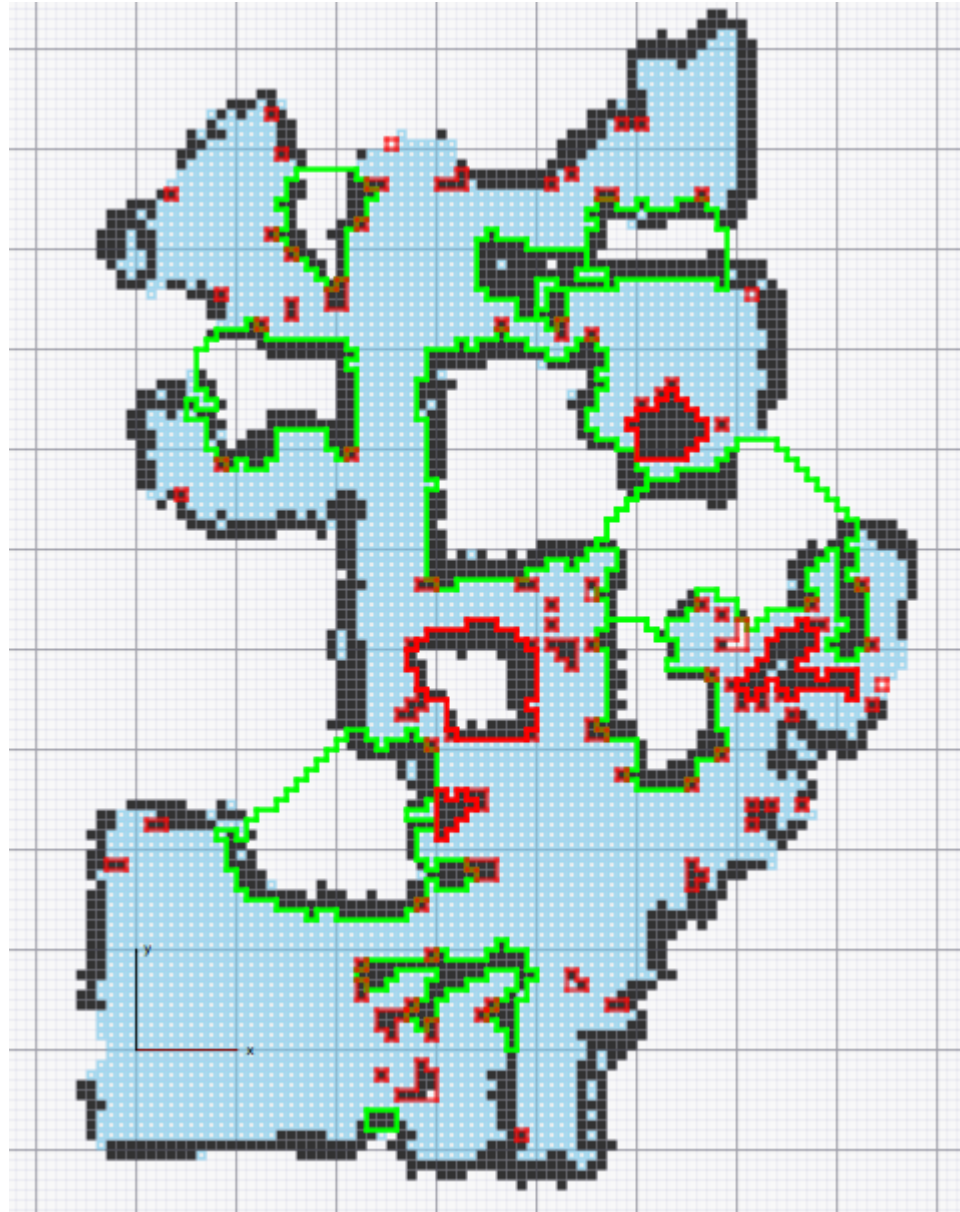
Misclassification Examples



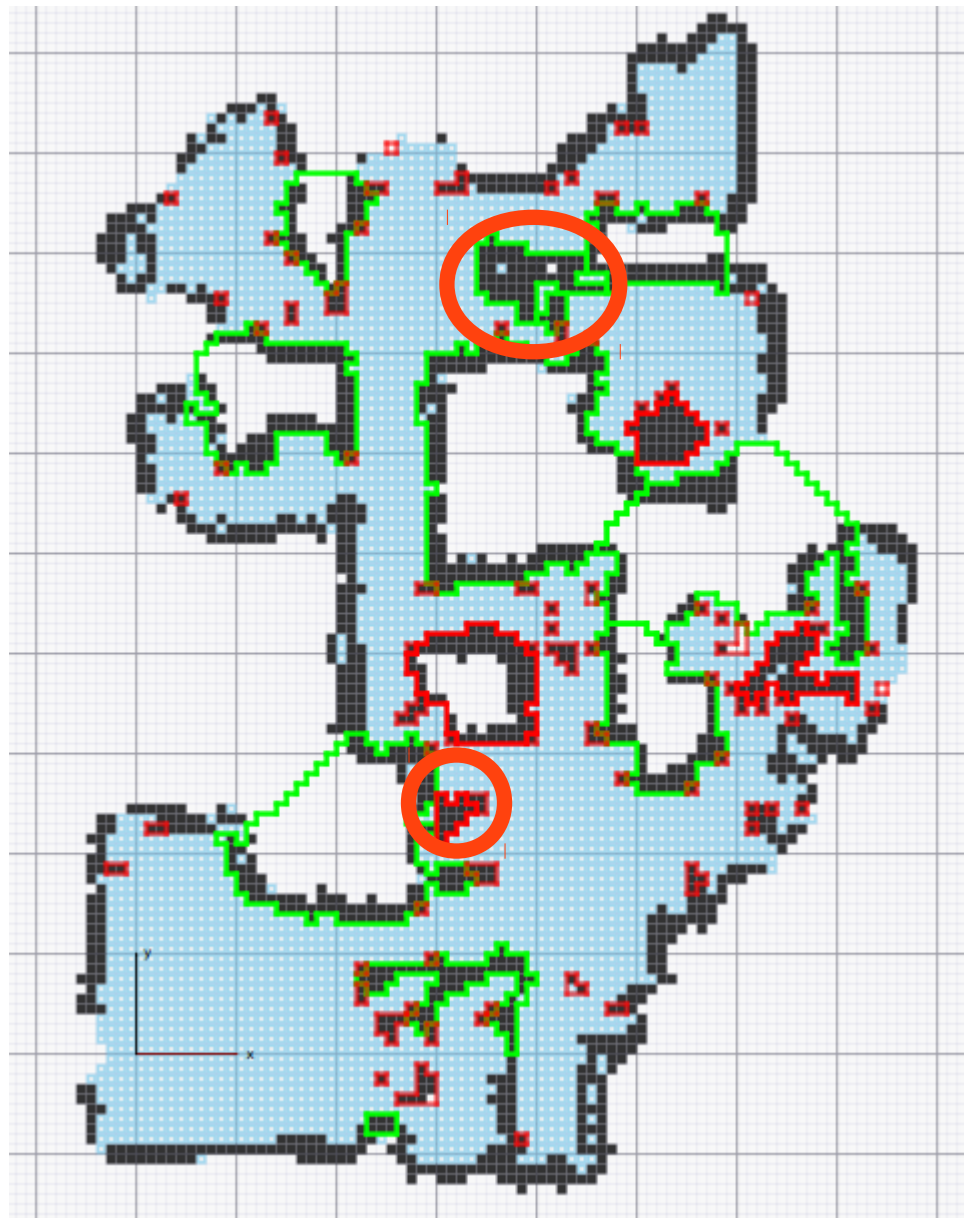
Misclassification Examples



Misclassification Examples



Misclassification Examples



Wall/Clutter Classification

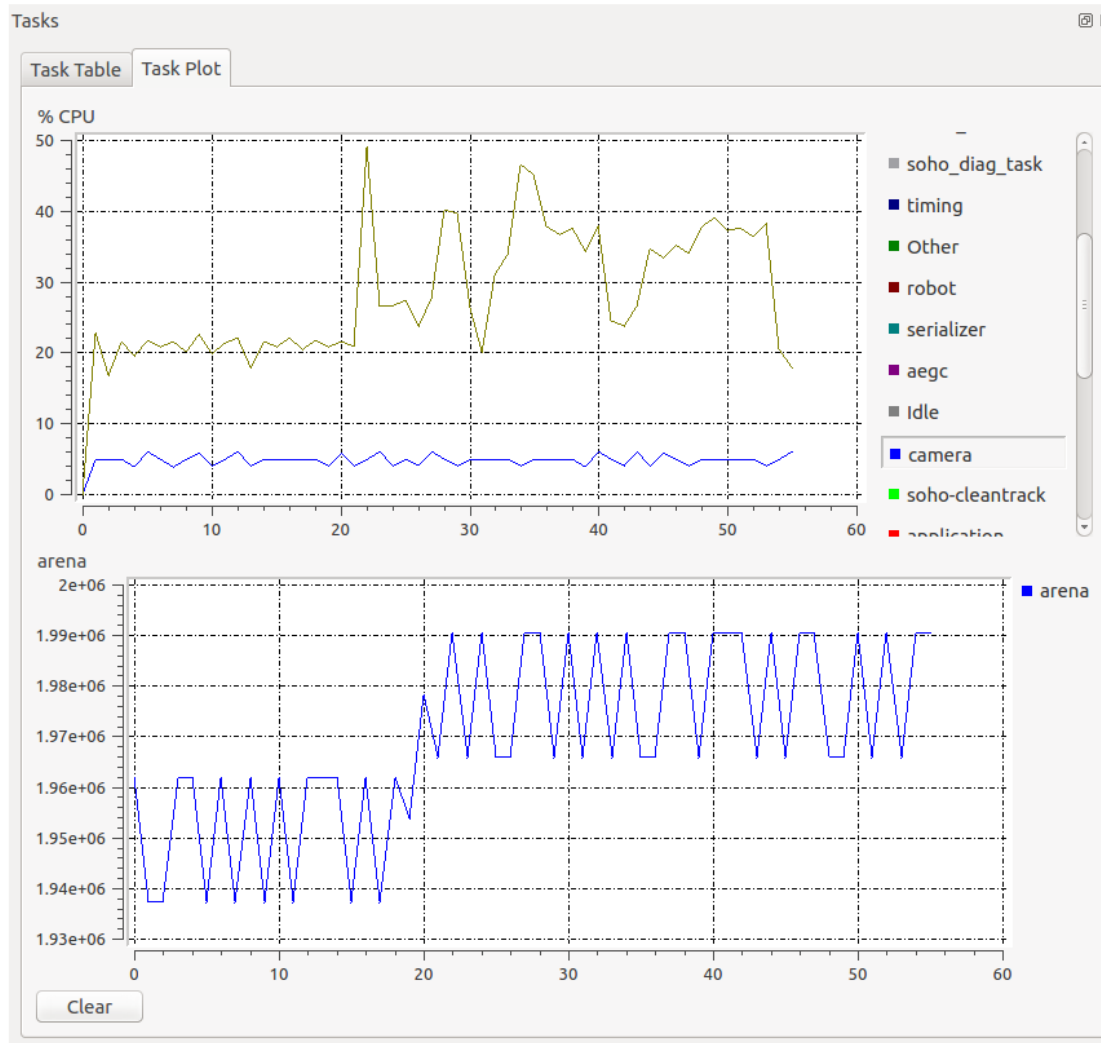
- Conclusions
 - Machine learning method can improve the classification performance compared to the intuitive classifier
 - Context information is important, then is the shape information
 - Background connected regions benefit more from the machine learning method than interior regions
 - Overfitting might still exist (or the labeled data might not be clean enough)
 - Decision tree suffers less overfitting due to its simple model
 - XGBoost seems to have a better overall performance

Wall/Clutter Classification

- Future Work
 - Work on larger dataset
 - Design better features according to the classification result, and filter out unimportant features
 - Might use the current result as a starting point to train some more advanced models

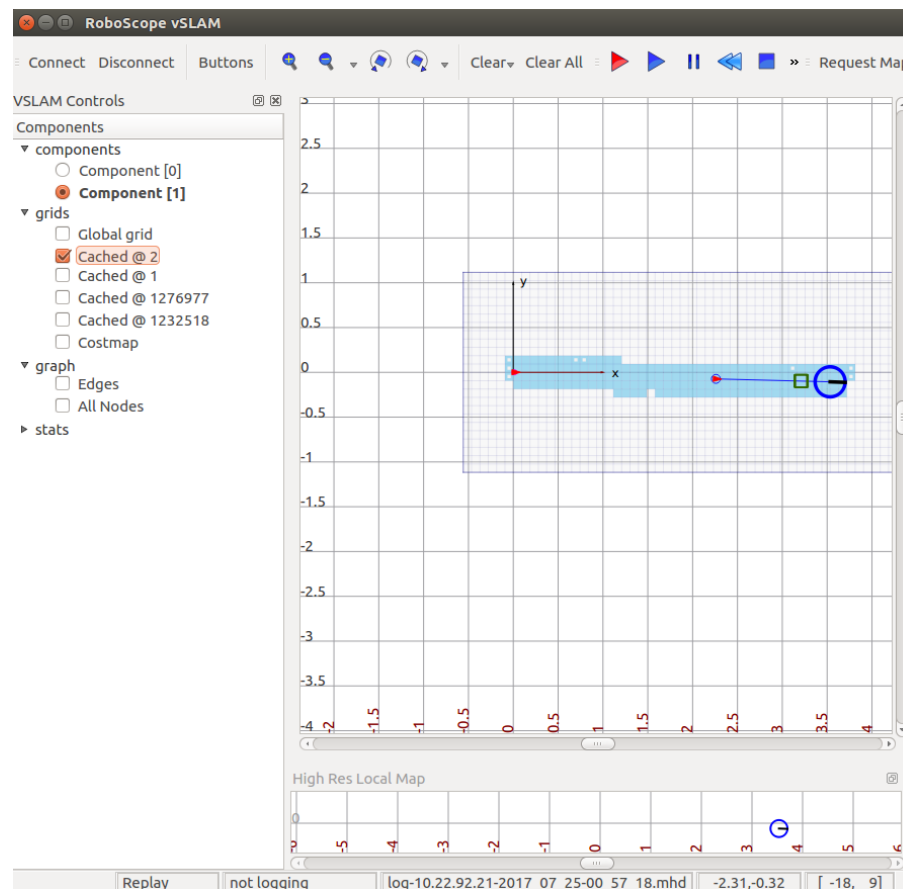
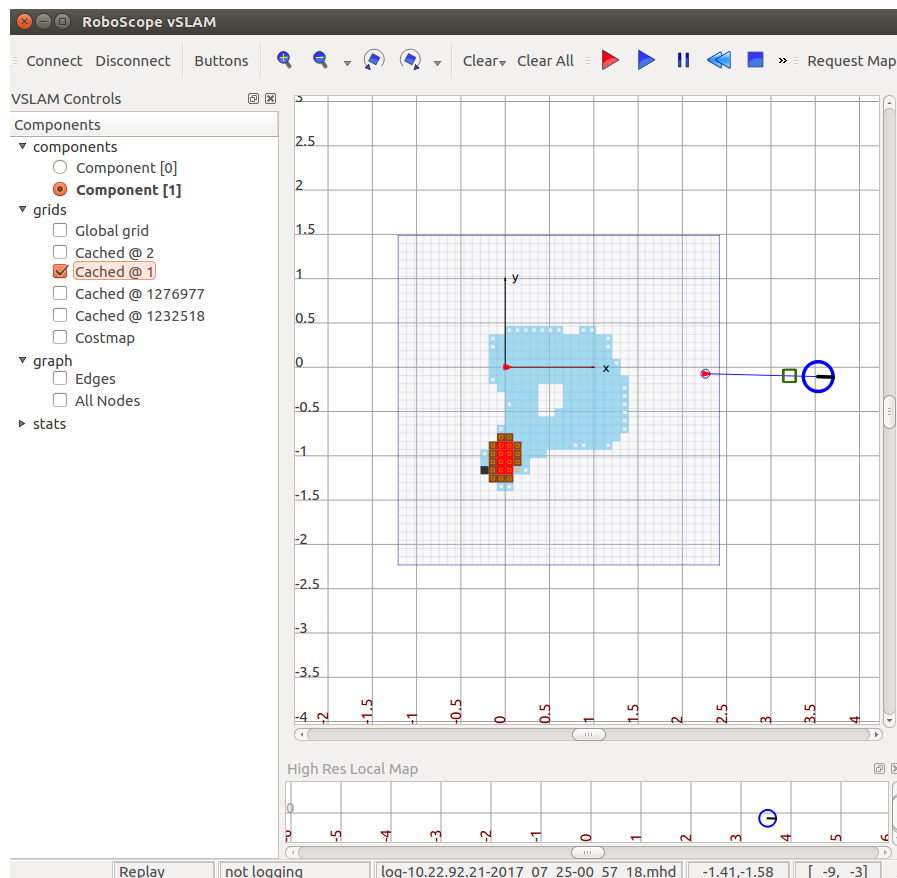
Some other projects...

- Task Plotting



Some other projects...

- Task Plotting
- Render all components



Some other projects...

- Task Plotting
- Render all components
- Cambot gyro rotation test

Thank you!