A Novel Active Learning Approach for Constructing High-Fidelity Mobility Maps

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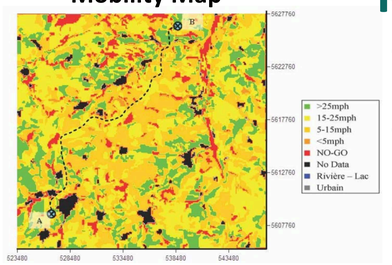
Motivation

- Constructing mobility maps requires thousands of physics-based simulations, each of which can take weeks using high-performance computing[1].
- Trained machine learning (ML) classifiers can quickly generate mobility maps[2].
- According to PAC learning theory, data that can be separated by a classifier is expected to require up to $O(1/\varepsilon)$ **randomly selected points**[3] (simulations) to train the classifier with error less than ε.

Mobility Map

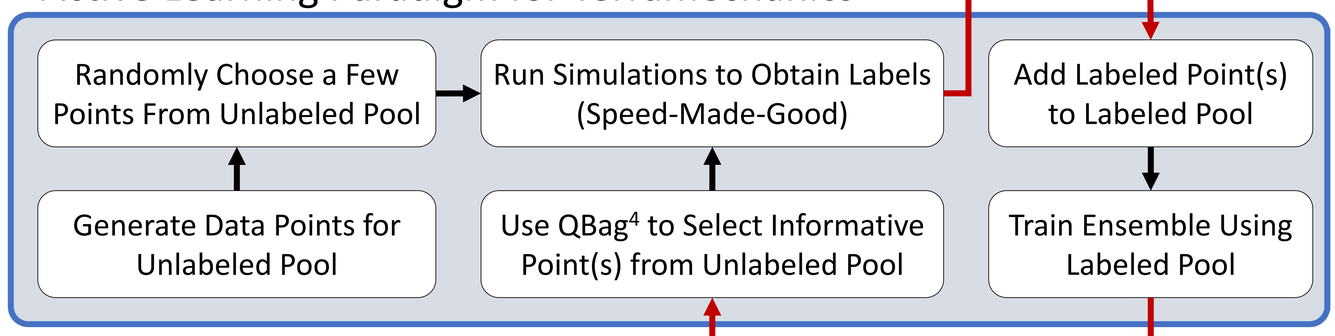


Objective

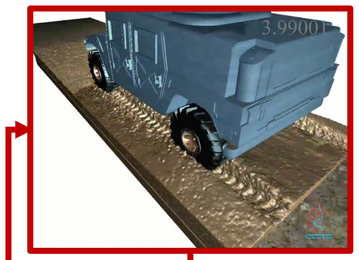
- Develop a sampling technique that will train ML classifiers using far fewer simulations.

Approach

Active Learning Paradigm for Terramechanics

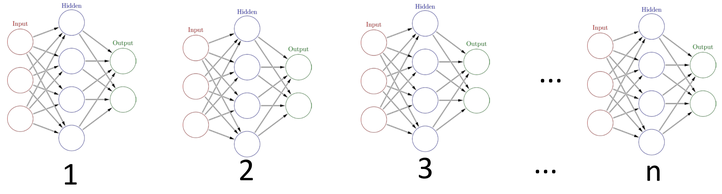


Physics-based Simulation



Ensemble of Classifiers

Each classifier is trained on a randomly chosen subset of the labeled data.



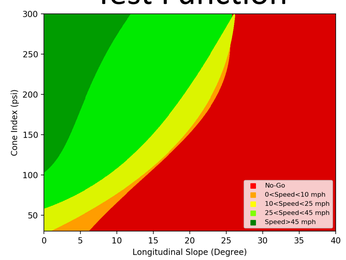
The ensemble consists of n classifiers.

Each classifier predicts the label of each point in the unlabeled pool. If the majority of the classifiers cannot agree on the label of a point, then the point is queried.

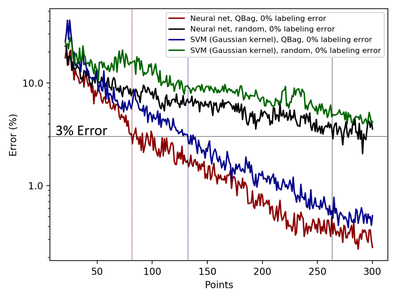
Results

- We constructed a test function using data from 528 physics-based simulations.
- QBag can significantly reduce the number of simulations needed to train multilayer perceptron (MLP) and SVM classifiers.
- With 100 points, the MLP that used QBag had comparable accuracies to the MLP that was trained with 300 randomly chosen points.

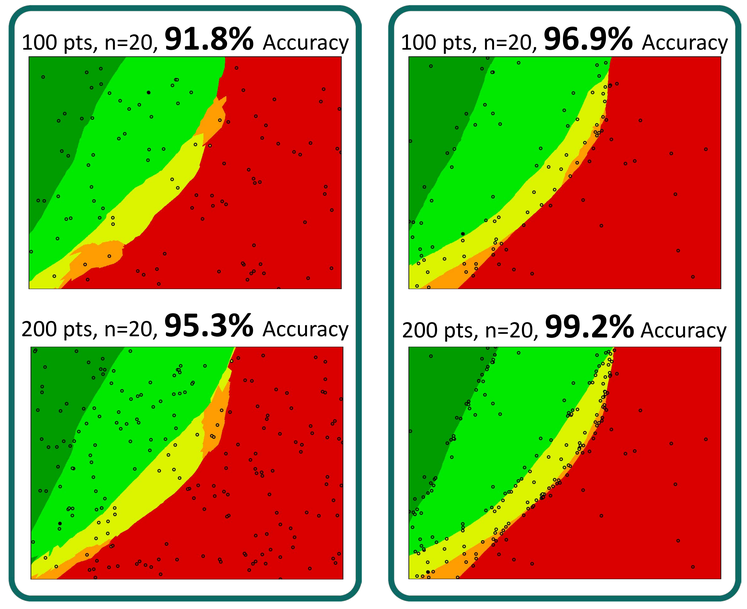
Test Function



Classifier Errors



Random Sampling vs Active Learning



Future Work

- Increase the size of the feature space to include more variables that affect mobility, such as the soil density, cohesion, and friction.
- Investigate tools for reducing redundancy when sampling in batches.
- Use simulations to label data points that are selected by the active learner.

References

1. McCullough, Michael, et al. "The Next Generation NATO Reference mobility model development." *Journal of Terramechanics* (2017).
2. Jayakumar, Paramsothy and Dave Mechergui. "Efficient Generation of Accurate Mobility Maps Using Machine Learning Algorithms." *Under review* (2018).
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4. Mamitsuka, Naoki Abe Hiroshi. "Query learning strategies using boosting and bagging." *Machine learning: proceedings of the fifteenth international conference (ICML'98)*. Vol. 1. Morgan Kaufmann Pub, 1998.