THE UNIVERSITY OF RHODE ISLAND
OCEAN ENGINEERING

Seafloor Mapping with Machine Learning

How can the efficiency and accuracy of seafloor mapping ML algorithms be increased?

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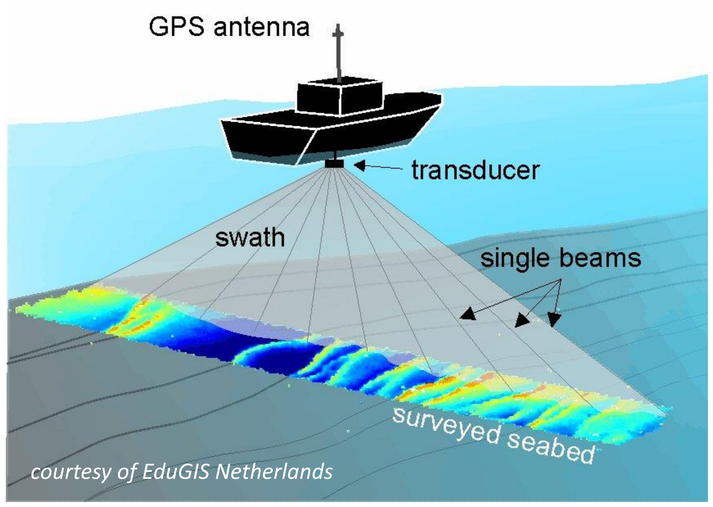
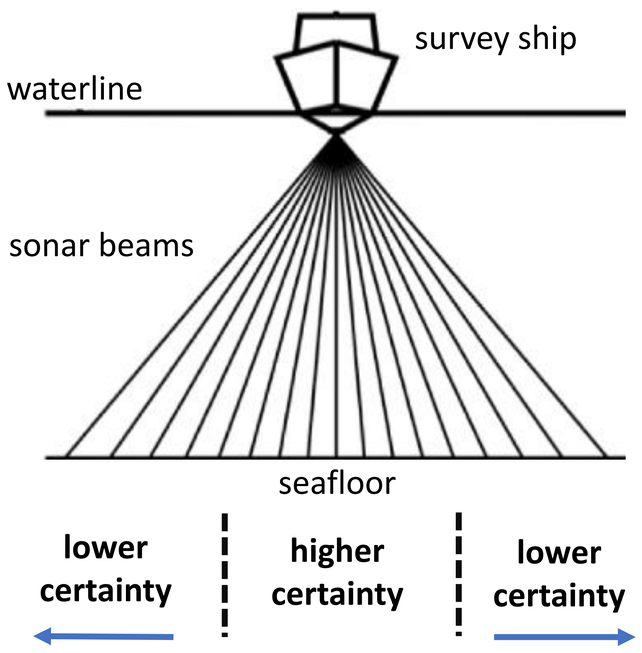
1. Seafloor Mapping

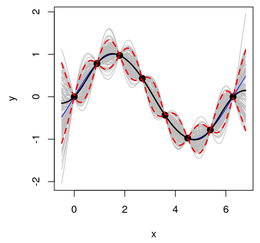


Multi-beam sonar systems reflect sound off the seafloor to determine water depth. Each sonar ping generates multiple sounds across the swath. Data from thousands of pings recorded during a survey are assembled to form a bathymetry (seafloor) map.



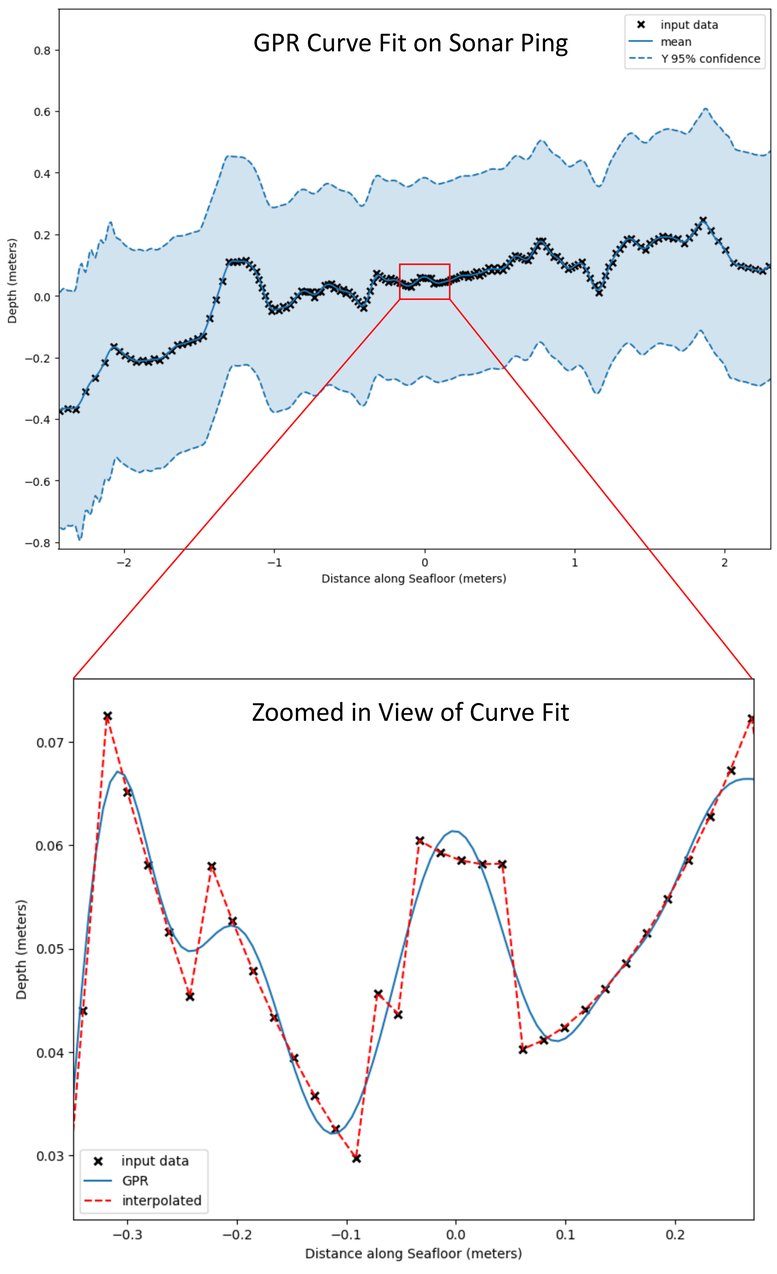
Not all sonar soundings have the same degree of certainty. In general, the central beams tend toward higher certainty (higher depth accuracy), whereas the outermost beams have lower certainty. These uncertainties serve as inputs to the machine learning model.

2. Machine Learning with GPR

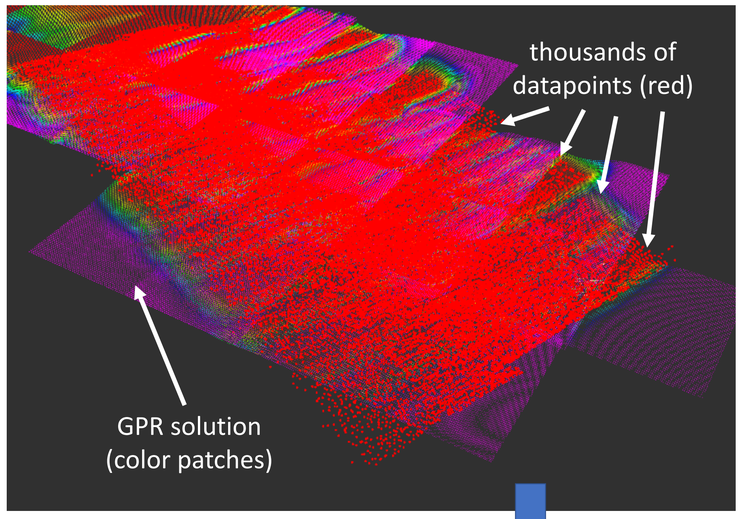


Gaussian Process Regression (GPR) is a machine learning (ML) approach that can be used to model relationships between input variables, such as the depth and position of sonar soundings, and produce a 'shape' estimate of the seafloor with uncertainty statistics. GPR models the soundings as realizations of a normally distributed set of functions specified by a length scale and uncertainty.

A GPR solution can be calculated on a single sonar ping or an entire survey. For a single ping, the black marks are raw data, the blue line is the best fit from GPR, and the shaded blue region shows uncertainty bounds (95% confidence).

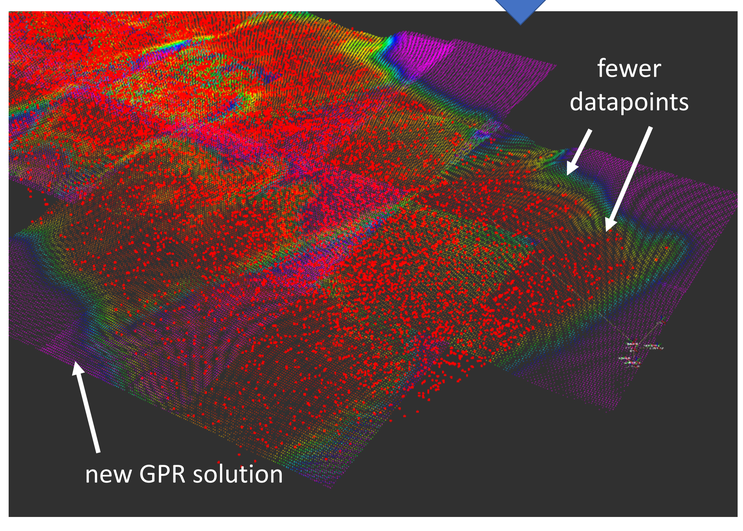


Time to compute the GPR model increases, O(N^3), as the number of datapoints increases. To reduce computation time, sonar data can be intelligently down-sampled prior to applying GPR using a variety of methods.



Down-sample Methods
- Uniform random
- Decimation (every j-th point)
- Hybrid (uniform + decimation)
- Point averaging
- Information Gain

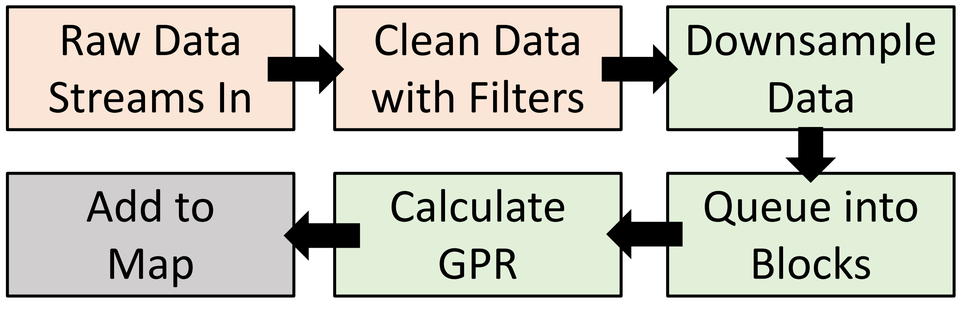
10% Uniform Random Down-sample



3. Online Processing

Processing bathymetry data online with GPR requires an onboard graphics processing unit (GPU) for parallel computing. Each step must be optimized to minimize compute time for the algorithm to approach 'real-time' operation.

Currently, the focus is on efficient down-sampling algorithms that can select representative datapoints quickly without significant losses in solution accuracy.



4. Conclusion

Highly accurate seafloor maps can be developed close to real time using an efficient GPR algorithm that incorporates sonar beam uncertainty.

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