Potential REU Projects

Cold Regions Research and Engineering Laboratory (CRREL)

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Project 1: Remote Characterization of Ocean Currents

Ocean currents play a significant role in the movement of sea ice and icebergs. However, accurately characterizing surface currents can be difficult. Direct observations from buoys are accurate but do not have good spatial coverage. Satellite observations have much better spatial coverage, but are less accurate and may not have adequate temporal resolution. Model predictions are a third source of information; they have good spatial and temporal resolution but are the least accurate.

With the aim of producing more accurate representations of ocean surface currents, this project will try to statistically combine multiple observation types (e.g., buoy and satellite measurements) to produce a single description of the ocean surface velocities that accounts for the relatively accuracy of each observation type. Gaussian processes [5] will be used extensively and a novel way of enforcing mass conservation using ideas from probabilistic numerics [4] will be explored.

Project 2: Tracking and Predicting the Location of Icebergs

Icebergs in the north Atlantic are a large tourist attraction but also a significant hazard for commercial fishing and shipping operations. It is important for both industries to be able to accurately track and predict iceberg locations. The National Ice Center (`http://www.natice.noaa.gov/`) uses satellite imagery to track the location of large icebergs, but does not provide any predictions of their future locations.

The goal of this project is to explore the use of data assimilation algorithms (e.g., Ensemble Kalman filter [2] or particle filter [1]) to National Ice Center observations with a simple ordinary differential equation (ODE) model describing the iceberg path. The goal is to not only predict future locations, but also to quantify the uncertainty in those predictions.

Project 3: Inferring Iceberg Drag Coefficients

Icebergs are driven by ocean and wind currents, but the forces that these currents exert on the iceberg depend on the iceberg geometry, which is generally not known. The goal of this project is to estimate the drag coefficients governing these forces given observations of iceberg movement and estimates of ocean and wind velocities. To solve this problem, a mixture of deterministic optimization methods and stochastic Markov chain Monte Carlo [3] techniques can be explored.

References

[1] Arnaud Doucet and Adam M Johansen. "A tutorial on particle filtering and smoothing: Fifteen years later". In: *Handbook of nonlinear filtering* 12.656-704 (2009), p. 3.

[2] Geir Evensen. "The ensemble Kalman filter: Theoretical formulation and practical implementation". In: *Ocean dynamics* 53.4 (2003), pp. 343–367.

[3] Charles Geyer. "Introduction to markov chain monte carlo". In: *Handbook of markov chain monte carlo* 20116022 (2011), p. 45.

[4] Philipp Hennig, Michael A. Osborne, and Mark Girolami. "Probabilistic numerics and uncertainty in computations". In: *Proceedings of the Royal Society of London A: Mathematical, Physical and Engineering Sciences* 471.2179 (2015).

[5] Carl Edward Rasmussen and Christopher KI Williams. *Gaussian Processes for Machine Learning*. MIT press, 2006.