LogDynamics
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Handling Uncertainty in Route Planning for Cargo Ships with Ancillary Wind Propulsion

Shipping companies are permanently trying to minimize fuel costs while also being able to guarantee fixed delivery times to their customers. In the future, diminishing fossil fuel resources as well as “green” taxes and duties will raise fuel prices, thus posing a challenge to logistic companies. A promising way to reduce fuel costs is to facilitate green propulsion technologies. The pictures show a Flettner rotor and a kite sail which already are well-tried wind ancillary propulsion drives that save a significant amount of energy under proper weather conditions. For that reason route optimization has to take into account the uncertainty induced by weather forecasts to maximize the beneficial effect of green propulsion technologies. The uncertainty in weather forecasts arises from errors in the climate model and chaotic weather dynamics. This thesis builds a model of the uncertainty of the expected energy consumption based on a given weather forecast. The objective is to provide accurate estimations of the energy consumption for a given route based on the current forecast. This will enable route optimization algorithms to find better solutions and shipping companies to give more accurate shipping time estimations to their customers.

Research Method: Scenario tree generation

A scenario tree may either describe a range of possible routes or can directly contain the associated energy consumption. In that case every edge of the tree is labelled with a weather forecast as input value and every node is labelled with the resulting energy consumption. Thus the tree describes a range of energy consumptions for a given route. Scenario generation techniques generate either edges or nodes of a scenario tree. They comprise:

- Statistical approaches
- Sampling
- Simulation
- Hybrid approaches

Statistical approaches create scenarios that match the statistical moments of the approximated probability distribution. This assumes knowledge about the distributions family. Sampling on the other hand samples random values from the marginal distributions and usually requires much more scenarios to guarantee convergence to the actual distribution. Simulation requires a sophisticated climate model in this case and is equivalent to meteorological ensemble calculations. Also several machine learning techniques such as clustering algorithms have been used to generate scenario trees.

Wind-induced ancillary propulsion techniques (left: ©Jörn Prestien, right: seen on http://www.skysails.info/, 05.05.2012)

Contribution to practice and business applications

Almost every real-world optimization problem involves uncertain model parameters. In some cases the uncertainty can be modeled by sampling or simulation but often this is computationally intractable. While numerous companies provide marine weather routing solutions they usually do not quantify the uncertainty of their route recommendations. Additionally the advent of wind ancillary propulsion techniques adds a degree of freedom to the route optimization problem that is hard to assess by human experts. Thus the result of this thesis may be applied as an assistance support tool that provides the uncertainty in energy consumption and arrival time for a given route. Given accurate training data every deterministic optimization model can be transformed into a stochastic optimization problem by the approach developed in this thesis.

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