The Sailing Problem

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The following problem was proposed by Jeff Westbrook in the Algorithm's Reading Group on January 26, 2015.

1 Introduction

In off-shore sailing competitions, sailors have to choose the best path from the source to the destination, depending on factors such as wind direction, water currents, weather, etc. Such factors are uncertain and only a forecast for the next couple of hours is available. Suppose the competition is from LA to Hawaii and takes on average 14 days. At the start, a forecast is available for the next 7 days. The forecast gets less reliable with time, that is, the forecast of day 1 would be much better than that of day 7. The sailors can always download a new, better forecast while on their route and depending on it, update the course they will take. What is the best way to model this? What algorithm/heuristic can help the sailors choose the best possible route so as to win the race?

A commercial program is available to help sailors navigate but is ineffective and expensive. Jeff Westbrook wrote his own program to solve this problem and it is available online at `http://www.bluewaterracing.com/`.

2 Possible Ways to Model

We could consider the geographical decision points as the nodes of a graph. The edges represent the time required to get from one end point to the other (based on wind velocity and speed of boat).

We could also consider a three dimensional graph with the one dimension being time, and the other two is the graph with nodes and edges with path length and wind velocity.

3 Discussion

A working heuristic, which Jeff has used, is to use Dijkstra at the start and compute the optimal route, follow the route till the next decision point. At this point, update the graph based on updated weather forecast and run Dijkstra from the current point as source and so on.

An obvious problem with the above greedy approach is that you might end up at a node (based on earlier decisions), which is the worst possible node to be on in the updated graph.

Jeff suggested studying the probability contours between the source and the destination and coming up with a learning algorithm that handles the dynamic updates. A possible concern raised by Jing was that the probability contours might not be continuous.

Steve pointed out that this problem was reminiscent of the problem in which one has to decide what bus to catch at a sequence of possible transit points. The proposed plan would depend on the time constraints and the events that occur. The plan in such cases would not be a path, but rather a tree based on events seen and the best decision to be taken.

4 A Related Problem

Joe called our attention to a similar problem in the context of air traffic management, for which a stochastic model for the weather was used in his paper [1]. This problem also involves making decisions ahead of time regarding the route that an airplane must take by estimating the maximum capacity of an airspace region. Although the objectives might be different (minimizing fuel usage vs minimizing time), the model might be useful to consider.

5 Extensions

A variation of the problem could involve taking the actions of the opponents into consideration. Since it is a competitive environment, the strategy of the other players might be a factor in what move a player wants to make. Can we propose a game theoretic modelling of the same problem?

Sometimes two factors affecting the speed of a sailboat are in different directions. For example, suppose the wind current is such that it helps the boat, but the water current opposes it. Can our model take into account different force vectors with directions?

References

[1] Joseph SB Mitchell, Valentin Polishchuk, and Jimmy Krozel. Airspace throughput analysis considering stochastic weather. In *AIAA Guidance, Navigation, and Control Conference*, 2006.