Optimal Path Finding in Dynamic Environment with Application to Vessels and Autonomous Vehicles

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- In collaboration with:
  - The Department of Naval Architecture and Marine Engineering at the University of Michigan
  - The Department of Electrical and Computer Engineering at the Ohio State University
  - The Applied Physics Laboratory at the University of Washington

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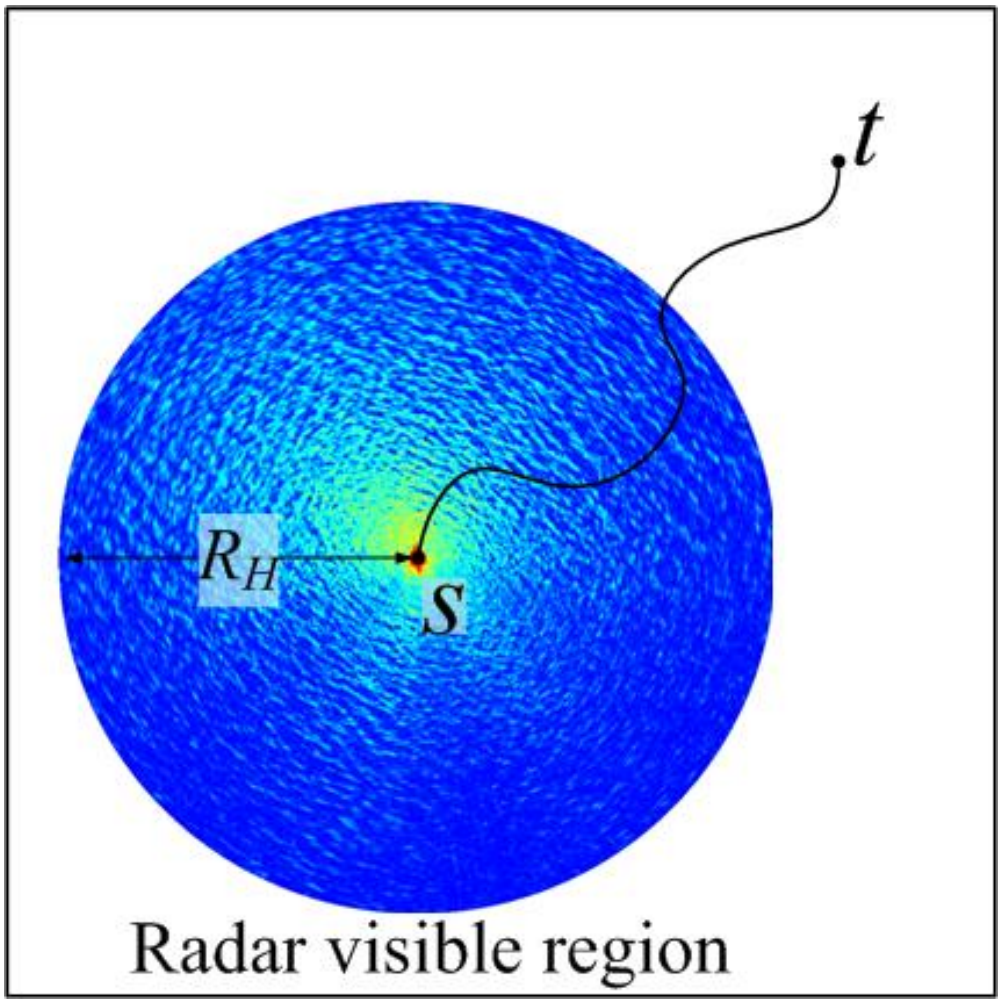
- Three objectives:
  - Minimize travel time, thus decreasing operational costs
  - Minimize fuel consumption, consequently reducing environmental effects
  - Minimize vessel motions, thus increasing passengers' comfort and crew's efficiency

Optimum Vessel Performance in Evolving Nonlinear Wave-Fields Project

- Real-Time Measurement of Ocean Wave-Fields



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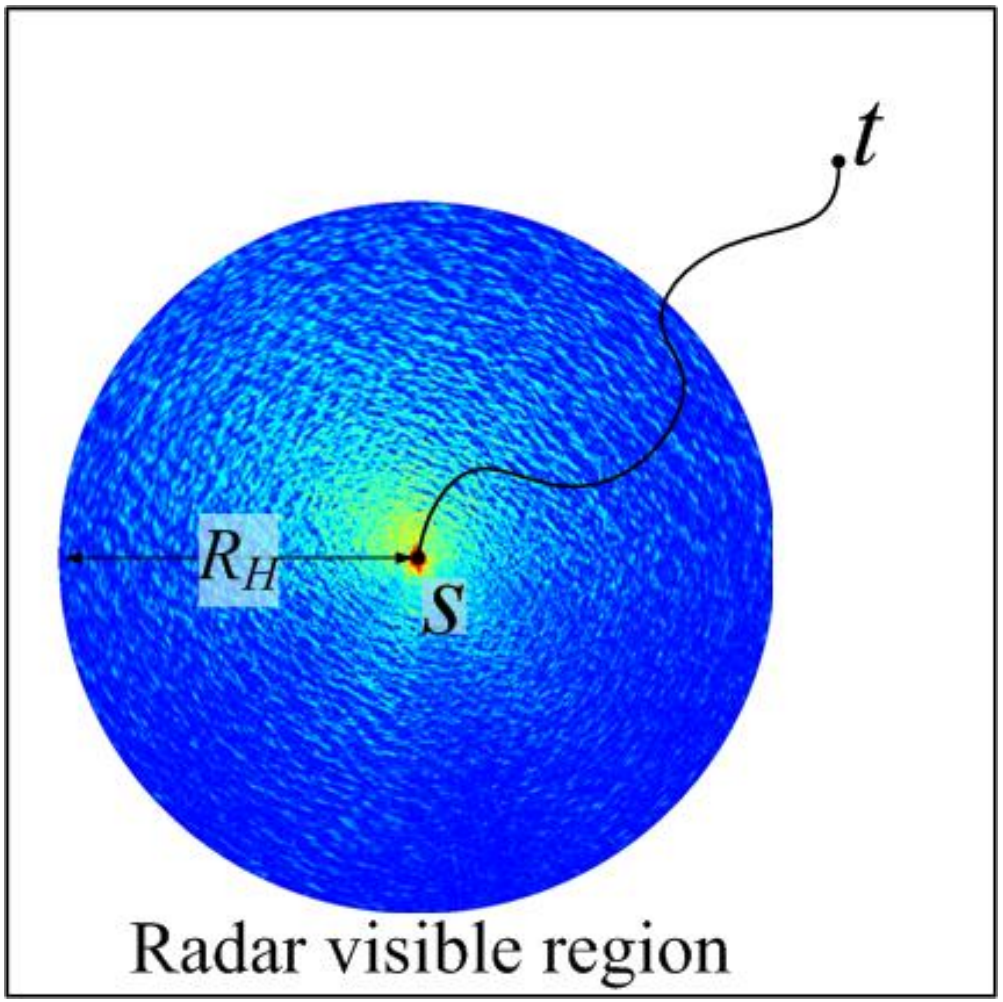
- Real-Time Measurement of Ocean Wave-Fields
- Short-Term Forecasts of Evolving Nonlinear Wave-Fields



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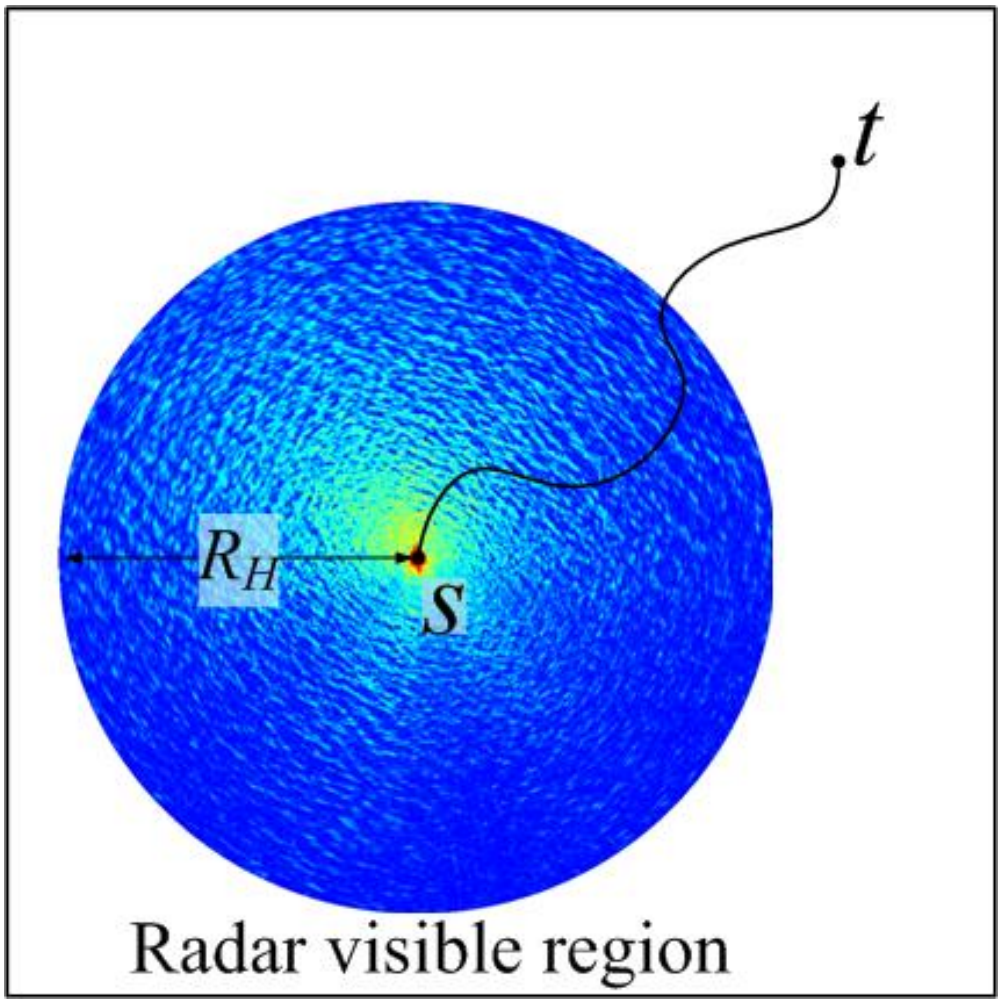

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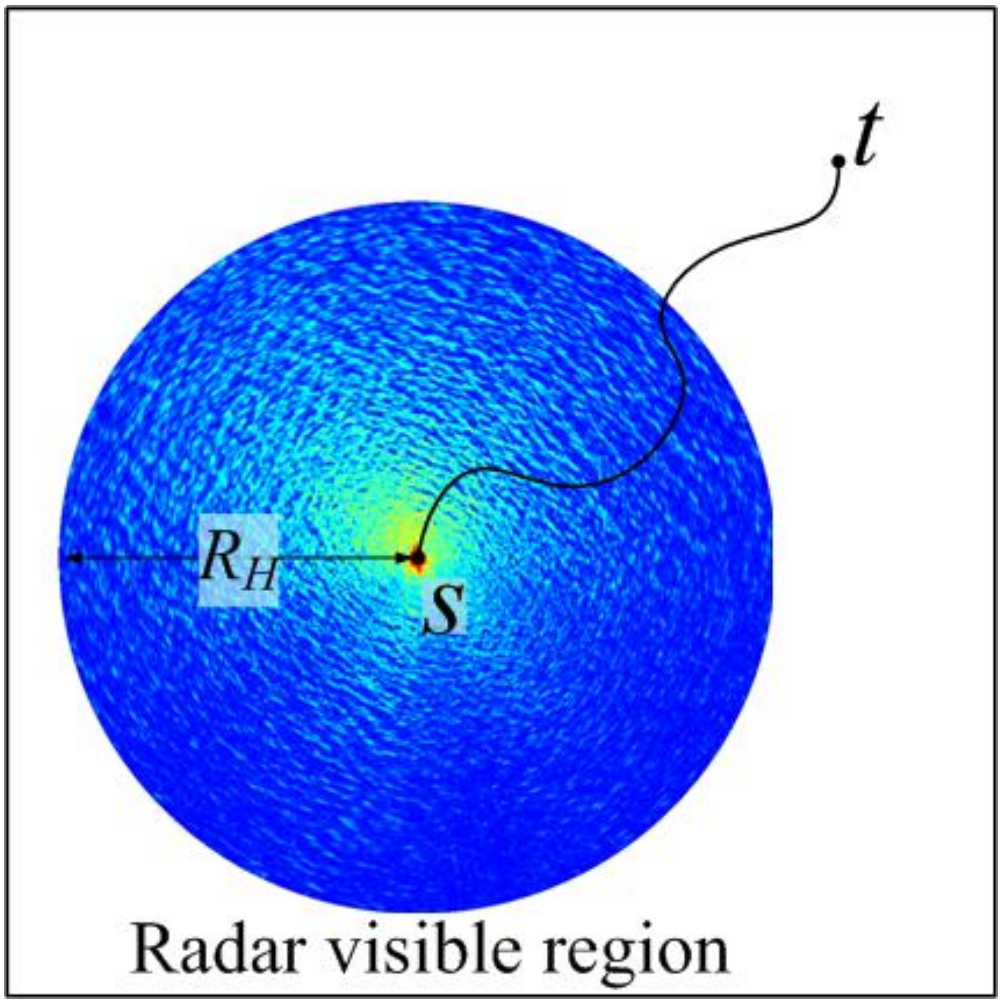
- Time-Domain Computation of Nonlinear Ship Motions
- Dynamic Real-Time Path Optimization and Vessel Control



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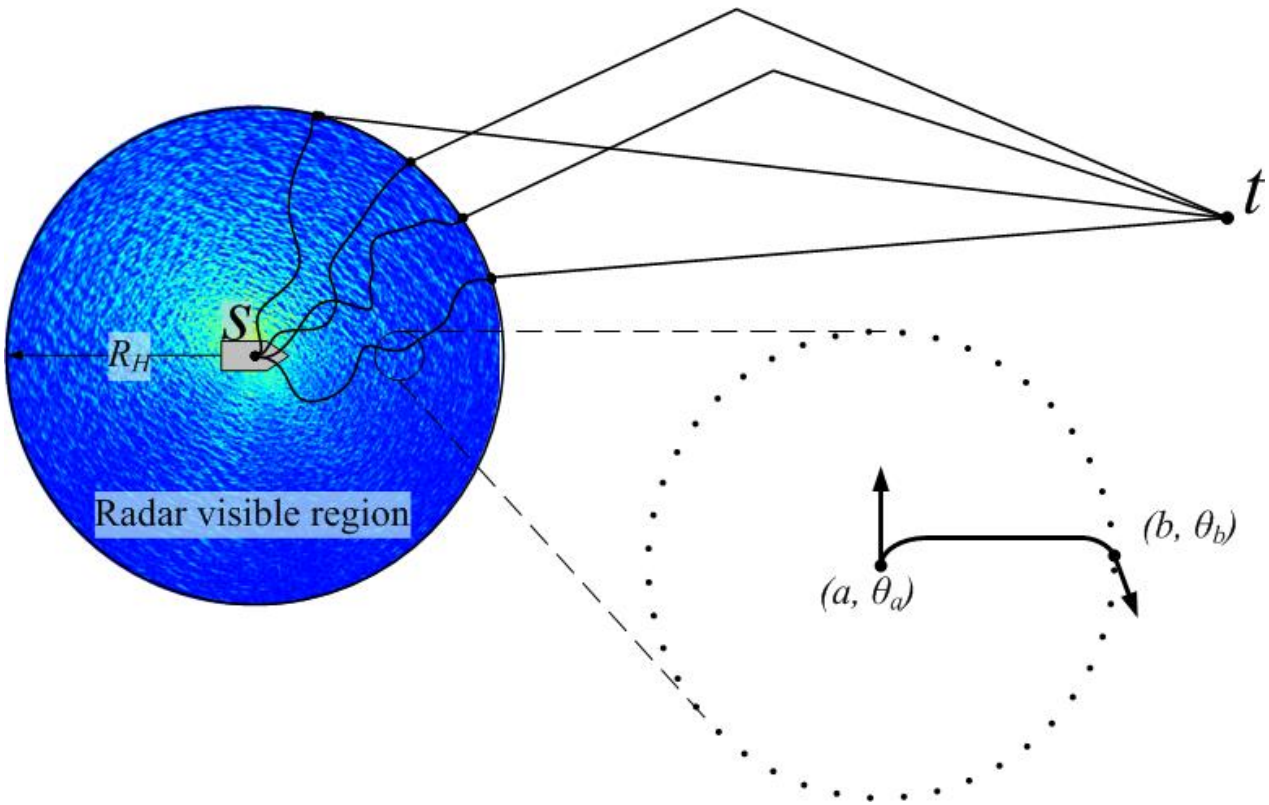
- Small run-time of an optimal path finding algorithm is essential for real-time implementation.

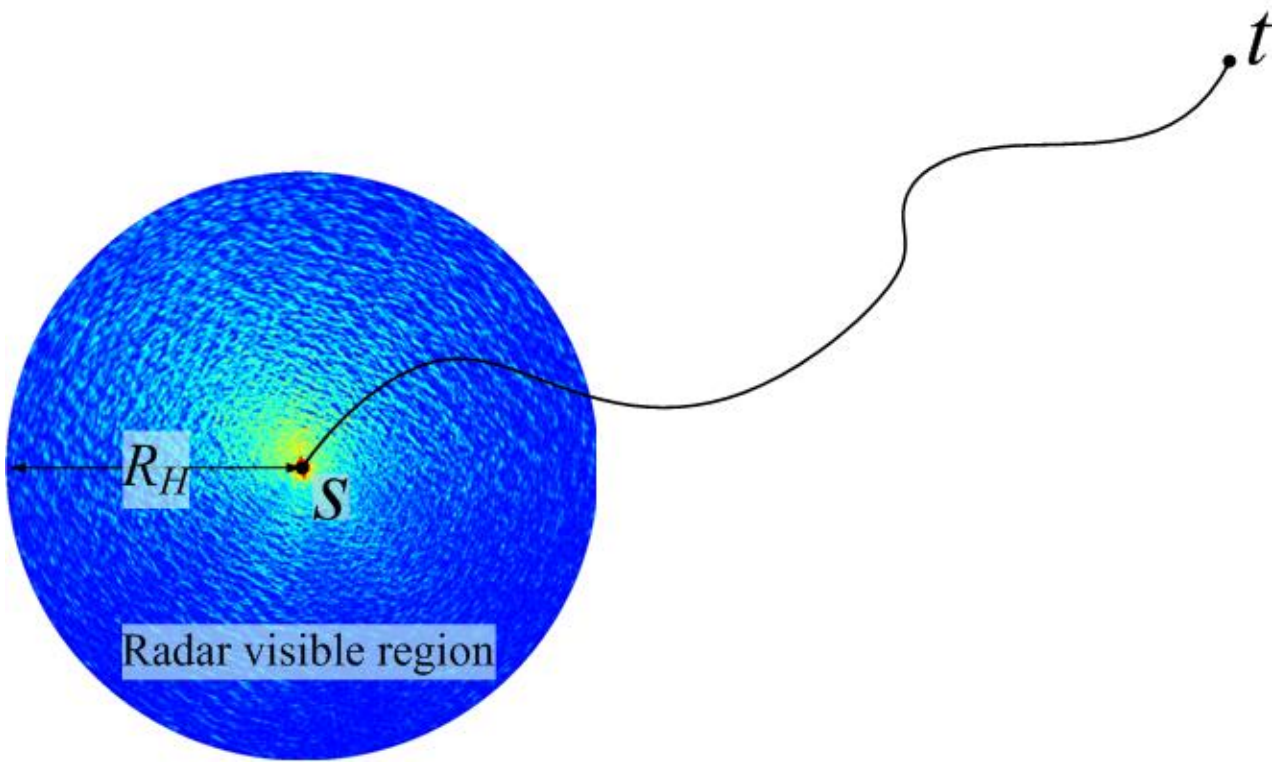
Dynamic Programming Model

- The dynamic programming model evaluates the fastest paths to each point on the border of the radar visible region, then our results for time and space homogeneous environment find the best path to continue to the target point.



Dynamic Programming Model

- As the mobile agent moves along a path, the information about surrounding environment is updated, and an optimal path is continuously reevaluated.



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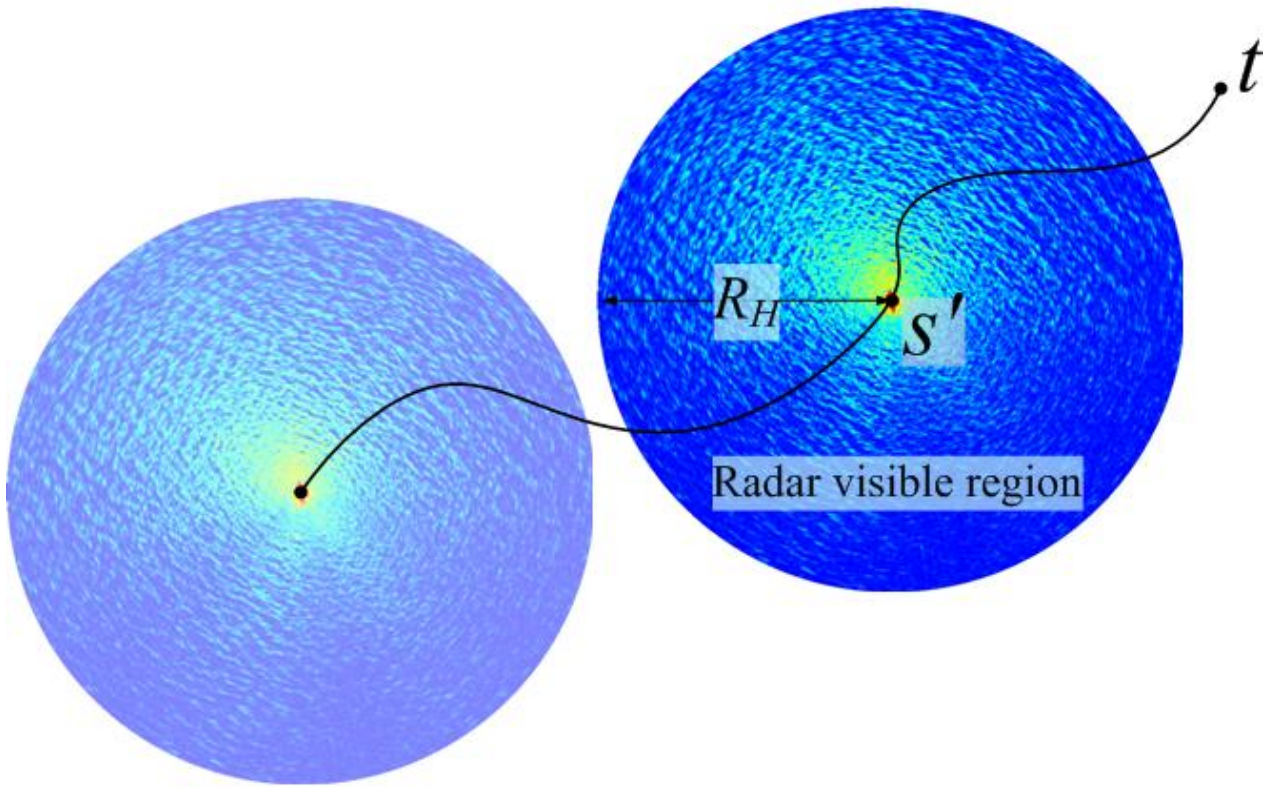
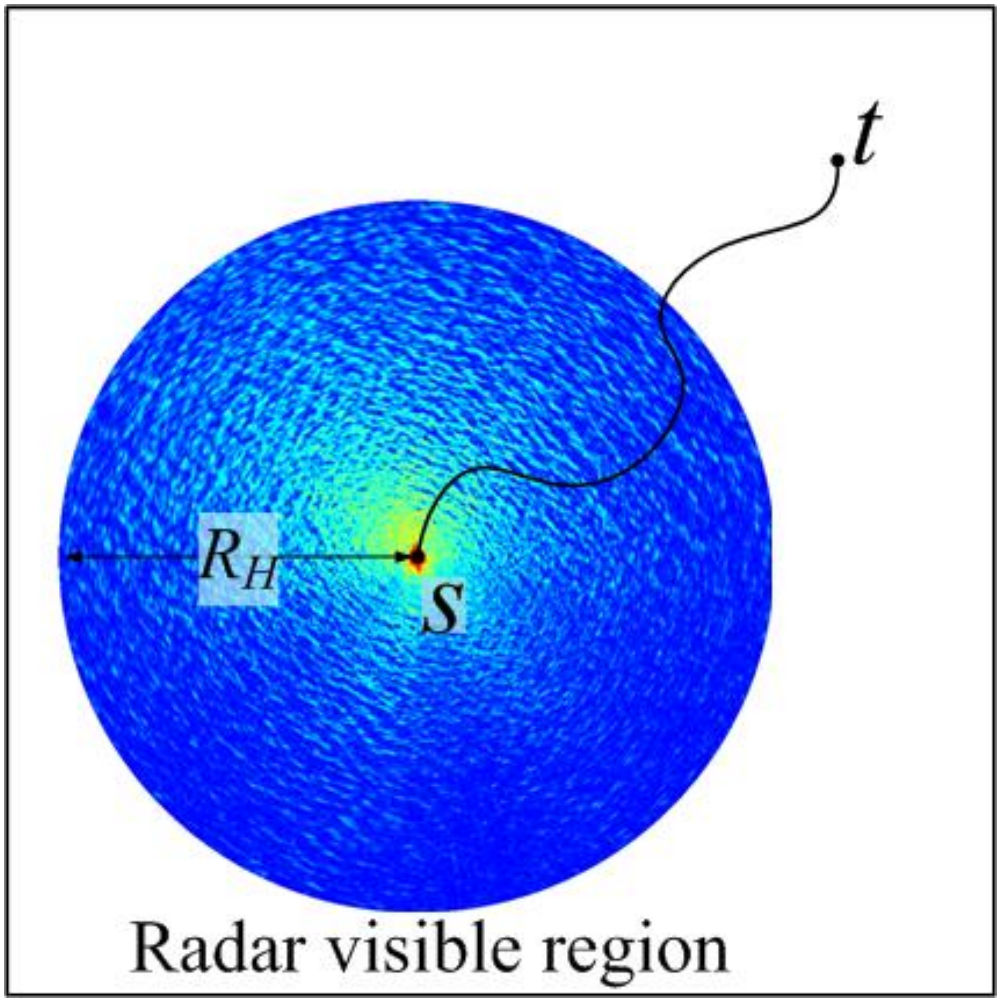


Application and Numerical Results

- S-175 Containership
- $R_H = 2500$ meters
- Nominal ship speed $= 11.4$ m/s
- Global sea state No. 6.5 (Sig. wave height 7 m)
- Maximum attainable speed range is $[8.4, 10.3]$ m/s
- $l = 250$ metes



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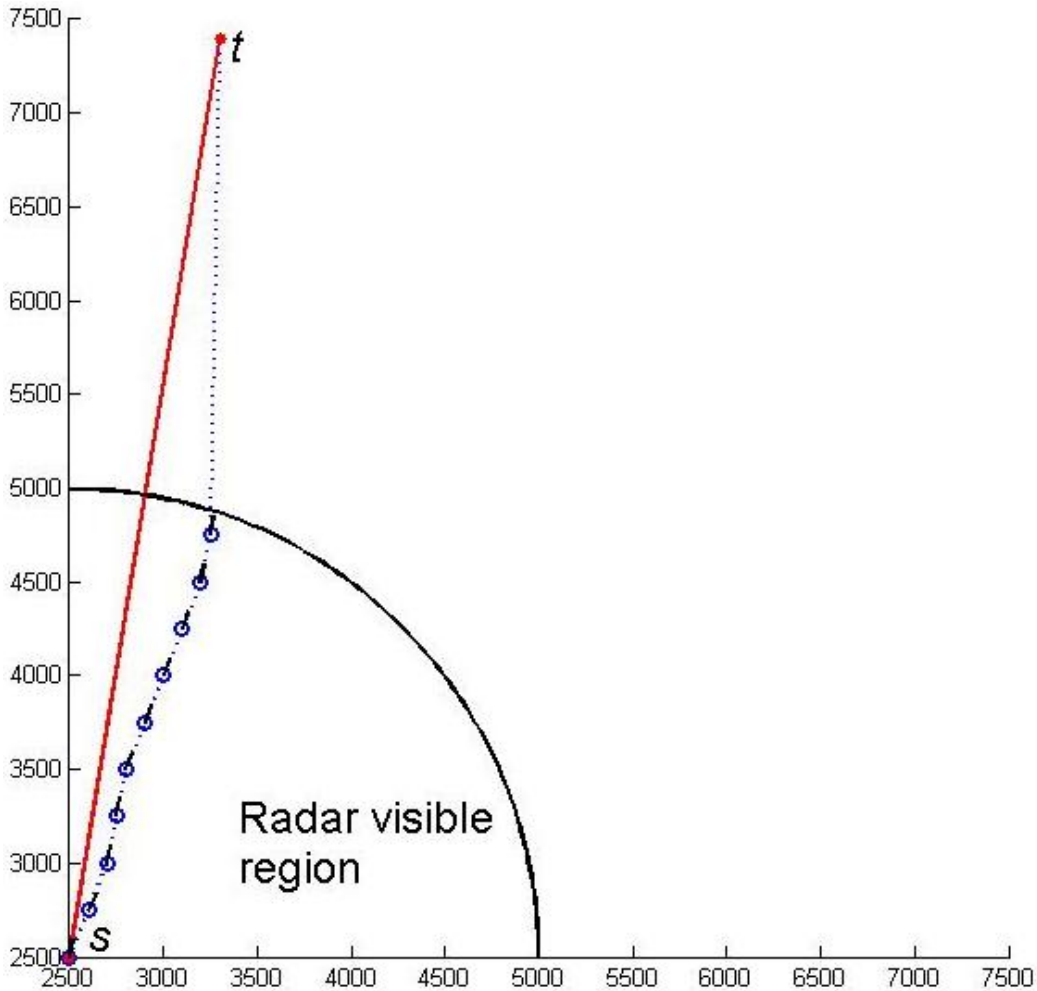
- Up to 9.5% improvement
- On average between 4% and 6% improvement over implementing our results for the case neglecting radar collected data.
- Due to number of limitations of the current simulation model these estimates are very conservative.
- The DP model not only improves the travel time, but also finds a **control-feasible** path.

Test Run Number 5: $\theta_{st} = 80$ degrees



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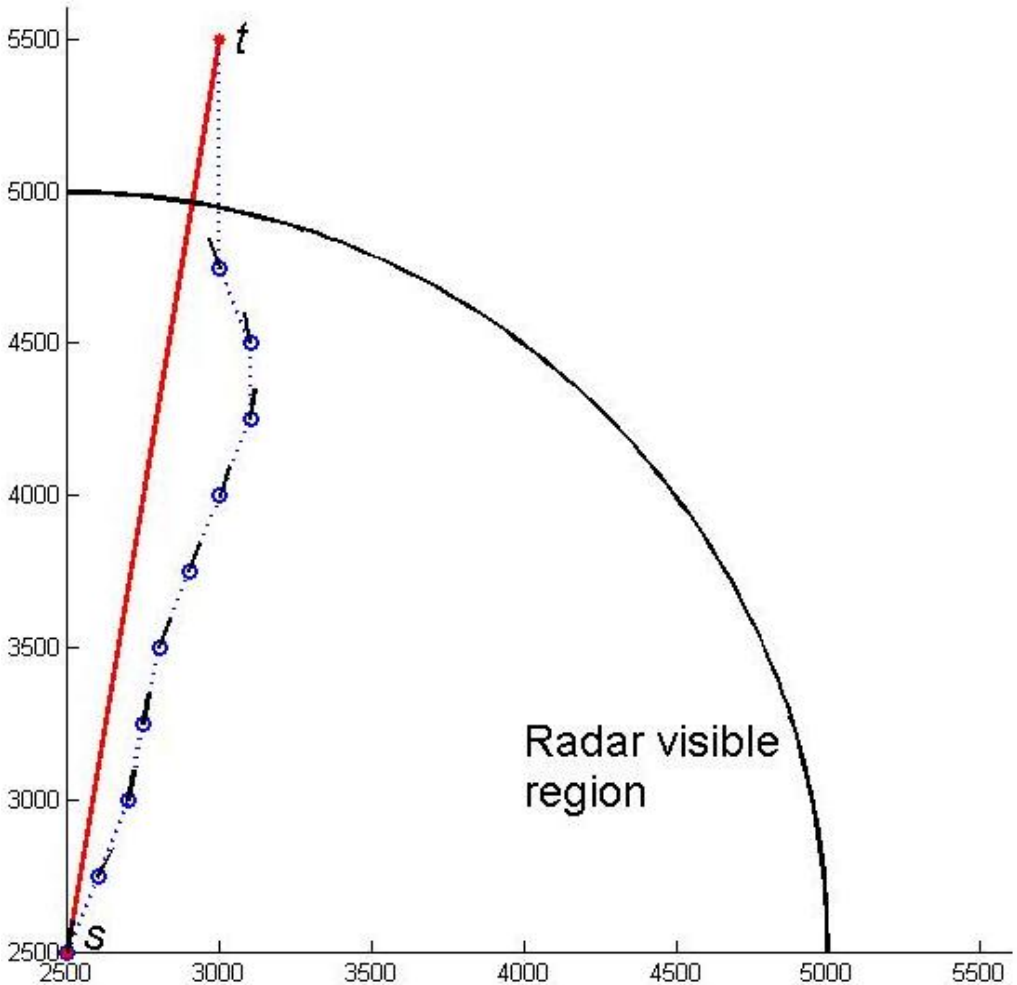
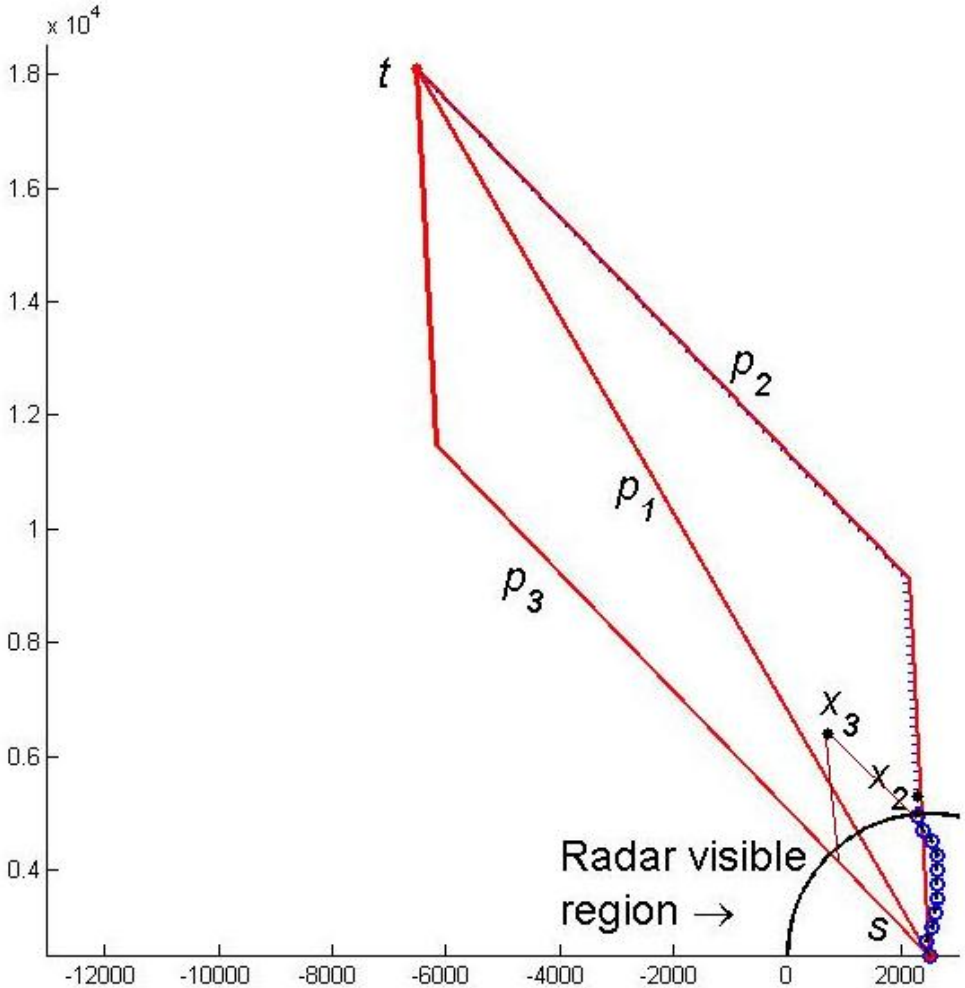


Test Run Number 7: $\theta_{st} = 120$ degrees



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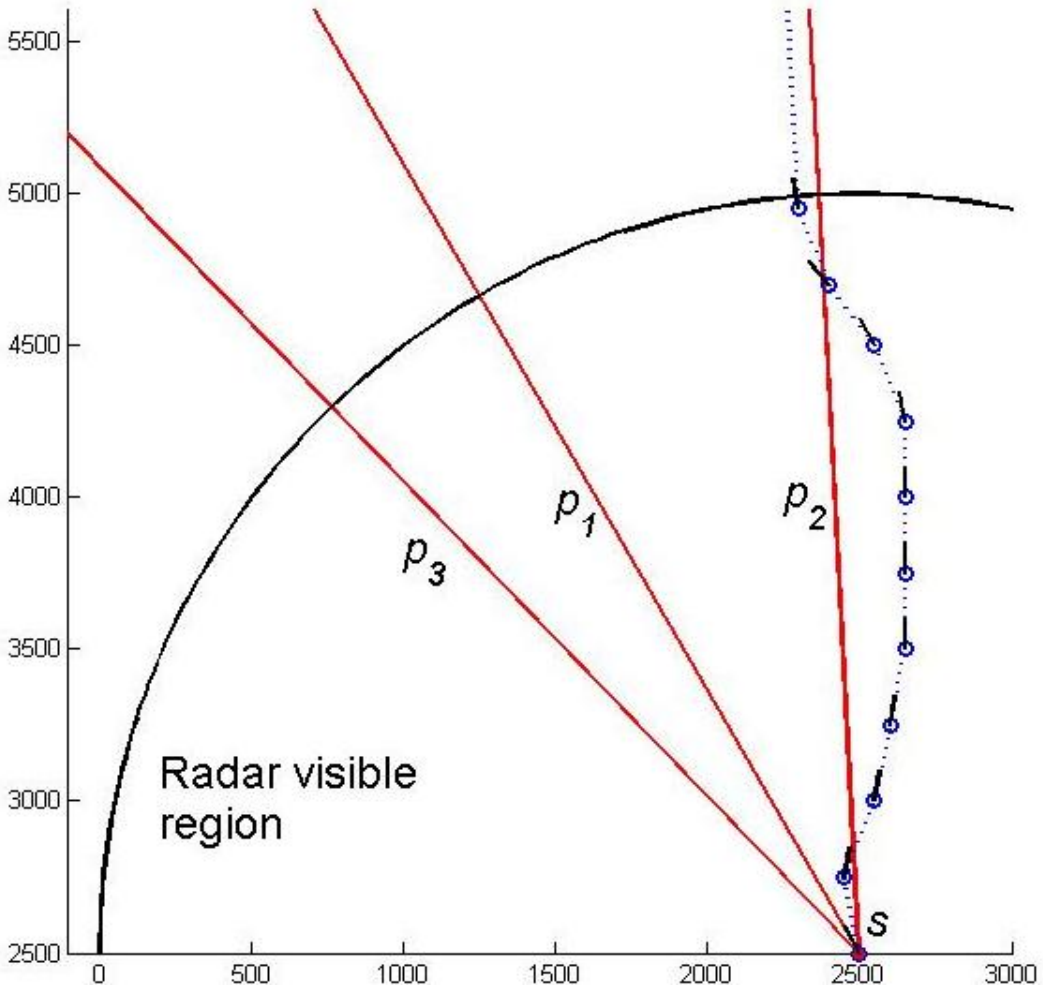
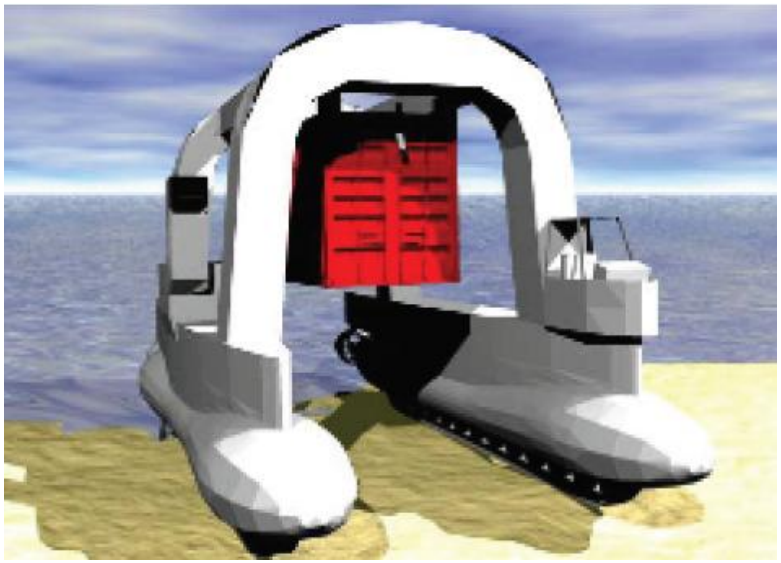


ONR Center for Innovation in Ship Design: Autonomous Navigation of an Amphibious Vehicle



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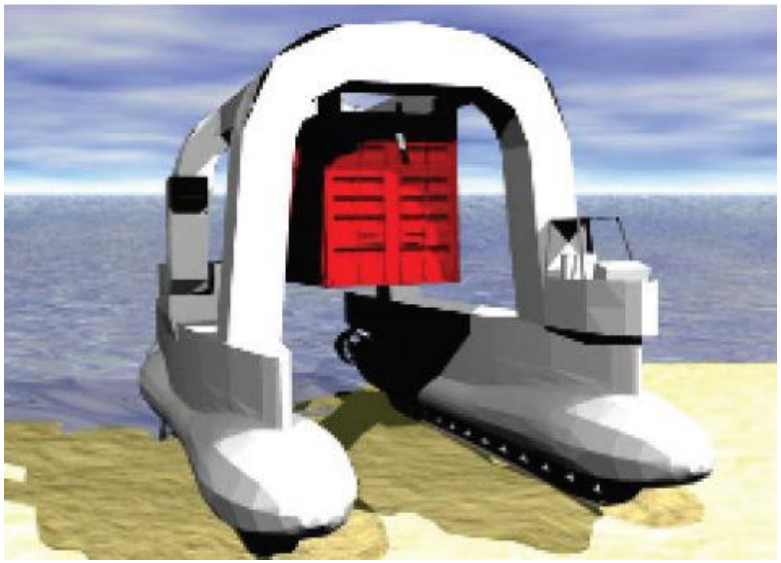

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- Unmanned amphibious vehicles are responsible for transporting the cargo from the ship to the target location inland.

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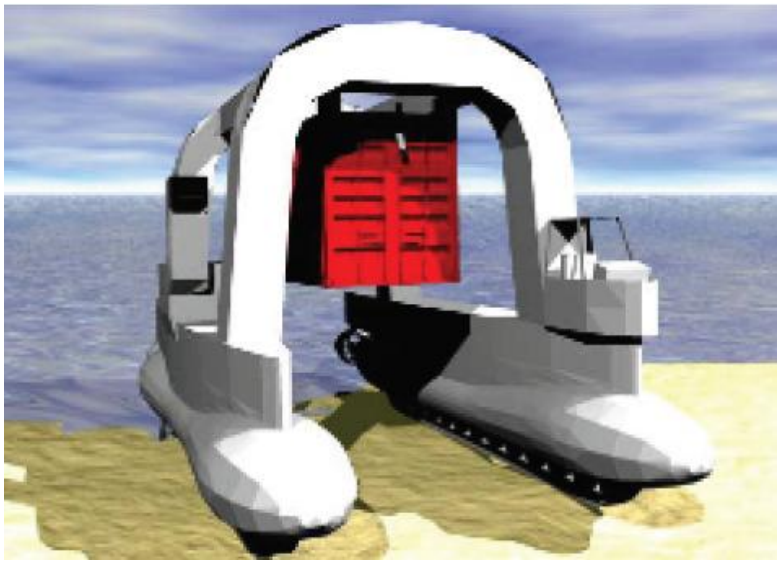

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- The selected path has to minimize travel time while avoiding dangerous regions, and must dynamically adjust as new information about the surrounding environment is obtained.

Unmanned Aerial Vehicles (UAVs)

- Optimal path finding for UAVs and other autonomous systems while integrating real-time dynamic environment (e.g., wind).
- Uncertainty in the environment and accuracy of the collected data.

Questions?