# *In Situ* AUV Survey Adaptation Using Through-the-Sensor Sonar Data

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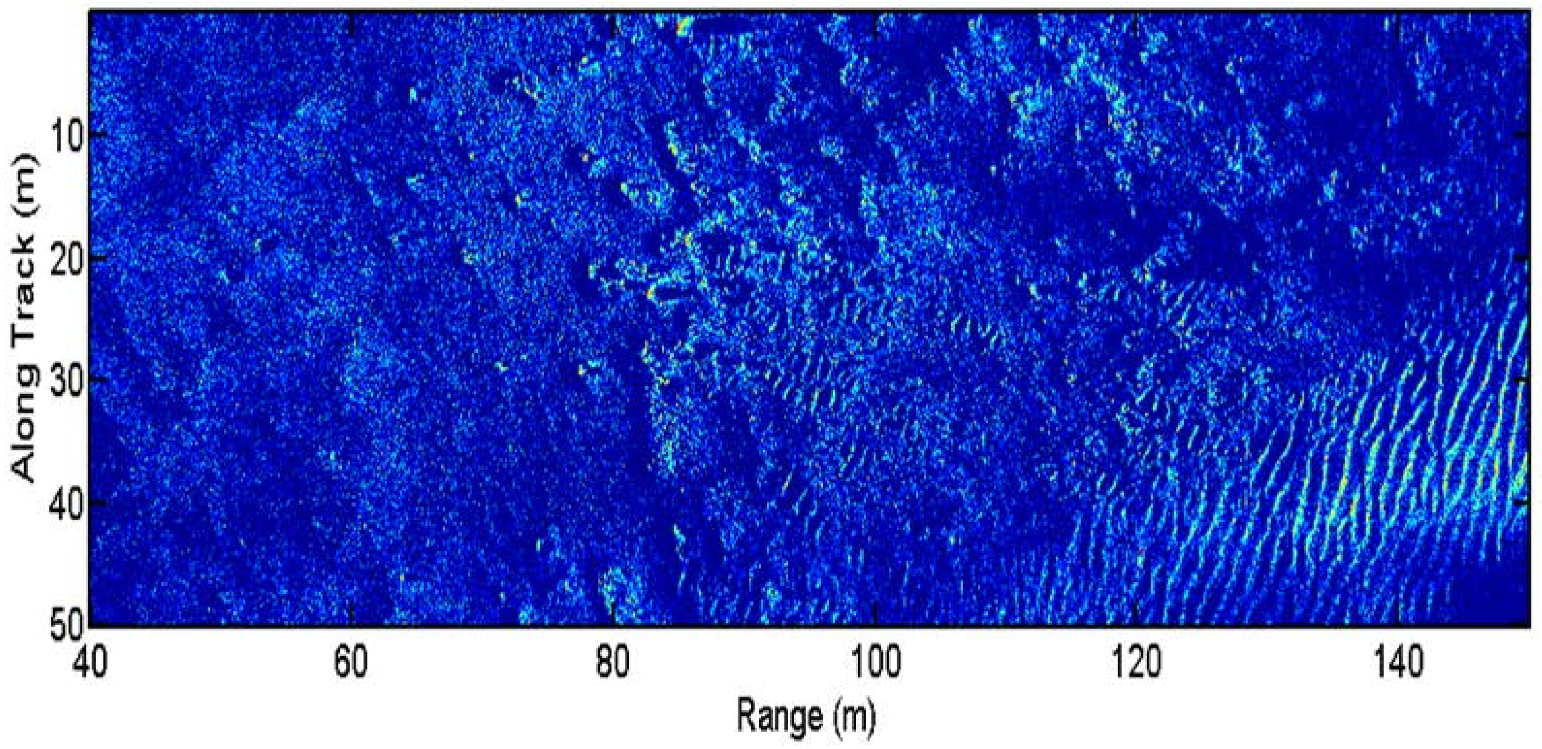
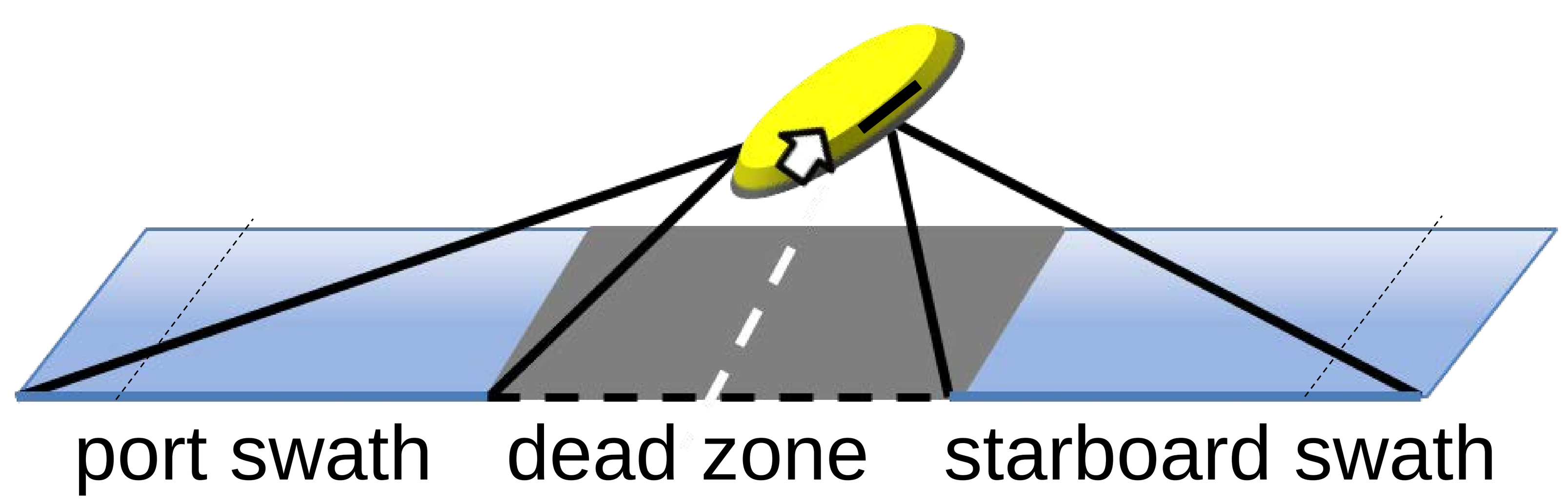
ABSTRACT

An algorithm for the *in situ* adaptation of the survey route of an autonomous underwater vehicle (AUV) equipped with side-looking sonars is proposed. The algorithm immediately exploits the through-the-sensor data that is collected during the mission in order to ensure that quality data is collected everywhere in the area of interest. By introducing flexibility into the survey of the AUV, various limitations of pre-planned surveys are overcome. Experimental results demonstrate the benefit of the proposed approach in terms of higher area coverage in shorter mission times. The signal processing required by the algorithm is fast and computationally efficient such that real-time implementation is feasible. As proof, the proposed adaptive survey approach was implemented on an AUV and executed during a recent live scientific experiment at sea using real, *in situ* measured data. Results from this experiment are also shown.

- **Objective**: Ensure good quality synthetic aperture sonar (SAS) data is collected everywhere in an area of interest.
- **Approach**:
  - Adapt autonomous underwater vehicle (AUV) survey plan *in situ* based on the through-the-sensor data collected.
  - Use ping-to-ping correlation, as function of range, as surrogate for image quality.
  - Fast, simple computations can be performed onboard AUV, allowing immediate, real-time, autonomous survey route adaptation.

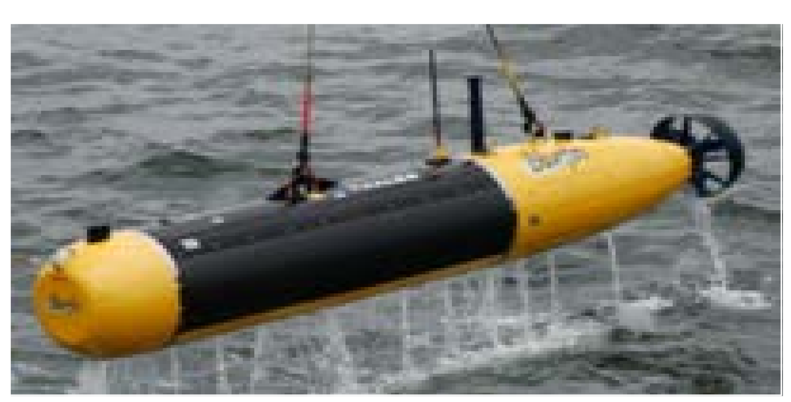


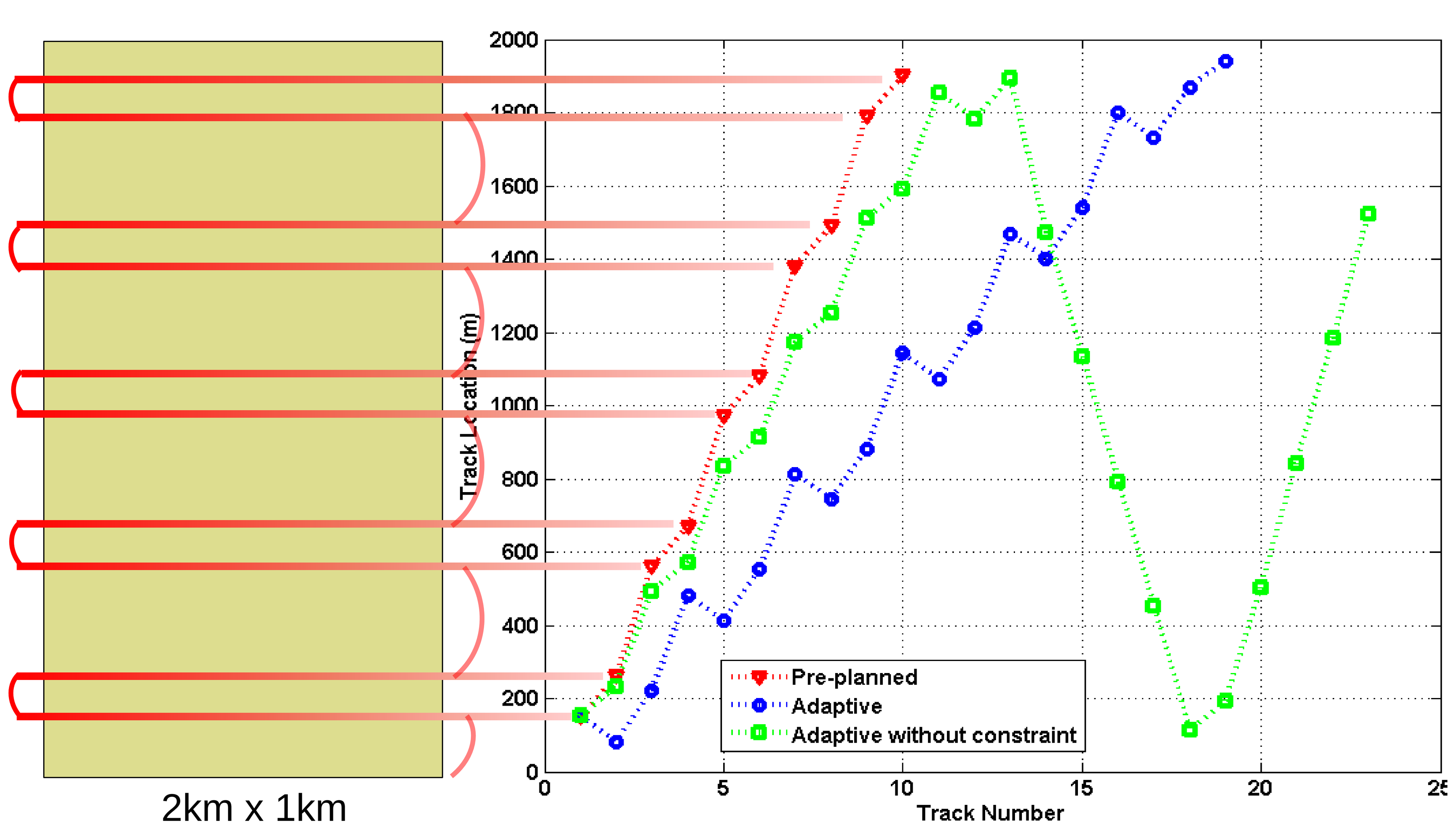

- Pre-planned survey assumes quality sonar coverage will be achieved up to a certain maximum range.
  - Data quality often inadequate at long range.
    - *e.g.*, due to attenuation or multi-path effects
  - No flexibility to adapt to operational conditions or sensed data.
- If coverage underestimated
  - Same area of seabed interrogated on consecutive tracks.
  - Coverage rate decreases, more time and resources expended to survey area.
- If coverage overestimated
  - Portions of survey area will lack coverage (*i.e.*, gaps exist).
  - Analysis (*e.g.*, object detection) impossible there.

## MUSCLE AUV

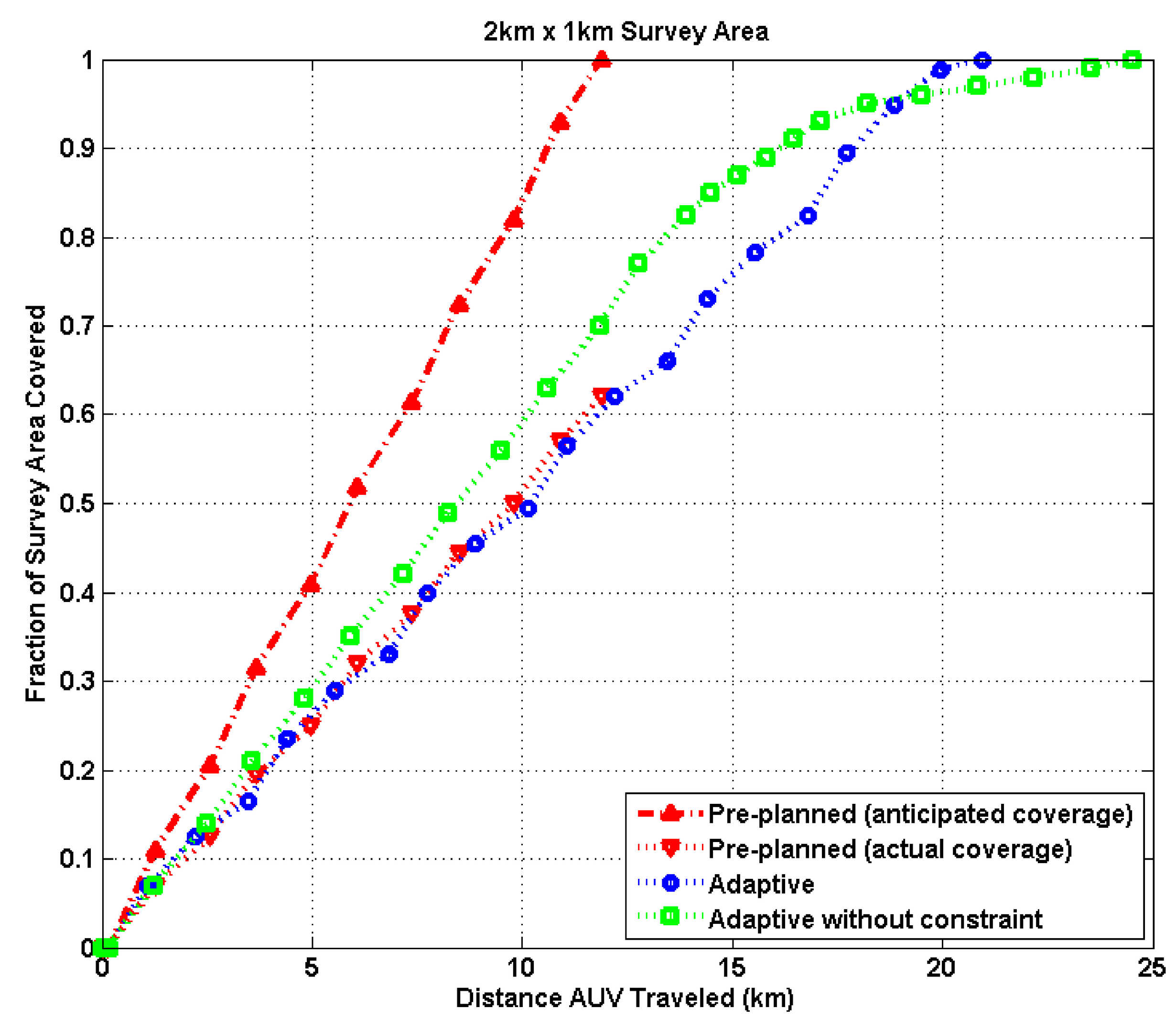
- Equipped with 300kHz SAS



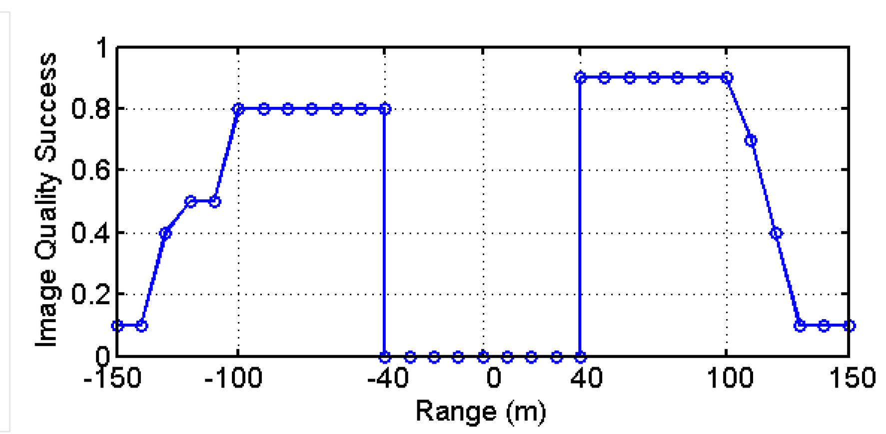
- Overestimation of maximum sonar range (assuming 150*m* instead of actual 110*m*) in pre-planned case results in incomplete coverage.
- Adaptive method immediately fills in gaps and achieves complete coverage.
- Eliminating constraint allows greater coverage faster, but survey takes longer (more tracks and inefficient transit) for complete coverage.




2km x 1km
Survey Area




- Historical success rate of collecting good quality data, *v(r,u)*, used to tie in-mission sonar performance to expected future performance in remainder of mission (*in situ* learning)




- Success = track's mean correlation for (*r,u*) is above threshold (2/3)
- Update success rate via full Bayesian model
  - Beta (conjugate) prior, Bernoulli likelihood
  - Posterior expectation used in calculation to select next track
- Select track that maximizes utility: benefit – cost
  - Benefit = weighted sum of expected new coverage
  - Cost = proportional to transit distance
  - Subject to constraint: track must have non-zero probability of covering "most extreme" (*e.g.*, left-most) uncovered swath
    - Effect: immediately fills in gaps, reduces transit time

$$B(t_i) = \sum_r \sum_u \mathbb{E}[\nu(r,u)](1 - \gamma(r,u))$$

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