Arc Carving: Obtaining Accurate, Low Latency Maps from Ultrasonic Range Sensors

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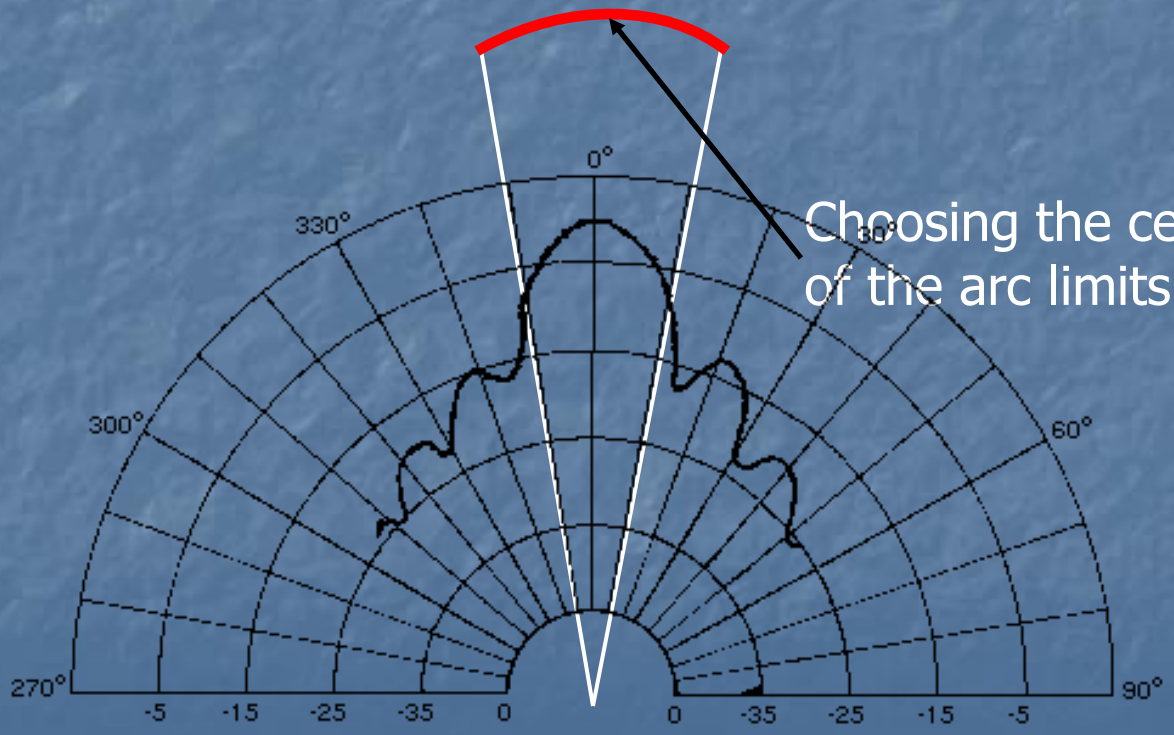
Why Ultrasonic Sensors?

- Cost
  - Laser Range Finder ~ $3000
  - Sonar Ring ~ $ 300
- Size
  - Laser Range Finder ~ 6”x6”x6”, 3 lbs
  - Single Sonar Transducer < 1”
- Special Environments
  - Detecting transparent/translucent material
  - Underwater

Centerline

- Only consider region of significant response
- Approximate response with an arc of uniform probability

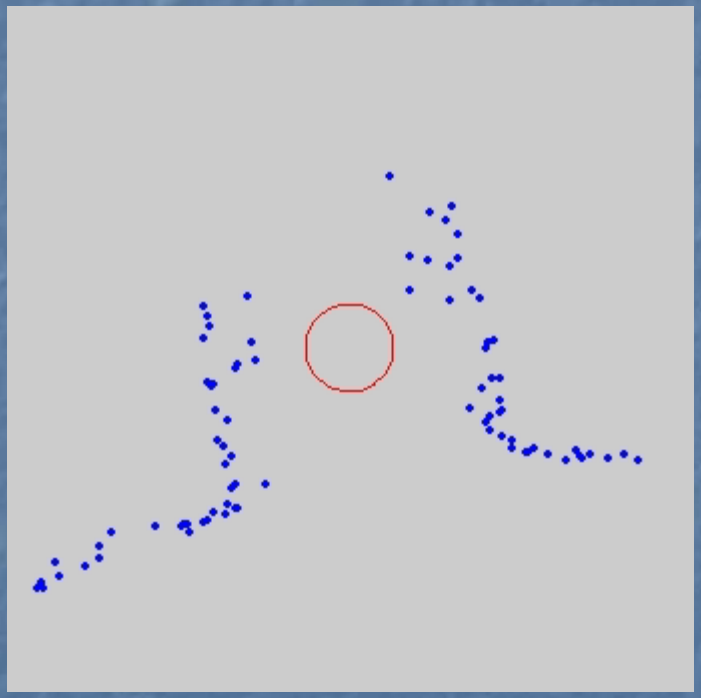


Choosing the center point of the arc limits error

Centerline

- Advantages
  - Minimal computation required per sonar reading
  - Low latency
- Disadvantages
  - Inaccurate
  - Open areas may appear occluded

only centerline points displayed

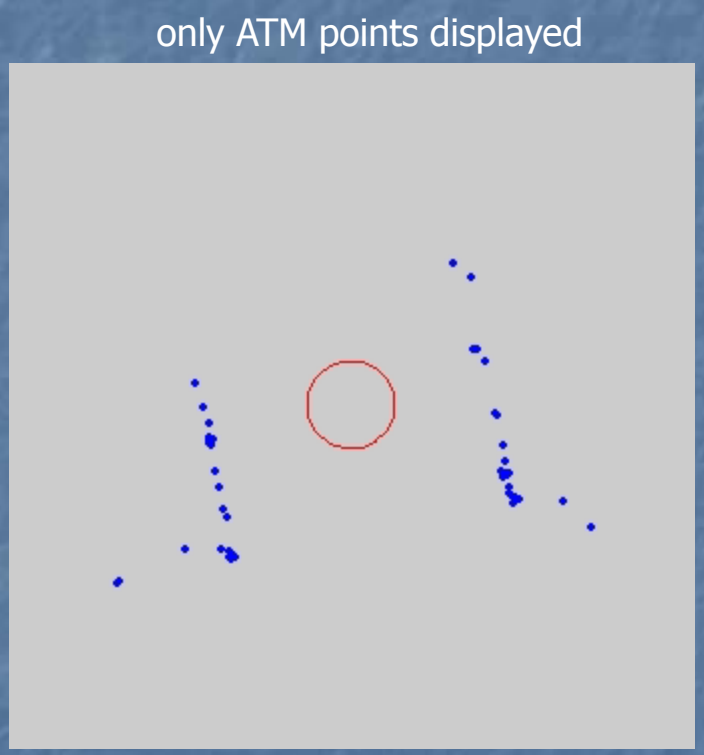


Fusing Multiple Readings

- Regions of Constant Depth (RCDs)
  - Leonard et al. 1995
- Arc Tangents
  - McKerrow 1993
- Arc Transversal Median (ATM)
  - Choset and Nagatani 1999
- Line Fitting
  - MacKenzie and Dudek 1994

Latency

- All the above approaches increase latency
  - Fusing multiple readings requires waiting for multiple readings
  - There can be a significant delay before processed data is available



Hybrid Techniques

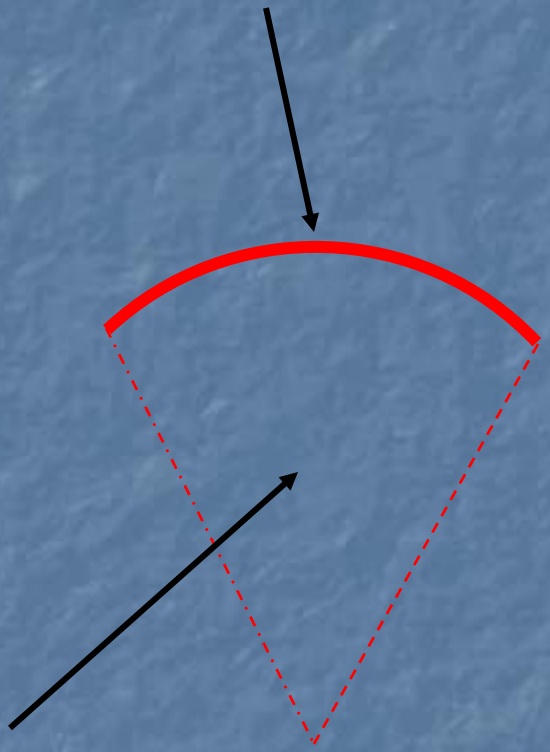
- Possible solution: use the centerline model for range readings that have not yet been processed
  - Centerline data always available
  - Problem: noisy centerline data can still cause planning failures, even when only a subset of all readings is used in this manner

Our Contribution: Arc Carving

- An approach that tries to give the best of both worlds
  - Low latency
  - High resolution
- An approximation of the probabilistic update used by occupancy grids
  - Does not require a discretization of the world

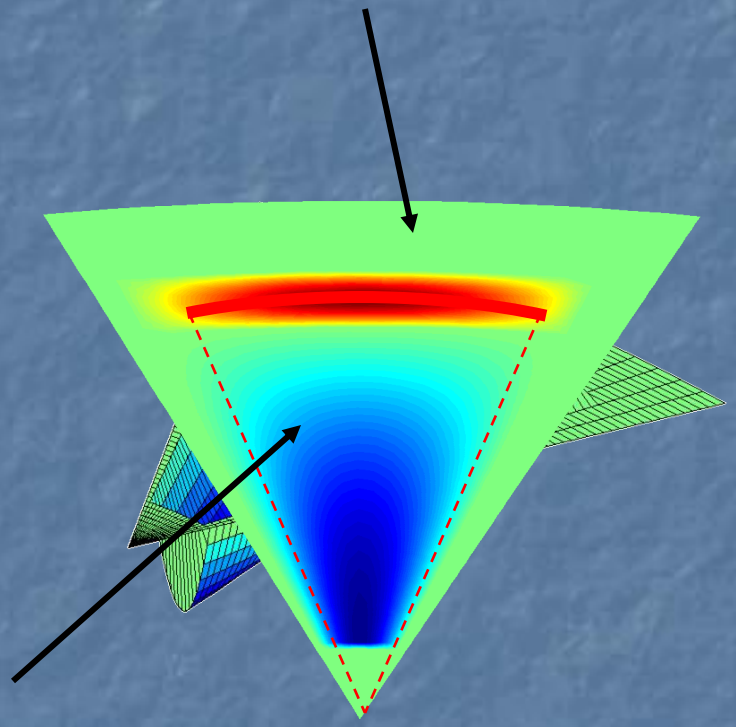
Arc Carving Sonar Model

- Represents a sonar return as a cone with an arc base
  - The arc approximates the sonar response
  - The interior of the cone represents a region of likely freespace



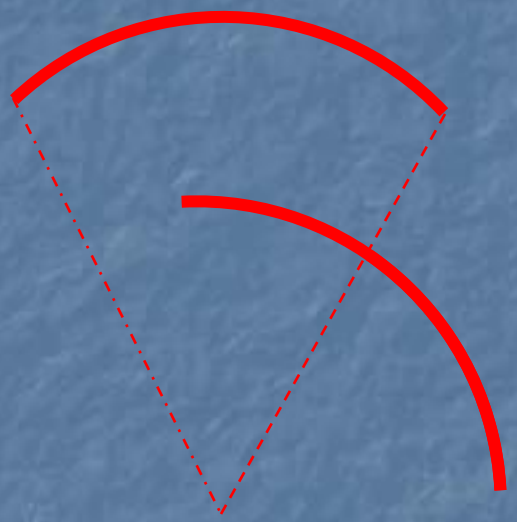
Occupancy Grid Sonar Model

- The arc carving model may be viewed as a binary approximation of the model used by Moravec and Elfes
  - An Arc with nonzero probability of occupancy
  - A cone with nonzero probability of freespace



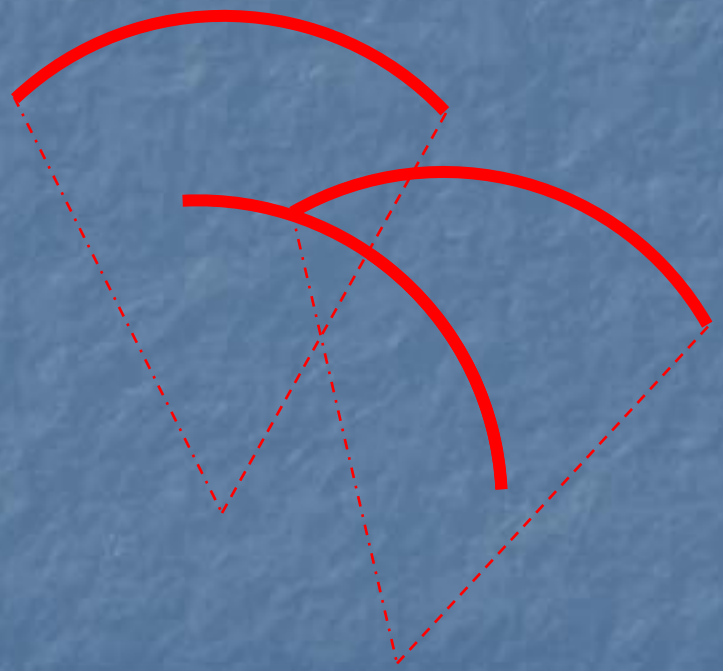
Arc Carving

- Each new sonar reading is checked against a history of previous readings
- If an arc is overlapped by the interior of a newer cone, the arc is "carved" to reflect this new information
- The updated arc is smaller, and therefore has a smaller bound on the error

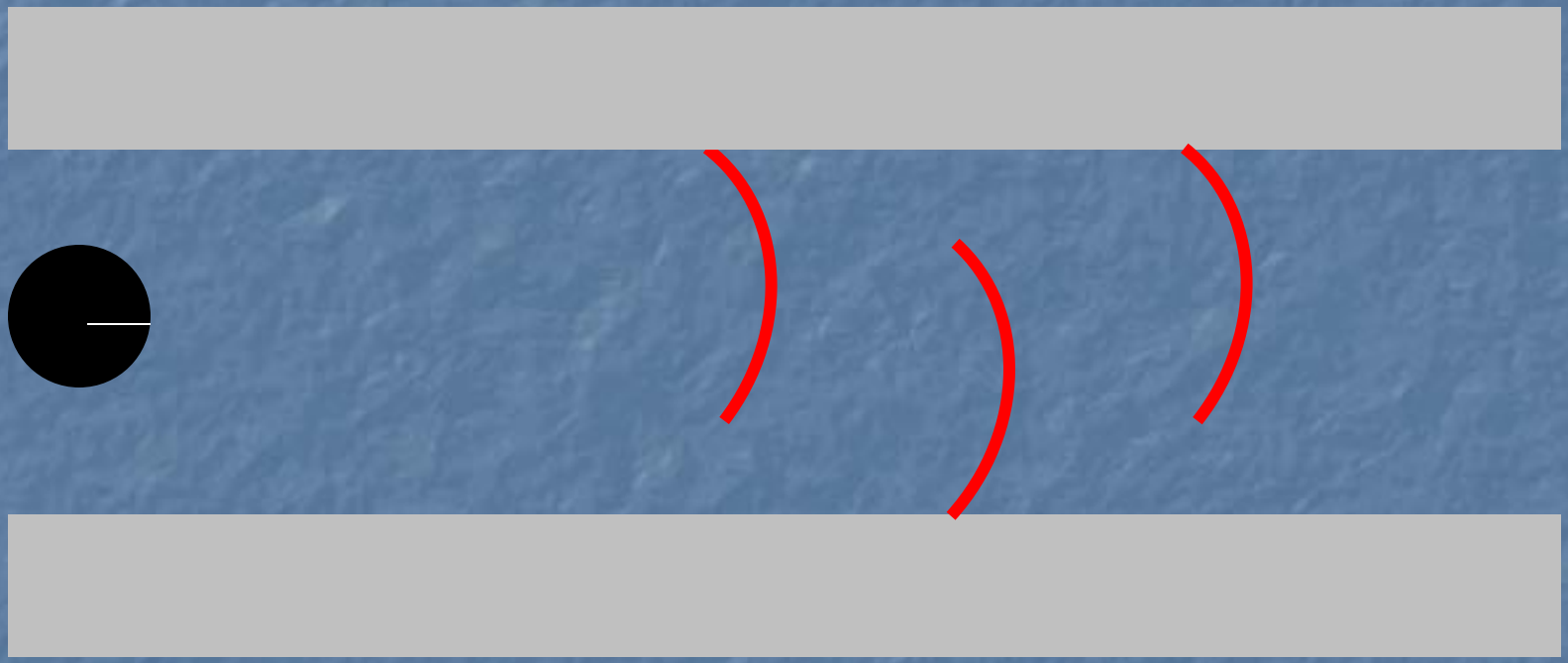


Arc Carving

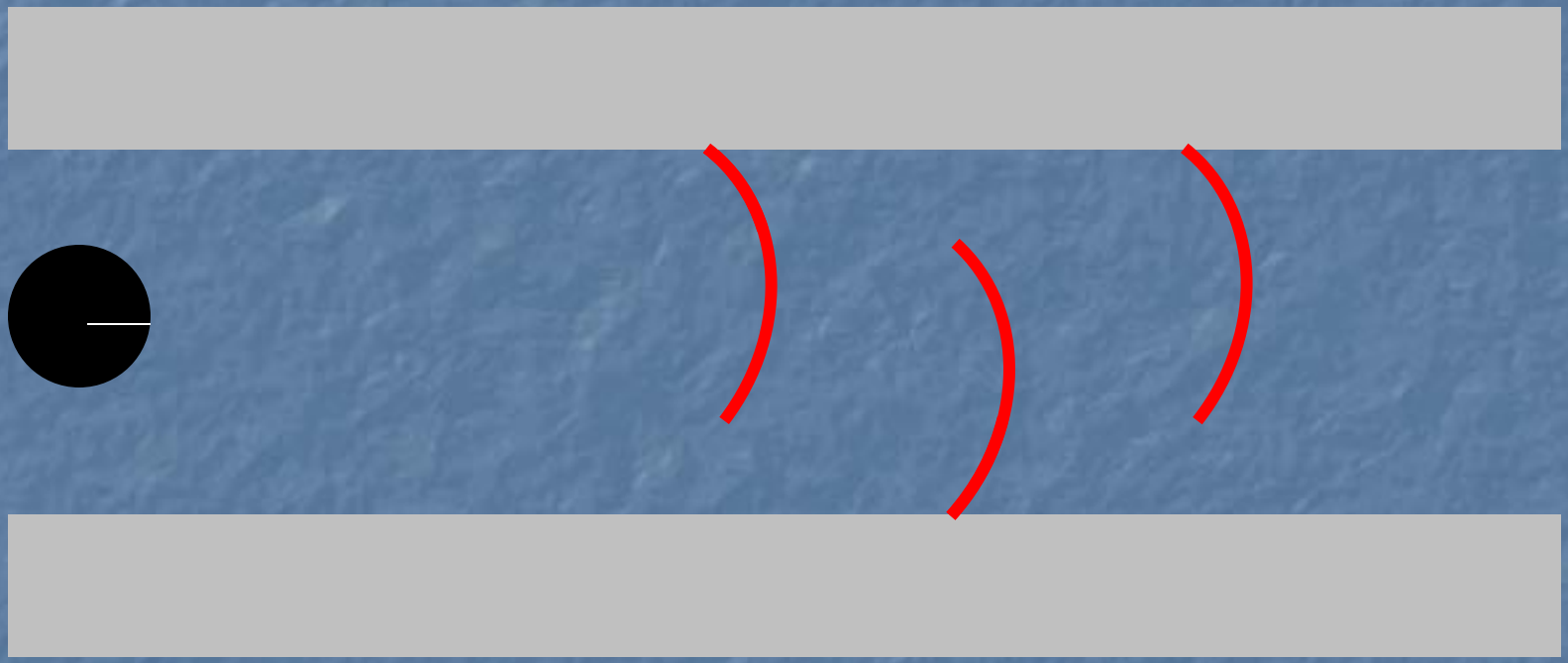
- Multiple passes of Arc Carving may completely remove an arc
  - Spurious sonar readings are removed
  - Response to dynamic environments is increased



Example – Ordinary Centerline



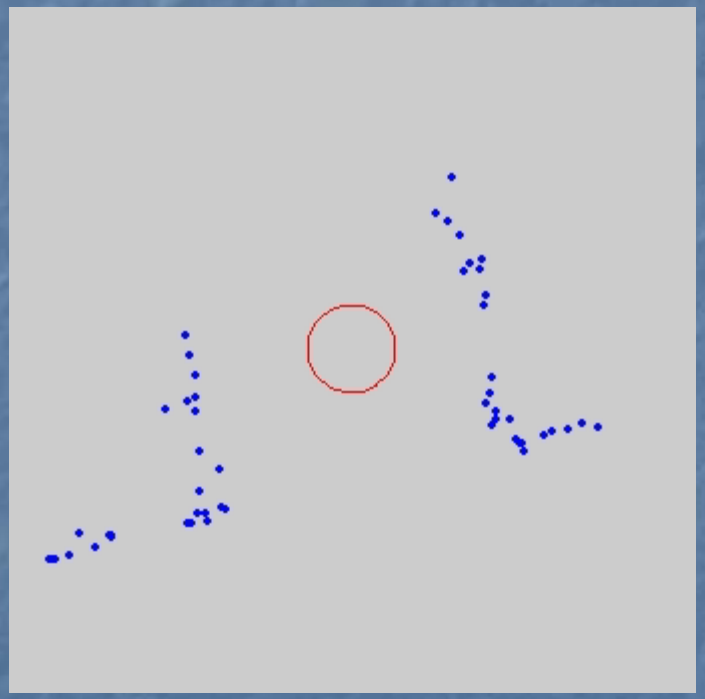
Example – Arc Carving



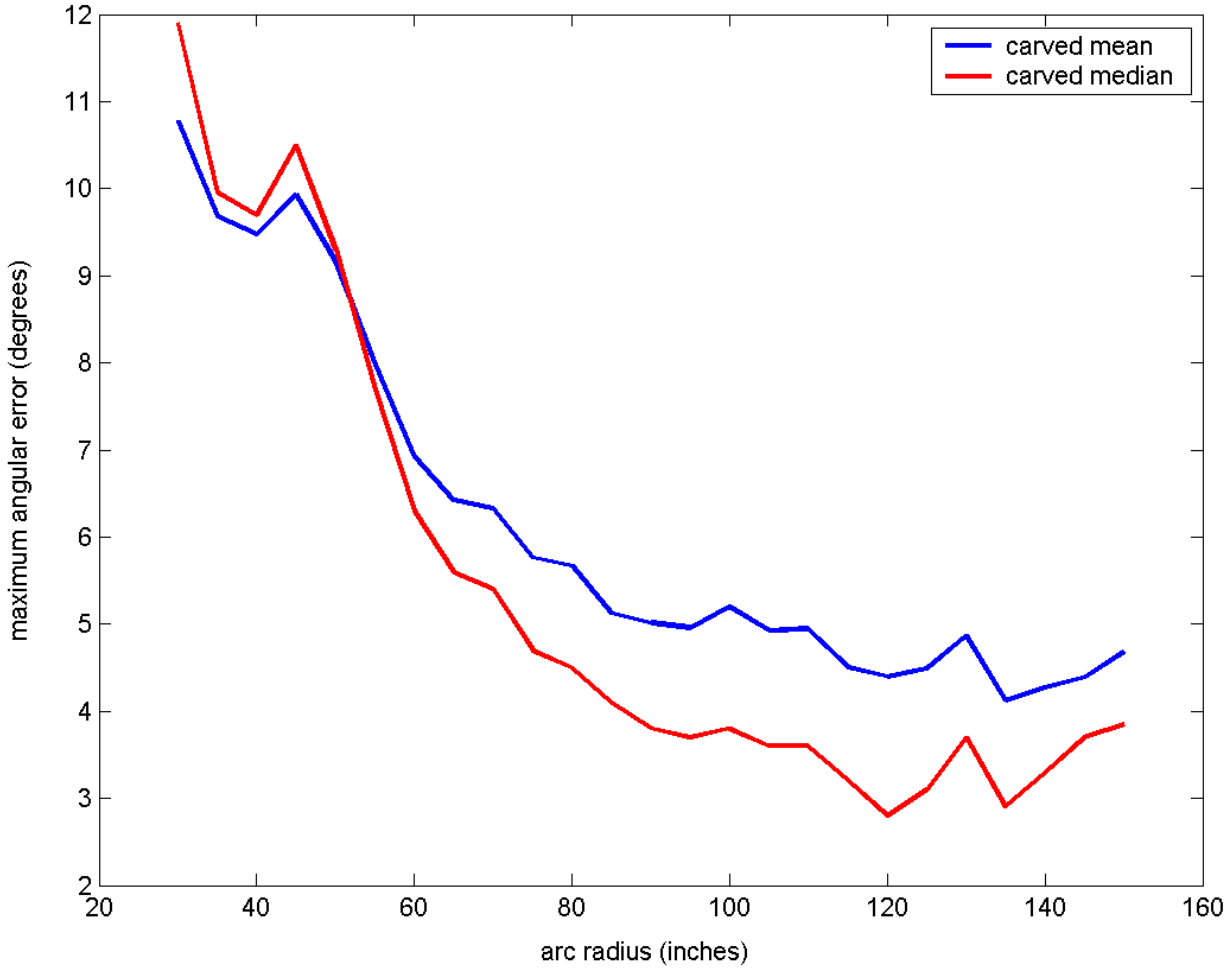
Arc Carving Video

- Latency issues are avoided
- The readings are more accurate than centerline
- Multiple reading approaches can be run off of the carved data

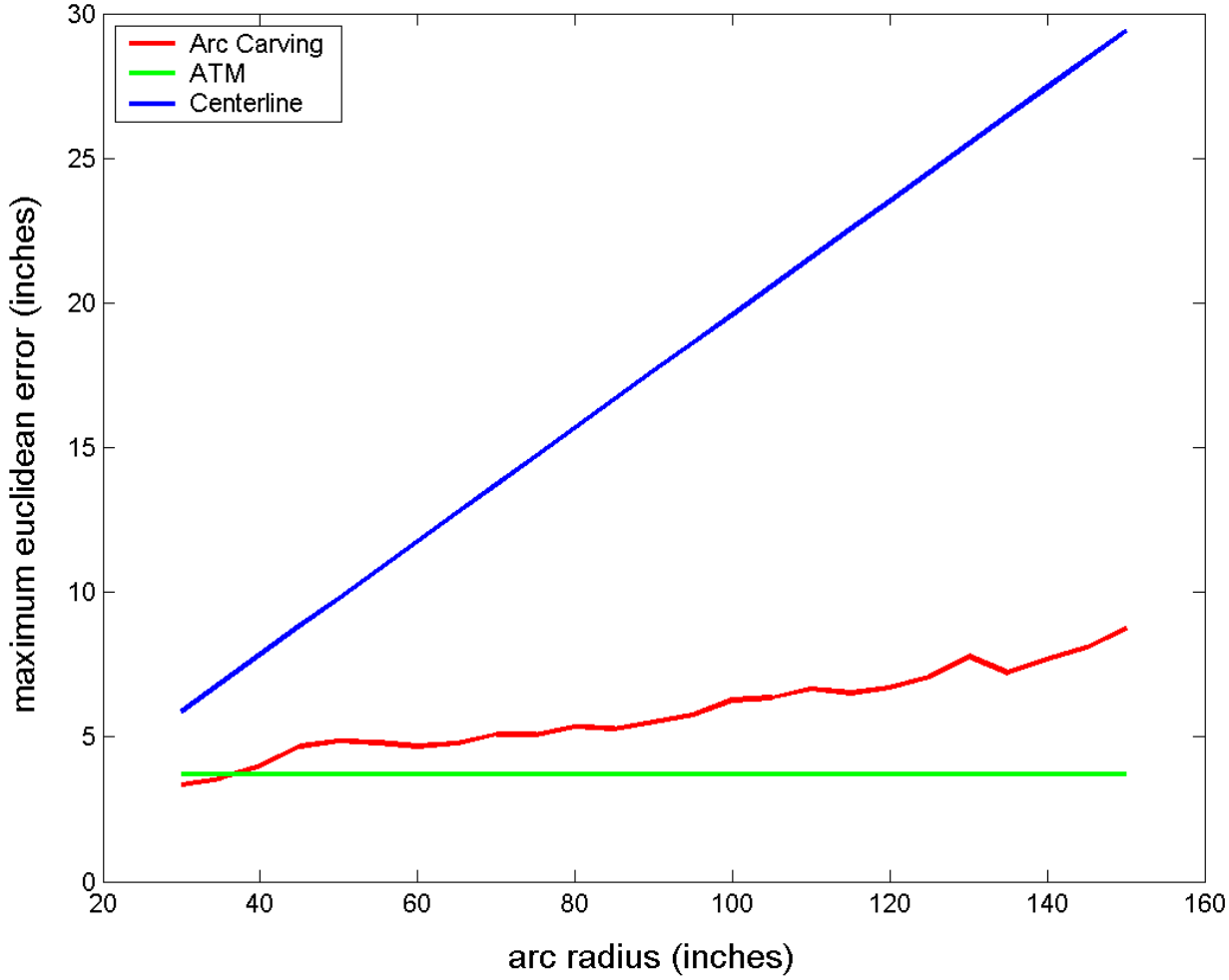
only carved points displayed



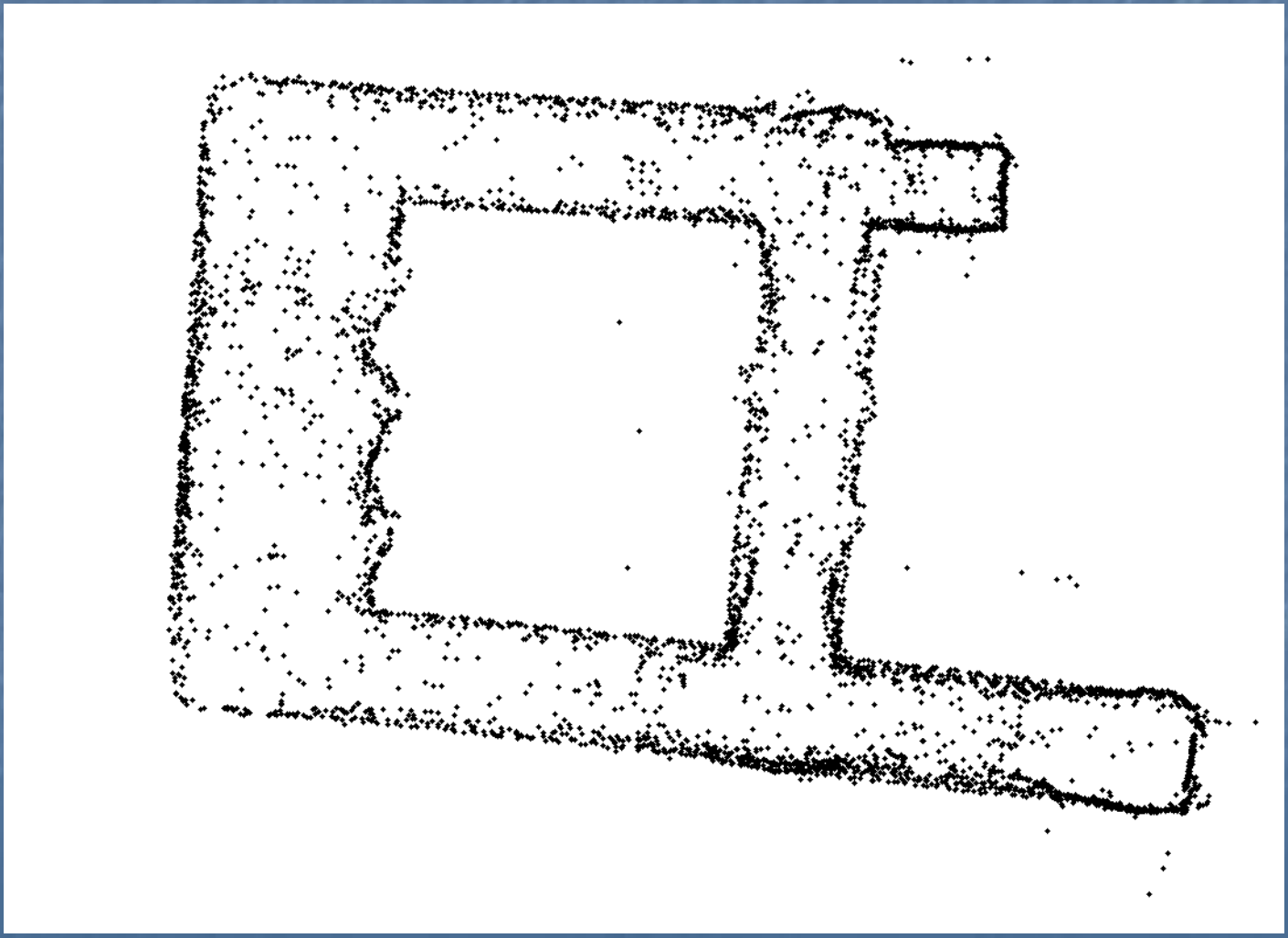
Experimental Results: Amount of Carving



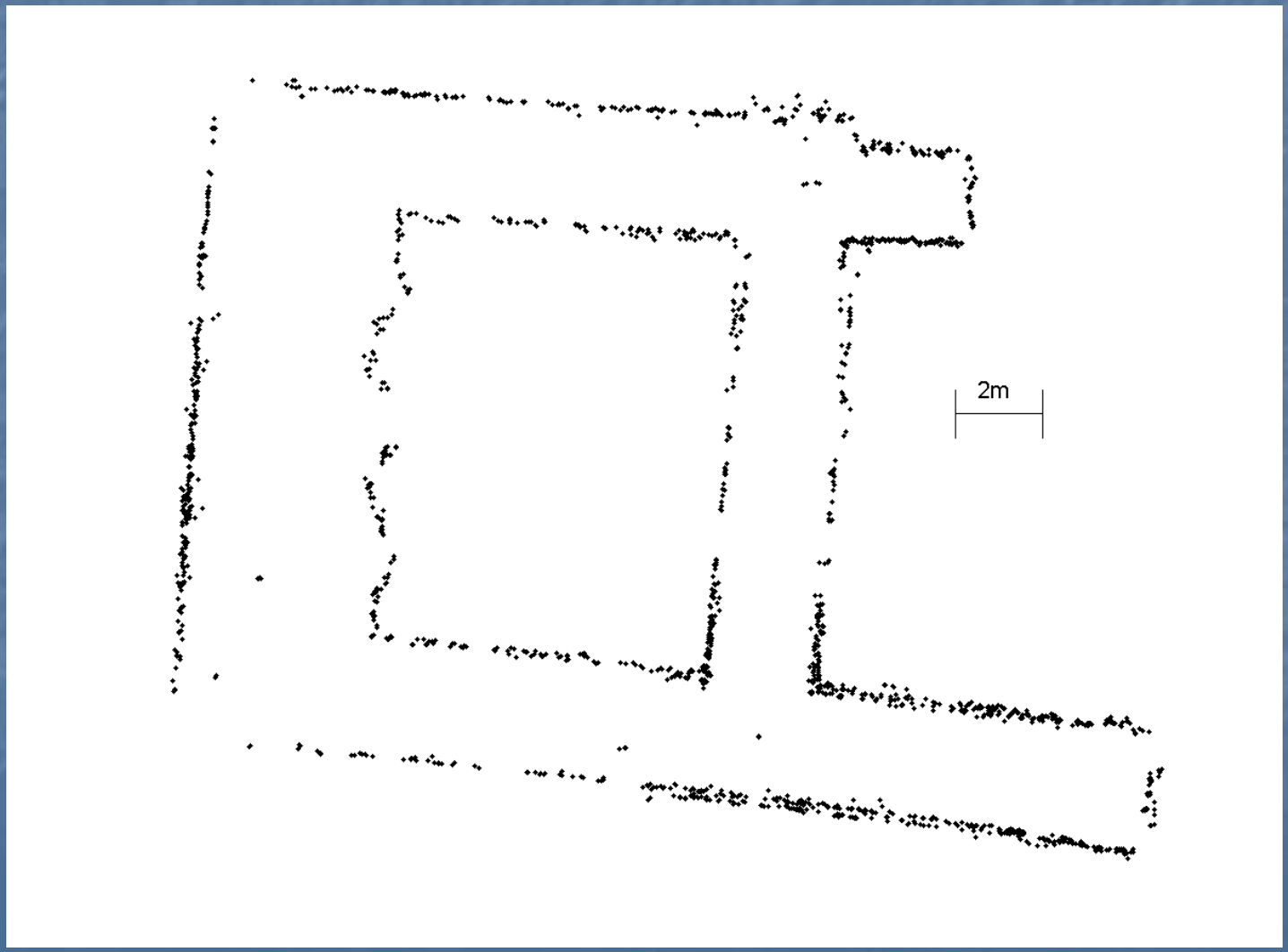
Experimental Results: Maximum Error



Experimental Results: Centerline Map



Experimental Results: Arc Carving Map



Conclusion

- Arc Carving provides a low cost approach to sonar processing
  - Increases azimuth resolution
  - Removes noise
  - Does not significantly increase latency
- Arc Carving can serve as a first pass approach that feeds into other processing algorithms

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Questions