



# Scene Modeling from Motion-Free Radar Sensing

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Ph.D. Thesis Proposal

May 13, 1999

# Motivation

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# Presentation

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- I. Research on Radar for Robots
- II. Work to Date
- III. Radar Issues
- IV. Technical Approach
- V. Research Plan
- VI. Summary

# Related Work

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1. M. Lange and J. Detlefsen, "94 GHz Three-Dimensional Imaging Radar Sensor for Autonomous Vehicles," 1991.
2. D. Langer, "Proposal for an Integrated MMW Radar System for Outdoor Navigation," 1996.
3. U.S Patent No. 5,668,739 "System and Method for Tracking Objects Using a Detection System", 1997.
4. S. Clark and H. Durran-Whyte, "Autonomous Land Vehicle Navigation Using Millimeter Wave Radar," 1998.
5. S. Boehmke, J. Bares, E. Mutschler, K. Lay, "A High Speed 3-D Radar Scanner for Automation," 1998.

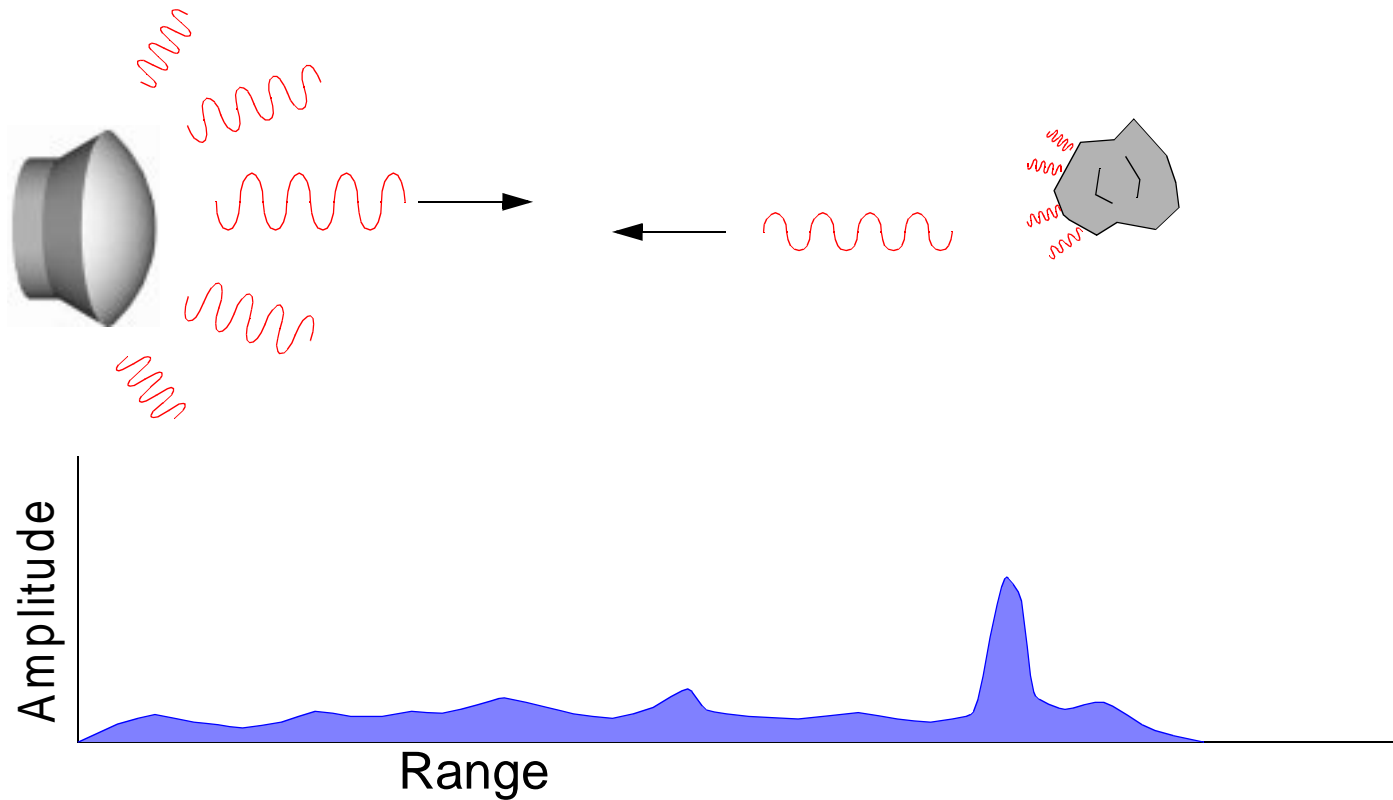
# Work to Date

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- Mechanically-scanning radar unit characterization  
*(experimental estimation of range accuracy, range resolution and beamwidth)*
- Motion-free scanning-antennas study  
*(reveals specific issues for radar interpretation)*
- 2-D evidence-grid implementation  
*(radar data merging tool, shows noise reduction)*

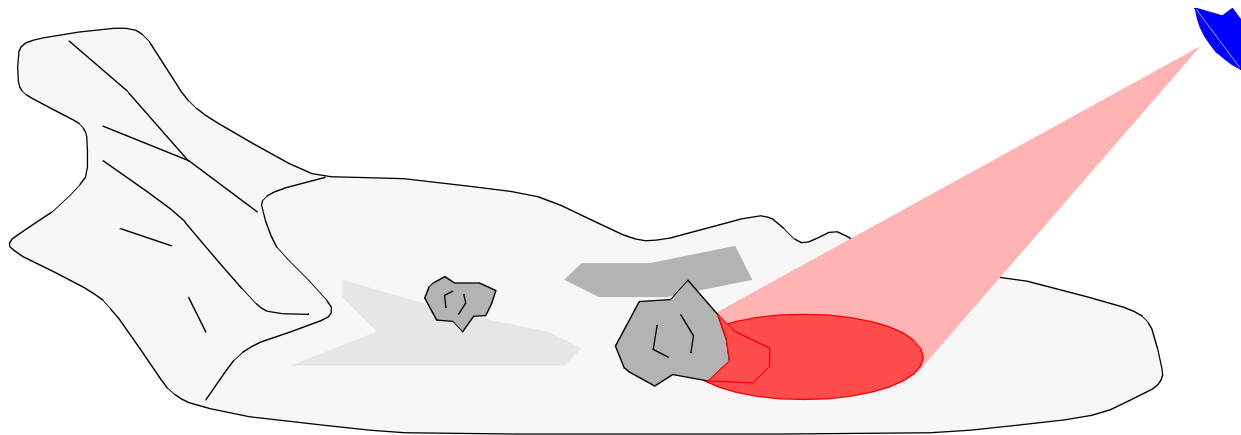
# RAdio Detection And Ranging



- Millimeter-wave band (4 mm)
- Range of interest from 1 to 100 m

# Wide-Beam Scene Sensing

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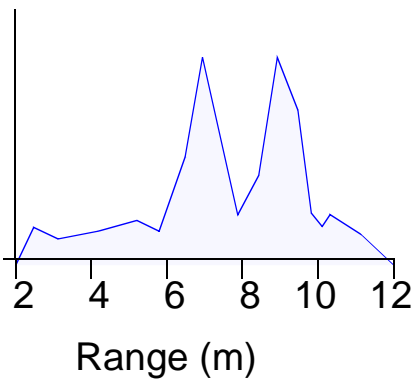


- Large footprint --> combination of echoes
- Three-dimensional modeling

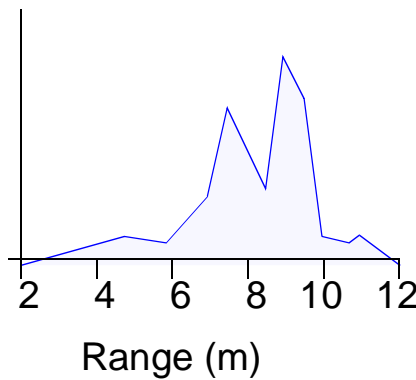
# Experimental Range Resolution



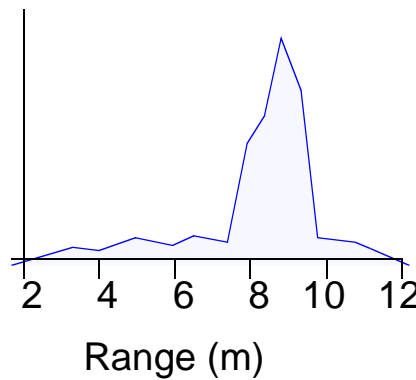
**Targets 2.0 m apart**



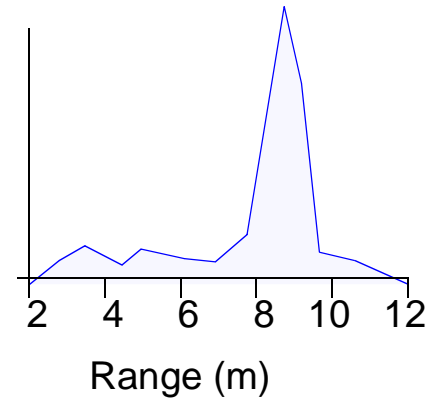
**1.5 m apart**



**1.0 m apart**



**0.5 m apart**

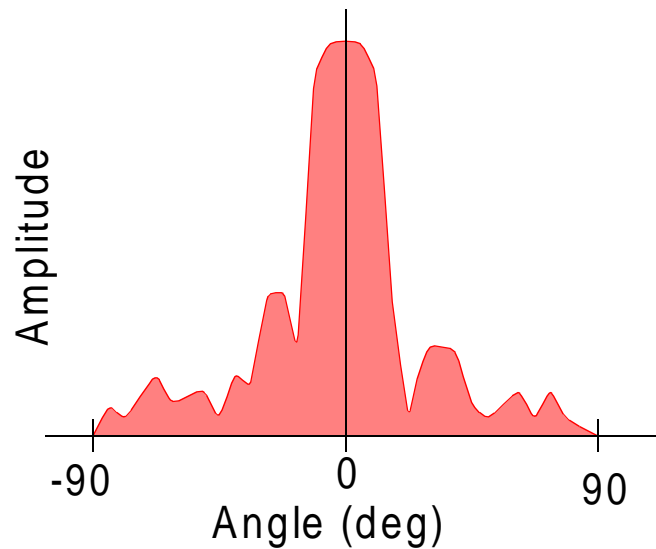


- Range resolution limited to two range intervals

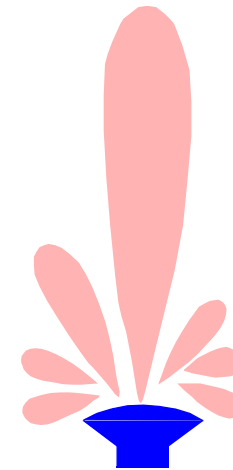


# Antenna-Radiation Pattern

**Graph  
Representation**

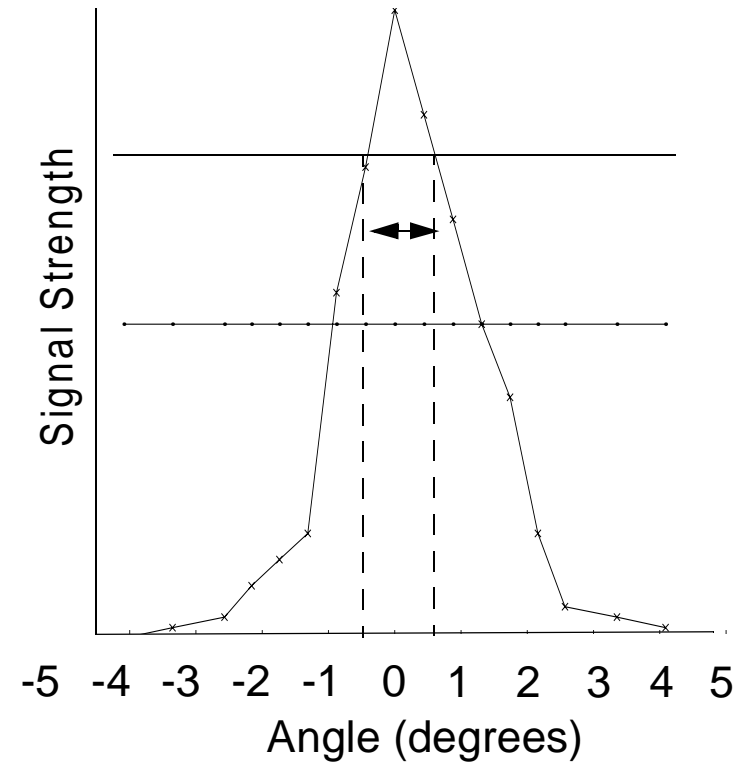
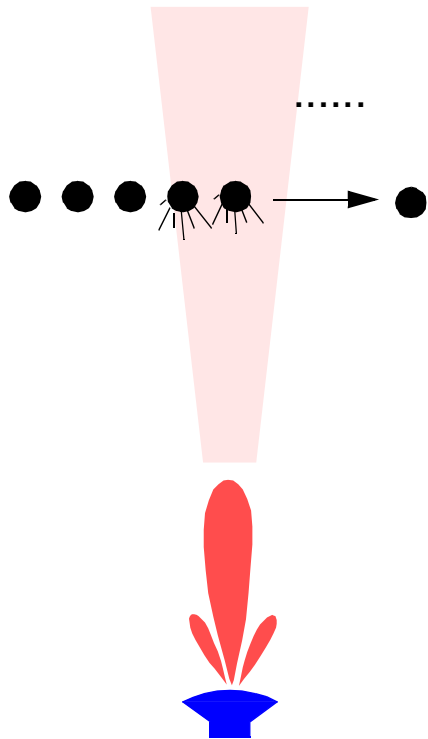


**Schematic  
Representation**



- Beamwidth less than 10 degrees

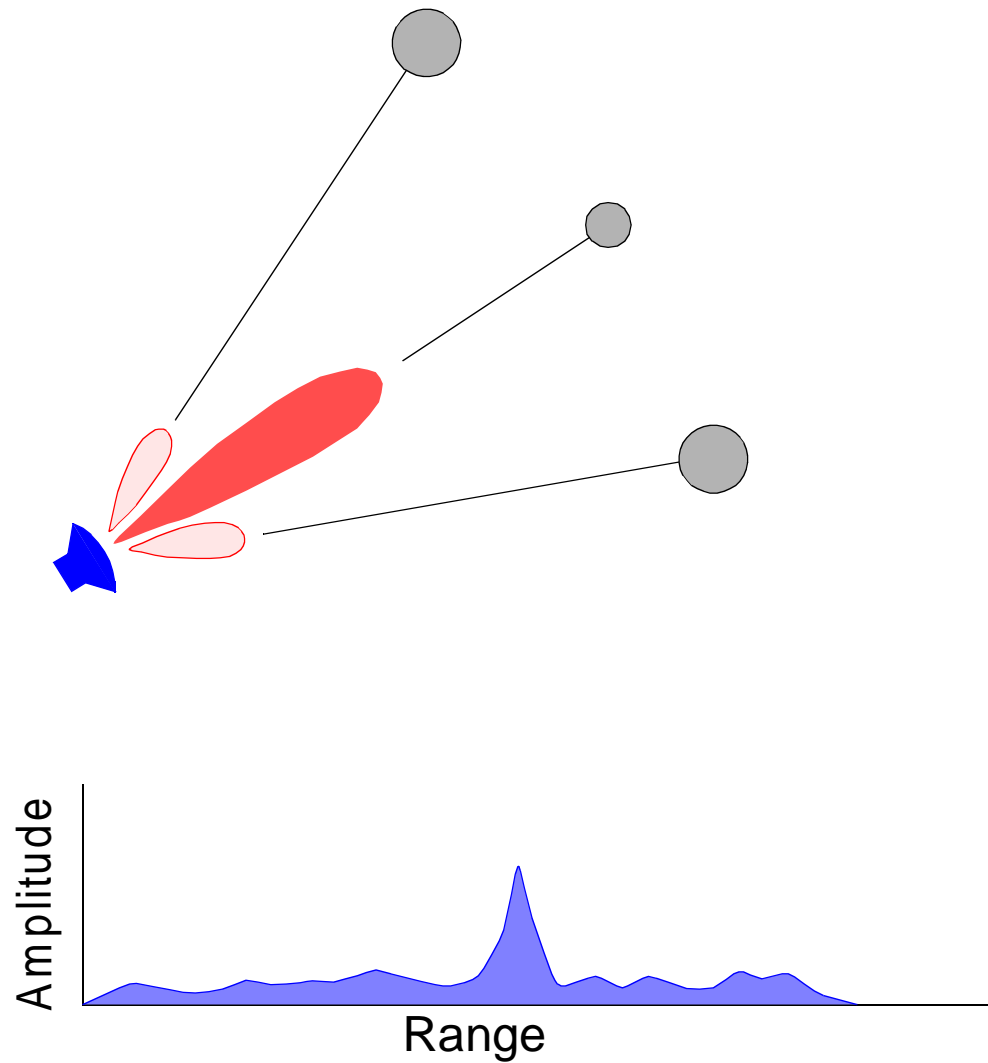
# Experimental Beamwidth



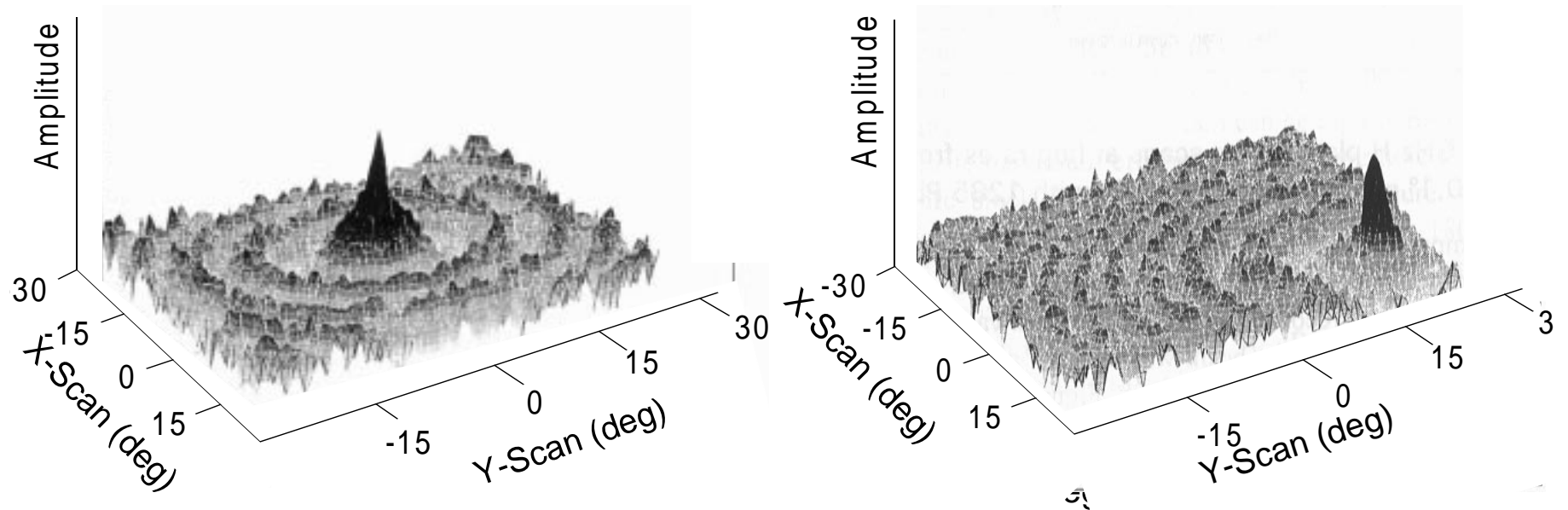
- Experimental estimation of beamwidth

# Multilobe Angular Ambiguity

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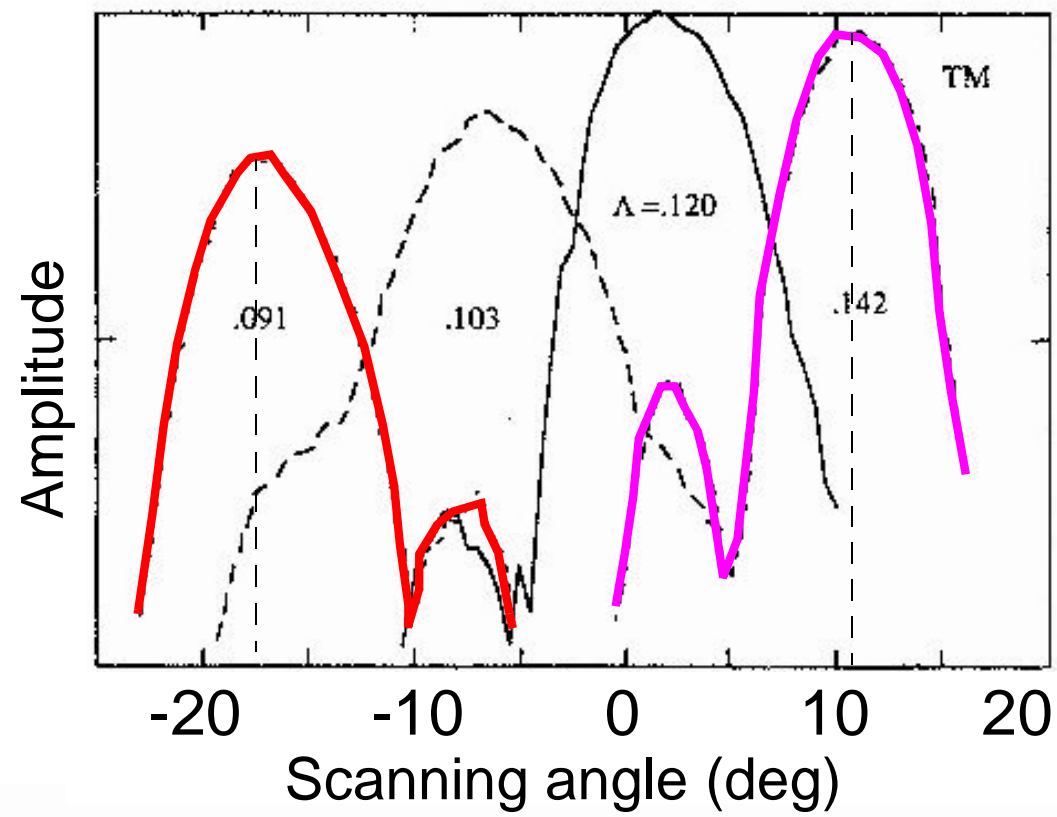
# Motion-Free Scanning Antenna



- Electronic scanning of the beam
- Provides size reduction and reliability improvement

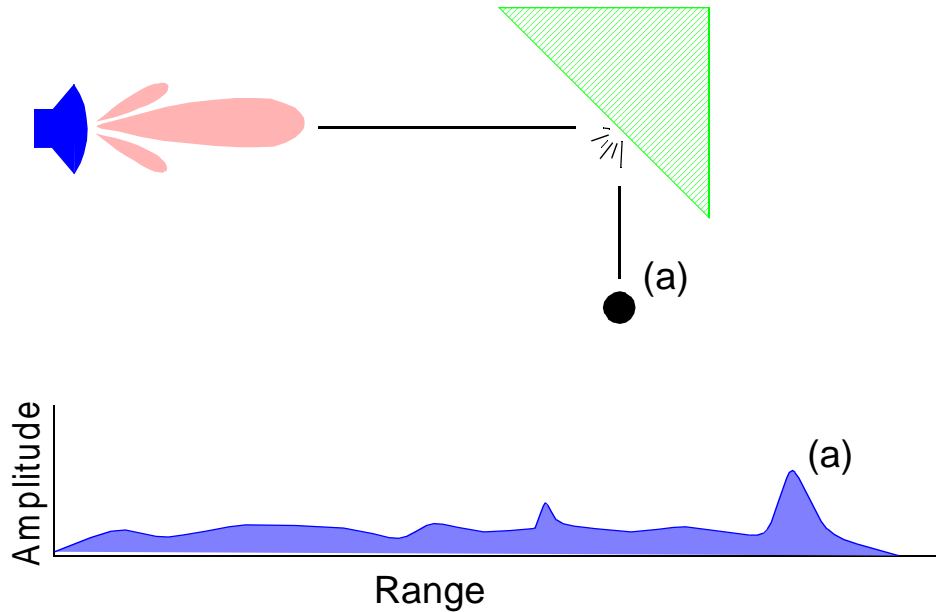
# Motion-Free Scanning Antenna

## *Varying Radiation Pattern*



- Scanning angle = -17 deg
- Scanning angle = +11 deg

# Specular Reflection



- Fails detection of specular surface
- Potential false target detection

# Radar-Issues Summary

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- Large footprint --> combination of targets
- Multilobe sensing --> angular ambiguity
- Motion-free scanning antenna --> varying properties
- Specular surfaces --> missing surface and false target
- Orientation and material determine radar energy return

# Technical Approach

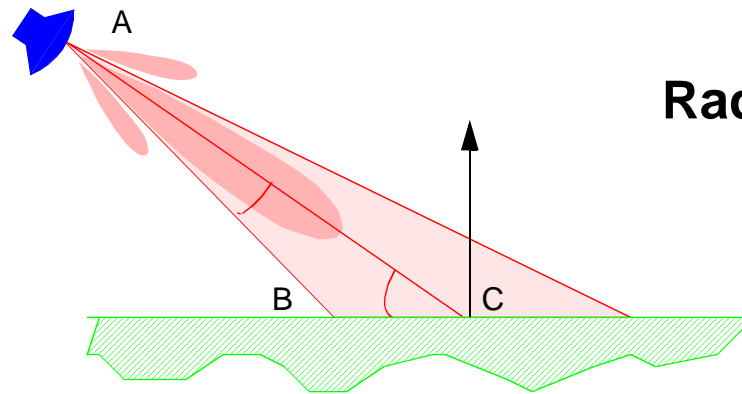
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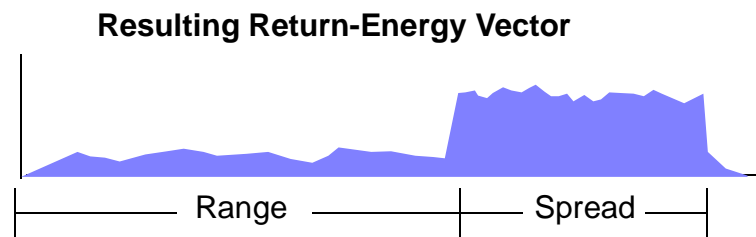
- Learn radar-signal heuristics
- Represent multilobe-sensor profile
- Enable varying profile capability
- Model surface reflectance and orientation
- Integrate in evidence grids appropriate for radar



# Identification of Planes



Radar Sensing a Plane

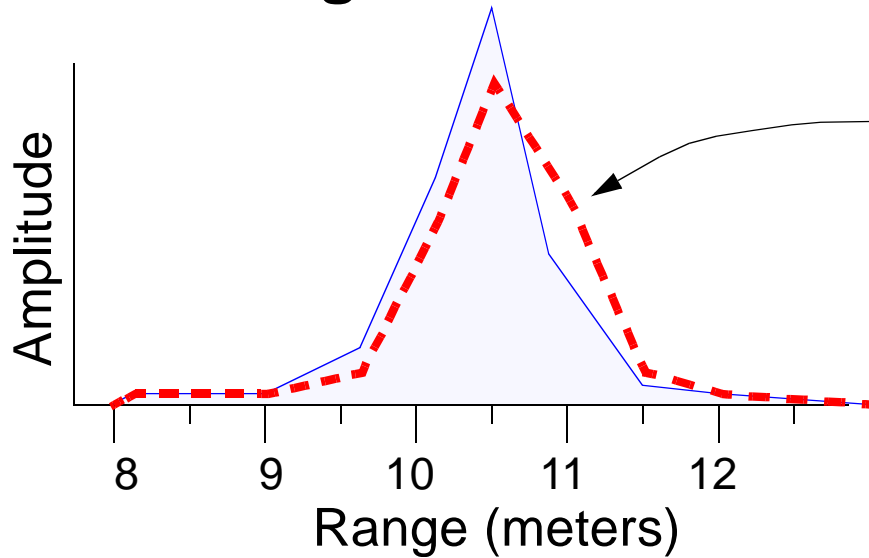


- Initial indication of a diffuse reflection plane

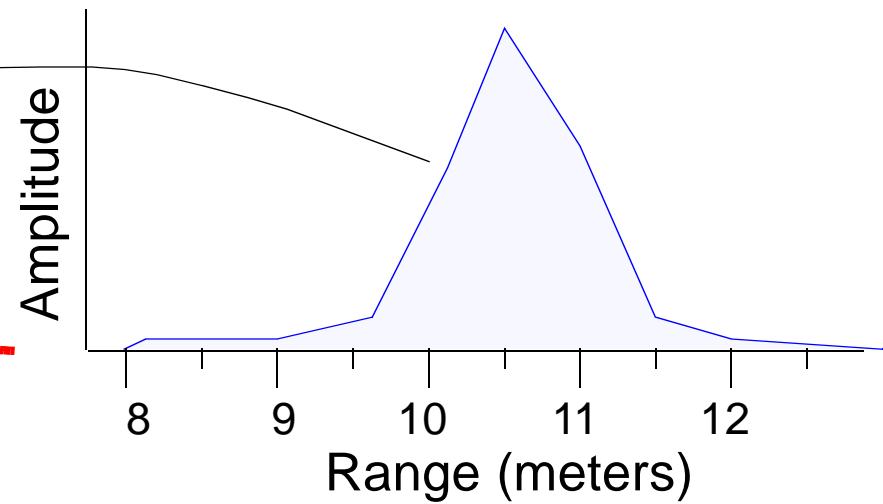
# Experimental Range Accuracy



Target at 10.5 m



Target at 10.6 m

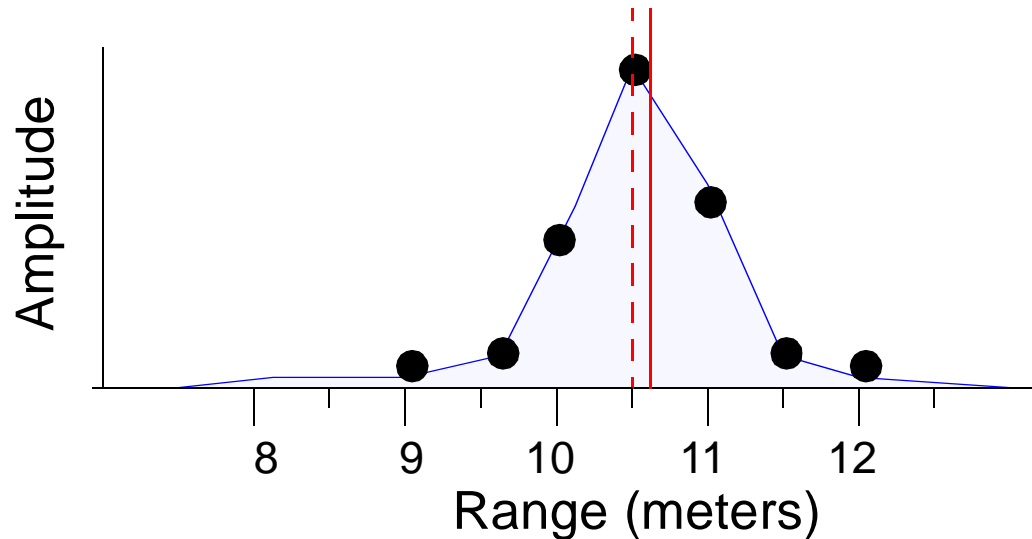


- Indicates accuracy can improve over range interval

# Improvement of Range Accuracy



## Experimental Data



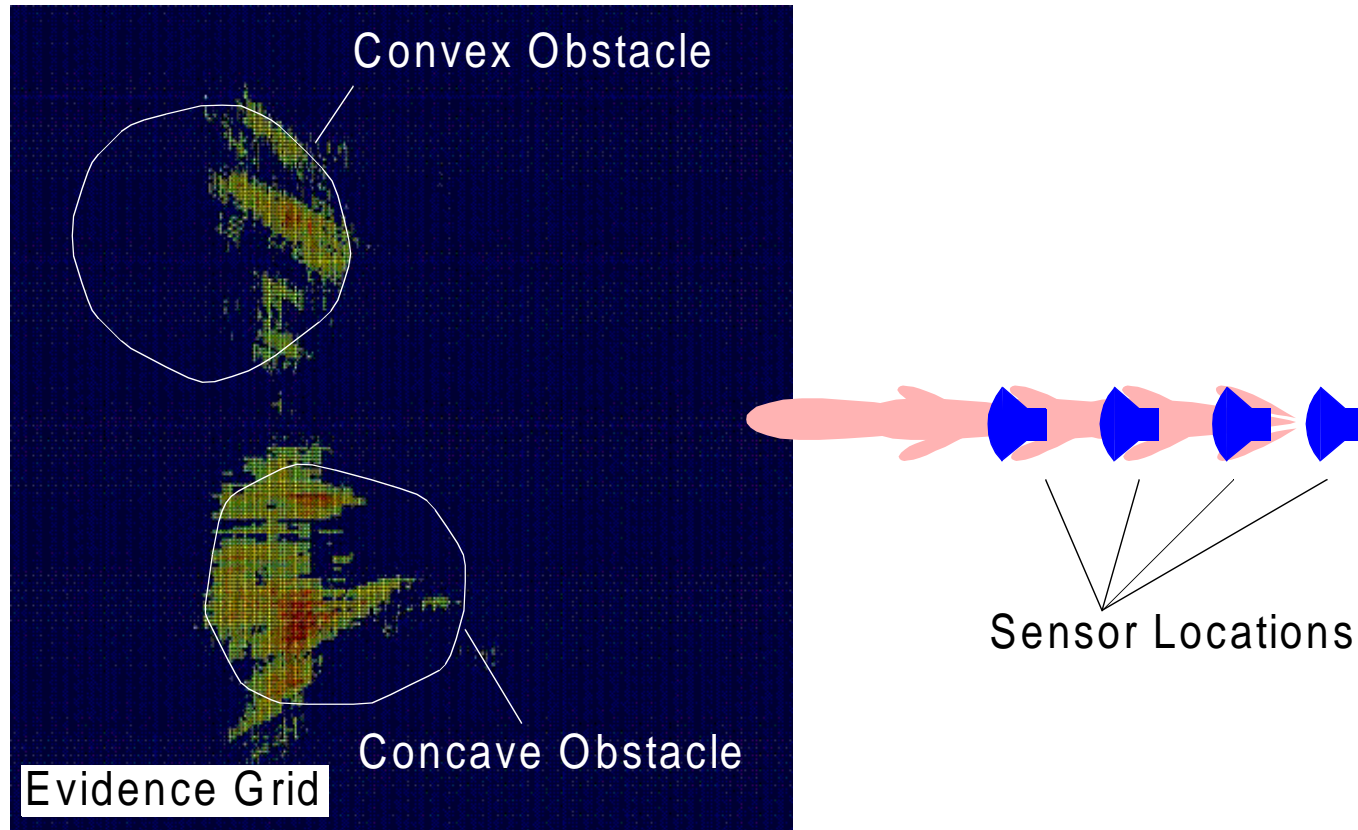
- Target at 10.6 m
- Max. value technique estimates 10.50 m
- Proposed technique estimates 10.58 m

# Evidence Grids, A Convenient Representation

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- Probabilistic scene representation for noisy sensors
- Works for wide-beam sensors
- Allows extension to multilobe profiles
- Facilitates representation of additional hypotheses (specifically, orientation and reflectance)
- Representation commonly used for robotic tasks

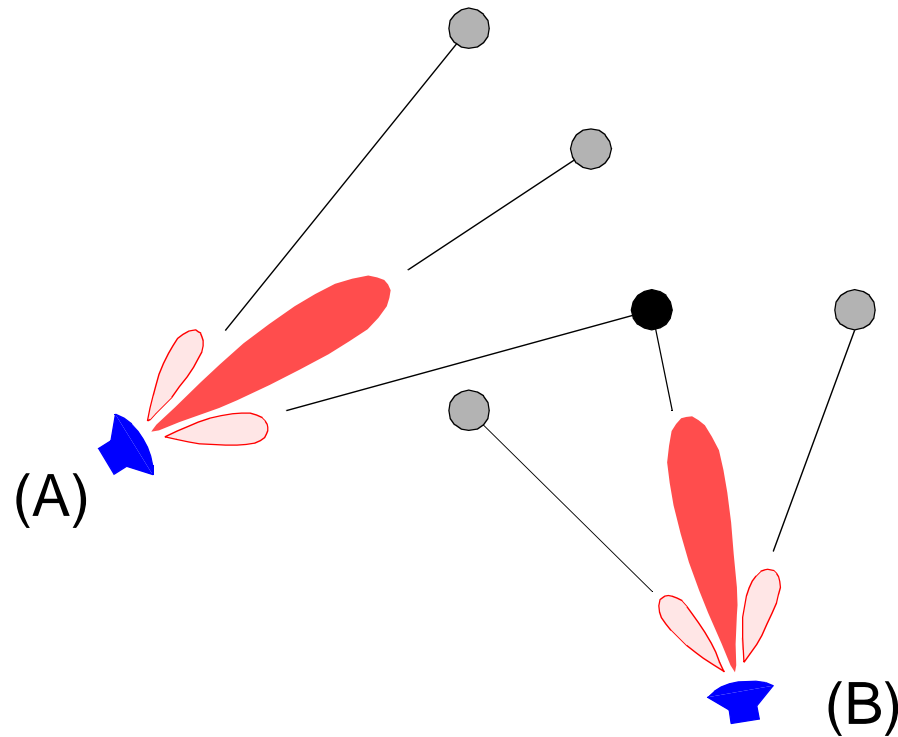
# Evidence-Grid Implementation



- Data merging results in noise attenuation

# Angular Ambiguity Resolution

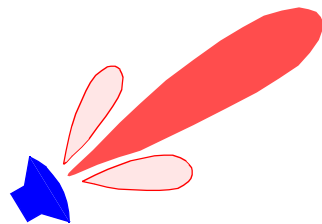
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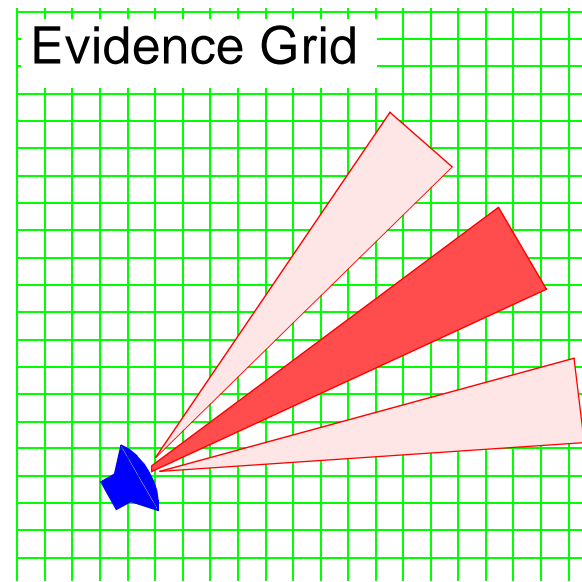
- Successive observations resolve angular ambiguity.

# Multilobe-Sensor Profile

Schematic Representation

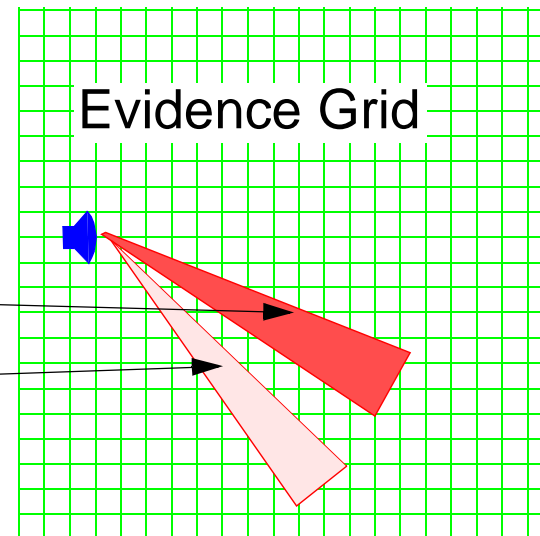
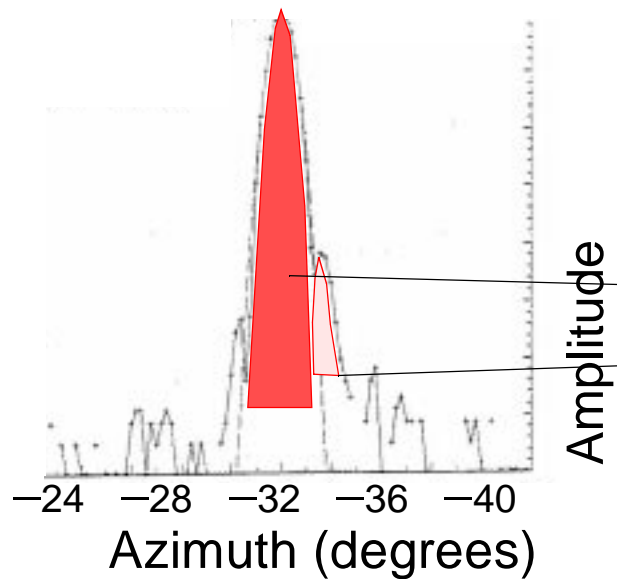
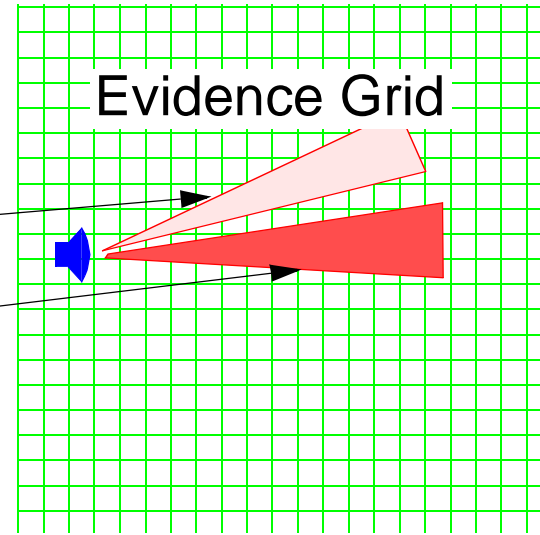
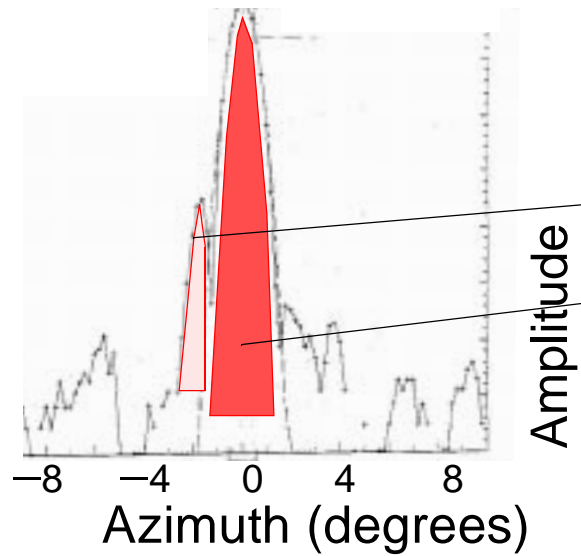


Sensor-Profile Geometry



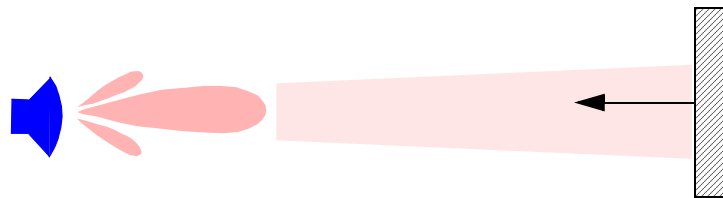
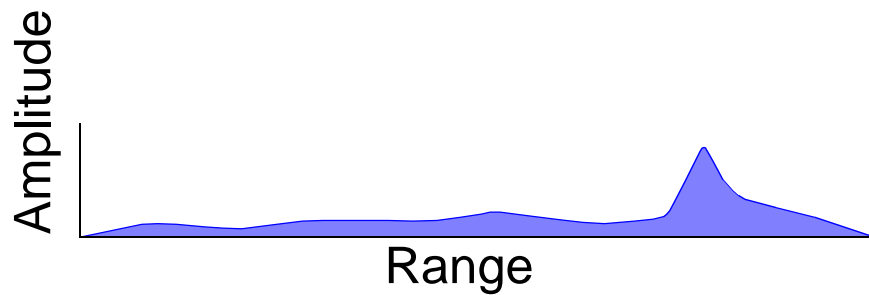
- Sensor profile represents sensor geometry

# Varying Radiation-Pattern





# Surface Orientation and Reflectance



High Evidence



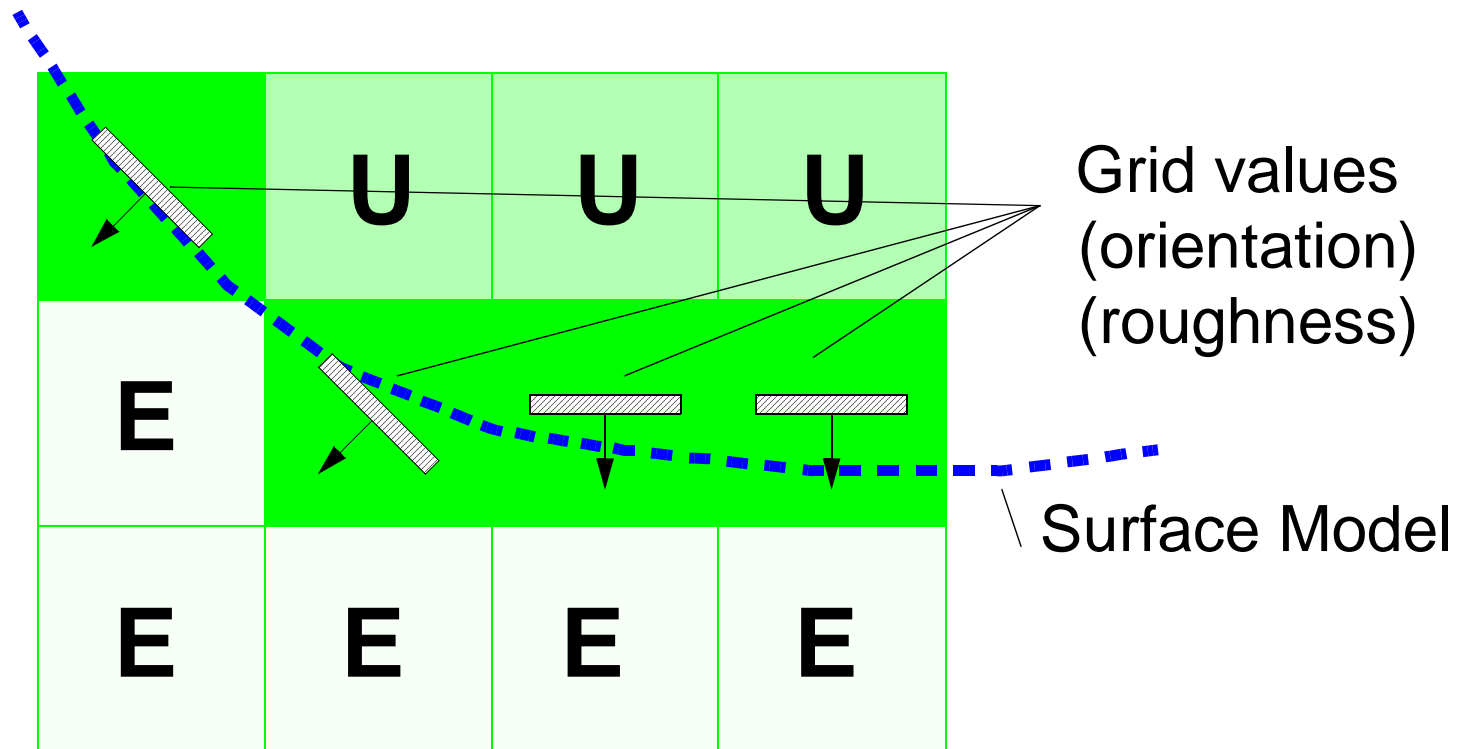
Evidence of diffuse reflection



Negative evidence

- Sensor profile updates additional hypotheses

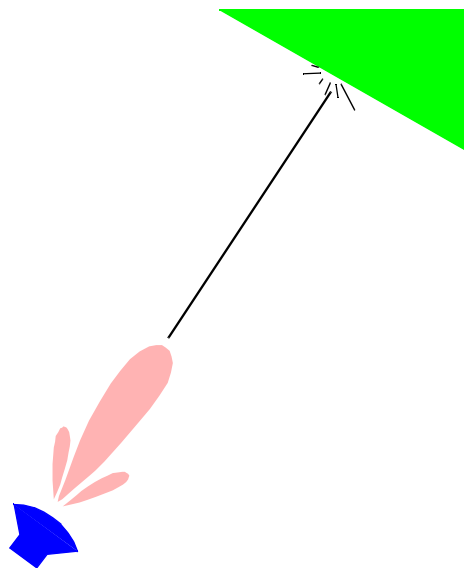
# Surface Model Enhancement



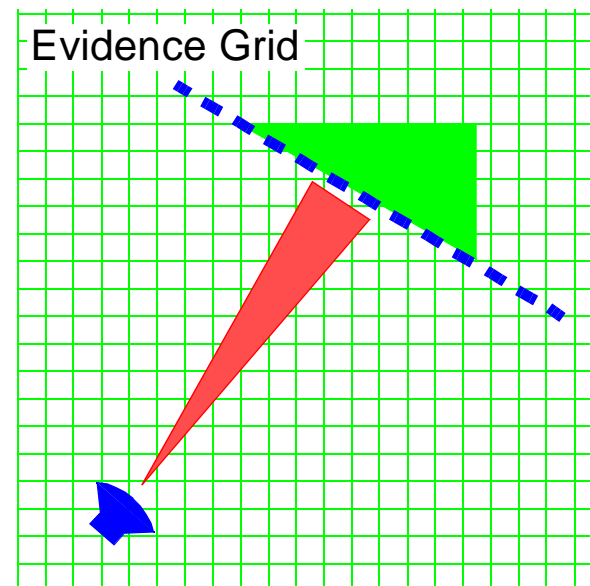
- Global approach for surface modeling

# Surface Model for Improved Interpretation

Schematic Representation



Sensor-Profile Geometry



- Known surface properties indicate stronger evidence

# Interpretation Process

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1. Obtain radar data
2. Apply radar-data heuristics
3. Build sensor profile
4. Update evidence grid
5. Model surface reflectivity and roughness
6. Iterate...

# Research Plan

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1. Radar-interpreter design (*Jun–Jul 1999*)
2. Radar-data heuristics development (*Aug–Sept 1999*)
3. Radar-sensor profile development (*Oct–Nov 1999*)
4. Surface-extraction development (*Dec 1999–Jan 2000*)
5. Integration of interpreter components (*Feb–Mar 2000*)
6. Interpreter evaluation (*Apr– May 2000*)
7. Dissertation composition, presentation (*Jun–Aug 2000*)

# Summary

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- I. Previous Radar Developments for Robotics
- II. Work to Date (*radar unit characterization, motion-free scanning antenna research, 2-D evidence grid*)
- III. Radar Shortcomings (*footprint, sidelobes, reflections, varying radiation pattern*)
- IV. Technical Approach (*heuristics, evidence grids, multilobe-sensor profile, surface modeling*)
- V. Research plan

# Questions and Answers

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