Universal Image Segmentation Framework on High-resolution Automotive Radar Map

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Contents

- Motivation
- Datasets – PolaRAD-79 and MIMO-DBS
- Distribution Feature Analysis
- Universal Image Segmentation Framework
- Segmentation Results on MIMO-DBS Maps
- Conclusions

Motivation

Why Image Segmentation on Automotive Radar Imagery?

Segment image and classify the surfaces and objects

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Identify the passable region

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Autonomous path planning and obstacle avoidance

The development of automotive radar allows high resolution and high sensitivity automotive radar imagery

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Achieve the full deep scene reconstruction similar to optical imagery

Why universal Image Segmentation on Automotive Radar Imagery?

The radar segmentation framework has been proposed and implemented on mechanically steering FMCW radar

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Q1: Whether the proposed method can be applied on the radar imagery produced with different beamforming method?

Q2: What kind of change do we need to do for achieving the transfer learning on the other data format?

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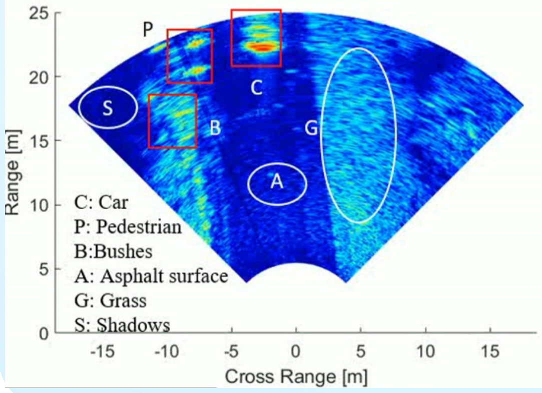
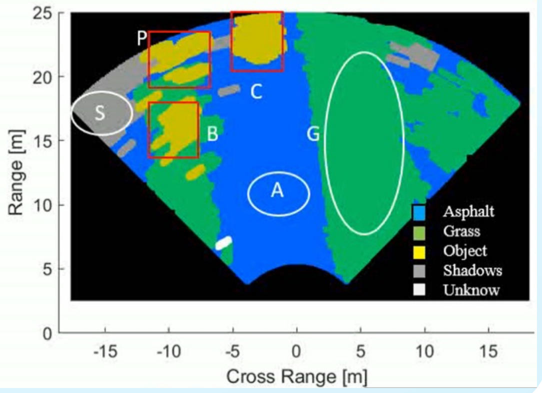
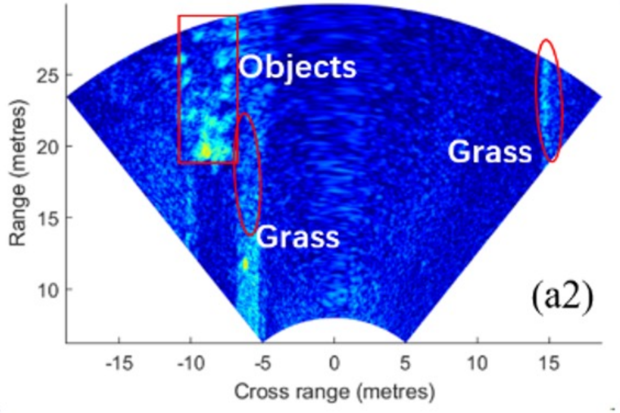
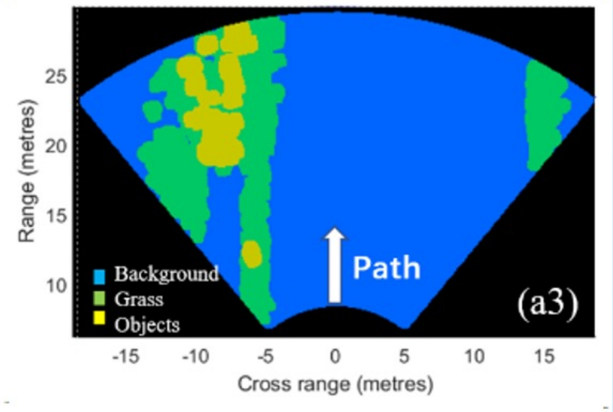
Learn the universality of the developed framework by applying to another kind of high-resolution automotive radar map

PolaRAD-79 radar map | Segmented radar map | MIMO-DBS radar map | Segmented MIMO-DBS map





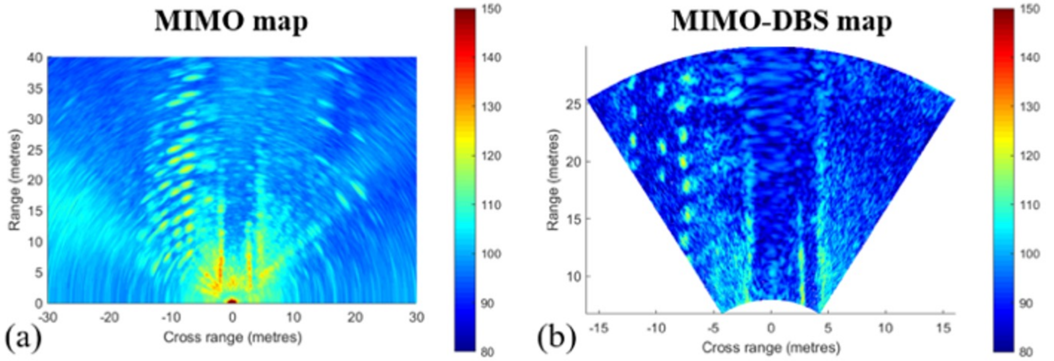




Datasets – PolaRAD-79 and MIMO-DBS

The characteristic parameters of radar systems.

Parameter	INRAS Radarlog	PolaRAD-79
Bandwidth	1 GHz	5 GHz
Start frequency	76 GHz	76 GHz
Mode of operation	MIMO	Mechanical steer FMCW
Tx antenna gain	14.4 dBi	30 dBi
Rx antenna gain	14.4 dBi	30 dBi
Transmit power	10 dBm	13 dBm
Range resolution	15 cm	3 cm

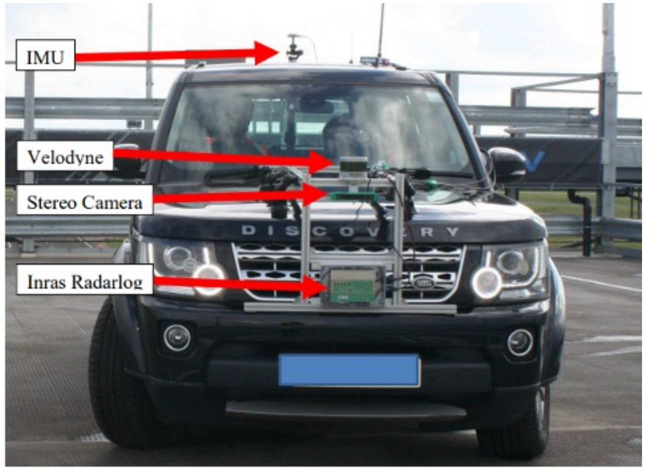


(a) the original MIMO map

(b) the radar map after DBS

(c) the corresponding optical imagery

PolaRAD-79 setup

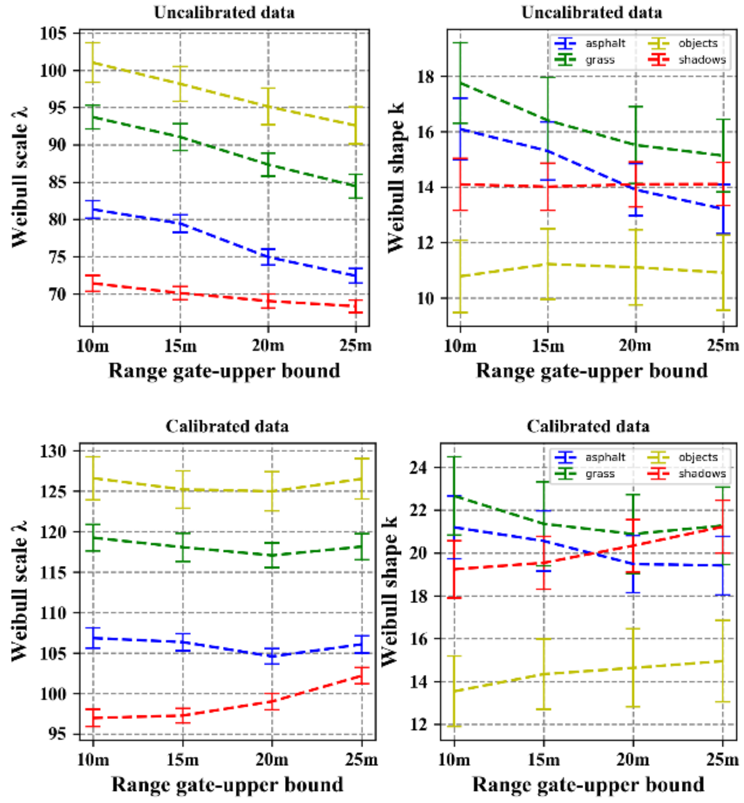


MIMO setup

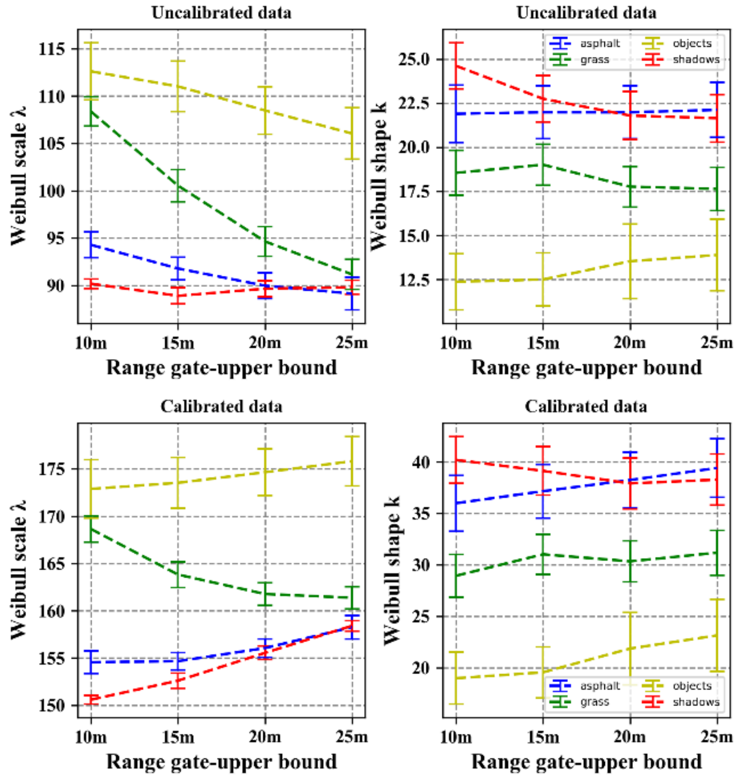
misl

Distribution Feature Comparison

Weibull distribution feature parameters obtained from the PolaRAD-79 dataset



Weibull distribution parameters obtained from the MIMO-DBS dataset



Conclusions obtained in comparison

- For both datasets parameters of classes of objects, grass, and asphalt demonstrate a clear contrast.
- Both Weibull scale λ and shape *k* parameters of asphalt and shadows merge at longer ranges for MIMO data that the MIMO radar has lower transmitted power and antenna gains.
- The scale parameter λ of MIMO-DBS is higher than PolaRAD-79, which is similar to shape parameter *k*.

Distribution Feature Parameter Compensation

The parameter shift procedure

Definition of Weibull distribution

$$f(x;\boldsymbol{\lambda},k)=\begin{cases}\frac{k}{\lambda}\left(\frac{x}{\lambda}\right)^{k-1}e^{-\left(\frac{x}{\lambda}\right)^{k}}, & x\ge 0\\ 0, & x<0\end{cases}$$

The shifted λ parameter of MIMO-DBS:

$$\lambda'_{DBS}=\lambda_{DBS}-a$$

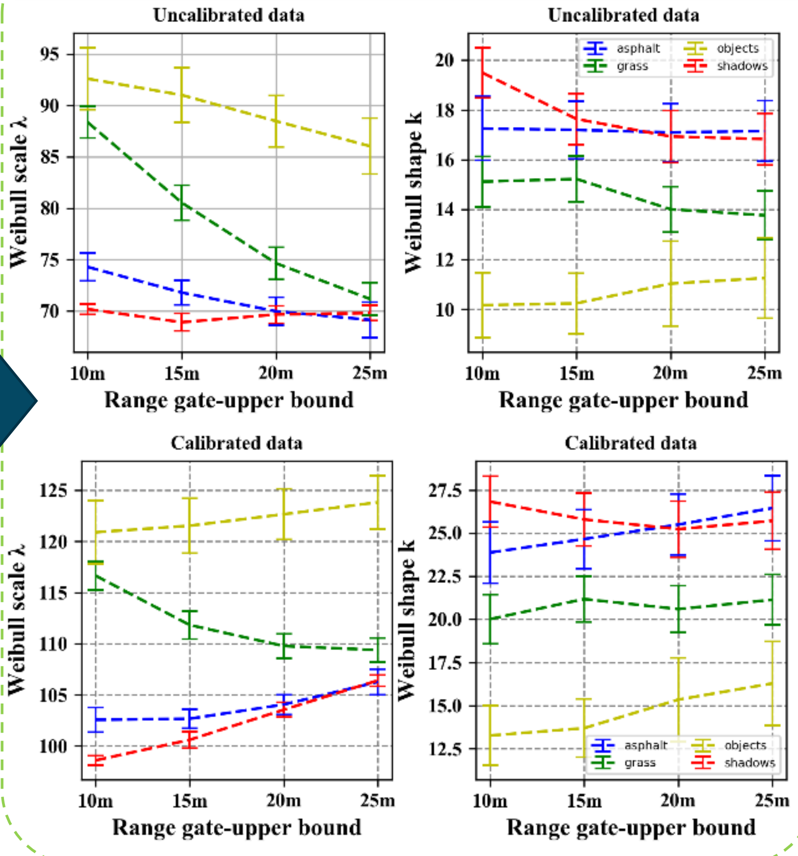
- a is the average power level difference
- λ_{DBS} is the original scale parameter.

The shifted k parameter can therefore be calculated as:

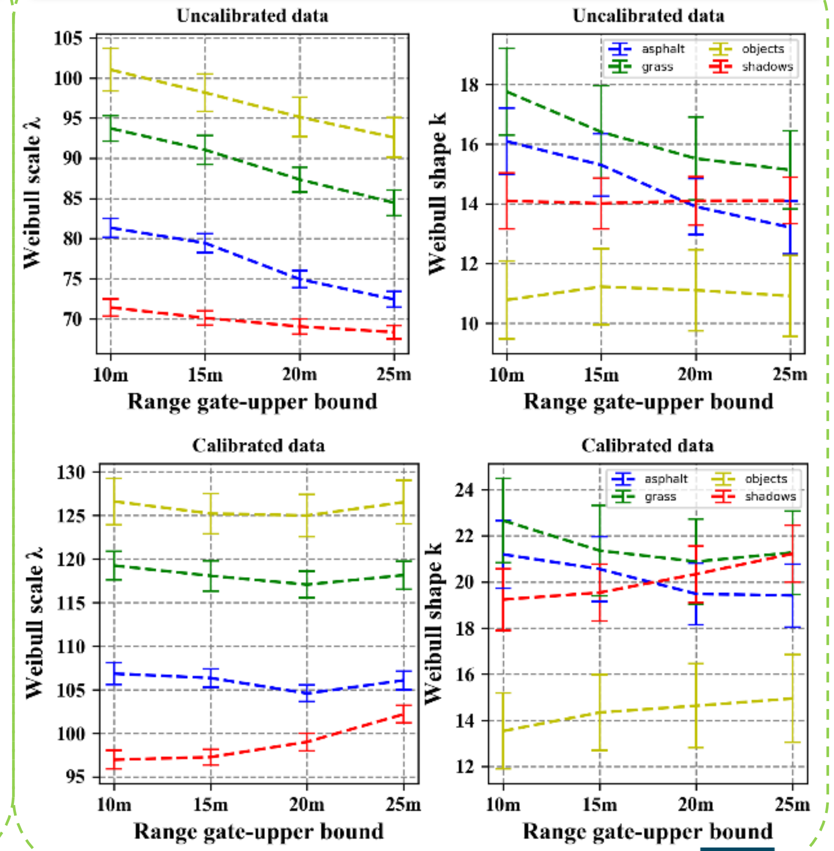
$$k'_{DBS}=\left(\frac{k_{DBS}}{\lambda_{DBS}}\right)*(\lambda_{DBS}-a)$$

- k_{DBS} is the original Weibull shape parameter.

The shifted feature parameters of MIMO-DBS dataset



The feature parameters obtained from the PolaRAD-79 dataset

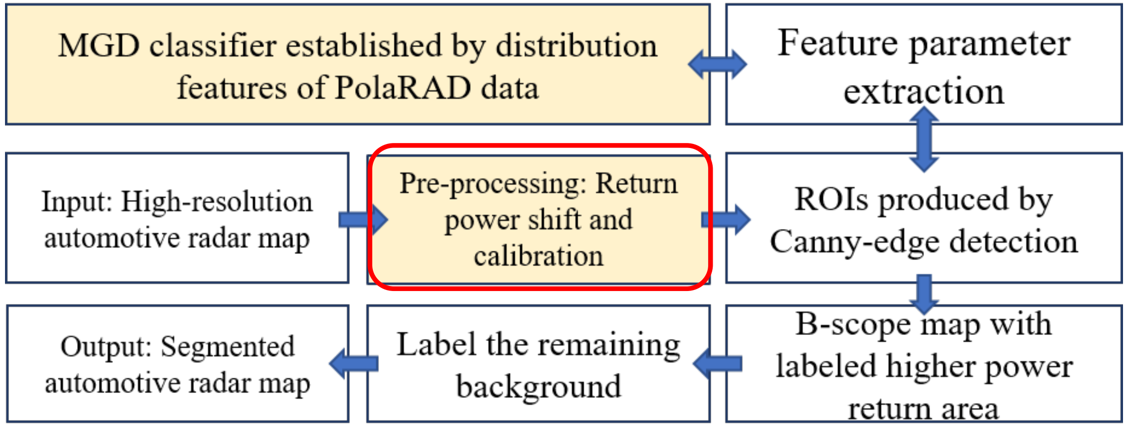


Conclusion:

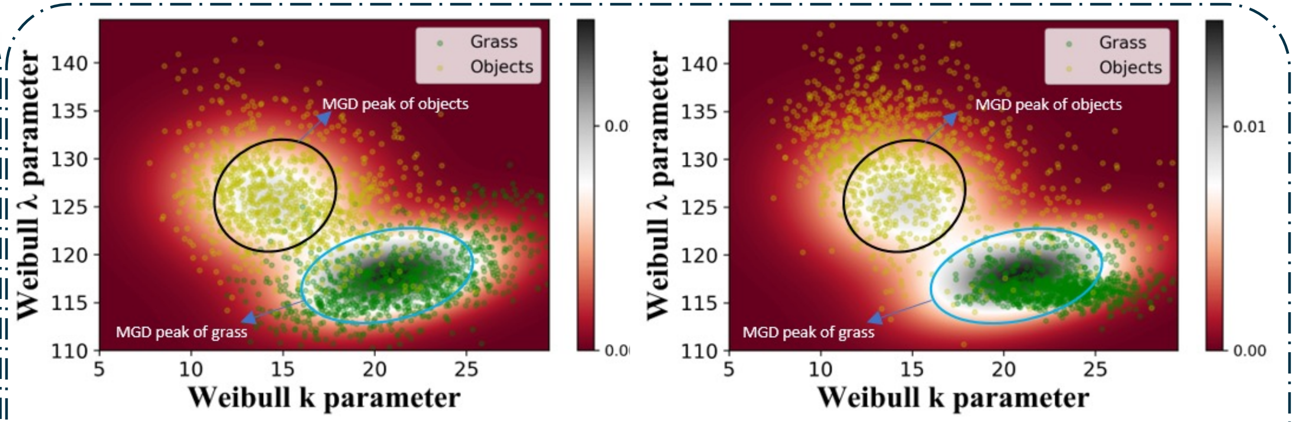
- ➢ MGD classifier is universal to multiple types of high-resolution automotive radar maps with return power distribution scaling in the pre-processing stage.
- ➢ The trained dataset on one radar beamformer can be applied directly to the others.

How to Implement the Universal Image Segmentation Framework?

The block diagram of the universal image segmentation framework



- The MGD region classifier is obtained by the manually labeled Polarad-79 data. The detailed equations are given in the paper for reference.
- The input is the MIMO-DBS radar map.
- The only changed procedure is the pre-processing stage, which is with added power shift operation stated above.



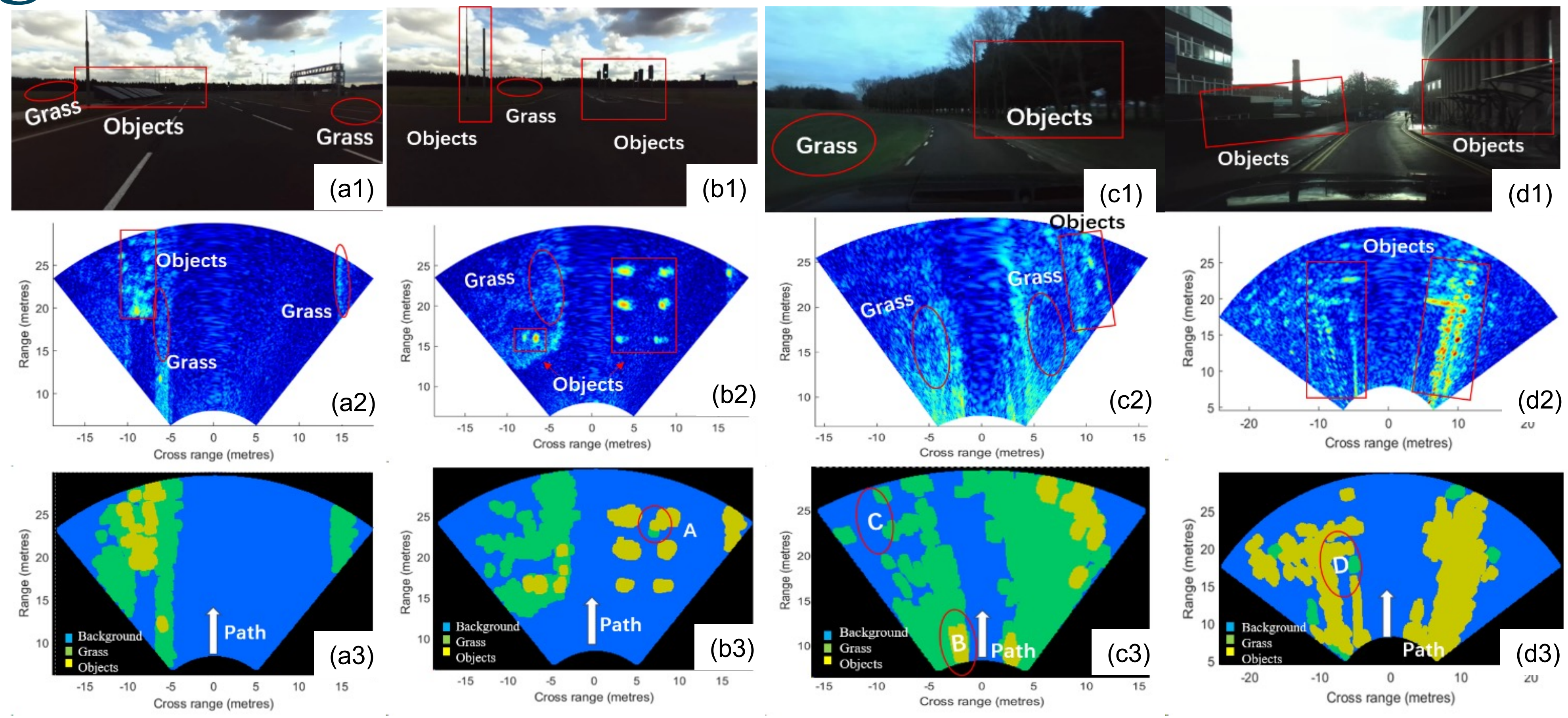
(a) (b)

- Color-coded background: surface plot of the pdfs of 2D MGD classifier calculated by PolaRAD-79 data for (a) and (b).
- Yellow and green dots: scattered feature points obtained from PolaRAD-79 (a) and MIMO-DBS (b).

Observation:

- ➢ Both dataset approaches to the MGD peaks of the corresponding area class.
- ➢ The MGD classifier can accurately describe the distribution of the features obtained from various data formats

Segmentation Results on MIMO-DBS Maps



Discussion on the confusions in the results:

- Region A in (b3) and Region D in (d3) can be improved by optimizing the pre-segmentation and using frame-to-frame tracking of regions
- Region C in (c3) is caused by the deviation of velocity estimation between the left and right sides used for DBS and can be improved by involving the velocity compensation in the DBS procedure when the vehicle is cornering.

Conclusions

- Propose the universal segmentation framework for high-resolution automotive radar imagery.
- The universality is estimated and discussed from two aspects:
  1) the analysis of the distribution features of different high-resolution radar imagery;
  2) the feasibility of implementing the framework developed based on the PolaRAD-79 data on the MIMO-DBS maps
- The transfer of the segmentation framework is possible between differently generated high-resolution automotive radar imagery by simply scaling the return power.
- The MGD classifier developed on one manually labelled training dataset can successfully be applied to another radar data without the necessity to repeat the tedious labelling process.

Thanks for your attention!