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# CNN-based ship classification method incorporating SAR geometry information

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# Motivation

**Ship classification enhances the performance of maritime surveillance**

Helps in quick identification of vessels involved in illegal activities



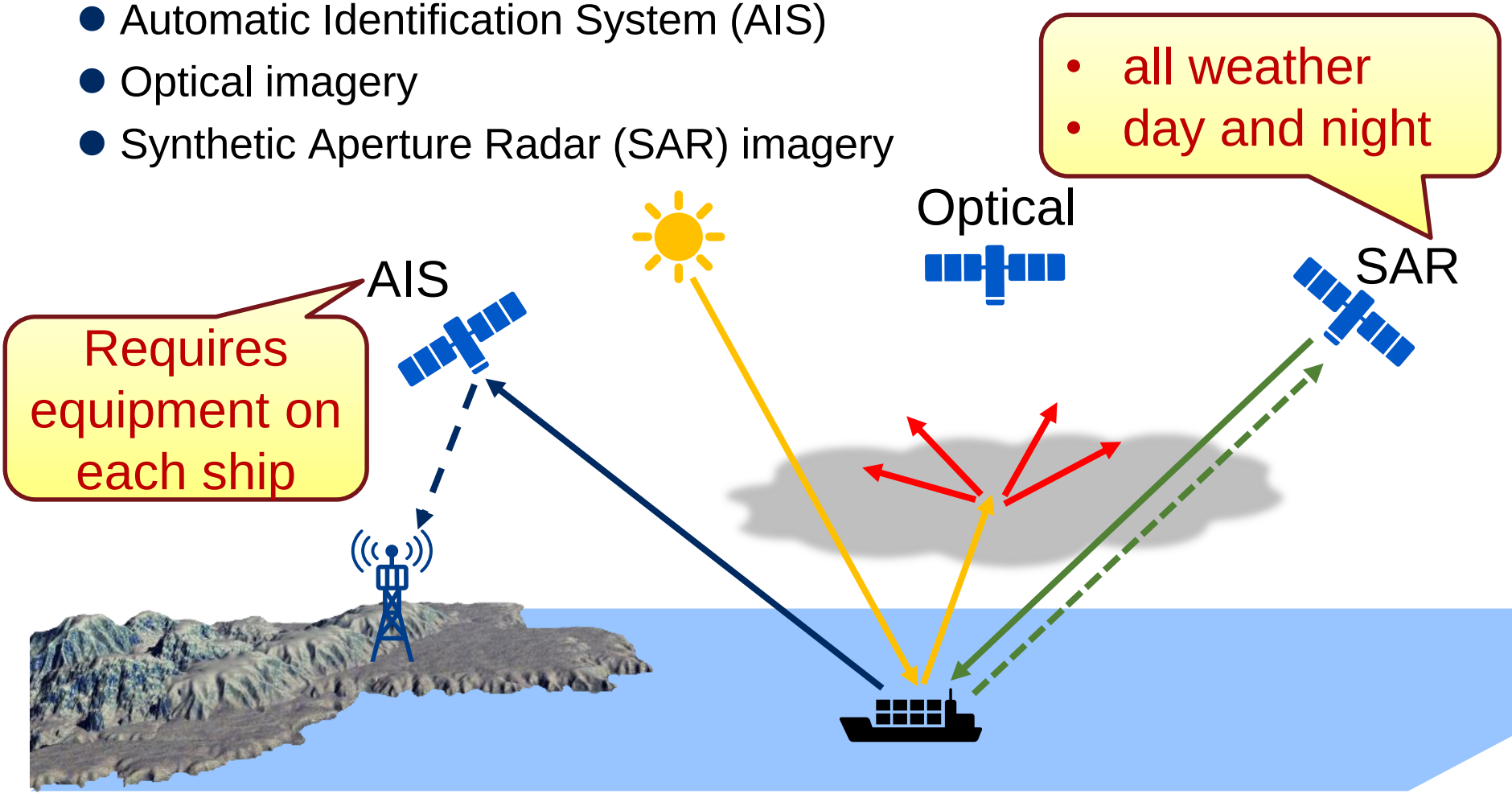


**An accurate ship classification technology is needed**

# Ship Monitoring from Space

## 3 major sources of information:

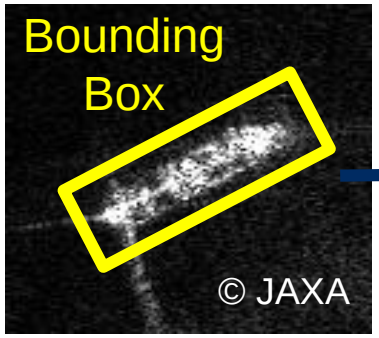
- Automatic Identification System (AIS)
- Optical imagery
- Synthetic Aperture Radar (SAR) imagery




**SAR images are now preferable for ship classification**

# Existing SAR Ship Classification Methods

## 1. Hand-crafted Features (HCF)-based



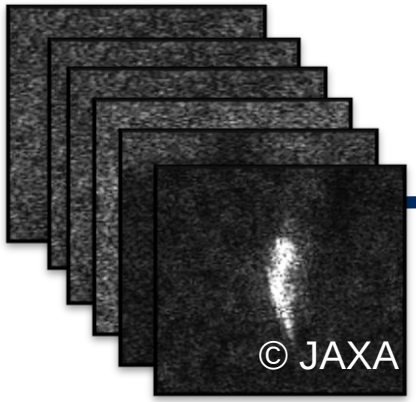

Feature* extractor → Classifier (SVM) → Class

*Length, Area, Intensity, … etc.

**Pros**
- Intuitive features

**Cons**
- Requires expert knowledge of ships

## 2. Convolutional Neural Network (CNN)-based




CNN → Class

**Pros**
- Does not require expert knowledge

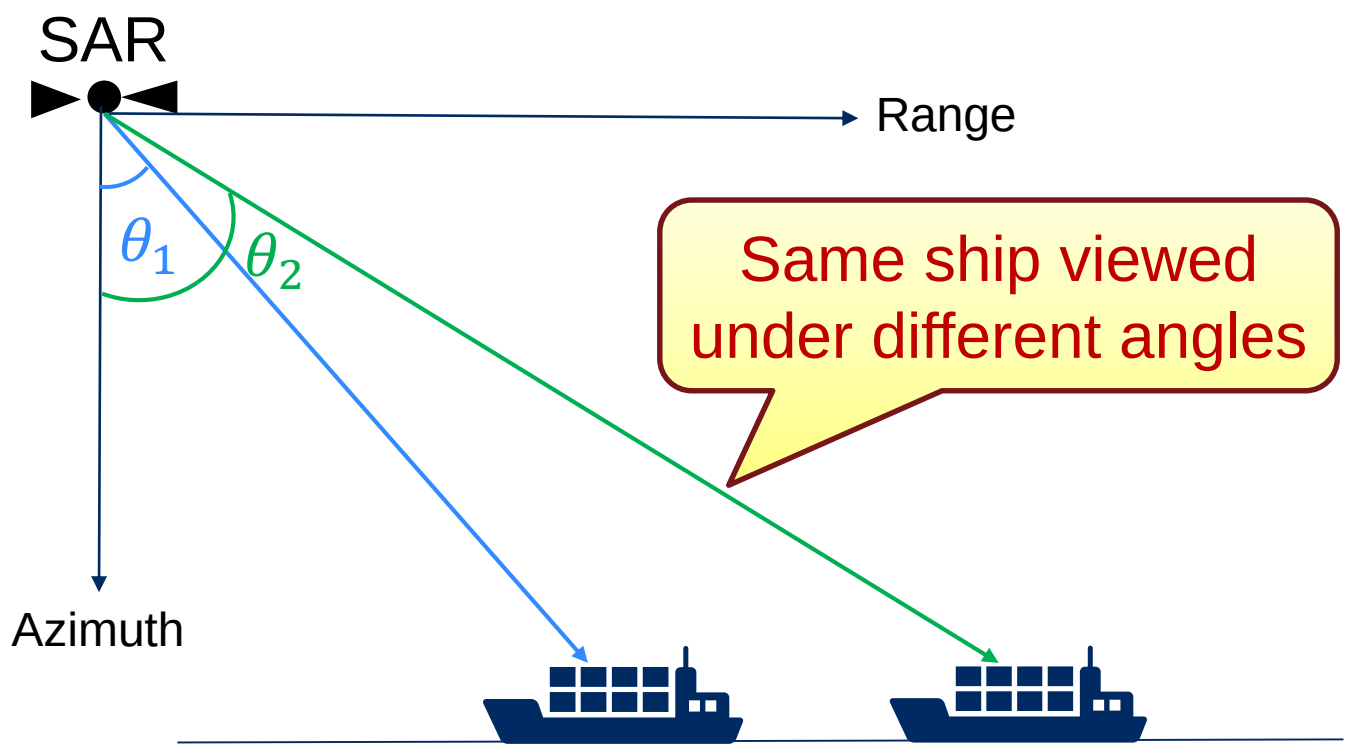
**Cons**
- Requires huge training data

**These methods classify a ship based on its appearance**

# Problem

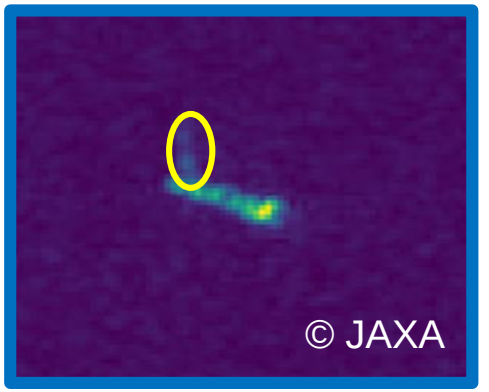
## Appearance of a ship varies with SAR geometry

Example:

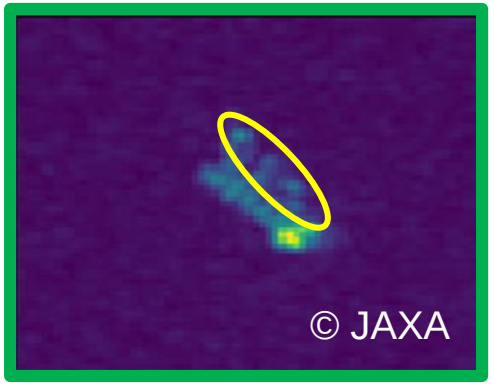



Same ship viewed under different angles

$\theta_1 = 30^\circ$




$\theta_2 = 40^\circ$



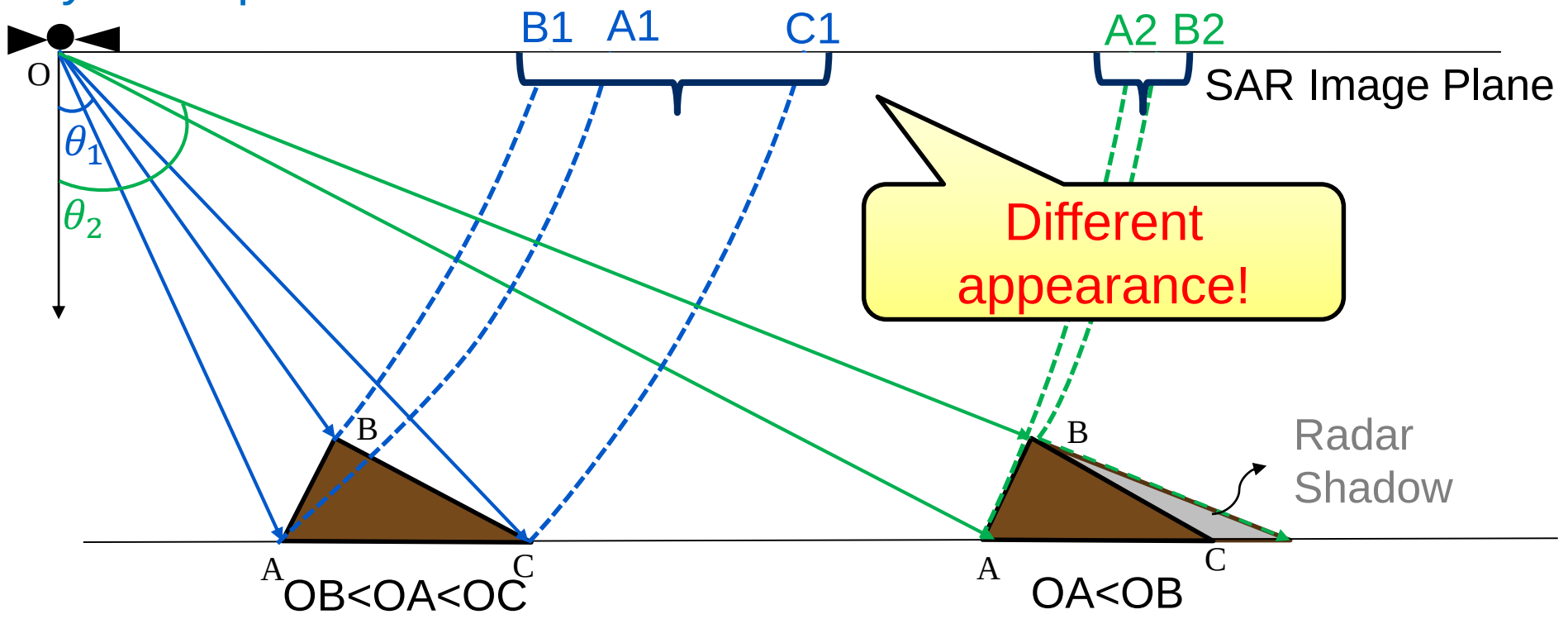

**Appearance information is not sufficient to achieve robust classification**

# Relationship between Appearance and SAR geometry

*Incident angle (θ)* is a key SAR geometry information which directly affects the appearance of a ship

$\theta$ changes the imaging order of the major scattering points

Toy Example:

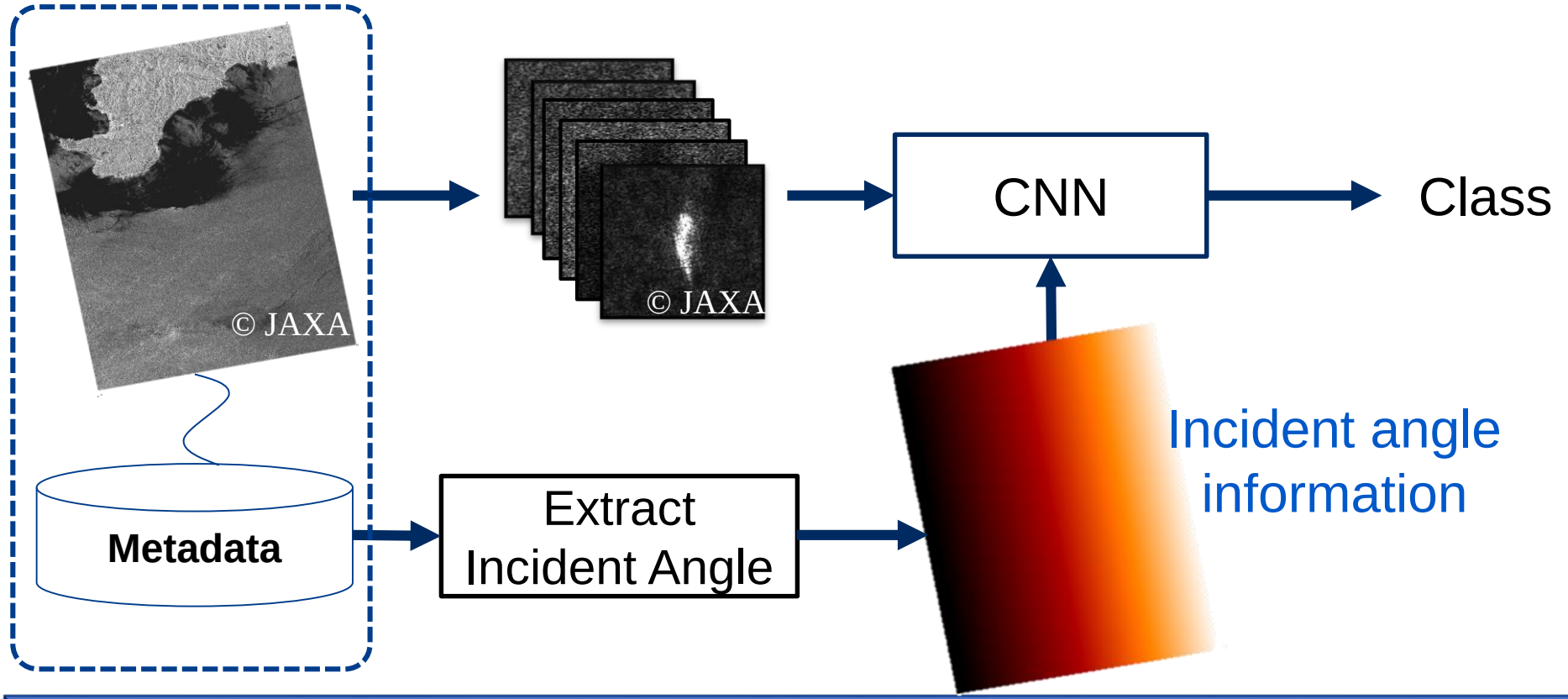



Incident angle indicates how appearance of a ship varies

# Proposed Solution

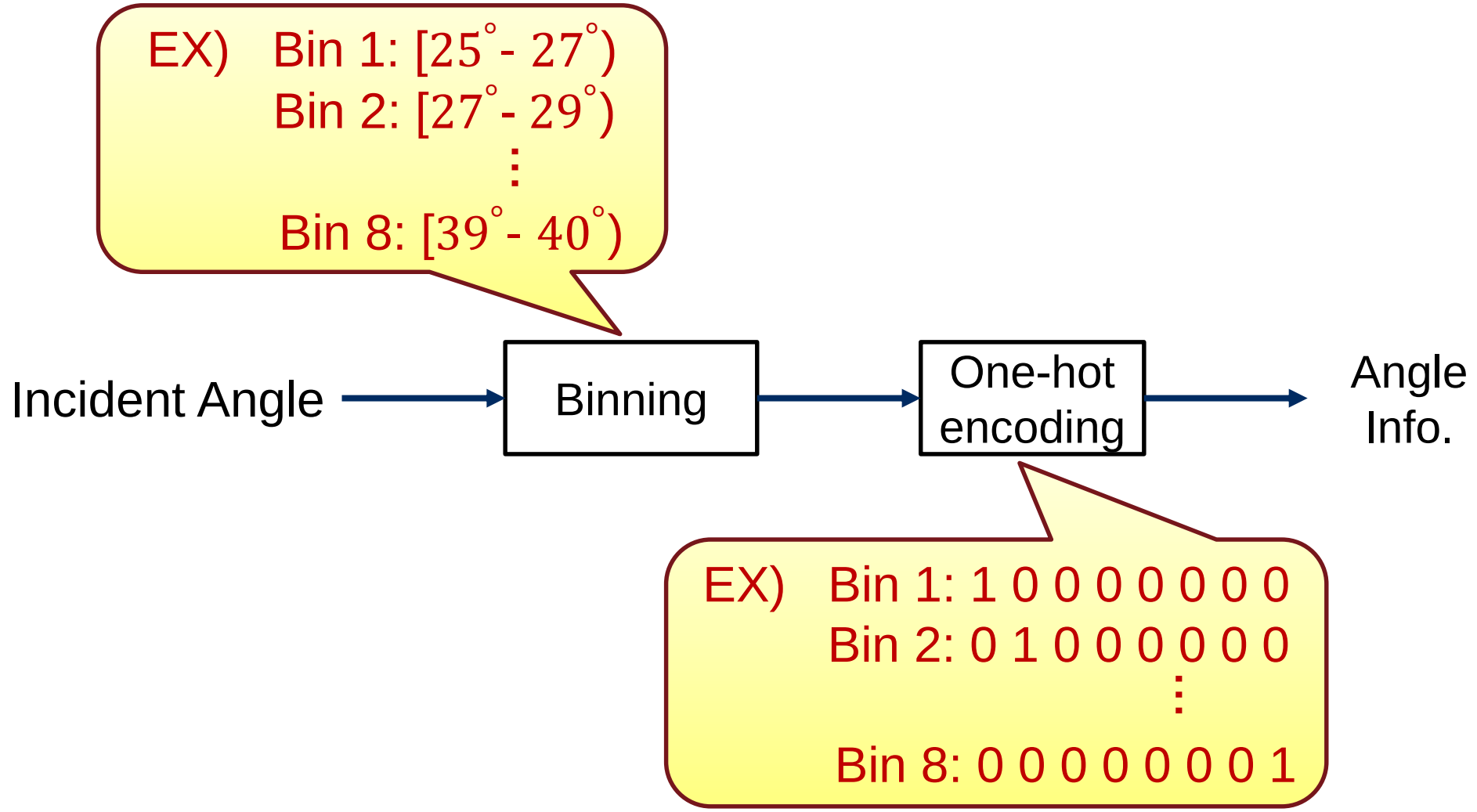
**Use incident angle as an additional information in a CNN**

Helps the CNN to combine feature information and geometry information in feature space



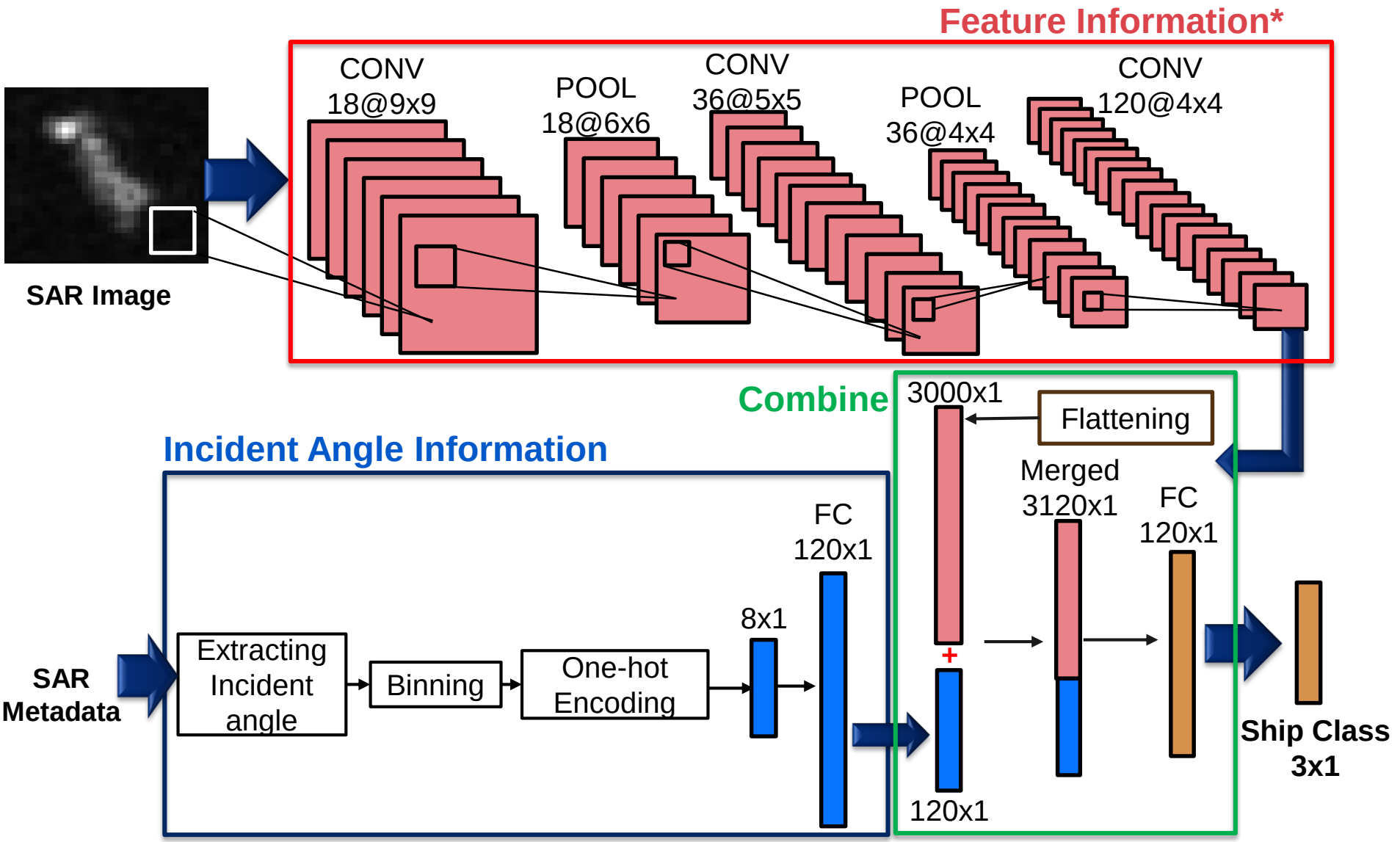

**CNN can follow SAR geometry changes**

# Representation of Incident Angle Information




Binning and one-hot encoding reduces the real-valued angles to discrete labels which accelerates CNN training

# Network of Proposed Method




* Bentes, C., Velotto, D. and Tings, B., "Ship classification in terrasar-x images with convolutional neural networks," IEEE Journal of Oceanic Engineering 43(1), 258-266 (2018)

# Evaluation

Test 1: Classification performance

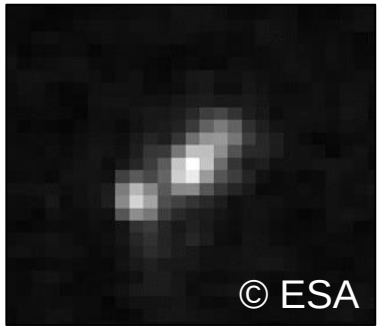
- Accuracy
- F-measure

Test 2: Dependence on training data size

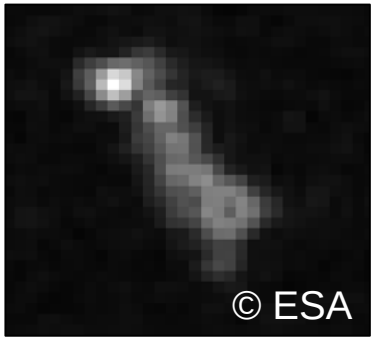
# Experimental Set-up

## Dataset: OpenSARShip*

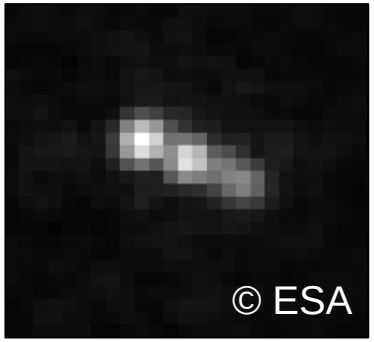
Container


Bulk-carrier




Tanker




## Specifications

| | |
|---|---|
| Satellite | Sentinel-1 |
| Resolution | 20m |
| Polarization | HH |
| Image size | 128x128 |
| No. images | 200/class |
| Ground truth | AIS + Marine Traffic |

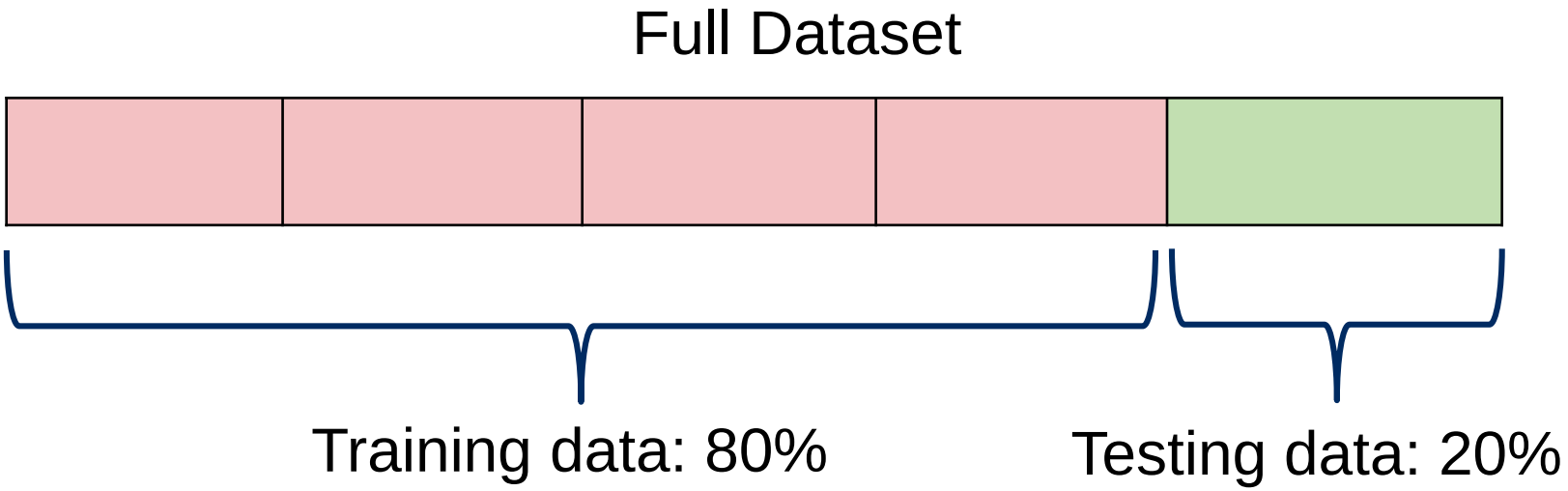
## Conventional Methods

| | |
|---|---|
| HCF | 10 Features + SVM |
| CNN | w/o incident angle |

*Huang, L et al., "OpenSARShip: A dataset dedicated to Sentinel-1 ship interpretation," IEEE Journal of Sel. Top. in App. Earth Obs. and Rem. Sen. 11(1), 195-208 (2018).

# Network Training and Testing

- Five-fold cross-validation

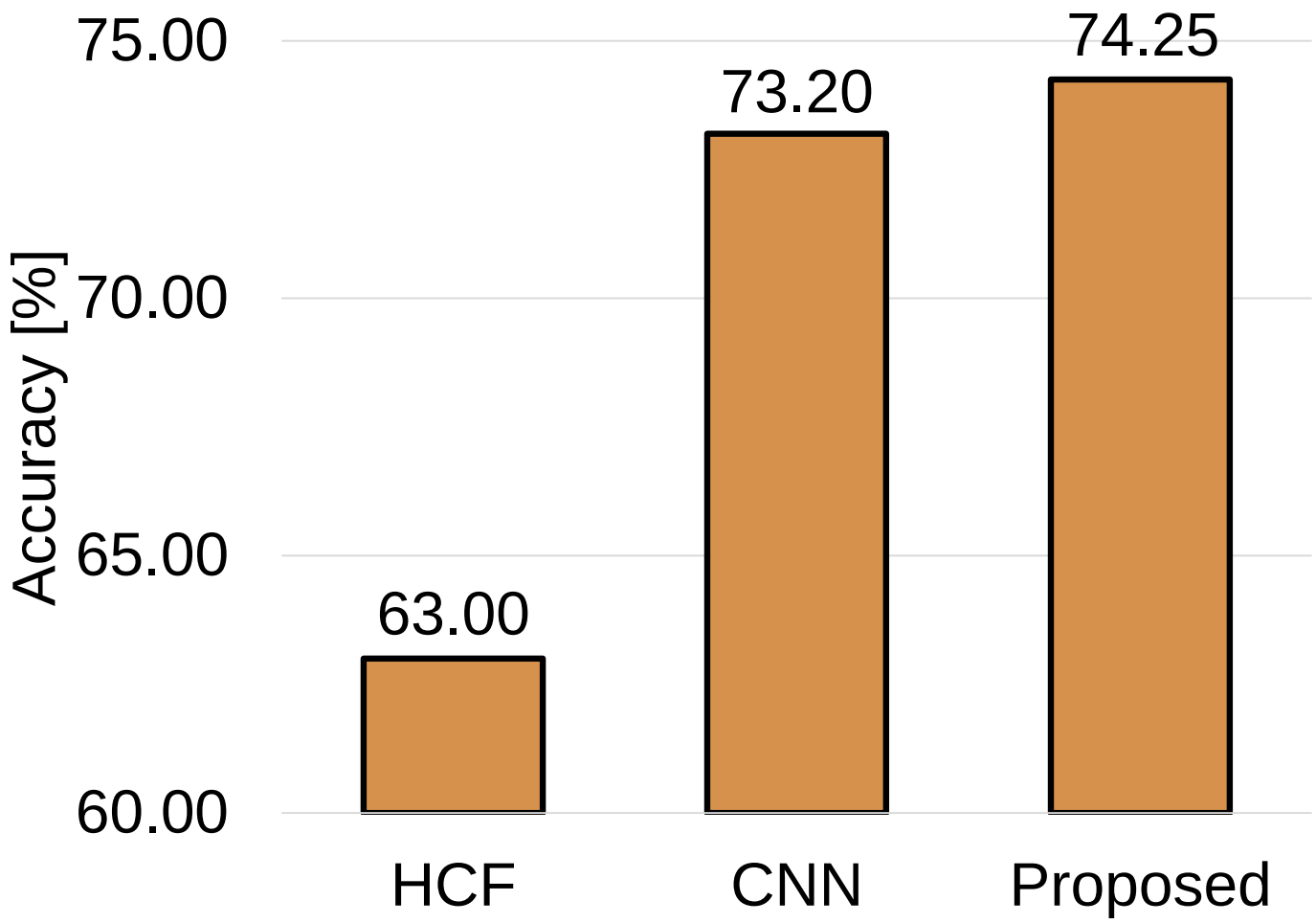



- Training data split into: 80%, 66%, 50%, 25%, 20% of full dataset to evaluate the effect of training data size

- 10 initial random seeds

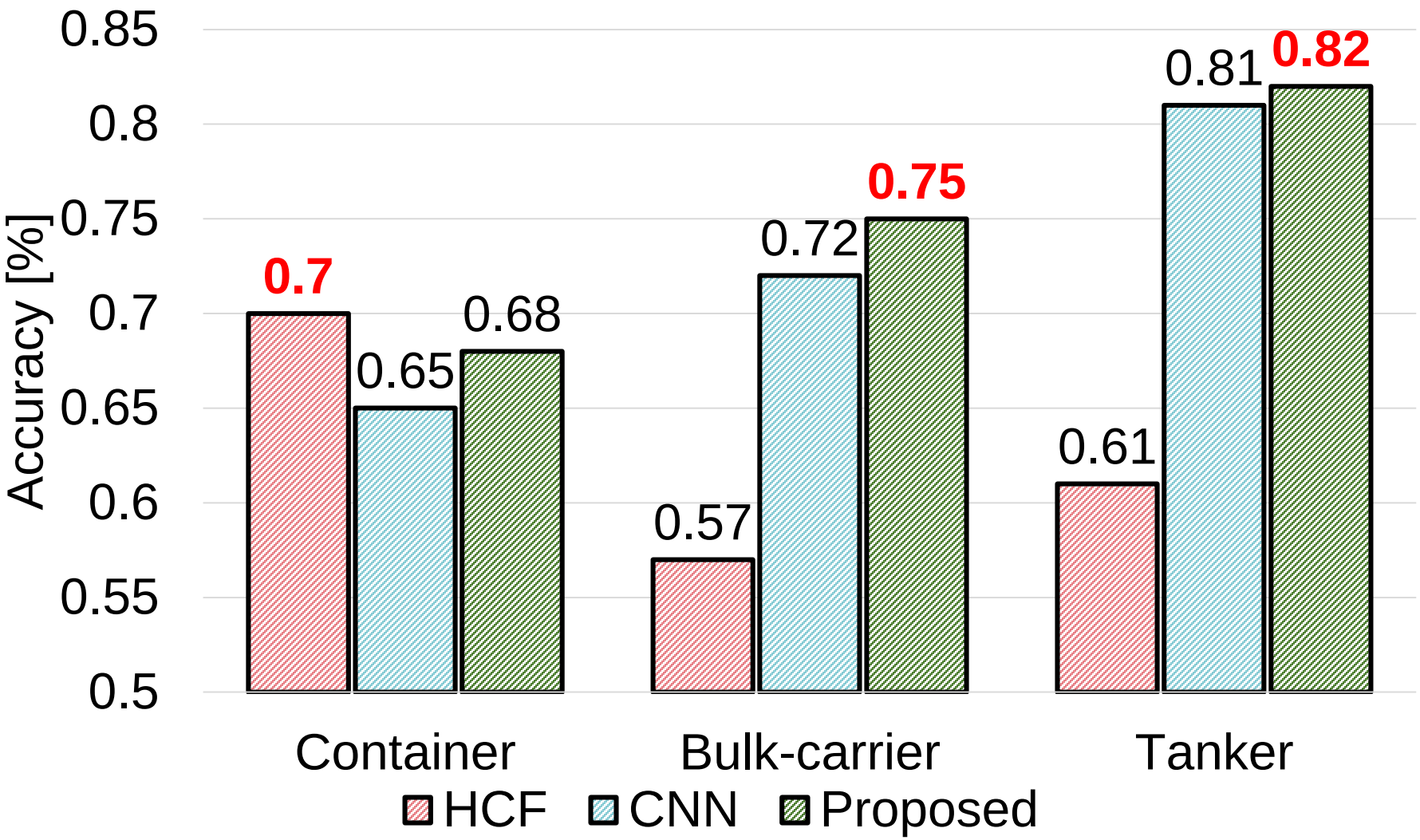
# Result 1: Classification Accuracy (Overall)

Results are averaged over 10 initial seed values



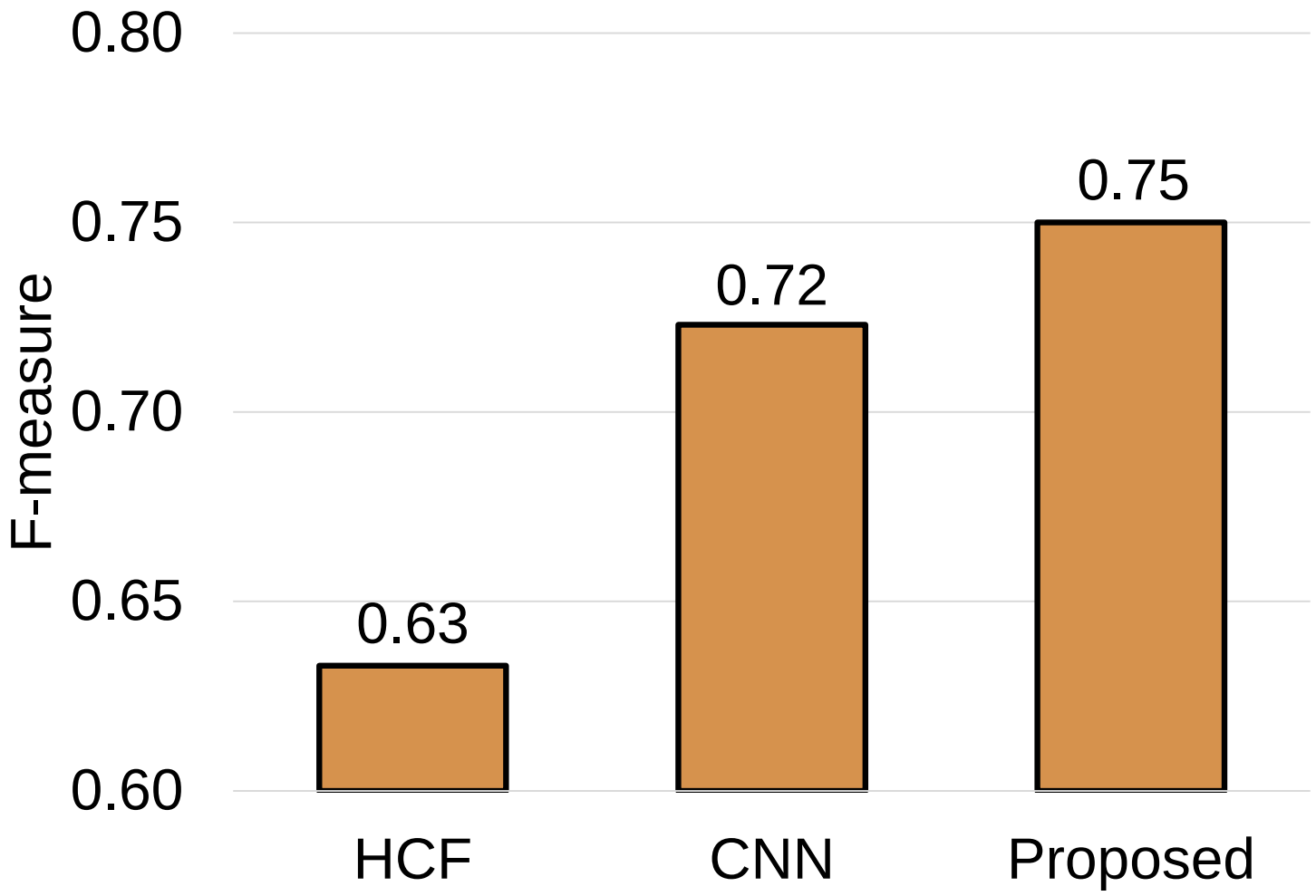

**Proposed method outperforms the conventional methods**

# Result 2: Classification Accuracy (Each class)



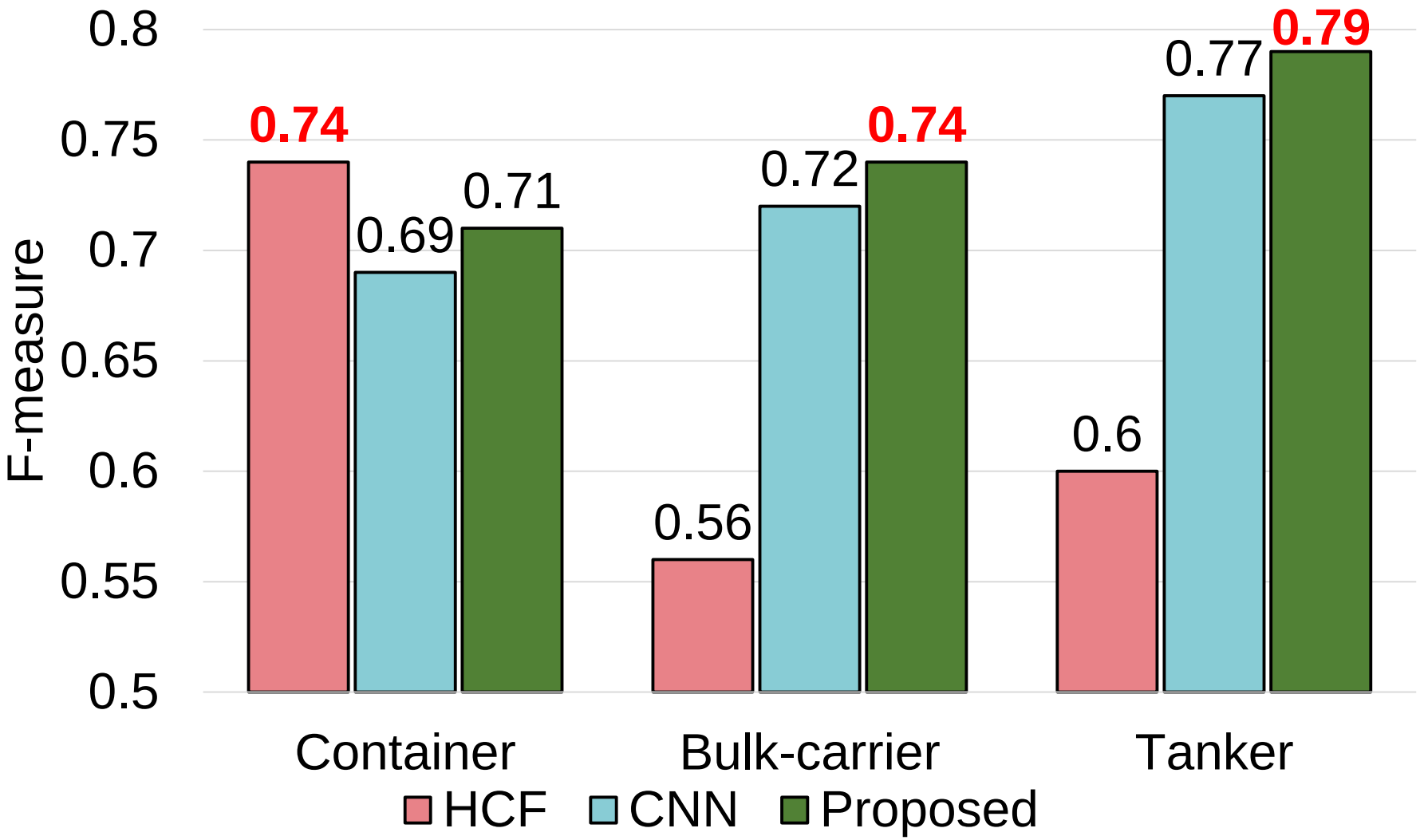

Accuracy of bulk-carrier and tanker has improved

# Result 3: F-measure (Overall)



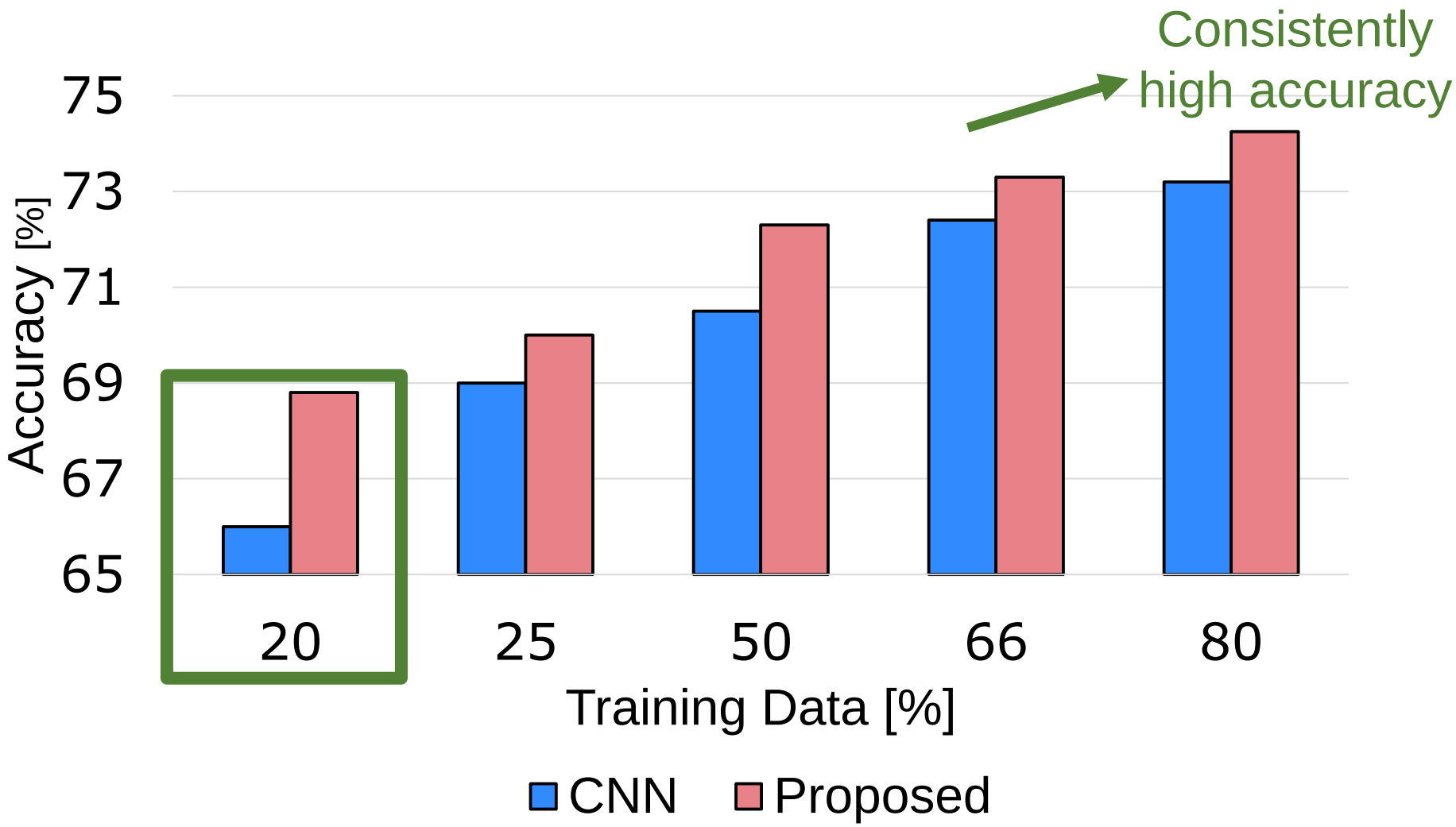

Proposed method achieves the best overall f-measure

# Result 4: F-measure (Each class)




Proposed method outperforms in bulk-carrier and tanker

# Result 5: Effect of Training Data Size




Proposed method requires less training data for high accuracy

# Conclusion

- A CNN-based ship classification method incorporating SAR geometry information is proposed
- The proposed method uses incident angle information to separate feature information and geometry information
- The proposed method outperforms the CNN without incident angle information by **1.05%** and HCF method by **11.25%**
- The proposed method achieves best f-measure for bulk-carrier and tanker but fails in container
- The proposed method requires **25% less** training data as compared to the conventional CNN method

# Thank you for attention!

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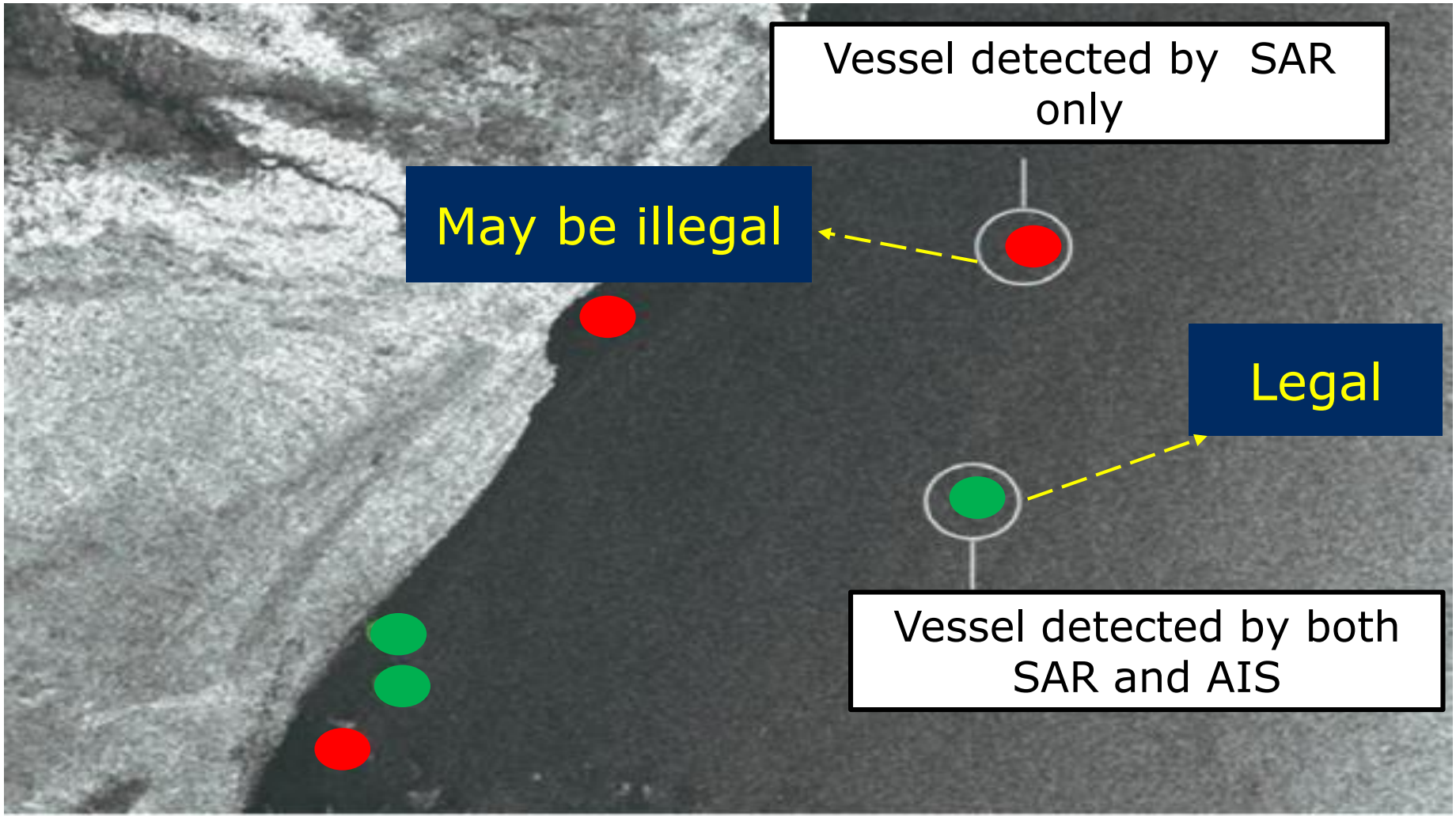
Every day, our innovative solutions for society contribute to greater safety, security, efficiency and equality, and enable people to live brighter lives.

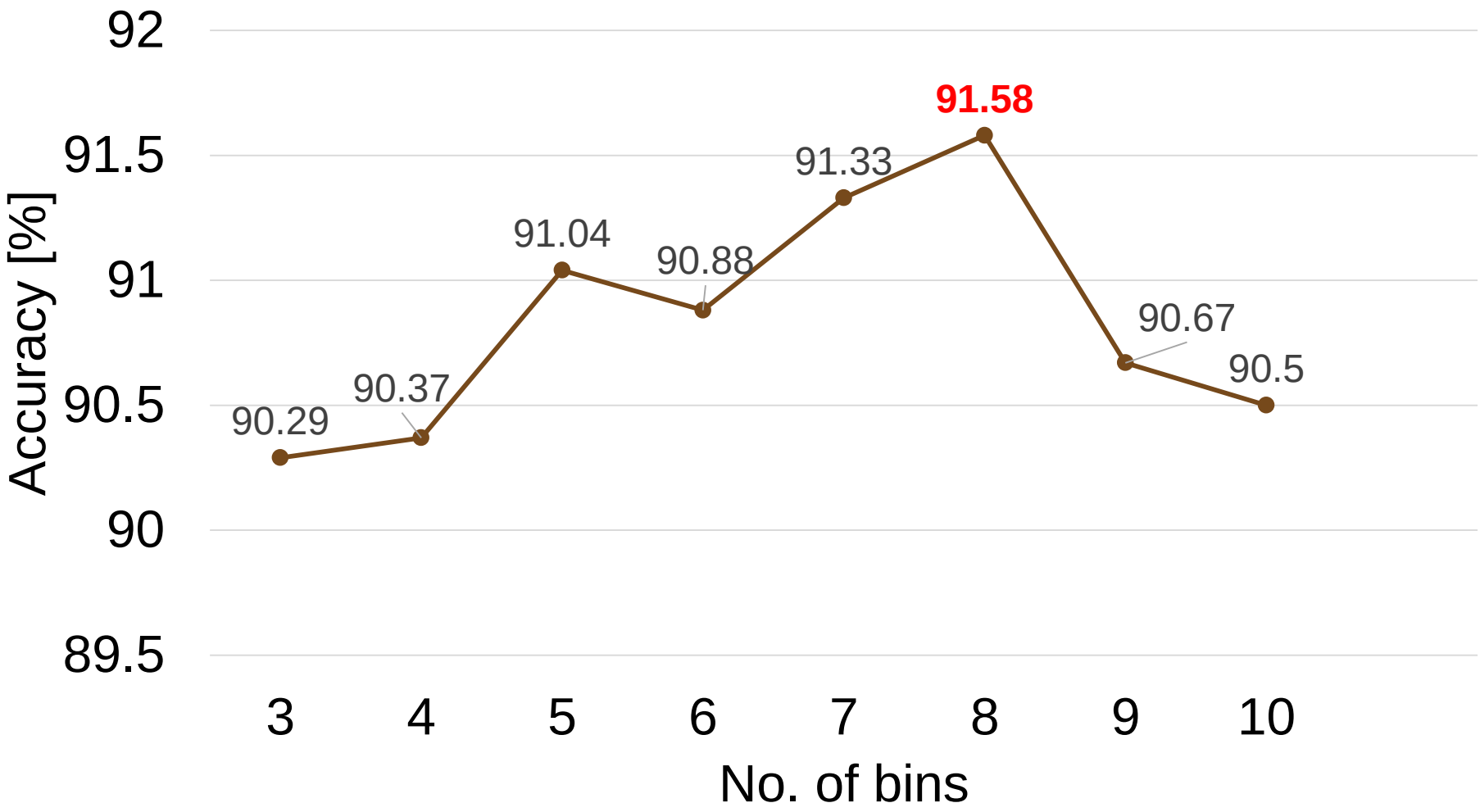
# Appendix

# A1: AIS + Synthetic Aperture Radar (SAR)




A SAR image can be used in conjunction with AIS data to detect illegal vessels in ocean

# A2: Effect of Number of Incident Angle Bins




Eight bins provides the best validation accuracy

# A3: Hand-crafted Features*

| Feature | Formula |
|---|---|
| Length | $L$ |
| Width | $W$ |
| Perimeter | $2 \times (L + W)$ |
| Area | $L \times W$ |
| Shape Complexity | $P/4\pi A$ P: Perimeter |
| Compactness | $P/2\pi L$ |
| Elongatedness | $L/W$ |
| Aspect Ratio | $W/L$ |
| Centroid X | $\frac{M_{10}}{M_{00}}$ $M_{ij}$: Image Moment |
| Centroid Y | $\frac{M_{01}}{M_{00}}$ $M_{ij}$: Image Moment |

*Lang, H., Zhang, J., Zhang, X. and Meng, J., "Ship classification in SAR image by joint feature and classifier selection," IEEE Geoscience and Remote Sensing Letters 13(2), 212-216 (2016).

# A4: Modification of conventional CNN

- Added *batch-normalization* and *dropout* layer after each convolutional layer to prevent overfitting

| Hyper-parameter | Value |
|---|---|
| Learning rate | 0.0001 |
| No. of epochs | 40 |
| Batch-size | 32 |
| Dropout ratio | 0.2 |
| Momentum | 0.6 |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