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# Optimizing ship detection efficiency in SAR images

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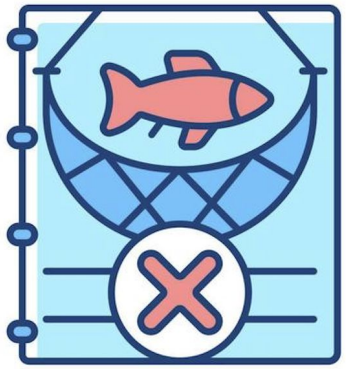
# Problem statement

**Illegal, Unreported and Unregulated (IUU) Fishing**

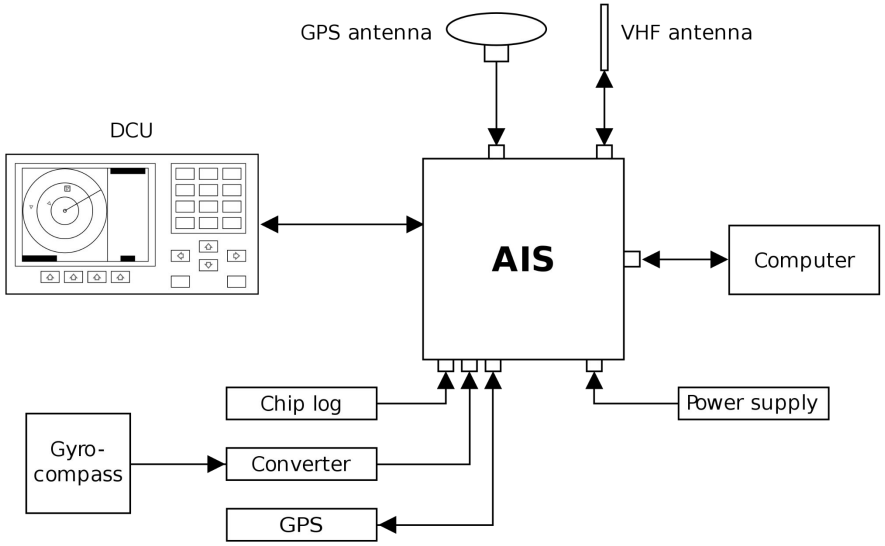
- The resistance of many marine species to *climate change* is compromised by **overfishing**, which increases the vulnerability of marine fisheries' production to ocean warming [1]
- 20% of wild-caught fish is either illegal or unreported
- Economic damages up to $23 billion a year [2]



# Detecting illegal fishing

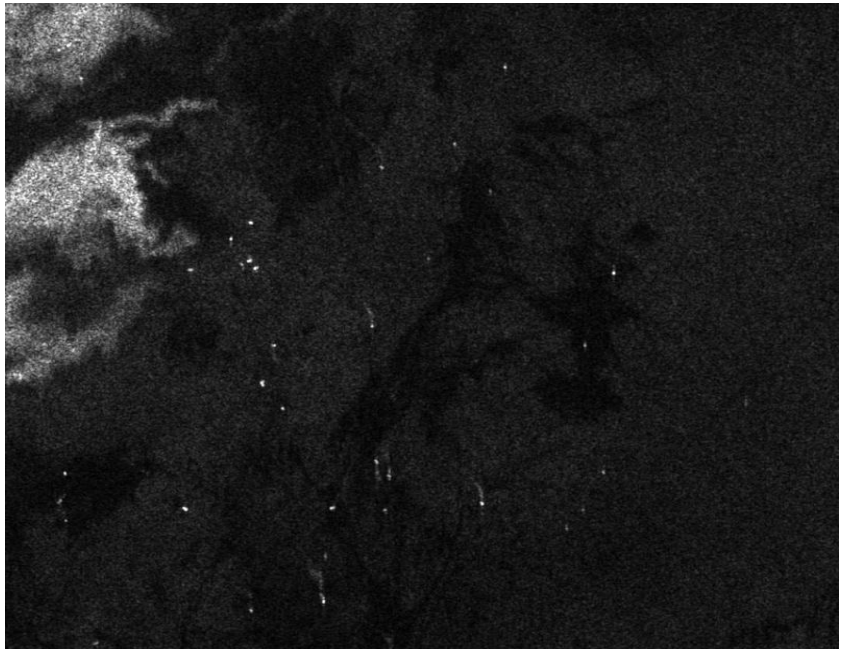
## Automatic Identification Signal [3]

- Signal with information such as position, speed, and general ship data




## Detecting ships in SAR imagery [4]

- Form of radar to create 2D images or 3D reconstructions of objects or landscapes





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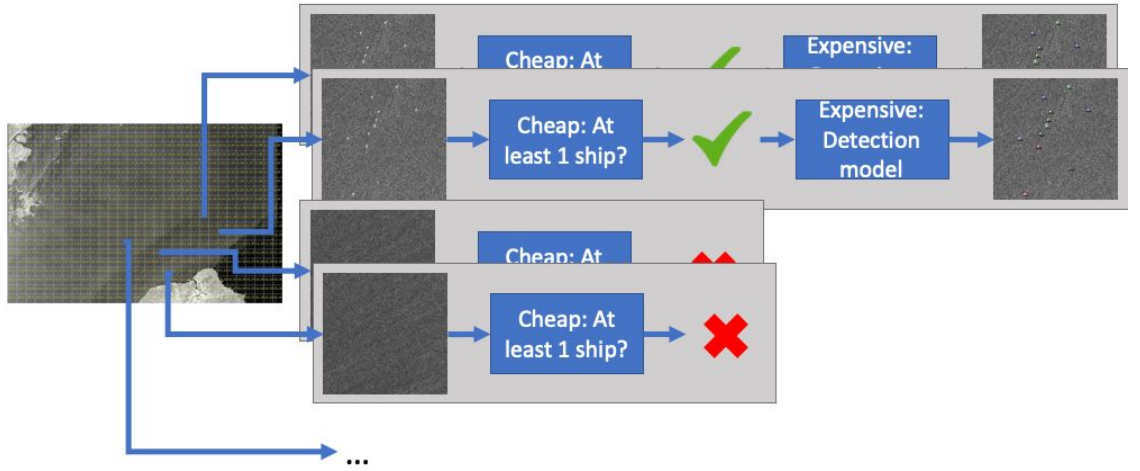
# Goal

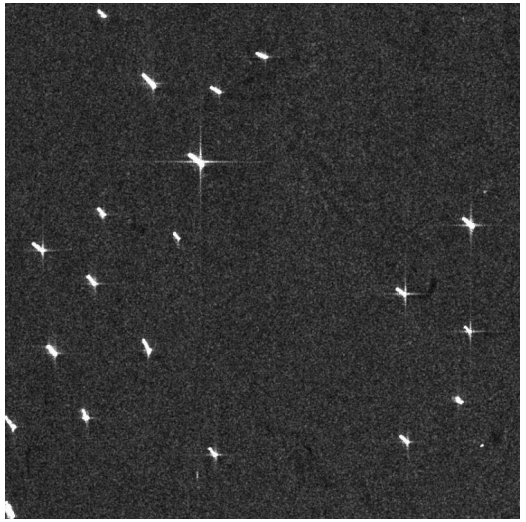
**Trade-off inference time and performance**

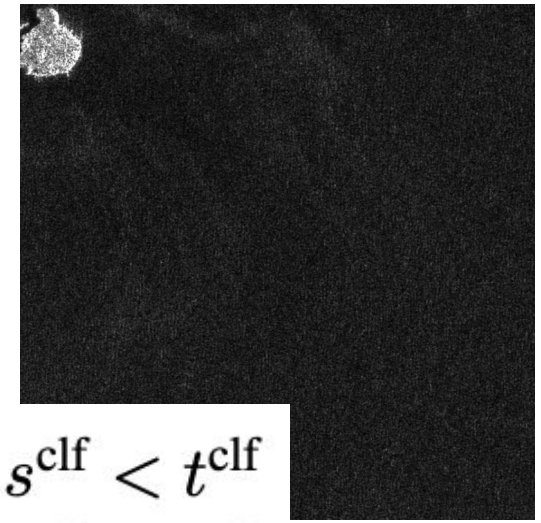
1. **Efficiently determine if at least one ship is present in an SAR sub-image**
   - Fast classification model
   - Statistical algorithm
2. Find the ships
   - Expensive detection model



# Fast classification with small CNN

1. Classify the sub-image (ship/no ship)
   - MobileNetV2 [5] ~ 10 ms
2. Object detection on a sub-image that contains a ship
   - Faster R-CNN [6] ~ 253 ms



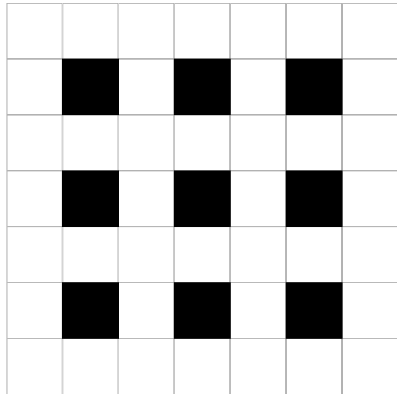


$$f_{\text{clf}}(I, t^{\text{clf}}) = \text{CNN}(I) = s^{\text{clf}} \begin{cases} I \text{ contains a ship} & \text{if } s^{\text{clf}} < t^{\text{clf}} \\ I \text{ does not contain a ship} & \text{if } s^{\text{clf}} > t^{\text{clf}} \end{cases}$$

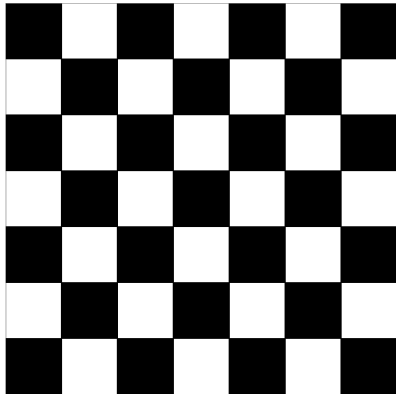
# Correlation in presence of ships between neighboring sub-images

1. Apply object detection on the black sub-images
2. Determine for the white sub-images if detection will be applied based on the presence of ships in neighbouring sub-images

*Alpha*



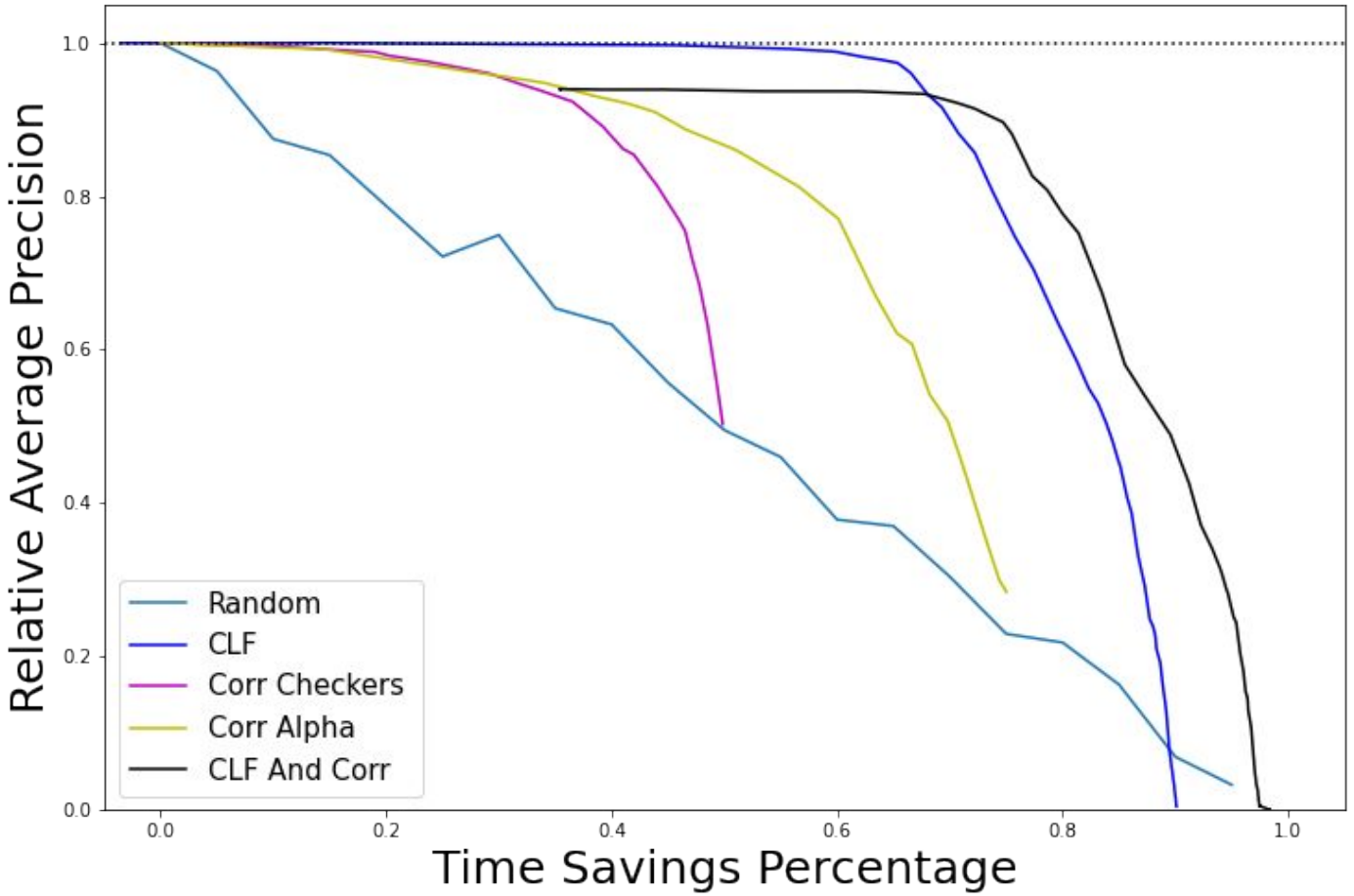
*Checkers*



$$f_{\text{cor}}(I, K, w, t^{\text{cor}}) = \sum_{j \leq K} \sum_{i \in N_j} w_j \mathbb{1}_i = s^{\text{cor}} \begin{cases} I \text{ contains a ship} & \text{if } s^{\text{cor}} > t^{\text{cor}} \\ I \text{ does not contain a ship} & \text{if } s^{\text{cor}} < t^{\text{cor}} \end{cases}$$

- Nj is the set of neighbours that are j tiles away
- wj is the weight given to all neighboring tiles that are j tiles away
- 1i indicates whether neighbor i contains at least one ship or not

# Results: Trade-off inference time vs performance




- LSSSDD dataset [7]
- Performance:
  Classification-optimization
  - Approximates baseline AP to 99.5%
  - In 44% of the baseline time
- Inference time:
  Correlation + Classification-optimization
  - Approximates baseline AP to 92.7%
  - In 25% of the baseline time

# References


1. Christopher M. Free, James T. Thorson, Malin L. Pinsky, Kiva L. Oken, John Wiedenmann, and Olaf P. Jensen. Impacts of historical warming on marine fisheries production. *Science*, 363(6430):979–983, 2019.
2. David J. Agnew, John Pearce, Ganapathiraju Pramod, Tom Peatman, Reg Watson, John R. Beddington, and Tony J. Pitcher. Estimating the worldwide extent of illegal fishing. *PLOS ONE*, 4:1–8, 02 2009.
3. Fábio Manzoni Vieira, François Vincent, Jean-Yves Tourneret, David Bonacci, Marc Spigai, Marie Ansart, and Jacques Richard. Ship detection using sar and ais raw data for maritime surveillance. In *2016 24th European Signal Processing Conference (EUSIPCO)*, pages 2081– 2085, 2016.
4. Alberto Moreira, Pau Prats-Iraola, Marwan Younis, Gerhard Krieger, Irena Hajnsek, and Konstantinos P. Papathanassiou. A tutorial on synthetic aperture radar. *IEEE Geoscience and Remote Sensing Magazine*, 1(1):6–43, 2013.
5. Mark Sandler, Andrew G. Howard, Menglong Zhu, Andrey Zhmoginov, and Liang-Chieh Chen. Mobilenetv2: Inverted residuals and linear bottlenecks. In *2018 IEEE Conference on Computer Vision and Pattern Recognition, CVPR 2018, Salt Lake City, UT, USA, June 18-22, 2018*, pages 4510–4520. Computer Vision Foundation / IEEE Computer Society, 2018.
6. Shaoqing Ren, Kaiming He, Ross B. Girshick, and Jian Sun. Faster R-CNN: towards real- time object detection with region proposal networks. In Corinna Cortes, Neil D. Lawrence, Daniel D. Lee, Masashi Sugiyama, and Roman Garnett, editors, *Advances in Neural Information Processing Systems 28: Annual Conference on Neural Information Processing Systems 2015, December 7-12, 2015, Montreal, Quebec, Canada*, pages 91–99, 2015.
7. Tianwen Zhang, Xiaoling Zhang, Xiao Ke, Xu Zhan, Jun Shi, Shunjun Wei, Dece Pan, Jianwei Li, Hao Su, Yue Zhou, and Durga Kumar. Ls-ssdd-v1.0: A deep learning dataset dedicated to small ship detection from large-scale sentinel-1 sar images. *Remote Sensing*, 12(18), 2020.