USING COMPUTER VISION TECHNIQUES ON ISAR IMAGES TO IMPROVE TRACKING AND CHARACTERIZATION OF NEAR SPACE OBJECTS

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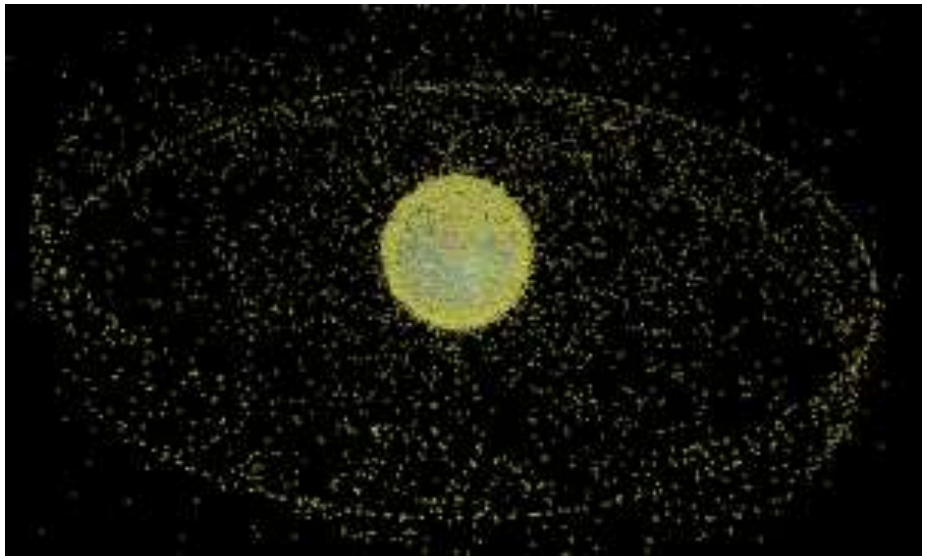
About Near Space Objects

- Near Space Objects in orbit have been increasing rapidly
  - This trend is expected to continue or even increase in near future
  - Besides satellites, it may include debris and spent rocket bodies
- Risk of interference between them increases as well
  - Instrumentation, orbital path

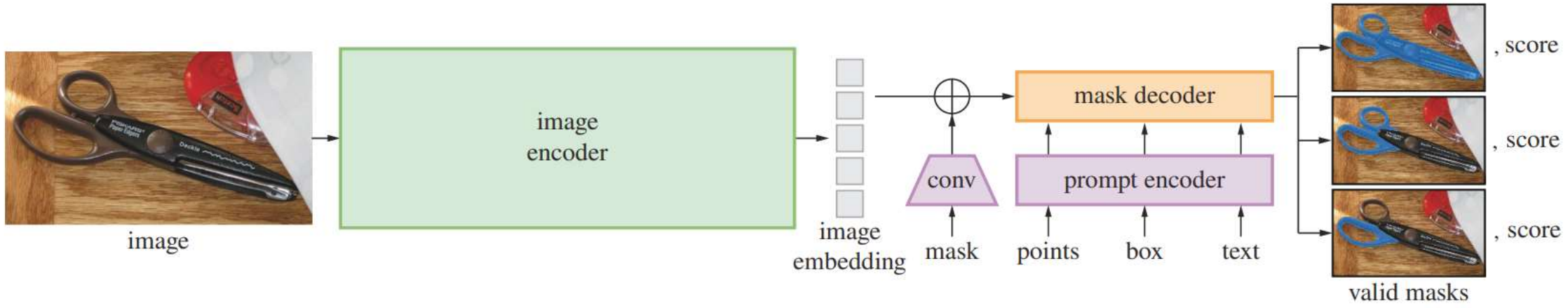


Objectives

- ISAR data information extraction
- Evaluate state of the art methodologies for image identification, object detection and/or segmentation
  - Facebook AI Research group (FAIR), Segment Anything (SAM), Grounded SAM, Detectron2:PointRend
- Assess their applicability on ISAR images
- Identify potential features of interest in ISAR images
  - That may be fused with other optical imaging modalities

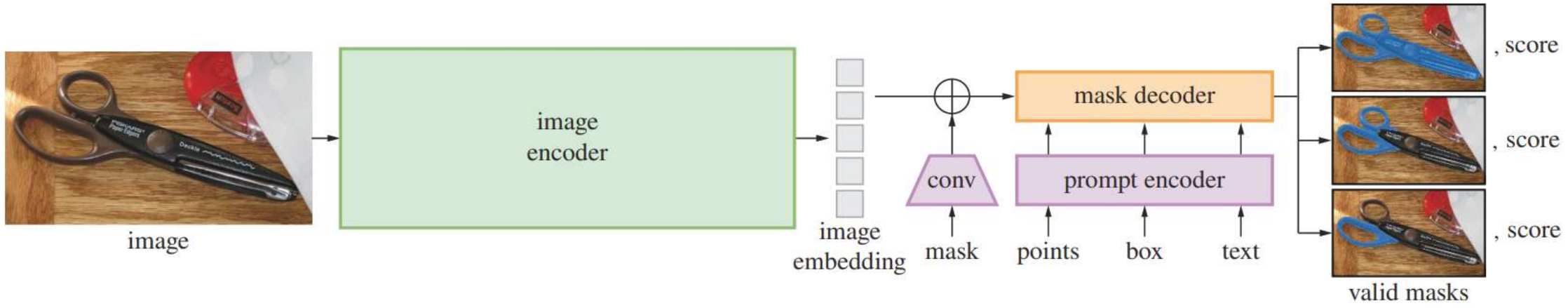
Segmentation Algorithms Overview

- Segment Anything (SAM), 2023
- Image encoder
- Prompt encoder
- Mask decoder



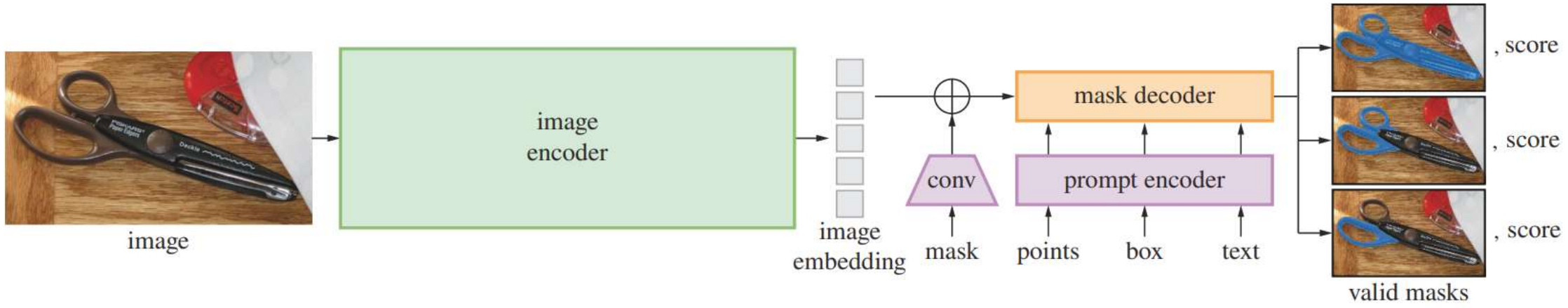
Segmentation Algorithms Overview

- Segment Anything (SAM), 2023
- Image encoder
  - MAE pre-trained Vision Transformer (ViT) minimally adapted to process high resolution inputs



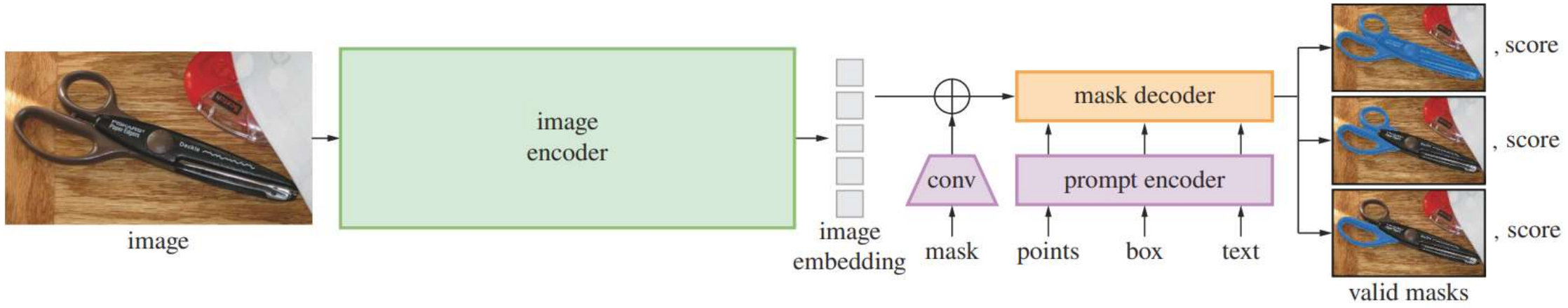
Segmentation Algorithms Overview

- Segment Anything (SAM), 2023
- Prompt encoder
  - Points and boxes by positional encodings summed with learned embeddings for each prompt type
  - Can be automated (sampled points)



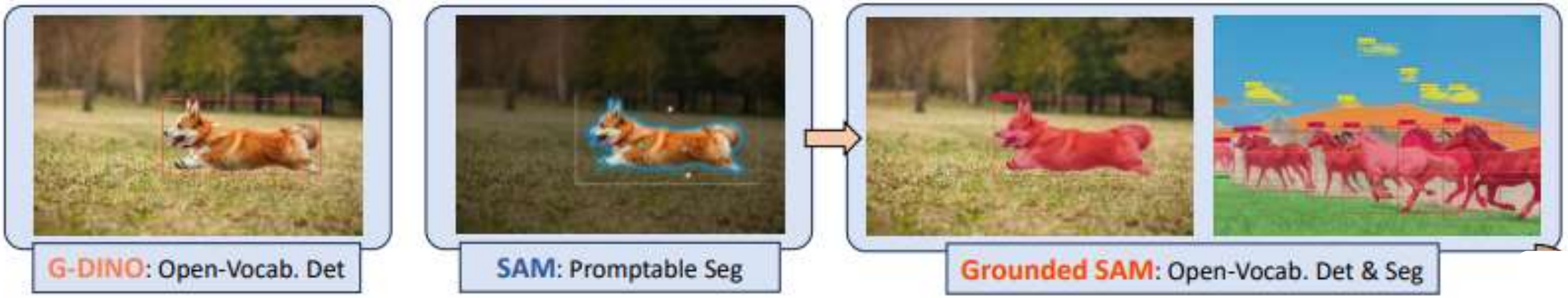
Segmentation Algorithms Overview

- Segment Anything (SAM), 2023
- Mask encoder
  - Maps image and prompt embeddings, and output token to a mask



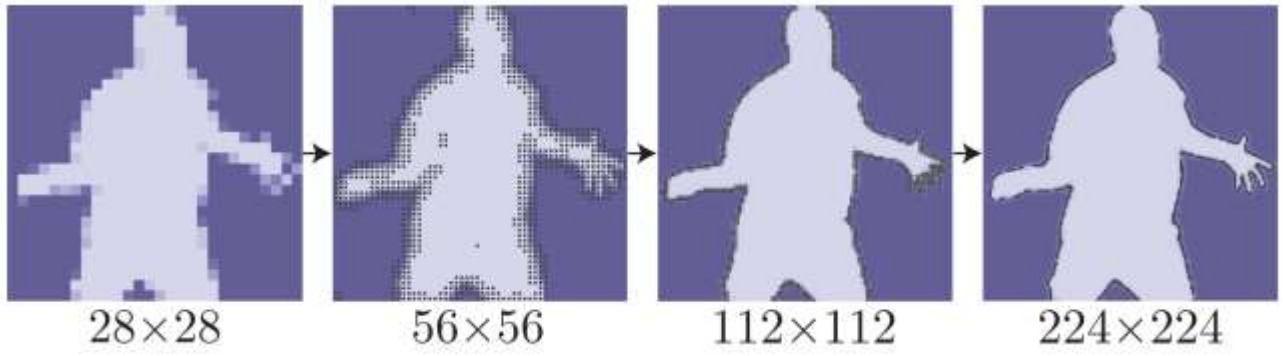
Segmentation Algorithms Overview

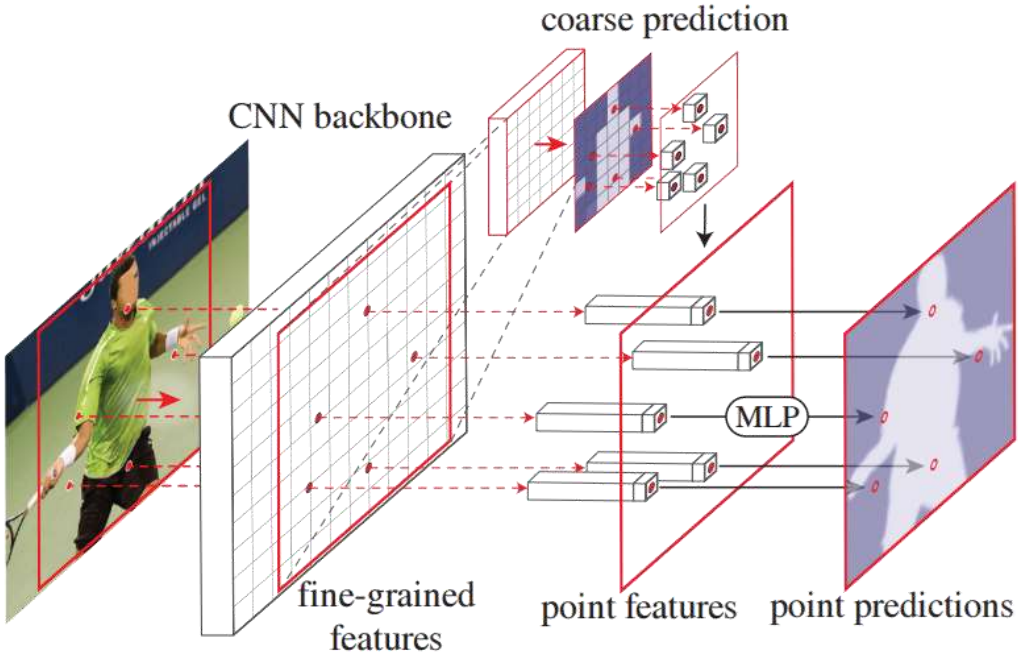
- Grounded SAM, 2024
- Enables detection and segmentation of any region
  - Based on arbitrary text imputs
  - Opens a door to connect various computer vision models in a chain



Segmentation Algorithms Overview

- Detectron2:PointRend, 2019
- Point-based segmentation predictions at adaptively selected locations
  - Based on an iterative subdivision algorithm



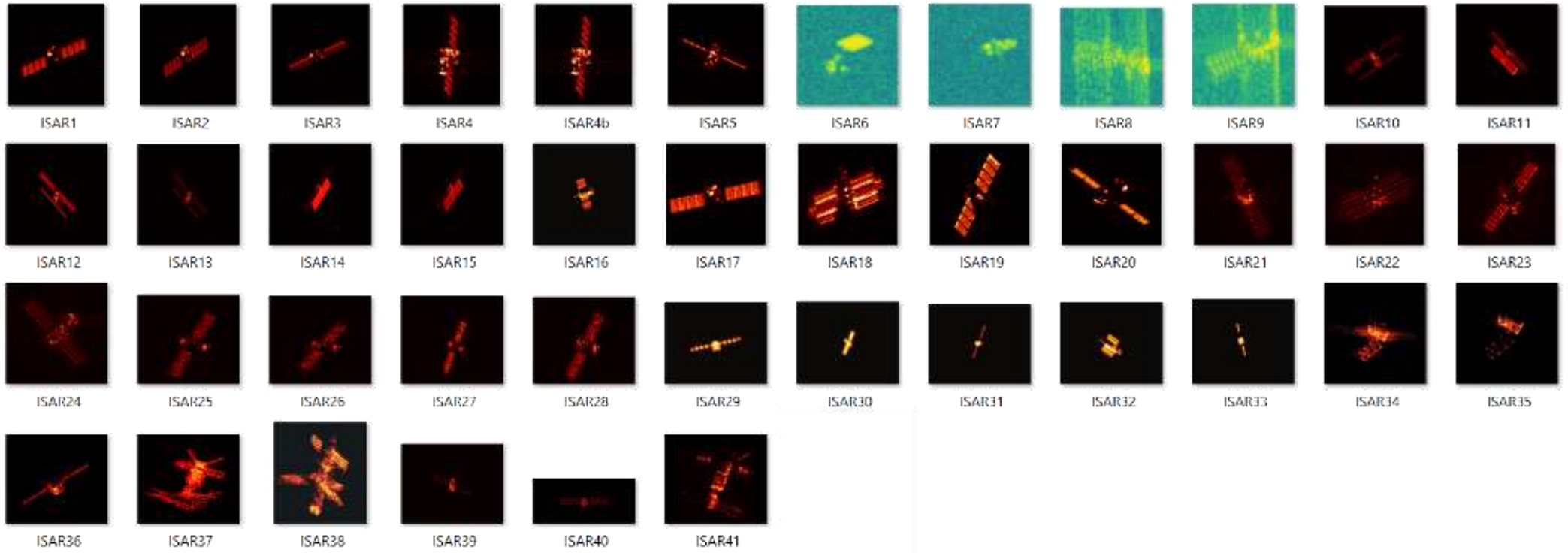


Experiments

- Limited amount of ISAR data from space objects
  - Most activity for SDA (classified)
- No annotated masks
- Rely on available optical satellite models
- Our results provide a proof-of-concept qualitative evaluation

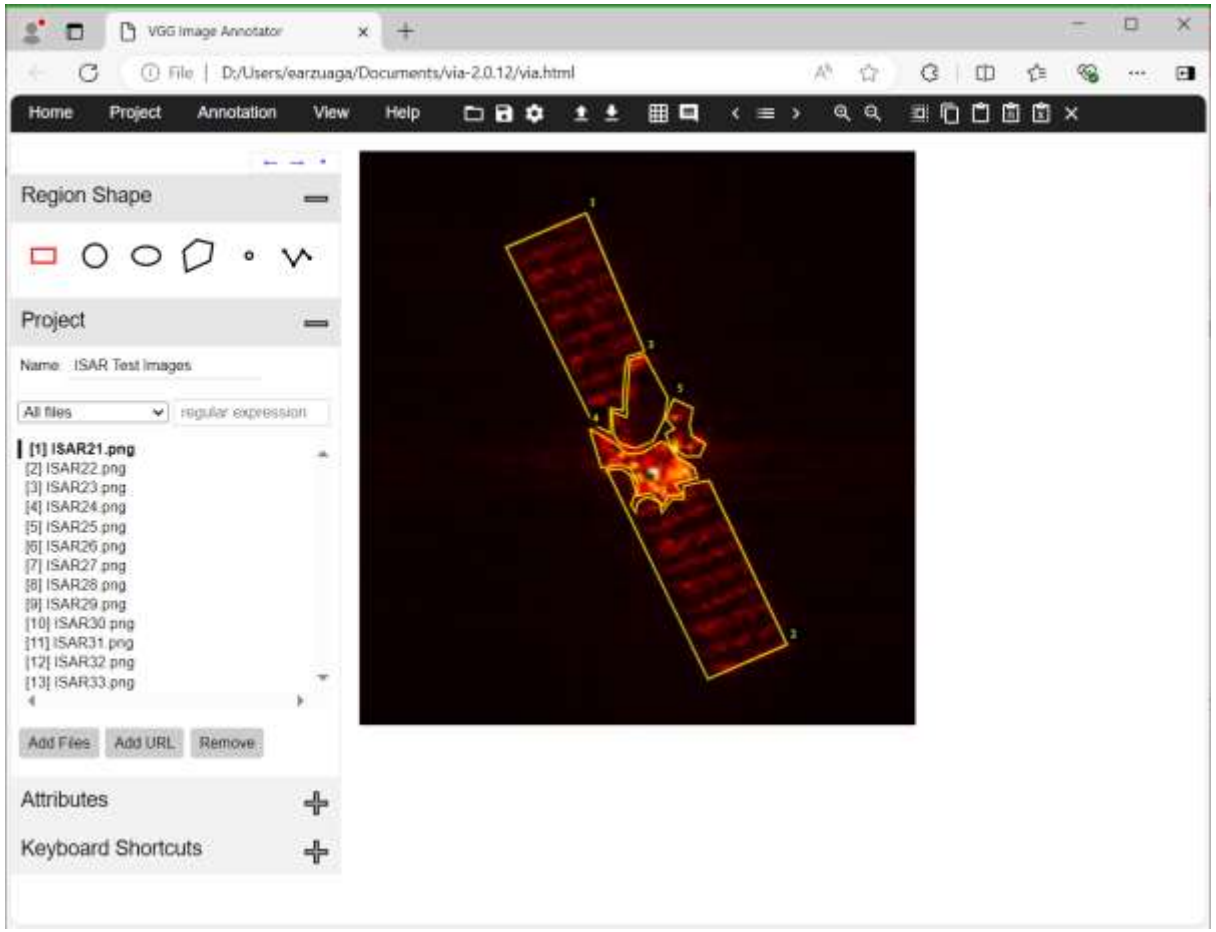
Experiments

- Training Dataset
- Categories: antenna, sensor, body, solar panel



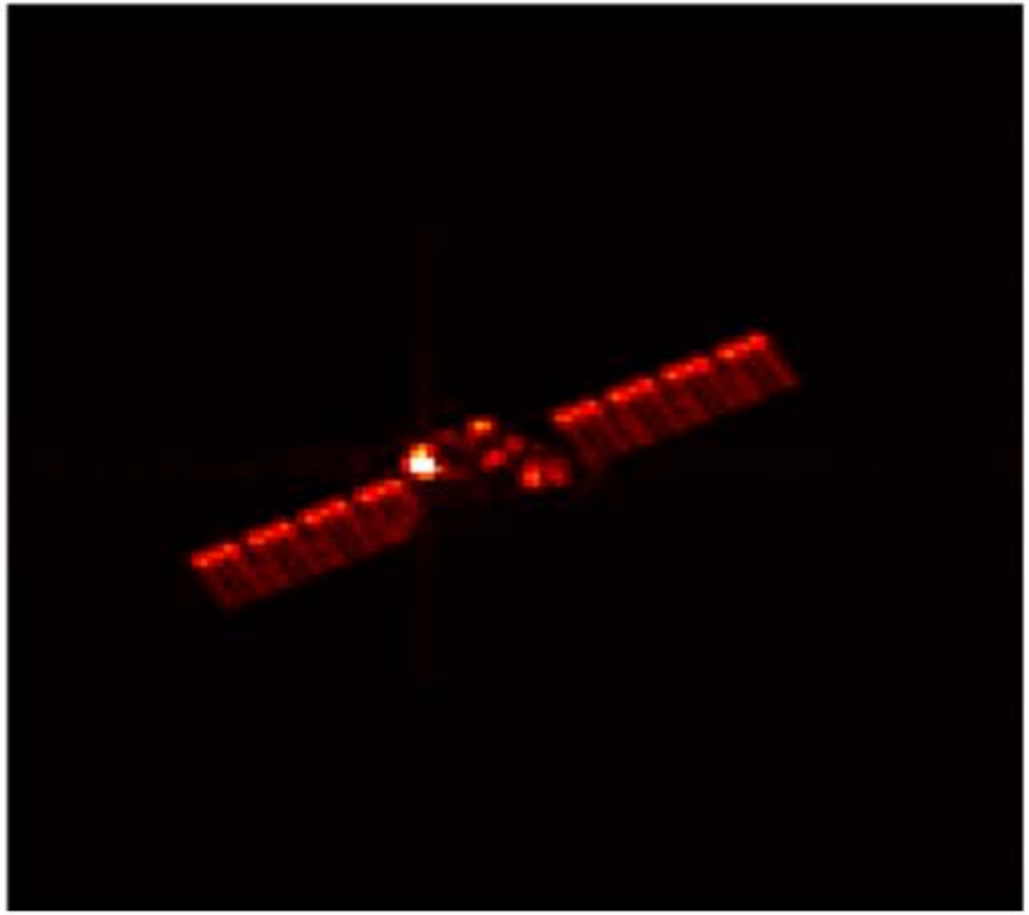
Experiments

- Data annotation tool
- VGG Image Annotator (VIA)
  - University of Oxford (UK)
  - Open source
  - Written in HTML, JavaScript & CSS
  - Runs in browser (local file)



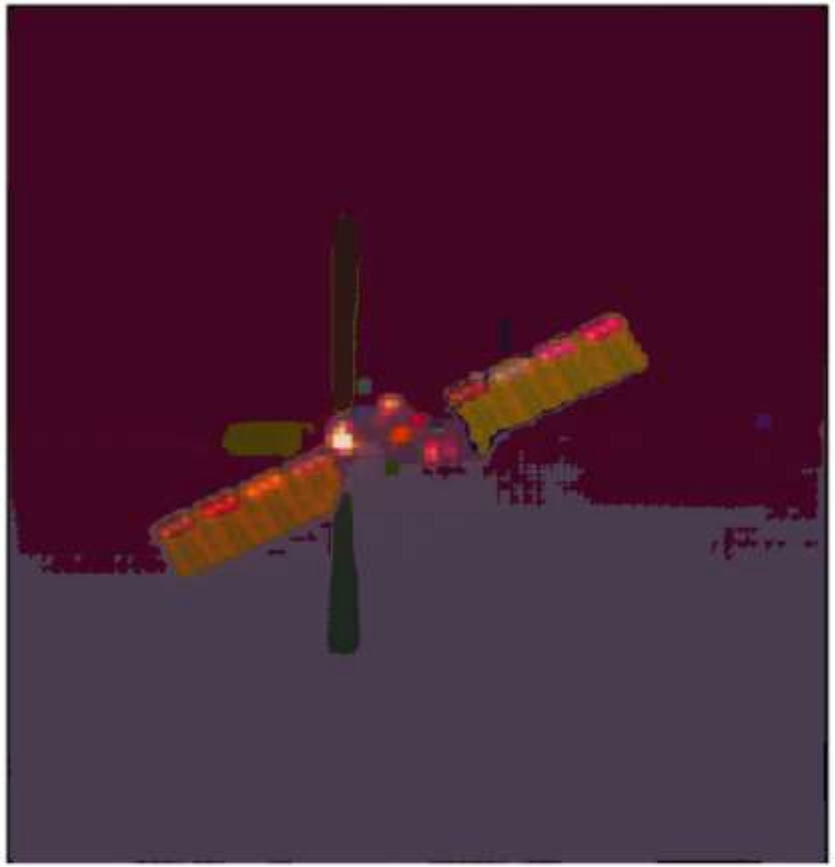
Experiments

- Train and Inference ISAR data samples



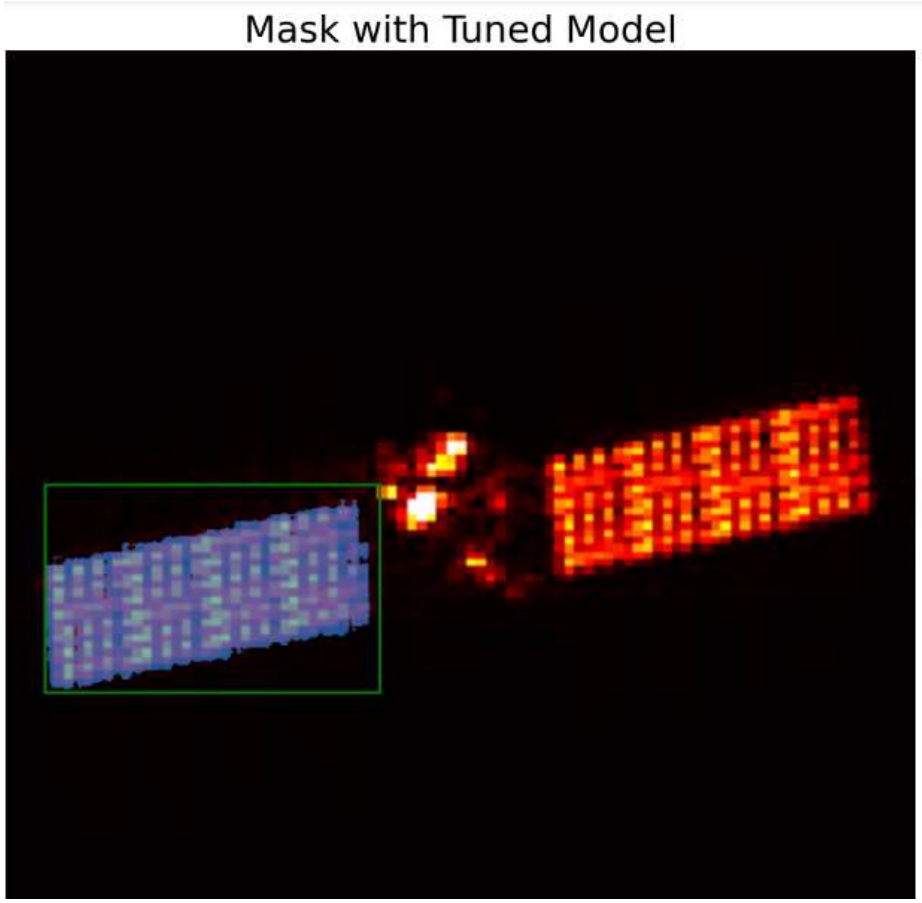
Experiments

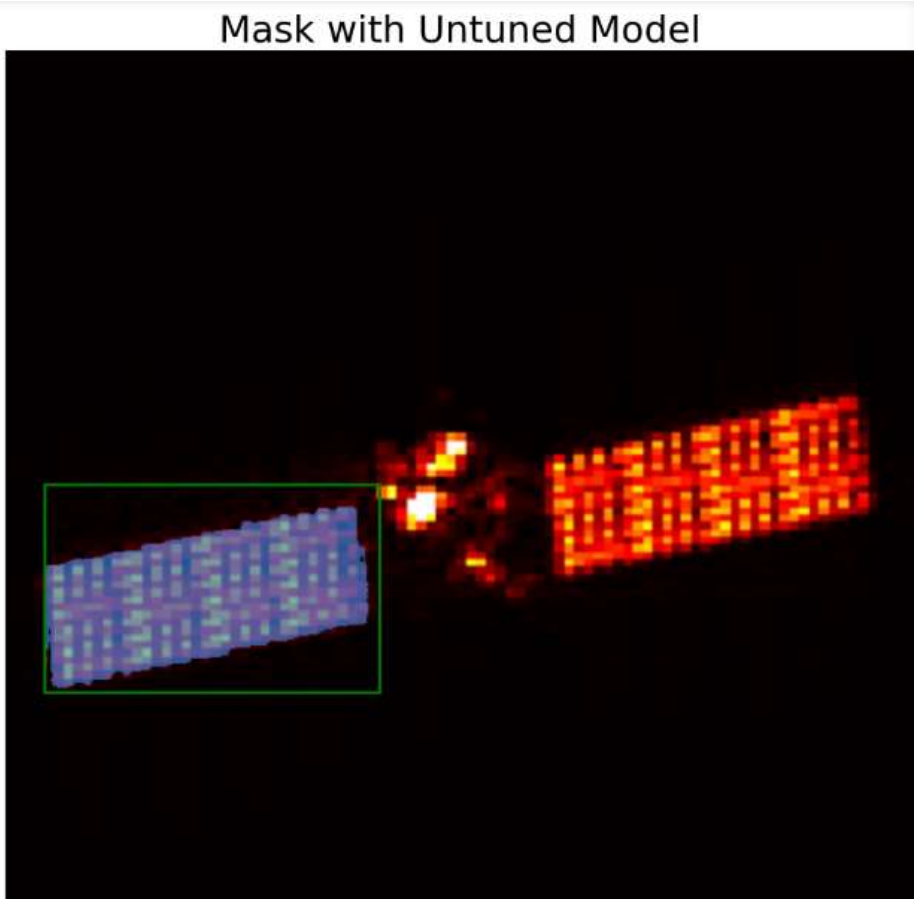
- Segment Anything (Automatic Mask Generator)



Experiments

- Segment Anything (Annotated Mask Provided)

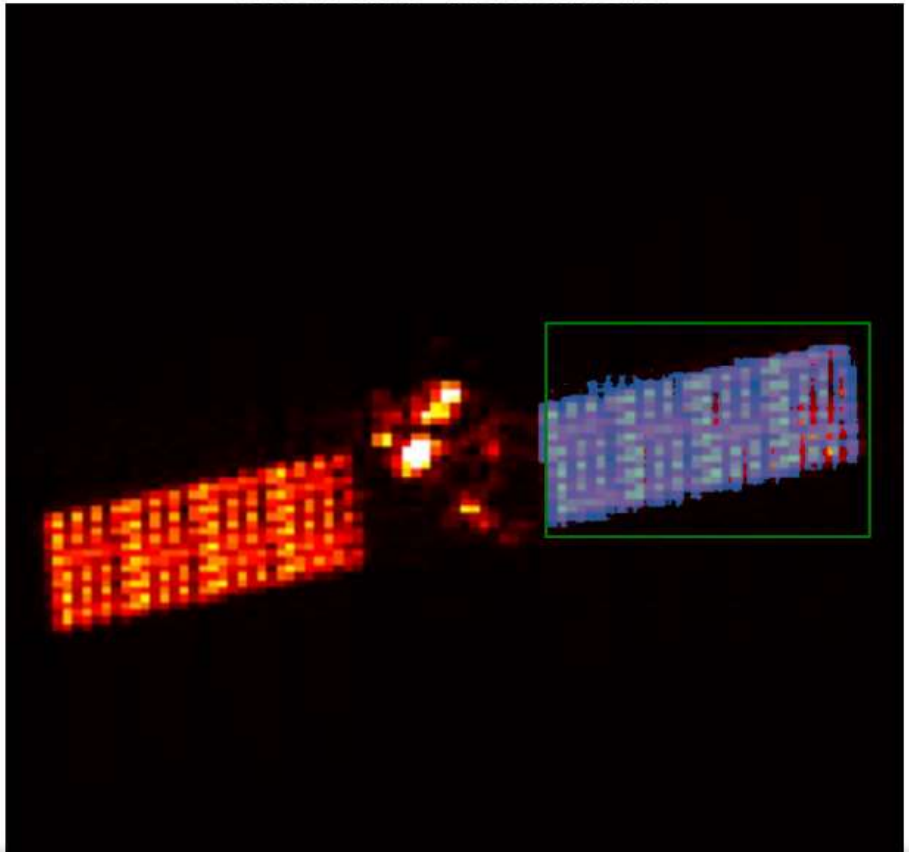




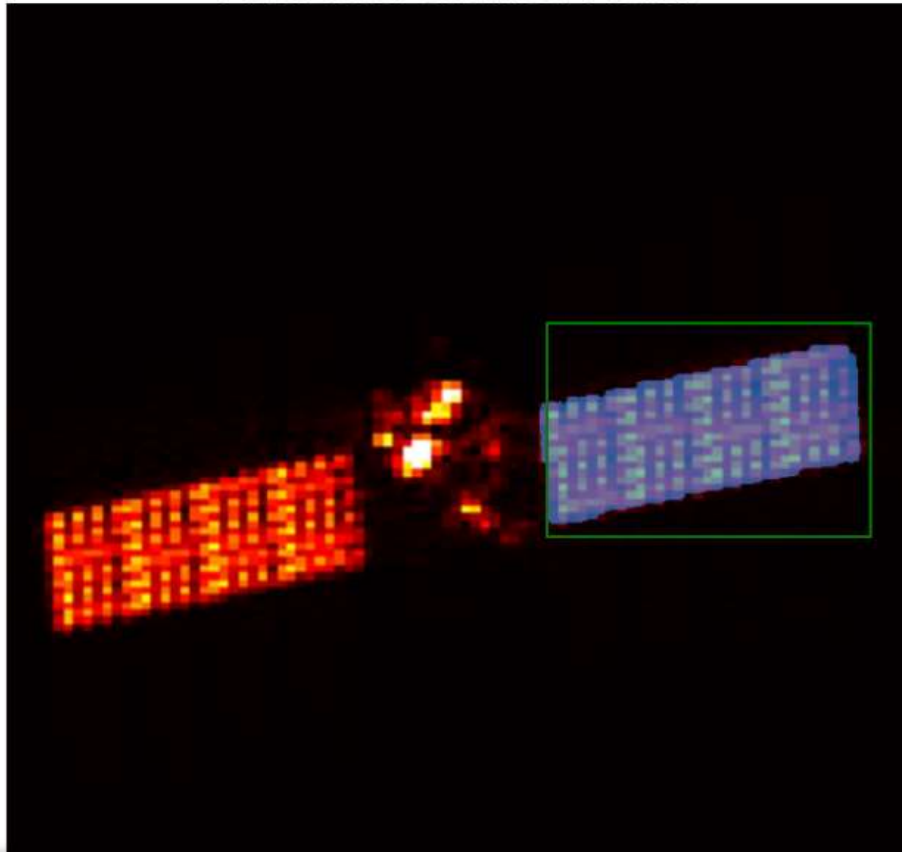
Experiments

- Segment Anything (Annotated Mask Provided)

Mask with Tuned Model

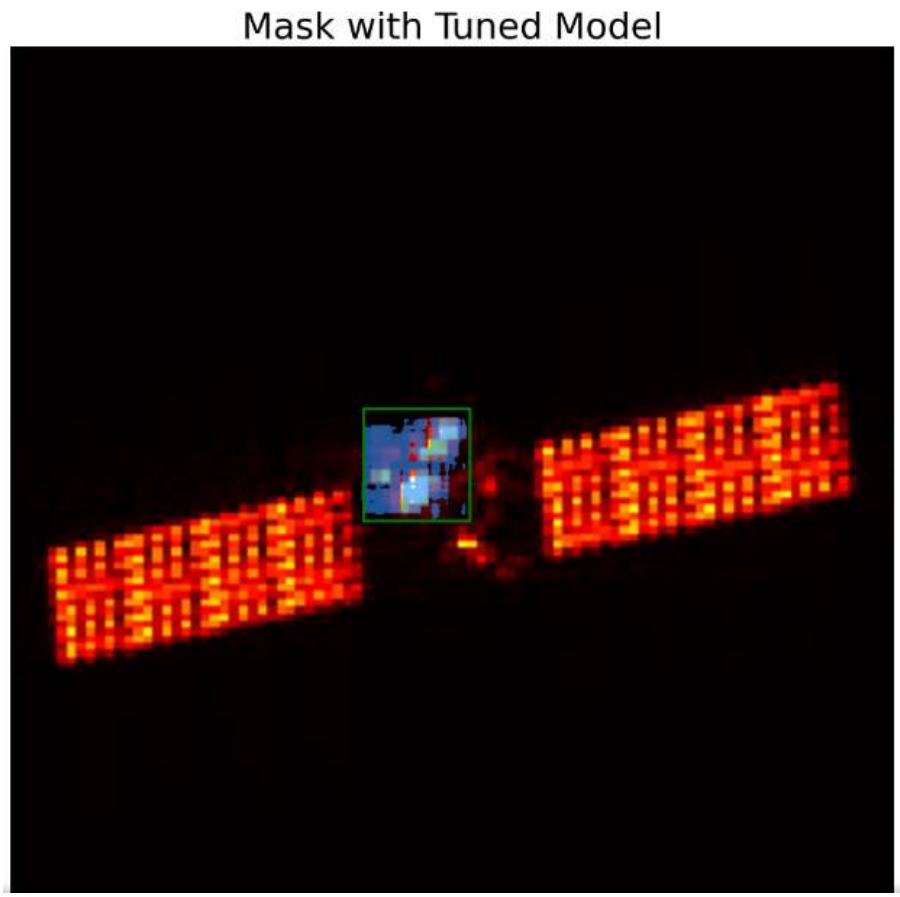


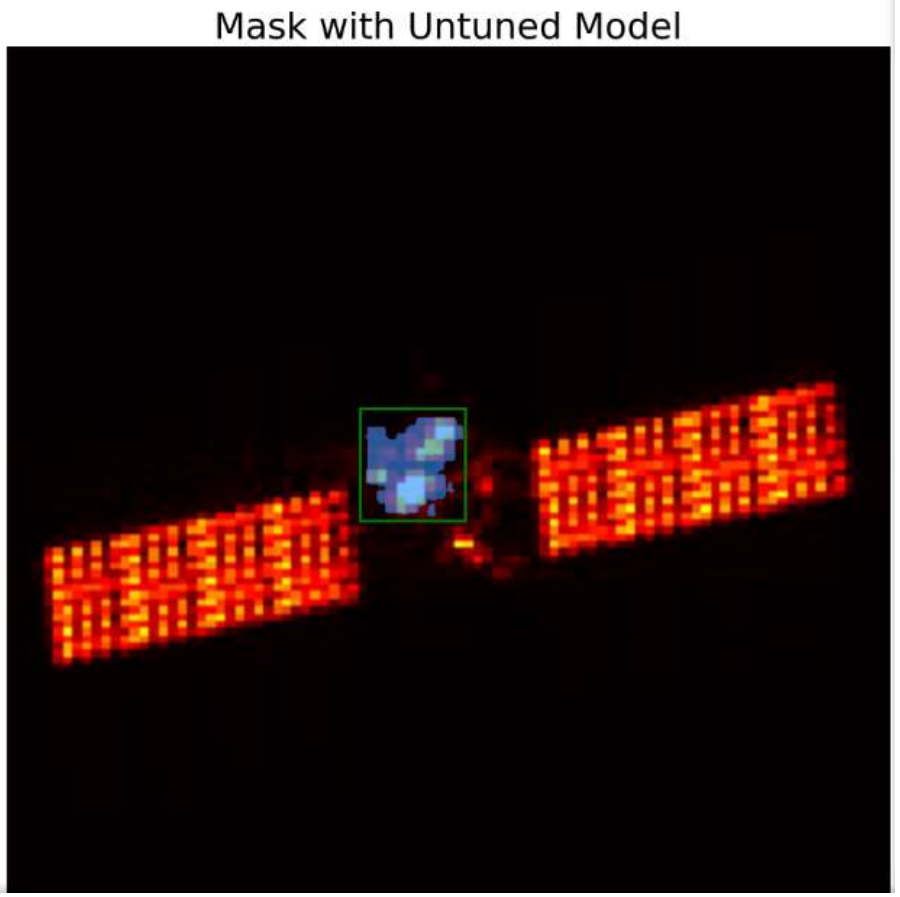
Mask with Untuned Model



Experiments

- Segment Anything (Annotated Mask Provided)

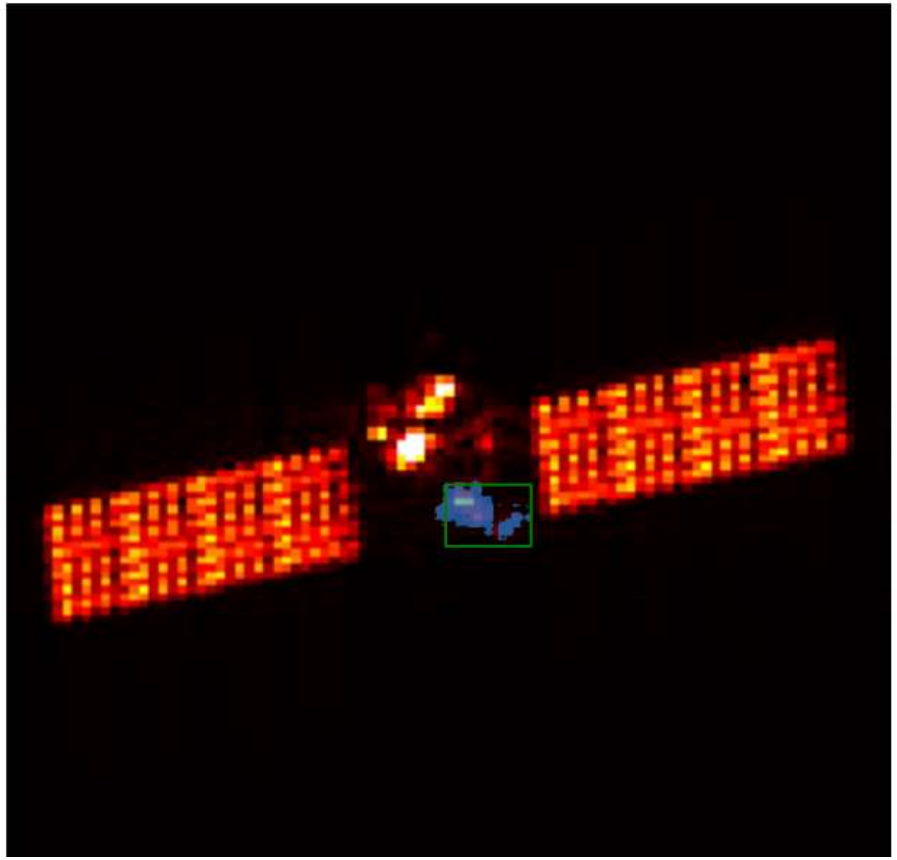




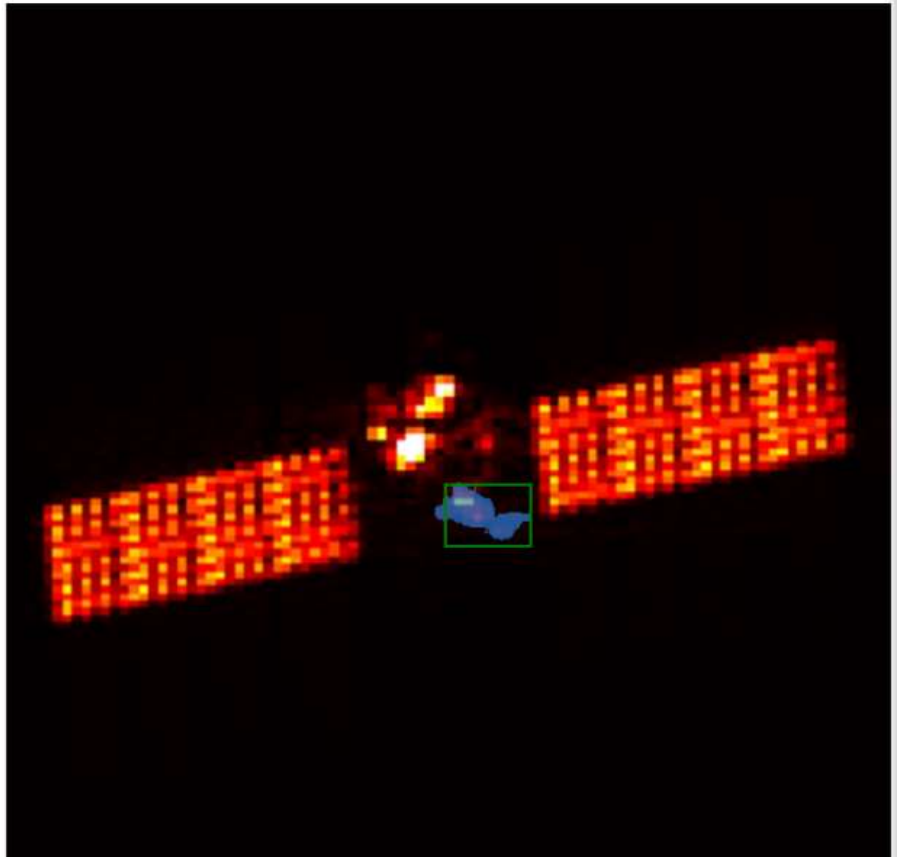
Experiments

- Segment Anything (Annotated Mask Provided)

Mask with Tuned Model

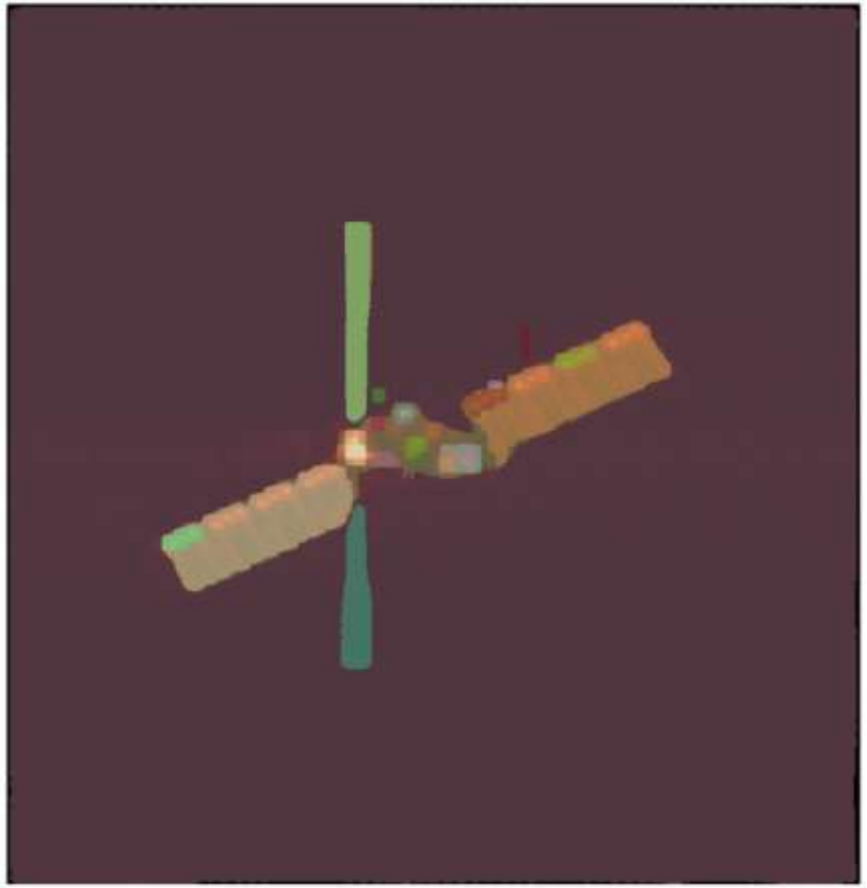


Mask with Untuned Model



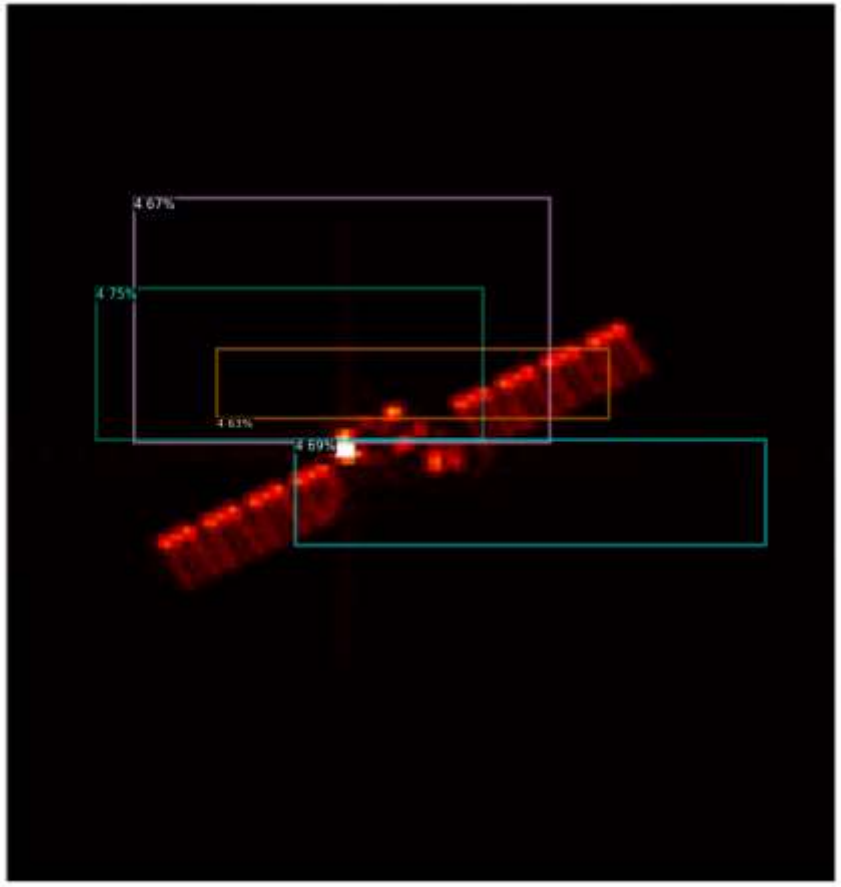
Experiments

- Grounded SAM

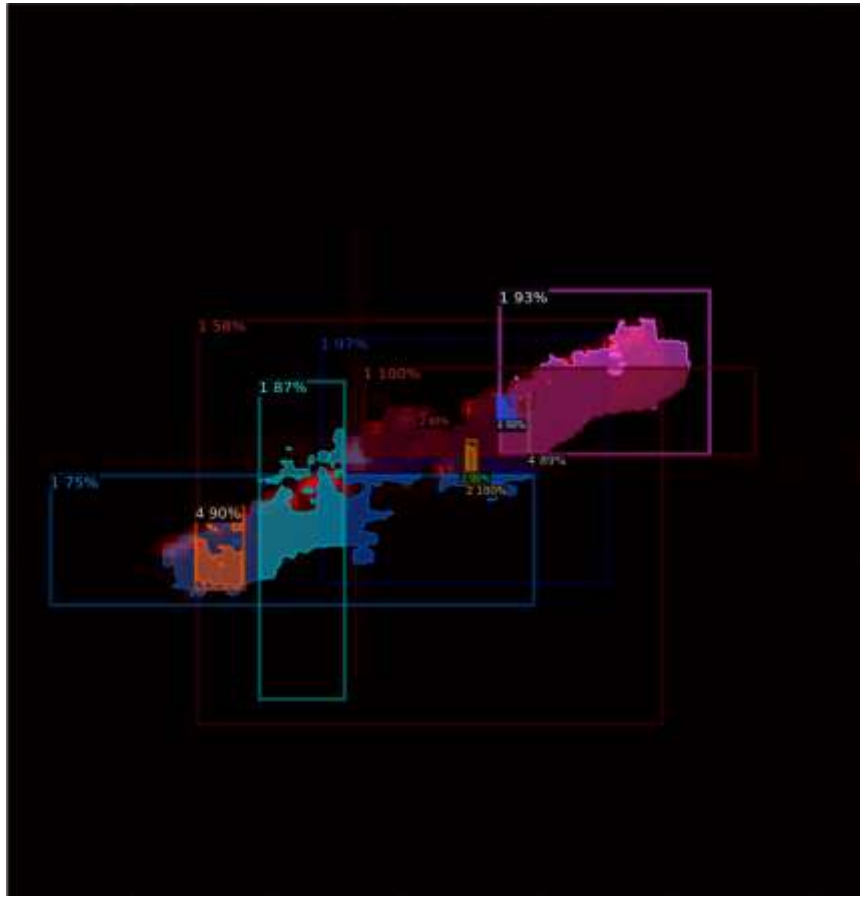


Experiments

- Detectron2:PointRend (Faster RCNN)



(Mask RCNN)



Discussion & Conclusions

- Although not designed for it, current segmentation approaches are very robust and show potential to detect structures within ISAR data
  - SAM model can be fine tuned for ISAR image object segmentation
  - Detectron2:PointRend with Mask RCNN has shown similar behavior
  - Models can be interconnected in a chain framework
- There is a need for open an easily accessible data to validate approaches

Acknowledgements and References

- This work was supported by a Summer Faculty Fellowship of the US Air Force Research Laboratory
  - DoD High Performance Modernization Program
  - Maui High Performance Computing Center (MHPCC)

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Thank You!

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