
AWS
re:Invent
NOV. 28 – DEC. 2, 2022 | LAS VEGAS, NV

AER001

Extend edge processing software to space: On-orbit imagery analysis

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Develop and deploy space-optimized machine learning applications using AWS

- Cloud-aware, space-optimized applications run on spacecraft
- Space applications are developed, deployed, updated, and managed using the same tools and techniques that are used with typical terrestrial applications
- Terrestrial AWS services can be accessed directly from the space segment over traditional radio frequency space networks

AWS worked with our customers to experiment with extending cloud services into the space segment to enable developers and engineers with little space experience to develop and deploy space-optimized machine learning applications with flexibility and scalability

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AWS IoT Greengrass machine learning components

Application	Greengrass component	Function
Greengrass Ship Detection Component	aws.xxx.ShipDetection.ModelStore	Download the ship object detection model to the device as artifact
Greengrass Ship Detection Component	aws.xxx.ShipDetection	Ship detection inference using TF Lite runtime and custom TF Lite model
Greengrass Fire Detection Component	aws.xxx.FireDetection.ModelStore	Download the fire detection image classification model to the device as artifact
Greengrass Fire Detection Component	aws.xxx.FireDetection	Fire detection inference using TF Lite runtime and custom TF Lite model
Greengrass Cloud Masking Component	aws.xxx.CloudMask	Cloud masking using cv2
Greengrass Outlier Detection Component	aws.xxx.OutlierDetection	Outlier detection using sklearn

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Machine learning model training and deployment

Data
ML components can process data that is either preloaded at launch on specified local storage or produced by onboard sensors

Machine learning model training
Train ML models with Amazon SageMaker and compile models using Neo Train TF Lite Model

AWS IoT Greengrass ML Inference
Deploy machine learning models optimized to run on AWS IoT Greengrass space devices

Configuration change
Configuration updates adjust the way that deployed components operate. Examples include changes to threshold over which a detected object is reported to the ground, or the percentage cloud cover over/under which an image is not downloaded to the ground

Model update
This functionality updates the models artifacts. An example is the inclusion of new classes of objects to the model output, such as the detection of aircraft in addition to ships

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Space applications

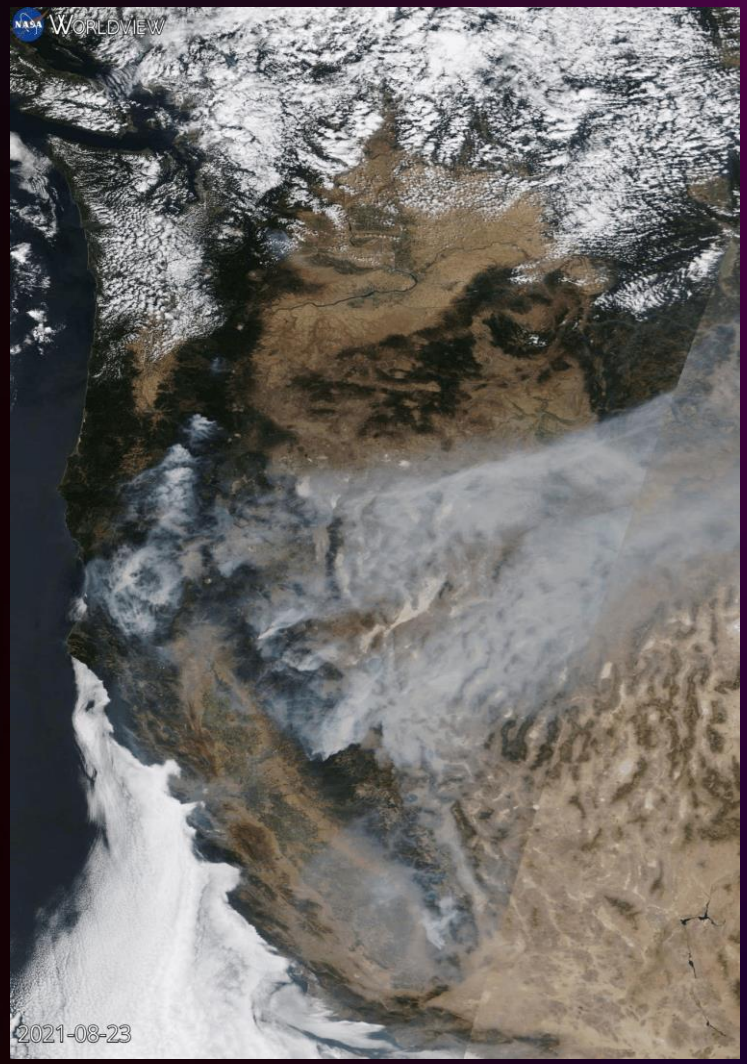
- Fire detection
- Cloud detection
- Sensor outlier detection
- Ship detection

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Fire detection



No fire

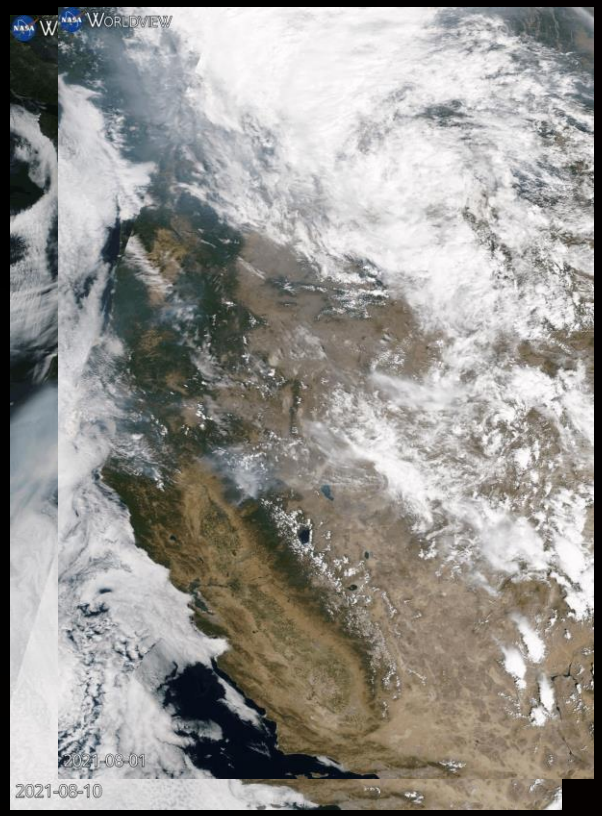


Fire

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TensorFlow (TF) Lite image classification model

Satellite images from NASA Worldview data

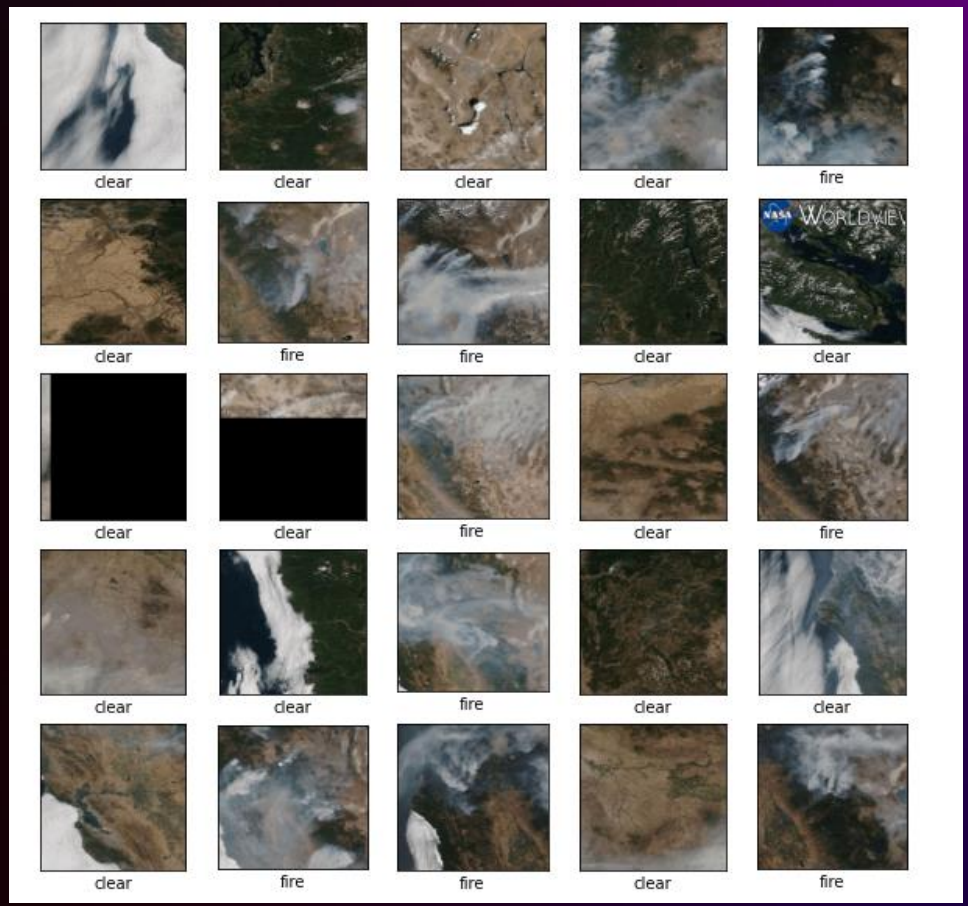


256 by 256 tiles

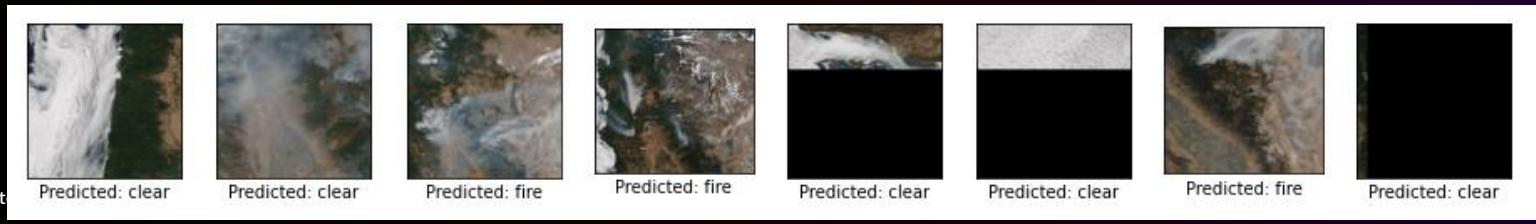
Classify as “fire” or “clear” per each tile

Data
- Fire
- Clear

Classified tiles



Predictions



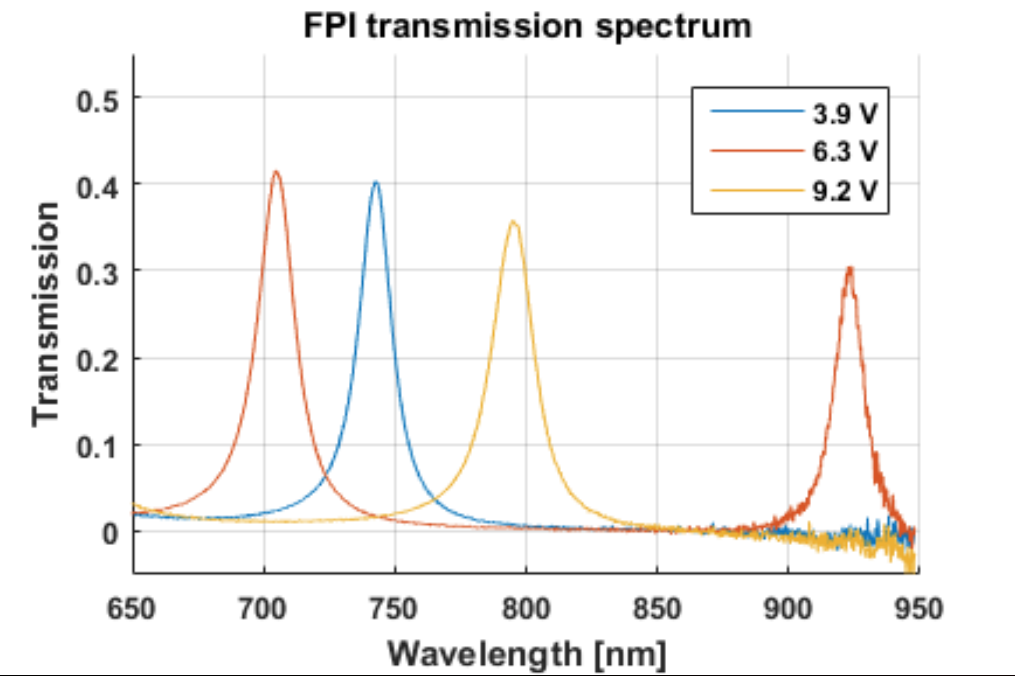
Train TF Lite image classification model using EfficientNet-Lite0

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Satellite image processing

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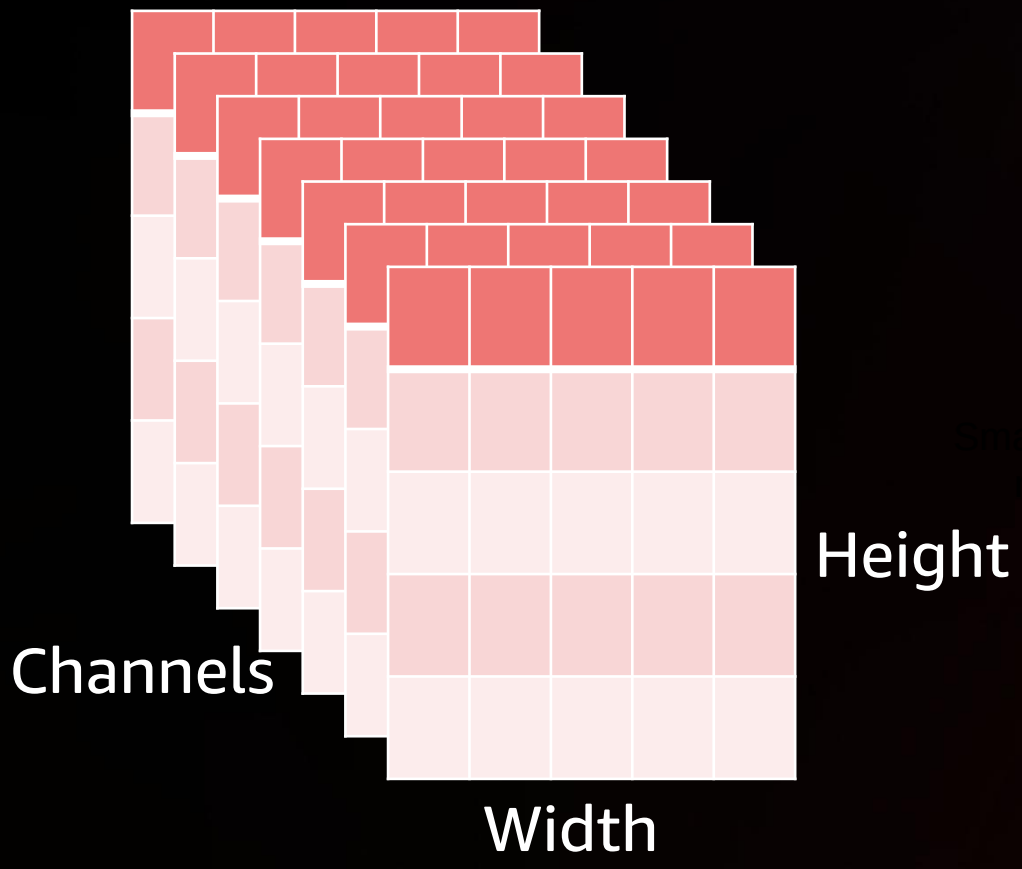
Image capture by the micro-opto-electro-mechanical systems (MOEMS) spectral imager



- By adjusting a voltage level, the imager can capture different wavelengths from 650 nm to 950 nm
- Up to 49 different wavelengths within the range can be captured in a single image
- The rGCP interface is used to specify the number and spacing of bands captured
- Exposure time can also be specified

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Image transformation and compression from 49 to 3 bands



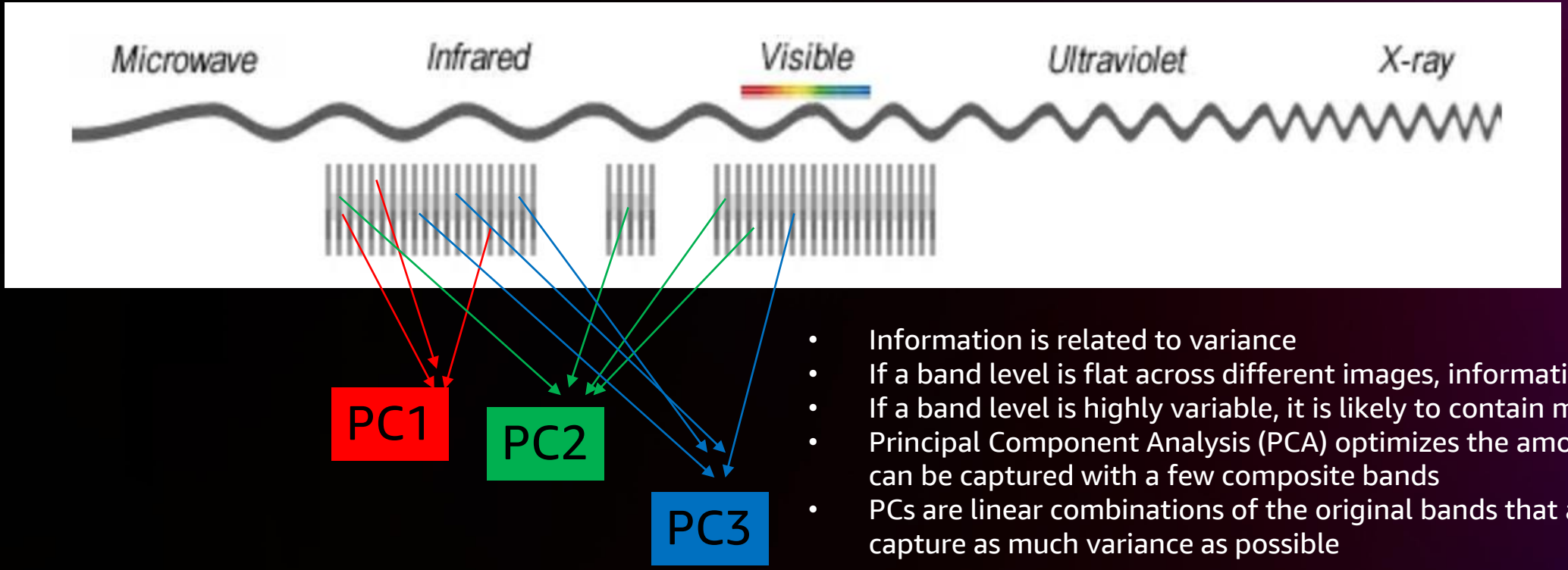


Small and fast models

- Imager produces very large images
- ML models (and vast majority of CV models) are pretrained on 3 band images
- Many advantages of 3 band images:
  1) Highly efficient pretrained models with low latency
  2) Possibility to use tools such as Amazon SageMaker Ground Truth to further annotate downloaded images (3 bands)
  3) Realistic to download sufficient number of images to ground Amazon S3 storage
- In WS2 an image compression approach was designed and implemented such that the raw 49 band images are compressed to 3 “band” images, saved as JPG files, and downloaded to ground

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Using PCA to efficiently compress multiband images



- Information is related to variance
- If a band level is flat across different images, information content is low
- If a band level is highly variable, it is likely to contain more information
- Principal Component Analysis (PCA) optimizes the amount of variance that can be captured with a few composite bands
- PCs are linear combinations of the original bands that are selected to capture as much variance as possible

- PCA projects the data on a smaller number of components to preserve variance
- An alternative is to choose the components according to other criteria
- PLS chooses components such that they are correlated to another variable, such as presence or absence of cloud cover
- Image data can be preprocessed pixel-wise, projected on 3 components
    - Next steps
        1. Input into deep learning models
        2. Use projected data to label high-dimensional multiband data

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SpaceNet colorized SAR imagery

Optical remote sensing (RS) data suffer from the limitation of bad weather and cloud contamination, whereas synthetic aperture radar (SAR) can work under all weather conditions and overcome this disadvantage of optical RS data. However, due to the imaging mechanism of SAR and the speckle noise, untrained people have difficulty recognizing the land cover types visually from SAR images. Therefore, we can fuse RGB and SAR imagery together to make target objects more recognizable.

SpaceNet 6: Multi-sensor all-weather mapping



RGB



SAR

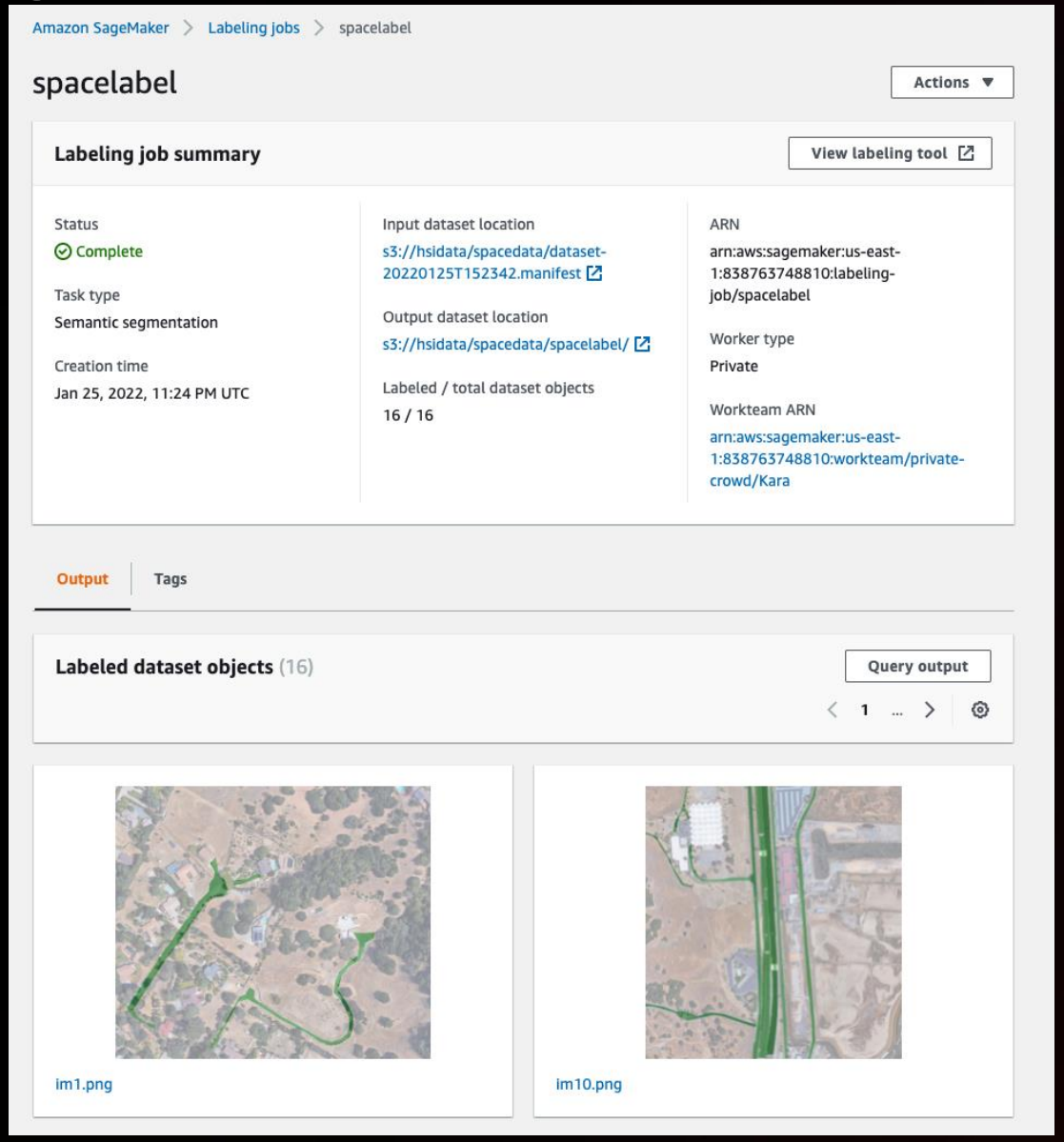


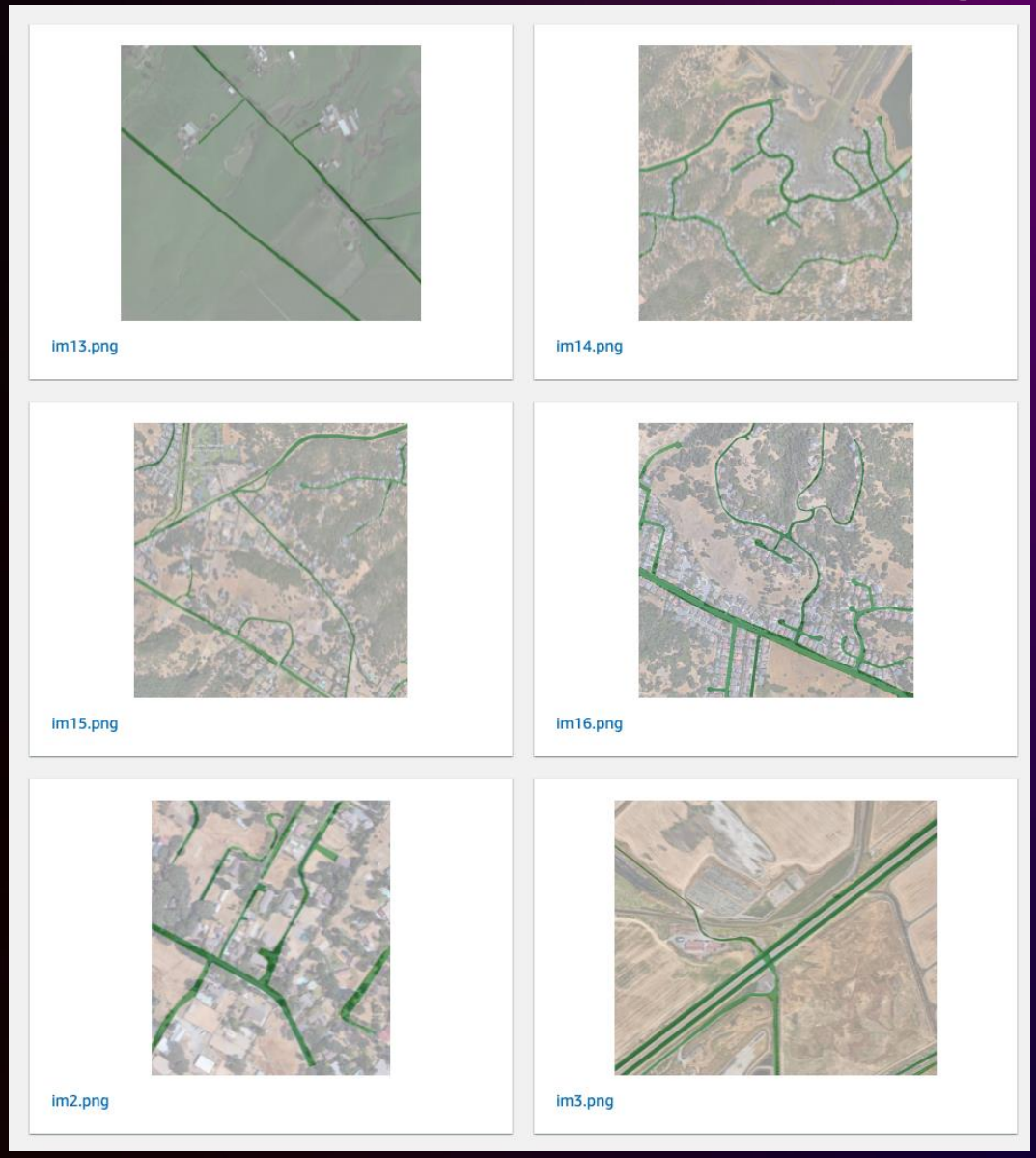
SAR + RGB

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SageMaker Ground Truth: Customize satellite images





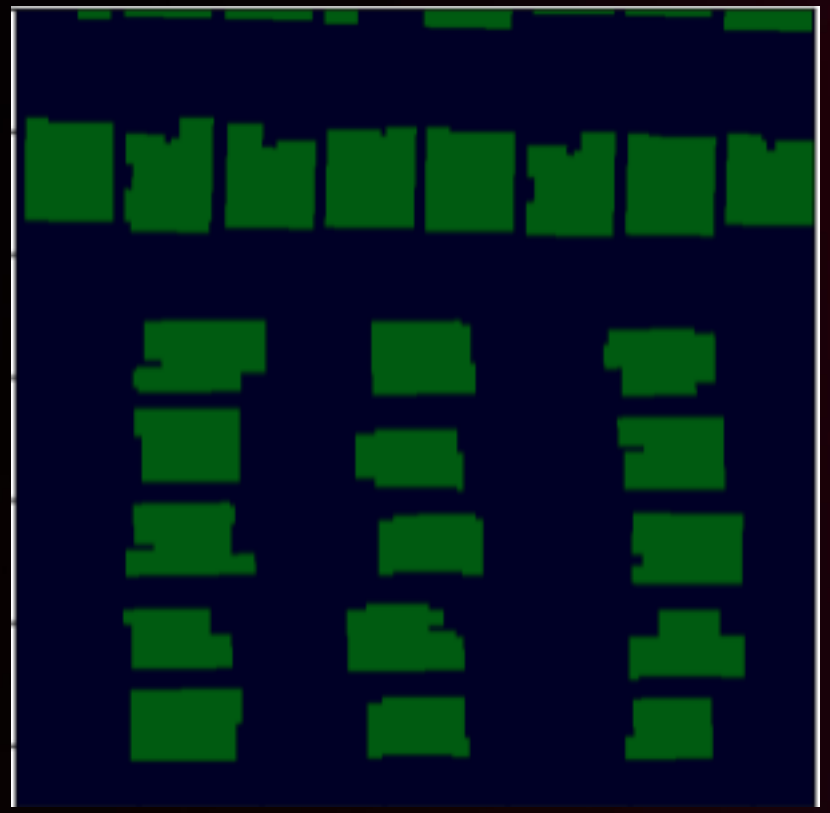
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Supervised image dimension reduction (PLS) to highlight target objects helping reduce labeling noises

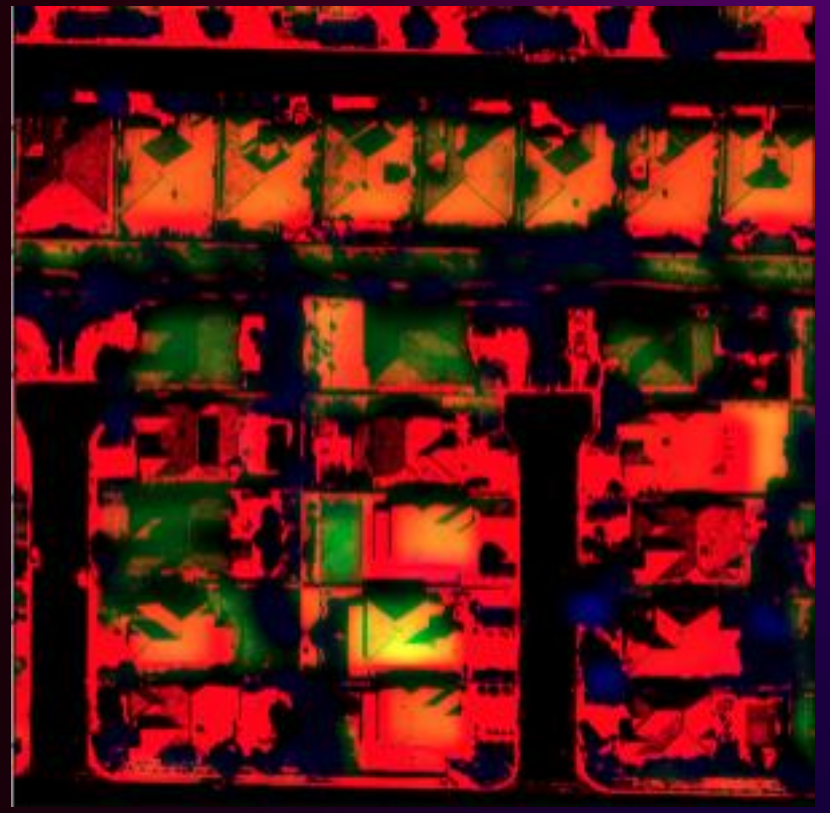
Satellite image



Building footprint masks



PLS processed satellite image



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PLS model transfer learning

Fit a PLS model on an image with its label and use it to reduce dimensions of a new image without giving its label

PLS model fit on this pair of images

image1



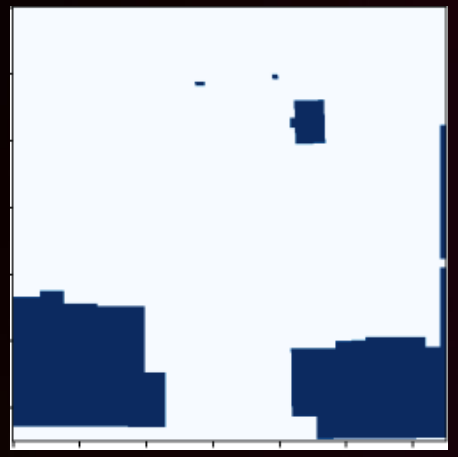
image1 label

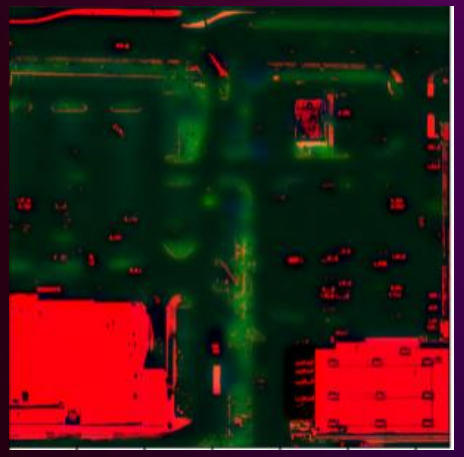


New image

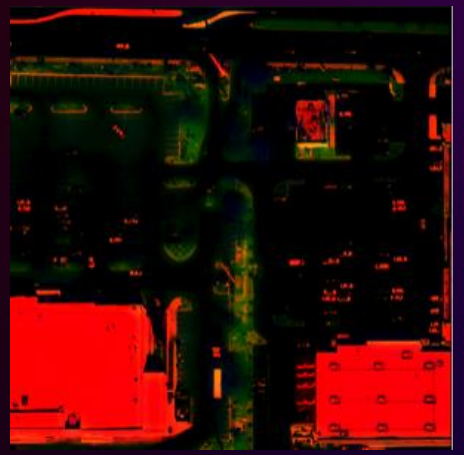


New image label





PLS model fitted by image1 & label



PLS model fitted by new image & its label

After a PLS model is fitted on an image with its label, it is likely to highlight unlabeled similar image target objects accurately

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Cloud detection

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Cloud masking component

Original image

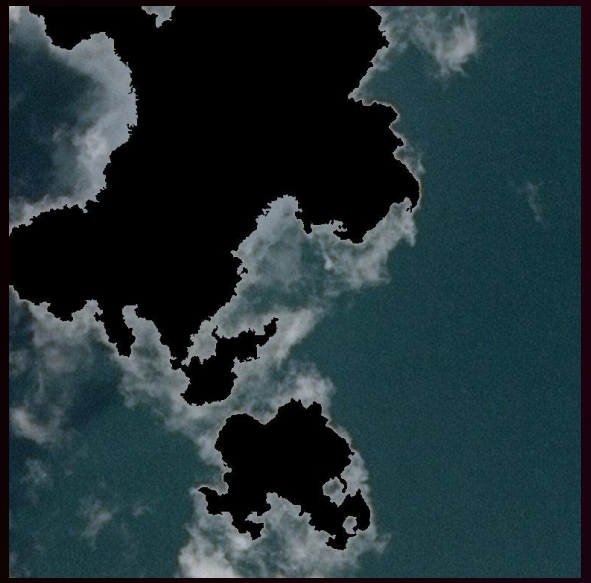






Masked image







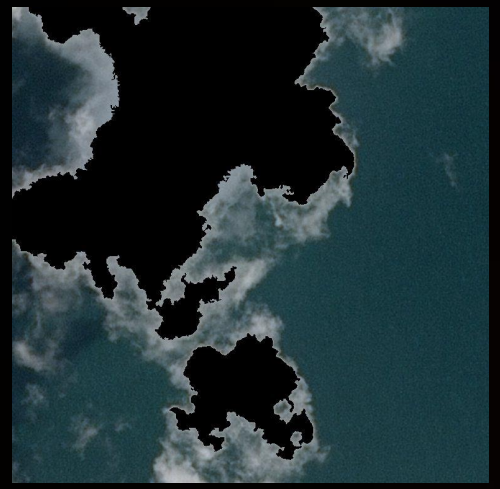
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Cloud masking component

Original image



Masked image

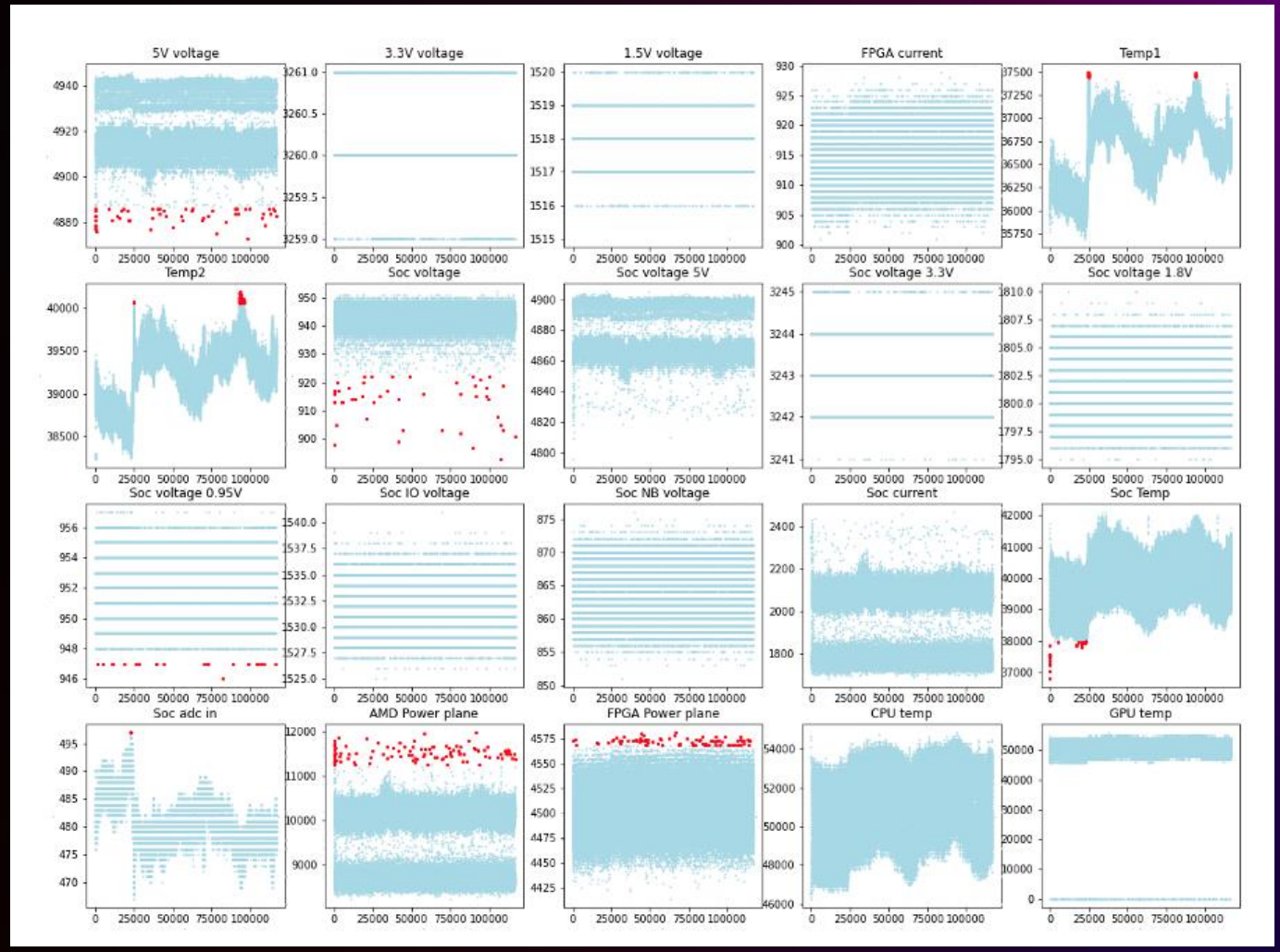


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timestamp	String	09_06_2021_16_13_35_
inference-type	String	cloud-mask
percent-cloud	Number	30.486
final size	Number	68203
percent size reducti...	Number	42.306

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Outlier detection

- The outlier detection component for AWS IoT Greengrass provides a mechanism to monitor the internal sensor readings of the craft (health data) and report values that are outside of the normal operating parameters. This detection is based solely on statistical properties of the data and does not consider prior knowledge about normal or expected parameter ranges.
- We use the Isolation Forest algorithm from sklearn for sensor data outlier detection. This algorithm explicitly isolates anomalies using binary trees.
- The figure on the right illustrates the detection of outliers in the time series data of sensor readings. Points in red are classified as outliers.



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Questions

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Thank you!

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