Innovations in Data Processing through Machine Learning

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Hydrographic Society Benelux – Workshop 6th of march 2019

Royal Boskalis Westminster nv, Papendrecht

1. Challenges in modern survey operations
2. Available cleaning tools
3. R&D in machine learning – creating a noise classifier
    3.1. Support Vector Machine (SVM)
    3.2. 3D Convolutional Neural Network (3D CNN)
    3.3. Results
4. Training the algorithm
5. Next steps

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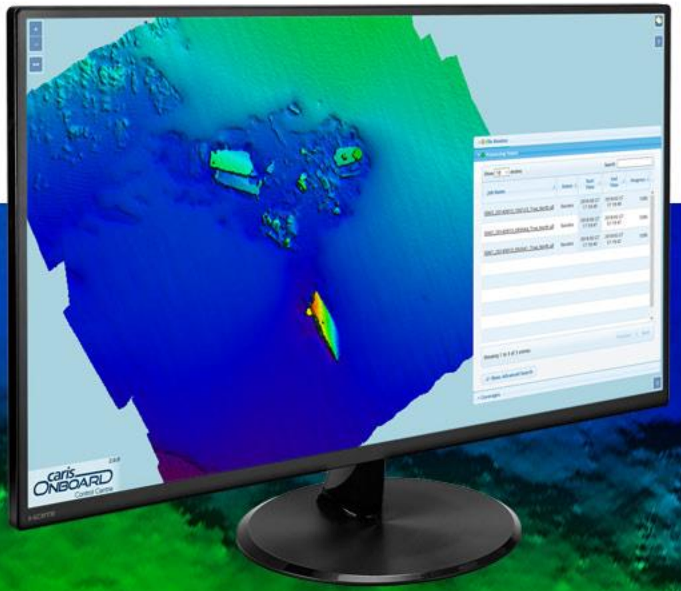
Challenges

in Modern Survey Operations

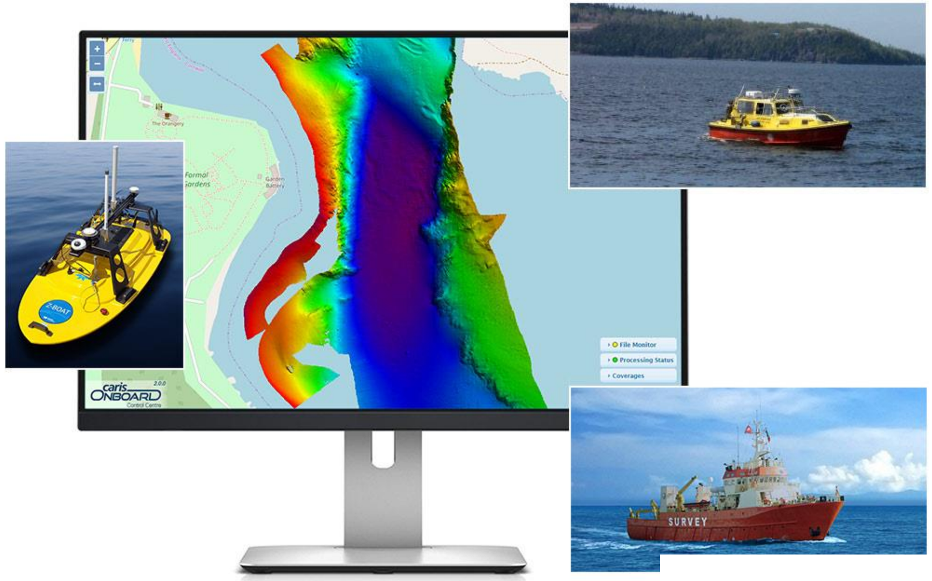


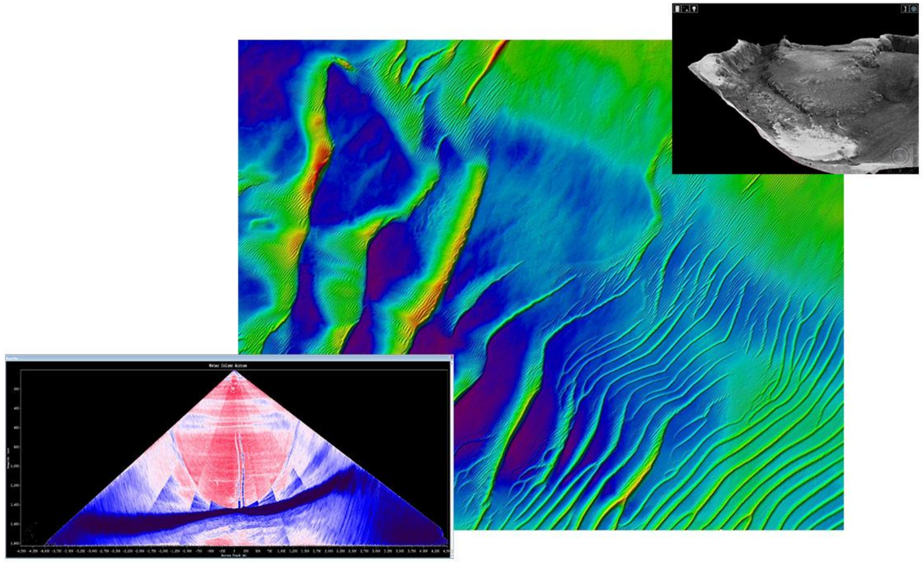
Acquisition

- Vessels of opportunity
- Hardware
- Experienced operators

Processing

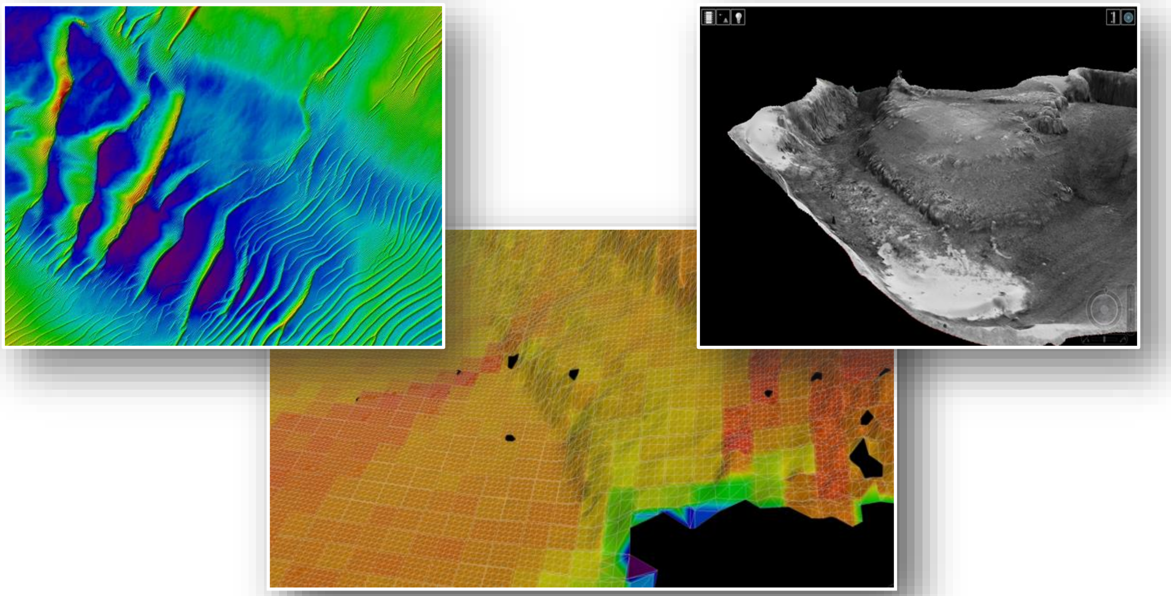
- Multiple sensors
- Inconsistent logging
- Inconsistent quality
- Large data volumes
- Experienced operators





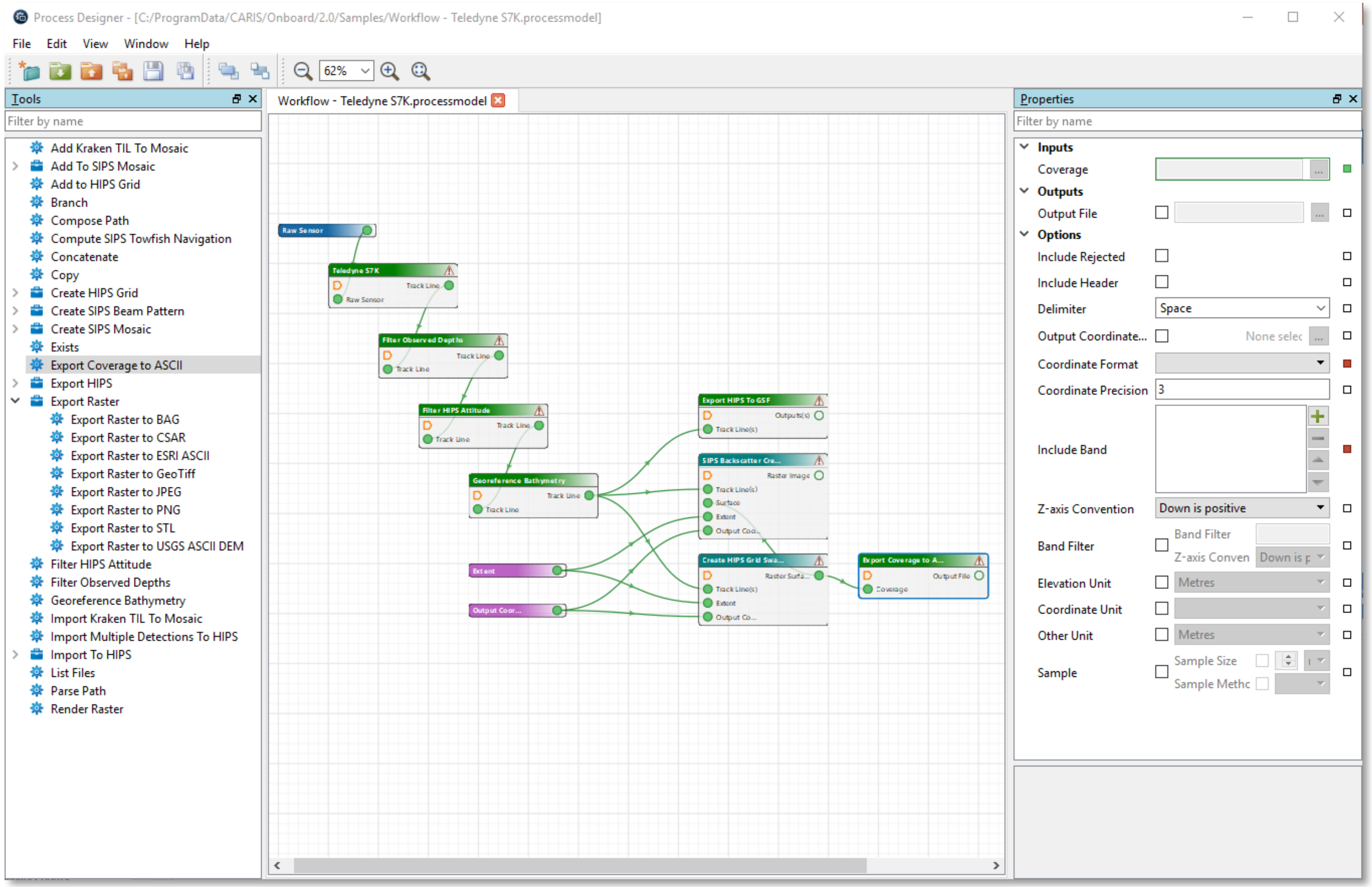
Process Automation

- On platform
- Post-recovery
- Post-survey



Process Designer

- Visually build the automated workflow
- Simple and complex workflows
- Trusted tools automated
  - Import
  - Filter Attitude
  - Filter Depths
  - Create Backscatter Mosaic
  - Create Surface
  - …



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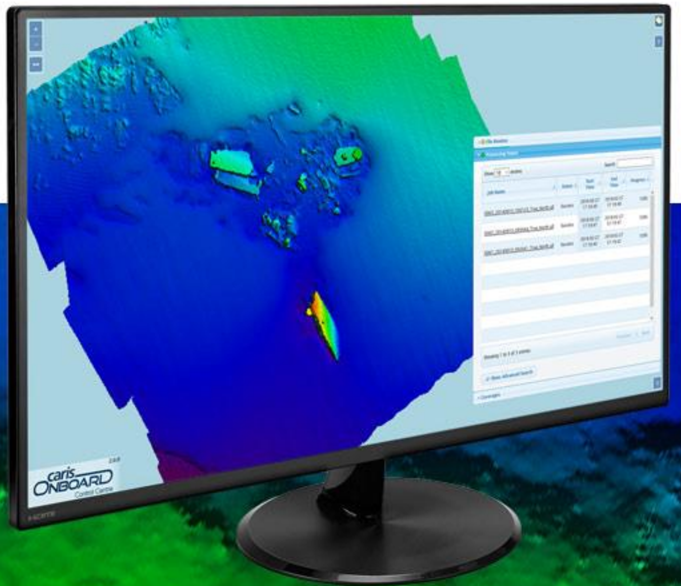
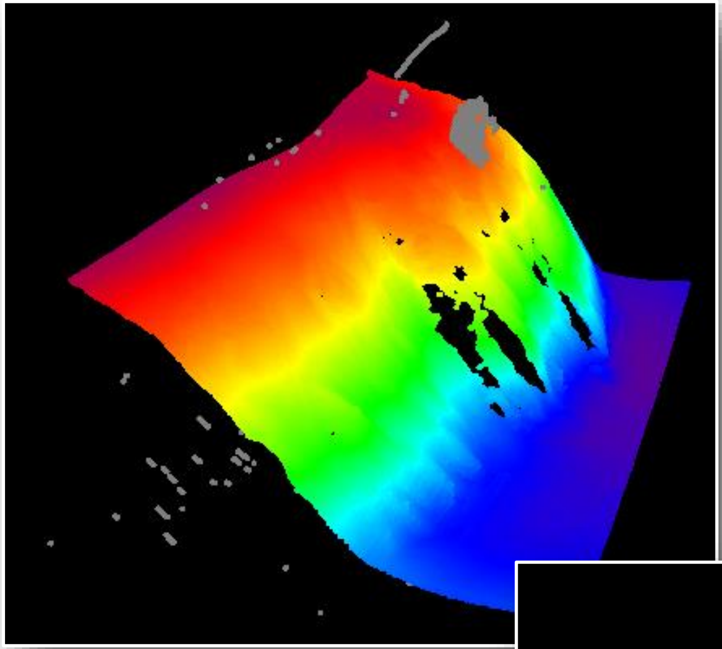
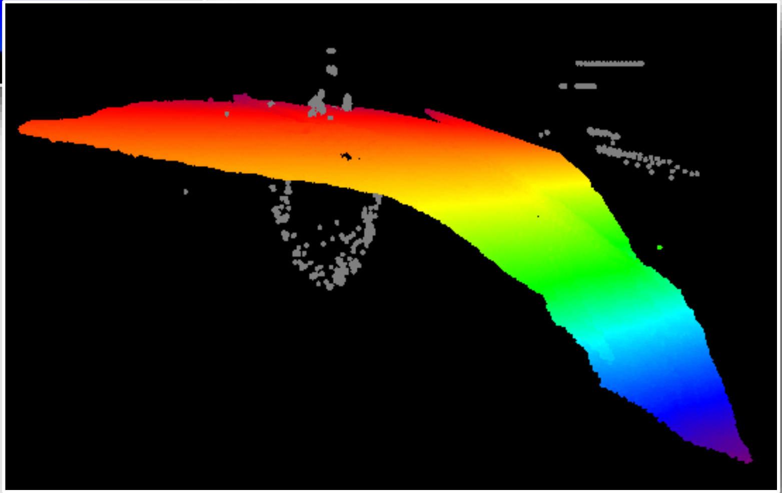
Available Cleaning Tools



- Manual cleaning
    - Most accurate
    - Most labor-intensive
- Simple filters
    - A priori knowledge of data
    - Good on systematic noise patterns
    - Not so good on random noise
- Terrain model filtering
    - CUBE
        - Good results on horizontal features
        - Reduces significantly manual labor
        - Not so good on steep slopes and vertical structures
        - Input parameters need adjusting depending on data





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R&D in Machine Learning

Creating a Noise Classifier

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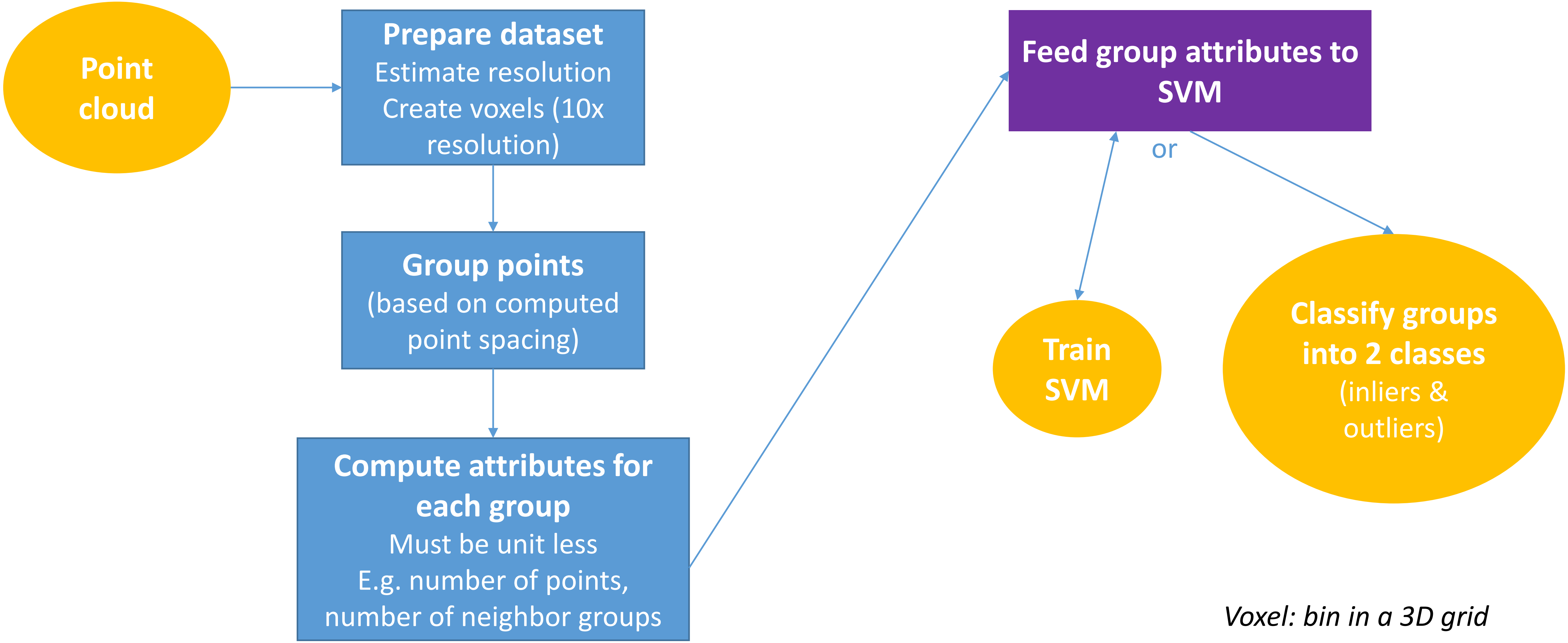
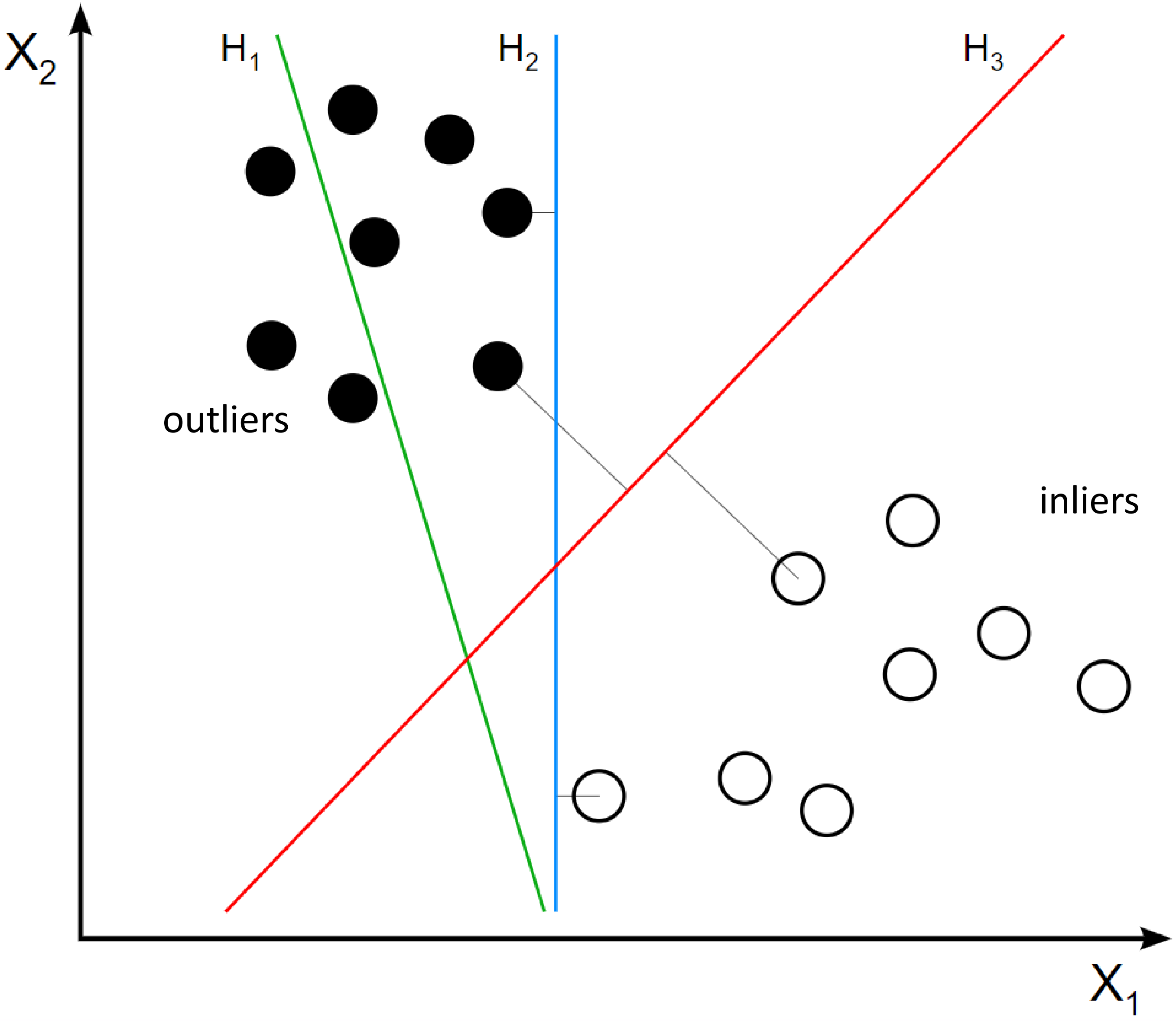
Support Vector Machine (SVM)



Voxel: bin in a 3D grid

Support Vector Machine (SVM)

Intuitively, a good separation is achieved by the hyperplane that has the largest distance to the nearest training-data point of any class



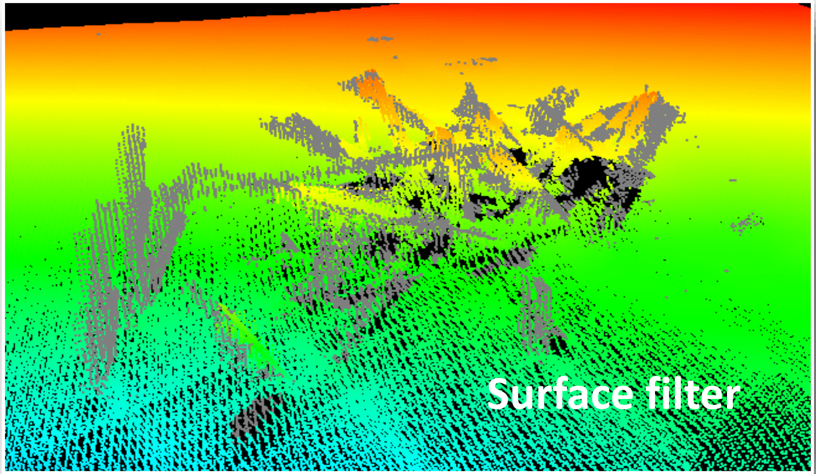
Support Vector Machine (SVM)

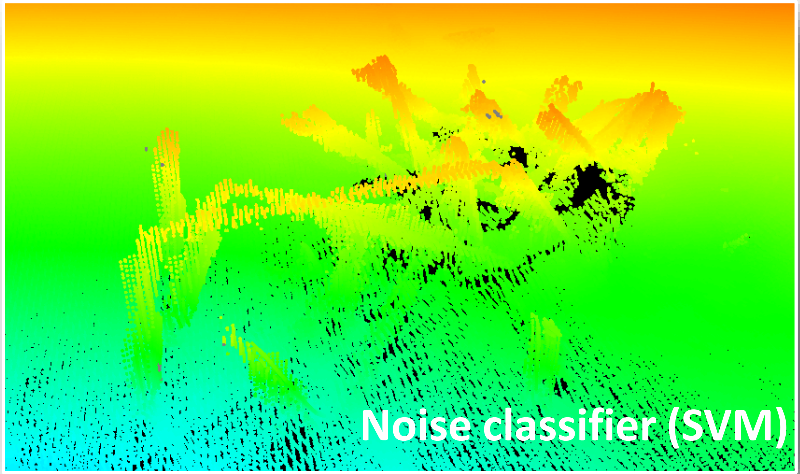
Pros:

- Practical and common technique
- Performs better than DTM based methods on slopes and vertical structures

Cons:

- Datasets are highly imbalanced (number of outliers is typically a small percentage of the overall dataset); not ideal for SVM (high accuracy on inliers detection, but not so much on outliers detection)
- Voxelization, grouping and feature extraction can be slow.
- Voxelization and grouping mean that we have a limit on the smallest feature we can detect.





3D Convolutional Neural Network (3D CNN)

Point cloud

Prepare dataset
Estimate resolution
Create voxels (at resolution)

Extract features
(convert voxel representation into feature-based representation)

1. Convolution (feature detectors- linear) -> n feature maps
2. Non-linear operation -> n rectified feature maps
3. Pooling (downsampling) -> n "features" somewhat equivariant to scale and translation

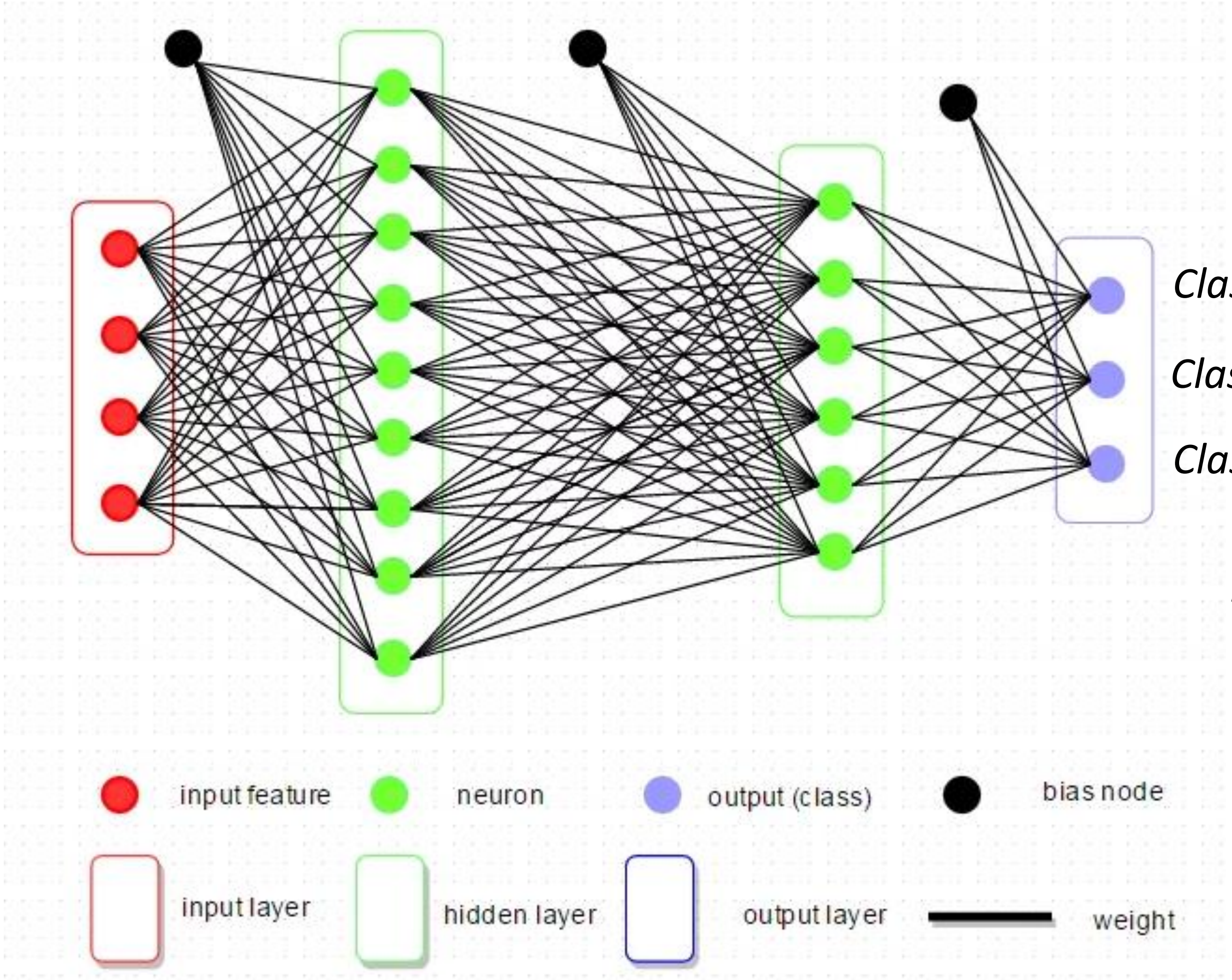
Classification
(through neural network)

or

Train network

Classify features into 2 classes (inliers & outliers)

Neural Network



Class 1 probability (p1)

Class 2 probability (p2)

Class 3 probability (p3)

p1+p2+p3=1

Train network:

- Get probabilities for input feature
- Compare against expected result
- Propagate errors back to the network
- Weights and filter values are adjusted accordingly

Classify:

- Get probabilities
- Get most likely class for input feature

3D Convolutional Neural Network (3D CNN)

Pros:

- Benefits from high parallelism computation on Graphics Processing Unit (GPU); very fast when using GPU, comparable to SVM with CPU
- Direct voxelization approach allows much finer details in the classification
- CNN can easily be extended from binary (inliers/outliers) to multiple classes classification
- Broad availability of CNN and similar libraries, purpose-built for cloud environments

Cons:

- Issues on shoals/deeps (for SVM and CNN)
- Resolution (for SVM and CNN): too few points passed to the classifier and everything is rejected; variable resolution technology seems to be working well to overcome this issue
- Hardware: our current implementation is much slower if no proper GPU is available
- Training: requires significant GPU hardware

3D Convolutional Neural Network (3D CNN)

Can 3D CNN solve current limitations of existing tools?

- Speed: can make use of GPU
- Promising results for noise removal
- Training needed for vertical structures
- Final manual check is still needed – but the algorithm works well on noise harder to clean manually
- Interesting on datasets where depth varies (no fixed resolution)
- Interesting on objects and features
- Easy to setup

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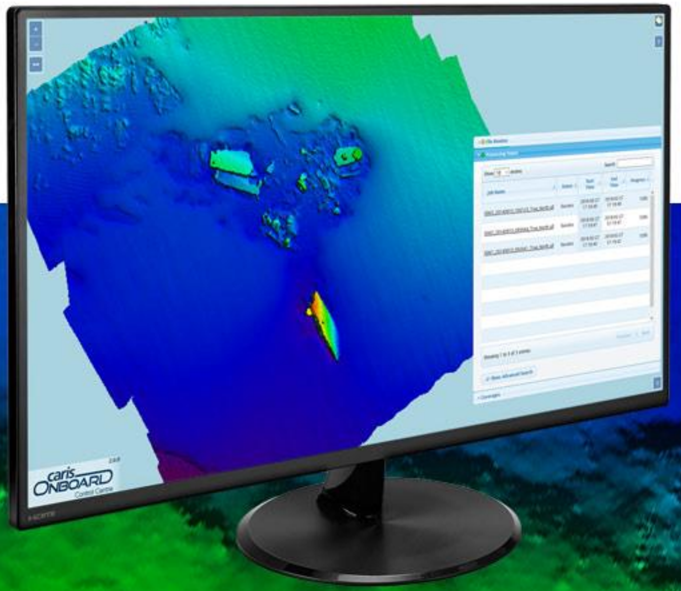
Training the Algorithm



Training the algorithm

Currently:

- One-time training from our side (requires very powerful hardware)
- We will update the model as more datasets are provided by users
- Single model for all datasets (results are good enough), but we could create different models for different tasks (e.g. shallow, deep)

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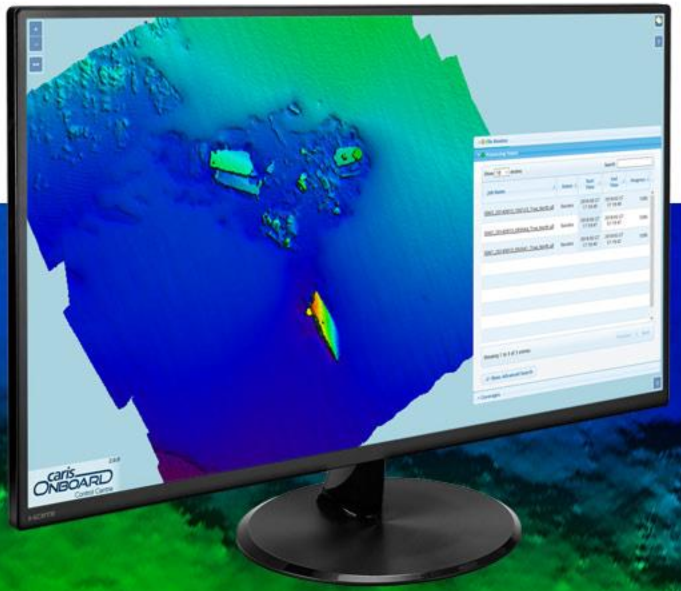
Next Steps



- Object/target detection and classification
  - Point clouds, imagery (multibeam and side scan)
- Fully semantic classification
  - Requires classified datasets for training