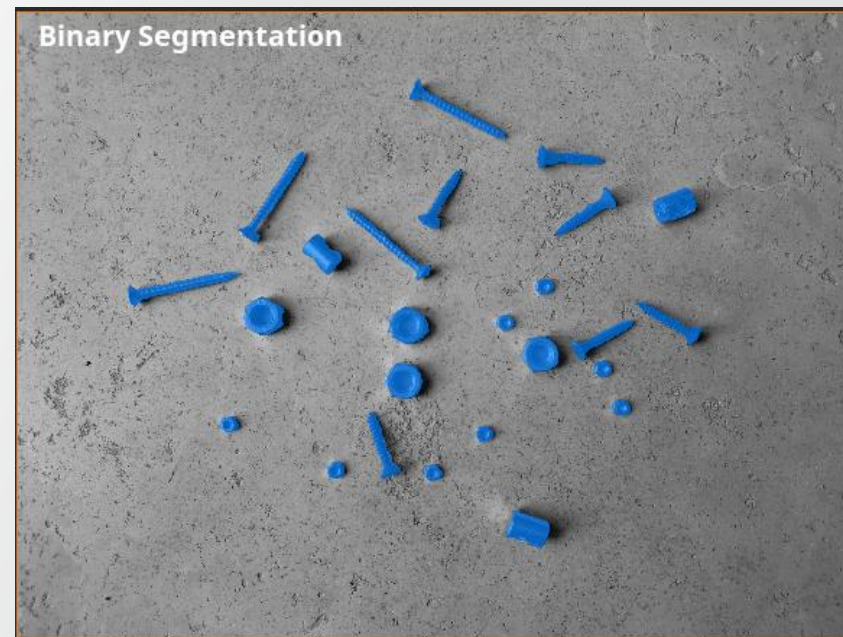


## Object Classification – Xtra modules

Explanations how to use Xtra modules for object classification

September, 2025

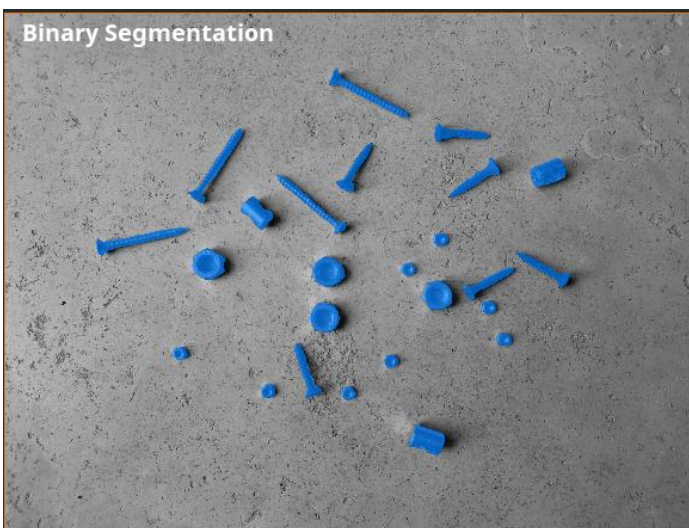
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- This presentation explains how to use the experimental modules proposed in this Xtra, to perform object classification using a simple dataset.
- Modules contained in the Xtra:
  - ML – Train Object Classifier: to train an object classifier,
  - ML - Predict Object Class: to predict classes of objects within a segmented image, relying on a trained classifier
  - Labels Matching: to quantify the quality of a proposed segmentation of objects, compared to a reference/ground truth segmentation
  - Labels Matching MultiClass: to obtain the class-confusion matrix, comparing a segmented & classified proposal, against a ground truth segmentation & classification
- Dataset provided with this Xtra, are derived from a set of photos of screws and bolts on various backgrounds. Converted to grayscale and stacked into Amira Mesh format. Segmentation was performed interactively using the AI-Assisted Selection tool introduced in Avizo version 2025.1, and classified manually.
  - ClassifData\_Test\_Gray.am, ClassifData\_Training\_Gray.am: grayscale images, split between a training, and a test set.
  - ClassifData\_Test\_Labels\_GroundTruth.am, ClassifData\_Training\_Labels.am: the result of interactive segmentation and classification of the above grayscale images
  - ClassifData\_Test\_Labels\_Binary.am: the binary segmentation of the test images, to be classified
  - ML\_ObjClassifierModel.model: the trained model. Note the demo project is configured to overwrite this file when recomputing the modules.
  - ML\_ObjClassifierModel.model.backup: as the model file can be overwritten, a backup is proposed in case of need
  - Classification\_DemoProject.hx: the project illustrating the Xtra, relying on the example data.

# Representation of 'objects'

- This Xtra focuses on the classification, not on segmentation.
- However, the modules heavily rely on the notion of 'objects', which need to correspond to connected components.
- The reader must be aware of the underlying concepts and modules.
  - Binary segmentation: a binary image of 'objects' versus 'background'
  - Label Field (of instances): typically obtained from a binary image, with modules 'Labeling' or 'Label Analysis', each connected component is given a unique ID (pixel value)
    - If separation is required, the 'Separate Object' module can propose an automatic separation into connected component, based on object convexity [which may under or over-split the objects depending on their configuration – and module parameters]. The alternative is to separate objects interactively using the Segmentation Editor.
    - Tip: using the 256-labels colormap may be a good idea to better visualize how well objects are separated.
  - Label Field (of classes): These are typically obtained with manual annotations using the Segmentation Editor, either directly creating the masks of objects and assigning them to appropriate classes (Materials), or by manually classifying a binary segmentation mask obtained automatically through a segmentation recipe.

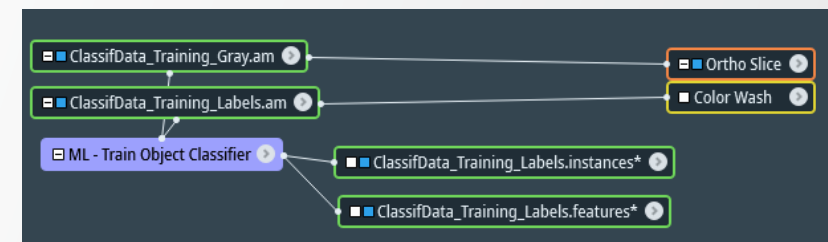




# Training classifier

## ML - Predict Object Class

- The training data is a Label Field of classes
  - It must fit in an Amira-Avizo dataset, either a single 3D volume, or a stack of 2D images
  - See next slide for its preparation
- Machine Learning classifiers learn how to associate a class, with a set of explicit object features (Measures)
  - This module can leverage all measures available from the Label Analysis module
  - Select a list of features that seem relevant for the task: e.g. size, shape factors, intensity, etc.
  - The measure group selected will be saved in the model file, and re-used during inference
  - This means the measure group should not be modified/edited between training and prediction.
- Press 'Apply' to train the classifier
  - This will generate a model file on the disk, as specified location and filename
  - And will also output a Label Field of the labeled instances, and a spreadsheet with indicating the requested measures associated with each of them, as well as the class they belong to.
  - Activating the 'Label Seek' feature in the spreadsheet and configuring visualization appropriately will allow navigating between the spreadsheet and the object locations in the images.



ClassifData_Training_Labels.features									
id	Class Name	Class ID	id	Class Name	Class ID	id	Class Name	Class ID	id
97.44	ClassifData_Training_Labels.features	1	97.44	ClassifData_Training_Labels.features	1	97.44	ClassifData_Training_Labels.features	1	97.44
10026.3	ClassifData_Training_Labels.features	2	10026.3	ClassifData_Training_Labels.features	2	10026.3	ClassifData_Training_Labels.features	2	10026.3
12876.4	ClassifData_Training_Labels.features	3	12876.4	ClassifData_Training_Labels.features	3	12876.4	ClassifData_Training_Labels.features	3	12876.4
8.00957	ClassifData_Training_Labels.features	4	8.00957	ClassifData_Training_Labels.features	4	8.00957	ClassifData_Training_Labels.features	4	8.00957
7.71910E+10	ClassifData_Training_Labels.features	5	7.71910E+10	ClassifData_Training_Labels.features	5	7.71910E+10	ClassifData_Training_Labels.features	5	7.71910E+10
6.89023	ClassifData_Training_Labels.features	6	6.89023	ClassifData_Training_Labels.features	6	6.89023	ClassifData_Training_Labels.features	6	6.89023
413.833	ClassifData_Training_Labels.features	7	413.833	ClassifData_Training_Labels.features	7	413.833	ClassifData_Training_Labels.features	7	413.833
166.083	ClassifData_Training_Labels.features	8	166.083	ClassifData_Training_Labels.features	8	166.083	ClassifData_Training_Labels.features	8	166.083
184.778	ClassifData_Training_Labels.features	9	184.778	ClassifData_Training_Labels.features	9	184.778	ClassifData_Training_Labels.features	9	184.778
202.654	ClassifData_Training_Labels.features	10	202.654	ClassifData_Training_Labels.features	10	202.654	ClassifData_Training_Labels.features	10	202.654
2713.09	ClassifData_Training_Labels.features	11	2713.09	ClassifData_Training_Labels.features	11	2713.09	ClassifData_Training_Labels.features	11	2713.09

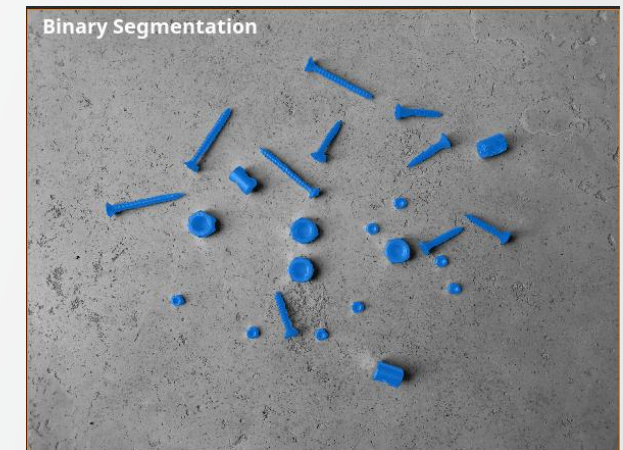
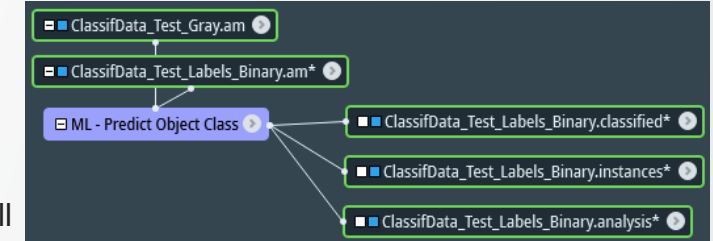
# Preparation of training data

- Manual labeling can be time consuming, tedious, and it may not be necessary to annotate all of the training data to train an efficient classifier.
- If you have an automatic binary segmentation recipe (or AI segmentation model), and wish to train a classifier to distribute your objects in meaningful classes, you can prepare your training data as follows:
  - Duplicate your binary image – for safety (Ctrl+D in the Project View)
  - Enter the Segmentation Editor. The segmentation mask will typically be associated to 'Material1'
  - Create a set of new Materials, to represent all your classes of interest. Assign appropriate names and colors (e.g. short screws, long screws...)
  - Use the 'Pick' tool (with option Connected Component) to select individual objects and assign them to the appropriate target class
  - In case objects were not separated during the segmentation, please introduce a thin interface of pixels labeled as 'Exterior' to enforce their separation
  - Once a *sufficient* number of *representative* examples are given for each target class, delete the 'Material1'. As for any supervised learning, the notions of 'sufficient' and 'representative' are task-dependent and may require experimentation.

# Classification

## ML - Predict Object Class

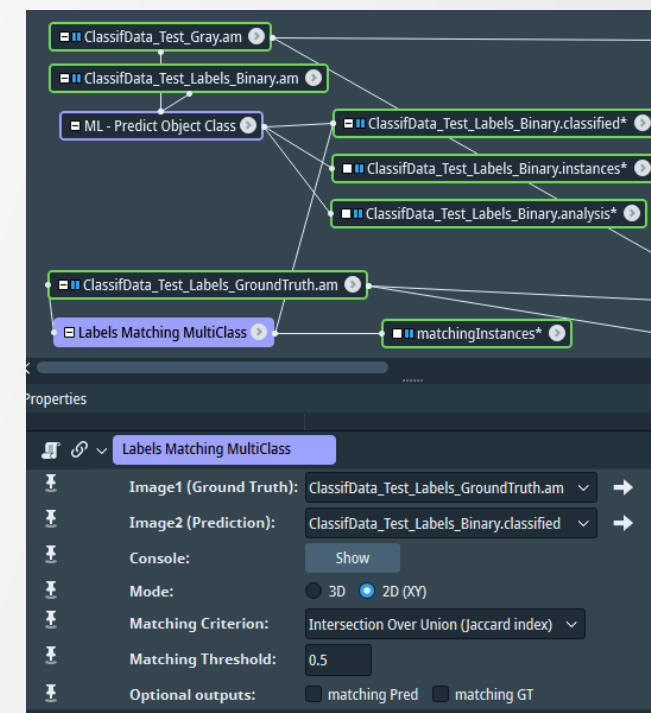
- Perform classification on a binary image (or Label Field of instances)
  - The same measure group that was used for training will be applied (if it was edited, or is not present, an error will occur) – search for 'Export Custom Measure Groups' in the documentation for more information
- Module Outputs:
  - Classification results (classified), using the same material names and colors as the training data
  - If the input was binary, a label field of instances is generated. If a label field was provided as input, it will be considered as the set of instances already.
  - A spreadsheet, reporting the measures leveraged by the classifier to take its decision, as well as the classifier results: the probability for the instance to belong to each candidate class (columns "Class Proba"), as well as the Class Name, Class Confidence (i.e. the class associated to the highest probability, and the value of that probability)



# Classification accuracy

## Labels Matching MultiClass

- If a ground truth is available, the quality of the classification can be quantified using the LabelsMatching MultiClass module
- This module internally relies on 'Labels Matching' module, which implements StarDist matching algorithm to associate instances between ground truth and prediction, even when masks of instances do not match exactly.
- Further, this MultiClass module generates a class confusion matrix, which indicate for each instance, the true and estimated classes.
  - If an instance is available in Ground Truth but not in prediction, it is counted as false negative ; and conversely False Positive are instances of the Prediction with no match in the Ground Truth.
- The Classification Summary Tab indicate that:
  - (bottom part) out of 76 instances, 75 were correctly classified, and 1 was incorrectly classified.
  - (top part) the confusion matrix, indicates that a 'cylindrical bolt' was wrongly classified as a 'large bolt'.
  - 0 False Positive and False Negatives in the confusion matrix, indicate that all instances are matched between Prediction and Ground Truth



	Pred Class 1-long_screw	Pred Class 2-short_screw	Pred Class 3-large_bolt	Pred Class 4-small_bolt	Pred Class 5-cylindrical_bolt	FN
1 GT Class 1-long_screw	12	0	0	0	0	0
2 GT Class 2-short_screw	0	18	0	0	0	0
3 GT Class 3-large_bolt	0	0	13	0	0	0
4 GT Class 4-small_bolt	0	0	0	24	0	0
5 GT Class 5-cylindrical_bolt	0	0	1	0	8	0
6 FP	0	0	0	0	0	0
7 ---	0	0	0	0	0	0
8 Total Nb GT instances	76	0	0	0	0	0
9 Total Nb Pred instances	76	0	0	0	0	0
10 Total Nb of TP instances	76	0	0	0	0	0
11 Total Nb of FN instances	0	0	0	0	0	0
12 Total Nb of FP instances	0	0	0	0	0	0
13 Total Nb of TP with correct class	75	0	0	0	0	0
14 Total Nb of TP with incorrect class	1	0	0	0	0	0



# Thank you

