Quentin GLAUDE
Ph.D Student

CRATERNET

A Fully Convolutional Neural Network for Lunar Crater Detection Based on Remotely Sensed Data

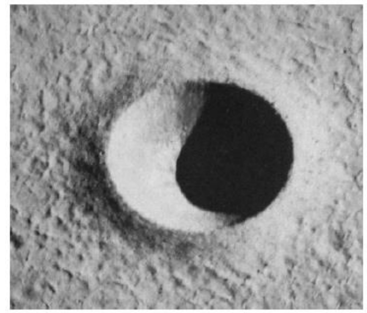
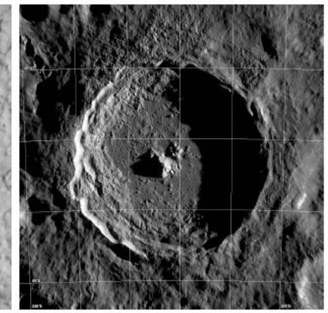
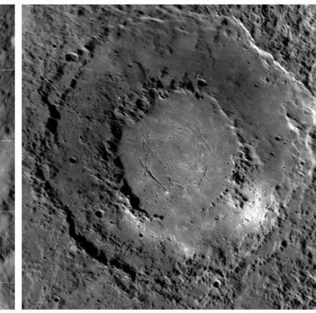
Supervised by Yves Cornet

CraterNet

Crater Description

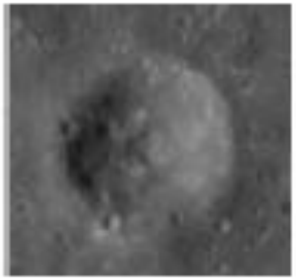
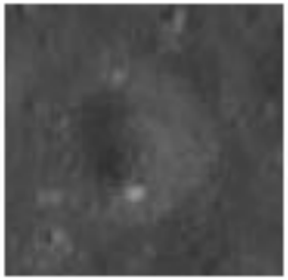
Typology related to aspect:

- Simple craters
- Complex craters
- Giant craters

Crater its-self is complex object :

- Highly variable size
- Overlapping
- Geological composition of the soil
- Illumination conditions
- Niveau de dégradation

Crater Detection Algorithms

Unsupervised :

- Edge detection : Canny, Robert, Sobel, Laplacian, …
- Shape reconstruction : mostly using Hough transform

→ No need for training data but disappointing results

Supervised :

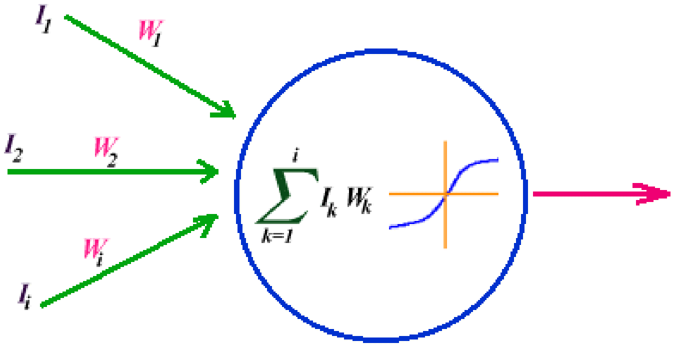
- Candidate search : mathematical morphology
- Post-classification with machine learning : decision tree, boosting, SVM, CNN, …

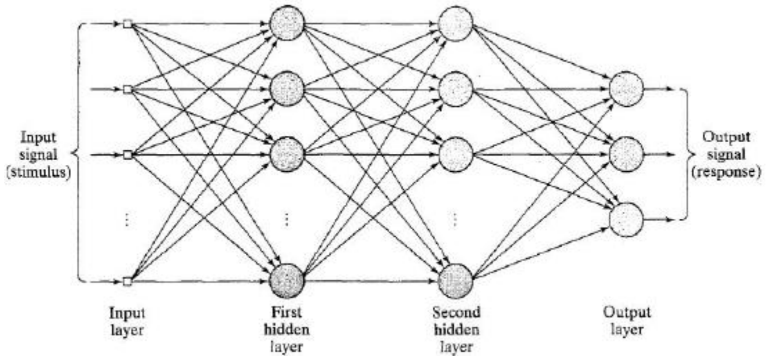
→ Sometimes very good results but need for a huge amount of data to train the model

Still no satisfying answer (despite 100+ publications)

Advances in Deep Learning

- Rapid and impressive progress
- Based on examples, able to predict unseen elements
- Deep Learning is only a « deeper » way to do machine learning
- Based on neural network

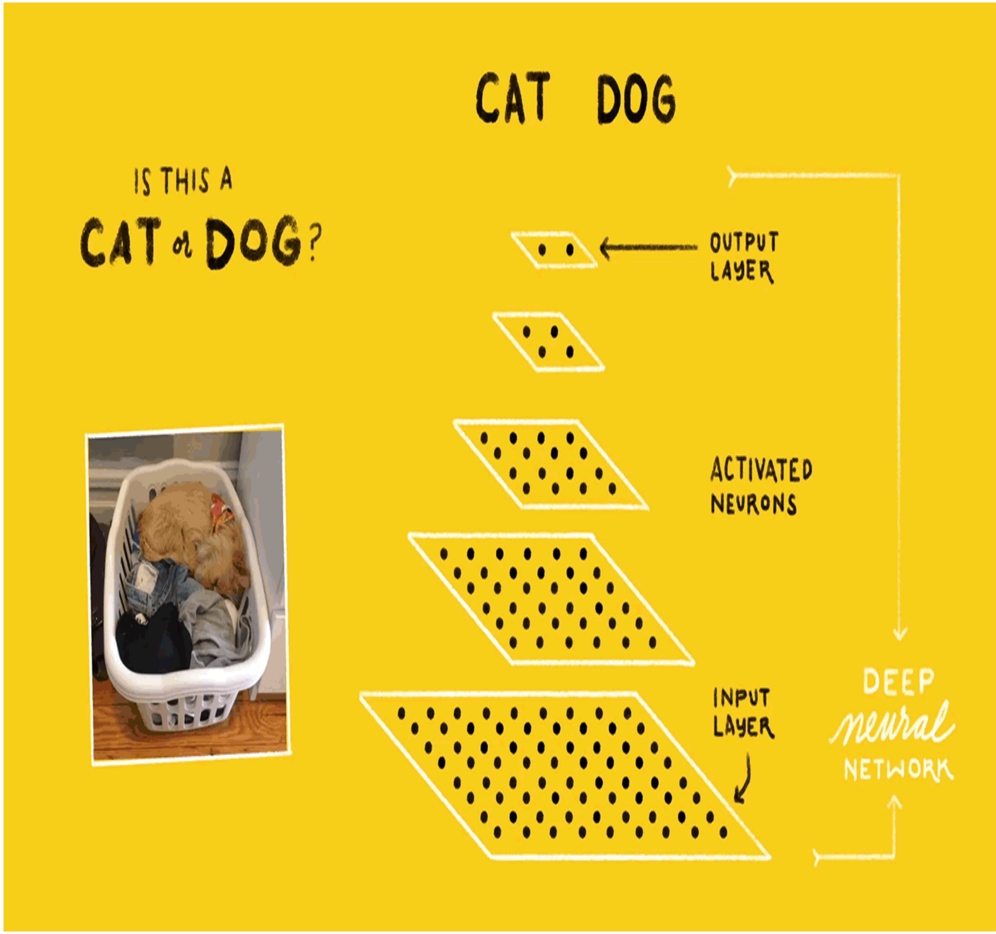




Convolutional networks

- Specific deep learning model broadly employed in image processing, using contextual information (CNN and FCN)
- Learn the image characteristics by training filters arranged in layers

« The first layer detect elementary contours, the second gathers thiese contours in patterns that will then be assembled in parts of objetcs, and so on » Yahn Lecun



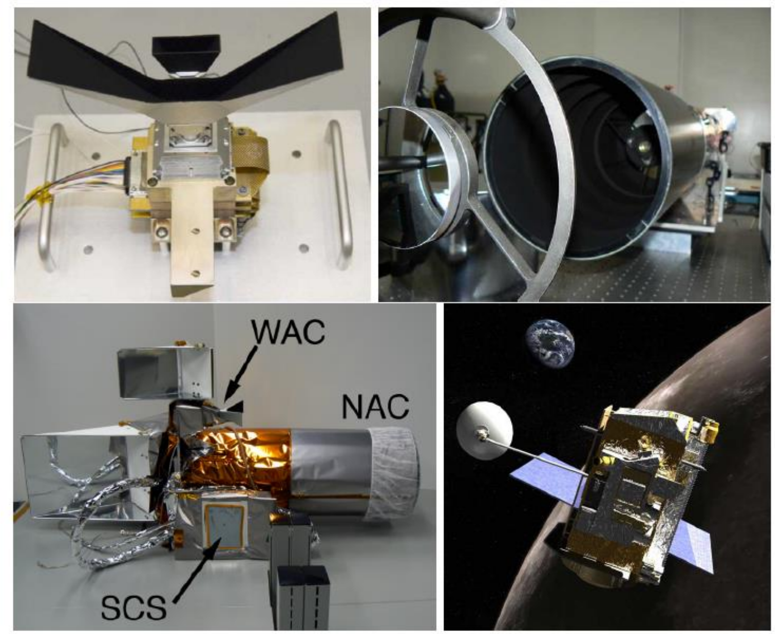
Hypothesis

Attempt to bring to the crater detection problem the advances related to deep learning :

A fully convolutional neural network is an innovative and convincing model for the detection of lunar craters based on remotely sensed data

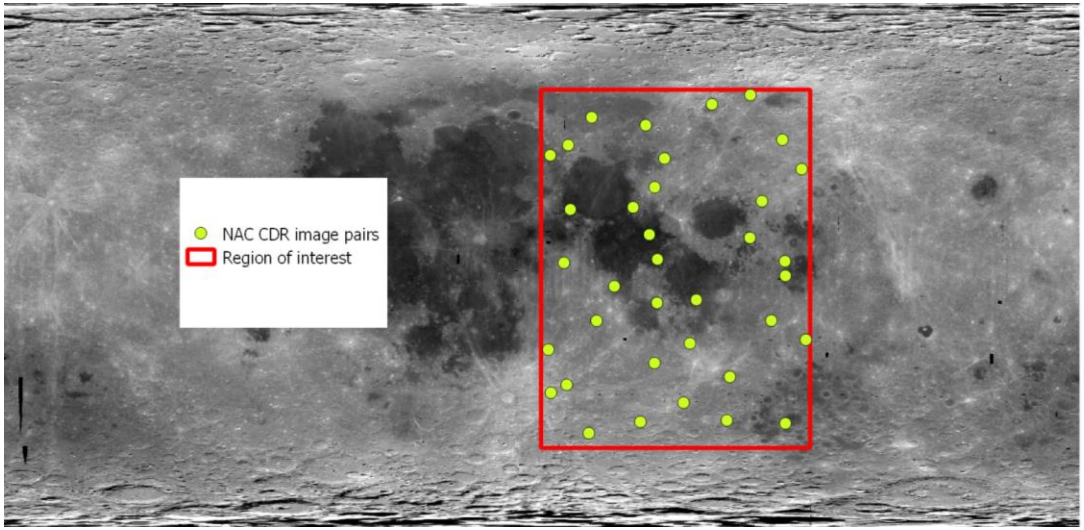
Lunar Reconnaissance Orbiter Camera

- LRO - NASA (2009)
- 1 des 7 acquisition devices
- Composed of 3 cameras
  - 1 with a large FOV (100m/pixel), called WAC (swath of 60 km)
  - 2 with a thin FOV (50cm/pixel), with small overlap, called NAC left or right (swath of 2x2.5km)
- Data available via NASA's archives



Description of the area of interest

- Representative dataset of all possible situations on the Moon



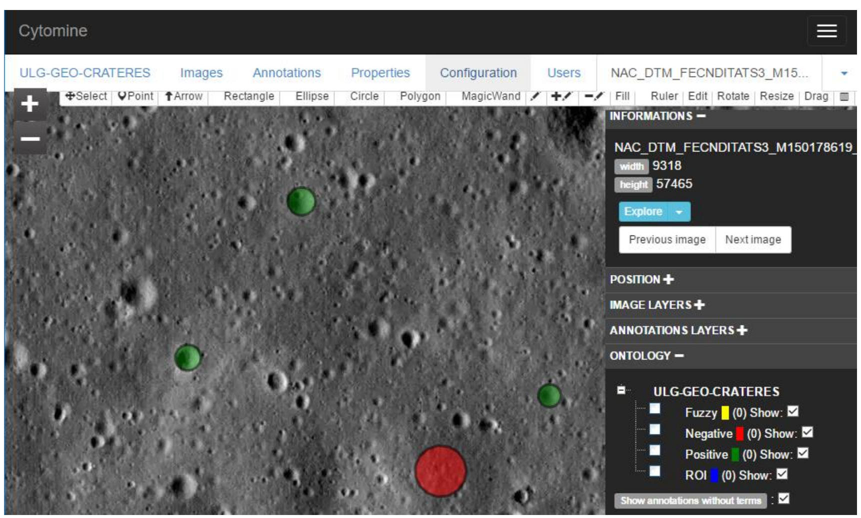
- Choice of 72 NAC images by random systematic sampling covering 120 degrees of latitude and numerous illumination conditions

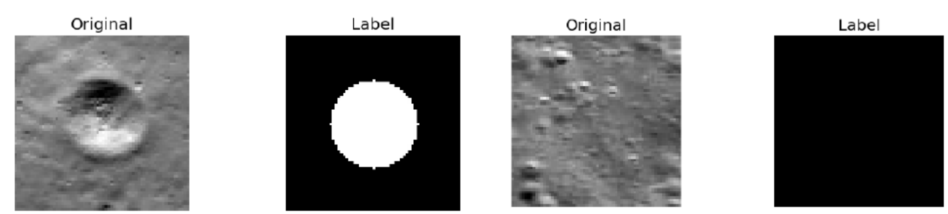
- In parallel to these images, we have orthorectified images produced by stereophotogrammetrypar (Arizona State University)

Description du dataset

- Deep learning requires training data
- No sub-kilometric dataset exists for the Moon
- Use of the Cytomine web-application to efficiently annotate our images
- Possibility to interact directly with Cytomine via a Python Client
- In total, **11 223** annotations have been manually created, available on my GitHub

cytomine

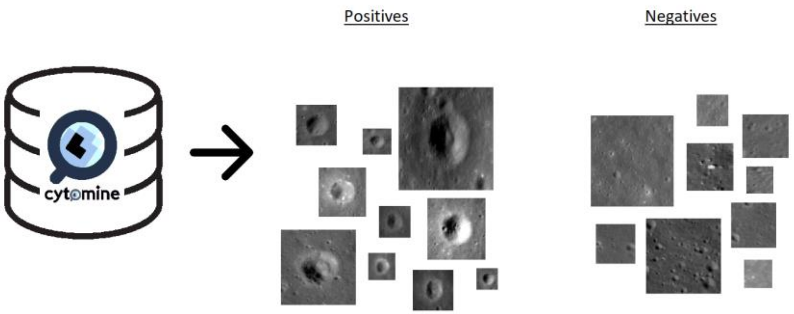




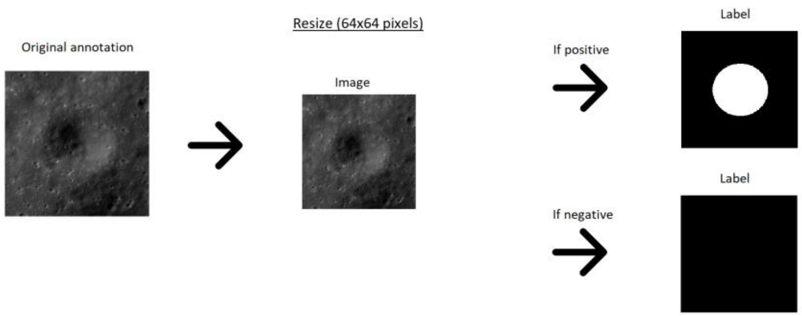
github.com/QuentinGlaude/CraterNet

Data importation

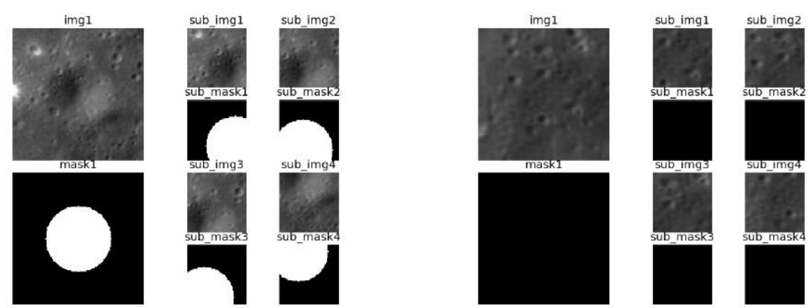
- Using the Python Client



- Creation of the image label

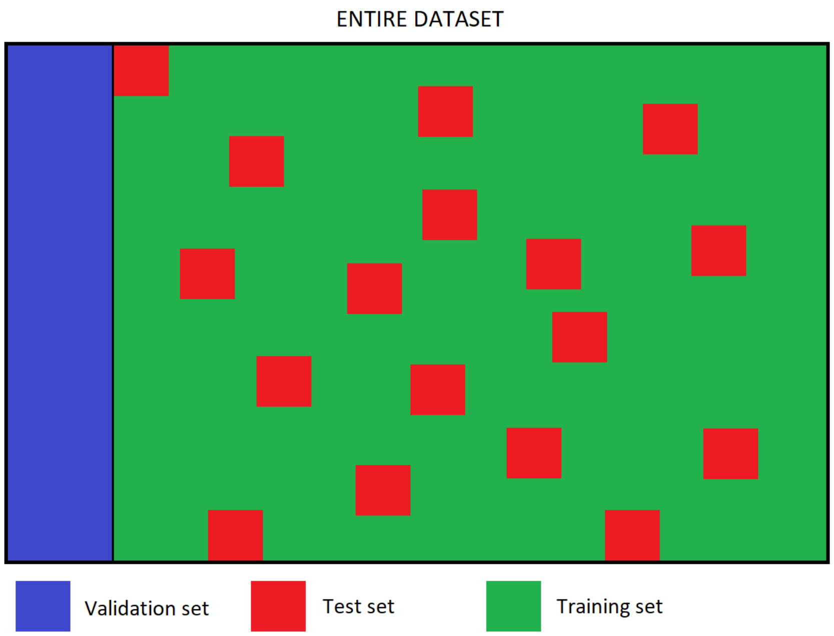


- Creation of a set of random patches



Learning Set / Test Set / Validation Set

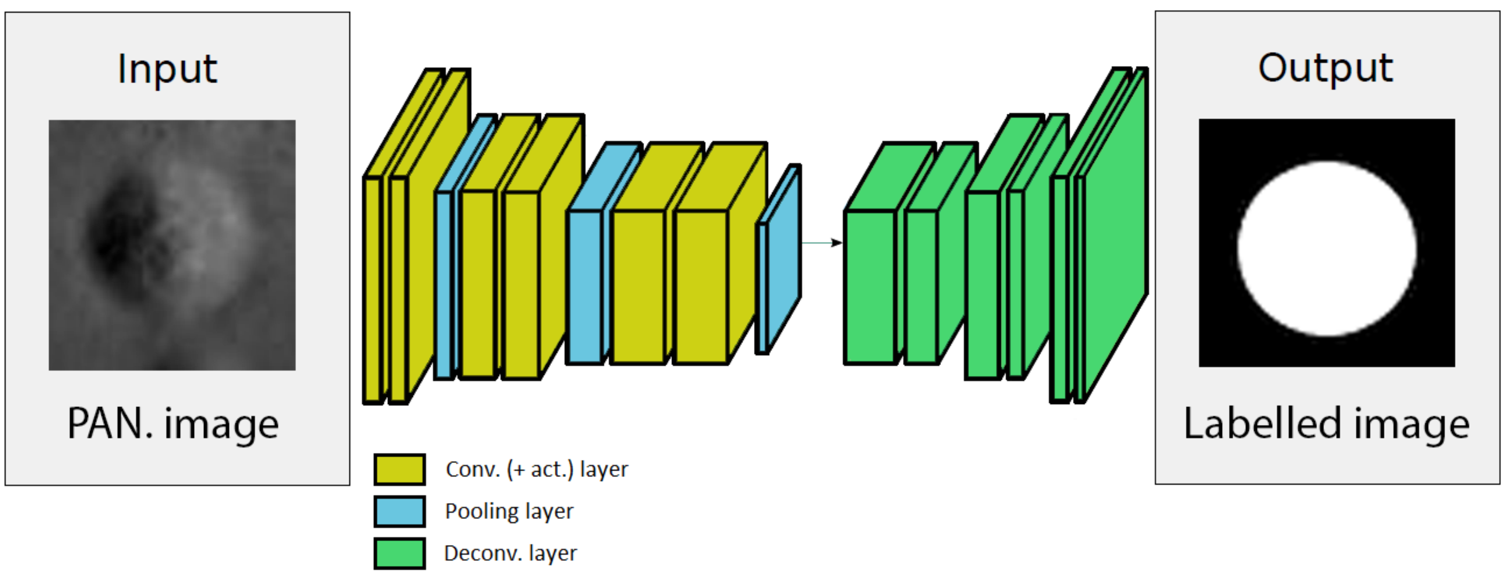
- Train the model with the learning set
- Optimize with the test set
- Assess with the validation set



Description of the model's architecture

Implementation via the TensorFlow library (GoogleBrain) GPU processing using CUDNN (Nvidia)

- Input layer
- Convolution layer
- Activation layer
- Pooling layer
- Deconvolution layer
- Output layer

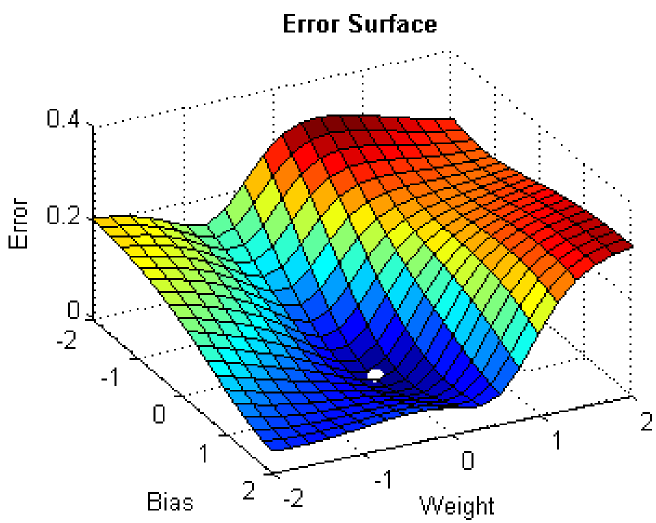


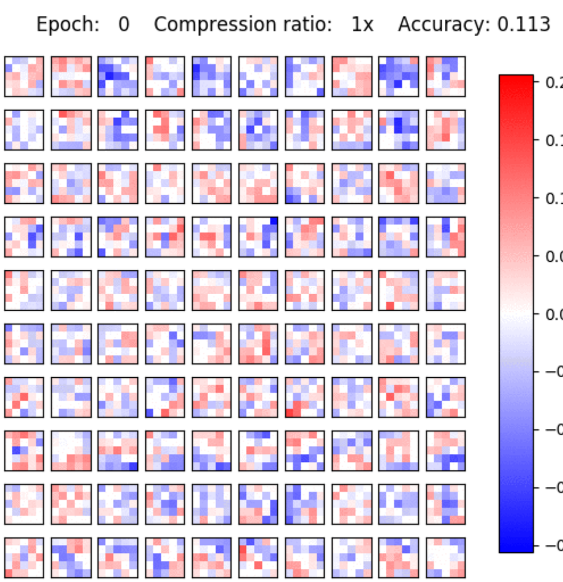
Entrainement du modèle

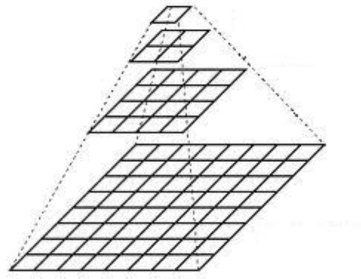
- Ajustement des poids par minimisation d’une fonction de coût
- Cette fonction = entropie croisée

$$H_y(\hat{y}) = -\sum_i \left(y_i * \log \hat{y}_i + (1 - y_i) * \log\left(1 - \hat{y}_i\right)\right)$$

- Minimisation par descente de gradient

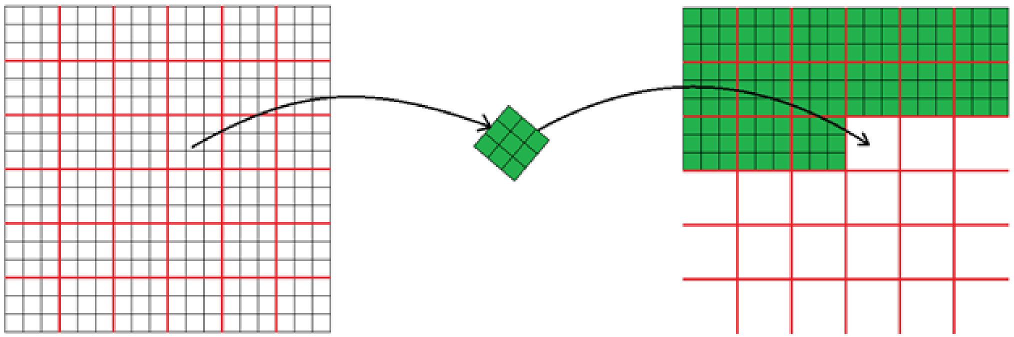






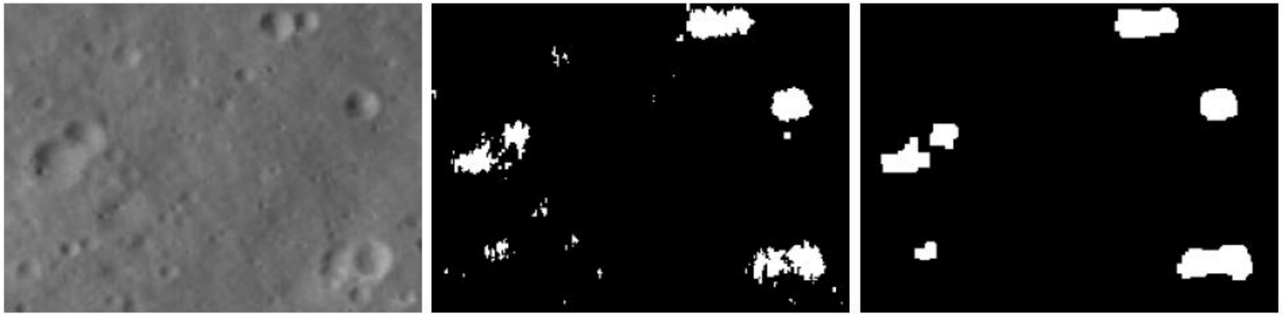
Analysing a scene

- Model pable de detect crater of a specific size
- Creation of a resolution pyramid and application of the model to each floor
- Technical limitations push us to implement an efficient image tiling system



Analysing a scene

- Post process by mathematical morphology to clean the segmanted image



Object extraction

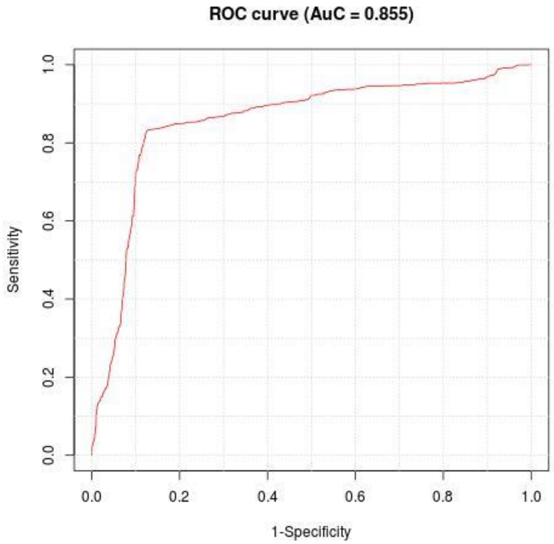
- Object extraction by connected-component labelling algorithms
- Computation of centroid and radius for each component

Framework for an objective evaluation of performances

- Willingness to define an evaluation methodology to enable comparisons between methods
- Error matrix:

		Predicted 0	Predicted 1
Ground Truth	0	TN	FP
	1	FN	TP

- Possibility to extract metrics
  - Recall (or sensitivity)
  - Precision
  - Specificity
  - Accuracy
  - F1-score
  - Intersection over Union
- And build classical ROC curve

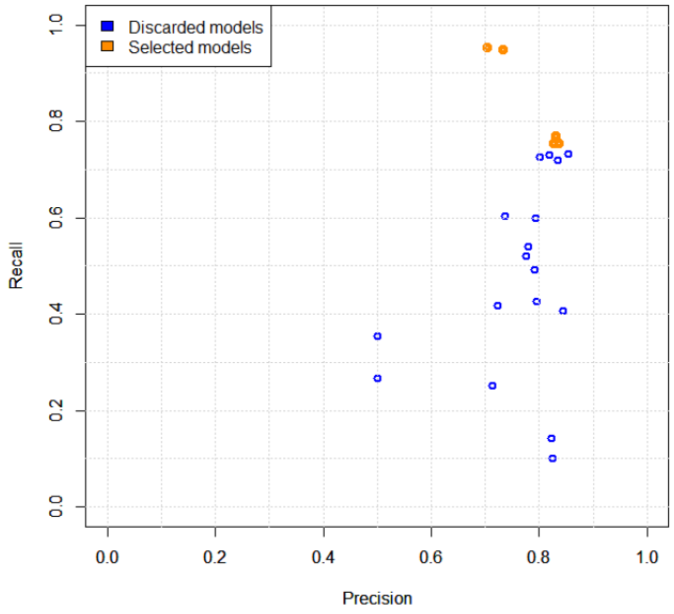


Results (raw)

- Long to produce
- Gradual elimination of non-convincing models
- Important correlation between the sub-dataset
- Important correlation between the metrics

R	Train	Test	Valid
Train		0.947	0.948
Test			0.913
Valid			

R	Precision	Recall	F1-Score	Accuracy	IoU
Precision		0.313	0.397	0.788	0.411
Recall			0.903	0.695	0.920
F1-Score				0.747	0.990
Accuracy					0.776
IoU					

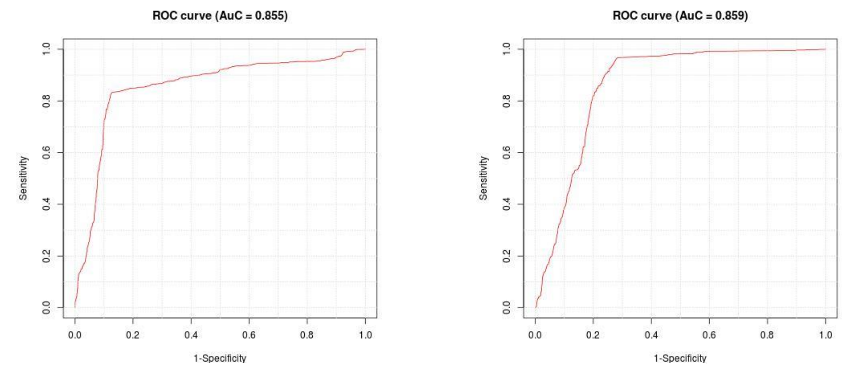


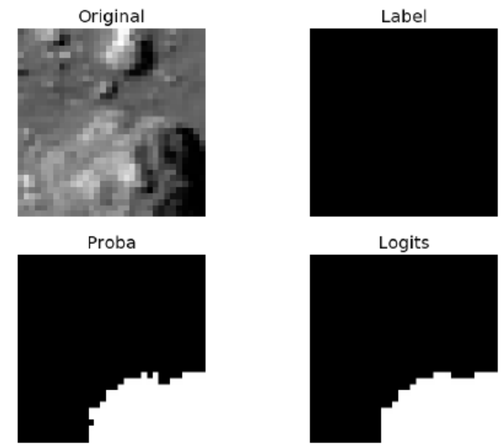
Raw results

- Performances varying according to the model

  (maximize sensitivity of specificity)

- Bad classification of some topographic elements

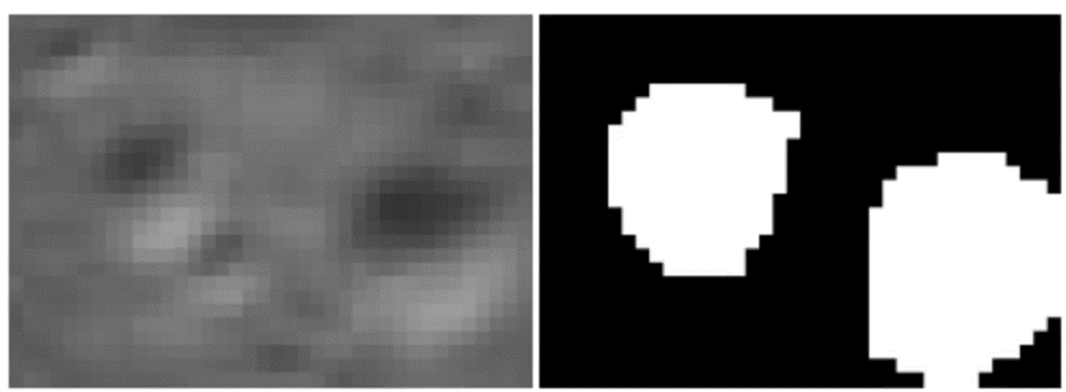




Accuracy ~ 90%

F1-Score ~ 0.8

IoU ~ 0.7



Stratification according to the latitude

- Stratifying the validation set shows that the model is more prone to detect craters near the lunar equator

Stratification according to the data source

- Stratifying the validation set shows that the model is more prone to detect craters on the NAC images than on the orthorectified images
- Detecting craters on another data source gives poor results

Conclusion

- Developpement of a deeplearning model to detect craters
- Contribution to the scientific community by providing an exhaustive set of crater/non-crater annotations available on my GitHub
- The model has some advantages but comparison with litterature is ill-suited

Ressources

NAC images : *goo.gl/7j8CjM*

Ortho-rectified images : *goo.gl/qivZYt*

My GitHub with all data and codes : *github.com/QuentinGlaude/CraterNet*

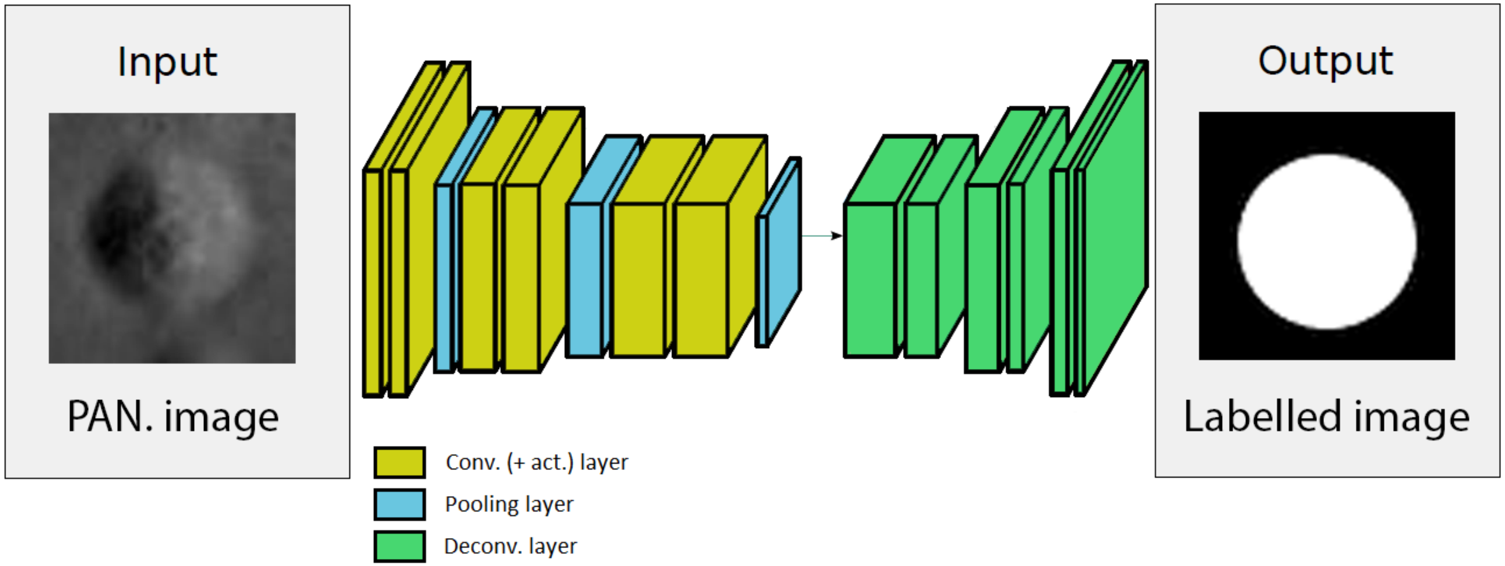
Cytomine Project : *cytomine.be*

Poster :

CraterNet

A Fully Convolutional Neural Network for Lunar Crater Detection Based on Remotely Sensed Data

(Quentin Glaude, session Geomatics)



More info/discussion about resources, GPU processing, Cytomine and other stuff !!