

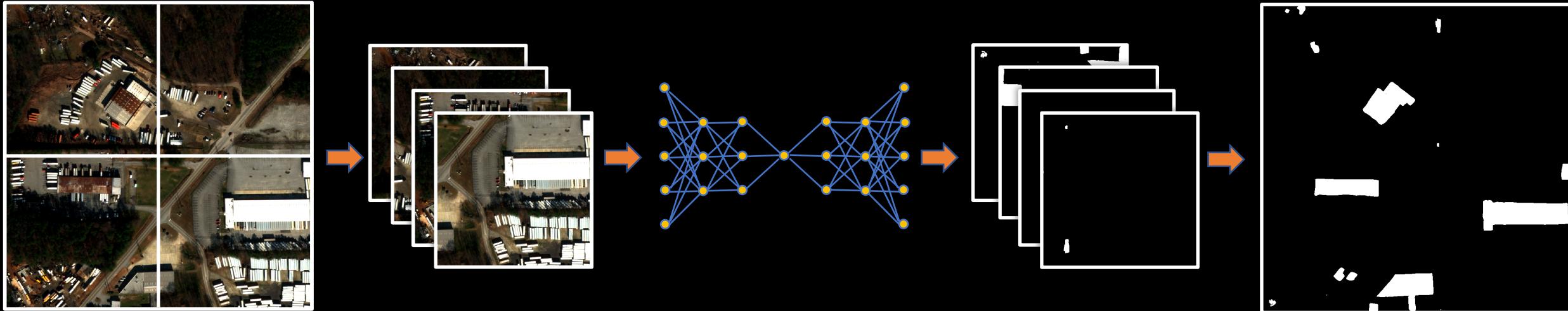
An introduction to neural network inference: Opening the black box



Solaris

From cosmiQworks®

A schematic view of inference



What the neural net sees

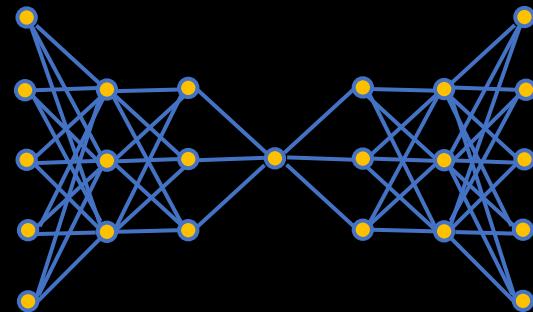


= $\begin{bmatrix} [0.1, 0.2, 0, -0.1, \dots], \\ [0, 0.12, -1, 1.5, \dots], \\ [\text{Etc. Etc. Etc. Etc}\dots\dots\dots] \end{bmatrix}$

What actually *is* a neural net?

In this case...

A series of distortions, shape changes, and other mathematical operations on the input image to convert it into $p(\text{building})$ for each pixel.



= Mathematical operation
(usually a combination of multiplication, addition, non-linearity)



= Values pass between
these sets of operations

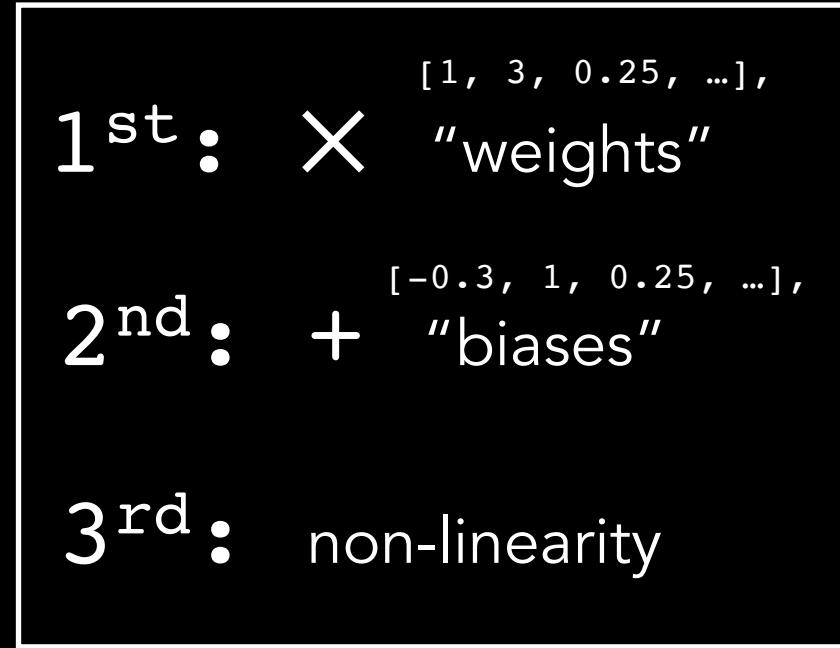
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[[0.1, 0.2, 0, -0.1, ...],  
 [0, 0.12, -1, 1.5, ...],  
 [Etc. Etc. Etc. Etc.....]]
```

What's happening in each ?

Example: one “neuron” in the first layer of a NN



$[[0.1, 0.2, 0, -0.1, \dots],$
 $[0, 0.12, -1, 1.5, \dots],$
 $[\text{Etc. Etc. Etc. Etc.} \dots]]$



[0, 1, 0.33, 0, ...]
Output vector
(or array for convolutions)

Results from input neurons (generally) get concatenated on a new axis when they're passed to the next “layer” of neurons.

What is the non-linear operation in the neuron?

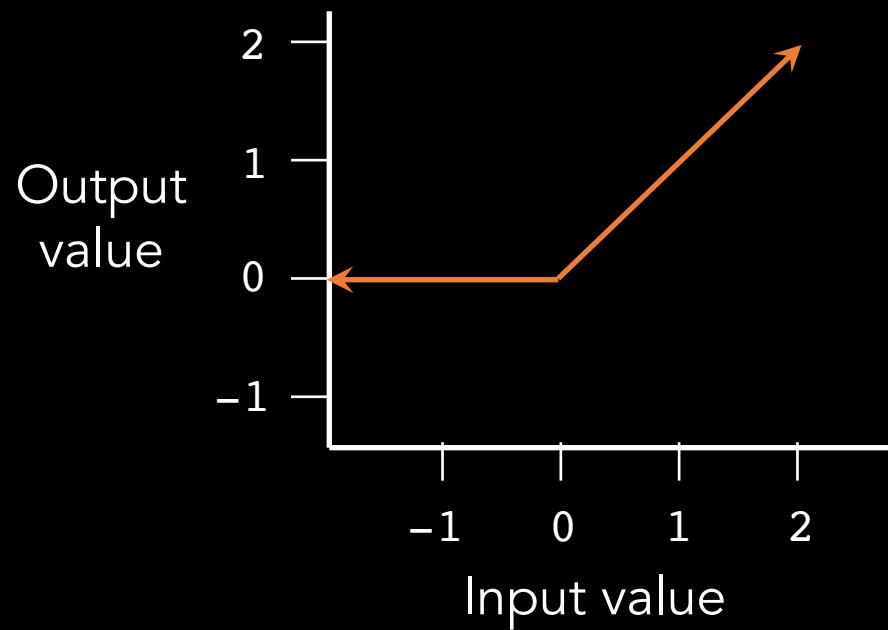
Most commonly Rectified Linear Unit (ReLU):

$$f(x) = \max(0, x)$$

ReLU written as an if-then:

If $x < 0$: $f(x) = 0$
Else: $f(x) = x$

Graphical display of ReLU

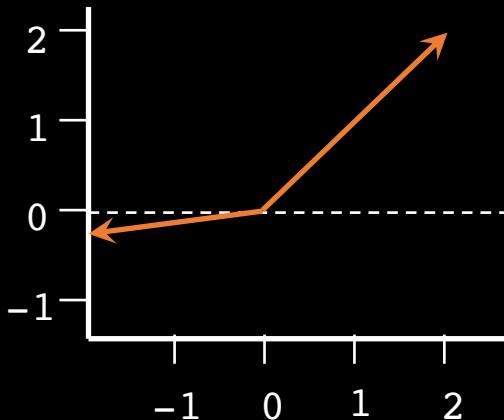


ReLU example:

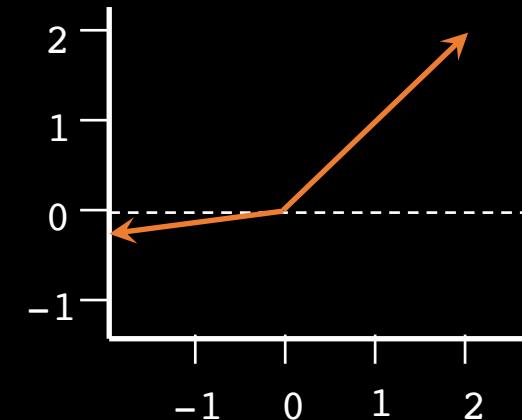
x : [-0.3, 1, 0.33, -2, ...]
ReLU(x): [0, 1, 0.33, 0, ...]

Other common non-linearities (AKA "activations"):

Leaky ReLU:
 $f(x) = \max(\alpha x, x)$
 α is usually in $[0.01, 0.1]$

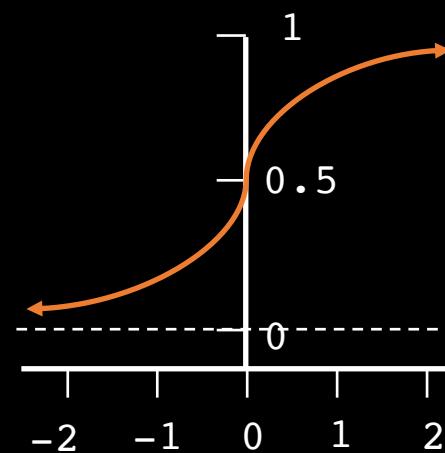


PReLU:
 $f(x) = \max(\alpha x, x)$
model learns α

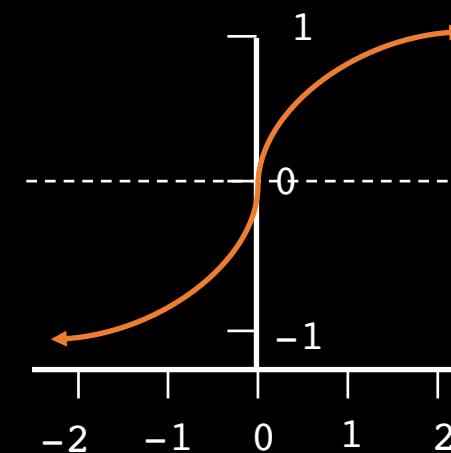


Sigmoid (logistic):

$$f(x) = \frac{1}{1+e^{-x}}$$



tanh:



$$f(x) = \frac{e^x - e^{-x}}{e^x + e^{-x}}$$

What do most segmentation networks look like?

Convolutional neural networks

Layers composed of convolutions rather than simple vector multiplications

Layer values correspond to convolutional filters, usually many filters per layer

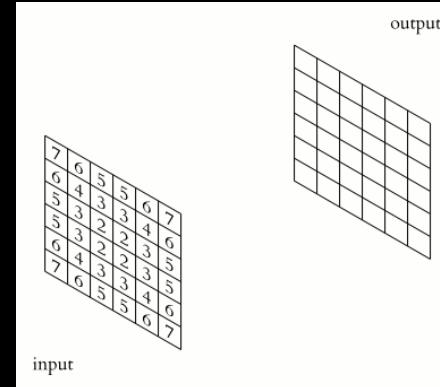
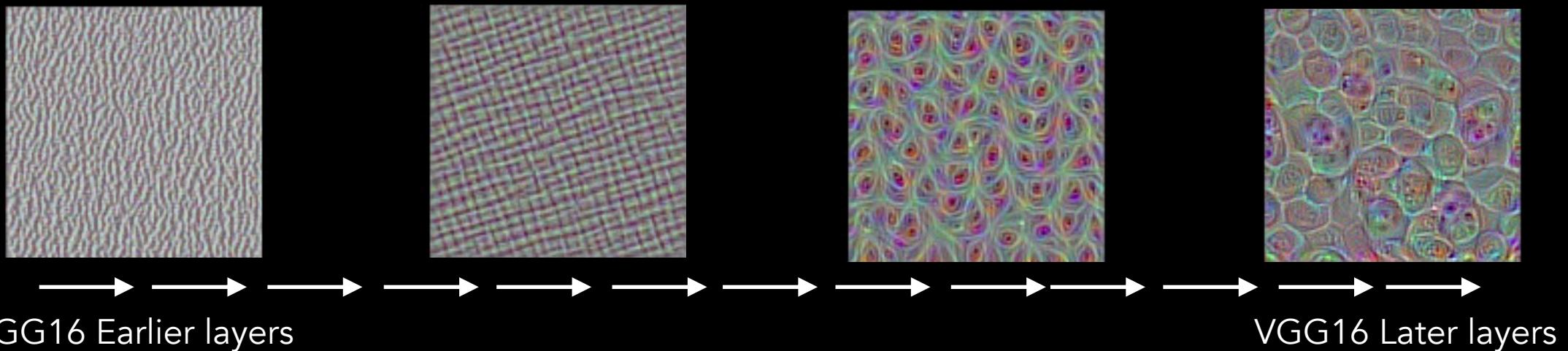


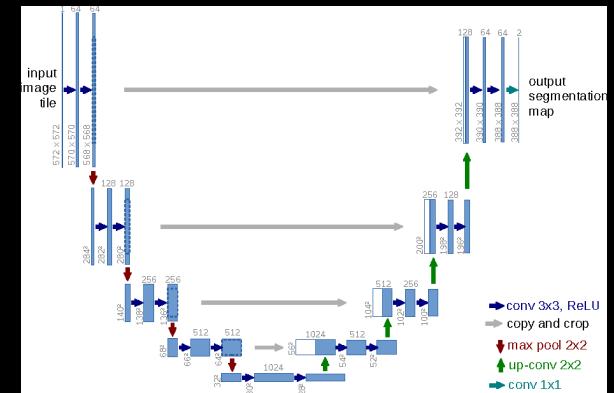
Image credit: Michael Plotke



What do most segmentation networks look like?

U-Nets

Images are compressed in x-y space to generate more compact representations, then re-grown to the original dimensions



<https://arxiv.org/abs/1505.04597>

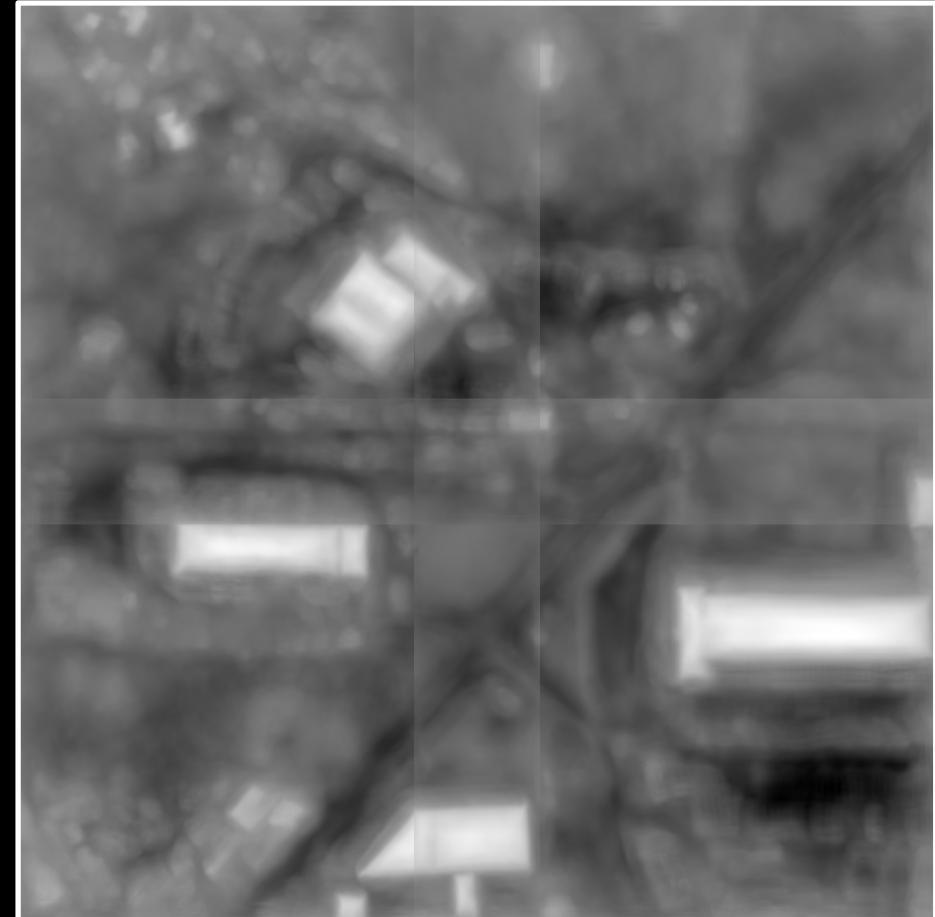
What pre-trained neural nets are currently available in Solaris?

SpaceNet challenge model name	General Architecture	Encoder	Training set	Input shape	# Params (weights + biases)
XD_XD	U-Net	<u>VGG16</u>	MVOI PS RGB	$3 \times 512 \times 512$	29.3M
selim_sef resnet	U-Net	<u>ResNet-34</u>	MVOI PS RGB+NIR	$4 \times 416 \times 416$	30.0M
selim_sef densenet121	U-Net	<u>DenseNet-121</u>	MVOI PS RGB	$3 \times 384 \times 384$	15.6M
selim_sef densenet161	U-Net	<u>DenseNet-161</u>	MVOI PS RGB	$3 \times 384 \times 384$	41.1M

What comes out of the neural net?

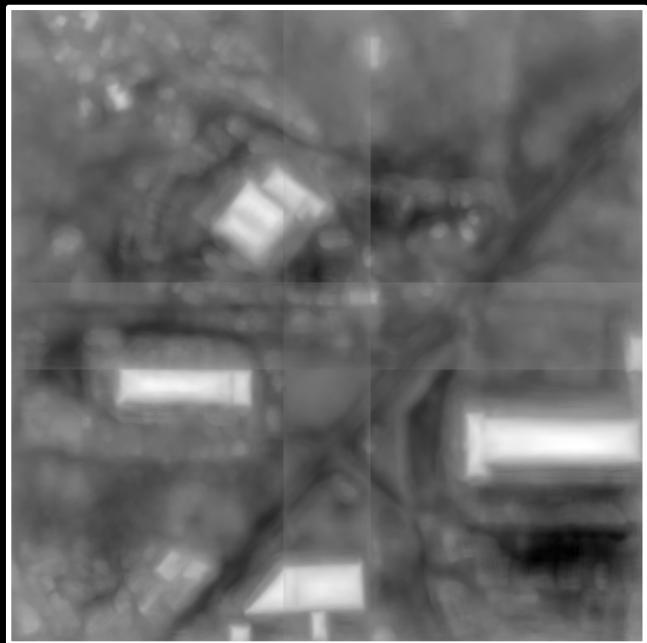


Input image

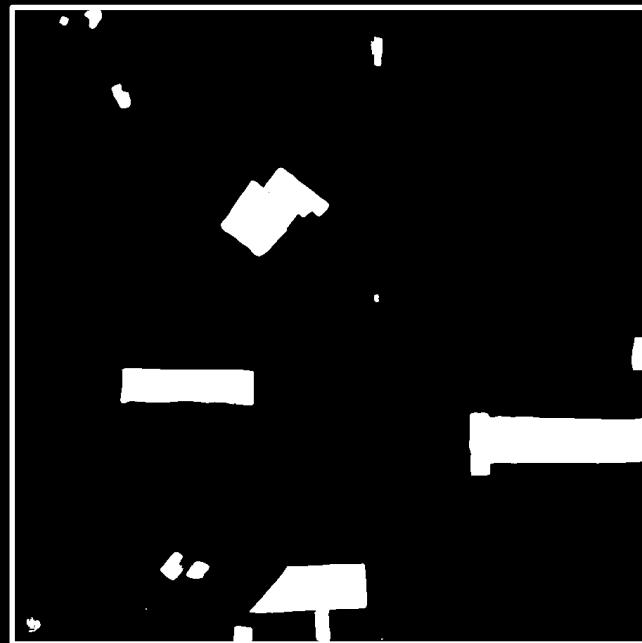


Raw output from XD_XD's model in the intro notebook

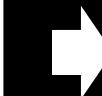
Solaris's automated prediction post-processing pipeline



Raw output from XD_XD's
model in the intro notebook



Binarized output



POLYGON ((745804.5 3726489, 745812.5 3726489, ...
POLYGON ((746007 3726470, 746008.5 3726470, ...
POLYGON ((745825.5 3726436.5, 745826.5 3726436, ...
POLYGON ((745940.5 3726377, 745941 3726377, ...
POLYGON ((746192.5 3726256, 746201 3726256, ...
POLYGON ((745829.5 3726234, 745842 3726234, ...
POLYGON ((746078 3726202.5, 746080.5 3726202.5, ...
POLYGON ((745865 3726103, 745868 3726103, ...
POLYGON ((745880.5 3726096.5, 745883.5 3726096, ...
POLYGON ((745763 3726056.5, 745764.5 3726056.5...)

Georegistered vector labels

Back to the notebook for a post-processing tutorial!