Special Topics in Applications (AIL861)
Artificial Intelligence for Earth Observation
Lecture 13

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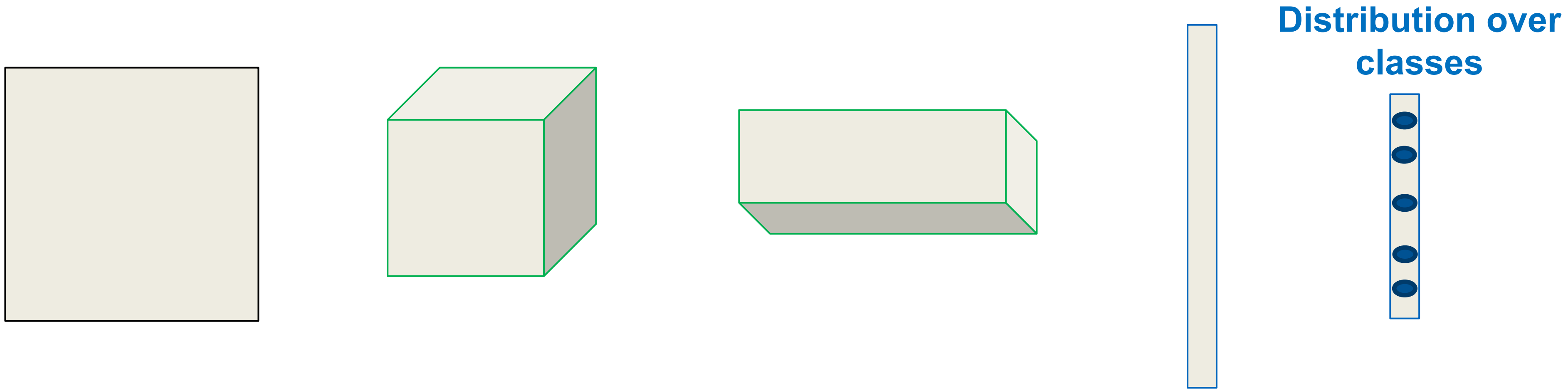
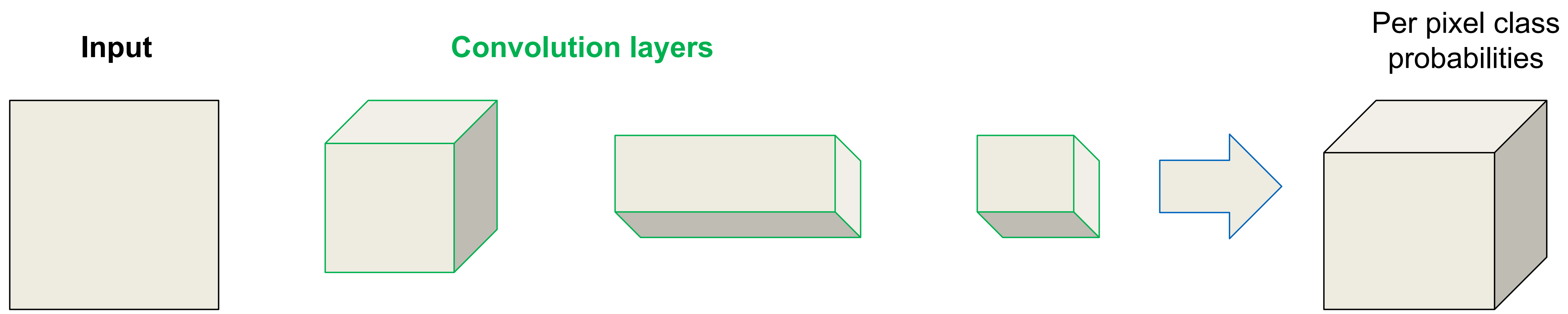
Uncertainty

- A boundary between knowing and not knowing
- Quantifying how much the model knows / or does not know

Classification Network



Segmentation network



Uncertainty Types

- ***Aleatoric***
  - Due to noise inherent in the data
  - Irreducible
- ***Epistemic***
  - Lack of knowledge
  - Reducible
- ***Distributional***

Different Uncertainties

Aleatoric or Data Uncertainty

- ✔ Information data cannot explain.
- ✔ More data might not reduce it.

Epistemic or Model Uncertainty

- ✔ Uncertainty in the model.
- ✔ Can be explained away by increasing training size.

Distributional Uncertainty

- ✔ Induced by some shift in data distribution.

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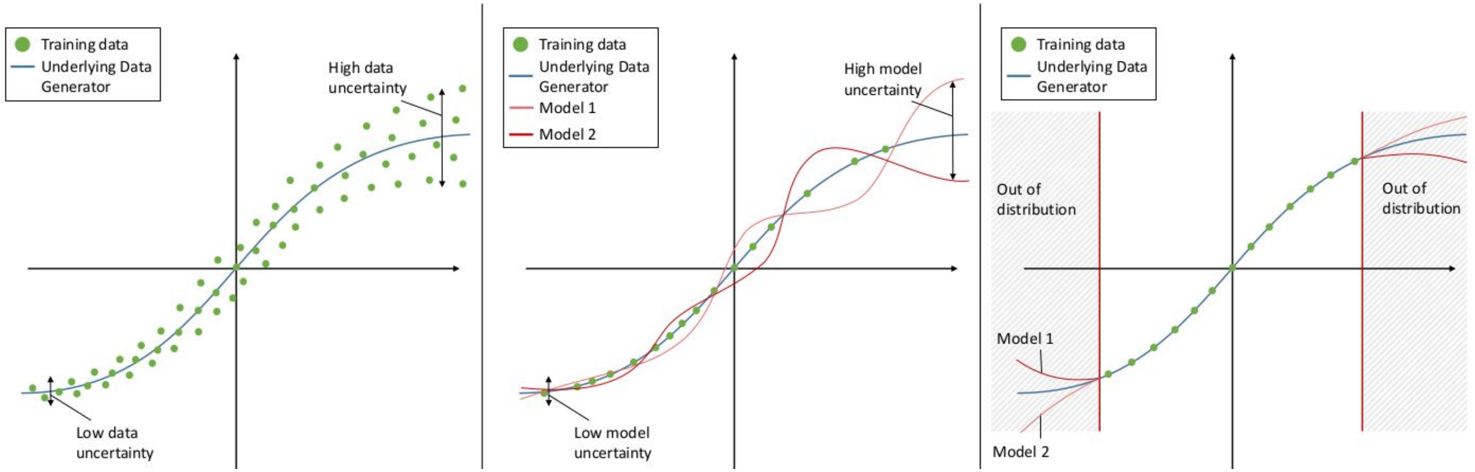


Not Reducible **Reducible** **Reducible**

Domain Differences

- ✔ A model trained solely using images from one domain do not generalize well to the other domains.
- ✔ It is important to know when our model does not know: **out-of-distribution (OOD).**

Concept	In-domain	OOD
Sensor	Sentinel-2	Worldview-2, Sentinel-1, …
Season	Summer	Winter, Autumn, Fall
Geography	Munich	HongKong, New York, …
Open Set Recognition	Classes A, B, C	Classes D, E, F, …

Open Set Problem

- ✔ Training under closed set

- ✔ Deployment under open-set conditions

Adversarial Attack

Image: building

+

Noise
(Not random)

=

To human eyes: still building

To ML method: a different label

Varying degree of noise

Noise or common corruptions

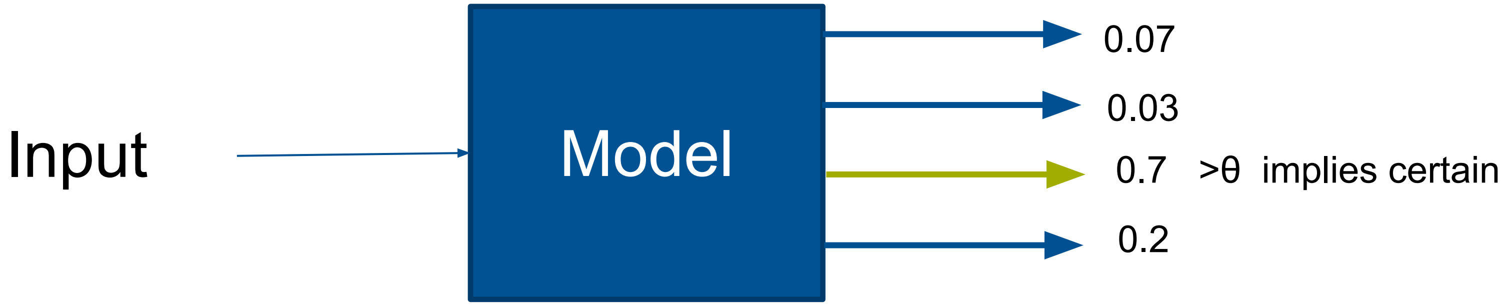
Cifar-C, Benchmarking neural network robustness to common corruptions and perturbations. 2019.

Good News: Self-Supervised

learning improves (in some cases) uncertainty and model robustness.

Using Self-Supervised Learning Can Improve Model Robustness and Uncertainty, 2019

Softmax-Based Uncertainty



U-Net Flood Segmentation

See “Flood segmentation on Sentinel-1 SAR imagery with semi-supervised learning”: an interesting case that combines U-Net based segmentation with softmax based confidence estimation.

Supervised Change Detection

✔ Dependent on the availability of training data.

✔ Yields good result if the training dataset is large.

✔ Yields good result if the training dataset is strongly related to the test data.

(Training and test data are drawn from same distribution)

What is the training dataset is small and localized in some sense (e.g., geographically)?

Small/Localized Training Data

- ✔ Normally during test, we inspect only the final outcome.
- ✔ May provide us with erroneous results even if the model is not confident.
- ✔ Is there a way to tell that my model is not confident on the target scene?

Is there a way to tell that my model trained on images solely from Paris, works on Montpellier or Dubai?

Softmax function

- ✔ Transforms the (unnormalized) output of K units (which is e.g. represented as a vector of K elements) of a fully-connected layer to a probability distribution (normalized).
- ✔ Output is represented as a vector of K elements, each of which is between 0 and 1 (a probability) and the sum of all these elements is 1 (a probability distribution).
- ✔ Correctly classified examples tend to have greater maximum softmax probabilities than erroneously classified and out-of-distribution examples.

"A baseline for detecting misclassified and out-of-distribution examples in neural networks.“ ICLR 2017

Max-softmax

- ✓ For binary CD, binary prediction: z_0, z_1
- ✓ z_{0pt}= max(z_0, z_1)
- ✓ Confidence indicator β_j is mean of z_{0pt} over all pixels in the scene.

AI4EO

Relative Confidence Evaluation

Test city	Sensitivity	Specificity	Kappa	Reliability (β'_j)
Montpellier	47.41	99.06	0.57	1
Rio	31.53	98.30	0.37	0.95
Brasilia	15.55	97.63	0.13	0.58
Valencia	20.95	96.20	0.04	0.45
Dubai	7.12	96.81	0.06	0

“Trusting small training dataset for supervised change detection.“ IGARSS 2021