AI4EO

Special Topics in Applications (AIL861)
Artificial Intelligence for Earth Observation
Lecture 2

Challenges

✔ Challenge 1: Many applications

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Applications

- ✔ Environmental monitoring
- ✔ Infrastructure monitoring
- ✔ Climate change
- ✔ Agriculture and food security

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- ✔ Environmental monitoring
- ✔ Infrastructure monitoring
- ✔ Climate change
- ✔ Agriculture and food security

Forestry
Urban Area
Vegetation
Sea and river
Glaciers

Species classification
Deforestation detection
Bio-mass/volume detection
Insect infection detection

Challenges

✔ Challenge 2: Active and passive sensors capture images with significantly different characteristics.

Challenges

✔ Challenge 3: Even within same category of sensor, there can be significant variation in the characteristics of the individual sensor, e.g., spatial, spectral, temporal variation.

We discussed challenge 3 wrt passive sensors. In this lecture, we will discuss this wrt active sensors.

Active sensors

- ✔ Synthetic Aperture Radar (SAR)
- ✔ Light detection and ranging (LiDAR)
- ✔ Provides information about terrain

Active sensors - advantages

- ✔ Can be used in night.
- ✔ Can be (mostly) used irrespective of weather condition.
- ✔ Can compute the difference / ratio of energy sent and received.
- ✔ Time of travel can be computed.

Synthetic Aperture Radar

- ✔ Can be different bands – X, C
- ✔ Different polarizations

Synthetic Aperture Radar

Different SAR bands

Band	Frequency	Application
X	8-12 GHz	High resolution monitoring, applications that need little penetration into vegetation
C	4-8 GHz	Applications that need low to moderate penetration
L	1-2 GHz	Biomass and vegetation mapping; high penetration applications

LiDAR

- ✔ Point cloud
- ✔ Advantageous for topographic data collection
- ✔ Forest mapping
- ✔ Monitoring landslide prone zone

LiDAR

✔ Given a LiDAR point cloud dataset, which one will you use: a generic CNN used for image classification or a PointNet?

For a LiDAR point cloud dataset, it would be more appropriate to use a PointNet instead of a generic CNN used for image classification. LiDAR point clouds are a type of 3D data that capture the geometry of objects in the environment by measuring the distances from a sensor to the objects. Point clouds have different characteristics than 2D images, such as irregular and unstructured data, missing data, and large amounts of redundant information.

A generic CNN used for image classification is designed to work with 2D images and is not well-suited to processing 3D point cloud data. It lacks the ability to handle the irregular and unstructured nature of point cloud data, and it also lacks the ability to capture the spatial relationships between the points in a point cloud.

On the other hand, PointNet is a type of deep learning architecture specifically designed for processing point cloud data. It is designed to handle the irregular and unstructured nature of point cloud data and to capture the spatial relationships between points. PointNet can also handle missing data and redundant information in point clouds, making it a more suitable choice for processing LiDAR point cloud data.

Therefore, if you have a LiDAR point cloud dataset, it would be more appropriate to use a PointNet instead of a generic CNN used for image classification, in order to effectively process and extract meaningful information from the 3D point cloud data.

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More challenges

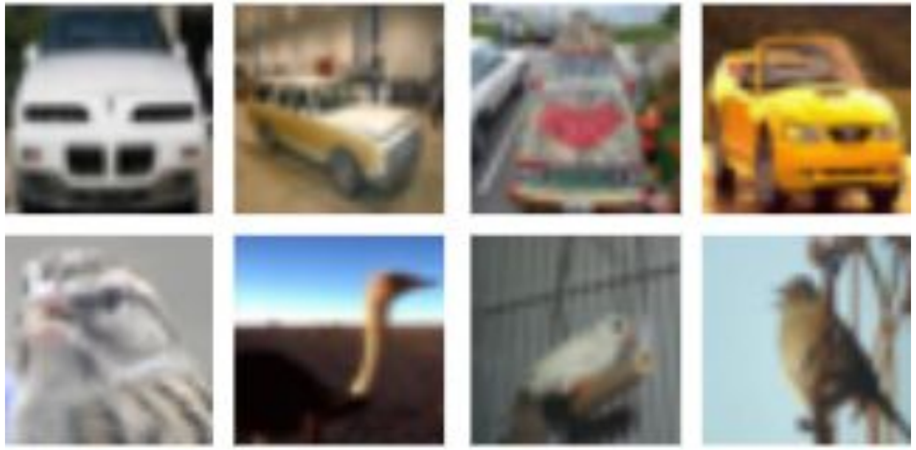
Label?

What type?

CV datasets

Automobile

Bird



Examples from CIFAR-10 dataset, source: https://www.cs.toronto.edu/~kriz/cifar.html

A typical RS dataset

Building, also road, cars

Example from UC Merced

Multi-label

- ✔ Single image = many labels
- ✔ Ideally semantic segmentation is preferred task in EO

Challenges

- ✔ Challenge 4: Ideally images contain more than one category/class of interest in a single image.

Label?

How?

Manual annotation is difficult

- ✔ Manually annotating every pixel is always difficult.
- ✔ What if the task is itself not intuitive?

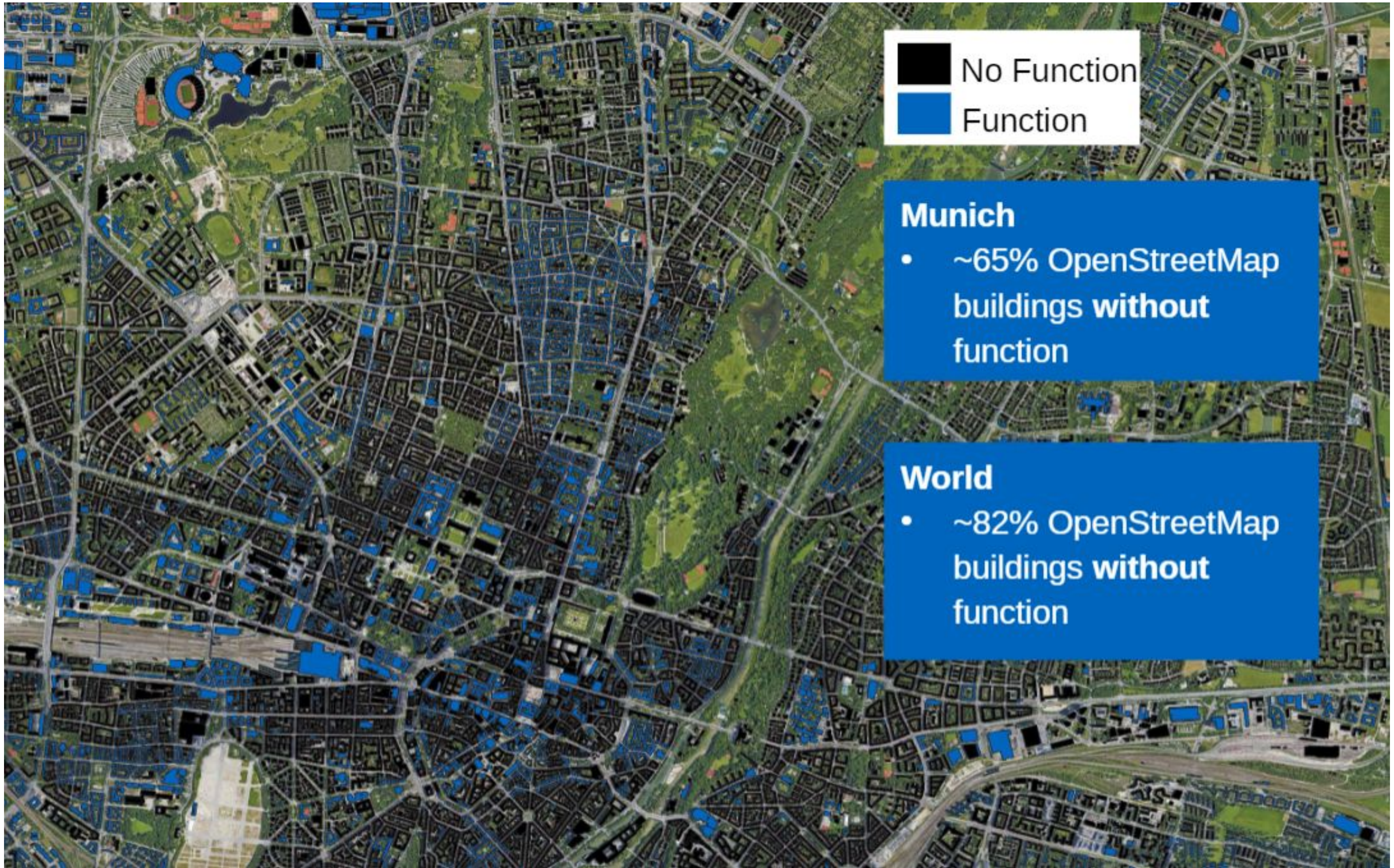
Challenges

✔ Challenge 5: Labeling may require extensive domain knowledge.

Label?

How (continued)?

Using OSM



Ack: Matthias H. (TUM) for this slide.

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OSM misalignment

- ✔ OSM georeferencing.
- ✔ Remote sensing images itself may have georeferencing issue, e.g. Sentinel-2 about 10 m.

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Challenges

✔ Challenge 6: Weak labels are often available, however they can be sparse and inaccurate.

Big data

Big data EO

- ✔ Data continuously collected.
- ✔ Especially LR data may be freely available.
- ✔ However, difficult to label.

Challenges

✔ Challenge 7: Large amount of data, however mostly unlabeled.

Multi-Sensor (complementary)

Multi-Sensor EO

- ✔ Using multi-sensor for the same problem.
- ✔ One sensor may complement the other.
- ✔ However, can they be processed using weight-sharing networks?

Multi-Modality

- ✔ Building type classification: images + tweets.
- ✔ Can they be processed using similar architectures?

Challenges

✔ Challenge 8: Simultaneous use of multiple sensor/modality can be challenging.

Spectral-Spatial considerations

Spectral or Spatial

- ✔ Depending on spatial resolution.

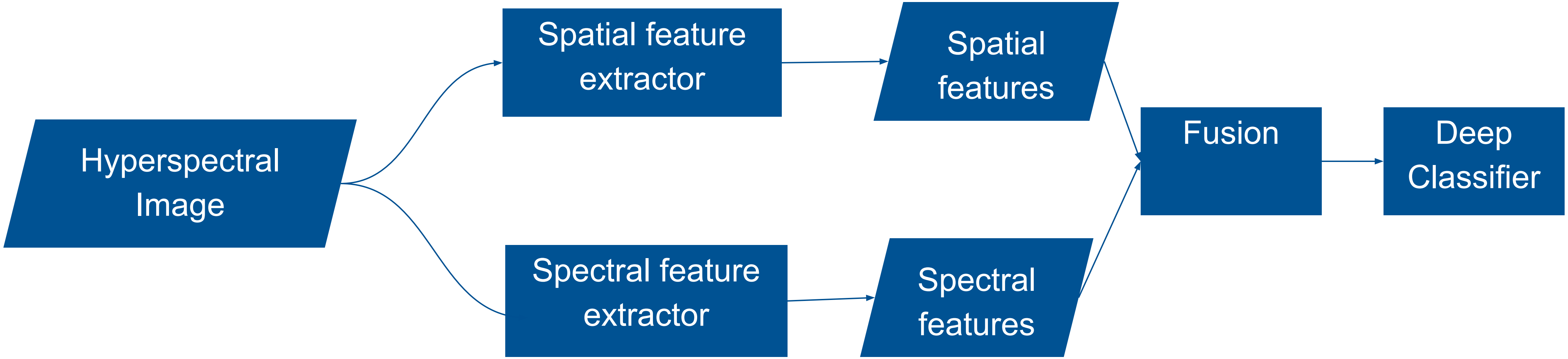
- ✔ Depending on number of bands.

Different spatial resolution within same sensor

Band	Resolution	Central Wavelength	Description
B1	60 m	443 nm	Ultra Blue (Coastal and Aerosol)
B2	10 m	490 nm	Blue
B3	10 m	560 nm	Green
B4	10 m	665 nm	Red
B5	20 m	705 nm	Visible and Near Infrared (VNIR)
B6	20 m	740 nm	Visible and Near Infrared (VNIR)
B7	20 m	783 nm	Visible and Near Infrared (VNIR)
B8	10 m	842 nm	Visible and Near Infrared (VNIR)
B8a	20 m	865 nm	Visible and Near Infrared (VNIR)
B9	60 m	940 nm	Short Wave Infrared (SWIR)
B10	60 m	1375 nm	Short Wave Infrared (SWIR)
B11	20 m	1610 nm	Short Wave Infrared (SWIR)
B12	20 m	2190 nm	Short Wave Infrared (SWIR)

Source:https://gisgeography.com/sentinel-2-bands-combinations/

Hyperspectral image classification



Challenges

✔ Challenge 9: Balancing between spatial and spectral features.

Course content?

Remote sensing or Machine Learning ?

✔ Not a course for Remote Sensing.

✔ Not another course for Machine Learning.

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Lecture Hours - Content

4-6	Different Types of Supervision
7-9	Semantic Segmentation
10-15	Change Detection
16-18	Applications: Urban Remote Sensing
19-21	Hyperspectral Image Analysis
22-27	Multi-Sensor Fusion
28-33	Applications: Agriculture and Other
33-39	Explainability and Uncertainty
39-42	Climate AI

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Evaluation

- ✔ Traditional evaluation:
- ❑ Mid sem (15)
- ❑ End sem (25)
- ❑ Assignments (10)

- ✔ Presenting a paper (15)

- ✔ Project (35 + up to 5 bonus)

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Possible Project Topics

- ✔ Building detection in sub-Saharan Africa.
- ✔ Domain generalization with a Graph Neural Network based model.
- ✔ Alleviating requirement of out-of-distribution training data by using synthesized data.
- ✔ Multi-sensor classification.