An Introduction to Deep Learning with CNNs Applied on Earth Observation Data

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An Introduction to Deep Learning with CNNs Applied on Earth Observation Data

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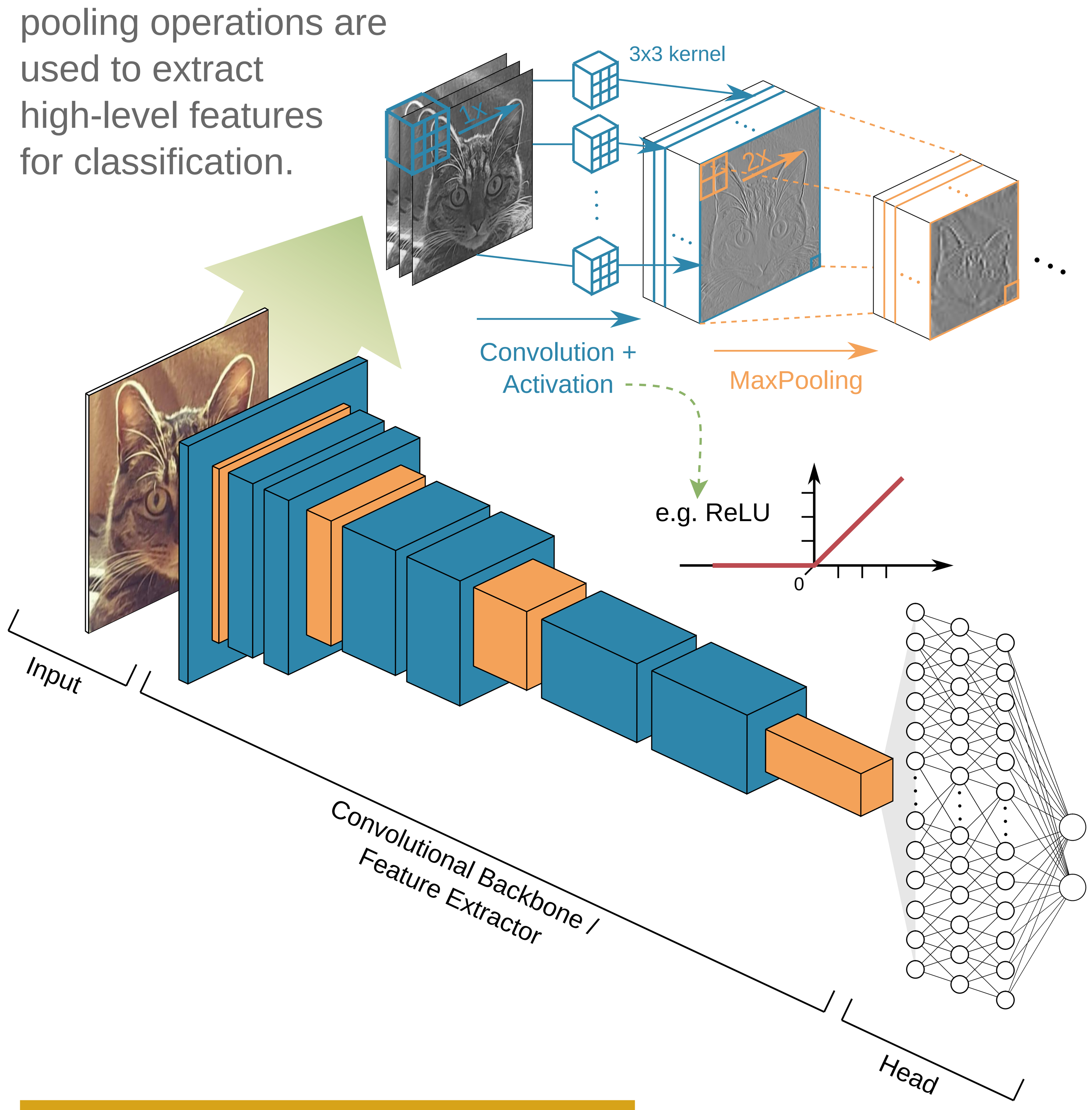
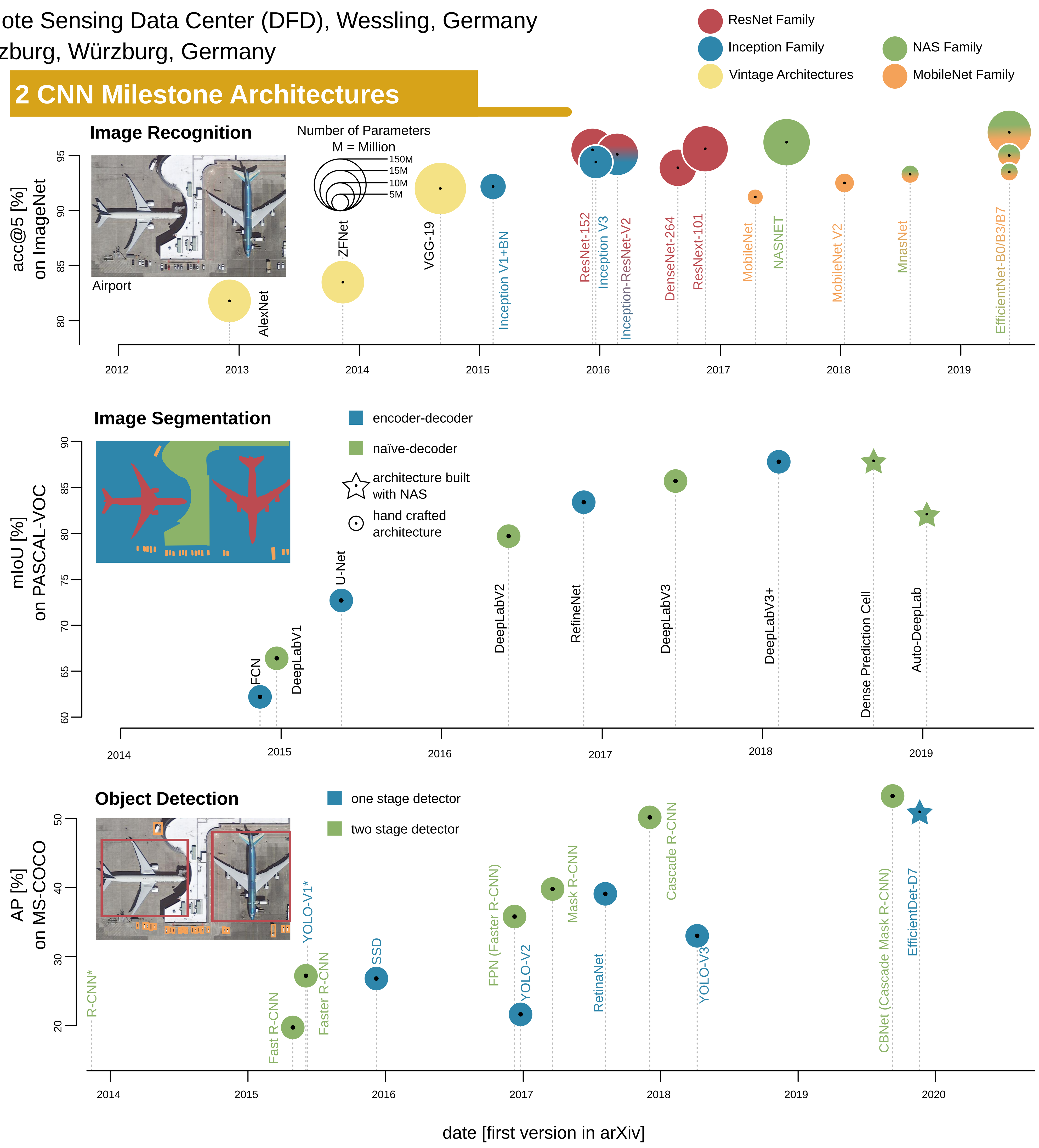
1 Motivation

Since 2012, Deep Learning with Convolutional Neural Networks (CNNs) is the state of the art approach for image recognition (IR), segmentation (IS) and object detection (OD). CNNs have mainly been developed in Computer Vision (CV). Here we introduce the evolution of CNNs in CV and its transition to Earth Observation (EO) applications, by reviewing CV [1] and EO [2] publications from 2012 to late 2019. Below a CNN for IR is depicted, which shows how convolution and pooling operations are used to extract high-level features for classification.

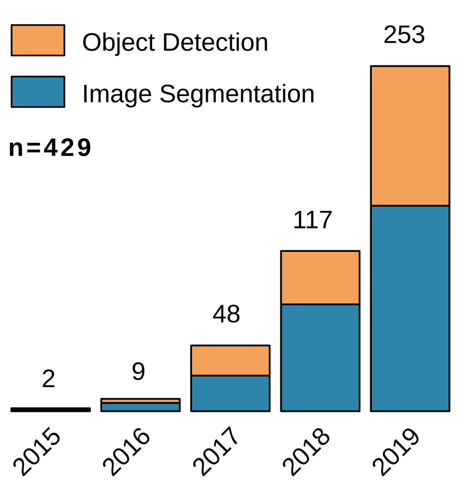


2 CNN Milestone Architectures



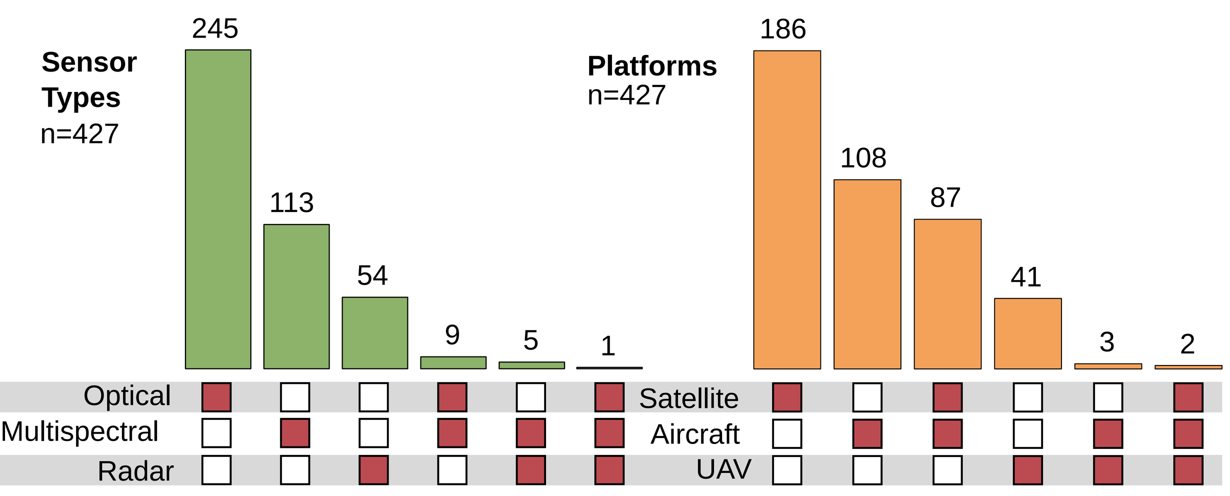
IIn IR, first relatively shallow vintage architectures with many parameters were used. Later, with concepts from Inception and ResNet, deeper networks with fewer parameters became possible. Lately, parameter efficient designs are developed. With FCN in 2014 a model design was proposed, that per-forms image segmentation in one pass of the entire image. The U-Net model and those from the DeepLab family are today the most widely used and adapted. For OD, two-stage detectors are more accurate but need more pro-cessing power. Still, the well established R-CNN models are the most widely exploited and adapted models, also due to their intuitive modular design.

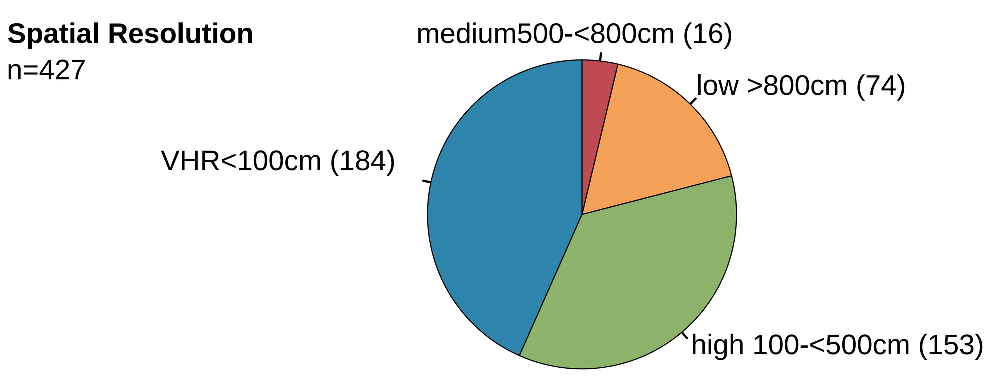
3 CNNs in Earth Observation



In order to give an overview of the most widely investigated data, applications, and CNN architectures in EO, 429 publi-cations in 16 EO journals were reviewed. Overall they picture CNNs in an advanced transition phase from CV to EO. A majority of these studies have a focus on method development and proof of concepts.

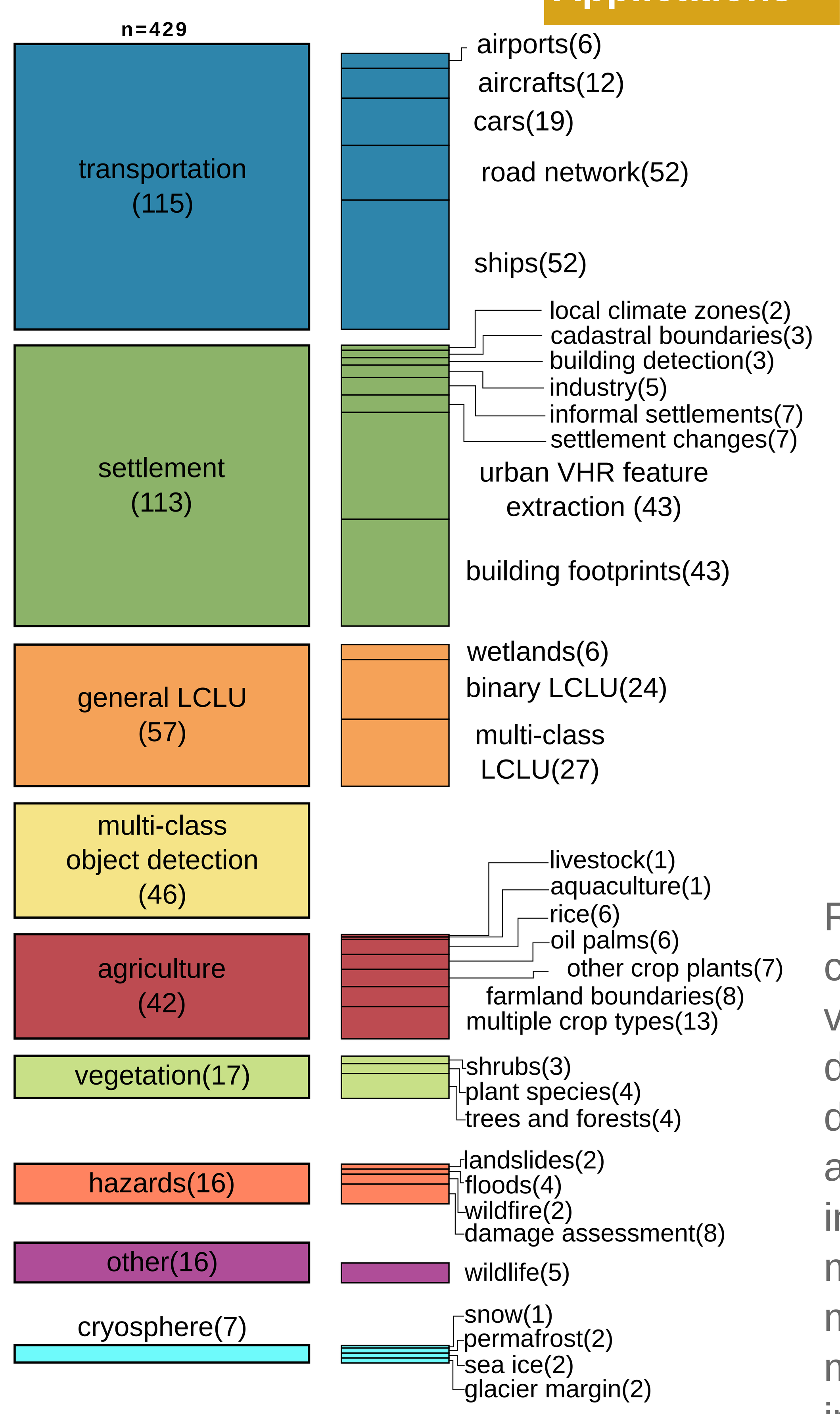
Sensor and Data Types



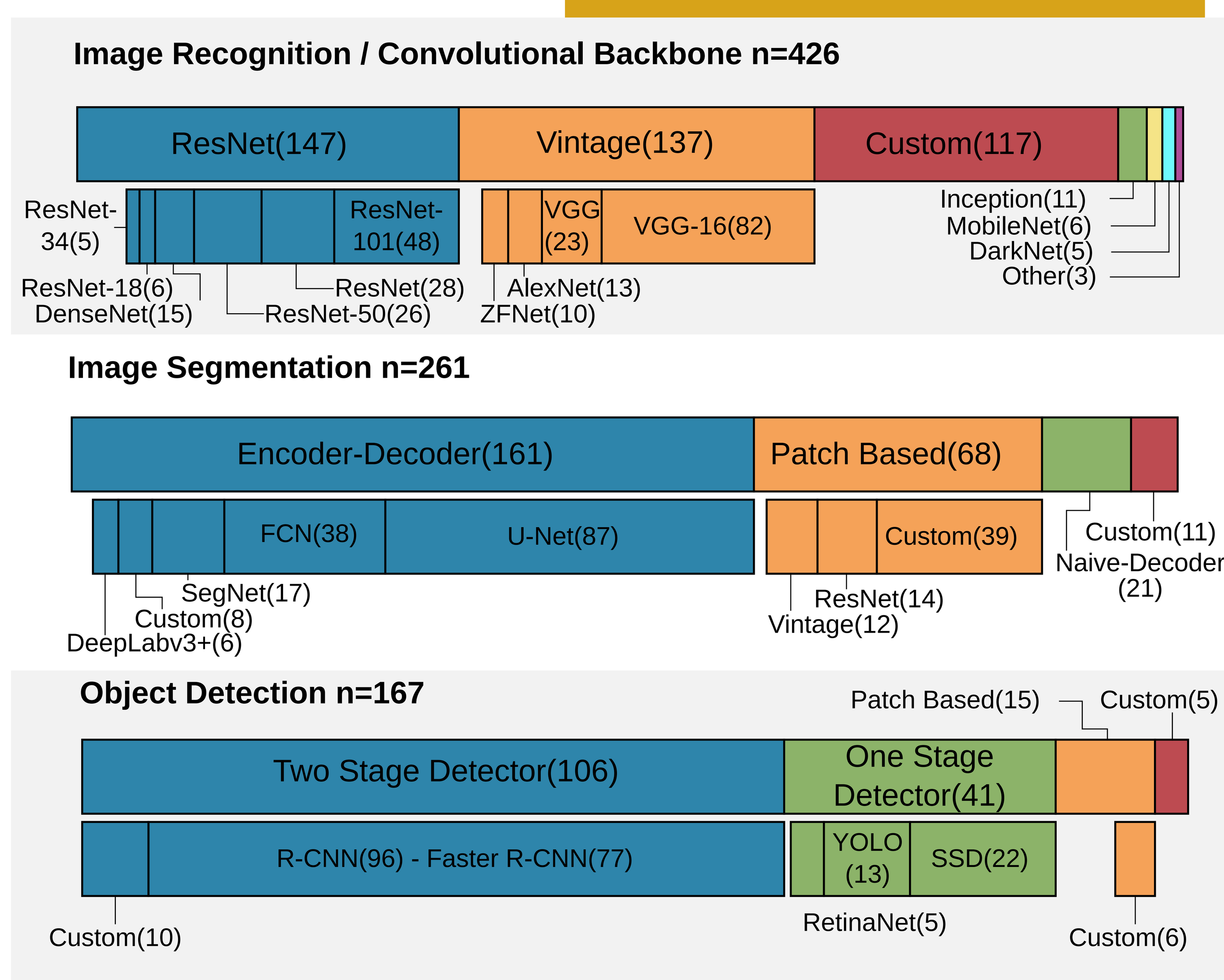


The large majority of the used data are optical images with a high to VHR spatial resolution detected from space. The usage of higher spatial resolution reflects the strength of CNN to extract spatially rich feature information. Those features are of high importance when looking for objects and classes, especially if they are small and with fine-grained details. CNNs are used in applications to detect entities in, e.g. transportation, settlements or agricultural, as shown to the right. However, to meet the requirements of remotely sensed data, adaptations of the CNNs are necessary.

Applications



CNN Architectures in EO



ResNet and VGG designs are the most commonly used convolutional backbones for feature extraction. Hereby, shallower variants are chosen in EO as in CV. In IS the encoder-decoder designs are the most prominent, especially the U-Net. These designs support a precise localisation during the decoding process and therewith are essential for small targets which are prominent in EO data. In OD, the Faster R-CNN is the most established model. With adaptations to predict rotated boxes or even instance masks, it reaches high performances in EO. Overall, the findings made in adaptations for EO will lead to a surge of studies which investigate objects dynamics.

[1] Hoeser, T. and Kuenzer, C. 2020 Object Detection and Image Segmentation with Deep Learning on Earth Observation Data: A Review-Part I: Evolution and Recent Trends. In: Remote Sensing, 12(10), 1667.
[2] Hoeser, T.; Bachofer, F. and Kuenzer, C. 2020 Object Detection and Image Segmentation with Deep Learning on Earth Observation Data: A Review-Part II: Applications. In: Remote Sensing, 12(18), 3053.

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