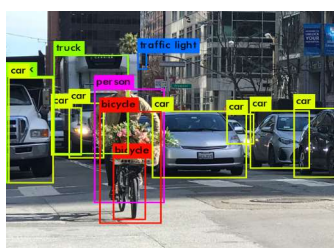
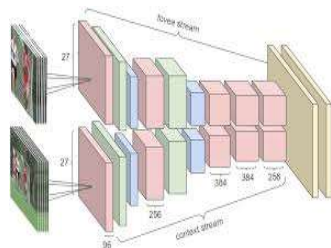


Neural Networks and Deep Learning



The first lecture is scheduled on January 12, 2027 at 9:00

Visit the course web page for registration and connecting to the channel.

<http://retis.sssup.it/~giorgio/courses/neural/nn.html>

Giorgio Buttazzo

Objectives: The aim of this course is to provide key concepts and methodologies to understand neural networks, explaining how to use them for pattern recognition, image classification, object detection and tracking, signal prediction, language processing, and data generation.

Hours: 40. CFUs: 4.

Course program

1. **Introduction to neural computing.** From classical AI to neural networks. Main network structures and learning paradigms. Hopfield networks and associative memories.
2. **Unsupervised learning and clustering algorithms.** Dimensionality reduction: Principal component analysis and Self-organizing maps. Hard clustering algorithms. Soft clustering algorithms.
3. **Supervised learning.** From the Perceptron to backpropagation. Applications of multi-layer networks. Performance evaluation metrics. Managing overfitting and class imbalance. Radial Basis Function networks. Physics-Informed Neural Networks.
4. **Deep networks.** Problems in training deep networks: overfitting and vanishing gradient. Regularization and dropout methods. Autoencoders and convolutional networks.
5. **Networks for classification.** Examples of CNNs and their key novelties: LeNet-5, AlexNet, VGG-Net, GoogLeNet, ResNet, Inception family, SqueezeNet, DenseNet, SENet, NASNet.
6. **Networks for object detection.** Two-stage detectors (the R-CNN family). Single-stage detectors (YOLO and SSD). Performance metrics. Pyramid networks (FPN, RetinaNet, the YOLO family).
7. **Networks for image segmentation.** Semantic, instance, and panoptic segmentation tasks. Fully Convolutional Network, U-Net, SegNet, ICNet, Mask R-CNN, YOLO-ACT.
8. **Recurrent neural networks.** Backpropagation through time. Language modeling. Word embedding. Machine translation. The attention mechanism.
9. **Transformers.** Encoder-Decoder architectures. Positional encoding. Self-attention and multi-head attention mechanisms. Masked attention.
10. **Semi-supervised learning.** K-nearest neighbors. Self-training algorithms. Co-training. One-shot learning. Siamese networks. Zero-shot learning. Contrastive learning.
11. **Neural networks for object tracking.** Generic object tracking. Tracking by detection: SORT, DeepSORT, FairMOT, BYTetrack.
12. **Generative networks.** Generative autoencoders, Generative adversarial networks (GANs), GANs for style transfer. Variational Autoencoders, Diffusion models.