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XXXV Cycle

Deep neural networks for multimedia signal processing

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Research context and motivation

Point cloud processing via graph convolutional neural network

- Point clouds are an **unordered collection 3D-points** sampled from an underlying surface
- **Challenging applications**: autonomous driving, medical imaging, virtual reality etc.
- Traditional methods for point cloud processing are optimization based
- Extending deep learning approaches to point clouds is a difficult task (**irregular domain** and **permutation-invariance**)
- **Graph-convolutional neural networks**: able to deal with irregular domain

Signal compression via implicit neural representation

- There is a growing interest in exploiting **deep neural networks for signal compression**.
- **Existing** end-to-end signal compression schemes using neural networks are largely based on an **autoencoder-like structure**
- Recently In 3D rendering problems neural implicit representations showed great capabilities in fitting **high-frequency components** of the signals.

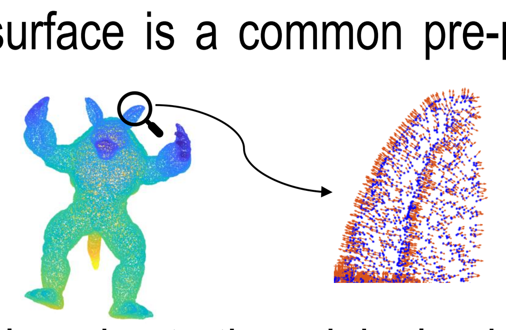
Lidar processing using transformer-based backbone

- Many **deep learning methods** for point cloud **are for indoor (dense) or small data**.
- **LiDAR** point clouds (autonomous driving) have more **sparse points** (varying point density)
- Lidar **feature representations** are mainly 3D-2D projections or voxel-based partitions → loss of geometric 3D structures

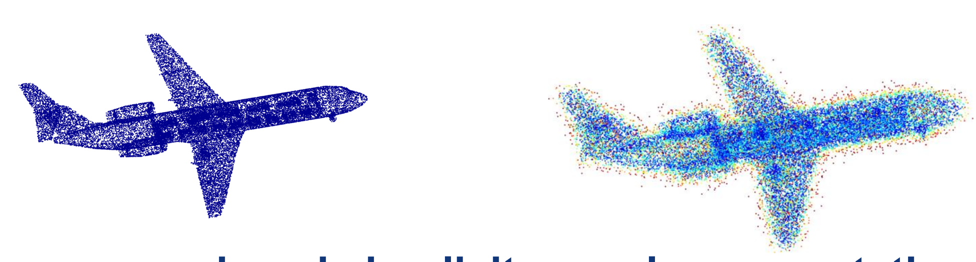
Addressed research questions/problems

Point cloud processing via graph convolutional neural network

- Point cloud normal estimation:
  - Estimating the normal vector of the surface is a common pre-processing step of a large variety of algorithms



- Point cloud denoising + outlier removal:
  - acquisition methods insert non negligible noise to the original point cloud

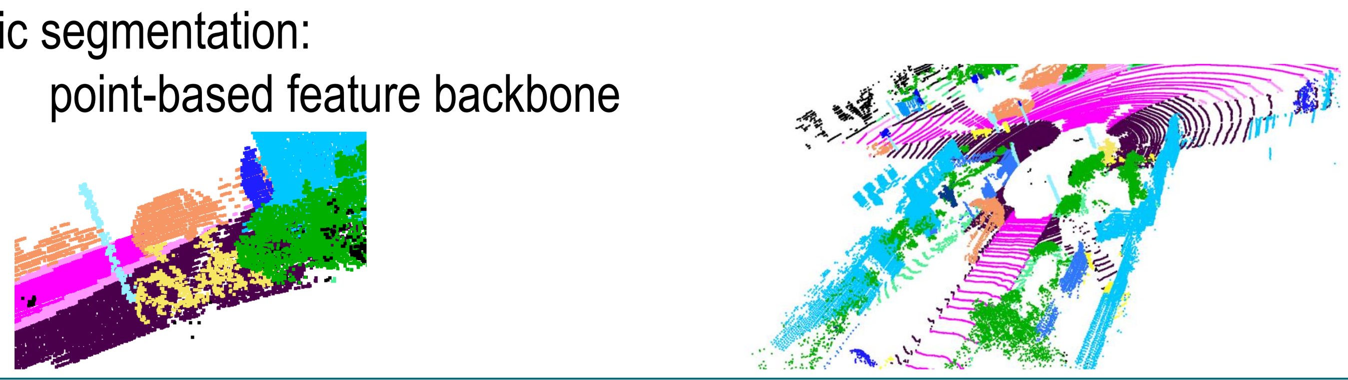


Signal compression via implicit neural representation

- Analyze implicit neural networks (INNs) to provide a general paradigm for signal compression

Lidar processing using transformer-based backbone

- Lidar semantic segmentation:
  - point-based feature backbone



List of attended classes

- 01UMNRV - Advanced deep Learning (didattica di eccellenza) (15/6/2021, 6 CFU)
- 01UJBRV - Adversarial training of neural networks (1/7/2020, 3 CFU)
- 01TRARV - Big data processing and programming (8/3/2021, 4 CFU)
- 02LWHRV - Communication (21/9/2020, 1 CFU)
- 01QTEIU - Data mining concepts and algorithms (1/2/2021, 4 CFU)
- 01UJARV - Data science for networks (23/7/2020, 4 CFU)
- 01SCSIU - Machine learning for pattern recognition (28/9/2020, 4 CFU)
- 01UMEKG - Principles of deep learning (18/9/2020, 4 CFU)
- 08IXTRV - Project management (26/11/2020, 1CFU)
- 01RISRV - Public speaking (11/1/2020, 1CFU)
- 01SYBRV - Research integrity (6/1/2021, 1CFU)
- 02RHORV - The new Internet Society: entering the black-box of digital innovations (7/1/2021, 1CFU)
- 01UNXRV - Thinking out of the box (26/11/2020, 1CFU)
- 01SWPRV - Time management (26/11/2020, 1CFU)
- 01QORRV - Writing Scientific Papers in English (5/6/2020, 3CFU)

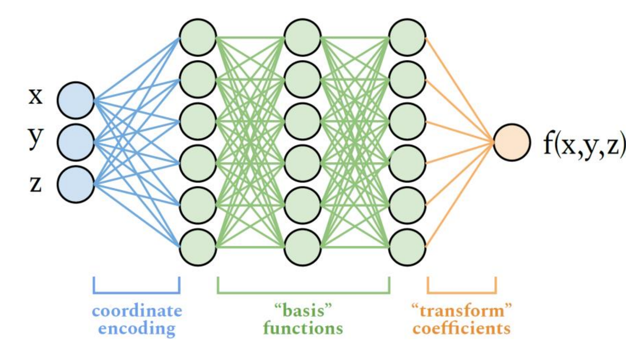
Novel contributions

Point cloud processing via graph convolutional neural network

- Investigate graph convolutional neural networks for normal estimation and denoising
- The proposed graph-convolutional layer implements the lightweight ECC.

Signal compression via implicit neural representation

- **NIC** (Neural Implicit Compression): a novel paradigm for signal compression where **the compact representation** of the signal **is** defined by **the very weights of the network**
- Inns are not able to exploit prior → meta learning to provide a good initialization point
- Novel methodology: **compress the difference** between the final weights and initialization



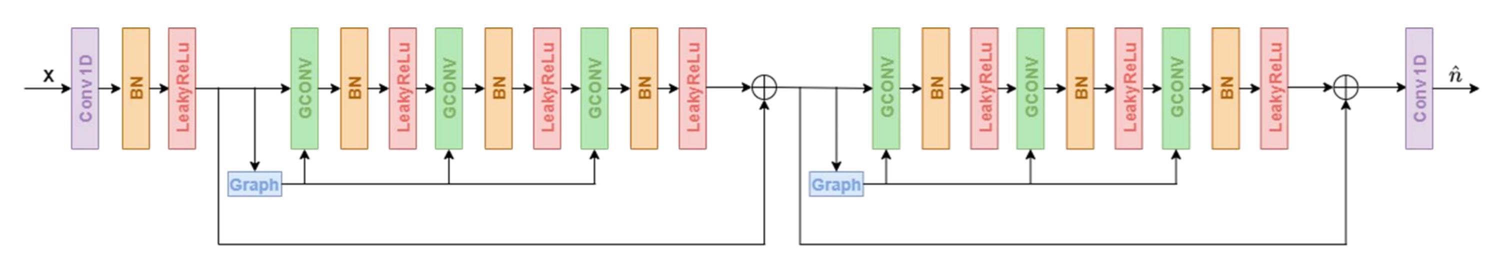
Lidar processing using transformer-based backbone

- Investigate point-transformer based backbone for Lidar
- Adapt classic subsampling procedure and transformer to Lidar data

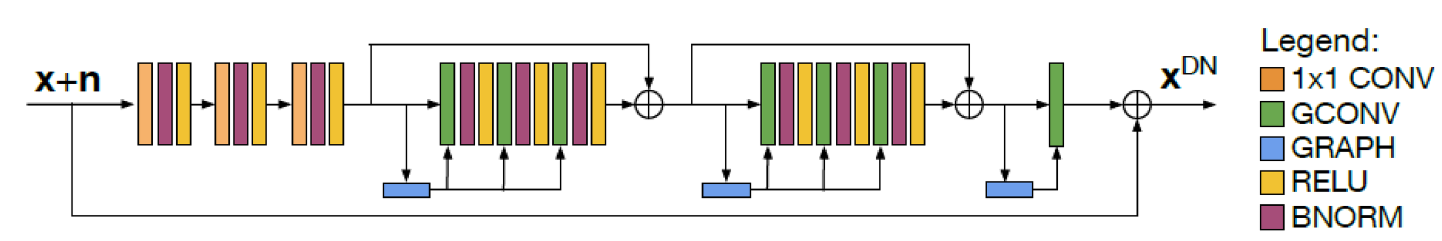
Adopted methodologies

Point cloud processing via graph convolutional neural network

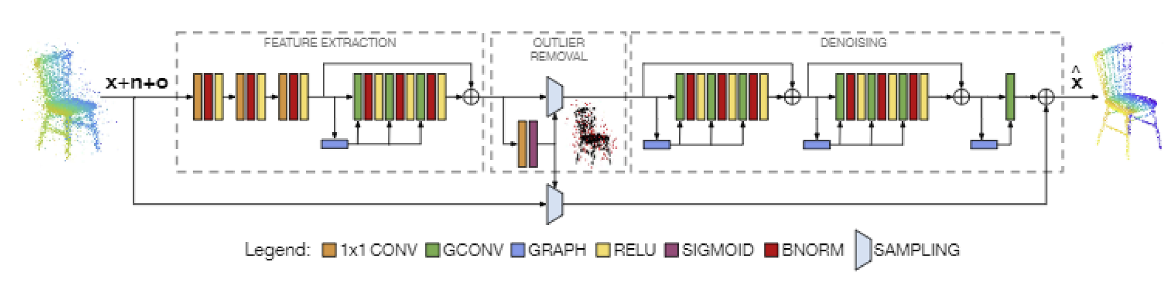
- Point cloud normal estimation



- Point cloud denoising



- Point cloud denoising + outlier removal

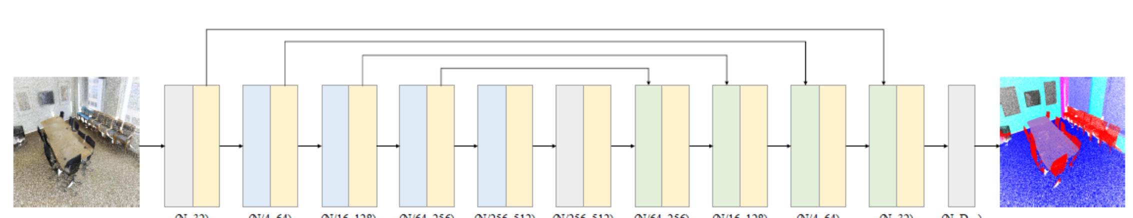


Signal compression via implicit neural representation

- General paradigm for signal compression (applied to point cloud colour compression)
  1. Define the **architecture** (type of net, number features, number of layers).
  2. **Train** the network by minimizing a suitable regression loss,
  3. **Compactly represent** the weights of the network.
  4. Use an **entropy encoder** on the quantized weights and biases and save any required side information

Lidar processing using transformer-based backbone

- Autoencoder structure with point transformer layers are building blocks



Future work

- Continue the project for Lidar semantic segmentation with a transformer-based backbone
- Extend the work on 4D Lidar point clouds

Submitted and published works

- F. Pistilli , G. Fracastoro., D. Valsesia and E. Magli, "Point Cloud normal estimation with graph-convolutional neural networks", IEEE International Conference on Multimedia & Expo Workshops (ICMEW), 2020, pp. 1-6
- F. Pistilli, G. Fracastoro, D. Valsesia and E. Magli, "Learning Graph-Convolutional Representations for Point Cloud Denoising", *Proceedings of the European Conference on Computer Vision (ECCV), 2020* , pp. 103-118
- F. Pistilli, G. Fracastoro, D. Valsesia and E. Magli, "Learning Robust Graph-Convolutional Representations for Point Cloud Denoising," in *IEEE Journal of Selected Topics in Signal Processing*, vol. 15, no. 2, 2021, pp. 402-414
- F. Pistilli, D. Valsesia, G. Fracastoro and E. Magli, "Signal Compression via Neural Implicit Representations," *ICASSP 2022 - 2022 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP)*, 2022, pp. 3733-3737