Change detection in 3D point clouds based on deep learning

Iris de Gélis[1,2], Sébastien Lefèvre[2] & Thomas Corpetti[3]

[1]Magellium, F-31000, Toulouse, France; iris.de-gelis@irisa.fr

[2]IRISA UMR 6074, Université Bretagne Sud, F-56000 Vannes, France

[3]LETG UMR 6554, CNRS, F-35000 Rennes, France

Motivation

Context:

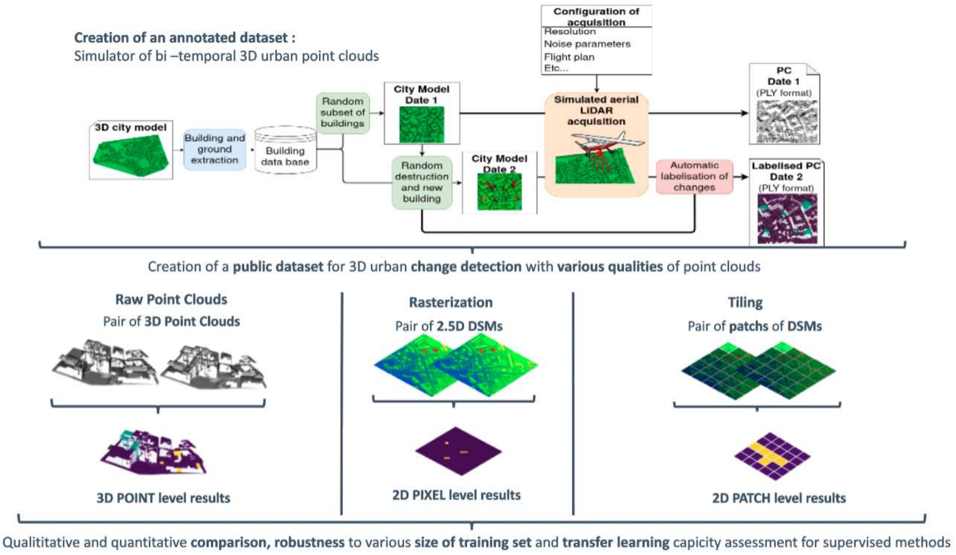
- From 2022, CO3D mission is set to map the globe in 3D. Temporal monitoring of zones of interest to track potential changes.
- **3D Point Clouds** (PCs) acquired by LiDAR sensor or photogrammetry process are becoming more common for **earth observation**.

Objectives: Explore and propose a solution for **change detection and characterization** over raw 3D PCs using **deep learning**.

Challenges:

- **3D PCs characteristics**: sparse, unordered, contain hidden parts, no matrix storage without loss of information
- **Change detection**: unchanged objects have different point distribution
- **Deep learning**: usual convolution used for 2D images are not applicable

State-of-the-art: 3D change detection and characterization [1]



Conclusion of state-of-the-art methods **benchmark**:

- Most of studies only focus on Digital Surface Models (DSMs) implying a loss of information
- **No deep learning methods** for change detection directly on **raw 3D PCs**
- Existing **traditional methods scores can be largely improved**

Convolution for 3D PCs: 3D KPConv [2]

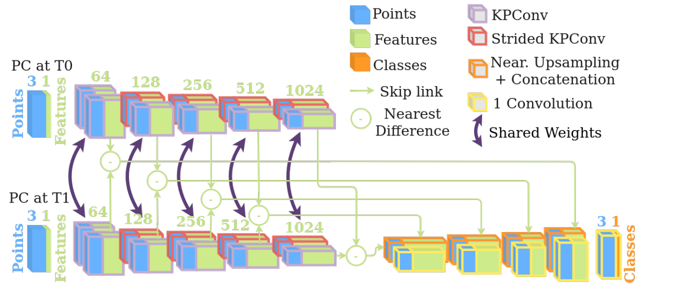
3D Kernel Point Convolution

Convolution by a kernel function g at a point $x \in R^3$:

$$(\mathcal{F} * g)(x) = \sum_{x_i \in \mathcal{N}_i} g(x_i - x) f_i$$

- x_i points from $\mathcal{P} \in R^{N\times 3}$ and corresponding feature f_i from $\mathcal{F} \in R^{N\times D}$
- $\mathcal{N}_i = \{x_i \in \mathcal{P} \| \|x_i - x\| \leq r\}$ with $r \in R$
- Kernel function g: applies weights to different areas inside a ball $\mathcal{B}^3_r = \left\{y \in R^3 \| \|y\| \leq r\right\}$ thanks to kernel points

Siamese Kernel Point Convolution Network [3]



Conclusions and Future Works

Outcomes:

- Creation of a public dataset made of annotated urban PCs for change detection and characterization
- Development of **Siamese Kernel Point Convolution Network** to address change detection and characterization in a single step
- **Improvement** of about **20%** of the mean per class IoU compared to random forest method with hand-crafted features

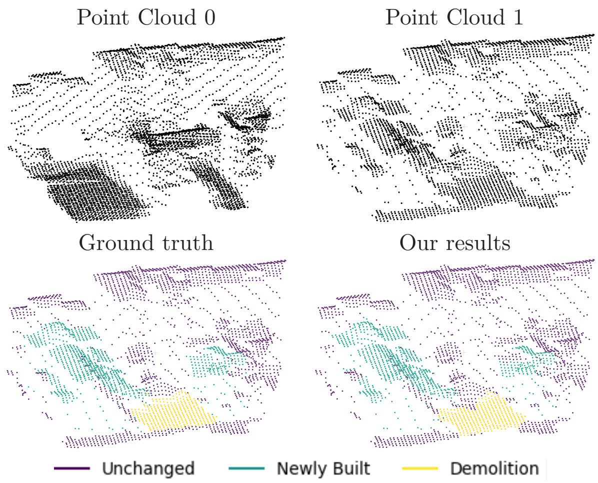
Perspectives:

- Test on real datasets not only in urban context (cliffs, ...)
- Focus on **self-supervised** methods in order to get rid of time-consuming data annotation

Results

Results over a simulated urban dataset composed of challenging low resolution PCs:

	mAcc	mIoU	mIoU over classes of change
RF [4]	91.14	74.53	63.41
Ours	**96.24**	**93.27**	**90.22**



References

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[2] Hugues Thomas, Charles R Qi, Jean-Emmanuel Deschaud, Beatriz Marcotegui, François Goulette, and Leonidas J Guibas. Kpconv: Flexible and deformable convolution for point clouds. In *Proceedings of the IEEE/CVF International Conference on Computer Vision*, pages 6411–6420, 2019.

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[4] Thi Huong Giang Tran, Camillo Ressl, and Norbert Pfeifer. Integrated change detection and classification in urban areas based on airborne laser scanning point clouds. *Sensors*, 18(2):448, 2018.