

Clustering for the Analysis and Enrichment of Corpus of Images for the Spatio-temporal Monitoring of Restoration Sites

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Context

This work focuses on the enrichment of a corpus of images for the spatio-temporal monitoring of Cultural Heritage restoration sites [1].

Beside their **visual content**, the images are characterized by **temporal**, **spatial** and **semantic** information, stored as native or user-added metadata. According to the type of data, clusters of images are built with the appropriate methods.

- **Aim:** Analyzing, structuring and enriching the corpus of images with clustering methods [2]
- **Data:** 1242 images distributed over 5 projects, defining 5 spaces of the cathedral (indoor and outdoor), acquired over a period of a year and a half, manually described with 331 user-defined annotations

Visual content

- Data: visual content of the images
- Method: image matching with hand-crafted methods (in accordance with the specificities of the corpus)

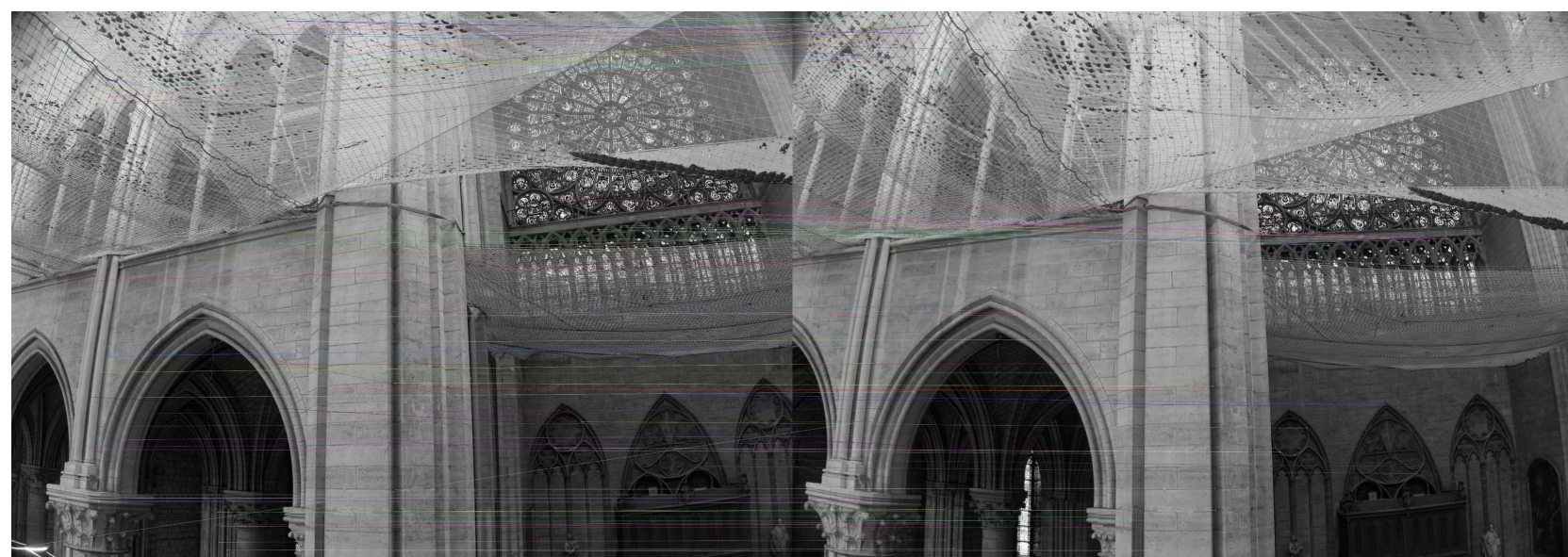


Figure: SIFT algorithm on a pair of images

- Analysis: pairs of images can be identified as visually (dis)similar
- Interpretation: image matching allows to highlight visual similarities between images that can be used as the base for further exploration of the corpus.



Figure: Image from Chapel 19

Temporal data

- Data: dates of acquisition
- Clustering method: beeswarm plot & visual exploration
- Analysis: 3 main clusters for 4 different acquisition phases

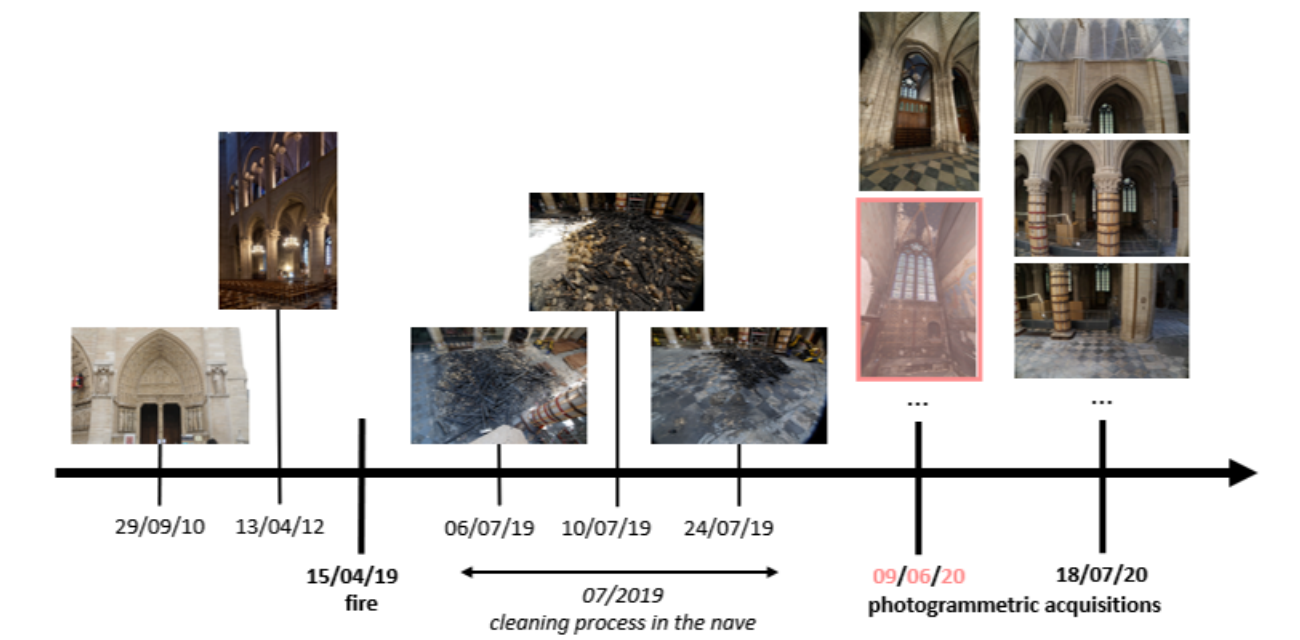


Figure: Timeline with some images' acquisition dates

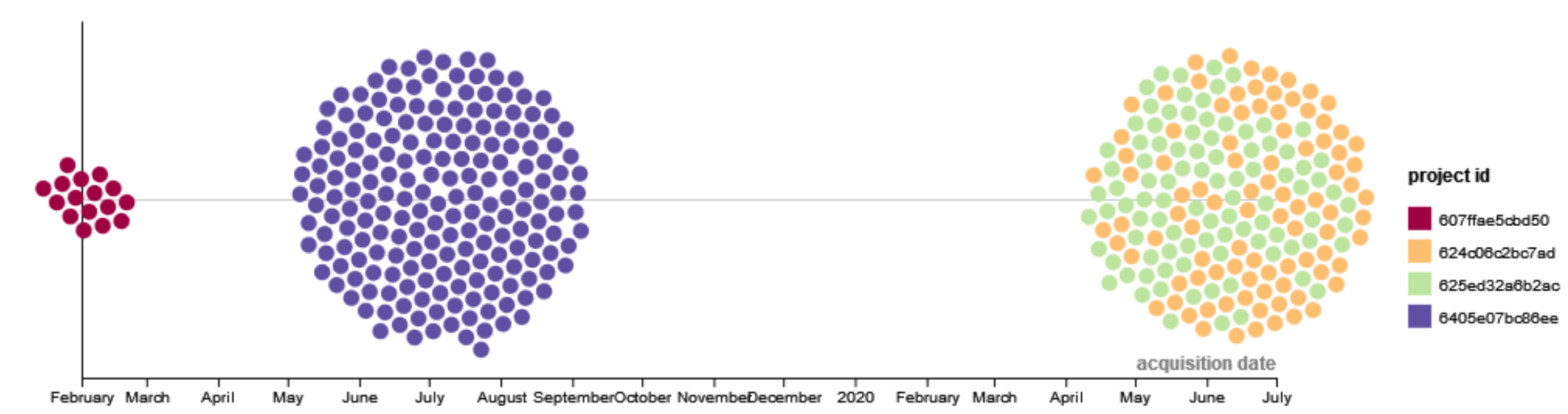


Figure: Beeswarm plot of the images' dates of acquisition

- Interpretation: these clusters show different periods of acquisition that can be labelled (eg, "cathedral's exterior") by crossing it with other known information about the images to go from a quantitative characterization (dates) to a qualitative one (labels).

Semantic data

- Data: hierarchical categorization of user-defined annotations

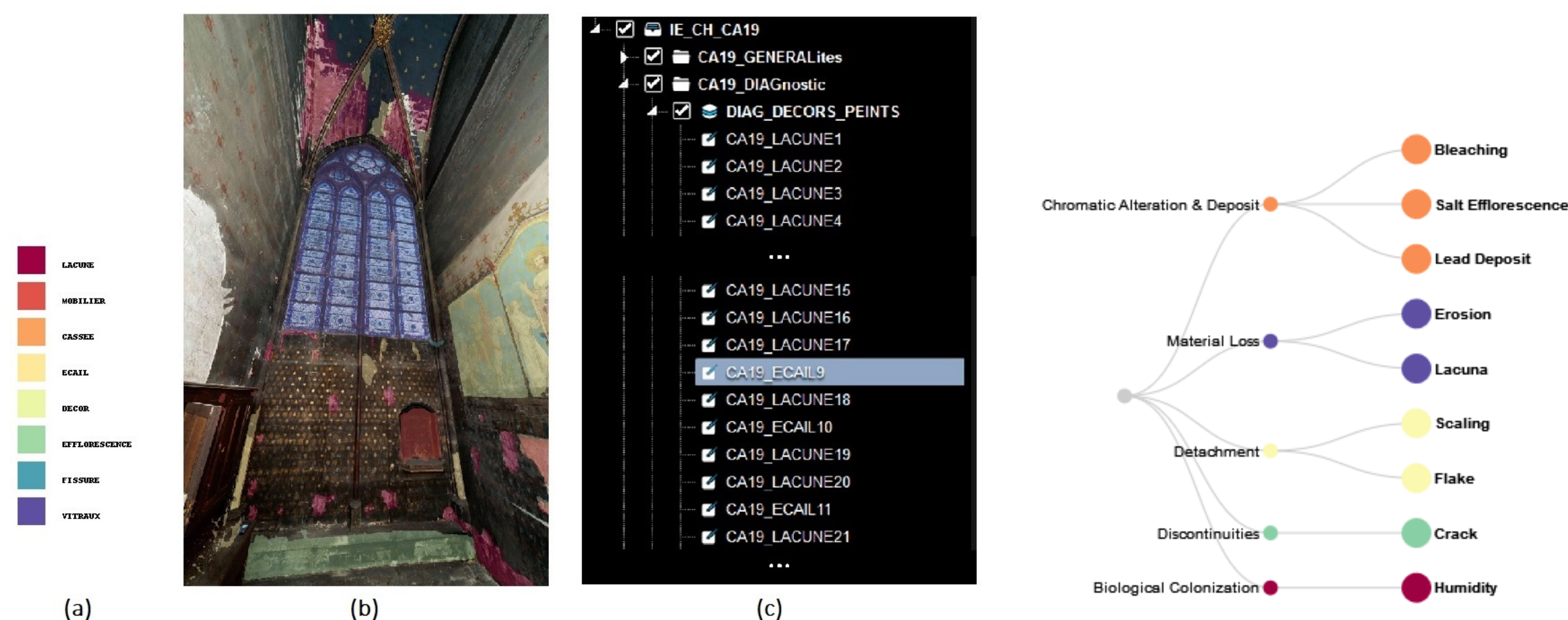


Figure: Images' annotations and their hierarchical categorisation - stone alteration patterns

- Clustering method: Tree-Edit Distance (TED) & hierarchical clustering
- Analysis: distribution of the images by cluster and project
- Interpretation: the clusters highlight stone alteration patterns common to several projects (ie: different zones of the cathedral) and groups of (dis)similar stone alteration patterns in a given project. These results further characterize the images' semantic aspect.

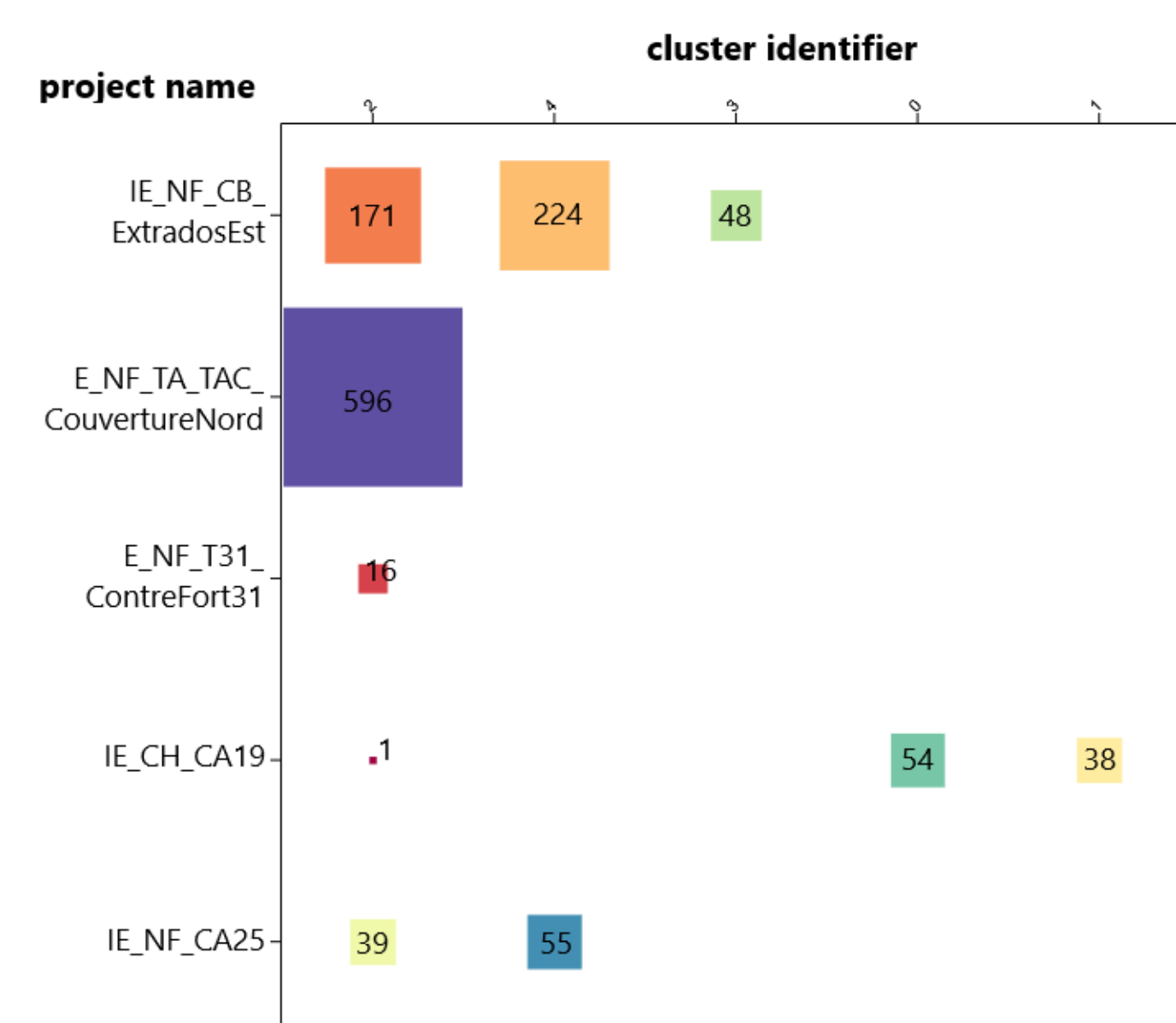


Figure: Hierarchical clustering based on TED

Spatial data

- Data: position and orientation of the cameras
- Clustering method: Principal Component Analysis (PCA) & visual exploration
- Analysis: 4 main clusters for 5 different spatial zones

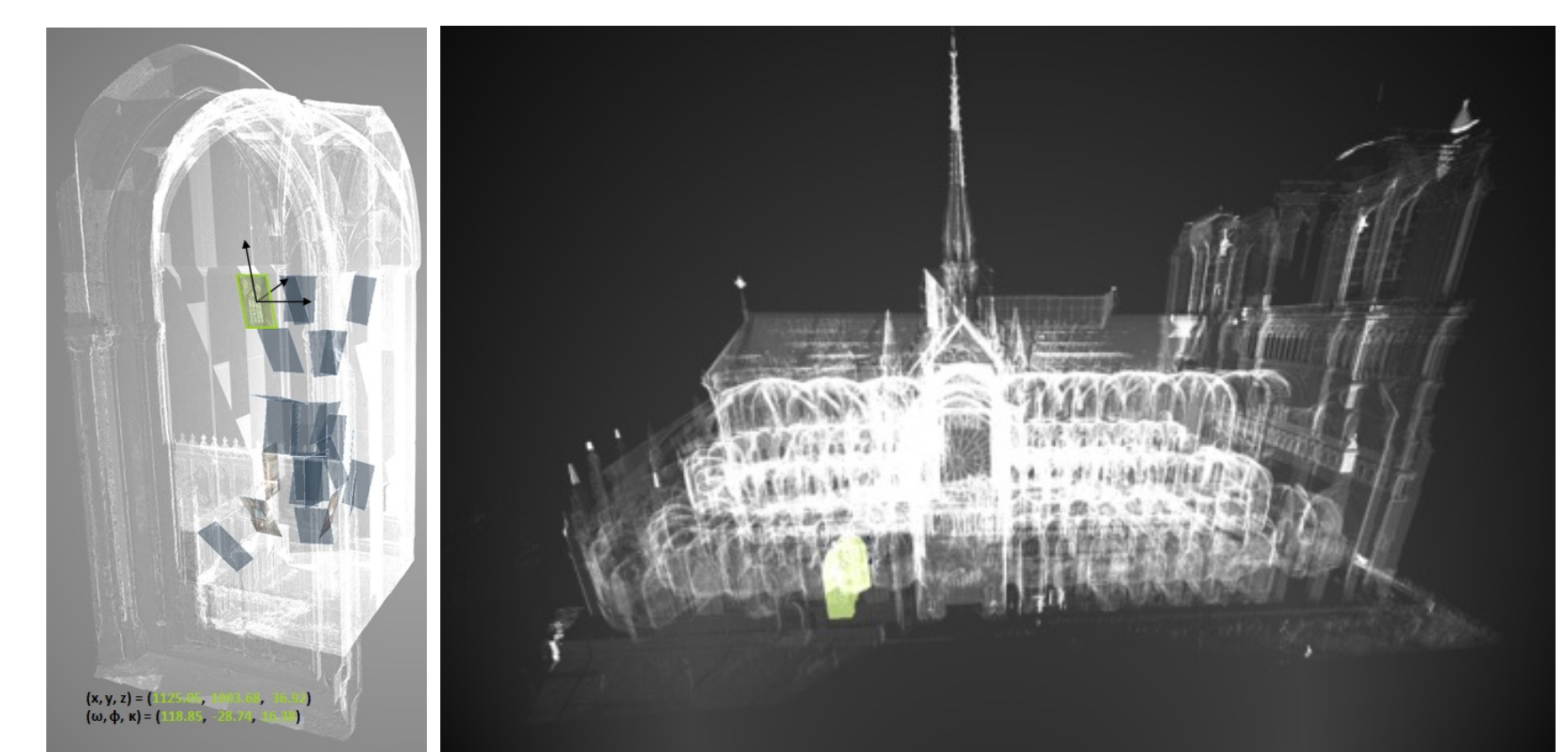


Figure: Spatialization of the images

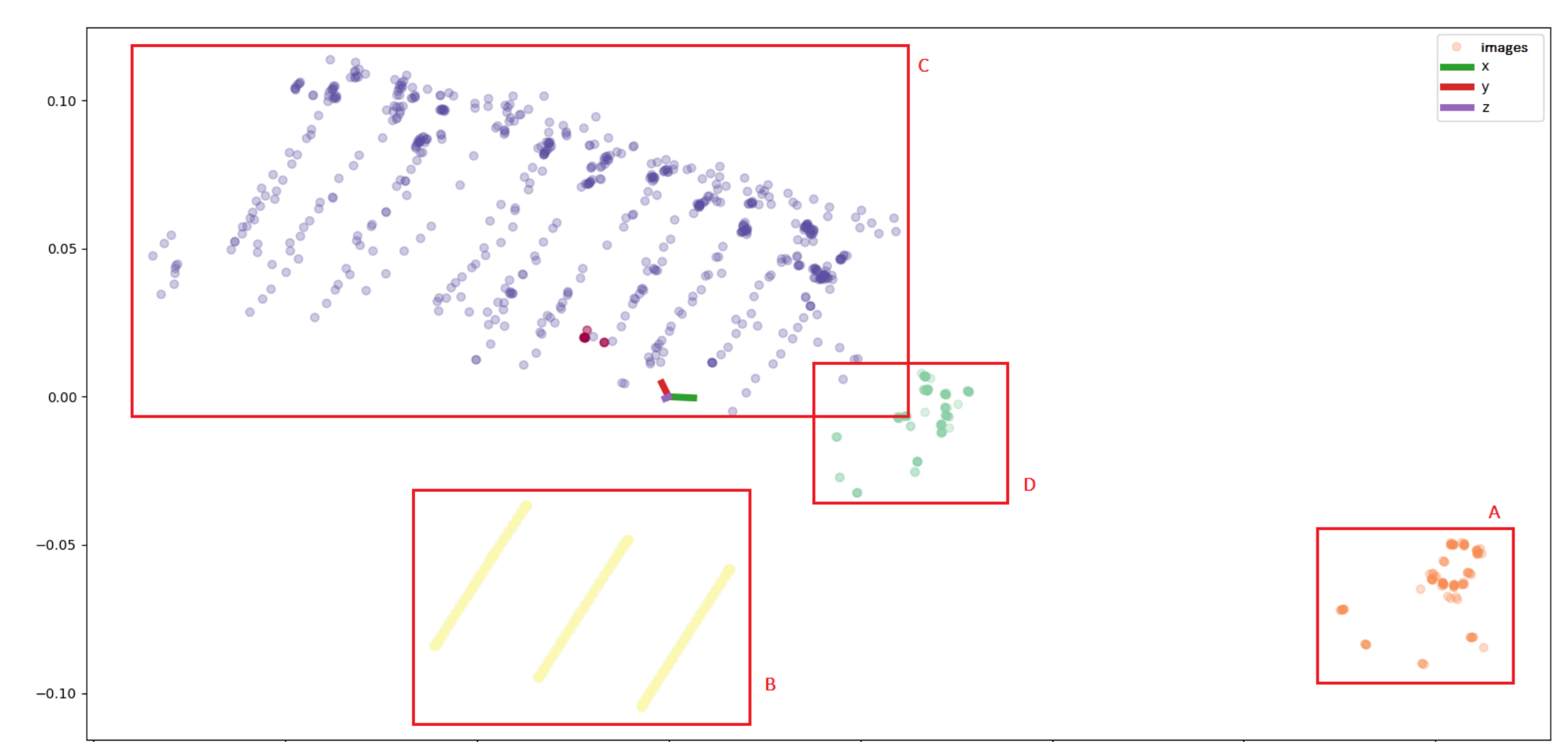


Figure: PCA on the (x, y, z) coordinates of the cameras' positions

- Interpretation: each cluster groups together images that have common spatialization, across and within projects. This highlights another spatial characterization of the images.

References

- [1] L. De Luca, V. Abergel, A. Guillem, O. Malavergne, A. Manuel, A. Néroulidis, R. Roussel, M. Rousset, and S. Tournon. L'écosystème numérique n-dame pour l'analyse et la mémorisation multi-dimensionnelle du chantier scientifique notre-dame-de-paris. page 1, Lyon, France, Oct. 2022.
- [2] A. Saxena, M. Prasad, A. Gupta, N. Bharill, O. P. Patel, A. Tiwari, M. J. Er, W. Ding, and C.-T. Lin. A review of clustering techniques and developments. *Neurocomputing*, 267:664–681, Dec. 2017.

Conclusion

We showed that new information can be inferred from the analysis of clusters built on the different axes (**visual**, **temporal**, **spatial** and **semantic**) characterizing the images. Further work will involve a more automatic validation method and the study of combined variables along with the exploration of visual (dis)similarities.

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