Analysis of urban 3D reconstruction improvements between Pléiades and Pléiades Neo using CNES 3D open source softwares

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1. Introduction

Launched in 2011 and 2012, the Pléiades satellite constellation (Gleyzes et al., 2012) designed by the French space agency CNES, has produced a large amount of very high-resolution images (70cm). The agility of these satellites enables stereoscopic acquisitions to create 3D models of the Earth's surface.

As a follow up the Pléiades mission, AIRBUS developed a new generation of satellites launched 10 years later: Pleiades Neo (Chouteau et al., 2022). Announced as a breakthrough in Earth observation[1], it provides new radiometric bands (deep-blue and red-edge) and an improved resolution (30cm). This publication aims to evaluate the impact of this resolution gain between Pléiades and Pléiades Neo in the case of 3D urban reconstruction.

2. CNES 3D Tools

Building on its experience in geometry and 3D reconstruction, the CNES, is developing new open-source tools for this field of application. This tool chain is intended to be part of the CO3D (Lebègue et al., 2020) ground segment core, and to serve the entire end-user ecosystem. Pending the availability of this mission data, we are already testing these tools on other sensors, including Pléiades and more recently Pléiades Neo. Processing this data requires the design of robust chains with the ability to scale up. For this reason, those tools are massively parallelizable, using multi-processor and multi-node technologies, while remaining hardware agnostic. This group of software products feature simple interfaces so that they can also be used outside operational processing workflows (e.g. Python API, QGIS plugin, etc.).

In this paper, we leverage the stereo reconstruction pipeline CARS[2] (Youssefi et al., 2020), which integrates PANDORA[3] (Sarrazin et al., 2021) for its crucial correlation step, to generate Digital Surface Models (DSMs). Solely based on the resulting DSM outputs, the Bulldozer[4] (Lallement et al., 2023) software extracts Digital Terrain Models (DTMs) in order to produce the final Digital Height Models (DHMs). The resulting digital elevation models are benchmarked using demCompare[5]. The CNES 3D tools are licensed under a free and non-contaminating license (Apache v2 License), enabling the exploitation of stereo acquisitions from Pléiades and now Pléiades Neo. They also offer the possibility of reproducing the results presented in the study.

[1] Earth Observation Portfolio: https://www.airbus.com/en/space/earth-observation/earth-observation-portfolio/pleiades-neo
[2] GitHub link: github.com/CNES/cars
[3] GitHub link: github.com/CNES/pandora
[4] GitHub link: github.com/CNES/bulldozer
[5] GitHub link: github.com/CNES/demcompare

3. A joint qualitative and quantitative assessment

Following the aforementioned processing chain, the first results clearly indicate potential quality improvements of 3D products derived from Pléiades Neo data. The following section presents a detailed comparison of 3D products generated from both Pléiades and Pléiades Neo acquisitions over urban areas with varying building density (dense urban/urban/peri-urban). The acquisition conditions between the two sensors are similar and suitable for urban restitution.

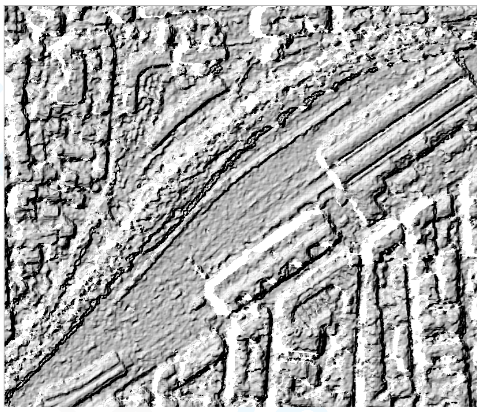
In order to assess the quality gap between Pléiades and Pléiades Neo, we chose to conduct qualitative and quantitative comparisons of 3D products using data from IGN's (French National Institute of Geographic and Forest Information) LiDAR HD® mission[6]. Given the point cloud resolution provided by this mission, the associated elevation information and its derived slope values can be considered as ground truth, as depicted in Figure 1. In addition we included semantic classes (buildings, ground) provided with the LiDAR HD® point cloud in our study, in order to make a finer-grained analysis of the gain in altimetric performance between Péiades and Pléiades Neo. In particular, this allows us to focus on the ability of each sensor to reconstruct the bottom of streets and the buildings roofs, as illustrated in Figure 2.

The produced DSMs from Pléiades and Pléiades Neo are compared both between the two sensors and with IGN's LiDAR HD® ground truth data. Similarly, the DTMs generated with Bulldozer, which are derived from the DSMs produced with CARS, are compared with IGN's RGE ALTI®[7], which is considered as a reference in terms of high-resolution DTMs.

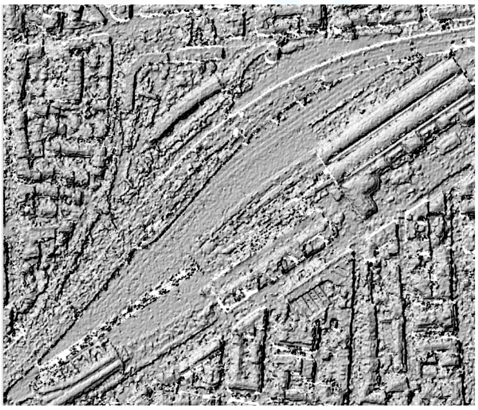
4. Perspectives

In future work, the analysis of additional semantic classes would allow for a more accurate and fine-grained qualification of potential resolution improvements. The quantification of the potential impact of varying acquisition angles on the final quality of 3D products constitutes another interesting field of research for future work. Concerning the tools used to generate the 3D models, another axis could be the analysis of parameter optimization. In this study, the 3D tools were used with identical parameters and default values for each kind of sensor. It could be interesting to compare the optimal configuration of tool options for each sensor, in order to analyze the 3D reconstruction improvements of the best possible versions of 3D products.

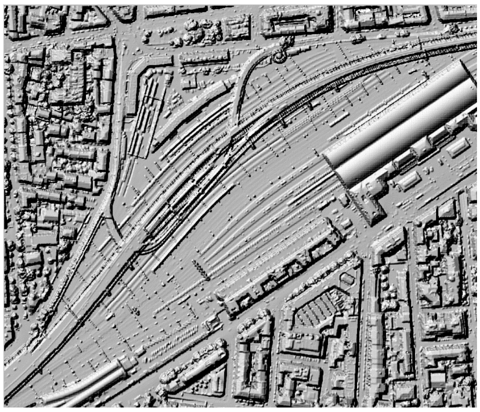
[6] LiDAR HD data access: https://geoservices.ign.fr/lidarhd
[7] RGE ALTI data access: https://geoservices.ign.fr/rgealti



(a) Pléiades



(b) Pléiades Neo



(c) LiDAR HD®

Figure 1. Qualitative evaluation of Pléiades Neo resolution improvements: visualization of DSMs in the Nice train station area with Pléiades (a), Pléiades Neo (b) and LiDAR HD® (c).

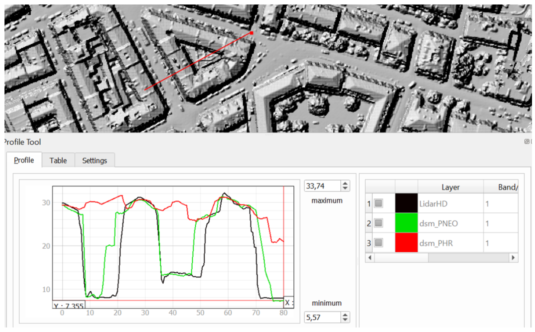


Figure 2. 1D profile on a city-center courtyard. The Pléiades Neo DSM (green) is closer to the LiDAR HD® DSM reference (black) than the Pléiades DSM (red).

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