From photogrammetric modelling of the built heritage to the evaluation of the durability of stones via GIS

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The “Porte de Mars”, is one of the most emblematic ancient monuments of the city of Rheims. This three-bay roman arch rises at the northern end of former *Durocortorum,* capital of *Gallia Belgica* province. Its construction dates from the mid 2nd to early 3rd c. AD. It was then integrated into the Late Roman rampart of the city. Encased, from 1162 to 1856, in the medieval city wall and then in the castle of the city's archbishops, it was completely cleared and restored during the 19th century. During this period, it was barely saved from being dismantled after the ruin of the archbishops'castle and its complete dismantling by the town's population. It is considered the largest "arch" of the Roman Empire north of Roma. It is 32.35 m long, 6.45 m wide and 12 m high today. Since its rediscovery and until today, the “Porte de Mars” is located in the centre of Rheims.

Prior to restore the monument, a campaign to study the materials of the arch was achieved. For this purpose, a photogrammetric survey was carried out using a total of 370 high-resolution photos. Part of the photos were taken by fixing the camera on a pole and using a tablet as a means of preview, georeferencing and remote control. Pictures were processed with the Agisoft Metashape software which allows to carry out all the operations of the photogrammetry calculation chain (Close range photogrammetry - Structure From Motion method). This method allows the reconstruction of 3D objects from 2D data. The technique is based on an algorithm that automatically matches points in a set of photos. The model spatial coordinates were calculated by the software from the sets of photographs. Then the distances between 125 key points of the monument were measured using a laser rangefinder to scale the model. The software enabled orthophotographs to be extracted from the 3D mesh according to the chosen orientations.

The 3D data and derived orthophotos were injected into an interoperable geographic information system (QGis 3.4). Considered objects were then digitized in the form of polygons and a multifactor database was associated with them. This data included architectural information (typology, position, renovation phases) as well as petrographic and petrophysical information. Historical documents were also digitised in order to trace the recent evolution of the monument. Qualitative data (nature of the stone, petrography, presumed origin, restoration phase, etc.) were used to support the work of the monument's restoration teams, while quantitative data (chemical composition, mineralogy, porosity, capillarity, etc.) were used to produce durability assessment maps on the old parts of the building. The maps of alterations carried out in situ were also superimposed in order to relate their location to the characteristics of the building and the nature of the stones concerned. This approach could be supplemented by the projection of multiscalar data from other sensors such as thermal imaging data or the monitoring of parameters over time (magnetic, chemical or colorimetric for instance) and become a 4D tool.

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