Poster 1028

Evaluating the Curvature Analysis as a Key Feature for the Semantic Description of Architectural Elements

J. Adrian [1,] D. Lo Buglio [1,2,] L. De Luca [1]

[1] Laboratoire MAP-GAMSAU CNRS/MCC, France

[2] Laboratoire AlICe, Faculte d architecture La Cambre Horta, Universite Libre de Bruxelles, Belgium

Introduction

In the last few years, the developments in the fields of photogrammetry and laser scanning has, on the one hand, allowed to obtain digital acquisitions with high level of accuracy and on the other hand made these technologies available to a broader audience. Digitization are a huge source of information, it is therefore crucial to isolate some of the data to conduct the object's study and thus extract knowledge.
In the case of an architectural object, the morphological analysis can be approached by two ways:
One way is an analysis based on a presupposed knowledge about the object. The object's study will be conducted as a comparison to the style established and codified by art historians or architectural treatises. Another way is an approach based on the object's specific characteristics, regardless of any knowledge and using only information contained in the model (e.g. size, texture, shape). Based on concrete data (e.g. surfaces, geometric discontinuities), this approach minimizes the interpretation degree.

Problem description and challenge

The idea is to perform a detailed observation of geometric and semantic decomposition to highlight similarities or morphological differences into an object's collection. It is then possible to codify the morphological variations of an object and therefore to have an analytical reading on a morphological level as well as a comparison of these surfaces.
But to be effective, this type of analysis requires working on a large data set.
Currently, one of the limitations in terms of architectural analysis is the ability to handle large databases. The fact that the analysis is primarily visual implies the need for a human operator to compare the data. However, a man, unlike a computer, can only compare a very limited amount of data.
The study we are proposing focuses on the shape analysis of a series of Romanesque columns from the cloister of Saint-Michel de Cuxa. Due to the fact that the semantic decomposition of columns has been largely discussed in art history theory, it may be appropriate to evaluate the morphological signatures of each of these elements and to understand the geometric variability within the collection.
This paper positions itself as the beginnings of a method for shape analysis and comparison in order to assess the degree of morphological correspondence or distance between objects within a collection.

Approach

One way to describe the variation of a surface is the use of curvature. This method was chosen because it allows to intrinsically describe the morphological variations of an object.
The Gaussian curvature is the product of the principal curvatures. The curvature can also be interpreted according to other criteria, we can thus mention the mean curvature and the absolute curvature [GGGZ05].

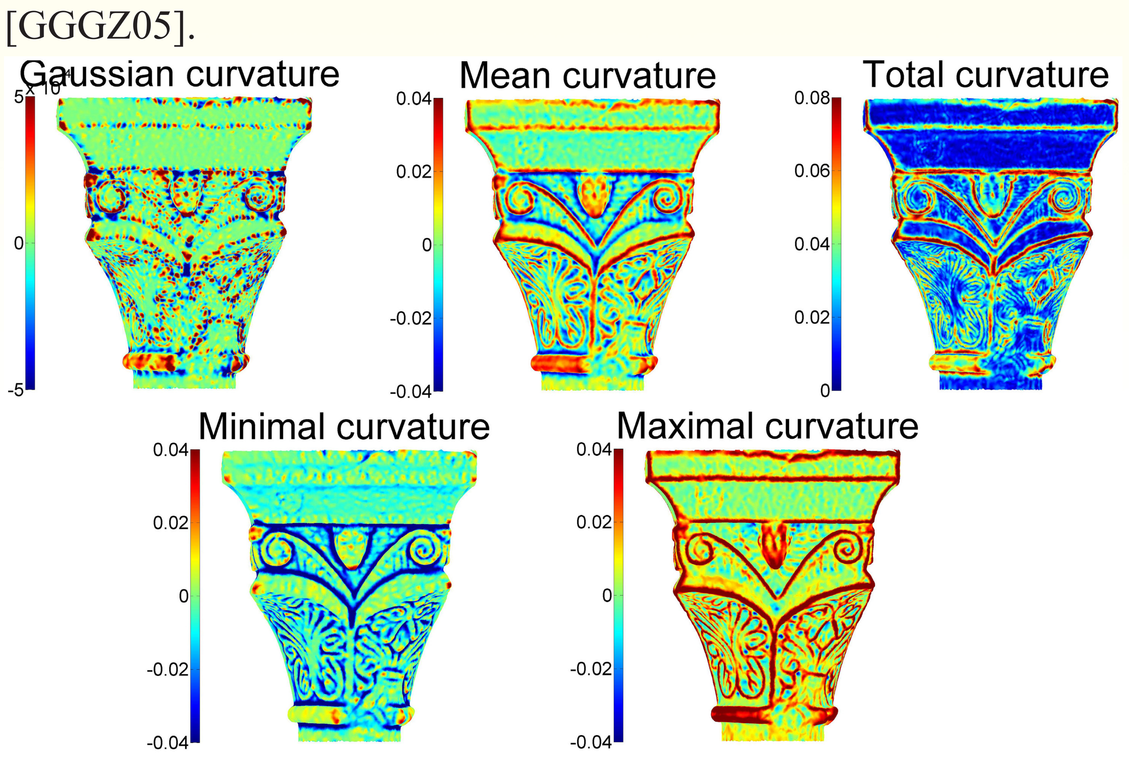

Figure 1: Gaussian curvature, Mean curvature, Absolute curvature, Minimal curvature, Maximal curvature

The digitization allows us to get a mesh surface approximating the object's surface. The approximation will depend on the digitization quality as well as the polygon amount used to transcribe the surface. This is what we call a discrete surface.
Indeed, contrary to the original object which is composed of a continuous and smooth surface, the mesh object is composed of facets approximating the shape and therefore the curvature of the object.
The Gaussian curvature properties are only valid for smooth surfaces; a curvature tensor will be used to estimate a surface without discontinuities caused by the wireframe. The Gaussian curvature properties can on that way be applied to the object.
The discrete curvature properties are described in articles[MDSB03] [DS08] [CSM03].
The advantage of working with discrete surfaces is to be able to modify some variables to achieve different levels of readability.
The result will firstly depend on the mesh quality, the chosen curvature tensor, the curvature type and finally the color scale assigned to the object.
The choice of parameters will primarily depend on the desired reading level of the object.
By varying these parameters, we notice that the major shape variations are present on all three studied models. These comparisons also correspond to the object's semantic segmentation. For instance, the astragal is recognizable by its blue/red/blue transition, that is to say, negative/positive/negative curvature. For the abacus and the plinth which have a similar morphological structure, the edges are specifically identified as a positive curvature (red) and the planar inner portion as a null curvature (green).

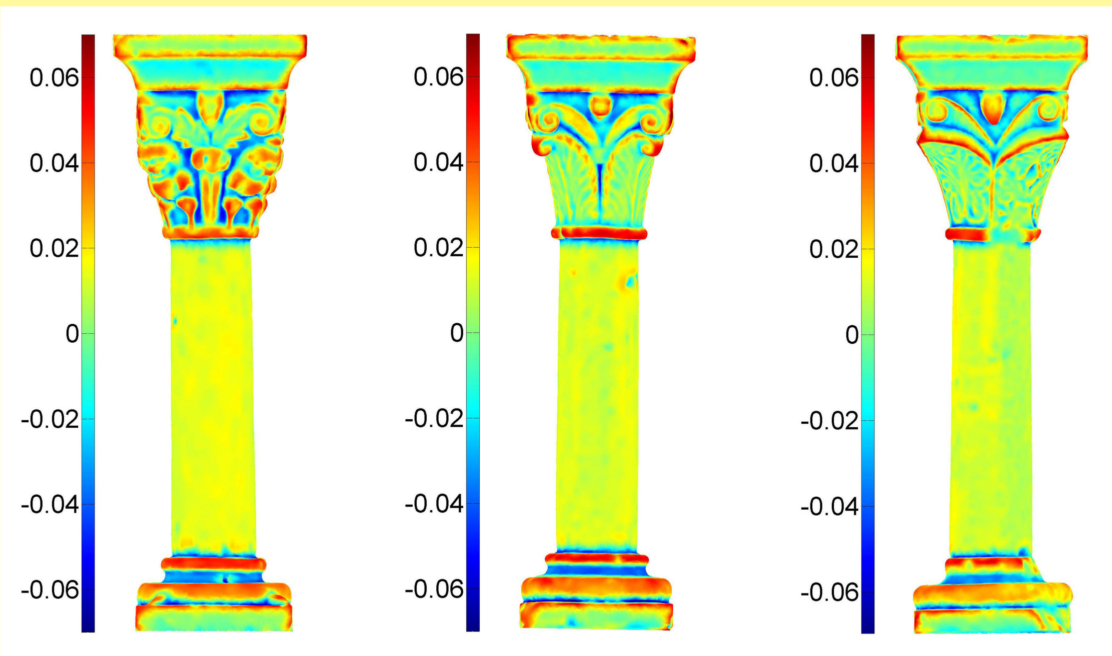

Figure 2: Mean curvature, smooth 5, QuadricEdge Collapse Decimation 1/10, comparison of three columns

Method

In this context, it is interesting to cross mathematics and the use of digital models in order to analyze and compare large data collections. The point will be to determine an average morphological signature of the elements we wish to compare in order to assess the degree of remoteness of each object or entity compared to that average signature.
That problematic is found in [LBLDL13]. The average morphological signature is considered as a reference mark representative of the collection on which the comparison is going to be based.
The curvature is a numeric value for each vertex, so it seemed interesting to calculate that average signature directly from the values.
The problem being that meshes extracted from digitization are triangulated meshes, without any apparent regularity in their structure. A comparison between the same vertices area on two objects is not possible. Vertices are randomly positioned on the surface and therefore cannot be transcribed in the form of digital matrices.
The proposed approach is to re-topology the mesh to obtain a mesh as close to a regular grid as possible. The mesh can then be transcribed directly into tabular form in order to compare the digital data of each point's curvature.
The idea is to project the same regular wireframe for each object based on the UV mapping of the original column mesh.
This allows to extract without any dark area the value of each vertex.

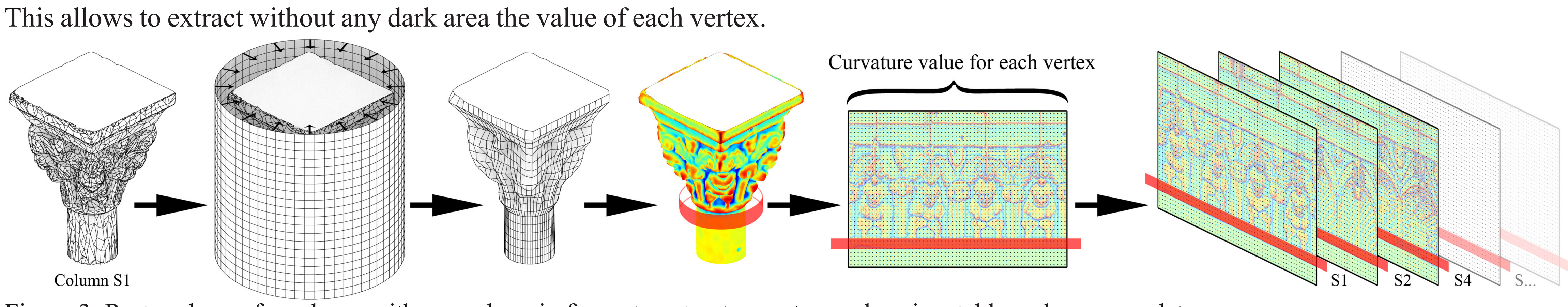

Figure 3: Re-topology of a column with a regular wireframe to extract curvature values in a table and compare data

Visualization and comparison are thus based on value tables. These matrices contain all the variations and the morphological complexity of the object. An accurate morphological comparison can be carried out.
This re-topology is paramount to continue working on rebuilding an average signature of the collection.
From these results, it is now possible to make a comparative study of the semantic entities in the table. The UV mapping of the object is used to display parts that we want to highlight for comparison.

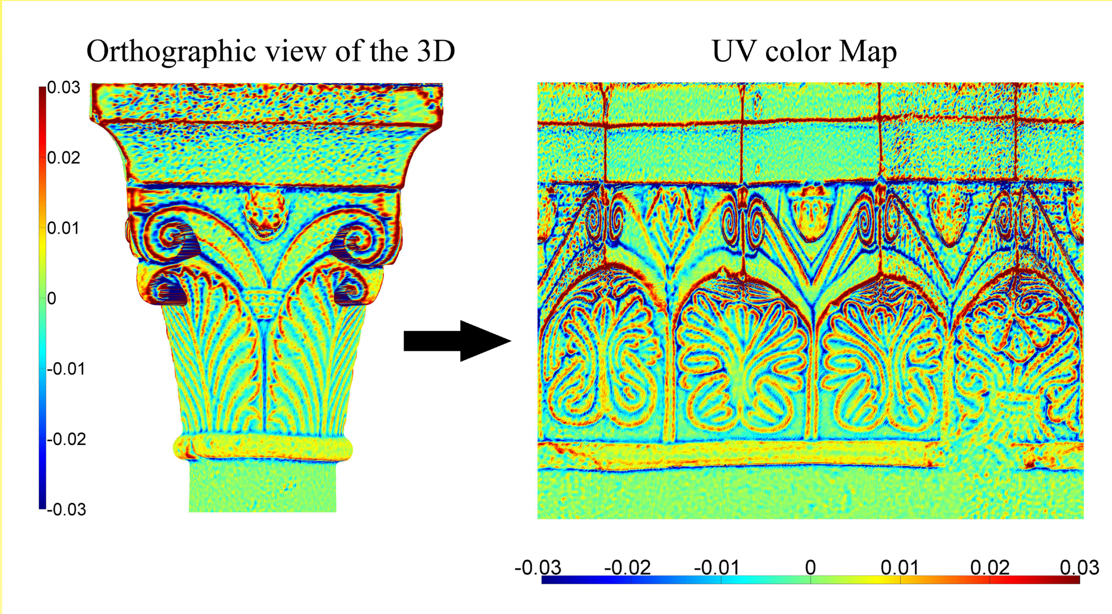

Figure 4: Orthographic view and UV Color Map

Conclusion

The performed tests, at the column level, already showed that the curvature map transcribes properly the geometric decomposition of the object and that this description coincides with the architectural treatises description.
From these initial observations, the goal is to compare in terms of surface the semantic/geometric entities belonging to a collection of elements.
The application of curvature maps in accordance with a regular mesh allowed to extract a matrix whose data can be compared and interpreted.
This method can thus be applied to large databases in order to identify formal and stylistic tendencies for a specific architectural element.
But one of the limitations of the present study lies in the automatic detection of formal discontinuities. This would be based on the work [LBLDL13] in order to continue the study.
However, the work progression allows us to see new possibilities in terms of semantic/geometric analysis.

References

[CSM03] COHEN-STEINER D., MORVAN J.-M.: Restricted delaunay triangulations and normal cycle.

[DS08] DEFLORIANI L., SPAGNUOLO M.: Shape analysis and structuring. Springer, Berlin, 2008.

[GGGZ05] GATZKE T., GRIMM C., GARLAND M., ZELINKA S.: Curvature maps for local shape comparison. Shape Modeling and Applications, 2005 International Conference (2005), 244–253.

[LBLDL13] LO BUGLIO D., LARDINOIS V., DE LUCA L.: Revealing shape semantics from morphological similarities of a collection of architectural elements. 465–472.

[MDSB03] MEYER M., DESBRUN M., SCHR´LODER P., BARR A. H.: Discrete differential-geometry operators for triangulated 2-manifolds. In Visualization and mathematics III. Springer,2003, pp 35–57.

GRAPHICS AND CULTURAL HERITAGE

12TH EUROGRAPHICS WORKSHOP

6th - 8th Oktober 2014, Darmstadt, Germany