



**HAL**  
open science

## Inference of geometric modeling operations

Romain Pascual, Hakim Belhaouari, Agnès Arnould, Pascale Le Gall

► **To cite this version:**

Romain Pascual, Hakim Belhaouari, Agnès Arnould, Pascale Le Gall. Inference of geometric modeling operations. Journées Nationales de l'Informatique Mathématique, Apr 2023, Paris, France. . hal-04068329

**HAL Id: hal-04068329**

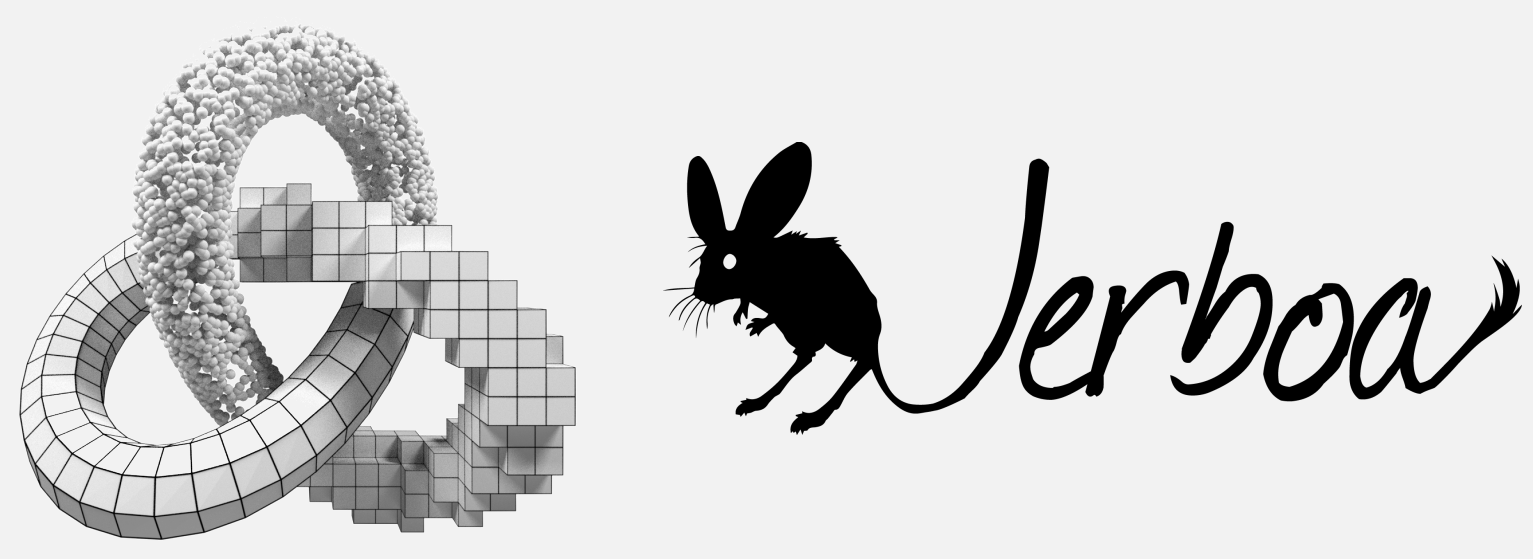
**<https://hal.science/hal-04068329v1>**

Submitted on 13 Apr 2023

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.





# Inference of geometric modeling operations

Romain Pascual<sup>1</sup>

Hakim Belhaouari<sup>2</sup>, Agnès Arnould<sup>2</sup>, Pascale Le Gall<sup>1</sup>

<sup>1</sup>MICS, CentraleSupélec, Université Paris-Saclay, France;

<sup>2</sup>Université de Poitiers, Univ. Limoges, CNRS, XLIM, Poitiers, France



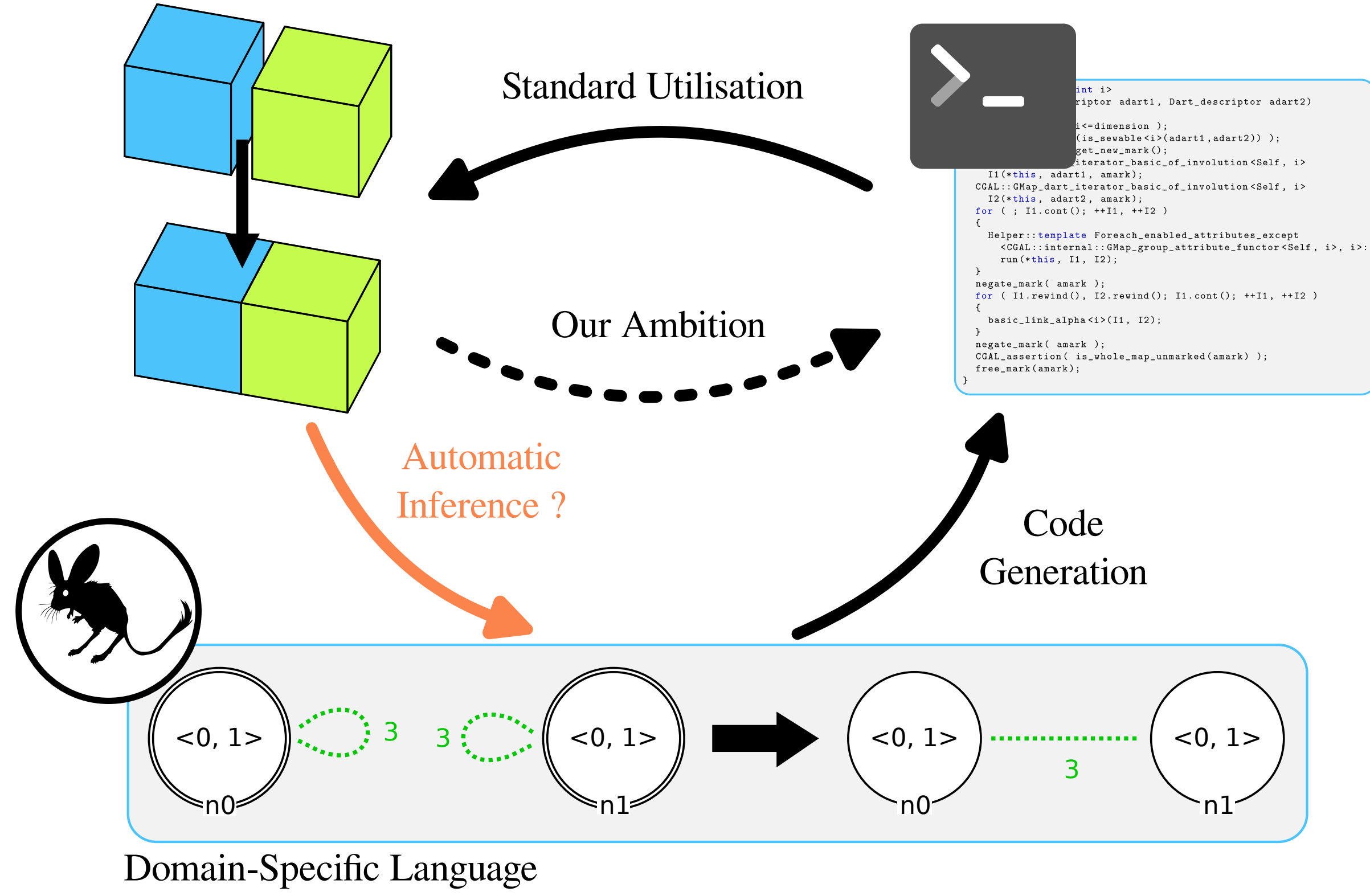
université  
PARIS-SACLAY

xlim

Université  
de Poitiers

## 1. Problematic and motivating context

Conceiving an operation can be a difficult task even though it may be easily described from an example. We propose a new paradigm exploiting a **domain specific language** as a guideline to retrieve an operation from an object before and after modification.

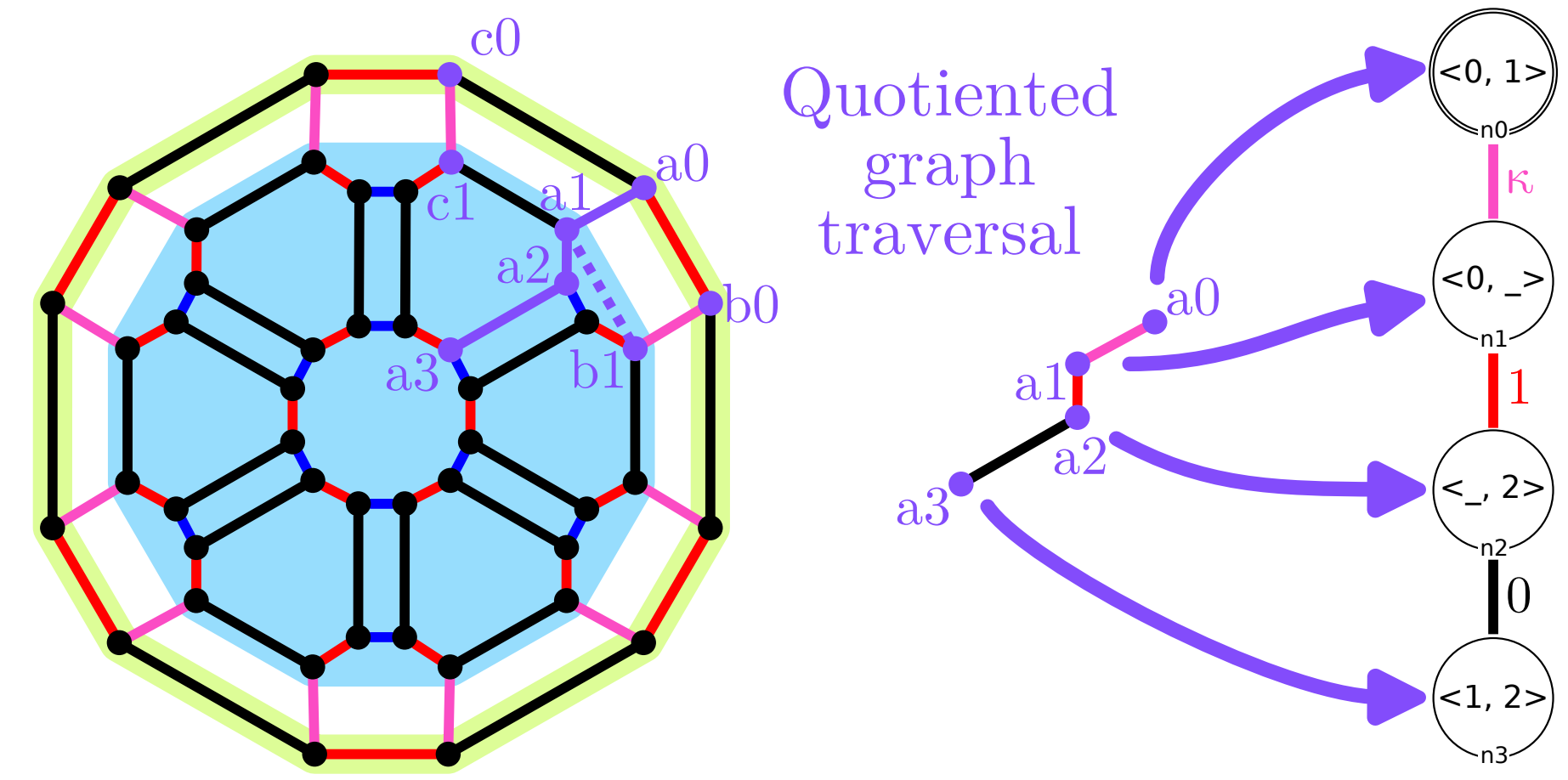


## 5. Topological folding algorithm [4]

**Input:** two partial Gmaps with preservation relation (arcs  $\kappa$ ), an orbit type  $\langle o \rangle$  and a dart  $a$ .

**Output:** a graph  $\mathcal{S}$  encoding the rule on  $\langle o \rangle$ , given that the operation is applied to  $a$ .

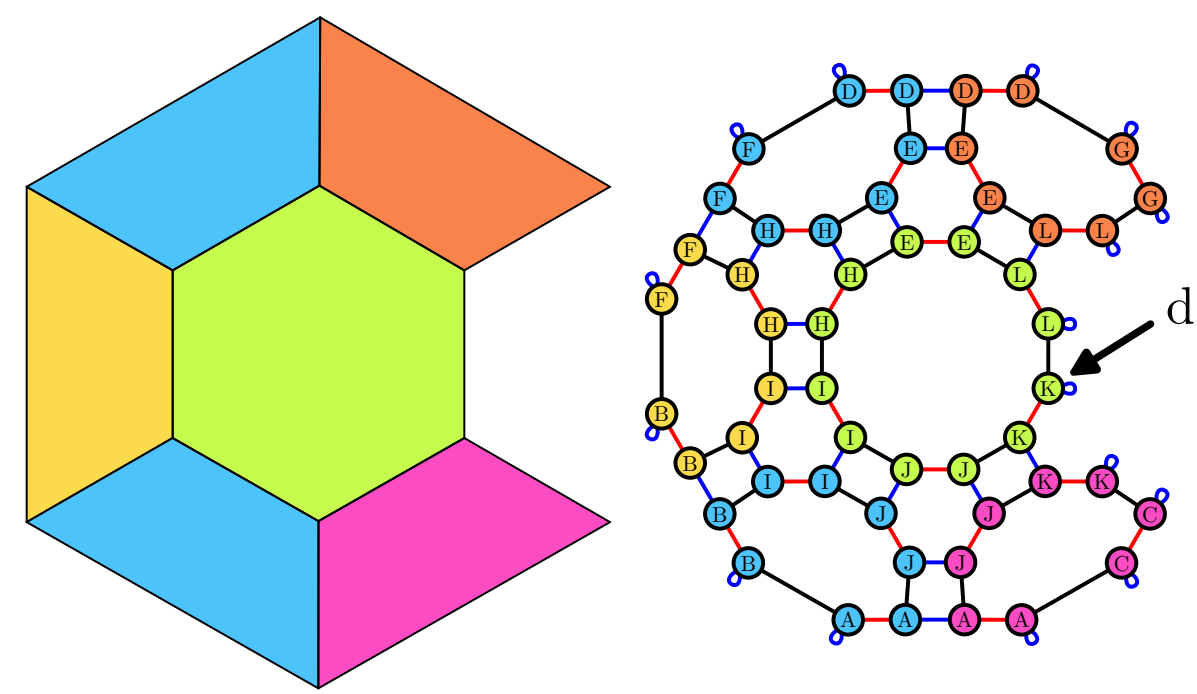
**General idea:** quotiented graph traversal algorithm iteratively folding nodes and arcs.



Color legend: 0, 1, 2,  $\kappa$ . Before instance in blue, after instance in green.

## 2. Object representation: embedded generalized maps

Topology-based geometric modeling uses combinatorial structures to encode the decomposition of an object's topological cells (vertices, edges, faces ...) which is embedded in a geometric space to store additional informations.



**Generalized maps** (Gmaps) [2] built as graphs:

- graph: incidence relations between the cells
- node attributes: geometric embedding values

**Orbits** encode the object's topological cells as subgraphs:

- positions on vertices (orbits  $\langle 1, 2 \rangle$ ).
- colors on faces (orbits  $\langle 0, 1 \rangle$ ).

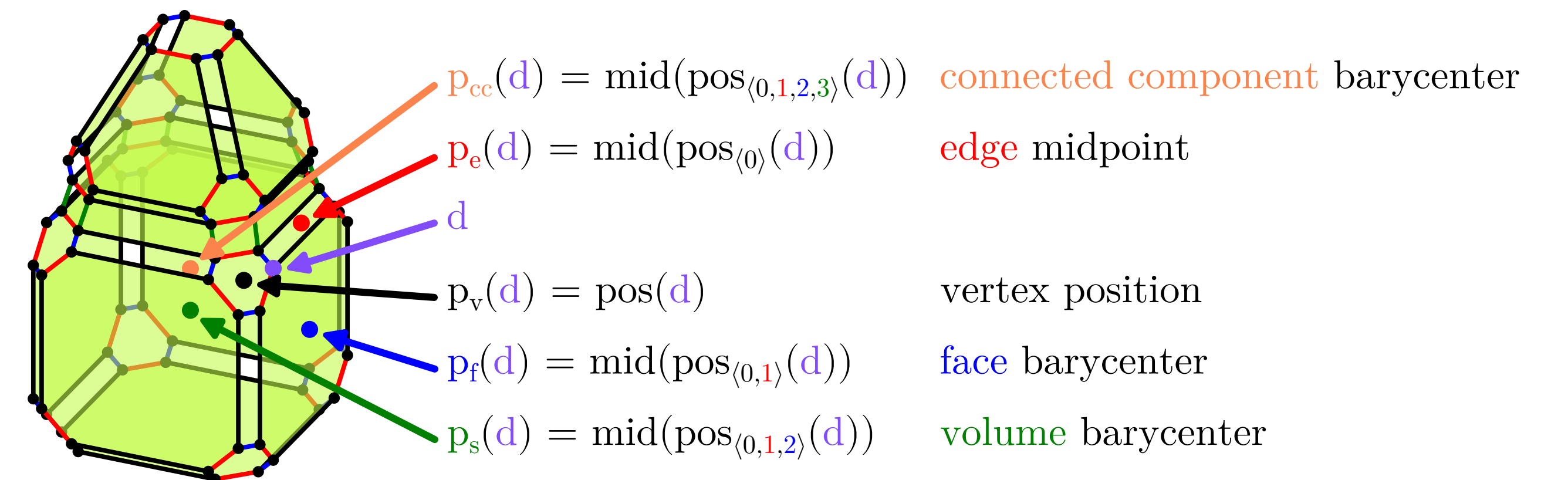
Color legend: 0, 1, 2.

## 6. Retrieving geometric expressions: linear hypothesis

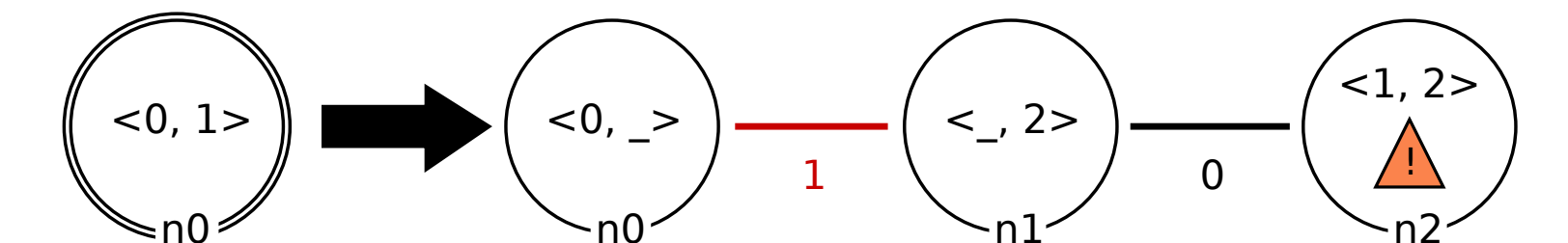
The output of the topological folding algorithm lacks expressions for the geometric computation.

**Problem:** Rules abstract topological cells meaning darts will share the same expression.

**Solution:** Values of interest that exploit the topology to express computations independently from the actual structure.



Triangulation operation:



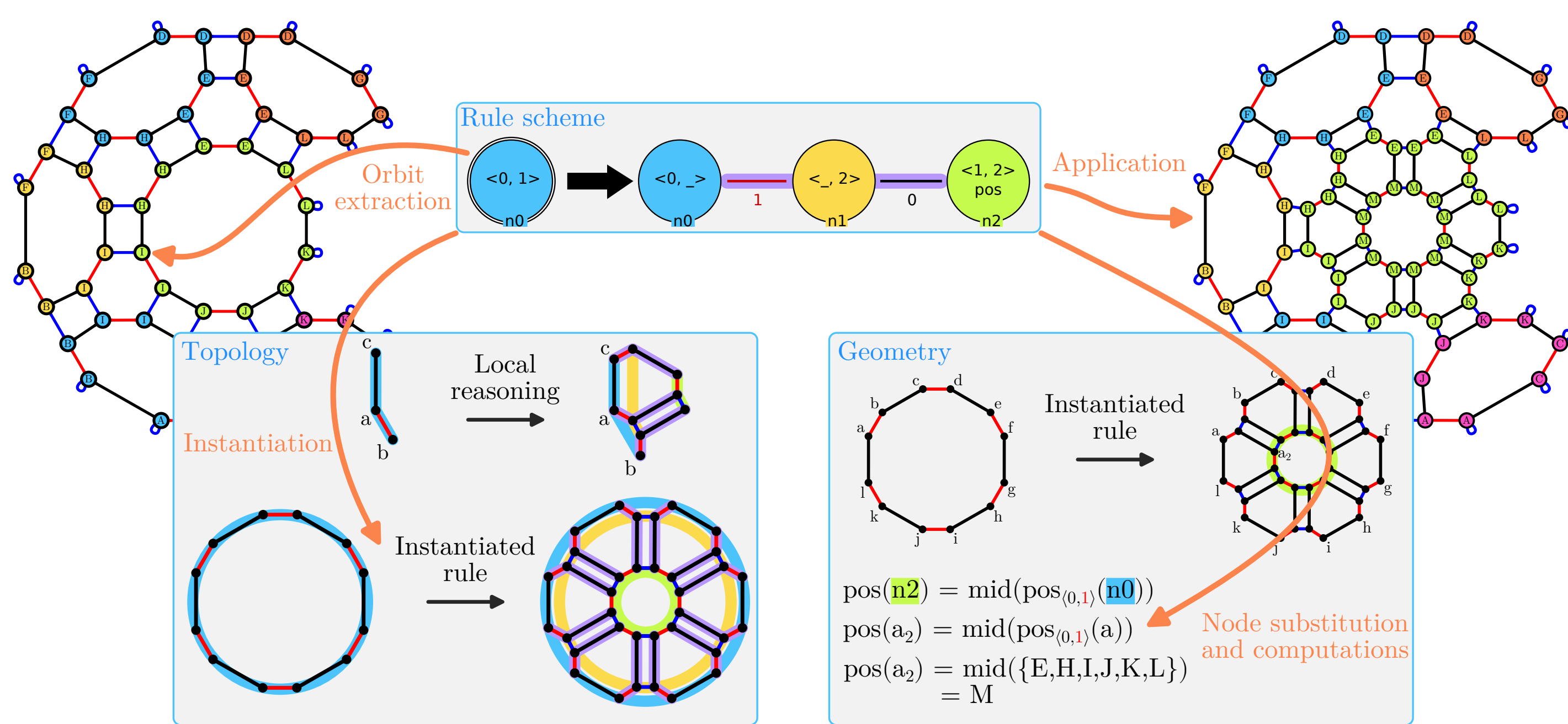
We obtain the following equation, which we solve as a constraint satisfaction problem.

$$pos(n_2) = \underbrace{w_v P_v(n_0)}_{\text{vertex}} + \underbrace{w_e P_e(n_0)}_{\text{edge}} + \underbrace{w_f P_f(n_0)}_{\text{face}} + \underbrace{w_s P_s(n_0)}_{\text{volume}} + \underbrace{w_{cc} P_{cc}(n_0)}_{\text{cc}} + t$$

Solution found:  $w_f = 1.0$  with all other variables being zero.

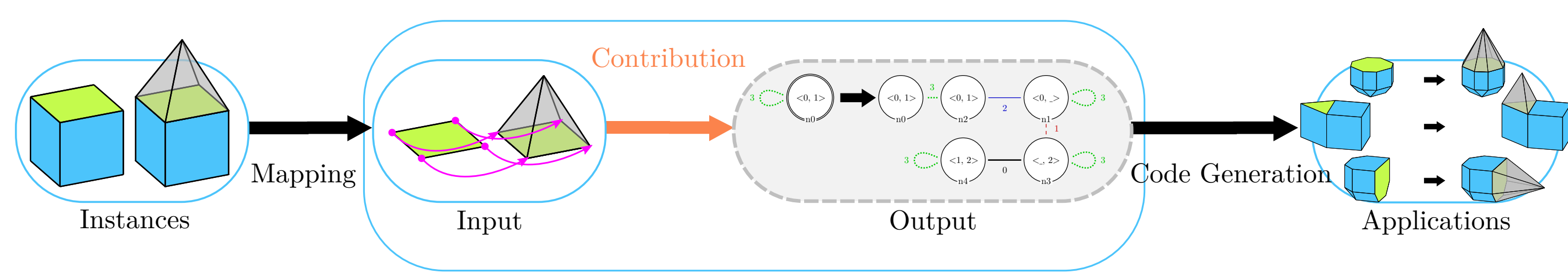
## 3. Modeling operations formalized as graph transformation [5, 1]

Graph transformation [3] extends rewriting to non-linear structures, allowing to formalize modifications of embedded Gmaps: a graph product extends rules to abstract over the underlying topology while algebraic data types and algebra morphisms describe geometric modifications.



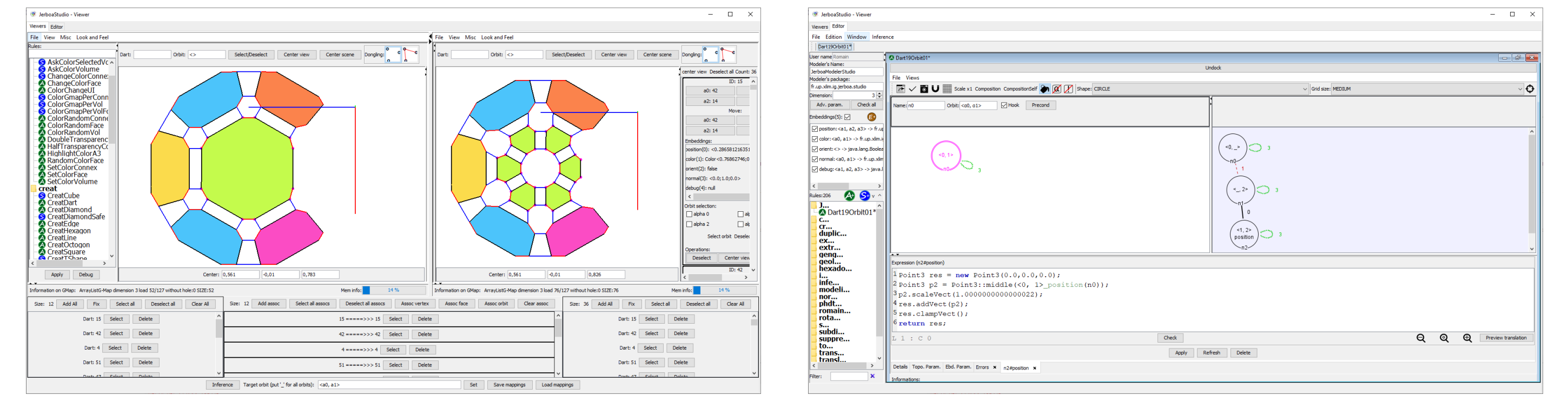
## 4. Method and global workflow

**General idea:** reverse the instantiation and application process.



## 7. JerboaStudio

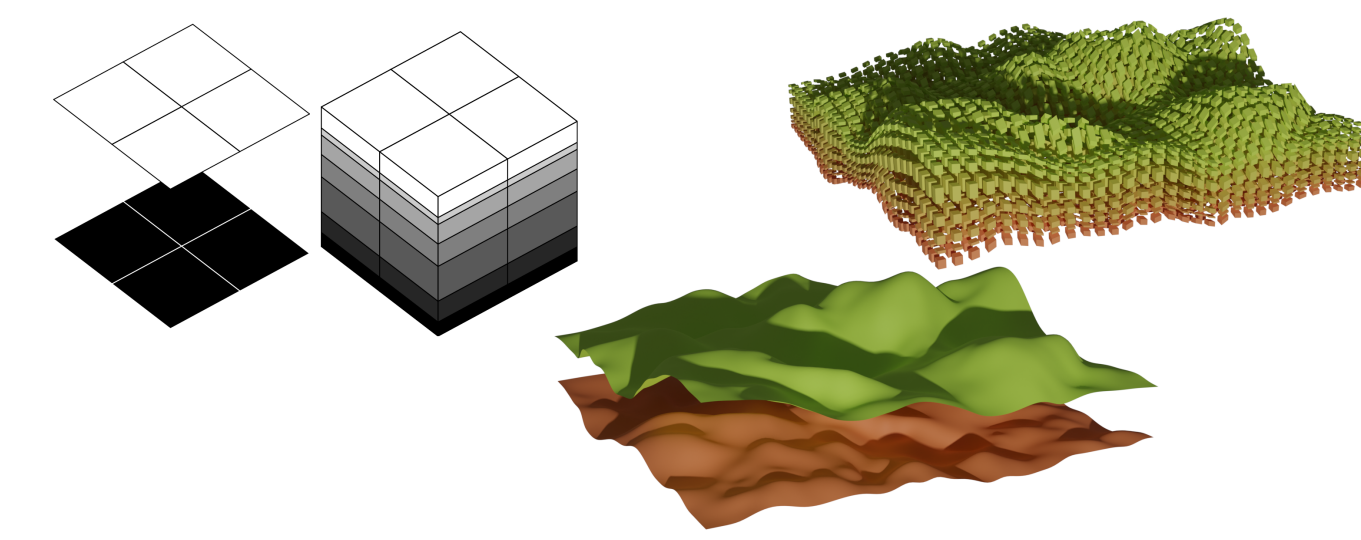
The **viewer** tab (left) contains both instances used for the inference while the **editor** tab (right) allows visualizing (and modifying) the inferred operations.



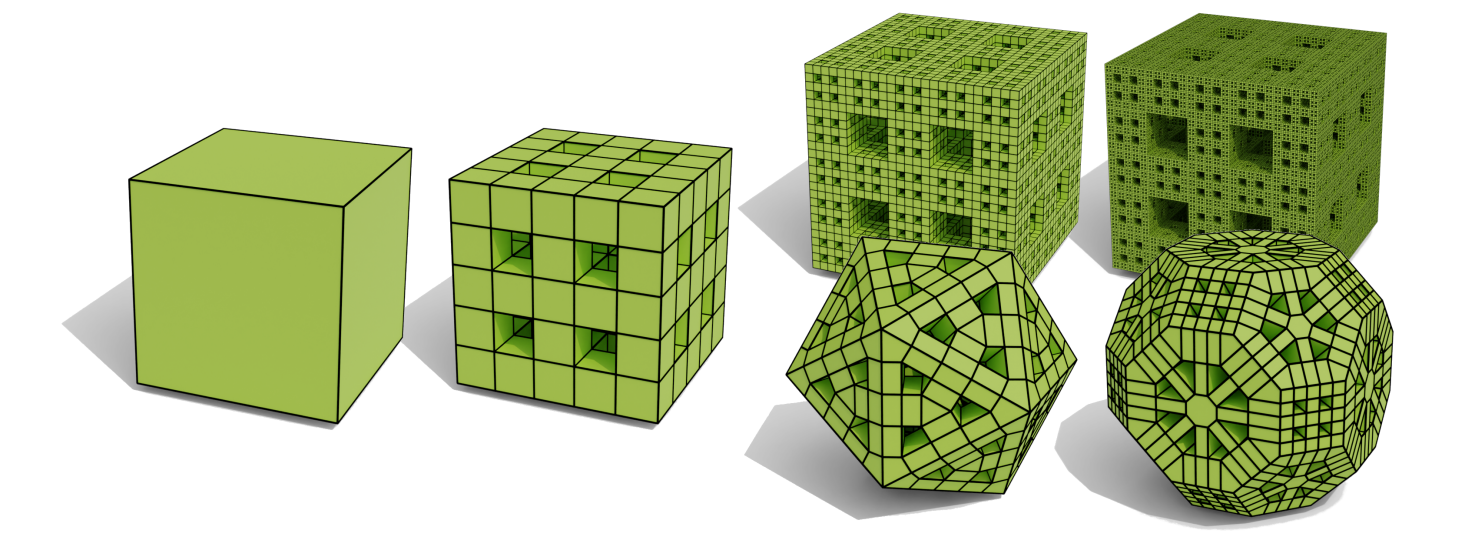
## 8. Results and conclusion

**Main results:** proof of correctness for topological folding algorithm [4], but some operations cannot be expressed directly in the language; retrieve computations with any embedding in a vectorial space by many cases remains out of the linear hypothesis.

Application to layering:



Menger (2, 2, 2) sponge [6]:



[1] A. Arnould, H. Belhaouari, T. Bellet, P. L. Gall, and R. Pascual. Preserving consistency in geometric modeling with graph transformations. *MSCS*, 2022.

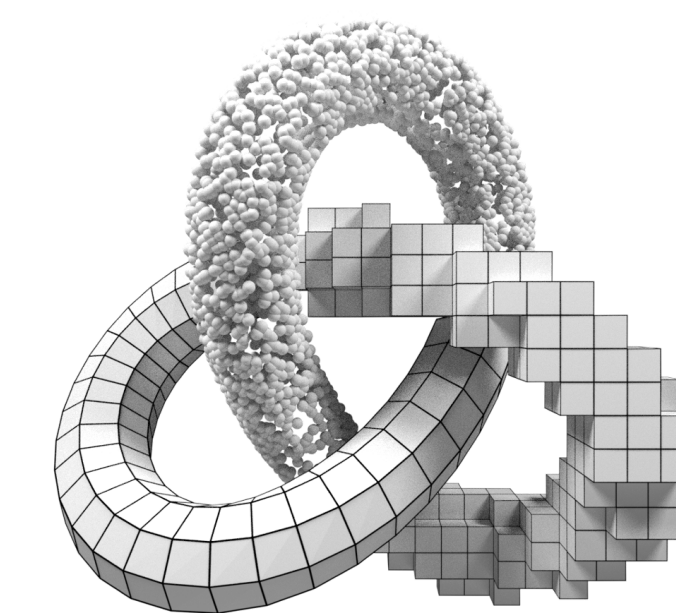
[2] G. Damiand and P. Lienhardt. *Combinatorial Maps: Efficient Data Structures for Computer Graphics and Image Processing*. CRC Press, 2014.

[3] R. Heckel and G. Taentzer. *Graph Transformation for Software Engineers*. Springer, 2020.

[4] R. Pascual, H. Belhaouari, A. Arnould, and P. Le Gall. Inferring topological operations on generalized maps: Application to subdivision schemes. *GVC*, 2022.

[5] R. Pascual, P. Le Gall, A. Arnould, and H. Belhaouari. Topological consistency preservation with graph transformation schemes. *SCP*, 2022.

[6] L. Richaume, E. Andres, G. Largeteau-Skapin, and R. Zrour. Unfolding Level 1 Menger Polycubes of Arbitrary Size With Help of Outer Faces. In *DGCI*, 2019.



GTMG : Groupe de Travail Modélisation Géométrique

La présentation de ces travaux a été primée lors des journées du GT en Mars 2022.