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VISUAL PROGRAMMING

FOR STRUCTURAL ASSESSMENT OF OUT-OF-PLANE MECHANISMS IN HISTORIC MASONRY STRUCTURES

GUIDE TO UNDERSTANDING

Visual programming for structural assessment of out-of-plane mechanisms in historic masonry structures

VISUAL PROGRAMMING

GUIDE TO UNDERSTANDING

This document is a support to approach the **visual scripting for structural assessment of historic masonry structures**. The guide will show the practical aspects of the methods theoretically developed in a paper recently published by Funari et al. (2020) in the Journal of Building Engineering. The visual script is openly available from the University of Dundee data archive at *https://doi.org/10.15132/10000153*, together with a a benchmark case study.

The script is making use of the following grasshopper's components:

- https://www.food4rhino.com/app/octopus
- https://www.food4rhino.com/app/nelder-mead-optimisation-eoc

These need to be downloaded and installed by the users.

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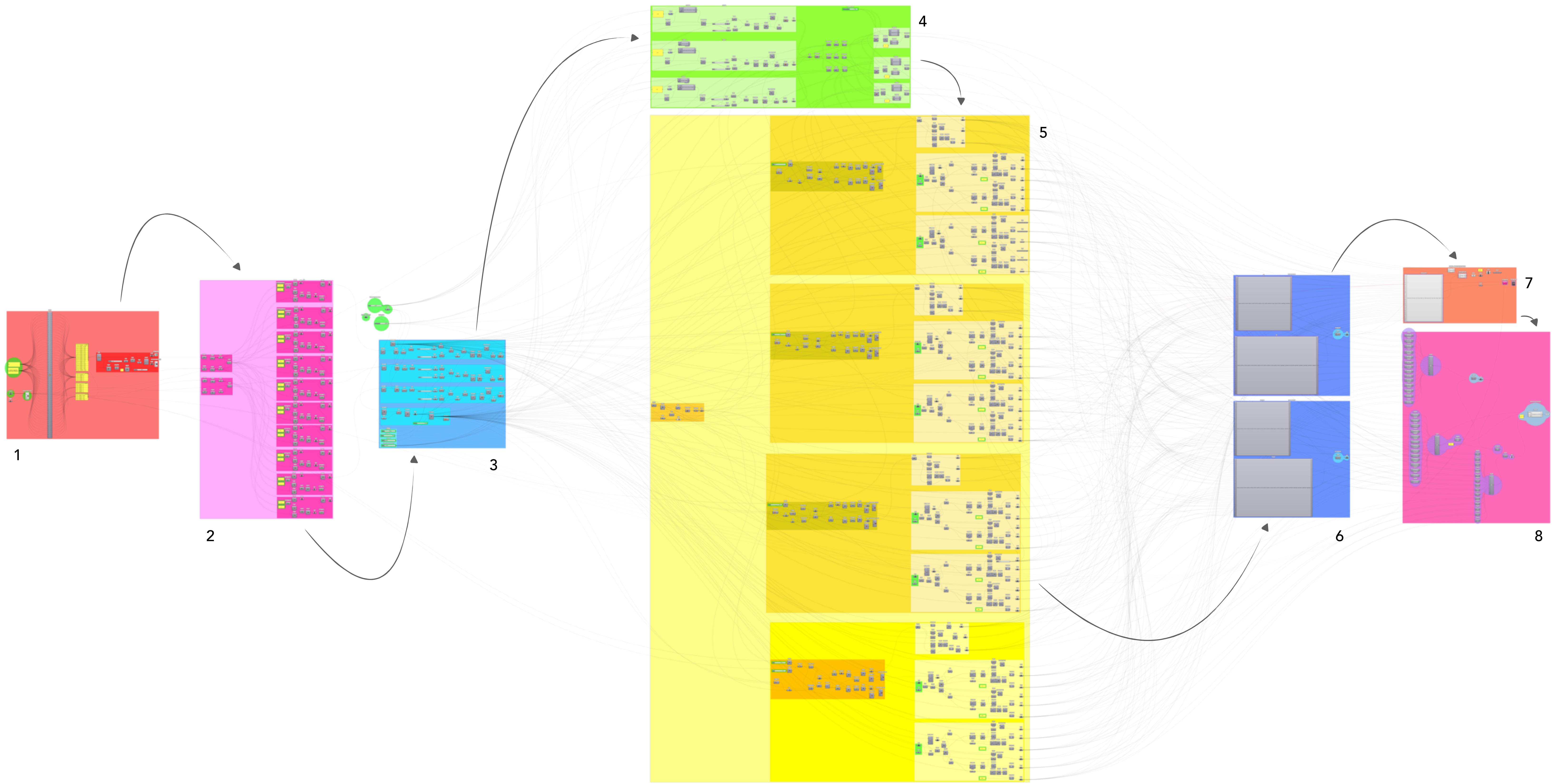
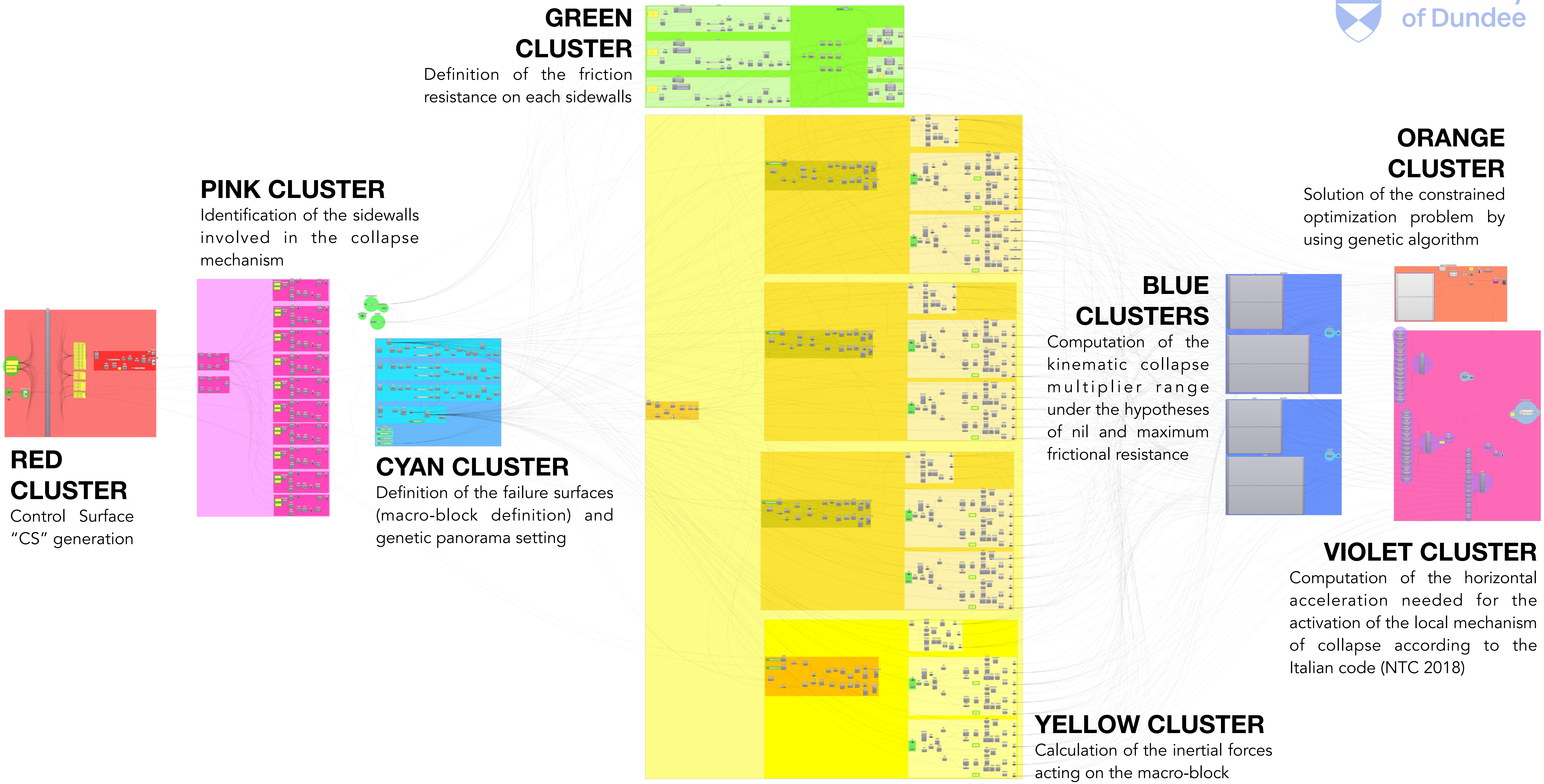
SYNOPTICAL DIAGRAM OF THE SCRIPT

What is the role of different clusters?



1	2	3	4	5	6	7	8


GREEN CLUSTER
Definition of the friction resistance on each sidewalls
PINK CLUSTER
Identification of the sidewalls involved in the collapse mechanism
RED CLUSTER
Control Surface "CS" generation
CYAN CLUSTER
Definition of the failure surfaces (macro-block definition) and genetic panorama setting
BLUE CLUSTERS
Computation of the kinematic collapse multiplier range under the hypotheses of nil and maximum frictional resistance
YELLOW CLUSTER
Calculation of the inertial forces acting on the macro-block
ORANGE CLUSTER
Solution of the constrained optimization problem by using genetic algorithm
VIOLET CLUSTER
Computation of the horizontal acceleration needed for the activation of the local mechanism of collapse according to the Italian code (NTC 2018)

1

RED CLUSTER
CONTROL SURFACE GENERATION

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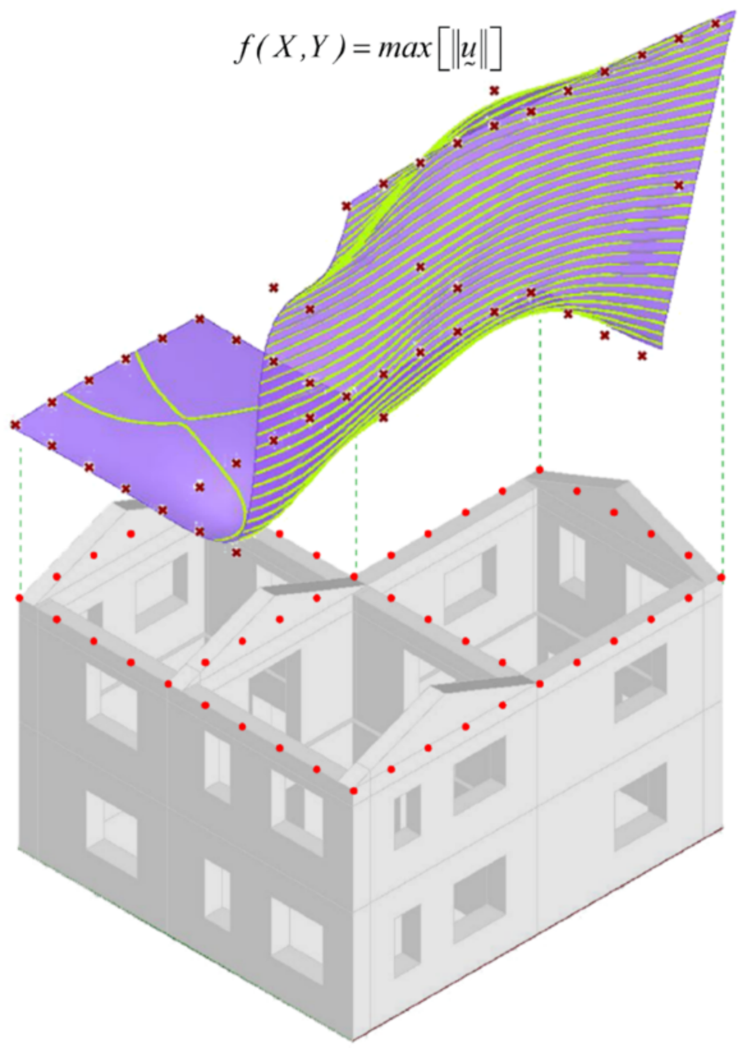
a Provide the path to the *.text file containing the results of the pushover analysis (a sample file is provided) [a].

b The visual script generates the Control Surface [b].



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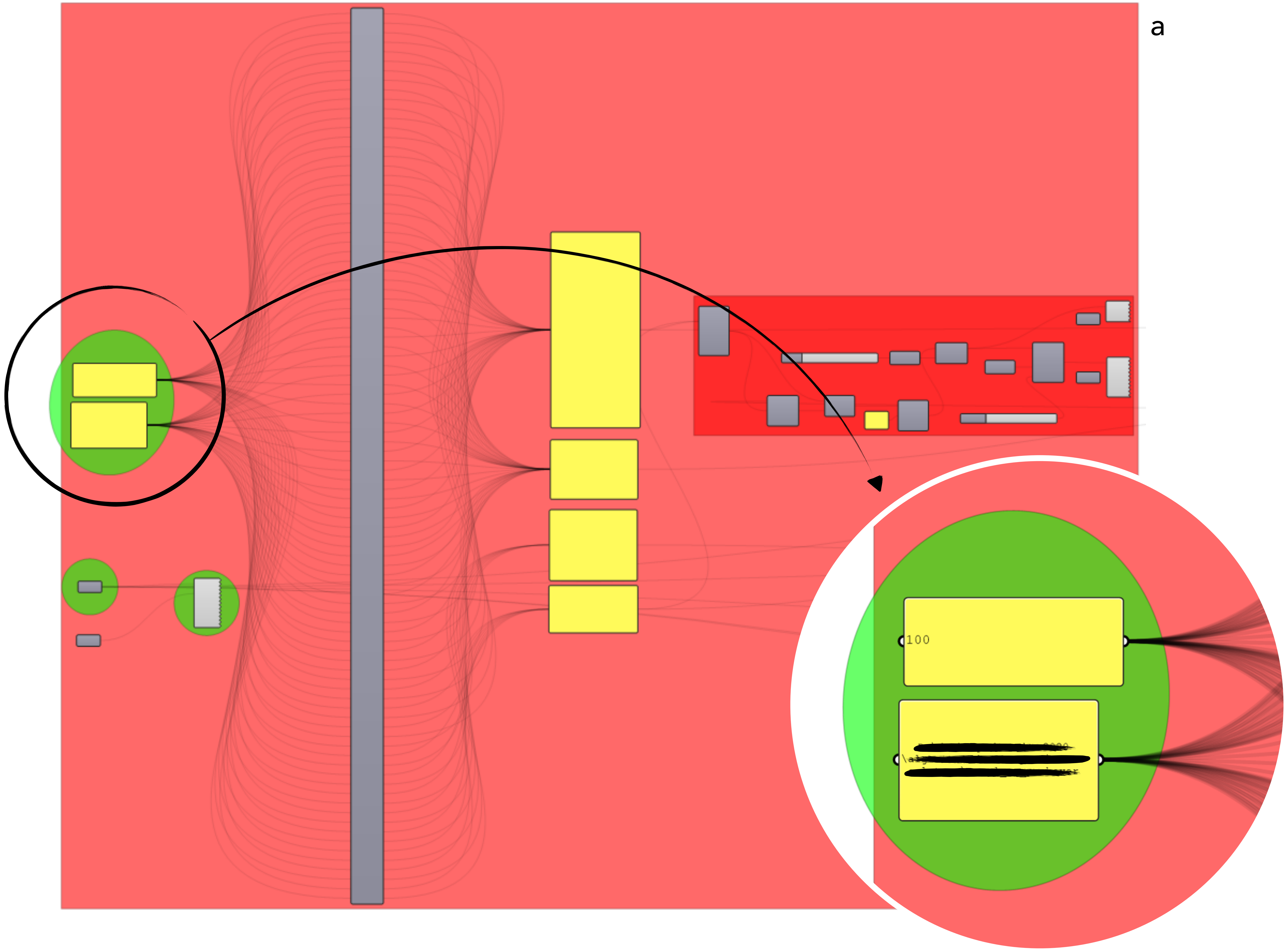


a

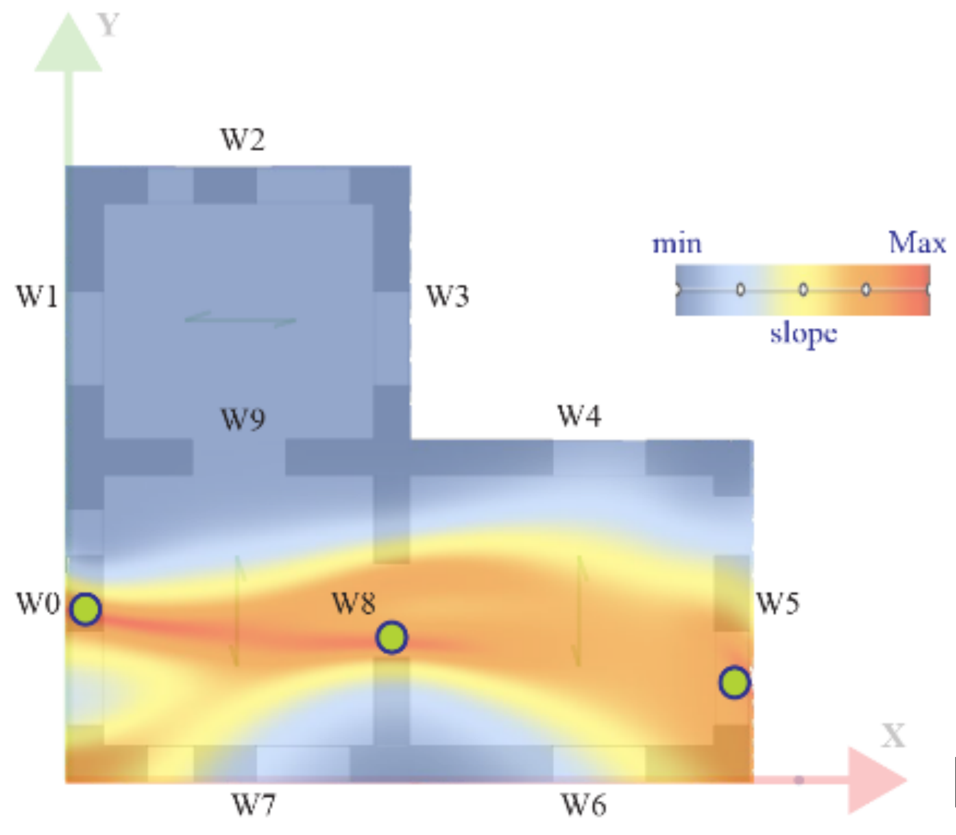
2

PINK CLUSTER

IDENTIFICATION OF THE SIDEWALLS INVOLVING IN THE COLLAPSE MECHANISM

a Each wall is associated with a pink box which performs a local slope analysis [a.1]. These define the range of the indexes of the control points associated with the wall (in agreement with the pushover analysis results file numbering) [a. 2].

b The user identifies the wall exhibiting the maximum slope. Figure [b] shows that higher values of the slope are obtained in correspondence of walls W0, W8 and W5.



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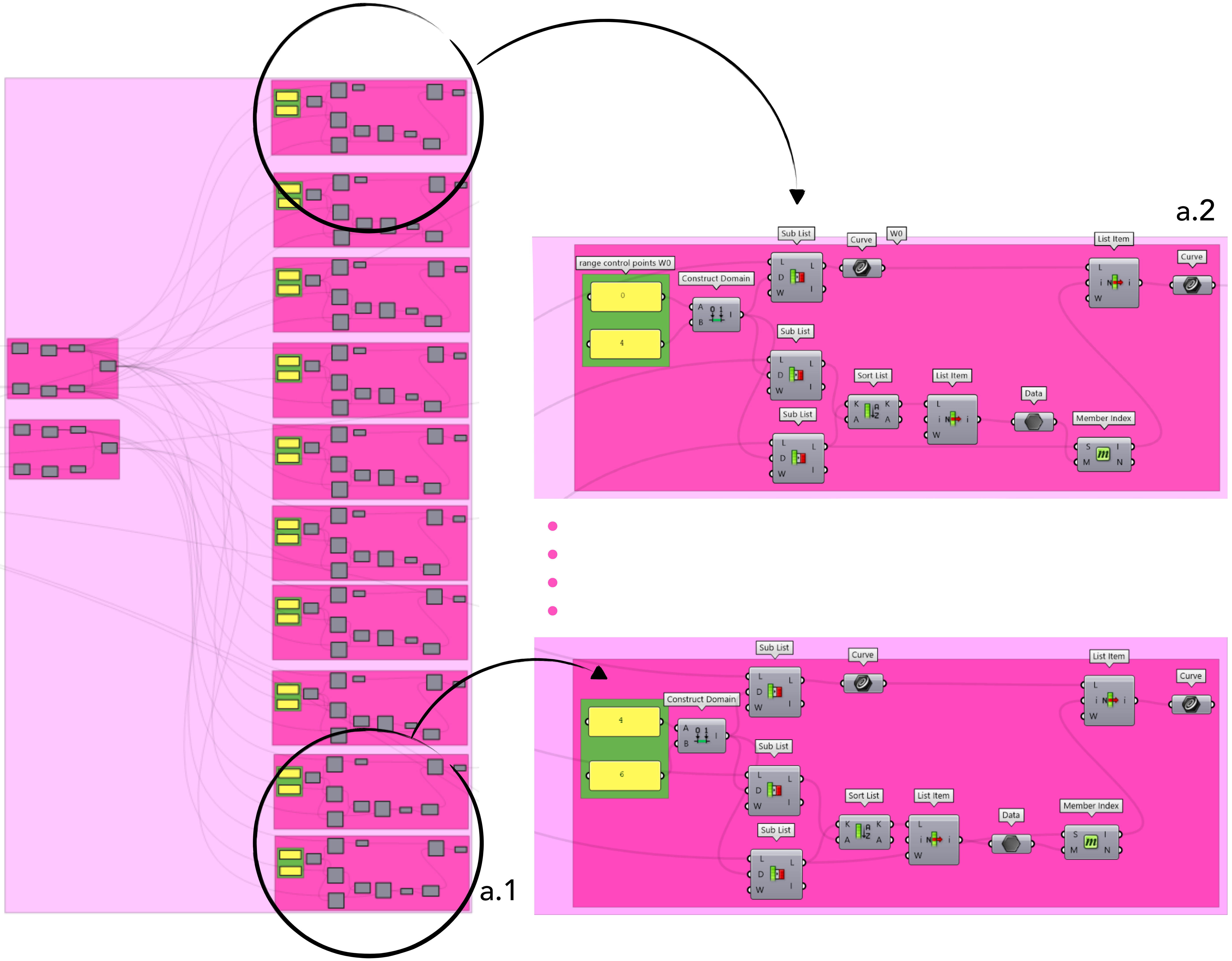
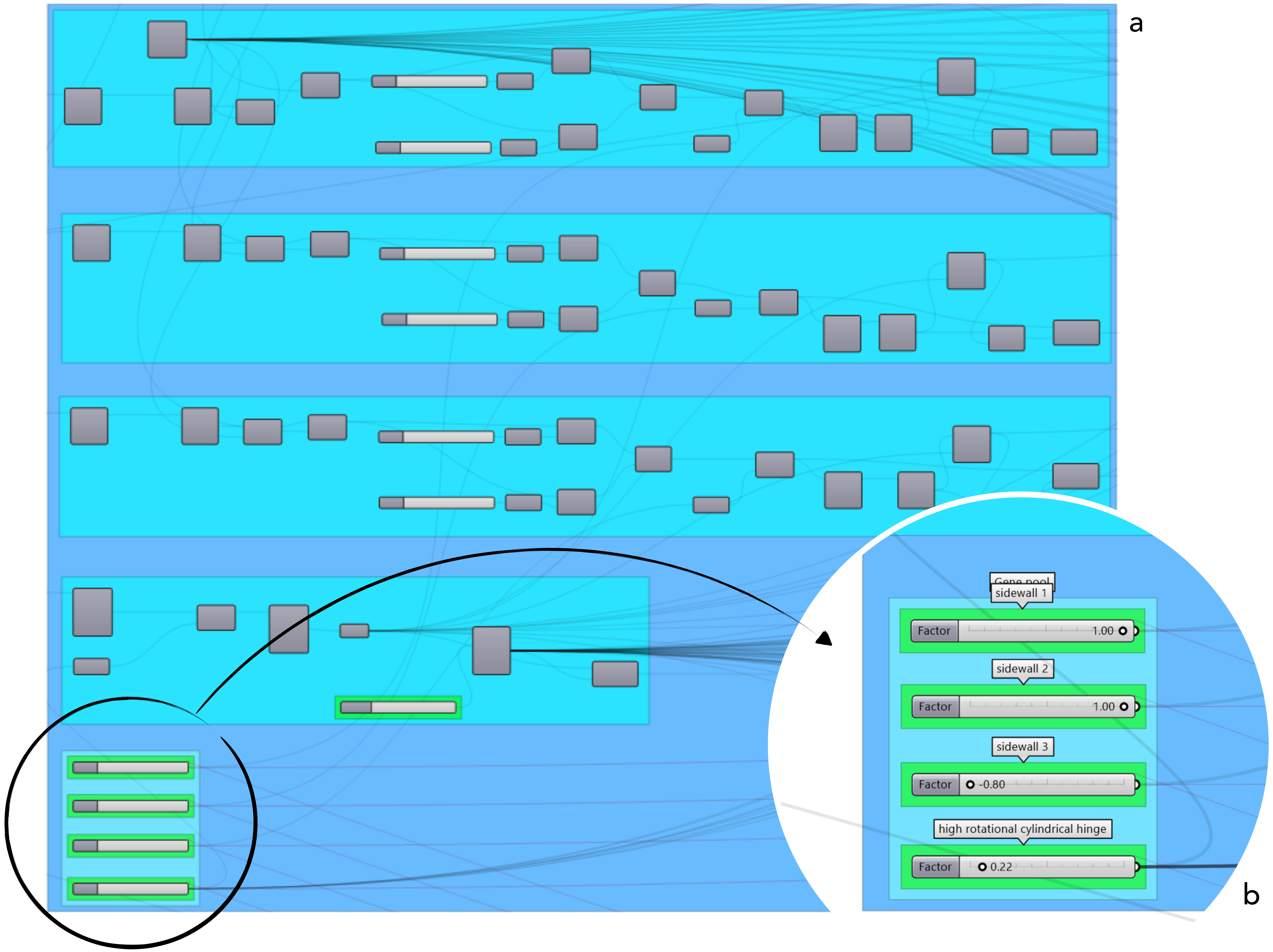


CYAN CLUSTER

DEFINITION OF THE FAILURE SURFACES

a W0, W8 and W5 are selected and analyzed separately in order to define the cutting planes [a].

b In the same cluster, some sliders are defining the genetic panorama [b].



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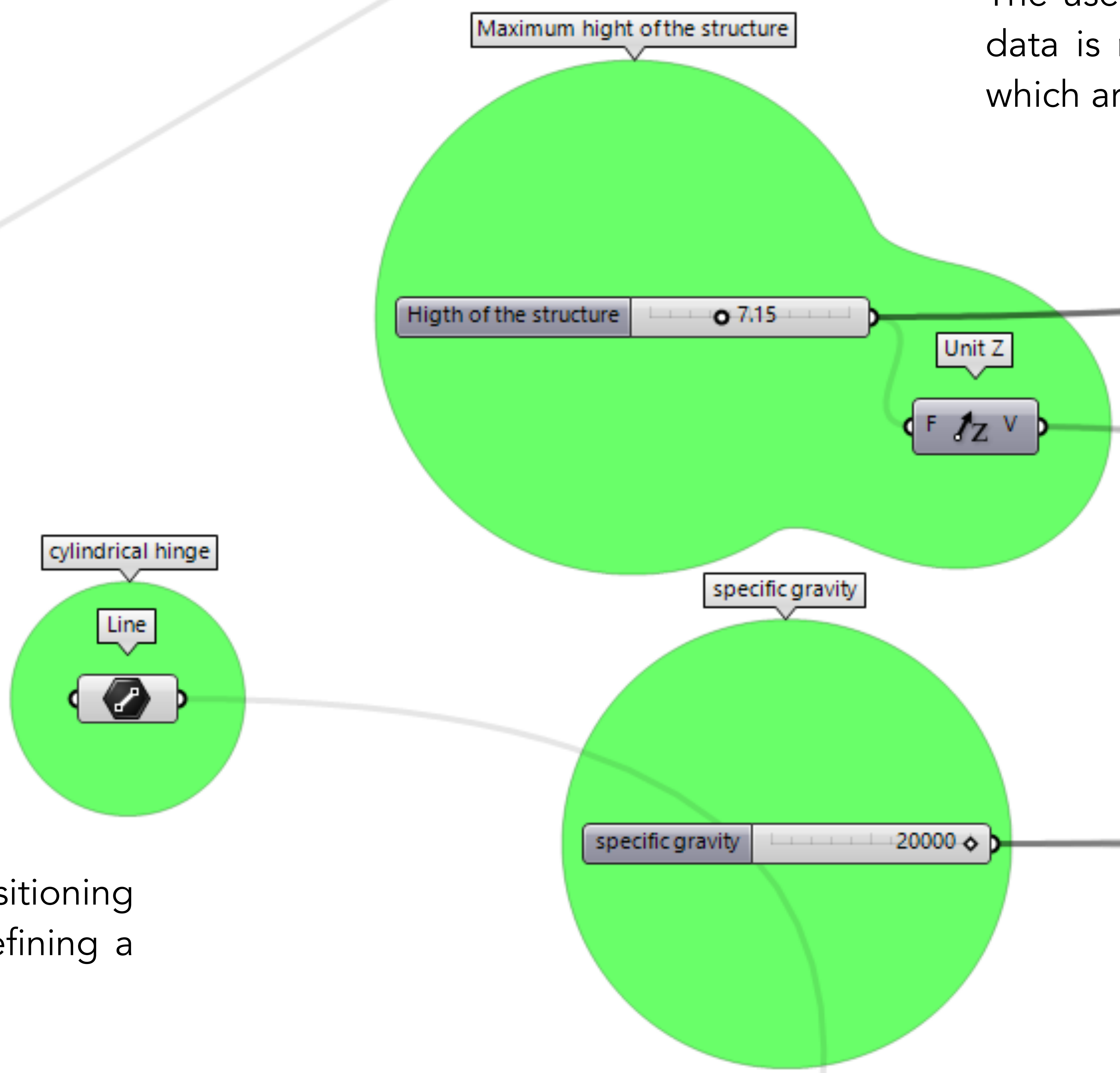
The user defines the height of the structure. This data is needed in the part of the visual code in which are defined the failure surfaces.



The user can influence the positioning of the cylindrical hinge by defining a line.

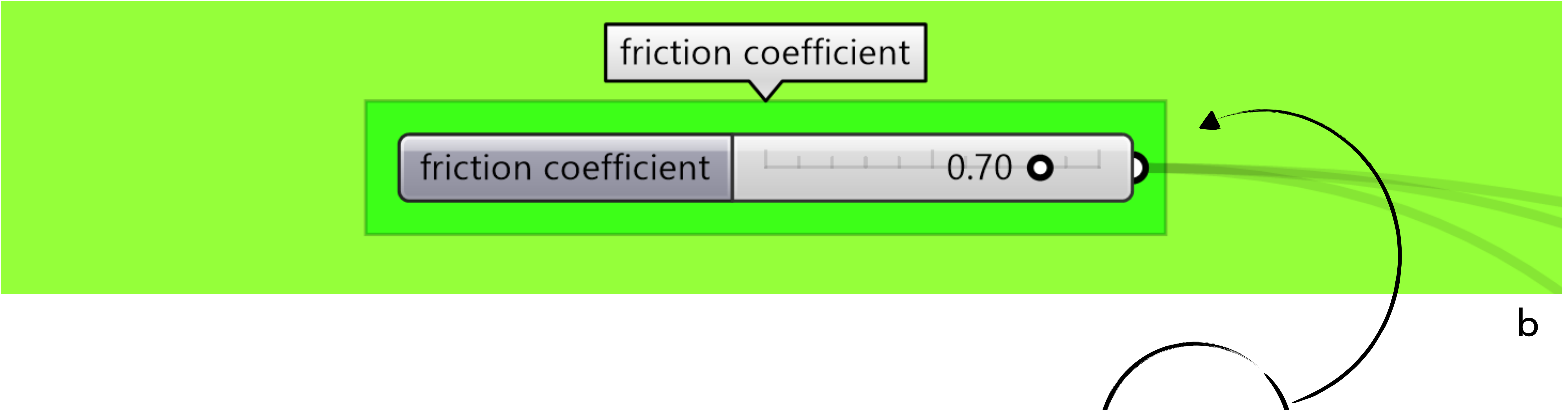
The user sets the specific gravity of the masonry.

GREEN CLUSTER

NUMERICAL DEFINITION OF THE FRICTION RESISTANCE ON EACH SIDEWALLS

a In this box, the visual code evaluates the friction resistance that the sidewalls are able to provide [a] (Casapulla et al., 2014).

b The user can conveniently modify the value of the friction coefficient by using a slider [b].



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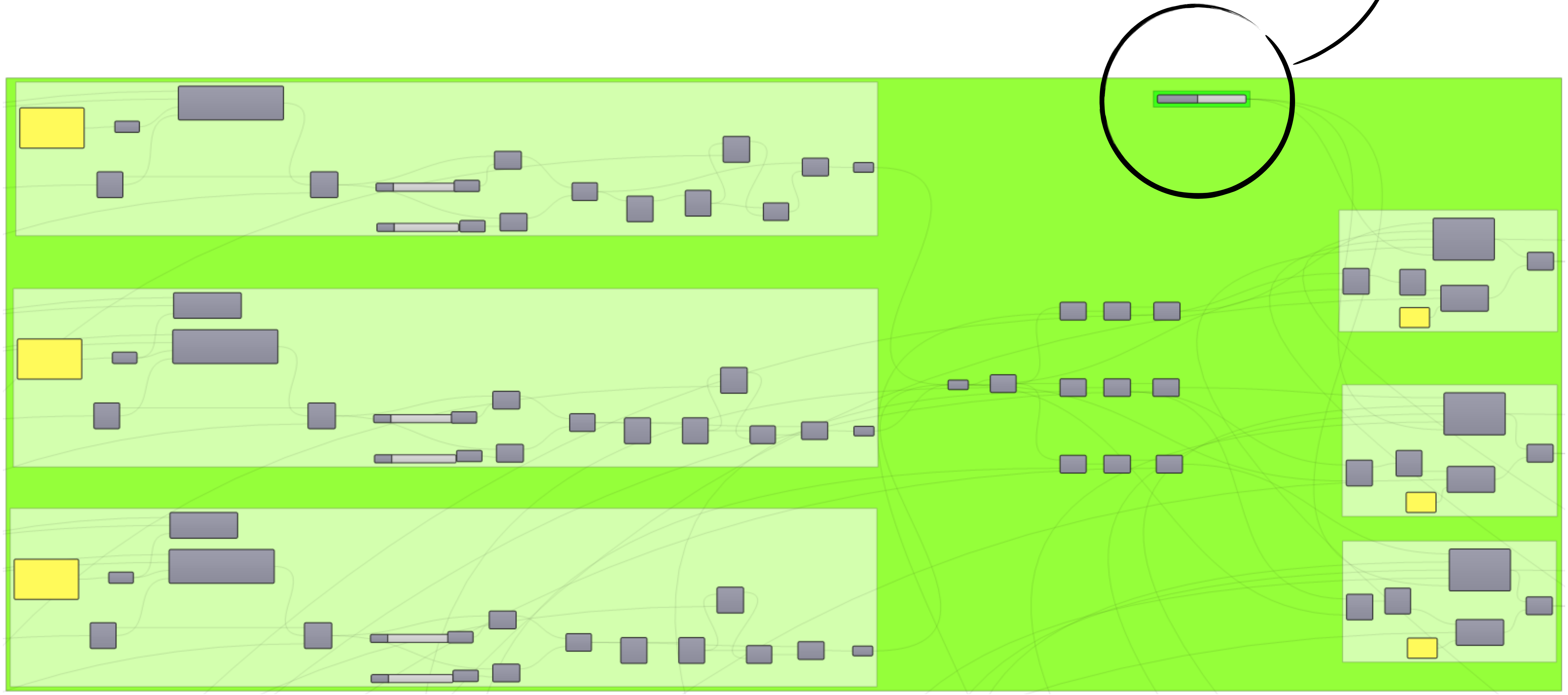


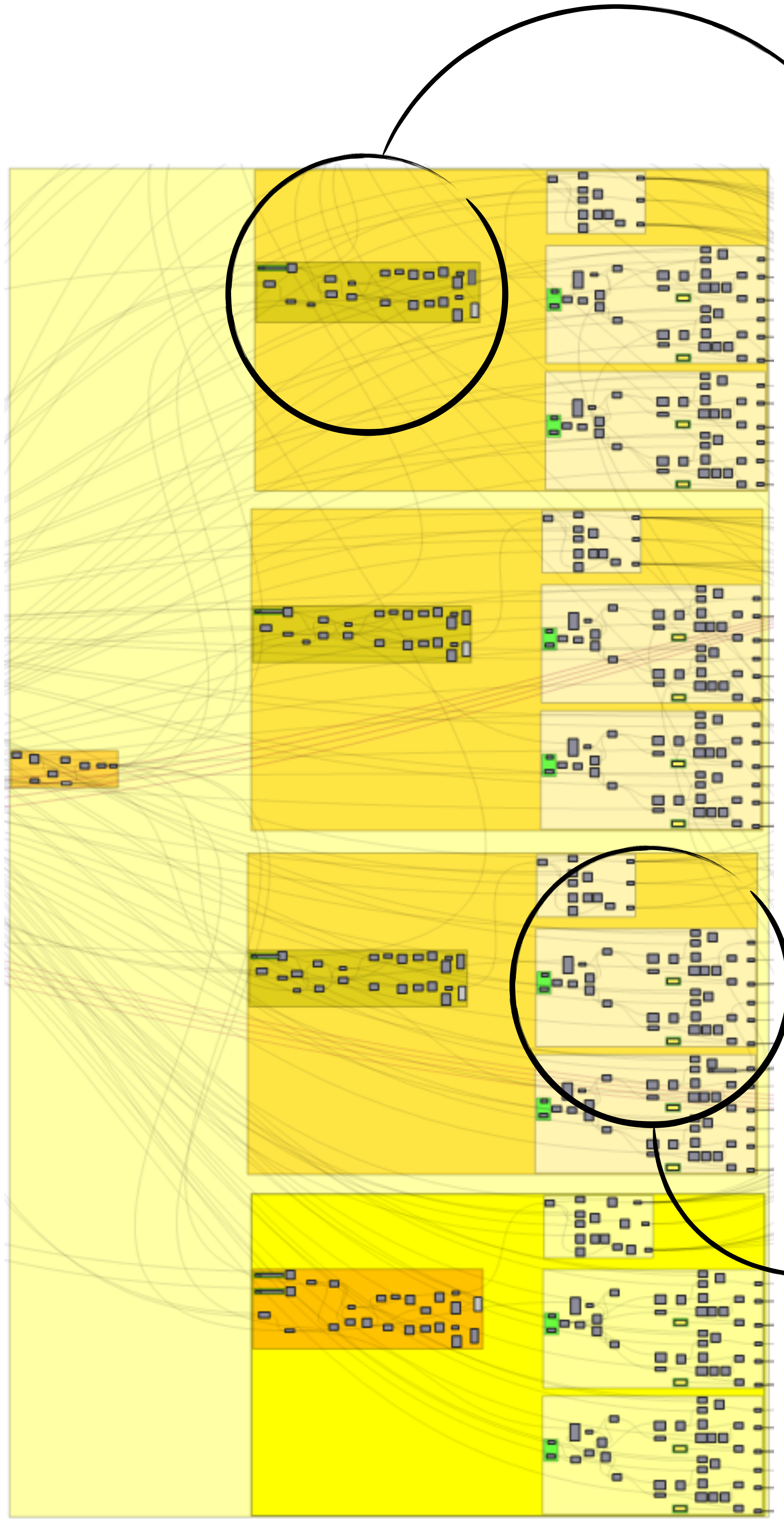
a

5

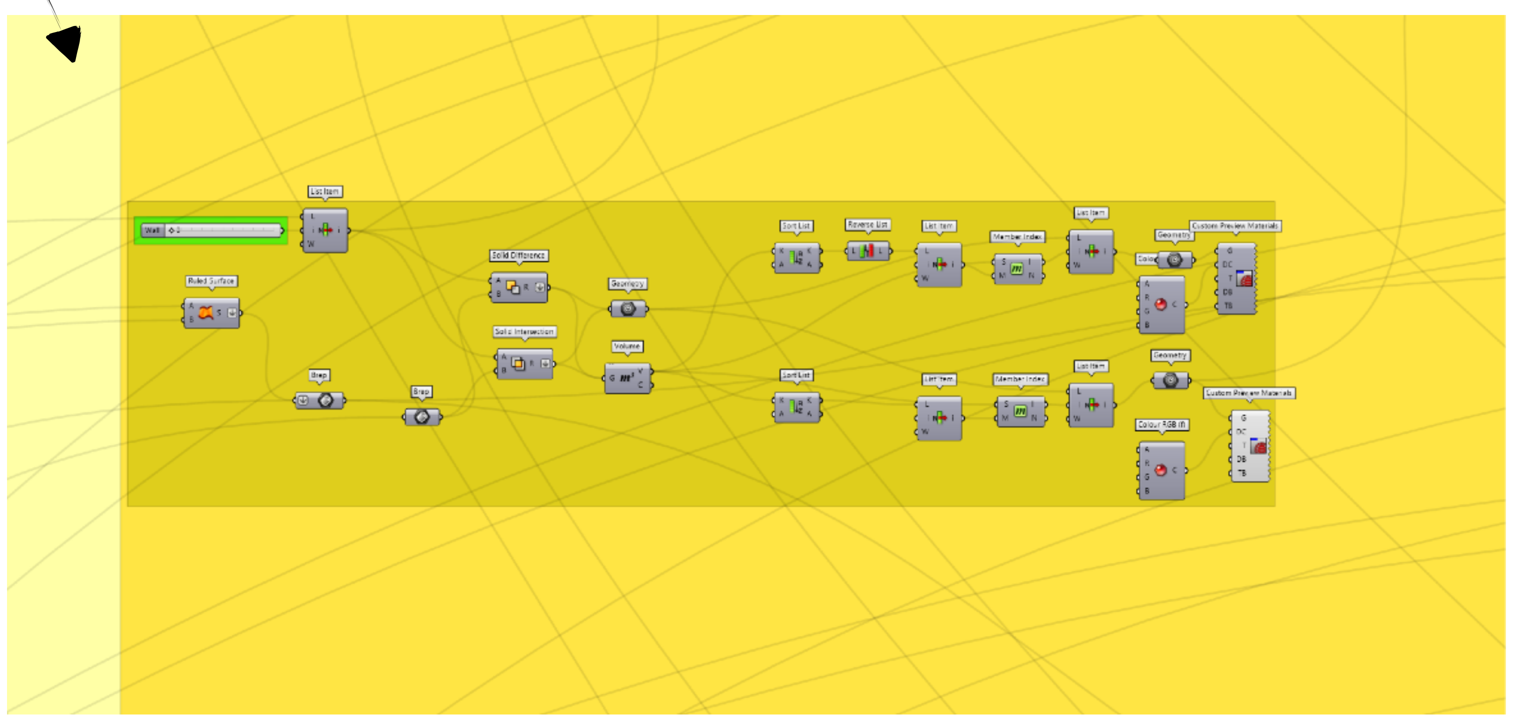
YELLOW CLUSTER
CALCULATION OF THE INERTIAL FORCES

a This cluster compute the inertial forces that involve into the structural system [a].

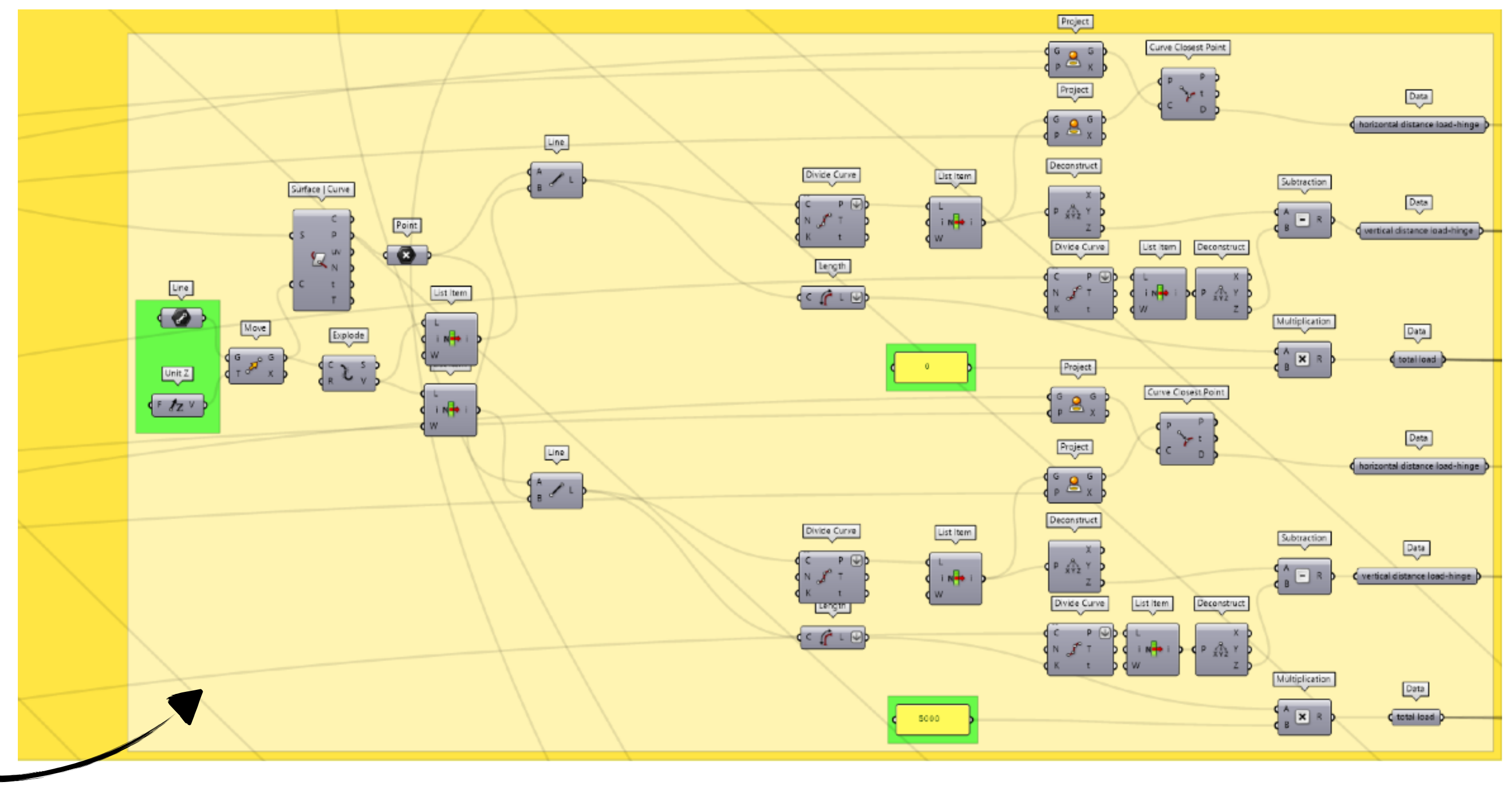
b Each wall embedded in the mechanism is associated with a box [b.1]. The user has to draw a line defining the floor or roof supports and introduce the weight per unit length [b.2].
The output of the cluster is the total force acting on each macro-block as well as the distance of its point of application from the overturning axis.



a



b.1



b.2

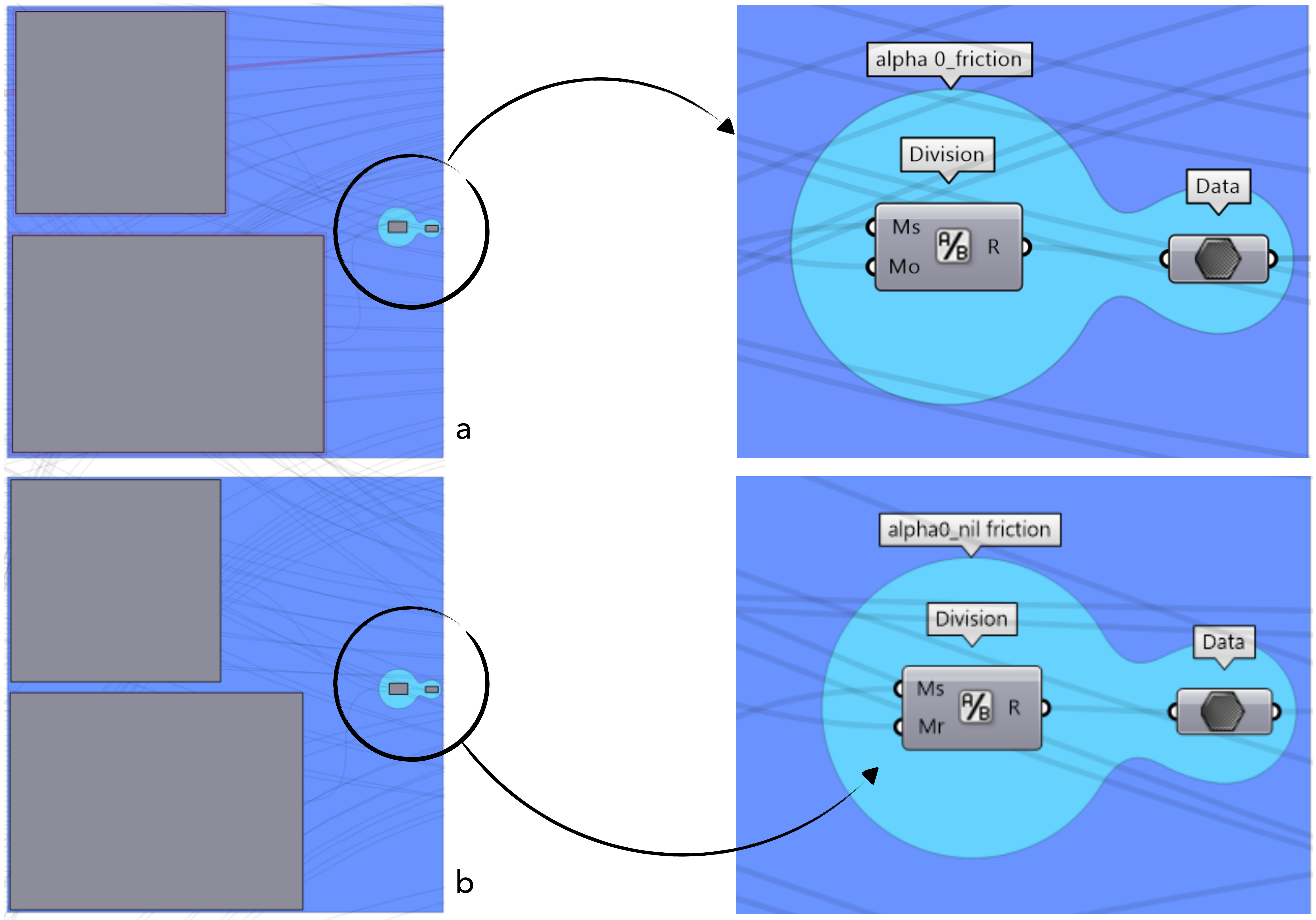
BLUE CLUSTERS

COMPUTATION OF THE KINEMATIC COLLAPSE MULTIPLIER

This cluster provides the evaluation of the kinematic multiplier by considering both hypothesis nil and maximum frictional resistance.

a The blue boxes is devoted to compute the load multiplier that generates the activation of the mechanism by adopting the procedure developed by Casapulla et al. [a].

b In parallel the kinematic multiplier under the hypothesis of nil friction resistance is calculated by considering the same macro block geometry [b].



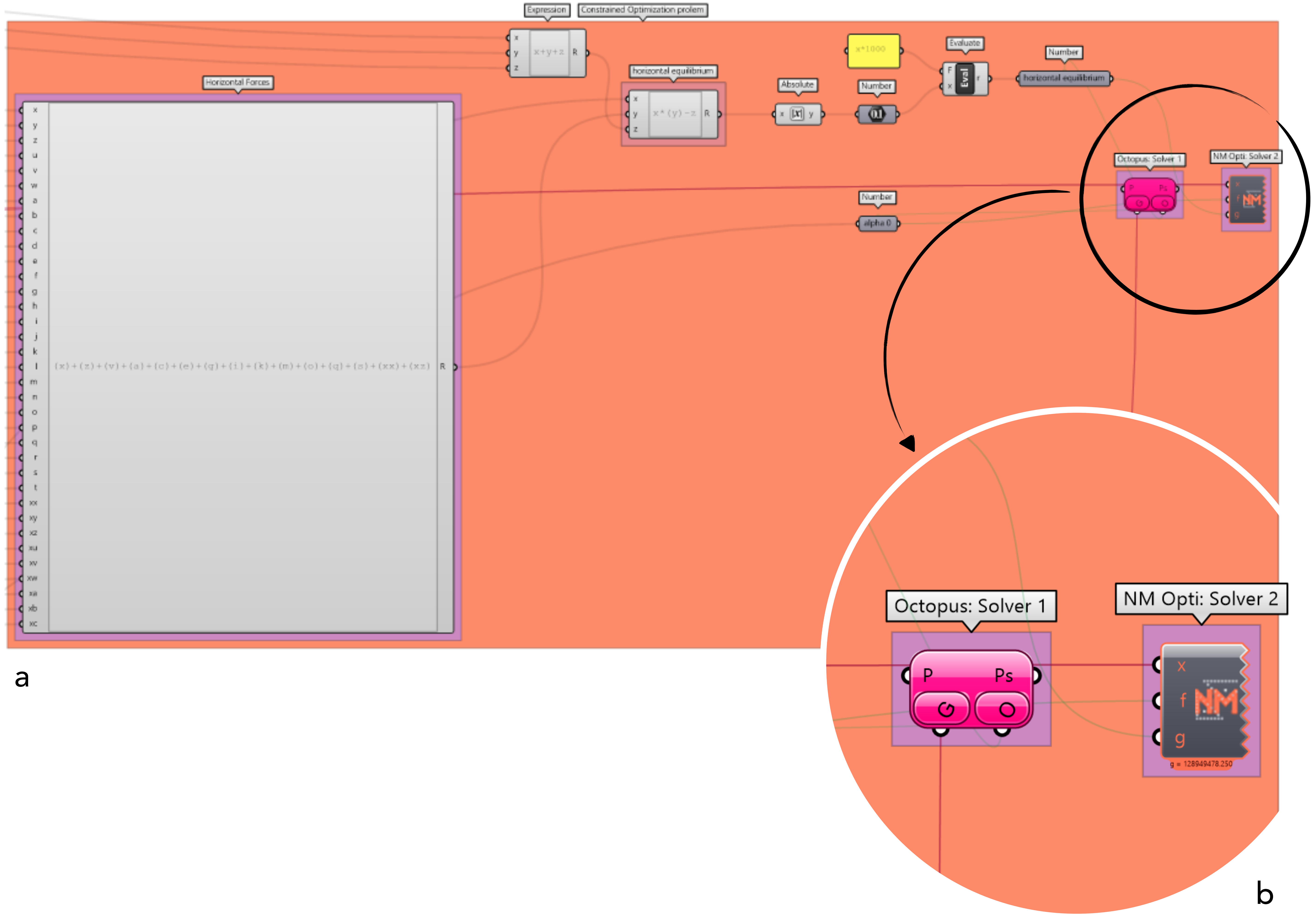
ORANGE CLUSTERS

SOLUTION OF THE CONSTRAINED OPTIMIZATION PROBLEM BY USING GENETIC ALGORITHM

a In its core component, the scrip finds the minimum kinematic multiplier by solving the following constrain minimization problem:

$$\begin{cases} \text{minimize} : \alpha_0 \\ \text{subject to} : \sum_{1}^{n} F_h^i = 0 \end{cases}$$

b The octopus component minimize the acceleration for the activation of the mechanism, which guarantees the horizontal equilibrium (first fitness function), by modifying the failure surface of the masonry structure in the 3D space and, consequently, the geometry of the macro-block considered for the equilibrium (second fitness function).
The solution process is also performed by using Nelder-Mead Optimisation (NMO) component, which uses a local search-based optimisation algorithm.



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VIOLET CLUSTER

COMPUTATION OF THE HORIZONTAL ACCELERATION NEEDED FOR THE ACTIVATION OF THE LOCAL COLLAPSE MECHANISM

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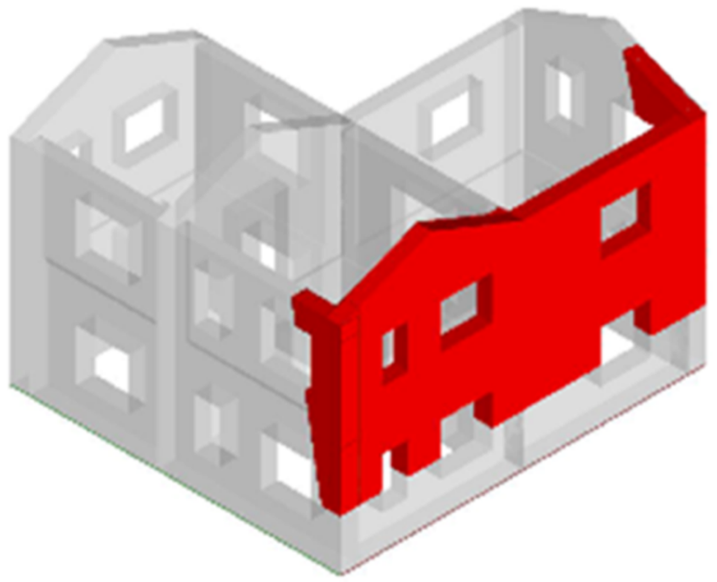
a Based on the results obtained in the previous step, this cluster allow to perform the code checks according to the Italian code (NTC2018).

b The horizontal acceleration that produces the activation of the local mechanism is represented in the picture.



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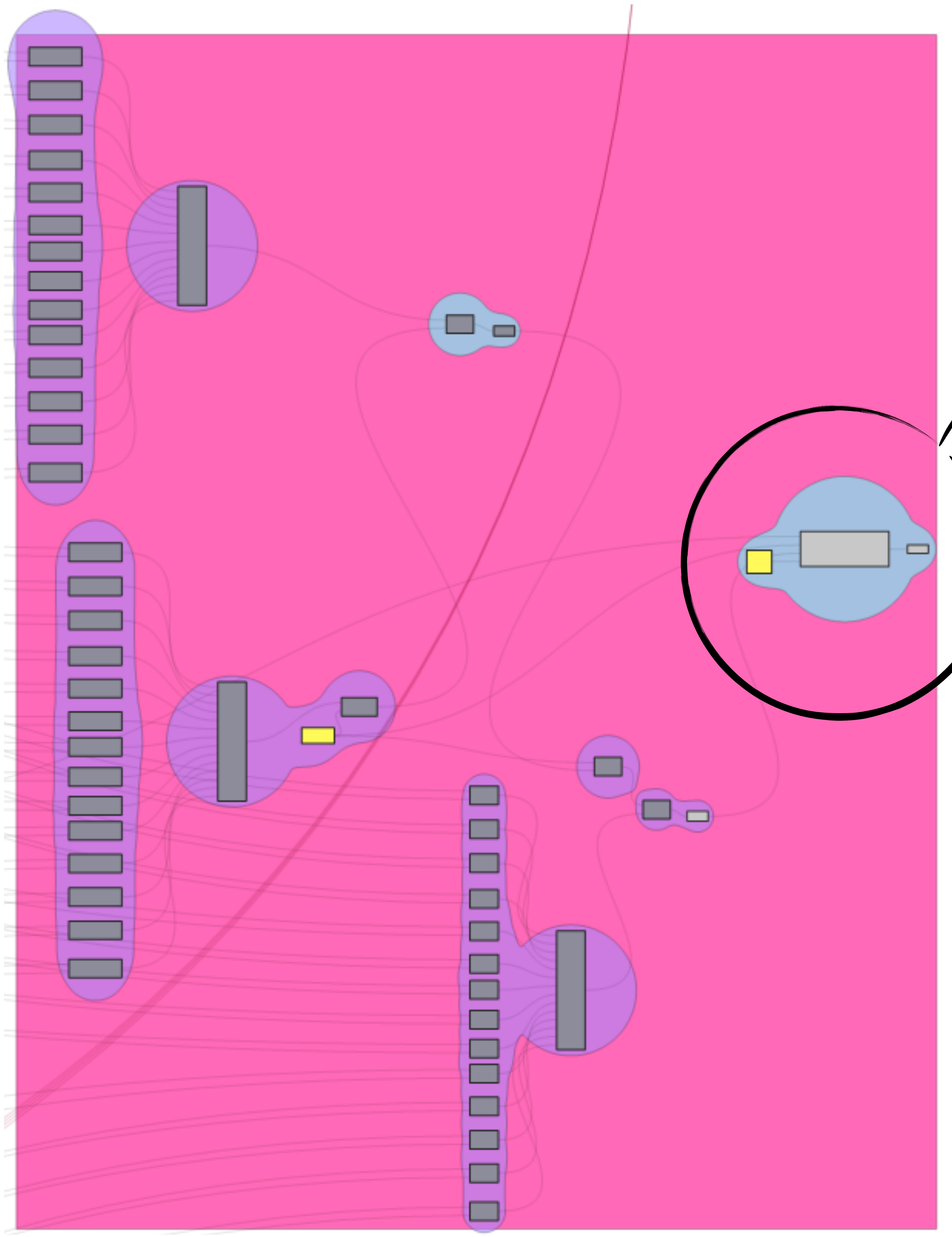
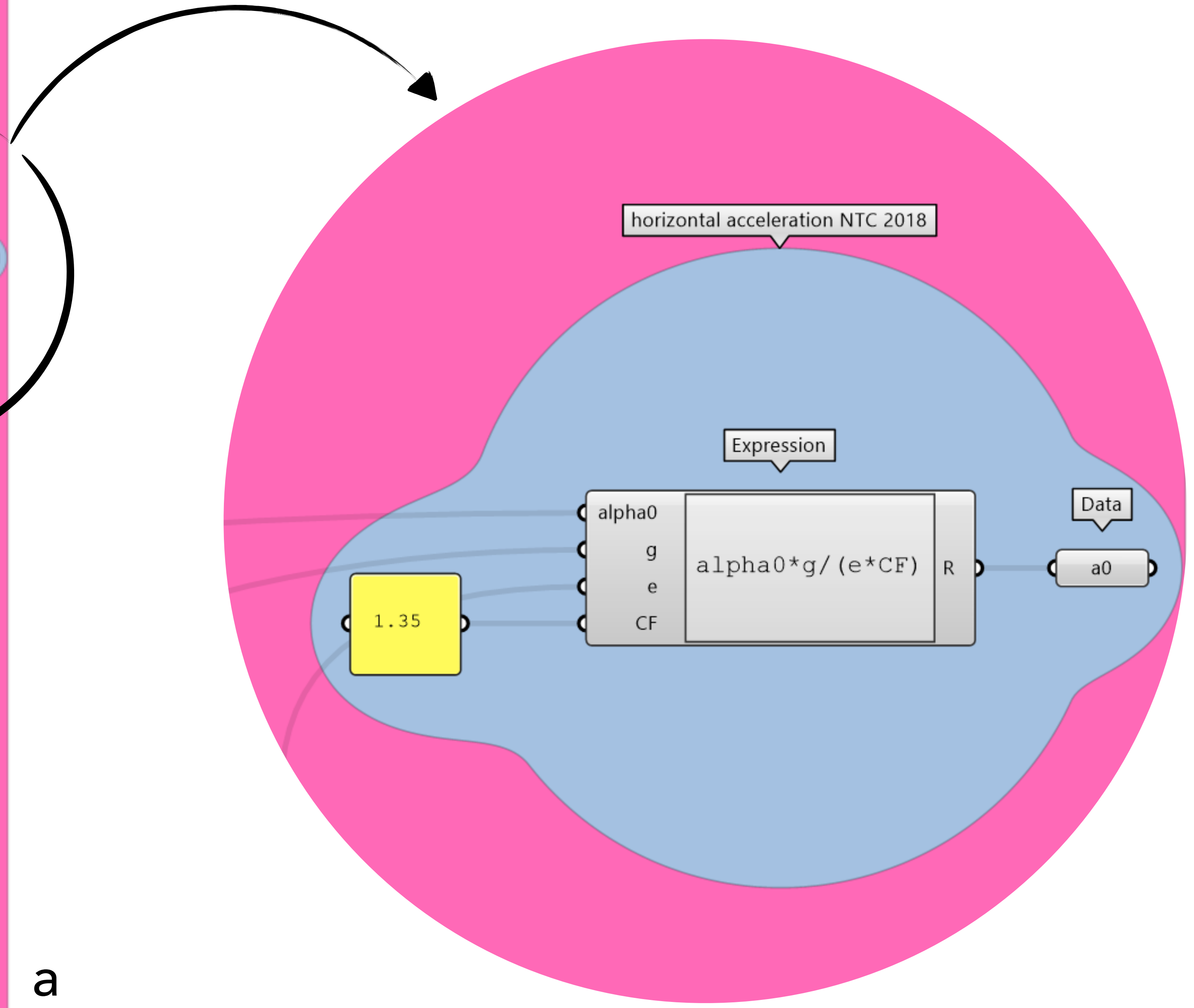


a



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References:

- M.F. Funari, S. Spadea, P. Lonetti, F. Fabbrocino and R. Luciano, *Visual programming for structural assessment of out-of-plane mechanisms in historic masonry structures.* Journal of Building Engineering.
- C. Casapulla et al., *3D macro and micro-block models for limit analysis of out-of-plane loaded masonry walls with non-associative Coulomb friction*. Meccanica, 2014. 49(7): p. 1653-1678.
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