

3D BUILDING RECONSTRUCTION WITH PARAMETRIC ROOF SUPERSTRUCTURES

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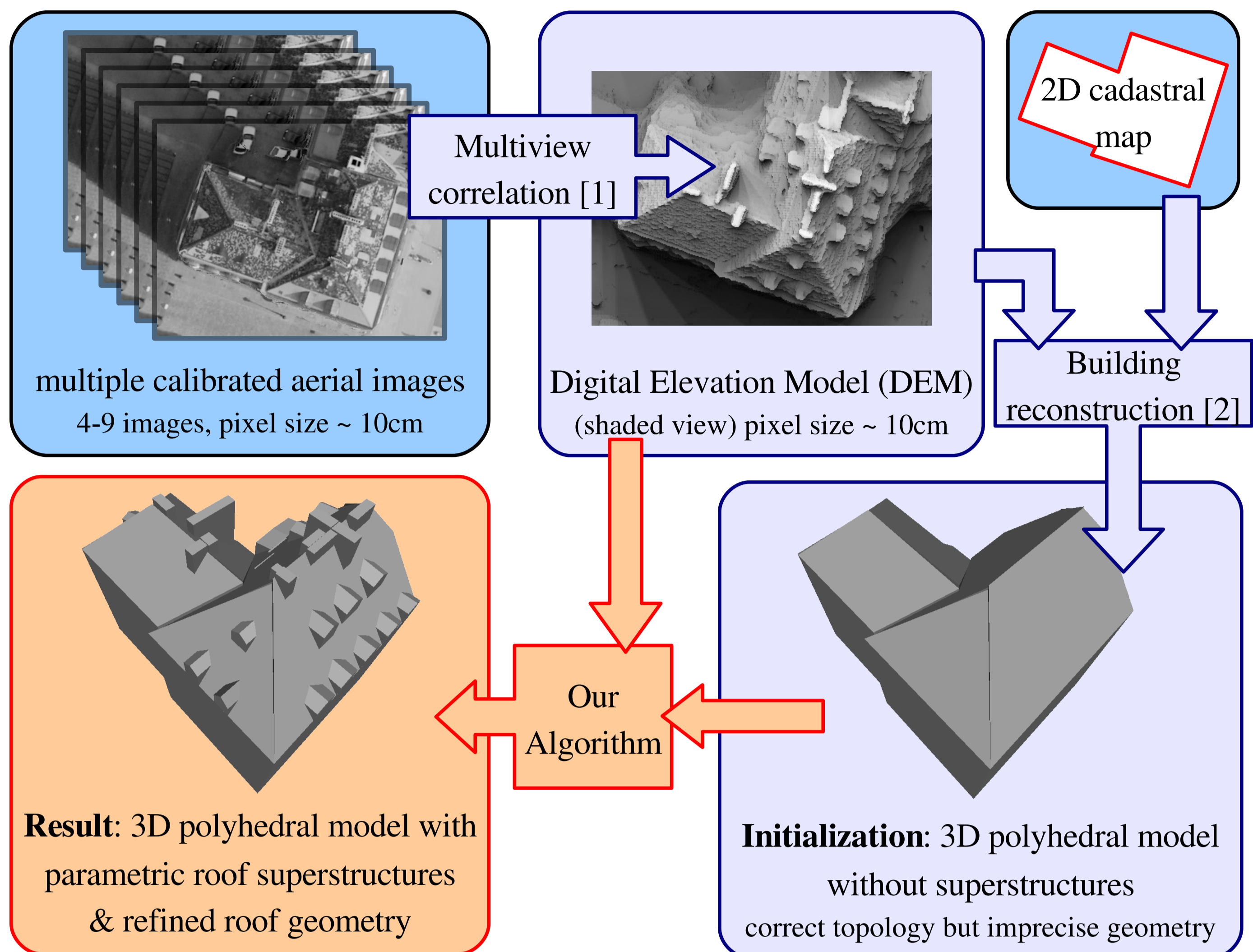


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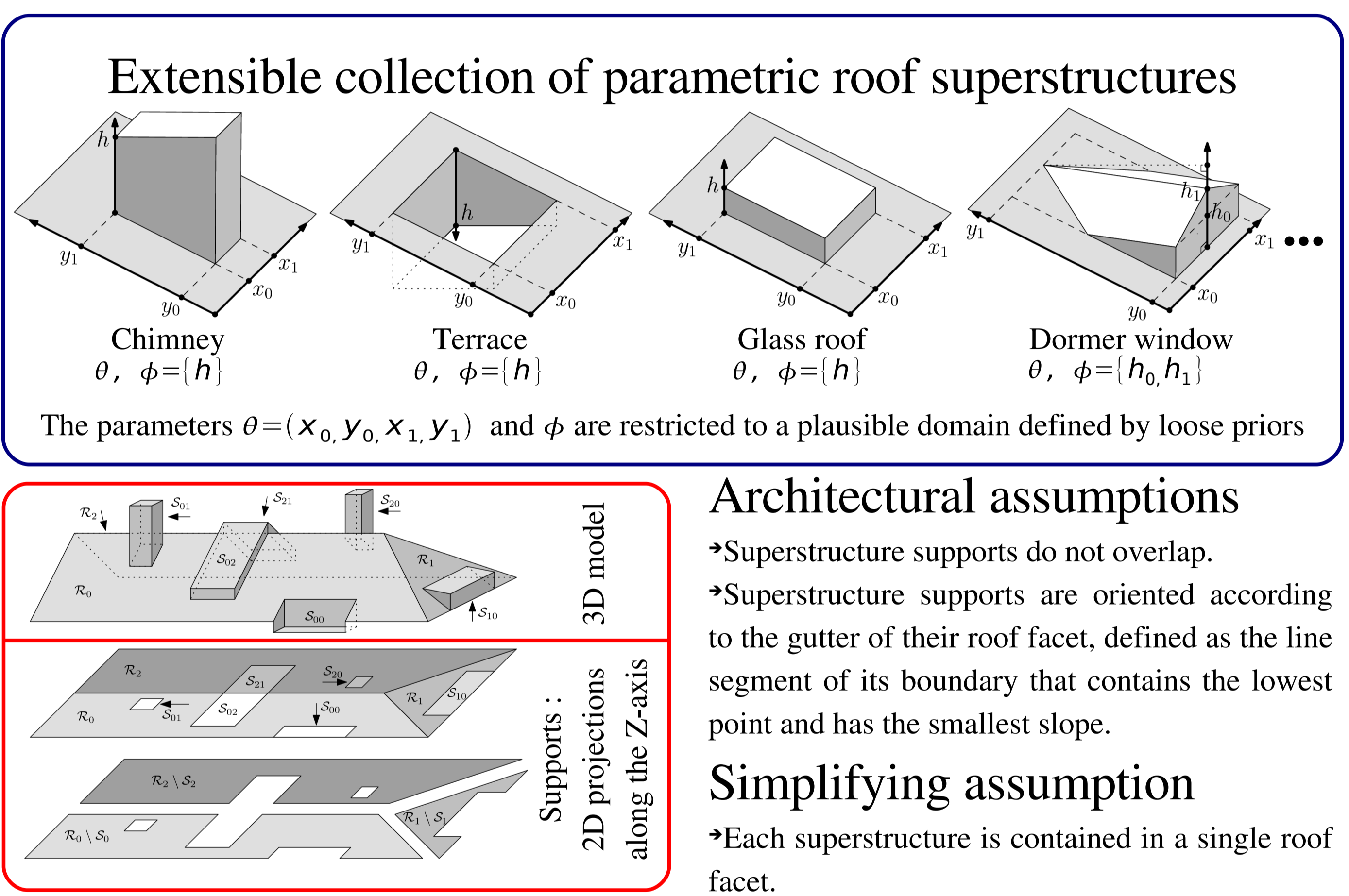
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I - Context



II - 3D Model



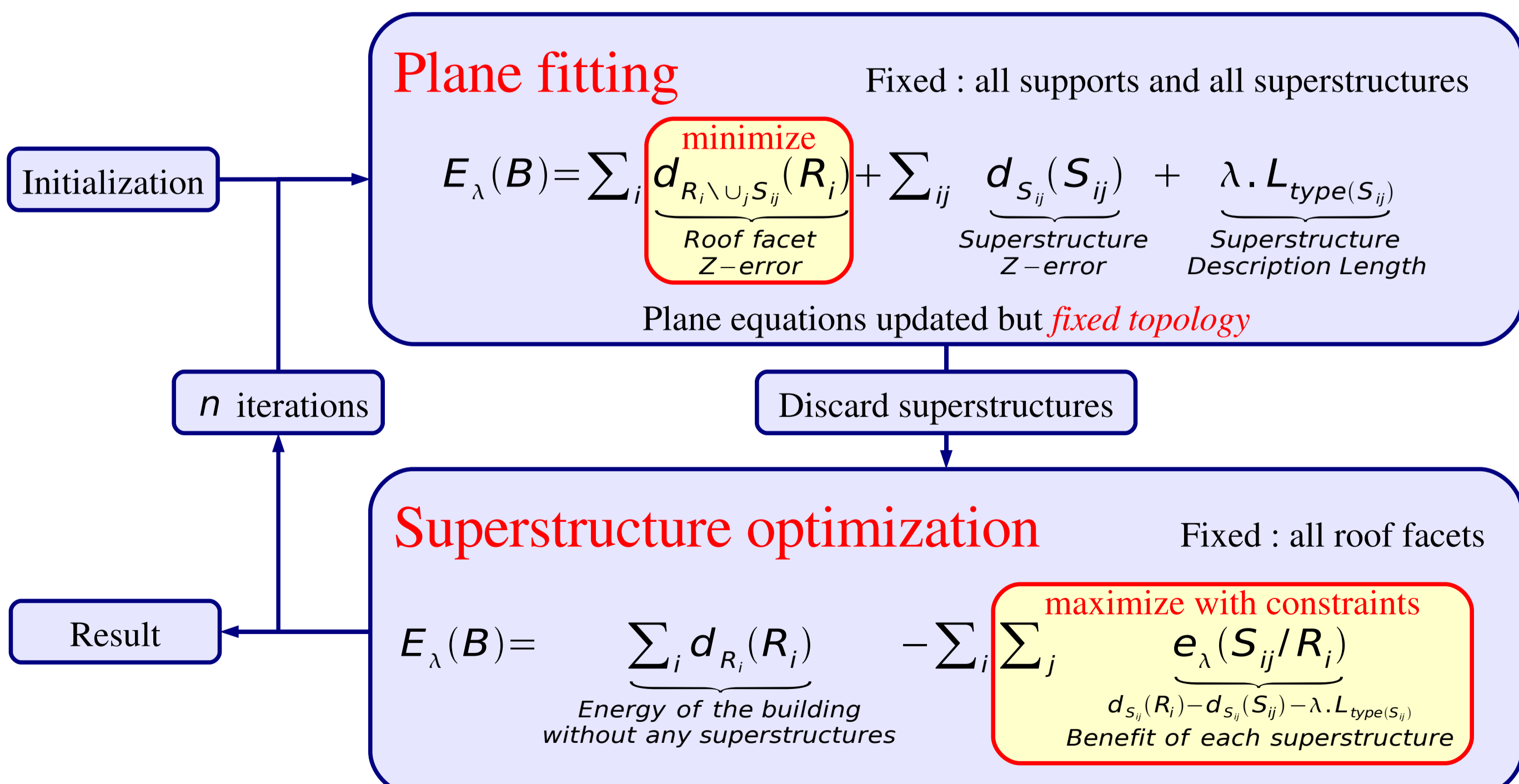
III - Energy formulation and Optimization overview

MDL Formulation $E_\lambda(B) = \underbrace{d_B(B)}_{\text{data term (Z-error)}} + \lambda \cdot \underbrace{L(B)}_{\text{DL term (Description Length factor)}}$ $\lambda \geq 0$: Description Length factor

Data term (Z-error): $d_{B_1}(B_2) = \int_{\text{support}(B_1)} \|z_{DEM}(x, y) - z_{B_2}(x, y)\|$

Description Length term: $L(B) = \sum_{ij} L_{\text{type}}(S_{ij})$ L_1 norm for robustness, L_2 norm for speed

Optimization overview and reformulations of the energy



References

- [1] Pierrot-Deseilligny, M. and Paparoditis, N., A Multiresolution and Optimization-Based Image Matching Approach: An Application to Surface Reconstruction from SPOT5-HRS Stereo Imagery. Proc. of the ISPRS com. 1, Ankara, Turkey, 2006.
- [2] Durupt, M. and Taillandier, F., Automatic building reconstruction from a digital elevation model and cadastral data: an operational approach. Proc. PCV, Bonn Germany, 2006, ISPRS.

IV - Superstructure optimization

1. Detection : exhaustive search of the roof facet R_i

This is the computation intensive step !

- For each superstructure type t
- For each discretized support parameters $\theta = (x_0, y_0, x_1, y_1)$ inside the roof facet R_i of dimensions $(x_1 - x_0)$ and $(y_1 - y_0)$ allowed by the type t .
- Optimize the continuous parameter(s) ϕ $\phi_{max} = \underset{\phi \in \{\text{loose priors}(t, \theta, R_i)\}}{\text{argmax}} (e_\lambda((t, \theta, \phi)/R_i))$
- If $e_\lambda((t, \theta, \phi_{max})/R_i) > 0$, add $s = (t, \theta, \phi_{max})$ to the set H of superstructure hypotheses

2. Filtering : keep in H only the local maxima of e_λ

- 2 superstructures are adjacent if their support parameters θ are within 1 discretization step.
- problem size reduction
 - prevents multiple detection of noisy features

3. Selection : branch and bound

Goal : find $x^{max} = \underset{\text{Constraint}(x)}{\text{argmax}} \sum_j x_j \cdot e_\lambda(h_j/R_i)$ with constraint C1 (no overlap)

$x = \delta_{h_j \in H}$ is selected in the optimal solution $\in \{0, 1\}^{|H|}$ (kronecker symbol)

Constraint	Corresponding problem	Difficulty
C1 $x_j = 0$ or 1 ; $\forall j \neq k, x_j = x_k = 1 \Rightarrow \text{support}(h_j) \cap \text{support}(h_k) = \emptyset$	Maximum Weighted Clique	NP-Complete
C2 $x_j = 0$ or 1 ; $\sum_j x_j \cdot \text{area}(\text{support}(h_j)) \leq \text{area}(\cup_j \text{support}(h_j))$	0-1 Knapsack	Complete
C3 $x_j \in \{0, 1\}$; $\sum_j x_j \cdot \text{area}(\text{support}(h_j)) \leq \text{area}(\cup_j \text{support}(h_j))$	Polynomial problem	Easy!

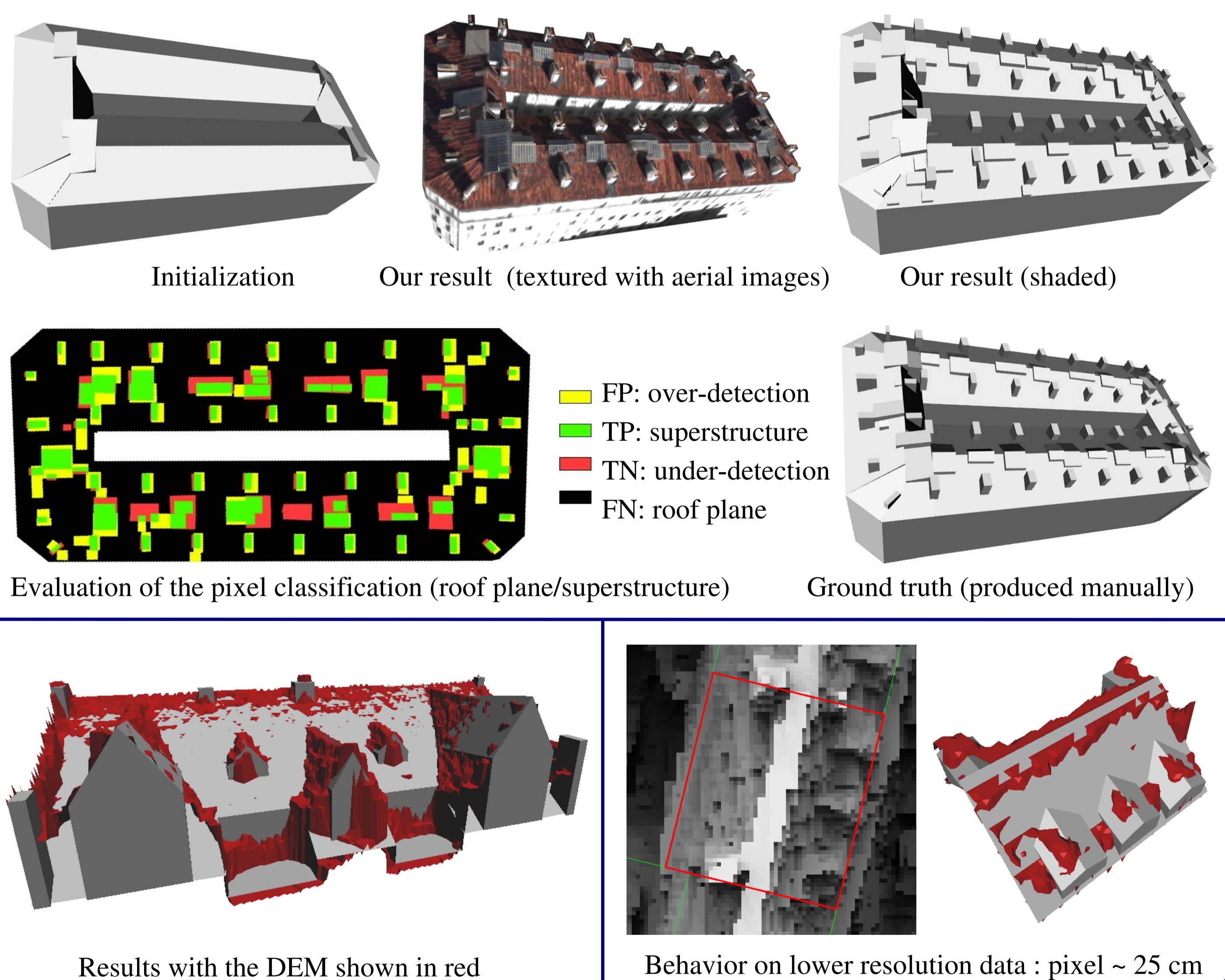
😊 Cheap upperbound : $C1 \Rightarrow C2 \Rightarrow C3$, so $\max_{C1(x)} \sum_j x_j \cdot e_\lambda(h_j/R_i) \leq \max_{C3(x)} \sum_j x_j \cdot e_\lambda(h_j/R_i)$

Algorithm : Process separately each connected component of H (connected w.r.t. the overlapping relation)

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select ( x , x^max , e^max , a ) : First call : select ( delta_true , delta_false , 0 , area( union support(h_j) ) )
if ( upperbound( x , a ) <= e^max ) then return ( x^max , e^max ) Pruning with upperbound test
let j_max = argmax_j ( x_j * e_lambda( h_j / R_i ) ) First descent is a good heuristic
let ( x^in , e^in ) = select ( x - delta_h_j , overlaps h_j_max , x^max , e^max - e_lambda( h_j_max ) , a - area( support( h_j_max ) ) ) Best in?
if ( e^in + e_lambda( h_j_max / R_i ) > e^max ) then ( x^max , e^max ) = ( x^in + delta_j_max , e^in + e_lambda( h_j_max / R_i ) )
let ( x^out , e^out ) = select ( x - delta_j_max , x^max , e^max , a ) Best out?
if ( e^out > e^max ) then ( x^max , e^max ) = ( x^out , e^out )
return ( x^max , e^max ) Return current maximum
    
```

V - Results



VI - Conclusion

- 😊 Fully automatic !
- 😊 Reasonably fast ! a few seconds (L_2 norm) to a minute (L_1 norm) per roof plane
- 😊 Extensible collection of parametric superstructures
- 😊 2 parameters : $n=2$ works well in practice, $\lambda > 0$ is only required on noisy or low resolution data

Current drawbacks that require future work :

- 😊 Superstructures cannot span multiple roof planes (like a chimney on a roof top)
- 😊 No interactions between the superstructures (alignment, similarity...)
- 😊 To increase the reconstruction accuracy, images must be handled directly