



ANR-18-CE38-0009-01



# Visual encoding of a 3D virtual reconstruction's scientific justification: feedback from a proof-of-concept research



CAA2023

50 years of synergy

Amsterdam 3 - 6 April 2023

Restitution analysée : XVIIIème siècle (Etat 4) Sol :

Granularité choisie : Objets individuels

Mode d'interaction :

Sélectionner une ligne (critère de fiabilité) puis valider : les éléments présents dans la maquette seront recolorés en fonction de leur fiabilité par rapport à ce critère spécifique

|                                  | Fiabilité   | 1 | 2 | 3 | 4 |
|----------------------------------|-------------|---|---|---|---|
| <input type="radio"/>            | existence   |   |   |   |   |
| <input type="radio"/>            | emplacement |   |   |   |   |
| <input checked="" type="radio"/> | forme       | ■ | ■ | ■ | ■ |
| <input type="radio"/>            | dimension   |   |   |   |   |

Zoom Pan

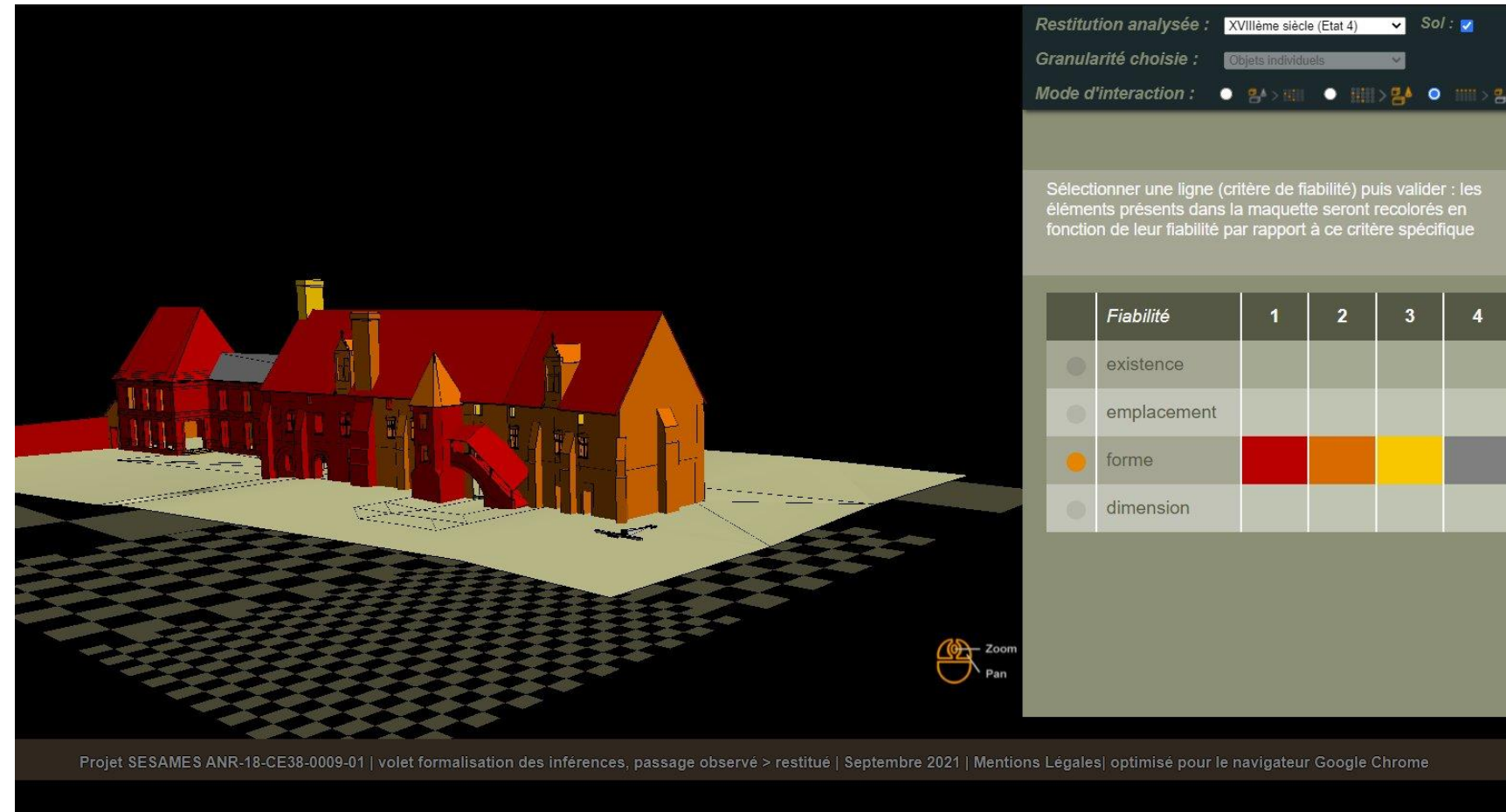
Projet SESAMES ANR-18-CE38-0009-01 | volet formalisation des inférences, passage observé > restitué | Septembre 2021 | Mentions Légales | optimisé pour le navigateur Google Chrome

J.Y Blaise, I.Dudek, L.Bergerot



G.Simon

*Yet another attempt to increase the interpretability of 3D models*



Restitution analysée : XVIIIème siècle (Etat 4) Sol :

Granularité choisie : Objets individuels

Mode d'interaction :

Sélectionner une ligne (critère de fiabilité) puis valider : les éléments présents dans la maquette seront recolorés en fonction de leur fiabilité par rapport à ce critère spécifique

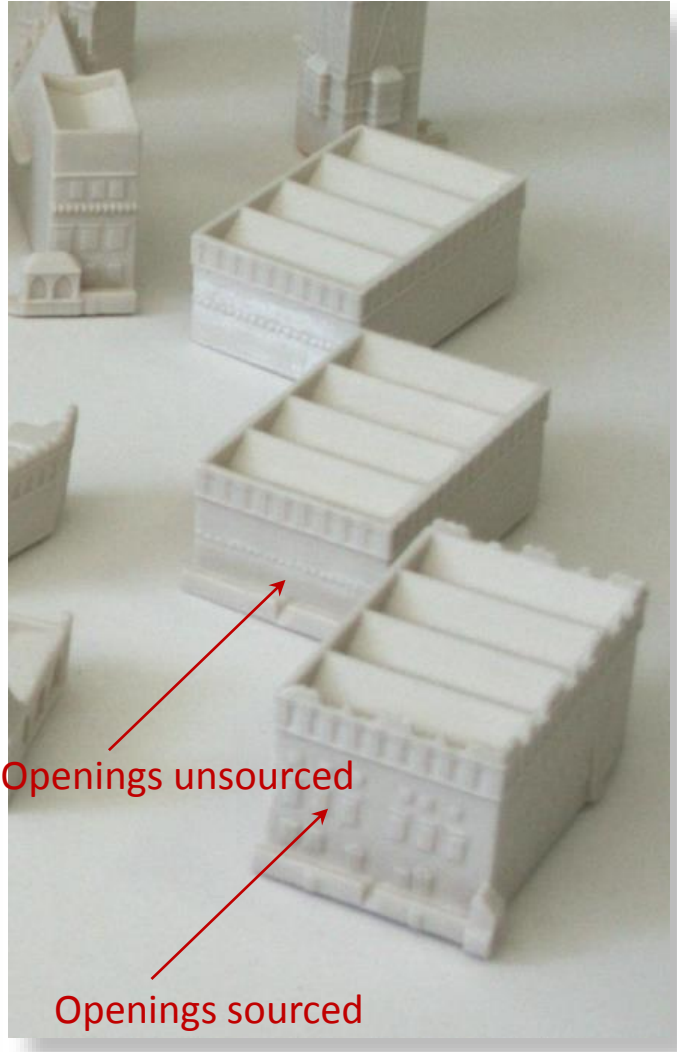
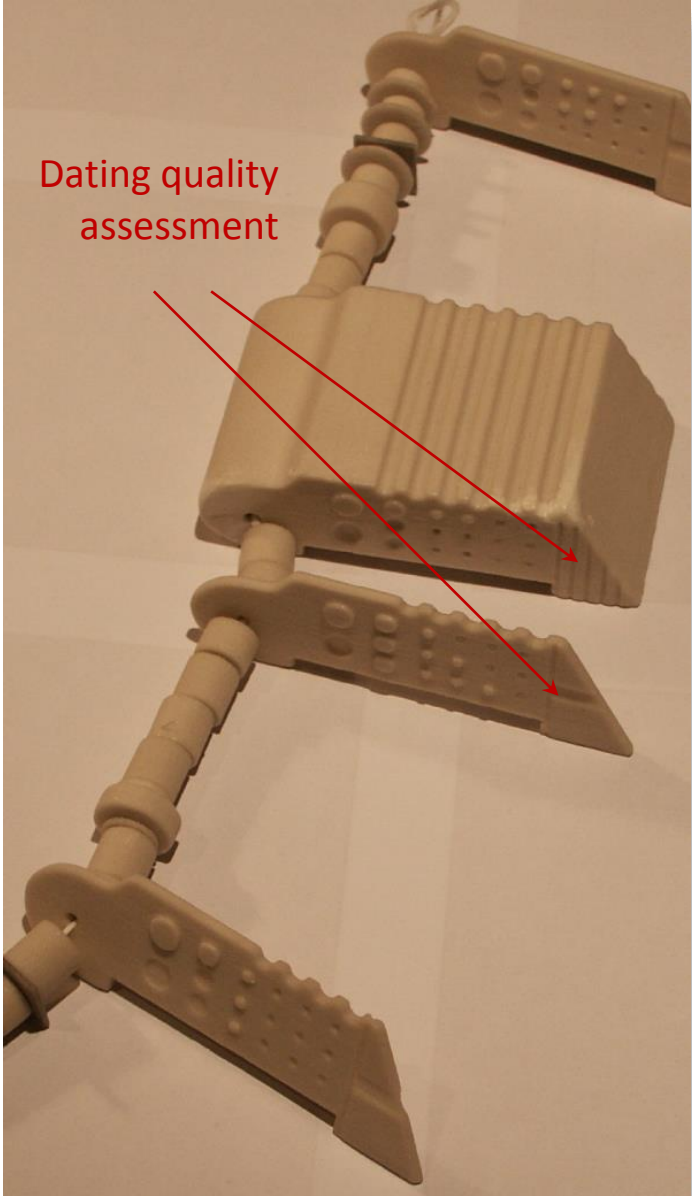
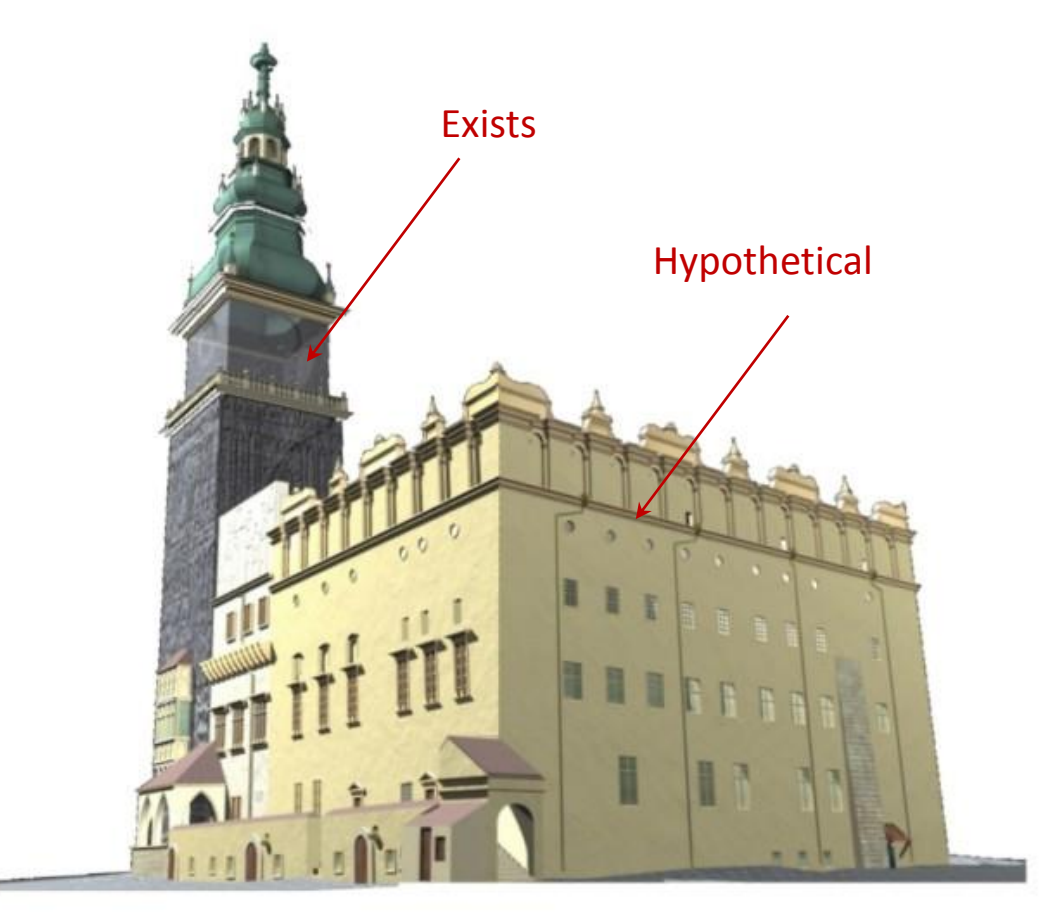
|                                  | Fiabilité   | 1 | 2 | 3 | 4 |
|----------------------------------|-------------|---|---|---|---|
| <input type="radio"/>            | existence   |   |   |   |   |
| <input type="radio"/>            | emplacement |   |   |   |   |
| <input checked="" type="radio"/> | forme       | ■ | ■ | ■ | ■ |
| <input type="radio"/>            | dimension   |   |   |   |   |

Zoom  
Pan

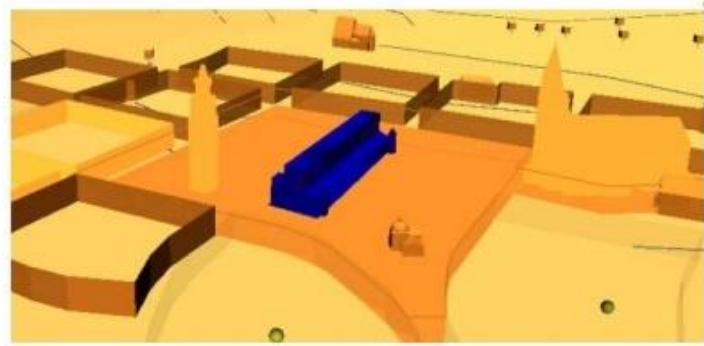
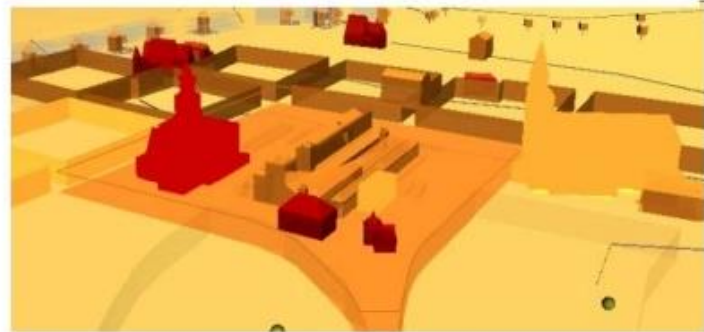
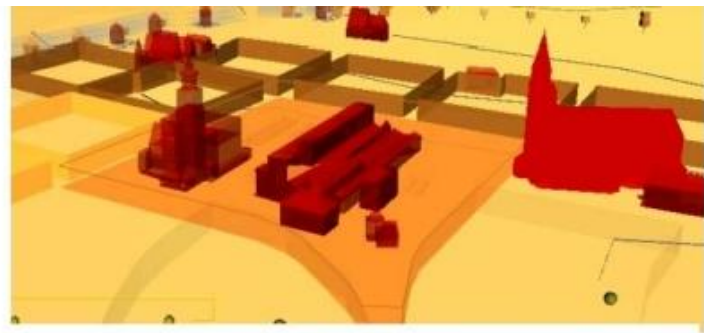
Projet SESAMES ANR-18-CE38-0009-01 | volet formalisation des inférences, passage observé > restitué | Septembre 2021 | Mentions Légales | optimisé pour le navigateur Google Chrome







(a move towards *realism*, i.e. the expression of doubts, of *reasons to think this or that ...*)

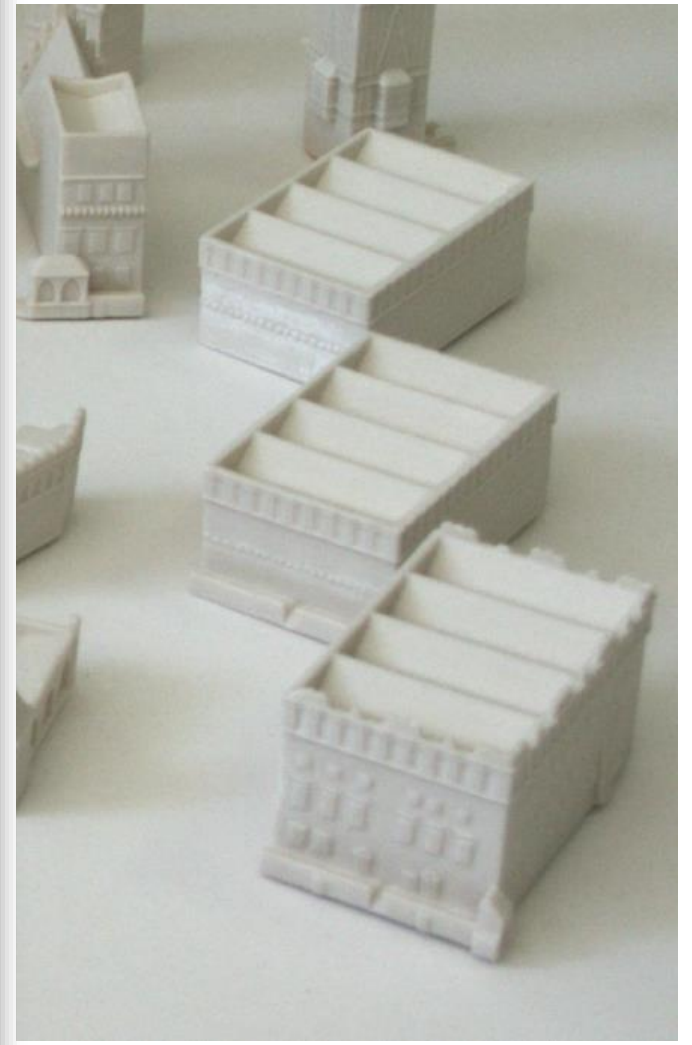
This research's origin : years of experimentation on the graphical and tangible encoding of 'doubts' inside 3D outputs



(virtual or tangible)


















|   |   |   |   |
|---|---|---|---|
| <b>codage graphique à la date de la requête</b>   |  |  | <b>documenté</b>                        |
| <b>analogique (fondée sur période précédente)</b> |  |  | <b>hypothétique</b>                     |
| <b>analogique (fondée sur période suivante)</b>   |  |  | <b>à préciser</b>                       |
|   | <b>Emissive colouring</b>   |   | <b>niveau de crédibilité non établi</b> |

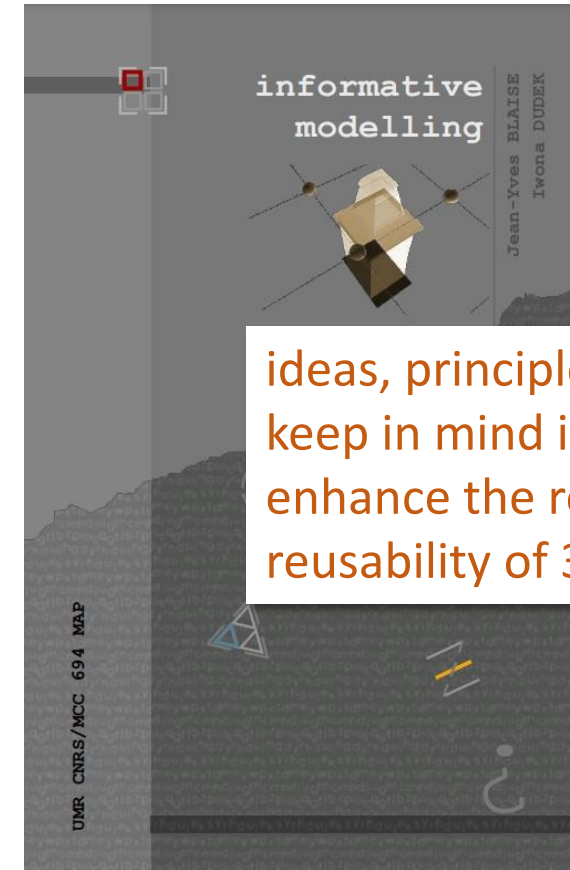


Various spatial granularities, various technologies

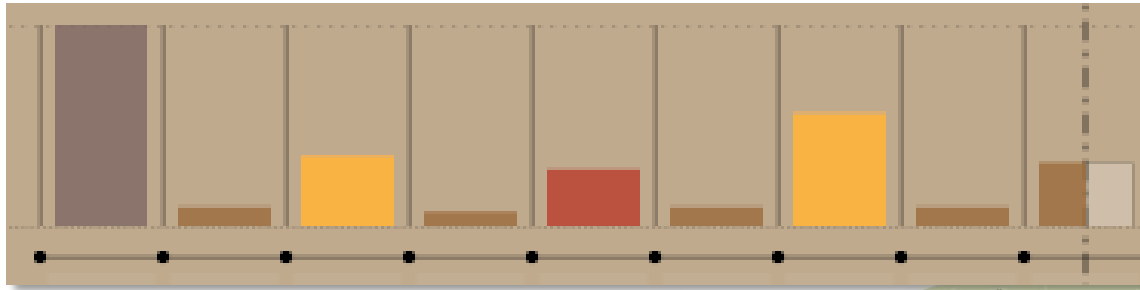
## 14 rules (plus one)

|   |  |
|---|--|
|    | Each piece of information about the object will be interpreted in order to distribute information among semantic layers called informative scales. . . 2   |
|    | The representation of an object will allow the user to retrieve data and information that justify the presence of the object at the time and date the representation shows. . . . . 8                  |
|    | The shape given to the object will stem from an interpretation of the data, stating the shape's credibility and making it visible. . . . . 14  |
|    | For each object, the representation will show what we know that we ignore, and will not contain unfounded affirmations that would not be justified by relevant data. . . . . 20                        |
|    | A theoretical model will describe architectural shapes in a structured way. . . . . 26   |
|    | Objects represented inside 2D/3D models will be instances of the above-mentioned theoretical model. . . . . 32   |
|    | The theoretical model's implementation will allow the reuse, the comparison and the sustainability of the information on the instances. . 38   |
|    | Each concept of the theoretical model will be attached to a given informative scale. . . . . 44  |
|    | 2D/3D model will be the visual answer, displayed thanks to the representation of architectural objects, to a query about our state of knowledge. . . . . 50  |
|    | 2D/3D models will be calculated in real time so as to reflect our current state of knowledge at query time. . . . . 56   |
|    | The appearance given to an object will use a set of graphic codes that should be developed in order to visualise the object's underlying information. . . . . 62                                       |
|  | The object will be displayed inside 2D/3D models with alternative levels of abstraction depending on both/either the scale and the level of knowledge reached in the investigation process. . . . . 68 |
|  | The investigation process will be implemented as a non-ordered process allowing the integration of disjoint sets of information. . . . . 74  |
|  | The level of knowledge reached in the investigation process on a given object will be represented in real time inside 2D/3D models. . . . . 80   |
|  | If a 2D/3D model does not produce a gain of insight into the underlying information - it should be considered worthless. . . . . 86  |

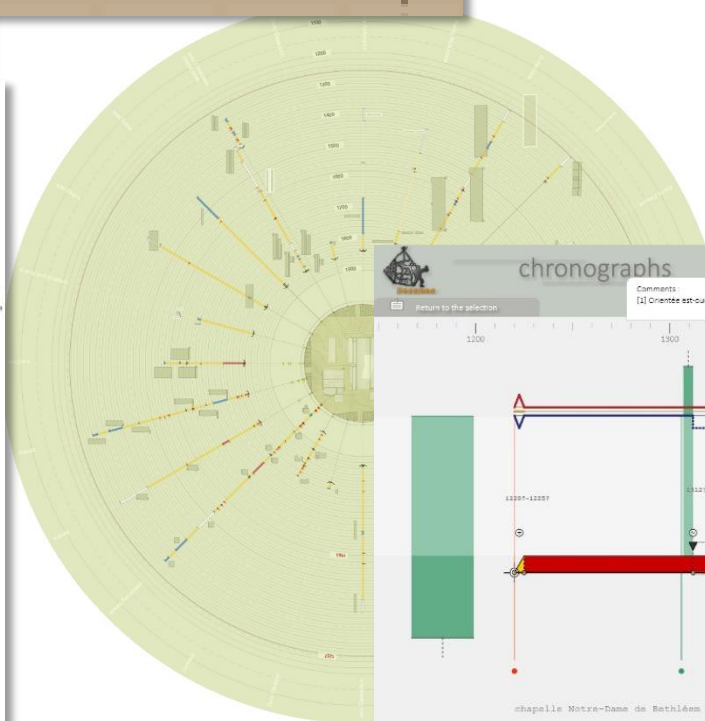
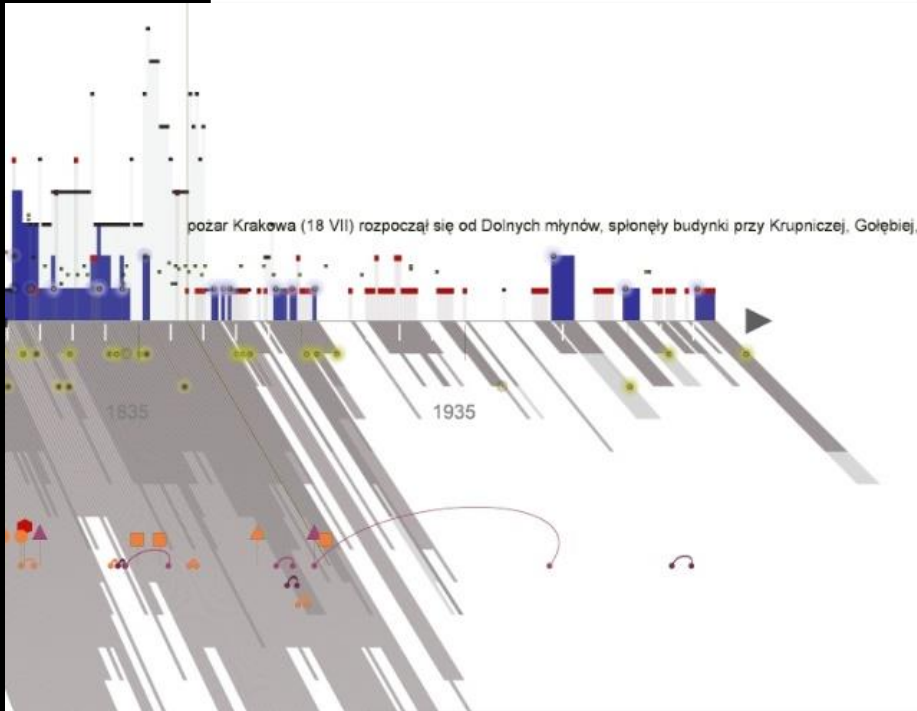
Ended up with a *best practices* booklet: '14 rules+1'



ideas, principles one can keep in mind if wanting to enhance the readability and reusability of 3Dmodels

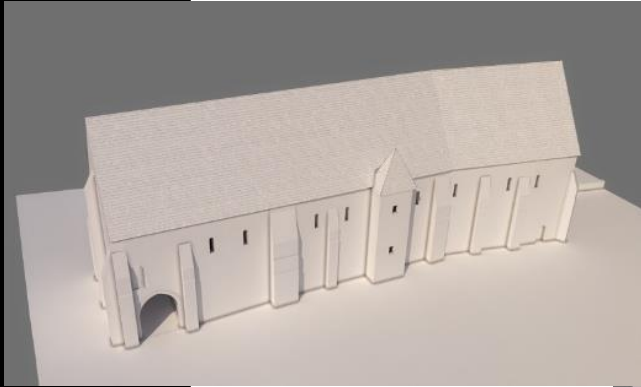


Ended up with a *best practices* booklet: '14 rules+1'

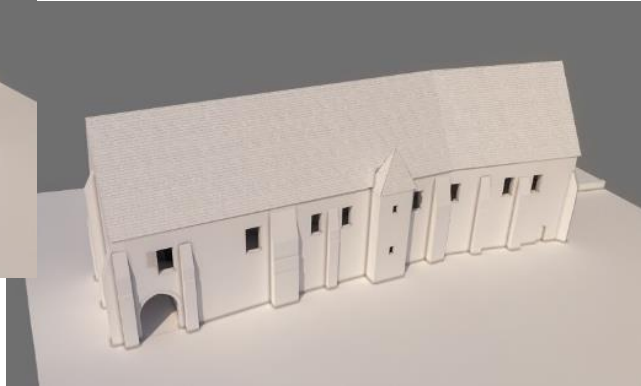


Move towards *information visualisation* practices, as applied to spatio-historical datasets – abstraction, large information spaces, focus on the time parameter

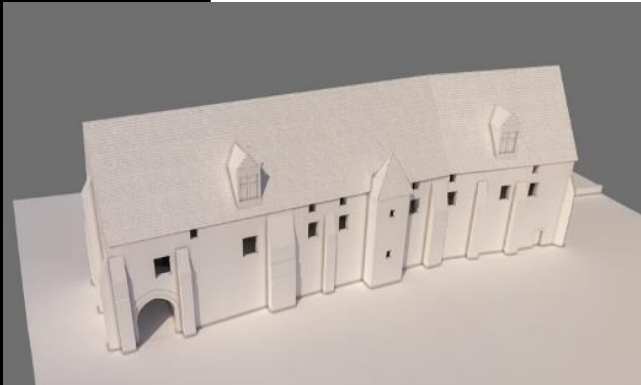
12<sup>th</sup> c.



End 13<sup>th</sup> c.



14<sup>th</sup> – 15<sup>th</sup> c.



18<sup>th</sup> c.

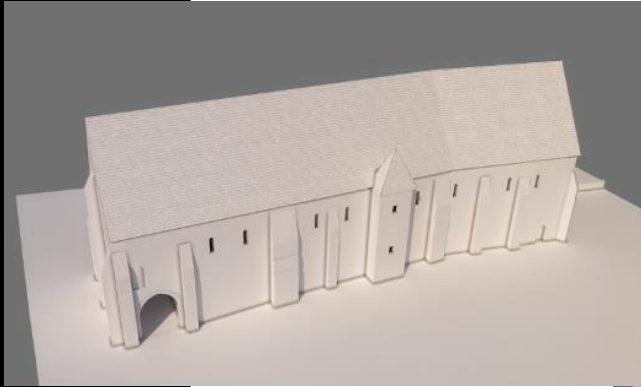


An issue reinvestigated in the context of a wider research programme focusing on methodological aspects such as reproducibility, traceability of research workflows

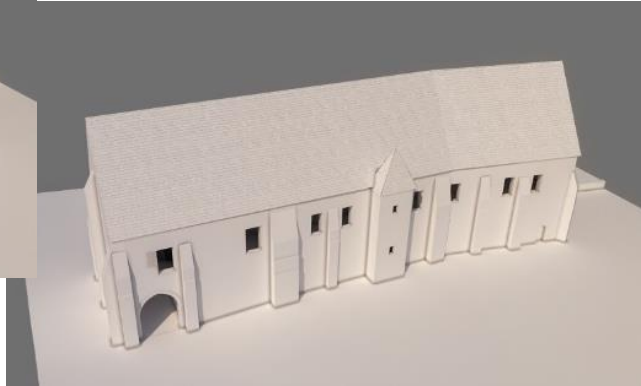
Three main reasons for this new attempt:

- new technological setups (3D js libraries, collada, etc.)
- A pre-existing set of 3D models (four synchronic states) produced by the LAT team, sort-of dead branch, needing repurposing, and acting as a test bench
- Finally, the idea that repurposability and interpretability are coming forward as part of the research agenda in heritage studies

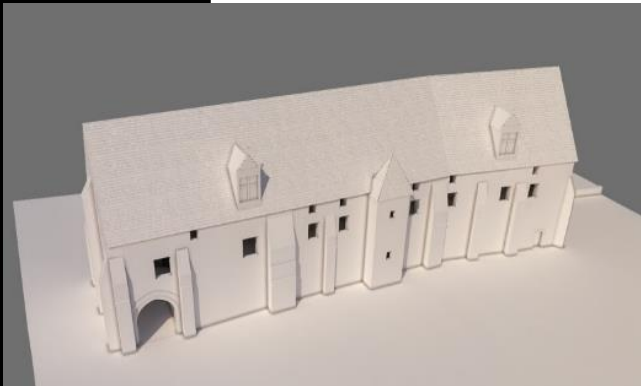
12<sup>th</sup> c.



End 13<sup>th</sup> c.



14<sup>th</sup> – 15<sup>th</sup> c.



18<sup>th</sup> c.



An issue reinvestigated in the context of a wider research programme focusing on methodological aspects such as reproducibility, traceability of research workflows

This to say that the result I am presenting here should be understood basically as a prof-of-concept experiment, a way to question ourselves on “why not (re)dig a bit further into the question of what a 3D model can say, and be used for?”



## Outline

### 1. The case study: Marmoutier's monastic hostelry (built 1179-89)

#### 2. This research's core contributions

- justification matrices : a model for assessing 'plausibility'
- Graphic encoding: mapping visually (in 3D) a plausibility analysis
- 3D models reusability : segmentation and repurposing of 3D components

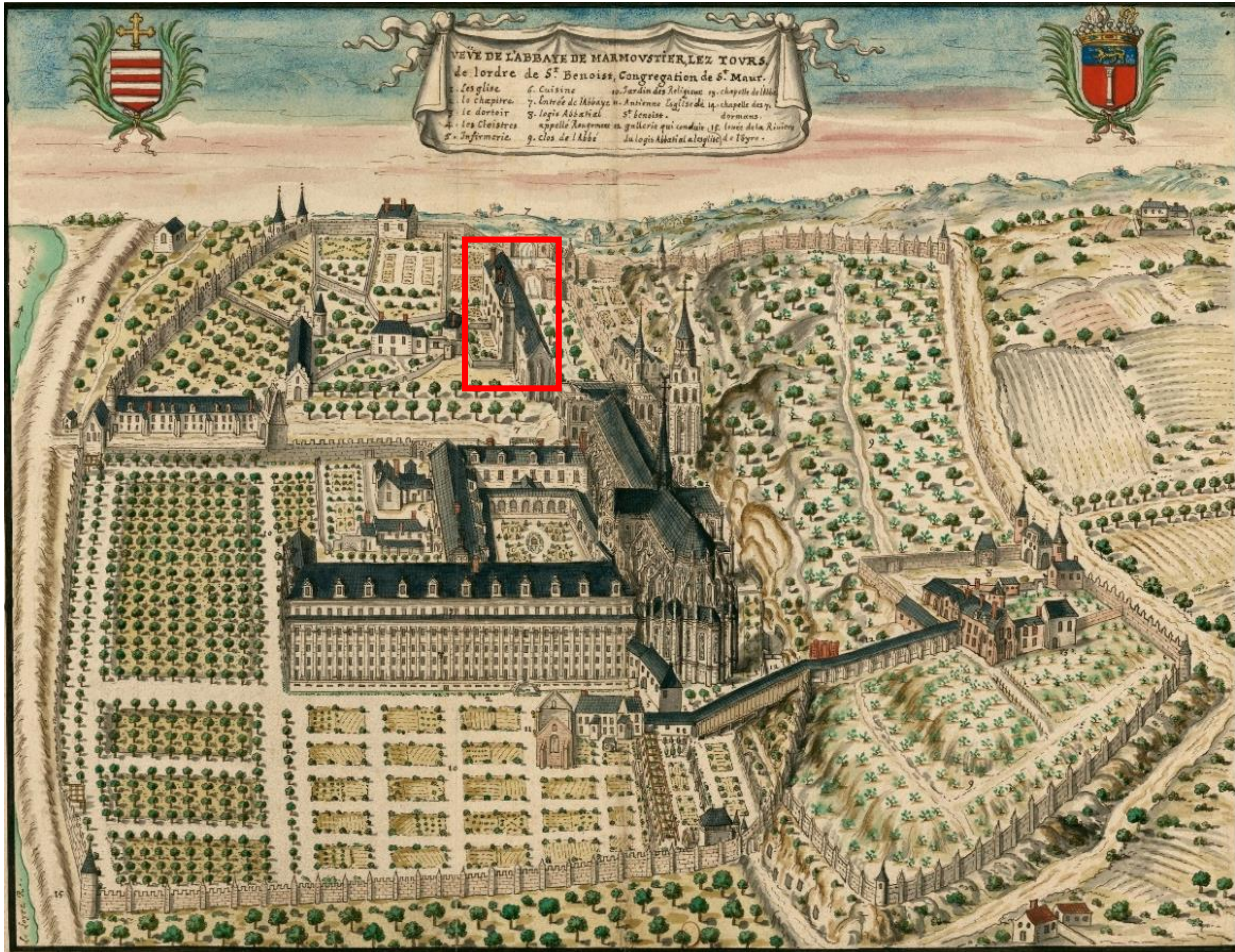
#### 3. The prototype : interaction modalities

#### 4. One step beyond: (visual) patterns of information

- The cumulative matrices concept
- Application: chronological patterns, typological patterns

#### 5. Limitations and conclusion

- A *proof of concept experiment* - more data *is* needed
- Rethinking the *information spaces* connectable to 3D datasets seen as pivot linkage between analytical layers – a way to enhance the interpretability of 3D scenes, as well as the repurposability of 3D components.



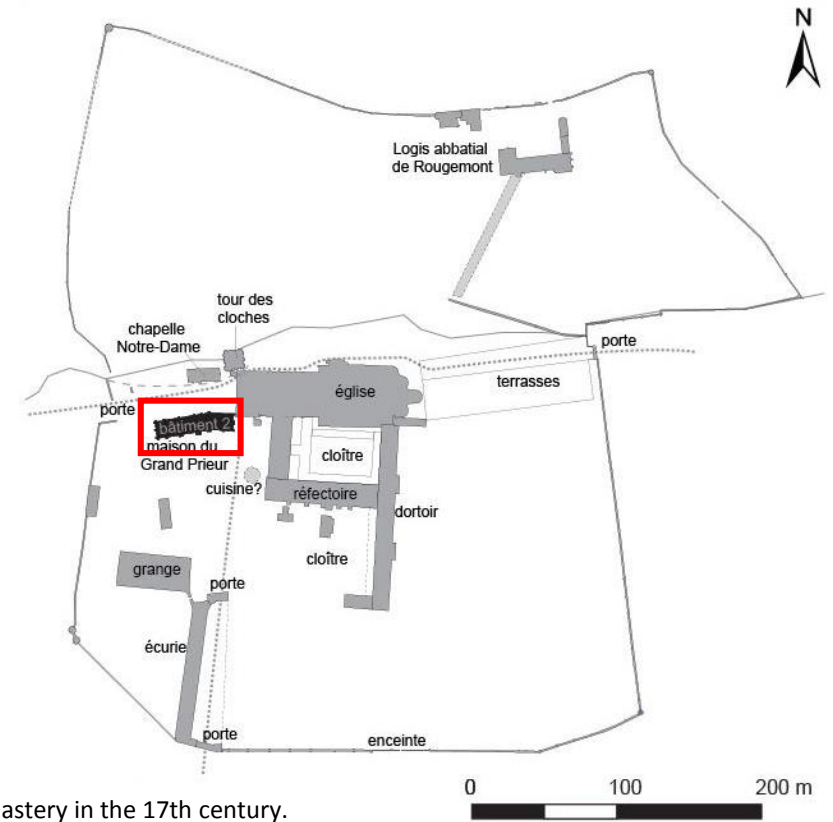
The monastery before the destruction of the 19th century.  
 Elevated view from Marmoutier Abbey from the east, 1699, Gaignières Collection  
 (BNF VA 407 (1) FT 4-H-183734)



**Case study:** The Marmoutier abbey, place chosen by Martin, bishop of Tours from 371 to 397 for his retreat and attracted to him disciples who gave rise to the first or second monastic community of the West.

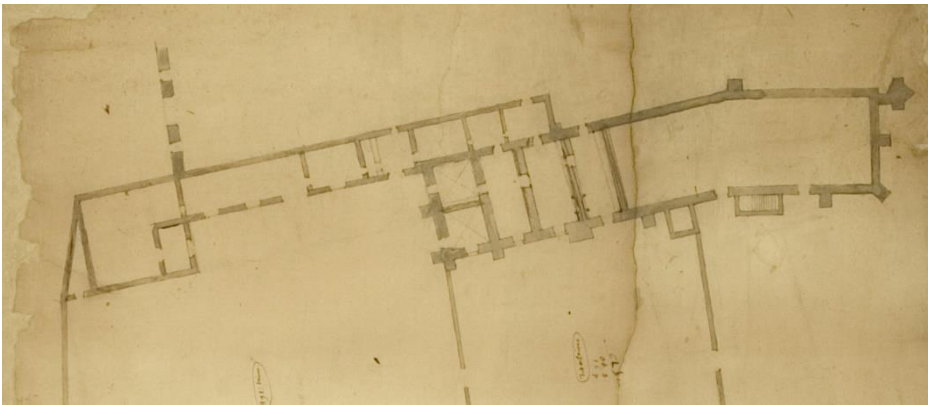
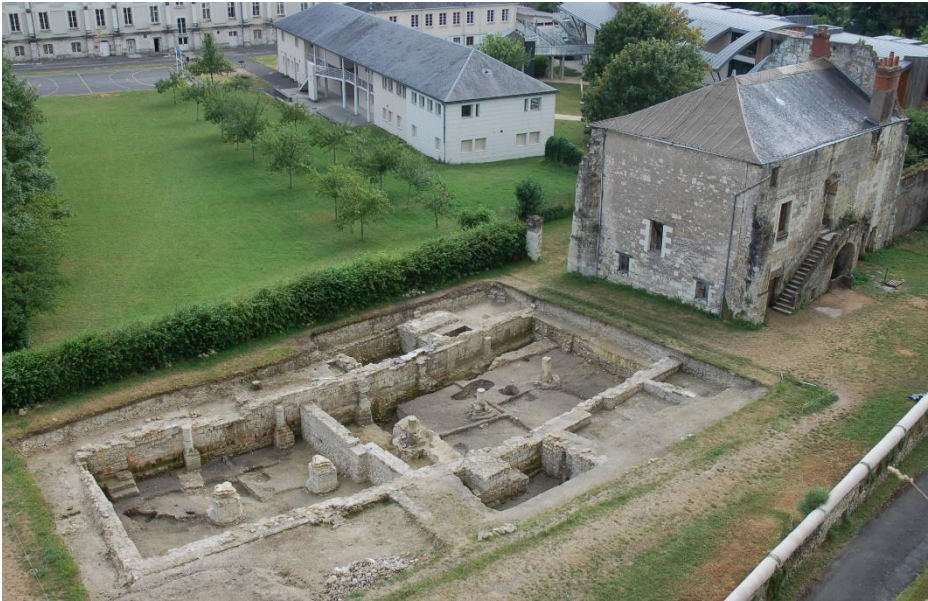
An architectural ensemble widely destroyed / dismantled during the revolution and in the early 19th century

Archaeological research conducted since 2004 by the LAT team



Reconstructed plan of the monastery in the 17th century.





A focus on the hostelry , still partly in elevation - Today preserved on 20m of length, it originally measured 55m (widely transformed / damaged)

Excavation campaigns / archaeological research since 2006 but also 'wide public' 3D simulations corresponding to four temporal slots

As a result, 3D models that face us with a twofold challenge : reusability (technical challenge) and interpretability (justification behind the shapes proposed)



Reconstruction of the first floor of the hostelry

justification matrices : a model for assessing 'plausibility'

1

2

| Levels of uncertainty | 1   | 2   | 3                              |
|-----------------------|---|---|--------------------------------|
| Existence             | Presence on the model because elements still fully or partially elevated in reality           | Presence on the model on the basis of symmetry, composition arguments, etc. | Possible presence on the model |
| Position              | Position on the model, attested because elements still fully or partially elevated in reality | Position on the model on the basis of symmetry, composition arguments, etc. | Possible position on the model |
| Shape                 | All the information to restore a form is available. (Complete archaeological)                 | Only part of the information used to restore a shape is available.          | Possible shape on the model    |
| Dimensions            | All dimensions of the element or a large part are known                                       | Some of the dimensions of the element are known                             | No dimensions are known        |

justification matrices : a model for assessing 'plausibility'

1

2

| Levels of uncertainty | 1   | 2   | 3                              |
|-----------------------|---|---|--------------------------------|
| Existence             | Presence on the model because elements still fully or partially elevated in reality           | Presence on the model on the basis of symmetry, composition arguments, etc. | Possible presence on the model |
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| Dimensions            | All dimensions of the element or a large part are known                                       | Some of the dimensions of the element are known                             | No dimensions are known        |



Four lines refine the reasons to express a doubt

- 1
- 2

L  
U  
E  
P  
S  
D



justification matrices : a model for assessing 'plausibility'

1

2

| Levels of uncertainty | 1   | 2   | 3                              |
|-----------------------|---|---|--------------------------------|
| Existence             | Presence on the model because elements still fully or partially elevated in reality           | Presence on the model on the basis of symmetry, composition arguments, etc. | Possible presence on the model |
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| Dimensions            | All dimensions of the element or a large part are known                                       | Some of the dimensions of the element are known                             | No dimensions are known        |



Four lines refine the reasons to express a doubt

## Core contributions (1)

Three columns for 'doubt' valuation (numerical; in this slide we show what each cell corresponds to)

| Levels of uncertainty | 1   | 2   | 3                              |
|-----------------------|---|---|--------------------------------|
| Existence             | Presence on the model because elements still fully or partially elevated in reality           | Presence on the model on the basis of symmetry, composition arguments, etc. | Possible presence on the model |
| Position              | Position on the model, attested because elements still fully or partially elevated in reality | Position on the model on the basis of symmetry, composition arguments, etc. | Possible position on the model |
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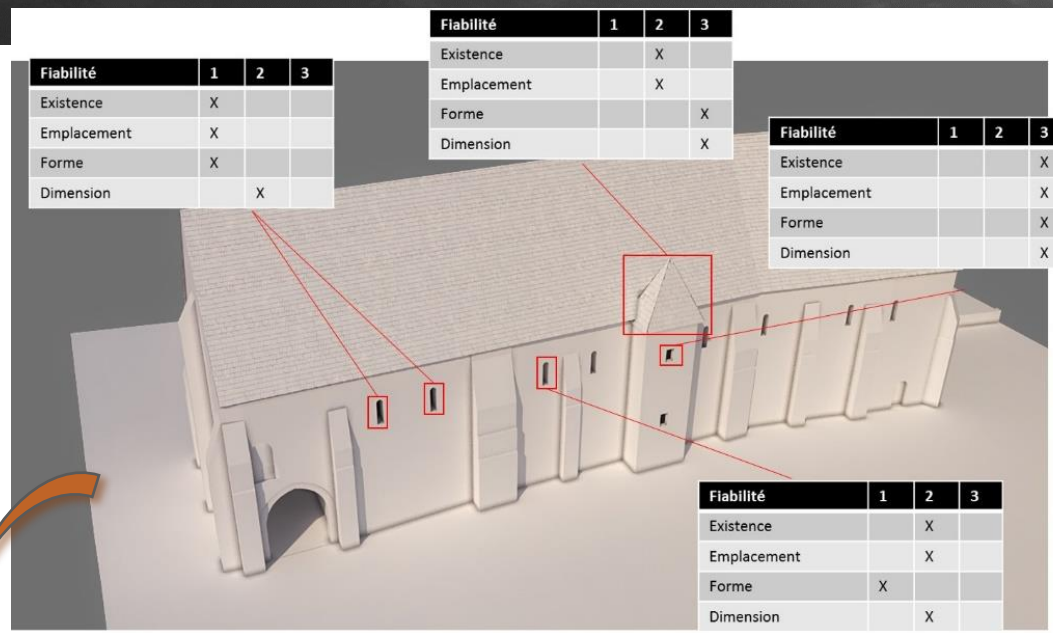


1

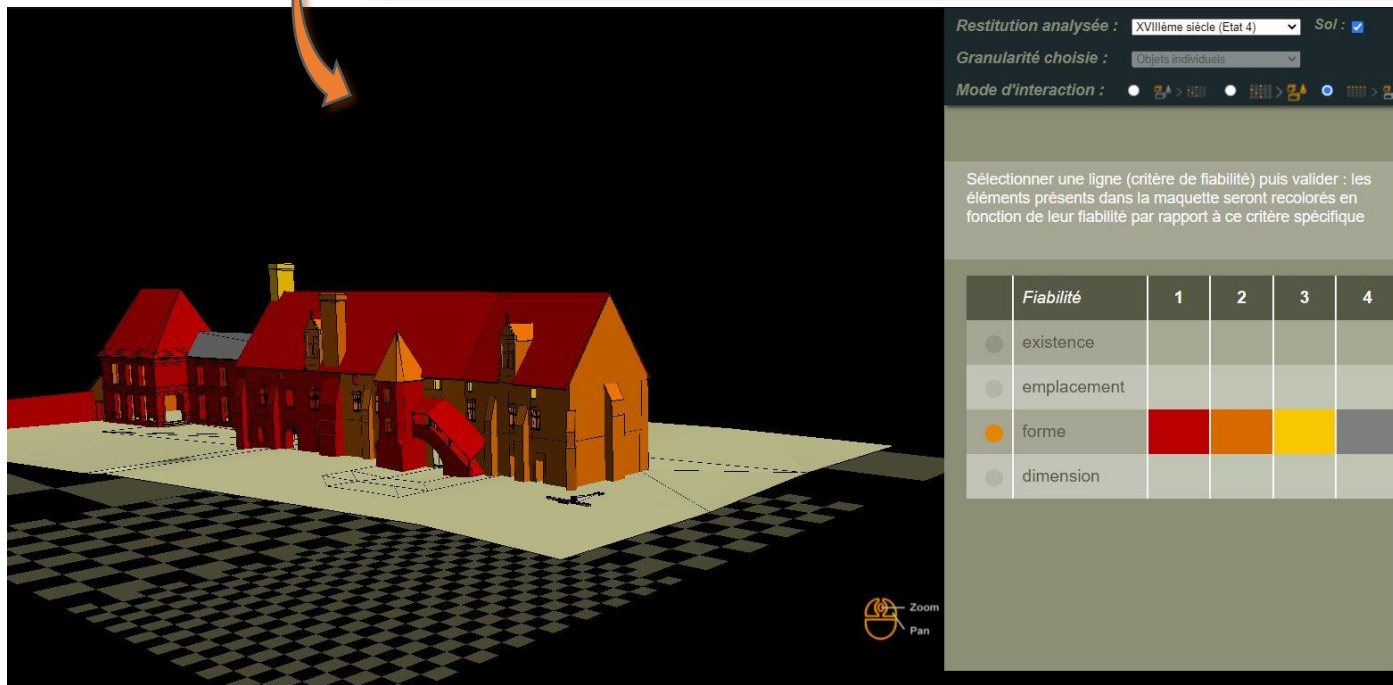
2

| Levels of uncertainty | 1   | 2   | 3                              |   |
|-----------------------|---|---|--------------------------------|---|
| Existence             | Presence on the model because elements still fully or partially elevated in reality           | Presence on the model on the basis of symmetry, composition arguments, etc. | Possible presence on the model |   |
| Position              | Position on the model, attested because elements still fully or partially elevated in reality | Position on the model on the basis of symmetry, composition arguments, etc. |                                | A fourth column added at implementation time : « not yet assessed » |
| Shape                 | All the information to restore a form is available. (Complete archaeological)                 | Only part of the information used to restore a shape is available.          | Possible shape on the model    |   |
| Dimensions            | All dimensions of the element or a large part are known                                       | Some of the dimensions of the element are known                             | No dimensions are known        |   |

## Core contributions (1)



A matrix is attached to each element in the 3D model, so that its values can be used to control the element's appearance



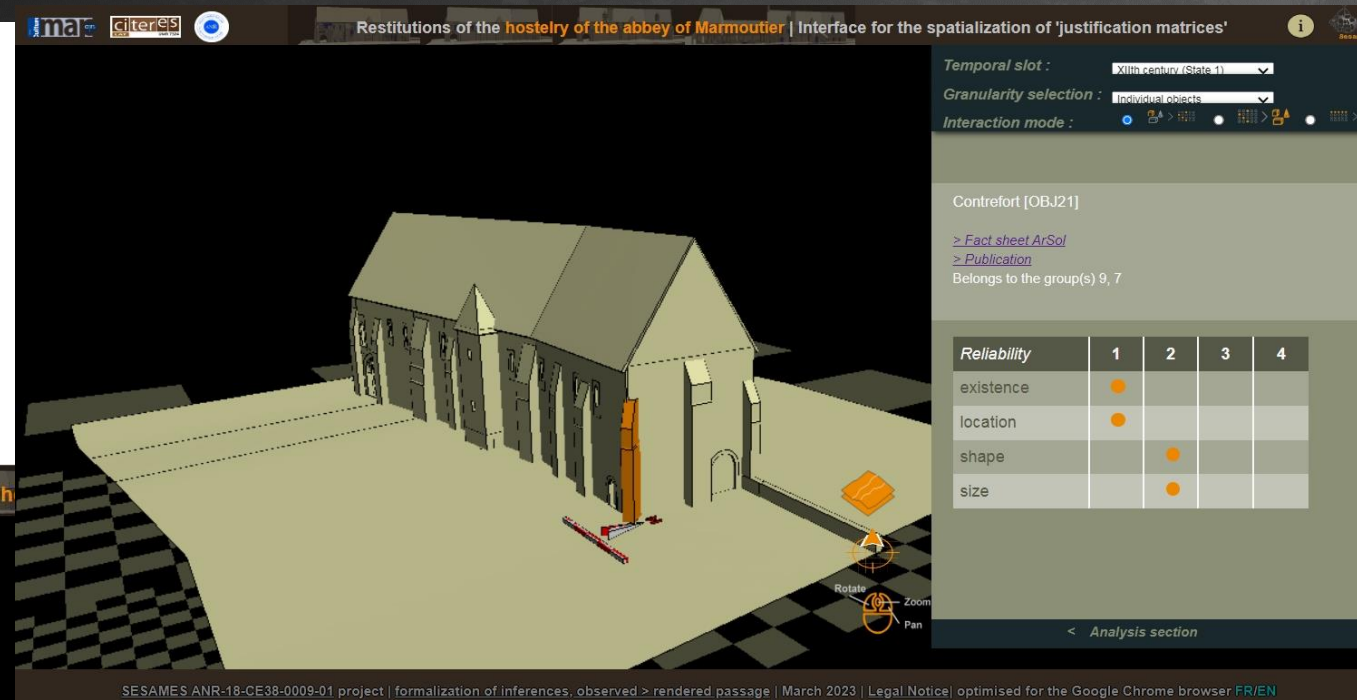
Restitutions of the **hostelry of the abbey of Marmoutier** | Interface for the spatialization of 'justification matrices'

Temporal slot : XIII century (State 1)  
Granularity selection : Individual objects  
Interaction mode : [Icons]

Contrefort [OBJ21]  
> [Fact sheet ArSol](#)  
> [Publication](#)  
Belongs to the group(s) 9, 7

| Reliability | 1 | 2 | 3 | 4 |
|-------------|---|---|---|---|
| existence   | ● |   |   |   |
| location    | ● |   |   |   |
| shape       |   | ● |   |   |
| size        |   | ● |   |   |

< Analysis section



SESAMES ANR-18-CE38-0009-01 project | formalization of inferences, observed > rendered passage | March 2023 | Legal Notice | optimised for the Google Chrome browser FR/EN

Composition du mur de façade 1002 - Sud [GRP7]

No archaeological evidence documented  
No linked publication

| Reliability | 1 | 2 | 3 | 4 |
|-------------|---|---|---|---|
| existence   | ● |   |   |   |
| location    | ● |   |   |   |
| shape       | ● |   |   |   |
| size        | ● |   |   |   |

< Analysis section



SESAMES ANR-18-CE38-0009-01 project | formalization of inferences, observed > rendered passage | March 2023 | Legal Notice | optimised for the Google Chrome browser FR/EN

Matrices are attached to elements, but also to groups : the plausibility of an ensemble **is not** the sum of the plausibilities of its components

## Core contributions (2)

Graphic encoding: mapping visually (in 3D) a plausibility analysis

1

2

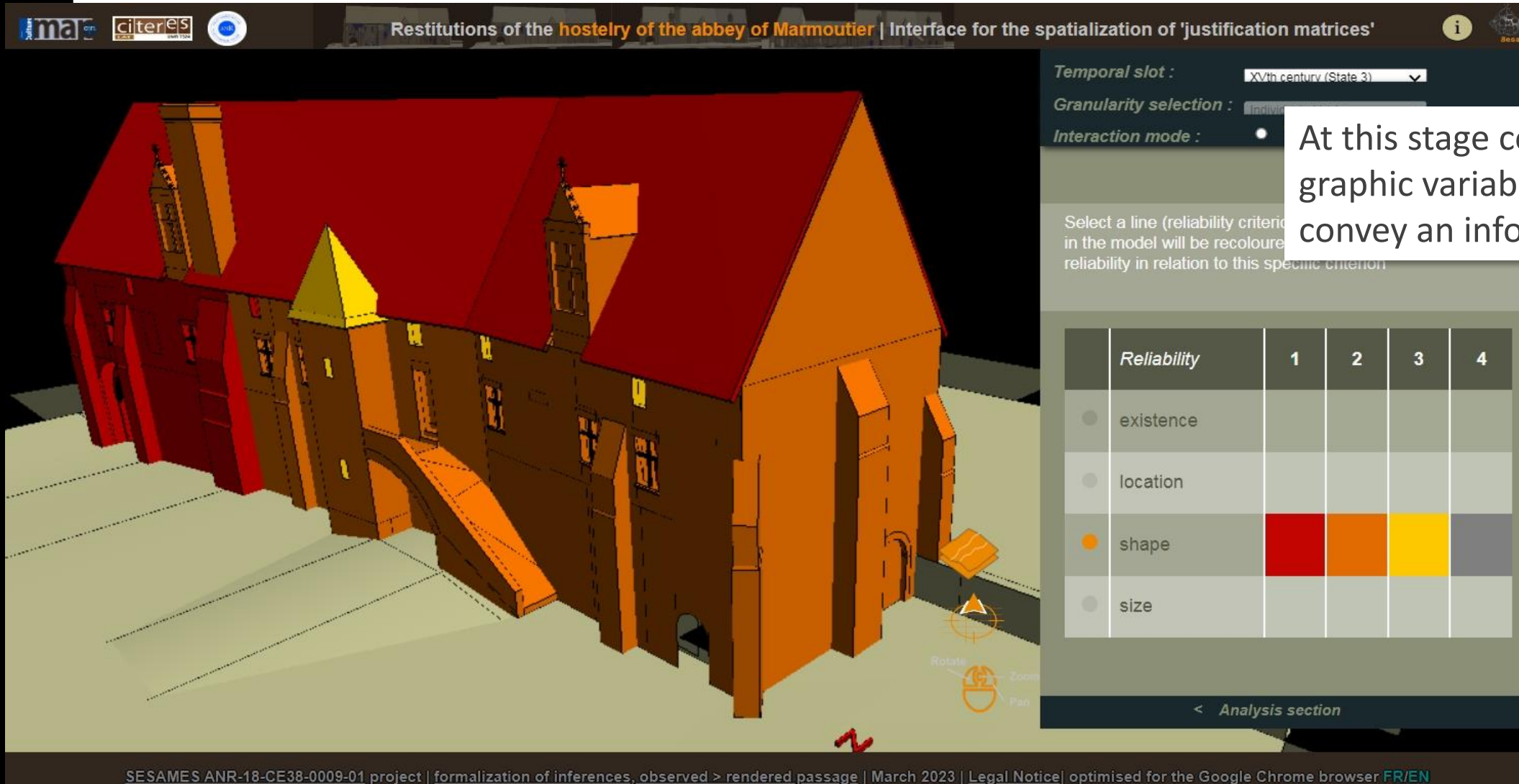
Restitutions of the **hostelry of the abbey of Marmoutier** | Interface for the spatialization of 'justification matrices'

Temporal slot : XV<sup>th</sup> century (State 3)  
 Granularity selection : [dropdown]  
 Interaction mode : [radio button]

Select a line (reliability criterion) in the model will be recoloured in relation to this specific criterion

| Reliability                            | 1   | 2      | 3      | 4    |
|--|-----|--------|--------|------|
| <input type="radio"/> existence        |     |        |        |      |
| <input type="radio"/> location         |     |        |        |      |
| <input checked="" type="radio"/> shape | Red | Orange | Yellow | Grey |
| <input type="radio"/> size             |     |        |        |      |

< Analysis section

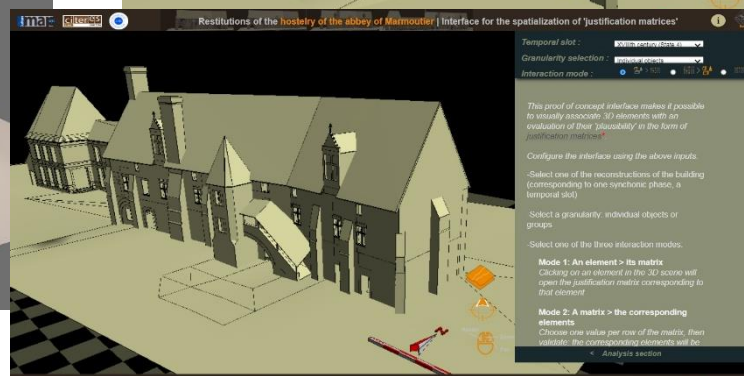
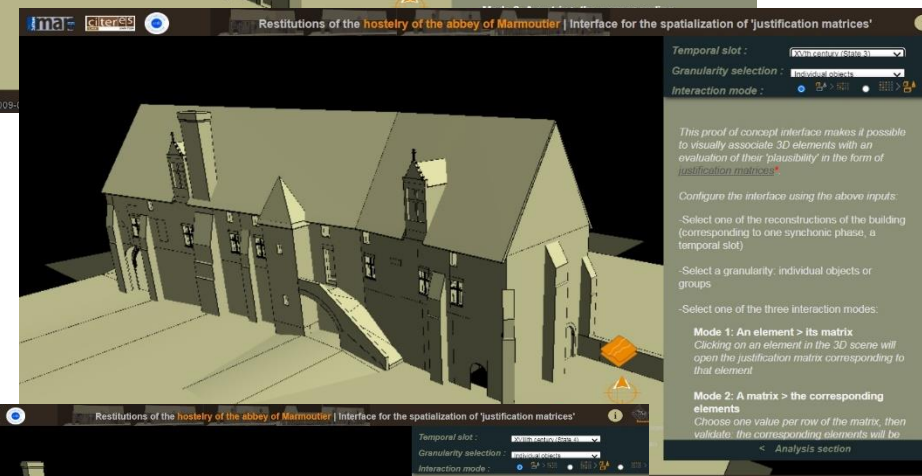
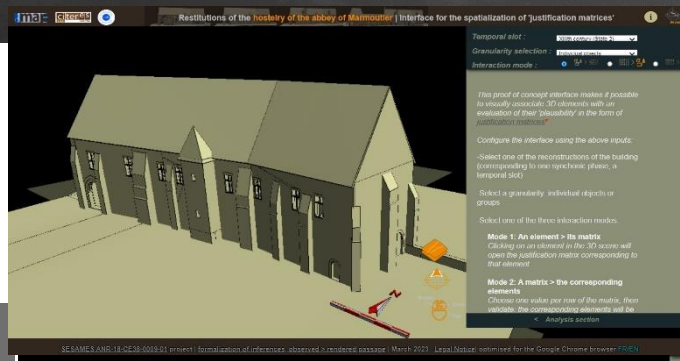
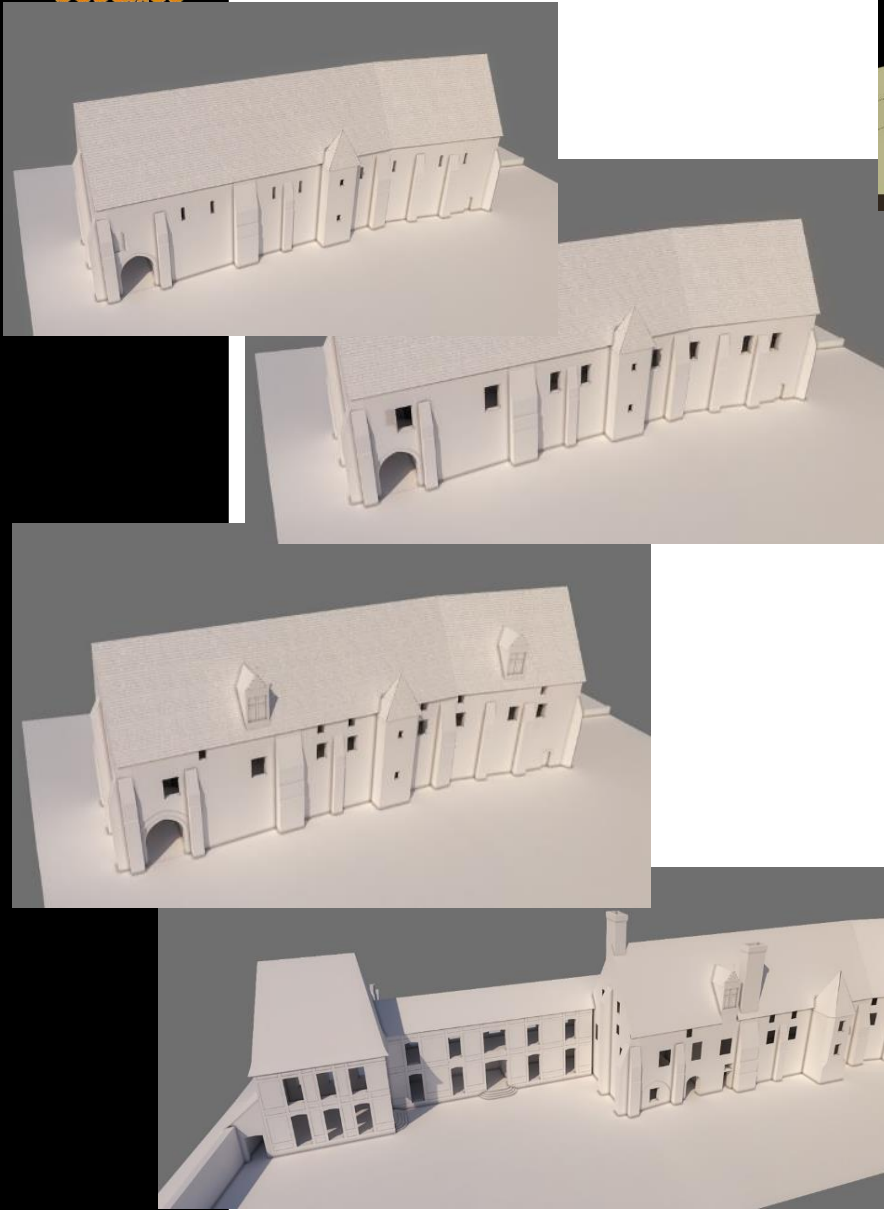


At this stage colour is the graphic variable used to convey an information

## Core contributions (3)

3D models reusability :  
segmentation and  
repurposing of 3D  
components

Done with some  
redrawing and  
simplification (..), in  
a shift from the CAD  
world to collada /  
three.js / RDBMS >  
ends up on a single  
web 3D interface



# The prototype : interaction modalities

- 1
- 2
- 3

Restitutions of the **hostelry of the abbey of Marmoutier** | Interface for the spatialization of 'justification matrices'

Temporal slot : XV<sup>th</sup> century (State 3)

Granularity selection : Individual objects

Interaction mode : 

Contrefort [OBJ21]

[> Fact sheet ArSol](#)  
[> Publication](#)  
Belongs to the group(s) 9, 7

| Reliability | 1 | 2 | 3 | 4 |
|-------------|---|---|---|---|
| existence   | ● |   |   |   |
| location    | ● |   |   |   |
| shape       |   | ● |   |   |
| size        |   | ● |   |   |

< Analysis section




*Mode 1:*  
selection of an architectural element in the scene opens its matrix

## The prototype : interaction modalities

1  
2  
3

Restitutions of the **hostelry of the abbey of Marmoutier** | Interface for the spatialization of 'justification matrices'

Temporal slot : XV<sup>th</sup> century (State 3)  
 Granularity selection : Individual objects  
 Interaction mode : [Icons]

Contrefort [OBJ21]  
 > [Fact sheet ArSol](#)  
 > [Publication](#)  
 Belongs to the group(s) 9, 7

| Reliability | 1 | 2 | 3 | 4 |
|-------------|---|---|---|---|
| existence   | ● |   |   |   |
| location    | ● |   |   |   |
| shape       |   | ● |   |   |
| size        |   | ● |   |   |

< Analysis section



*Mode 1:*  
 selection of an element in the scene also displays links to associated urls – here archaeological DB and report)

# The prototype : interaction modalities

Restitutions of the **hostelry of the abbey of Marmoutier** | Interface for the spatialization of 'justification matrices'


Temporal slot : XVth century (State 3)  
 Granularity selection : Individual objects  
 Interaction mode : [Icons]

14 element(s) correspond to these matrix values.

| Reliability | 1 | 2 | 3 | 4 |
|-------------|---|---|---|---|
| existence   | ● | ● | ● | ● |
| location    | ● | ● | ● | ● |
| shape       | ● | ● | ● | ● |
| size        | ● | ● | ● | ● |

Confirm

< Analysis section




*Mode 2:*  
 On selection of a matrix (four values) all elements corresponding to these values are dynamically highlighted




# The prototype : interaction modalities

Restitutions of the **hostelry of the abbey of Marmoutier** | Interface for the spatialization of 'justification matrices'

Temporal slot : XVth century (State 3)

Granularity selection : Individual objects

Interaction mode : 

Select a line (reliability criterion): the elements present in the model will be recoloured according to their reliability in relation to this specific criterion

| Reliability                            | 1   | 2      | 3      | 4 |
|--|-----|--------|--------|---|
| <input type="radio"/> existence        |     |        |        |   |
| <input type="radio"/> location         |     |        |        |   |
| <input checked="" type="radio"/> shape | Red | Orange | Yellow |   |
| <input type="radio"/> size             |     |        |        |   |

< Analysis section



**Mode 3:**  
On selection of a line, all architectural elements are coloured according to their respective values for that line

## One step beyond: (visual) patterns of information

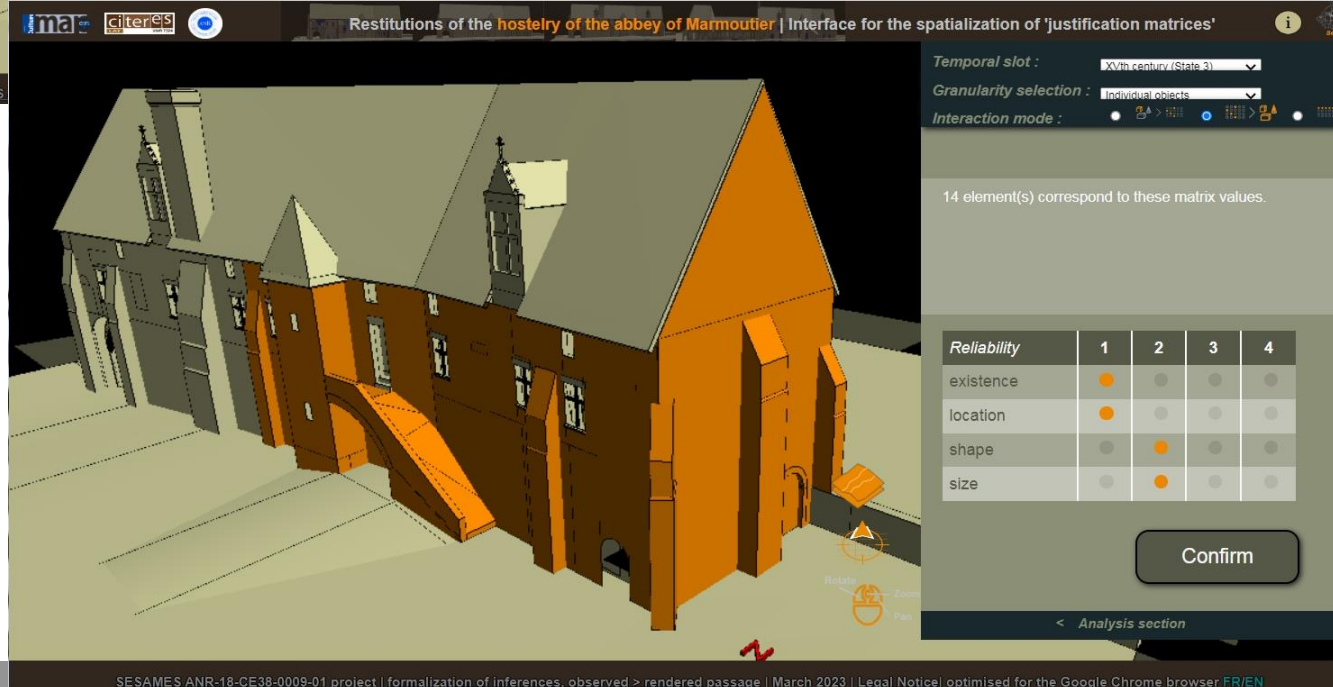
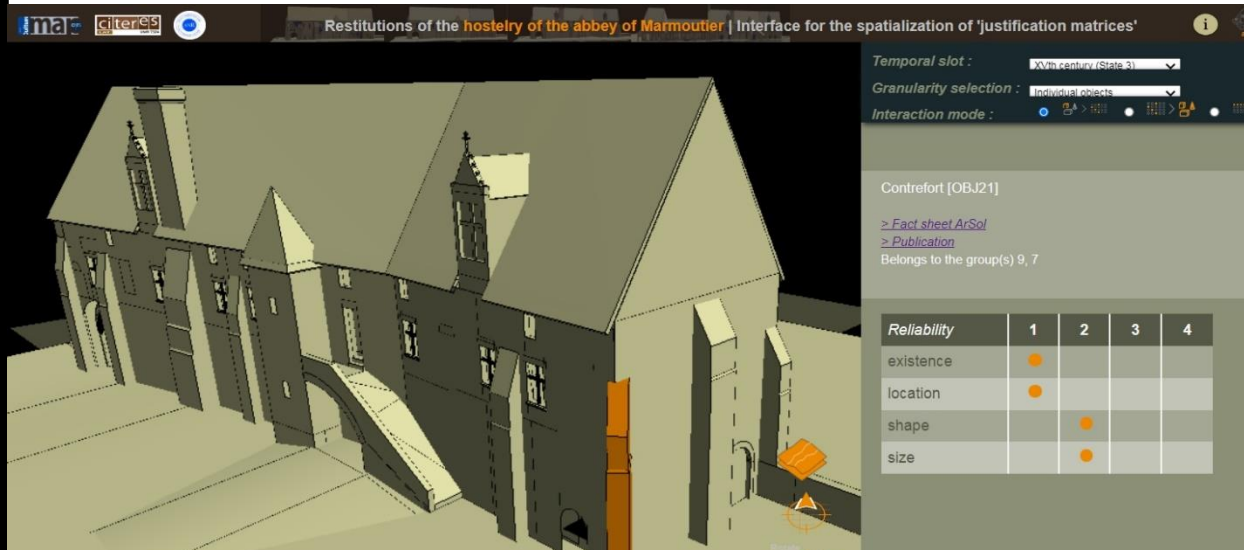
The cumulative matrices concept

*The idea: going beyond the reading of one architectural element, or one synchronic state.*

Buttresses vs. openings ?

State 1 vs. State 3 ?

- 1
- 2
- 3
- 4



- 1
- 2
- 3
- 4

Restitutions of the **hostelry of the abbey of Marmoutier** | Interface for the spatialization of 'justification matrices'

**Cumulative matrices in chronological order of refunds**

XVth century (State 3)    XVIIIth century (State 4)

**Cumulative matrices by architectural type: comparison**

Individual objects    All    Individual objects    All

Dominant values, by number of occurrences    Distance to the average cumulative matrix

Dominant values, by number of occurrences    Distance to the average cumulative matrix

Temporal slot : XVth century (State 3)  
 Granularity selection : Individual objects  
 Interaction mode :

Chronological

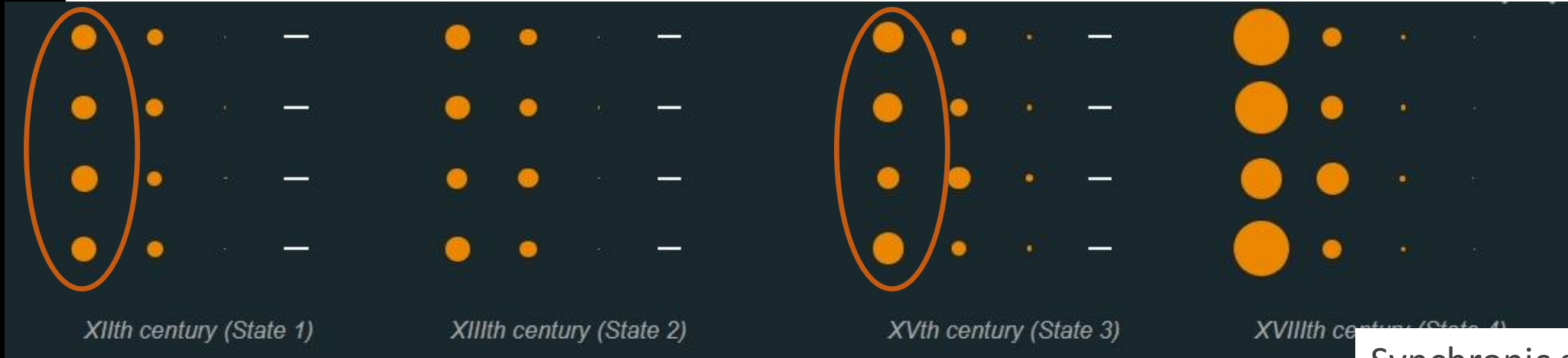
Typological

Cumulative matrices base on the same visual arrangement but show in an abstract way values for collections of elements

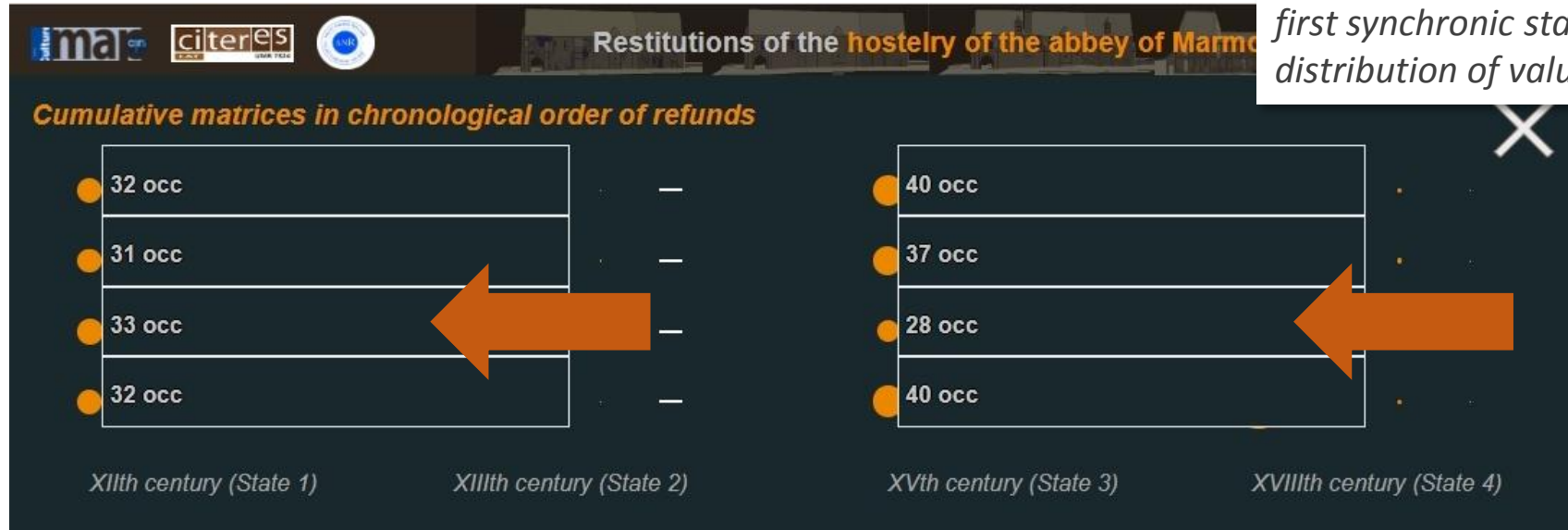
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One step beyond: (visual) patterns of information

- 1
- 2
- 3
- 4



Synchronic states  
 for the third synchronic state the  
 plausibility of shapes is  
 significantly lower than for the  
 first synchronic state, and the  
 distribution of values is less even



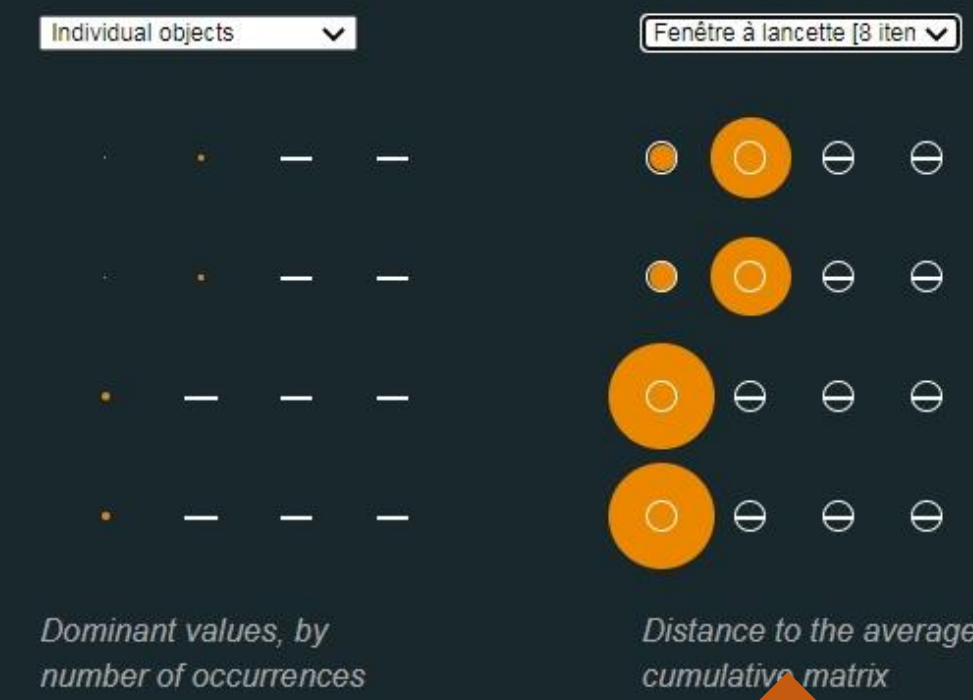
- 1
- 2
- 3
- 4

Typological analysis  
*Two architectural types, two divergent patterns*

**Cumulative matrices by architectural type: comparison**



Buttresses



Lancet windows

- 1
- 2
- 3
- 4
- 5

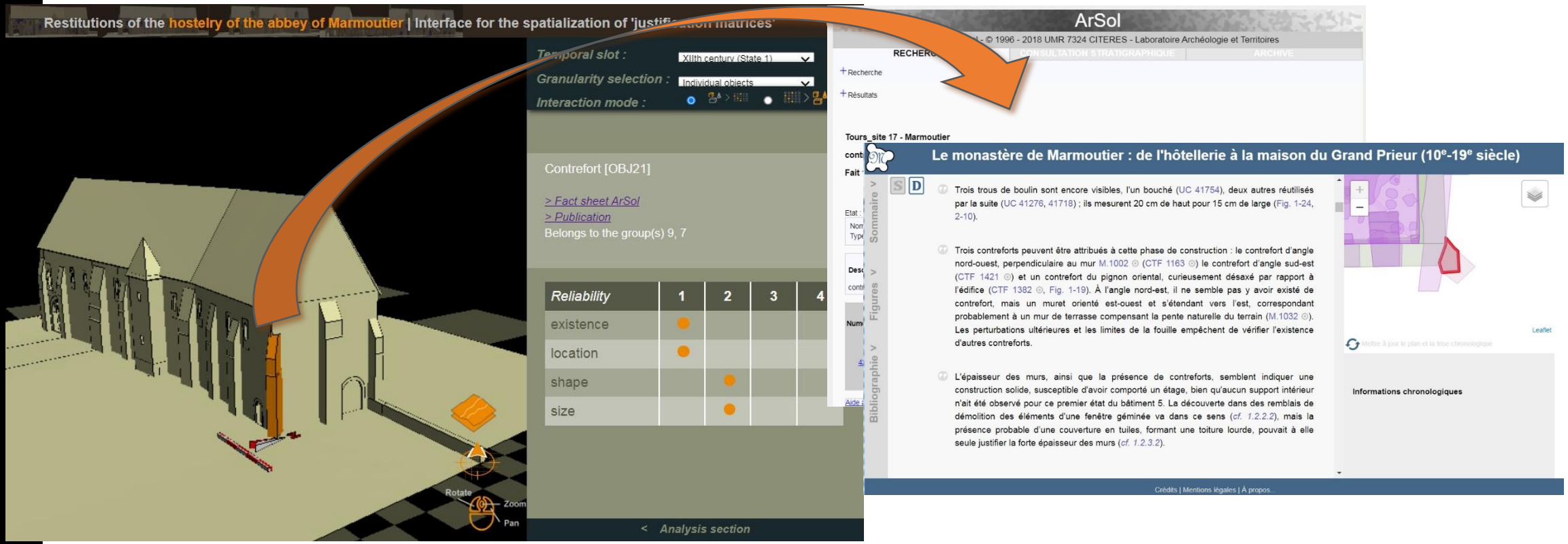


Archaeological phasing of the south façade

- The plausibility analysis was carried out a posteriori (several years after the creation of the 3D models), and not by the 3D models' creators : what we present is a method, not conclusive results on this specific case.
- An evaluation of the applicability/efficiency of the matrix itself would be needed
  - The model's discretization is architecture-based – potentially a bias (although a grouping mechanism has been tested)
- The graphic encoding is not really far-fetched – colours, mainly, some research on that aspect could be welcome too

- The technology, and the research agenda, may open an opportunity to rethink the *information spaces* connectable to 3D datasets, to enhance the interpretability of 3D reconstructions, as well as the repurposability of 3D components.

- 1
- 2
- 3
- 4
- 5



Restitutions of the **hostelry of the abbey of Marmoutier** | Interface for the spatialization of 'justification matrices'

Temporal slot : XIIIth century (State 1)

Granularity selection : Individual objects

Interaction mode :

Contrefort [OBJ21]

> [Fact sheet ArSol](#)

> [Publication](#)

Belongs to the group(s) 9, 7

| Reliability | 1 | 2 | 3 | 4 |
|-------------|---|---|---|---|
| existence   | ● |   |   |   |
| location    | ● |   |   |   |
| shape       |   | ● |   |   |
| size        |   | ● |   |   |

Le monastère de Marmoutier : de l'hôtellerie à la maison du Grand Prieur (10<sup>e</sup>-19<sup>e</sup> siècle)

Trois trous de boulin sont encore visibles, l'un bouché (UC 41754), deux autres réutilisés par la suite (UC 41276, 41718) ; ils mesurent 20 cm de haut pour 15 cm de large (Fig. 1-24, 2-10).

Trois contreforts peuvent être attribués à cette phase de construction : le contrefort d'angle nord-ouest, perpendiculaire au mur M.1002 (CTF 1163) le contrefort d'angle sud-est (CTF 1421) et un contrefort du pignon oriental, curieusement désaxé par rapport à l'édifice (CTF 1382, Fig. 1-19). À l'angle nord-est, il ne semble pas y avoir existé de contrefort, mais un muret orienté est-ouest et s'étendant vers l'est, correspondant probablement à un mur de terrasse compensant la pente naturelle du terrain (M.1032). Les perturbations ultérieures et les limites de la fouille empêchent de vérifier l'existence d'autres contreforts.

L'épaisseur des murs, ainsi que la présence de contreforts, semblent indiquer une construction solide, susceptible d'avoir comporté un étage, bien qu'aucun support intérieur n'ait été observé pour ce premier état du bâtiment 5. La découverte dans des remblais de démolition des éléments d'une fenêtre géminée va dans ce sens (cf. 1.2.2.2), mais la présence probable d'une couverture en tuiles, formant une toiture lourde, pouvait à elle seule justifier la forte épaisseur des murs (cf. 1.2.3.2).

[http://anr-sesames.map.cnrs.fr/viewer\\_ply\\_dxf/SESAMES\\_Justifieur/application/SESAMES\\_Justifieur\\_Bilingue.html](http://anr-sesames.map.cnrs.fr/viewer_ply_dxf/SESAMES_Justifieur/application/SESAMES_Justifieur_Bilingue.html)

Temporal slot :

Granularity selection :

Interaction mode :

| Reliability | 1 | 2 | 3 | 4 |
|-------------|---|---|---|---|
| existence   | ● |   |   |   |
| location    |   | ● |   |   |
| shape       |   | ● |   |   |
| size        |   | ● |   |   |

Rotate  Zoom  Pan

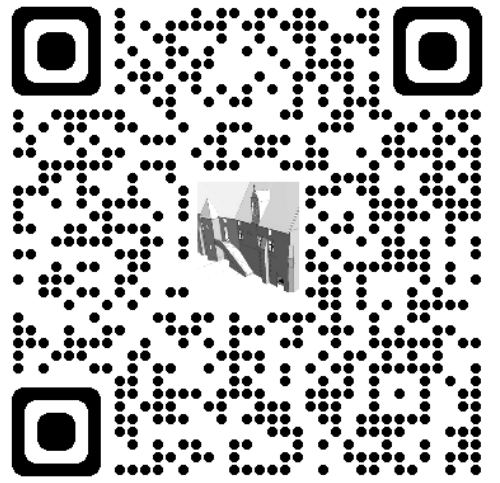
< Analysis section

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