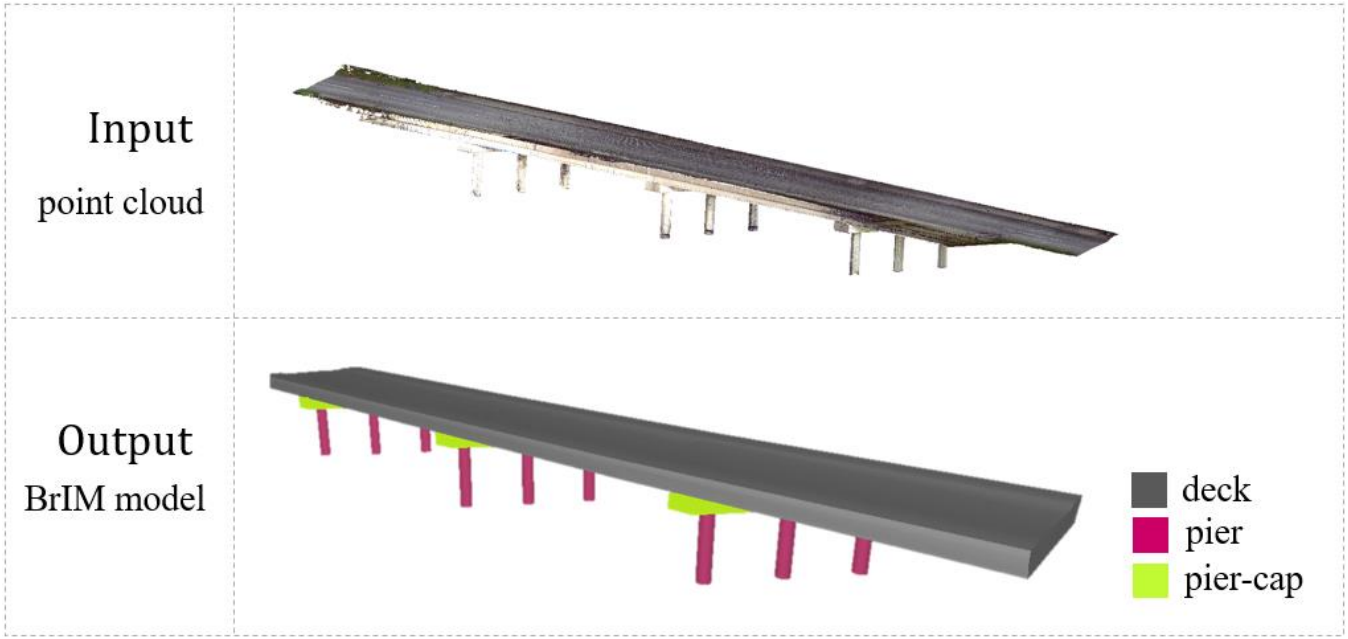
Point Clouds to IFC/BrIM

Objective:

Develop and demonstrate a point cloud data processing solution, which takes a point cloud of a bridge obtained from laser scanning as *input*,

… and generates a solid model estimate of the bridge structure with semantic labels for its constitutive components as *output*.



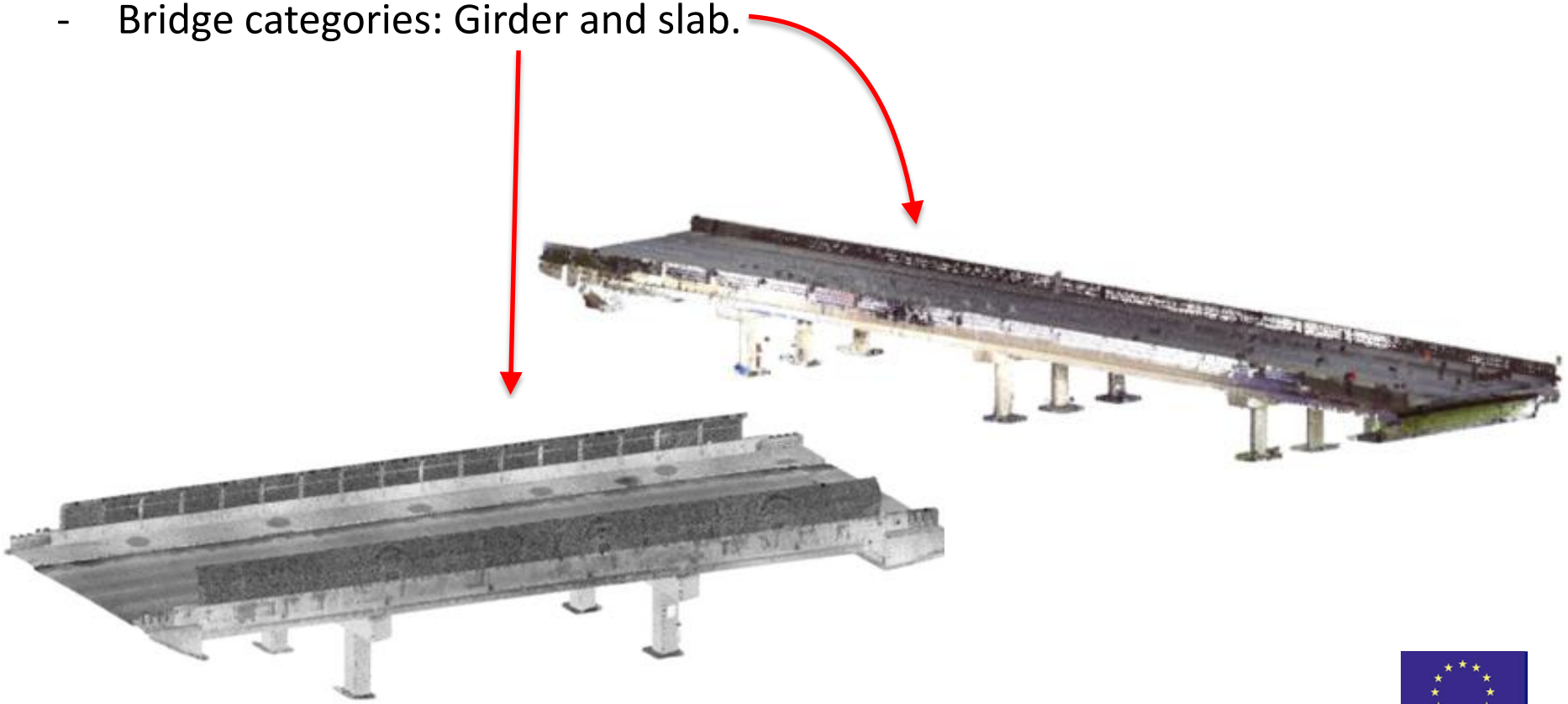
Point Clouds to IFC/BrIM

Infravation
An Infrastructure Innovation Programme

SeeBridge
Semantic Enrichment Engine for Bridges

Scope:

- No pre-existing BIM/IFC model.
- High-level information regarding bridge available (from user).
- Bridge categories: Girder and slab.



Point Clouds to IFC/BrIM

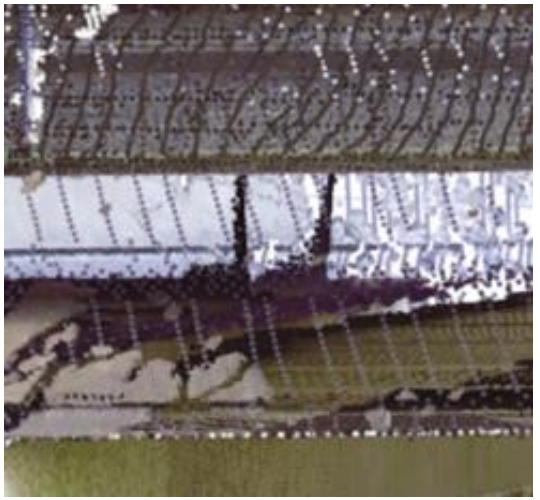
Infravation
An Infrastructure Innovation Programme

SeeBridge
Semantic Enrichment Engine for Bridges

Input:

- Point cloud.
- Minimum viable density (about 1 pt/cm).
- Some user guidance (< 30 minutes).

Sufficient

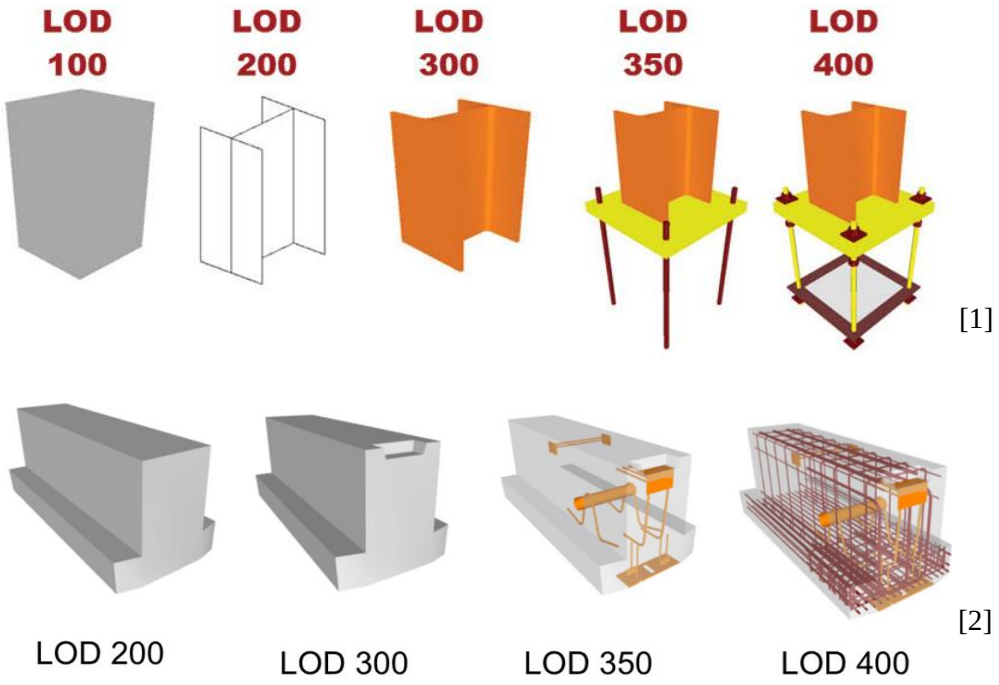


Insufficient

Point Clouds to IFC/BrIM

Output:

- Industry Foundation Class (IFC) formatted model file.
- Output level of development (LOD) around 200-300.



[1]

[2]

Expectation: First pass 'best-guess' classifications, tagging the objects as

- columns,
- girders,
- slabs,
- etc.

where possible.

[1] Structure Magazine
[2] Mundo BIM

Point Clouds to IFC/BrIM

What are strategies for going from dense or fine grain collections of raw data to its re-organization into components associated to a bigger entity?

e.g., from points to bridge model?

Point Clouds to IFC/BrIM

Bottom-Up Processing

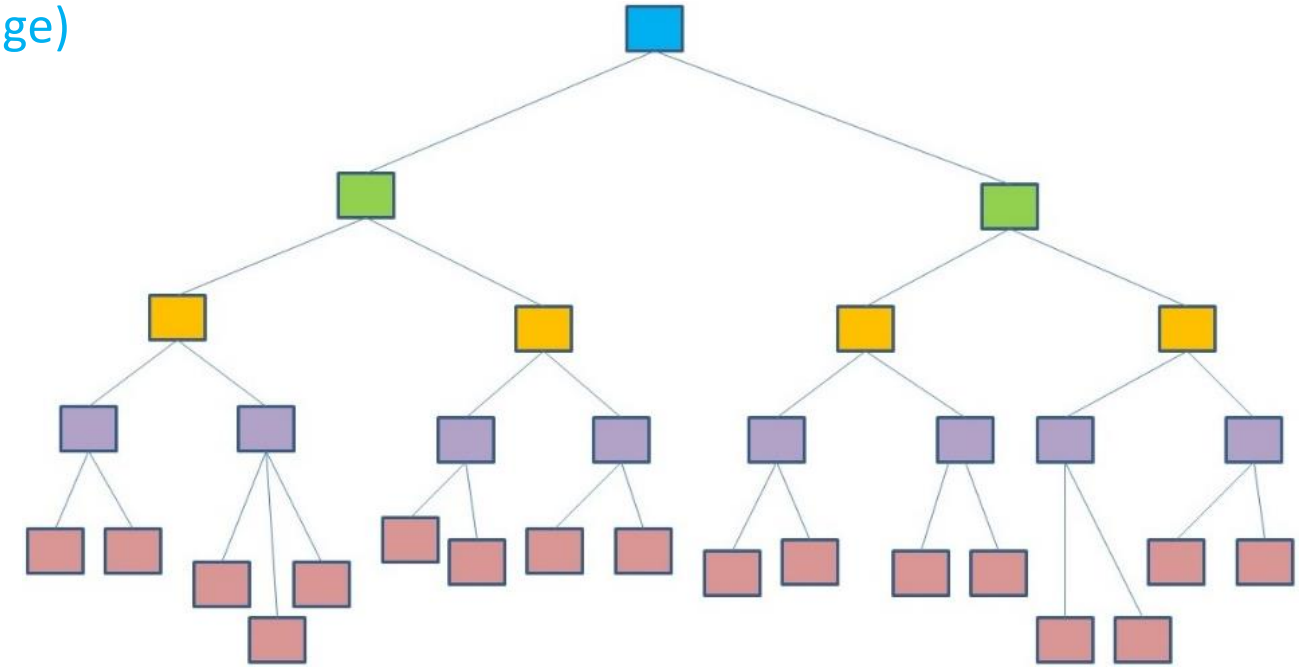
model (e.g. bridge)

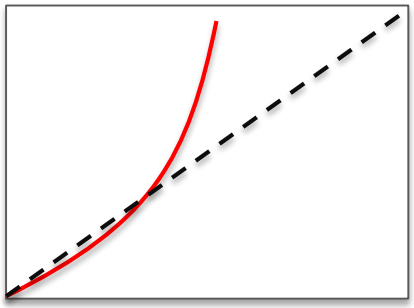
assemblies

components

surfaces

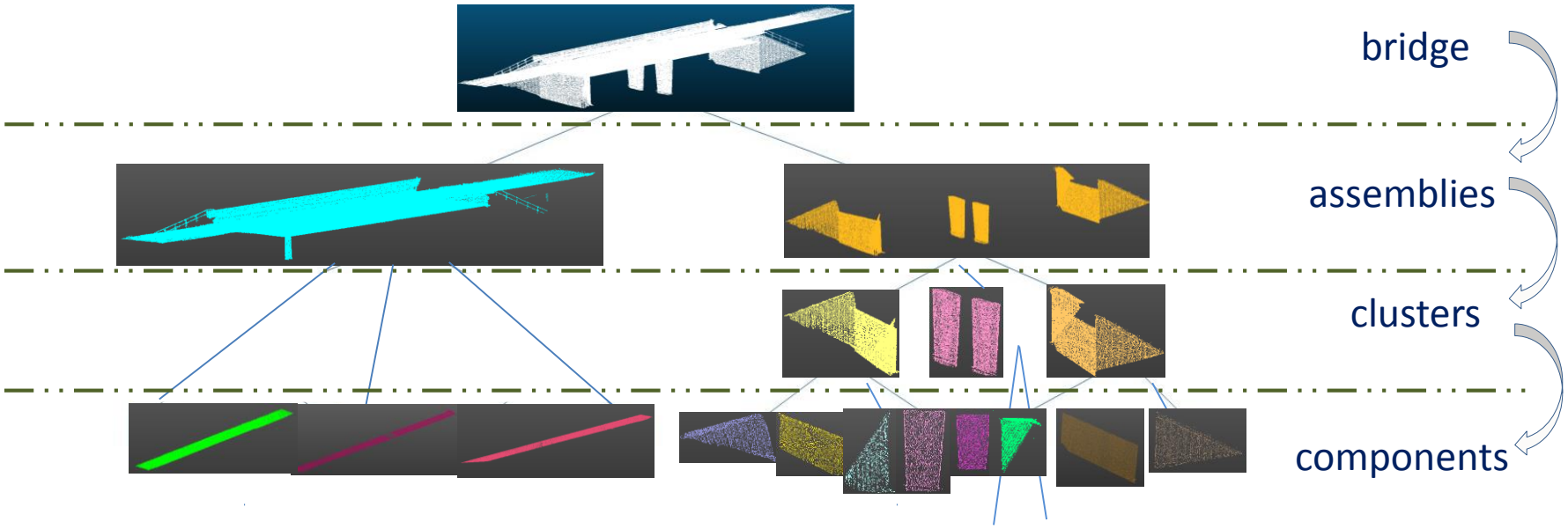
points





Point Clouds to IFC/BrIM

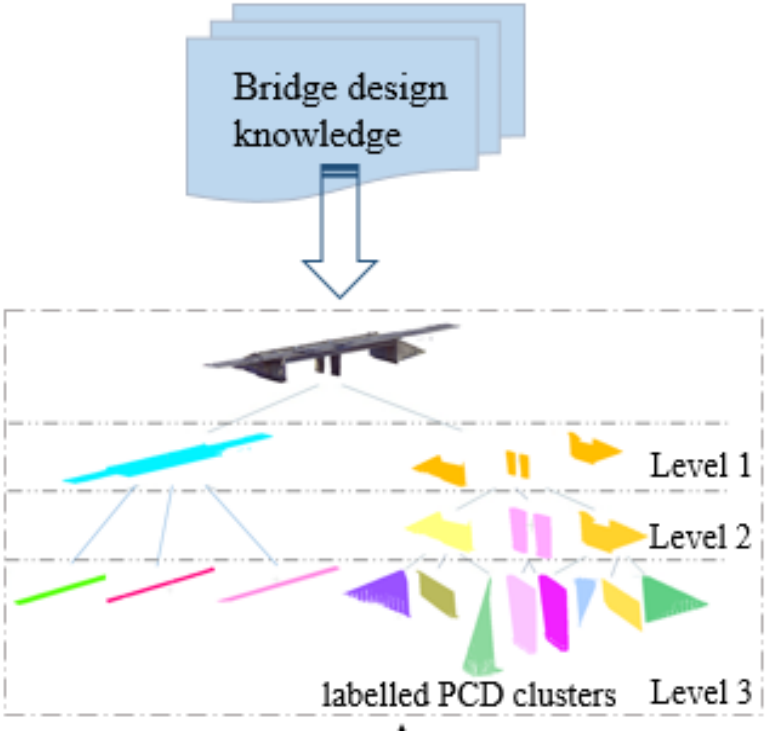
Top-Down Processing

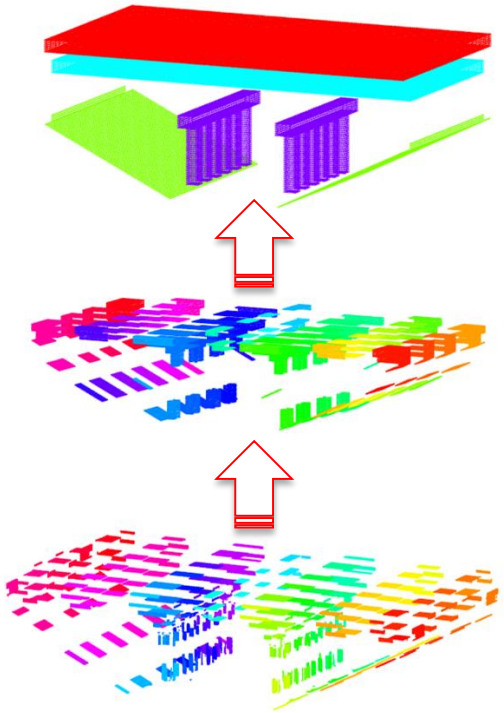


Point Clouds to IFC/BrIM

Both approaches were pursued:

1. Top-Down
2. Bottom-Up with Top-Down partitioning





Point Clouds to IFC/BrIM

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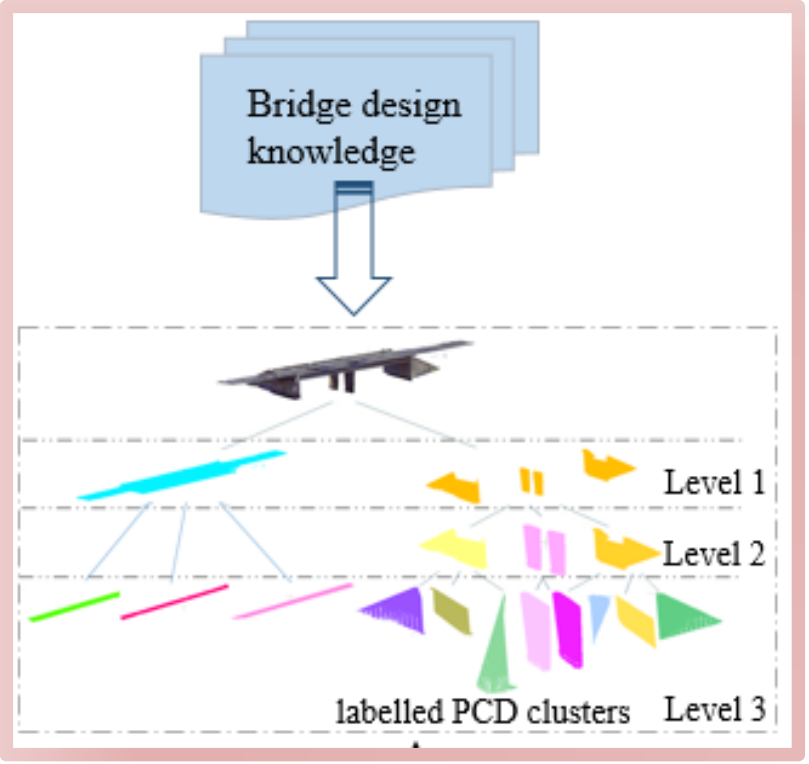
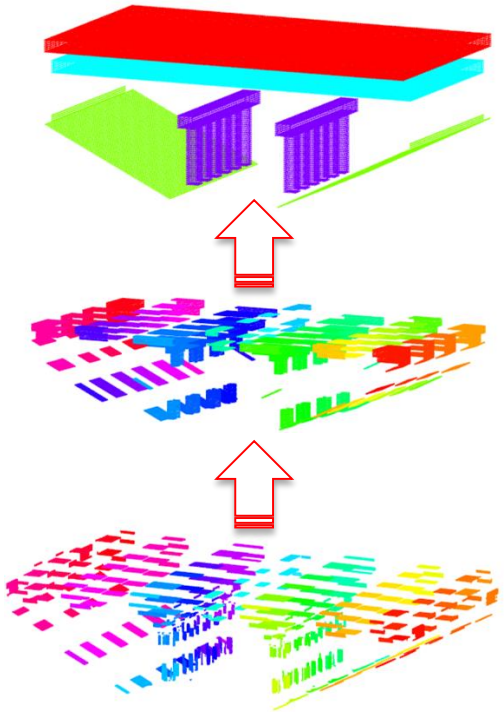


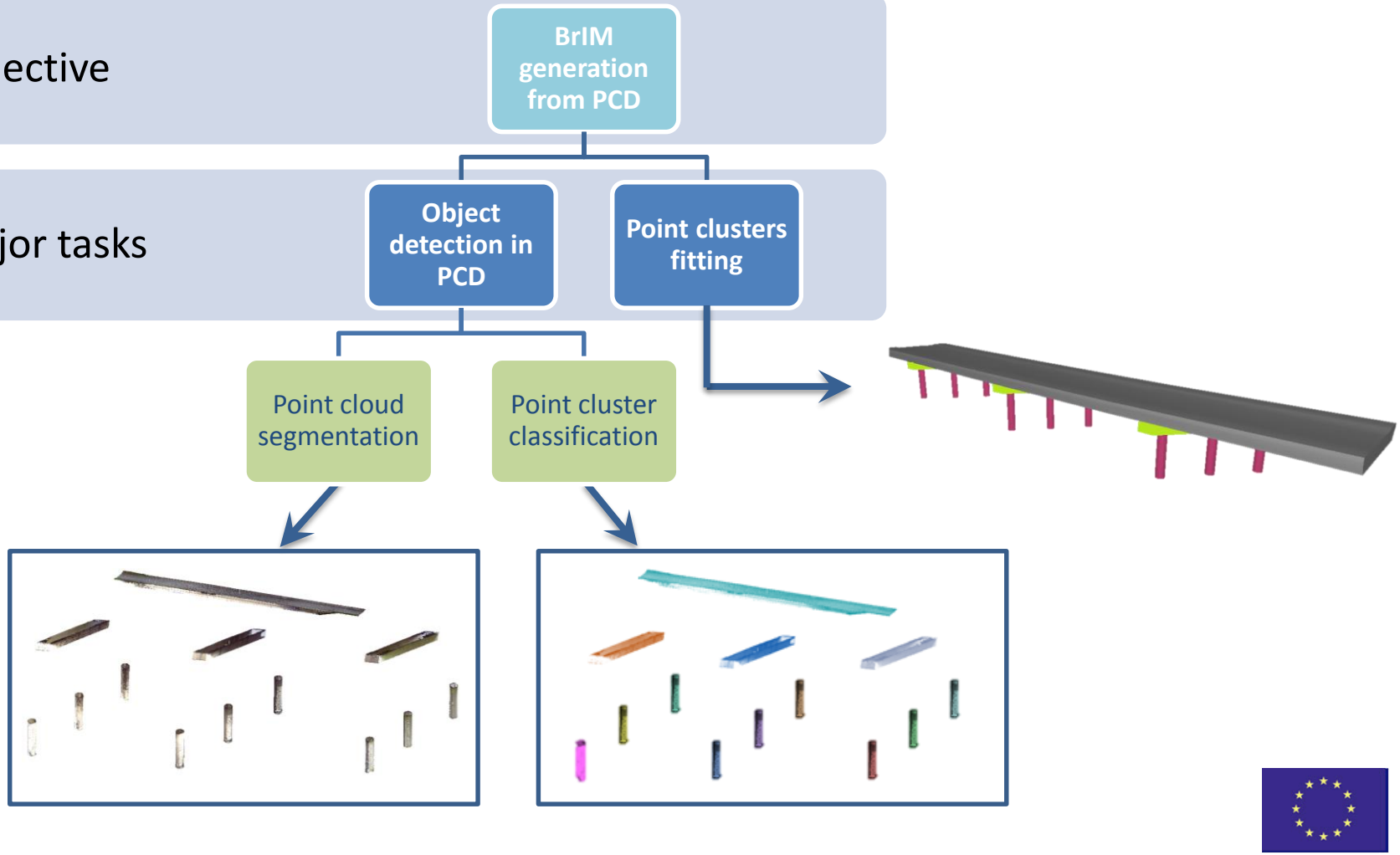


Top-down 3D geometry

Goal :

objective

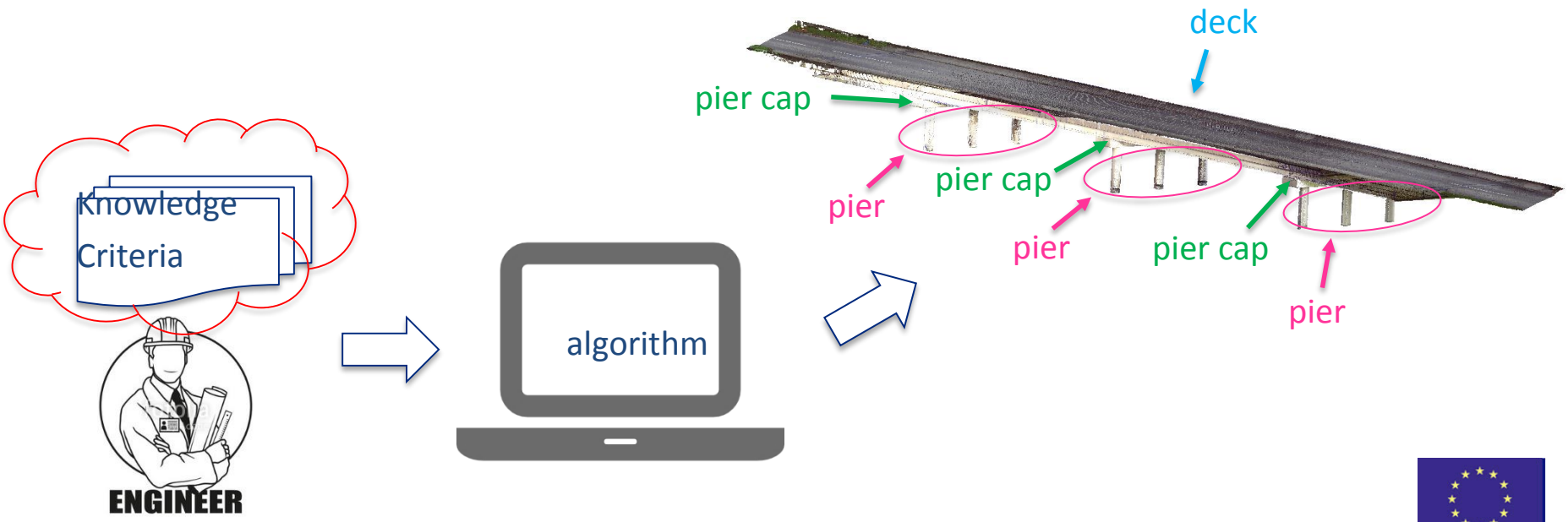
2 major tasks



Top-down 3D geometry

Top-down procedure

- A heuristic approach to the problem of object detection and object fitting
- Begins with a broad-picture view
- Explicitly incorporates engineering criteria as segmentation heuristics.
- General idea is to use the bridge topological and physical constraints.

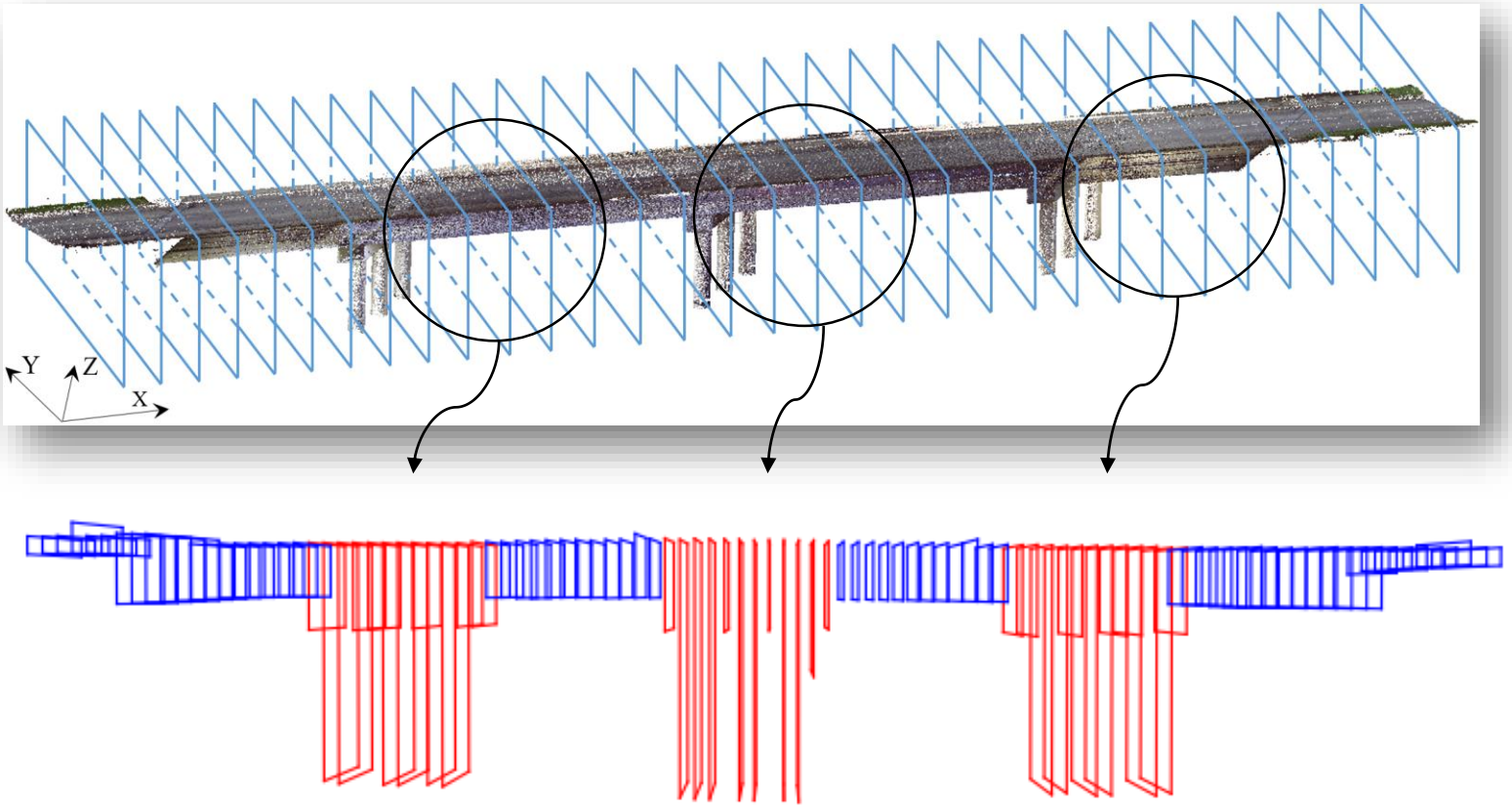


Top-down 3D geometry

Infravation
An Infrastructure Innovation Programme

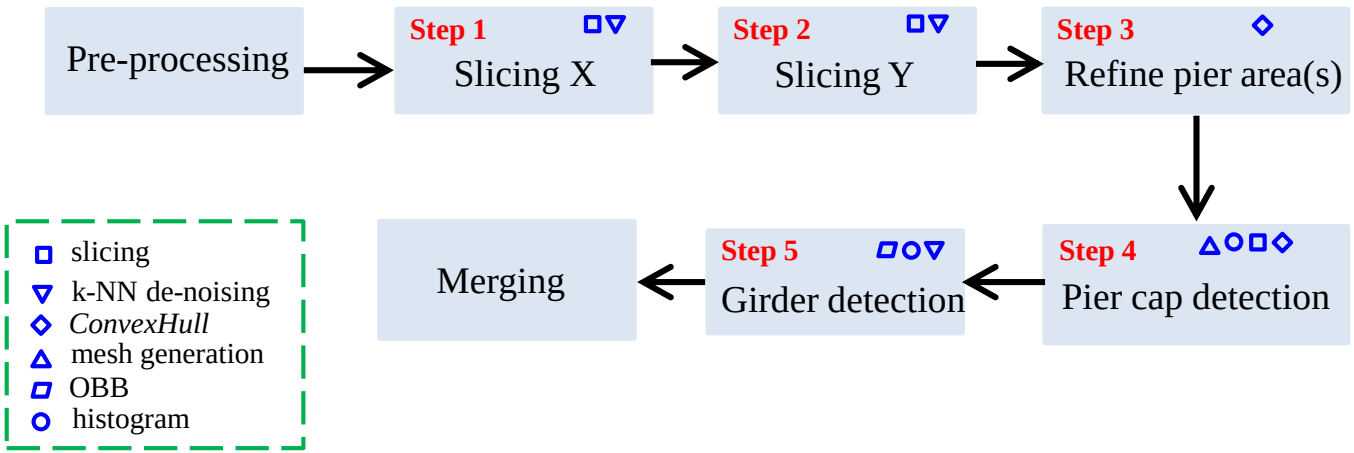
SEEBRIDGE
SEMANTIC ENRICHMENT ENGINE FOR BRIDGES

Partition span-wise to illuminate structure.



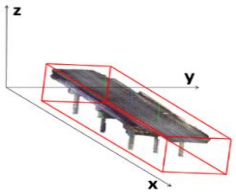
Top-down 3D geometry

Refining and sub-dividing segmented components



Top-down 3D geometry

Refining and sub-dividing segmented components



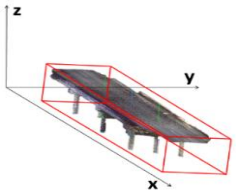
START

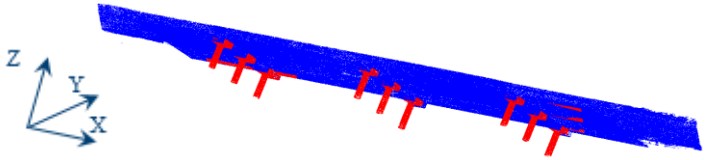
Pre-processing → Step 1 Slicing X → Step 2 Slicing Y → Step 3 Refine pier area(s) → Step 4 Pier cap detection → Step 5 Girder detection → Merging

- slicing
- k-NN de-noising
- *ConvexHull*
- mesh generation
- OBB
- histogram

Top-down 3D geometry

Refining and sub-dividing segmented components





START

Pre-processing → **Step 1** Slicing X → **Step 2** Slicing Y → **Step 3** Refine pier area(s)

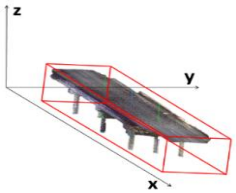
Piers

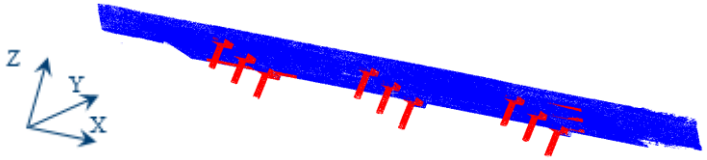
Step 4 Pier cap detection → **Step 5** Girder detection → Merging

- slicing
- k-NN de-noising
- *ConvexHull*
- mesh generation
- OBB
- histogram

Top-down 3D geometry

Refining and sub-dividing segmented components



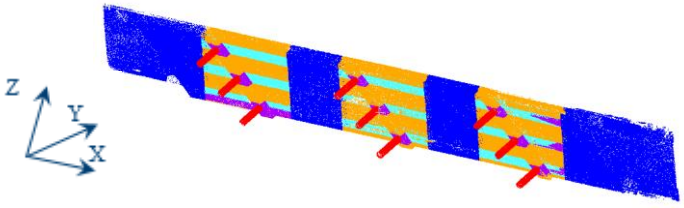


START

Pre-processing → **Step 1** Slicing X → **Step 2** Slicing Y → **Step 3** Refine pier area(s) → **Step 4** Pier cap detection → **Step 5** Girder detection → Merging

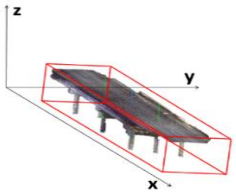
- slicing
- k-NN de-noising
- *ConvexHull*
- mesh generation
- OBB
- histogram

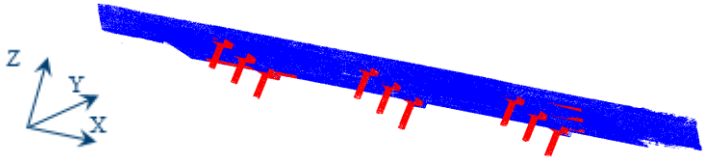
Pier caps



Top-down 3D geometry

Refining and sub-dividing segmented components

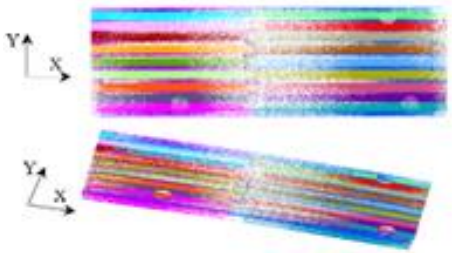


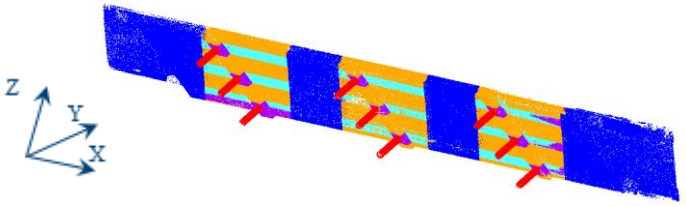


START

Pre-processing → **Step 1** Slicing X → **Step 2** Slicing Y → **Step 3** Refine pier area(s) → **Step 4** Pier cap detection → **Step 5** Girder detection → Merging → END

- slicing
- k-NN de-noising
- *ConvexHull*
- mesh generation
- OBB
- histogram

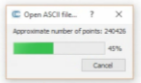


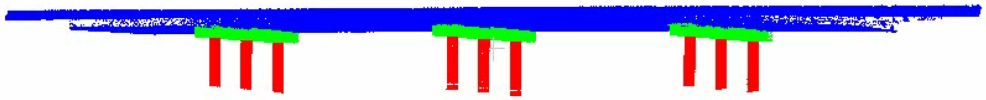


Girders

Top-down 3D geometry

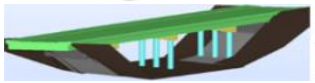
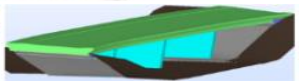
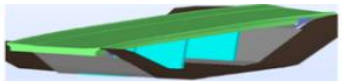
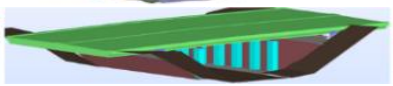
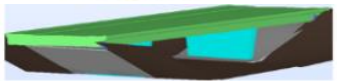
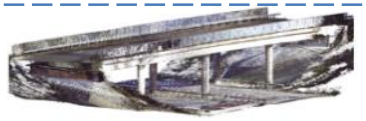
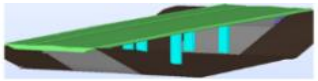
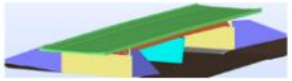
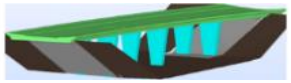
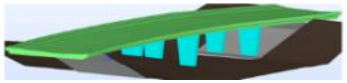
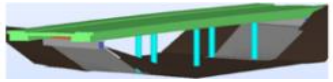
Refining and sub-dividing segmented components





Top-down 3D geometry

Ground Truth Preparation:

	Bridge 1	Bridge 2	Bridge 3	Bridge 4	Bridge 5
PCD					
BrIM					
Scanning(h)	3.5	3.3	3.2	4	3.2
Segmentation(h)	3.5	3.3	3.2	4	3.2
Modelling(h)	50	31	30	26	22
	Bridge 6	**Bridge 7**	**Bridge 8**	**Bridge 9**	**Bridge 10**
PCD					
BrIM					
Scanning(h)	2.5	2	2.3	2.2	2
Segmentation(h)	2.5	2	2.3	2.2	2
Modelling(h)	25	27	23	20	22

average time (h) per bridge		
Scanning	Segmentation	Modelling
2.82	1.52	**28**

Top-down 3D geometry

Infravation
An Infrastructure Innovation Programme

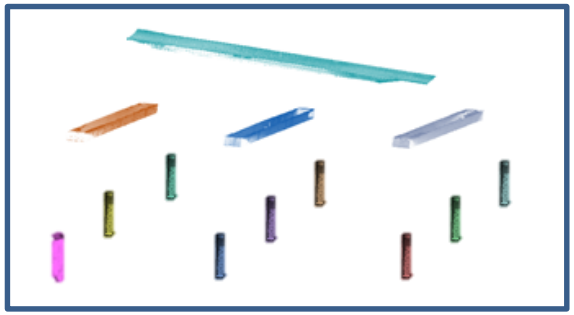
SEEBRIDGE
SEMANTIC ENRICHMENT ENGINE FOR BRIDGES

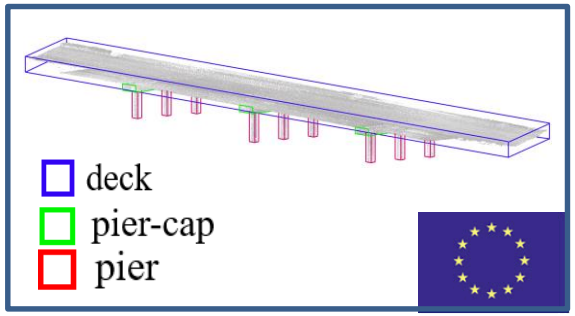
Experiments
Data Preparation

	Bridge 1	Bridge 2	Bridge 3	Bridge 4	Bridge 5
Raw data					
	Bridge 6	**Bridge 7**	**Bridge 8**	**Bridge 9**	**Bridge 10**
Raw data					

Manual segmentation

Manual labelling



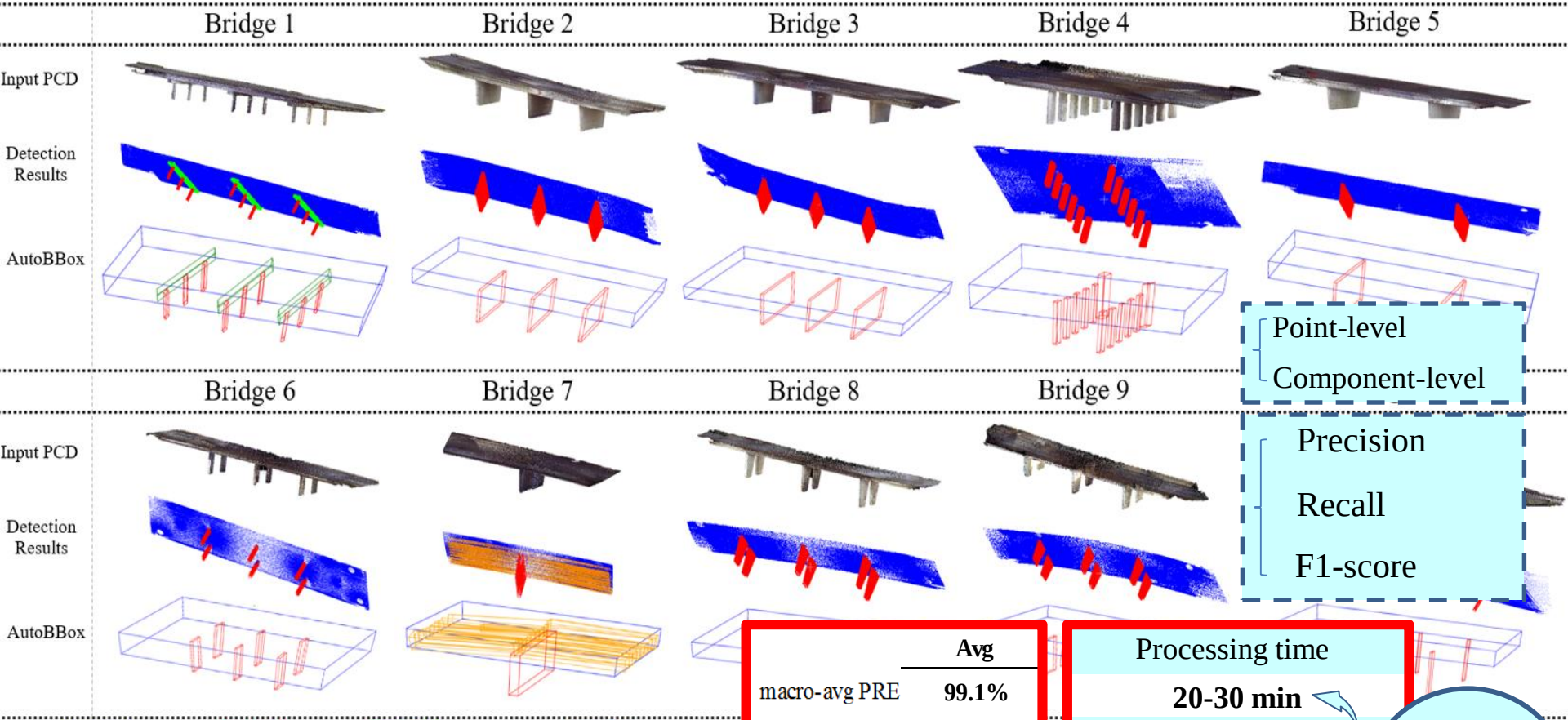


Top-down 3D geometry

Infravation
An Infrastructure Innovation Programme

SeeBridge
Semantic Enrichment Engine for Bridges

Results



- Point-level
- Component-level

- Precision
- Recall
- F1-score

	Avg
macro-avg PRE	**99.1%**
macro-avg REC	**98.1%**
macro-avg F1	**98.6%**

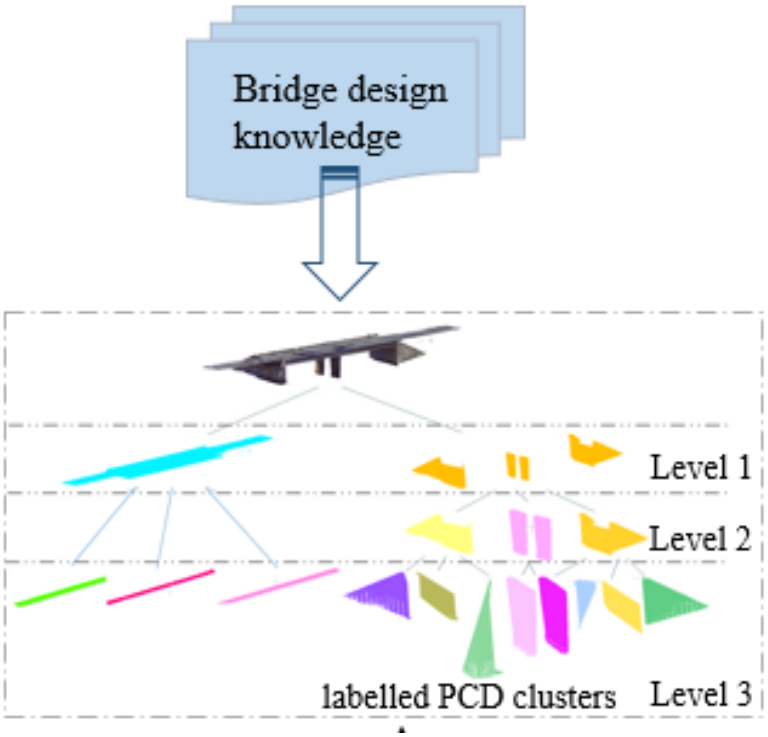
Processing time
20-30 min
Manual
91.2 min

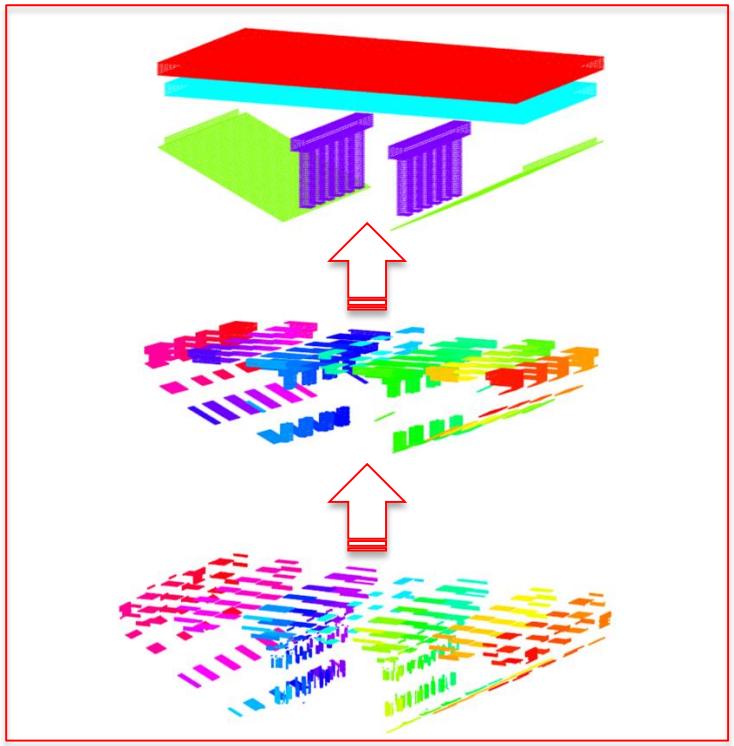
~70% time saving

Point Clouds to IFC/BrIM

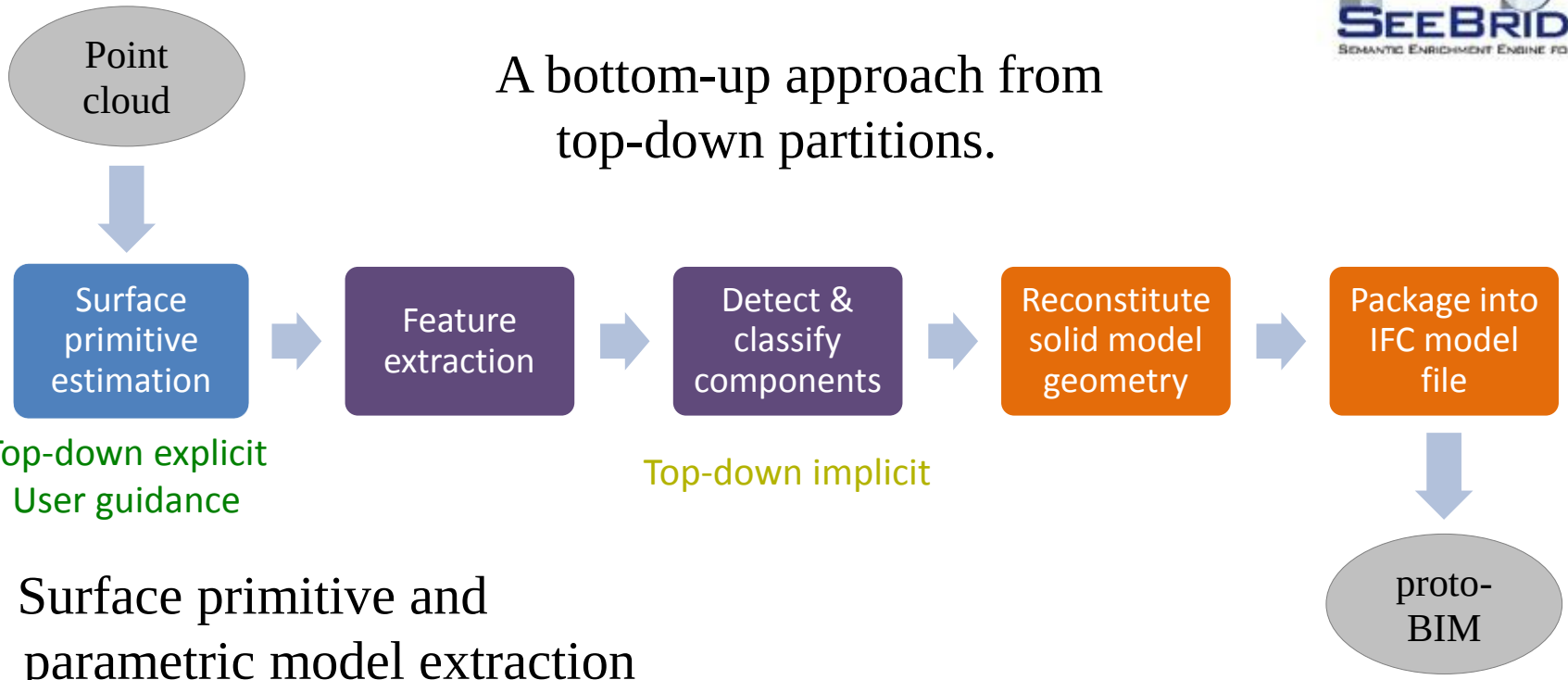
Both approaches were pursued:

1. Top-Down
2. Bottom-Up with Top-Down partitioning





Bottom-Up modeling

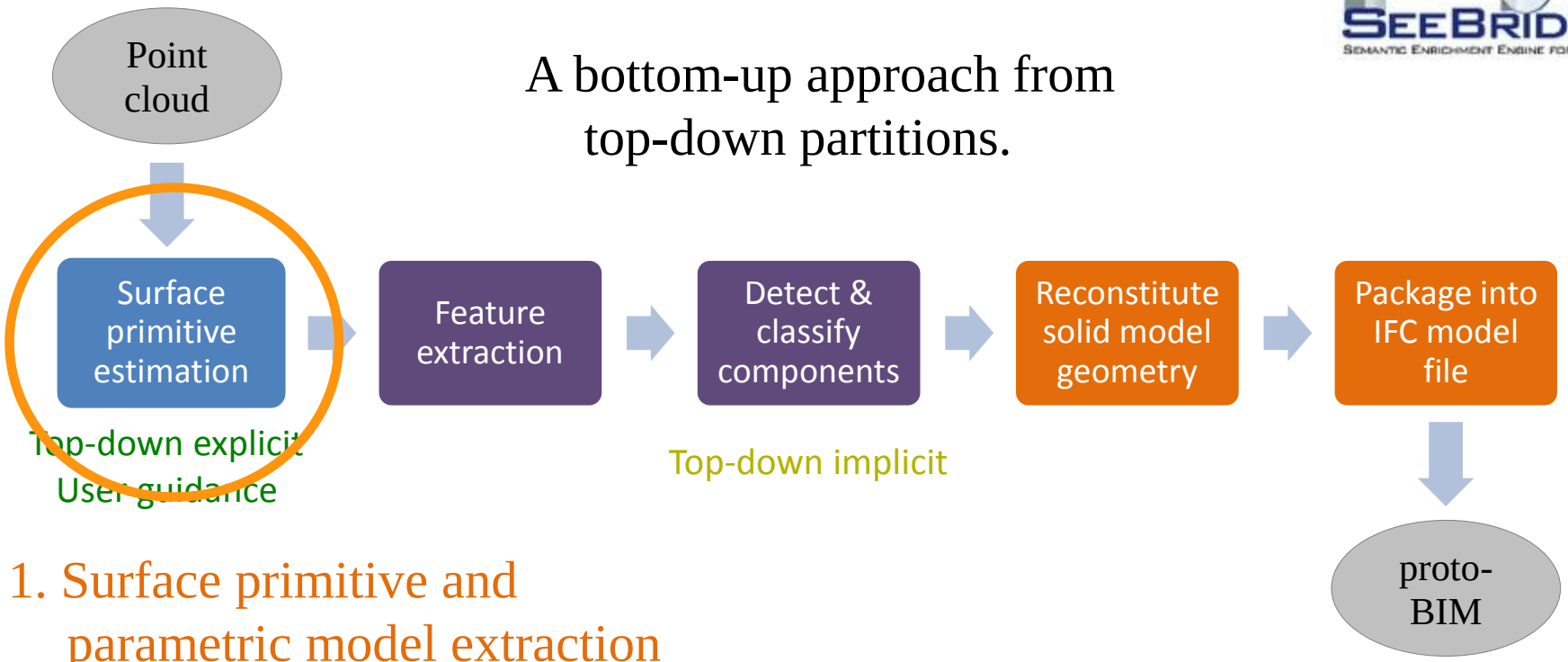


1. Surface primitive and parametric model extraction

2. Detection and classification of bridge components from primitives

3. Bridge component parser for generating IFC model files.

Bottom-Up modeling



1. Surface primitive and parametric model extraction

2. Detection and classification of bridge components from primitives

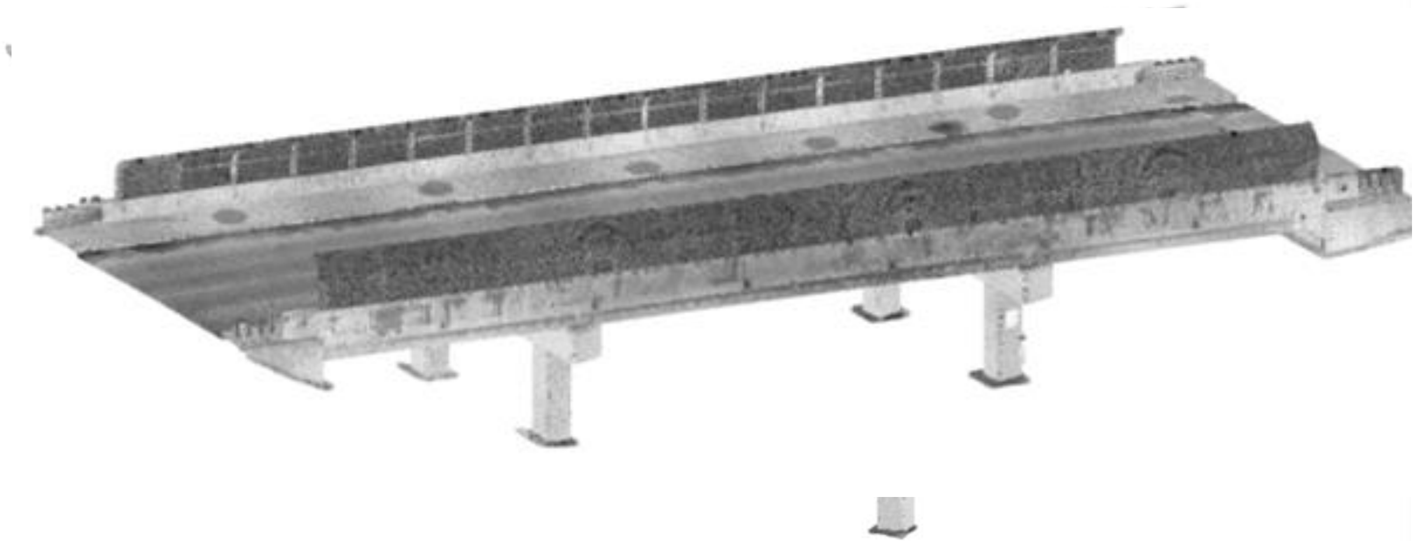
3. Bridge component parser for generating IFC model files.

Bottom-Up modeling

Point cloud → Clean/Partition Point Cloud → Quadratic Surface Primitive Segmentation → Model Estimation → Model Merging → Partition Merging → Surface Models

Get user input to clean point cloud and define bridge frame.

10-20 minutes



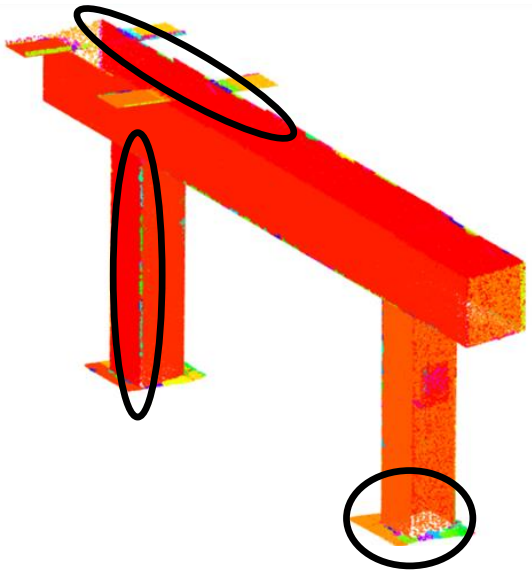
Bottom-Up modeling

Infravation
An Infrastructure Innovation Programme

SeeBridge
Semantic Enrichment Engine for Bridges

Point cloud → Clean/Partition Point Cloud → Quadratic Surface Primitive Segmentation → Model Estimation → Model Merging → Partition Merging → Surface Models

Input
points only



few big surfaces
many smaller ones

Automated algorithm.

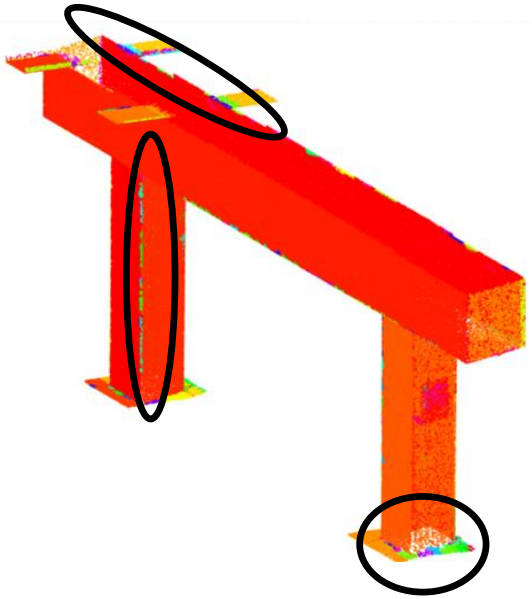
5-10 hours

Bottom-Up modeling

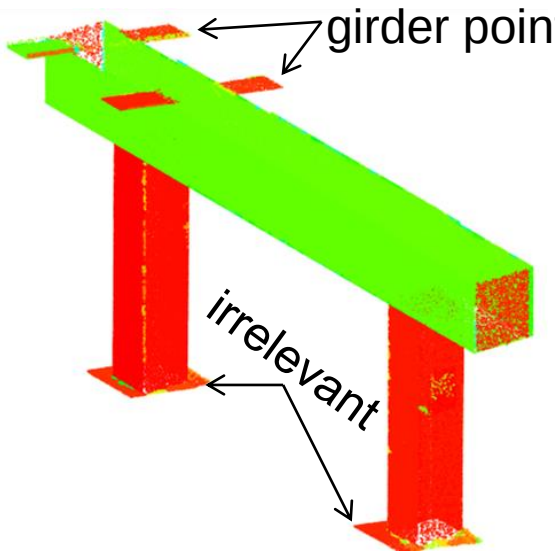
Infravation
An Infrastructure Innovation Programme

SeeBridge
Semantic Enrichment Engine for Bridges

Point cloud → Clean/Partition Point Cloud → Quadratic Surface *Primitive* Segmentation → Model Estimation → Model Merging → Partition Merging → Surface Models



few big surfaces
many smaller ones



few big surfaces
some medium ones

Automated algorithm.

5-10 hours

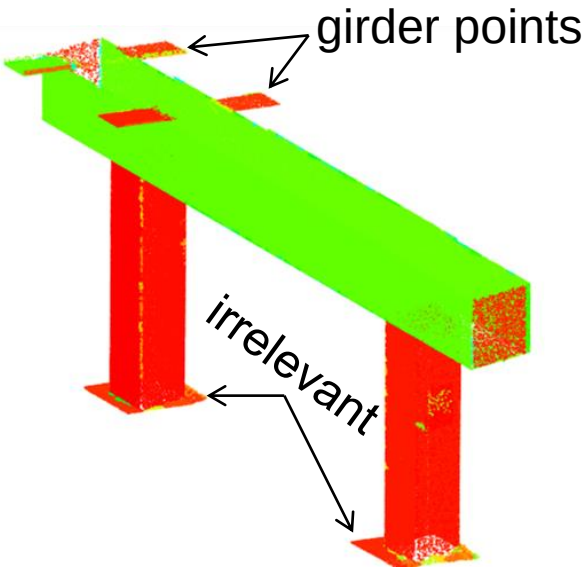
Bottom-Up modeling

Infravation
An Infrastructure Innovation Programme

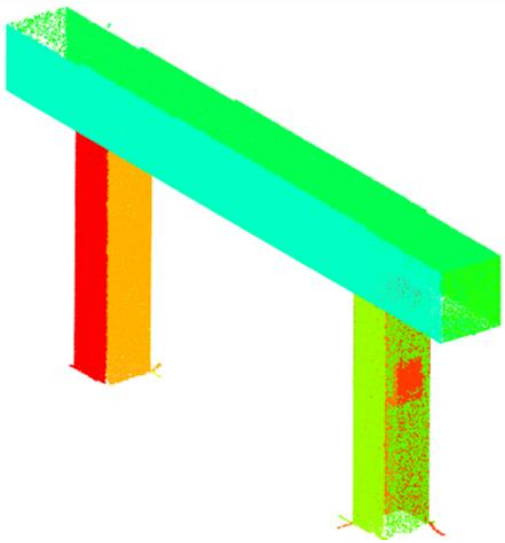
SeeBridge
Semantic Enrichment Engine for Bridges

Point cloud → Clean/Partition Point Cloud → Quadratic Surface *Primitive* Segmentation → Model Estimation → Model Merging → Partition Merging → Surface Models

Correct over-segmentation.



few big surfaces
some medium ones



Output
only important surfaces

User feedback.

5-10 minutes

Bottom-Up modeling

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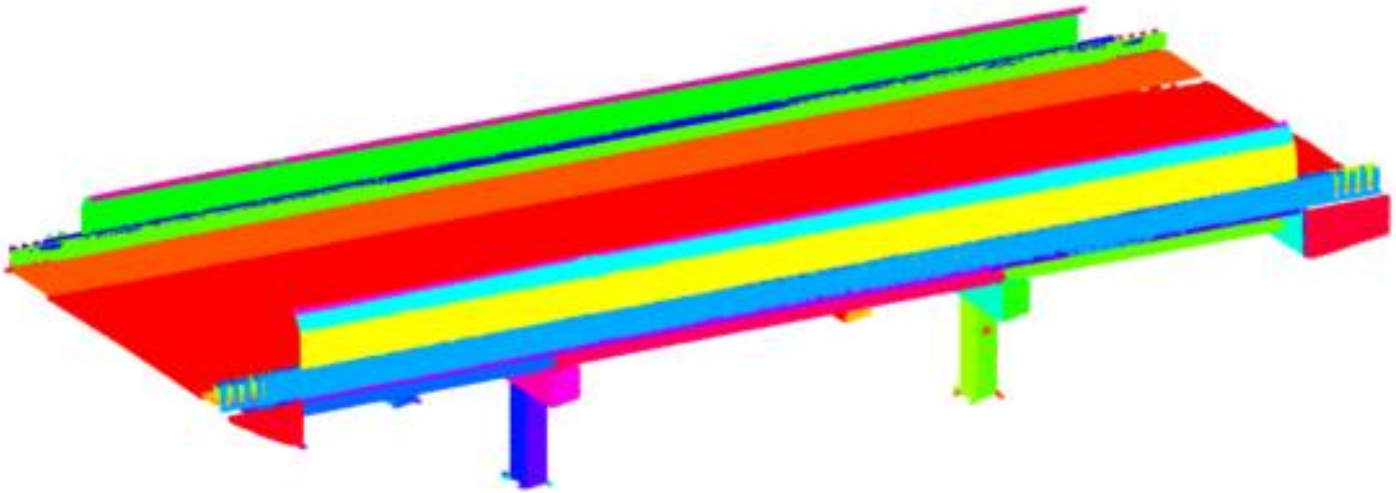
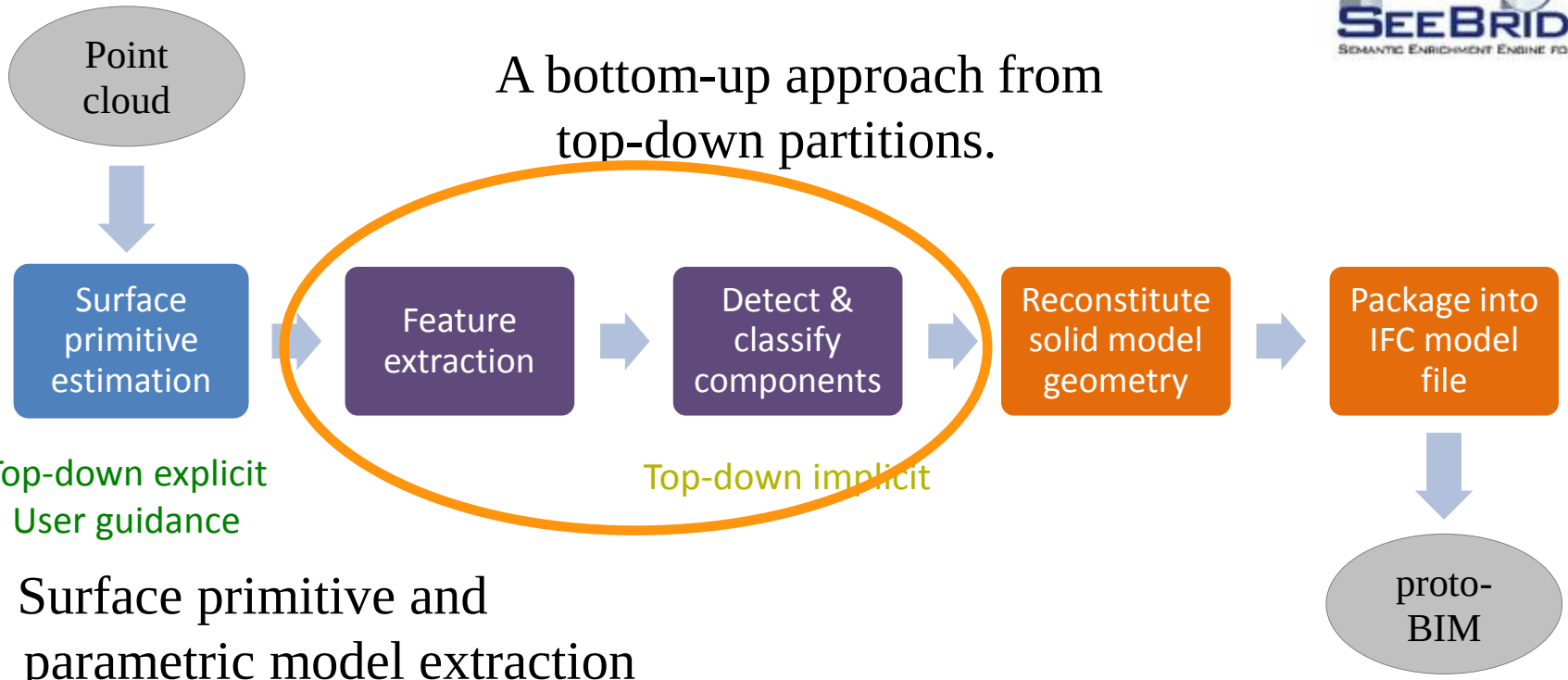
Undo top-down partitioning.



Piers + Superstructure (with girders) + Abutments + Soffits + Deck + Road

Bottom-Up modeling



1. Surface primitive and parametric model extraction

2. Detection and classification of bridge components from primitives

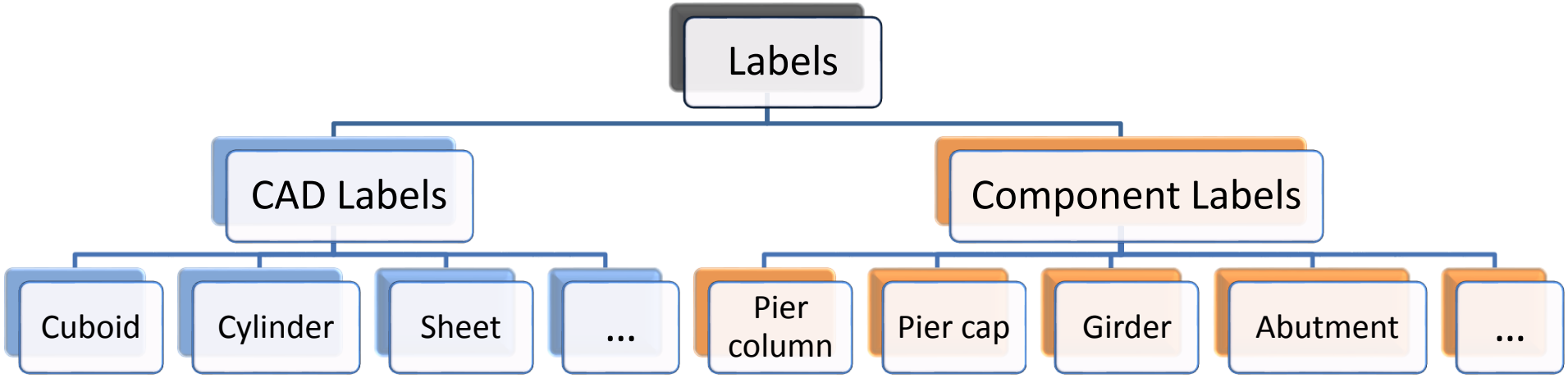
3. Bridge component parser for generating IFC model files.

Bottom-Up modeling

Classifier to output both

hypothesized CAD model labels and

hypothesize bridge components labels.



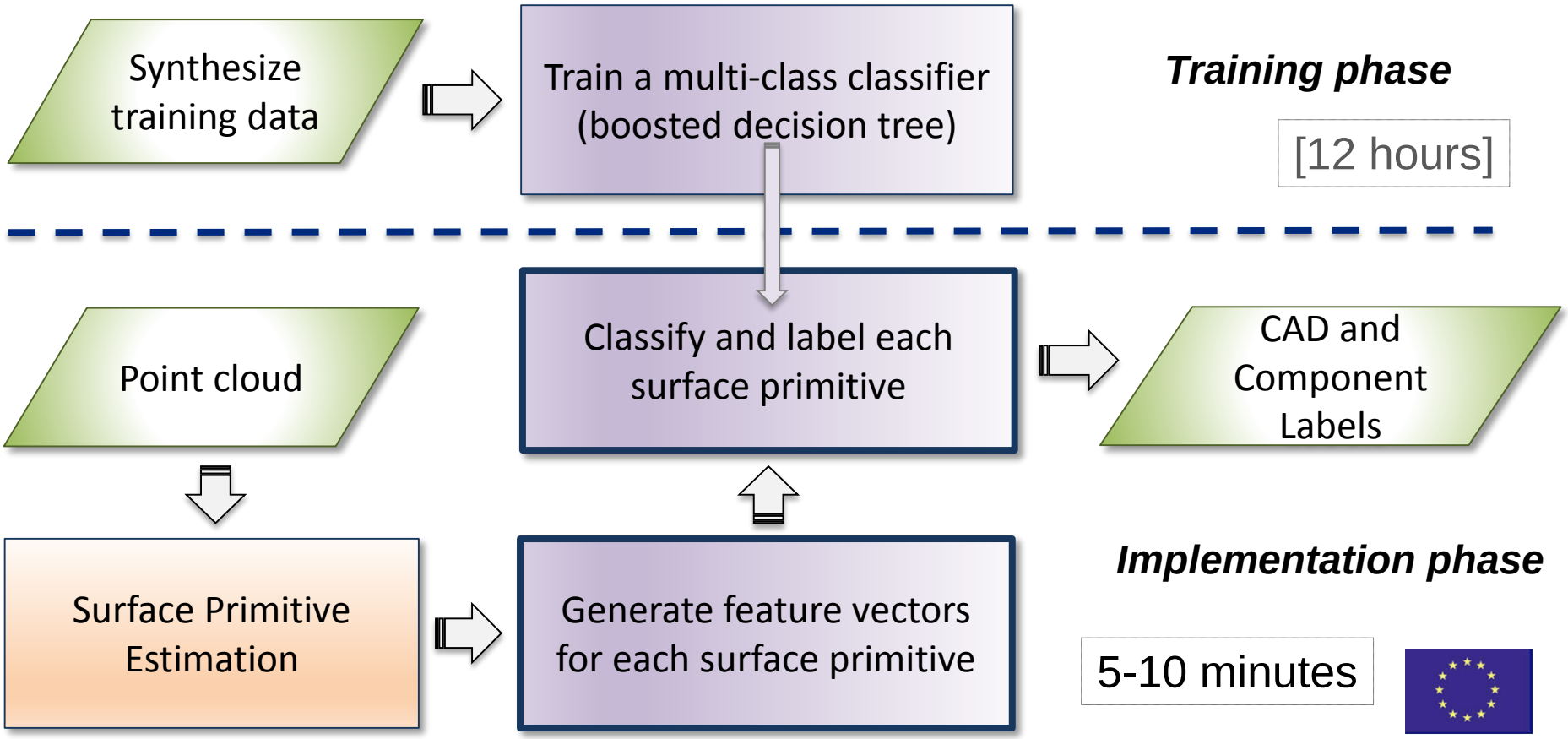
Purpose: Reverse engineer the top-down process.

Training requires top-level structure and lower-level equivalent.

Implementation takes lower-level information to hypothesize top-level structure.

Bottom-Up modeling

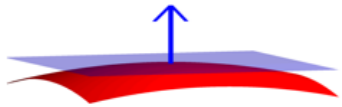
Classifier will output both hypothesized CAD model labels and hypothesize bridge components labels.

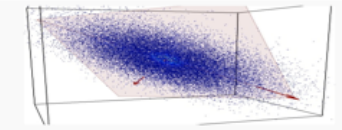


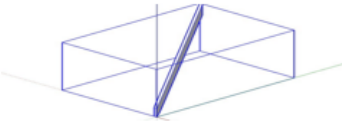
Bottom-Up modeling

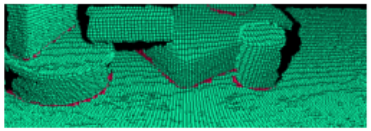
Feature vector description of each surface element.

- T_i Type of the surface primitive
- n_i Normal of each surface primitive
- V_i Principal direction of the support
- B_i Relative scale of bounding box size
- L_i Connecting neighborhood statistics





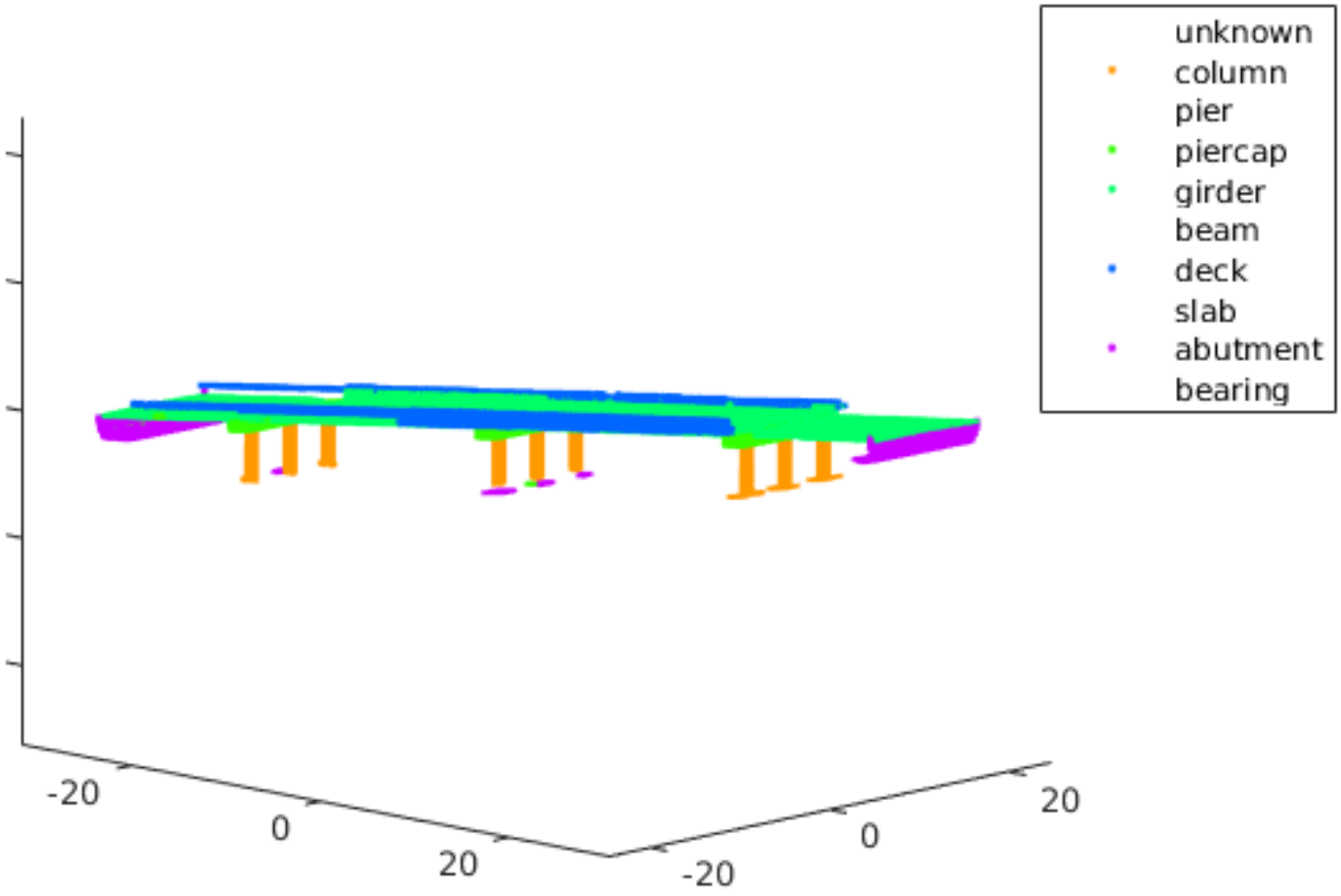




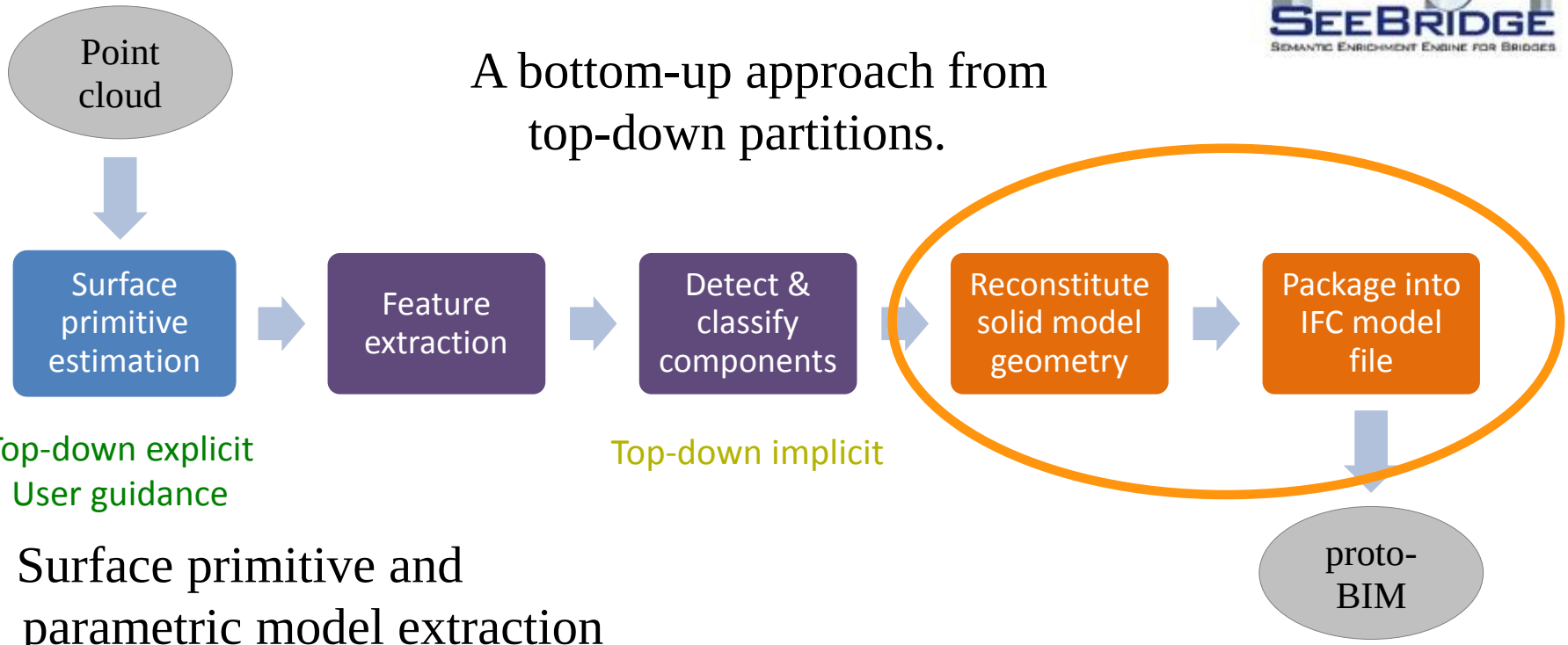
* N_p is the number of the primitive types

Bottom-Up modeling

Sample output of bridge component classification.



Bottom-Up modeling



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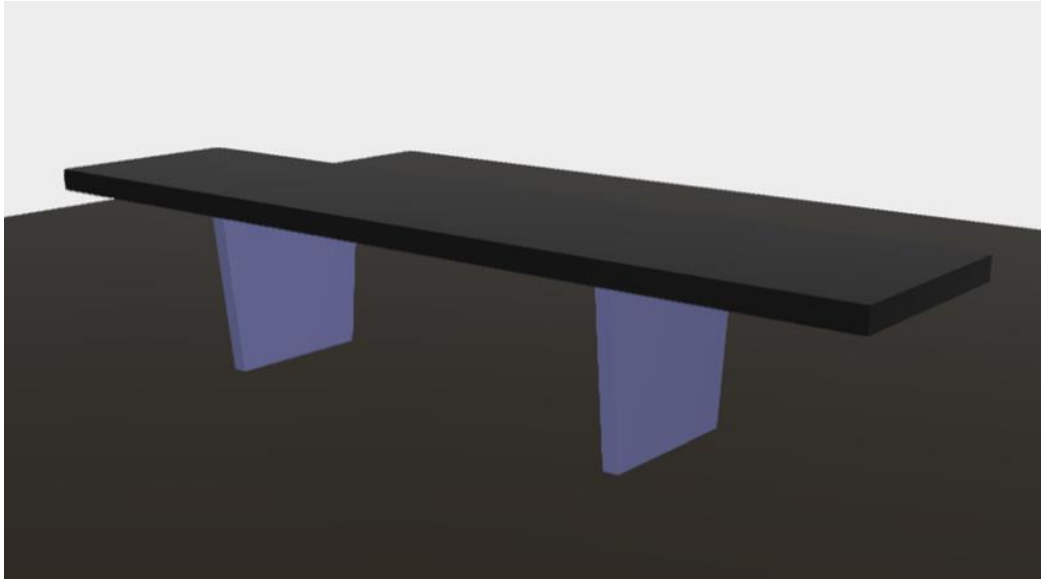
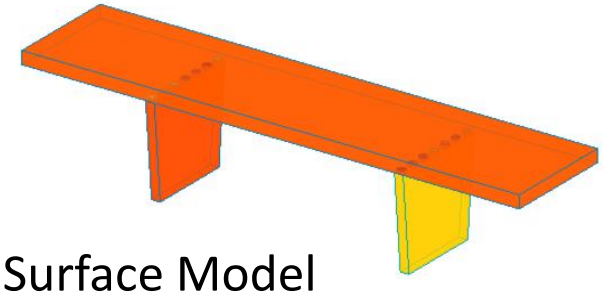
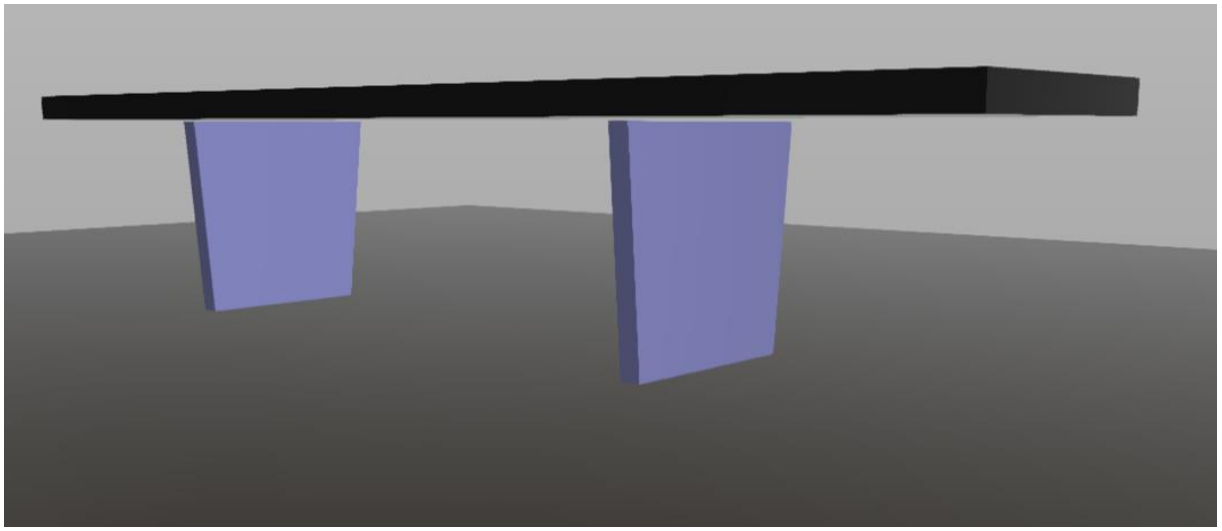
Bottom-Up modeling



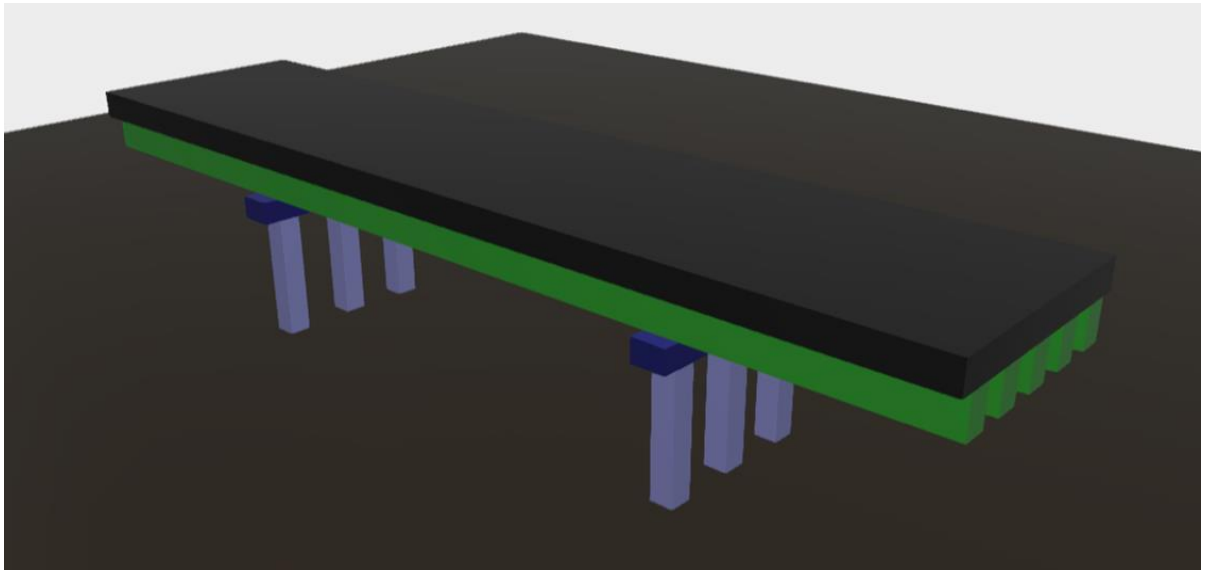


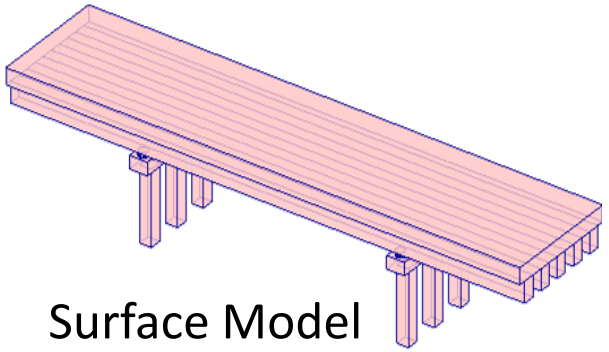
Surface Model

IFC Model



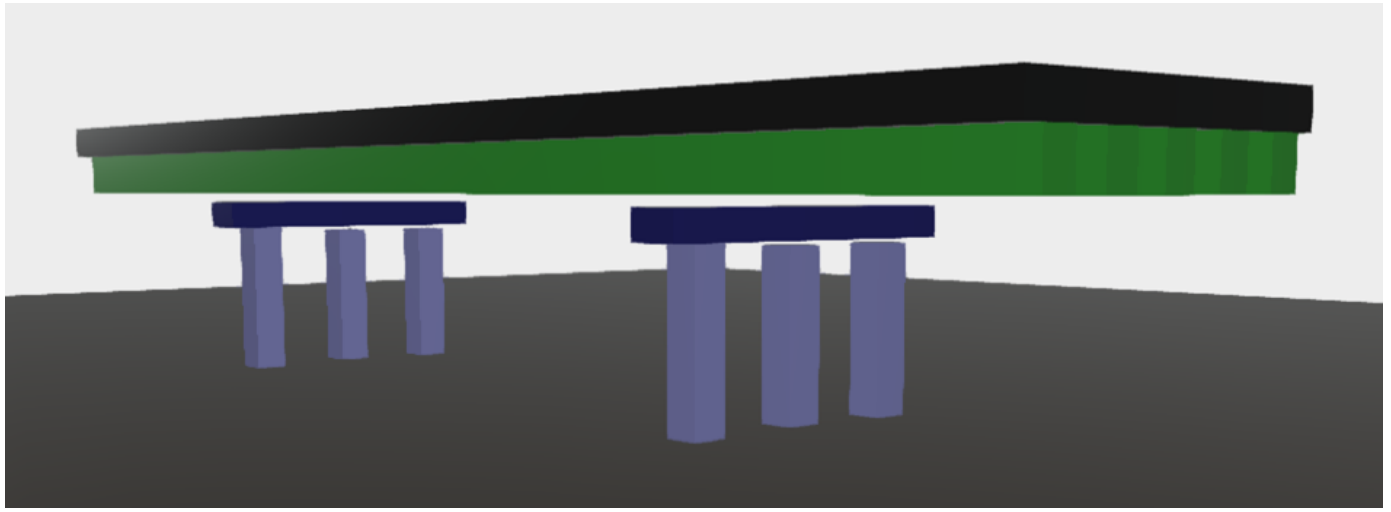
Bottom-Up modeling





Surface Model

IFC Model



Top-down 3D geometry

Remaining work - Fitting