Deep Learning technologies to reconstruct fragmented artefacts

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can we do something with these?

What problem are we trying to solve?

- We start from a set (hundreds or more) of fragments, probably belonging to a statue (or more statues), of which we can know the shape (the surface) through a 3D scan
  - possibly some characteristic of the realization (drapery, complexion, ...)

- We aim to implement a methodology that helps archaeologists' reconstruction work by providing different types of information that facilitate the matching.
  1. classify (separate) fragments between internal (fracture surfaces only) and external (at least one surface of the artifact)
  2. classify which of the fragments have contact surfaces and are therefore "close”
  3. identify the contact surface between two fragments to test an alignment
  - …… with a certain ”level of accuracy”

- The additional information that can be obtained from objective measurements on fragments material is fundamental to separate the classes of samples
  - (e.g. for example the marble type)
  - just “the geometry” in this case does not help

Which type of artificial neural network should be used?

- There are many types of artificial neural networks. For our problem What kind of network should be used?

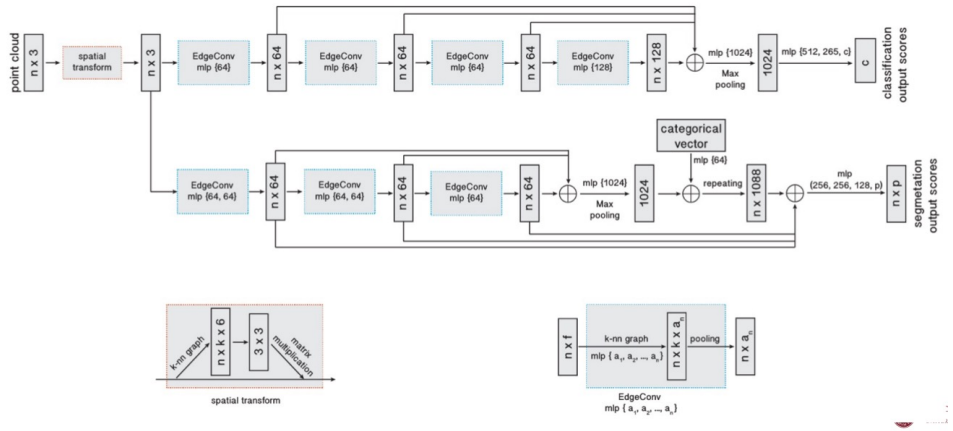
- There are types of networks that, when properly implemented, are able to use the information that can be obtained from the shape of an object (from geometry) to classify it

- These networks use a set of points (a point cloud) that corresponds to a sampling of the surface of the object that follows its profile

- The surface can be obtained from a laser scan

DGCNN

arXiv:1801.07829



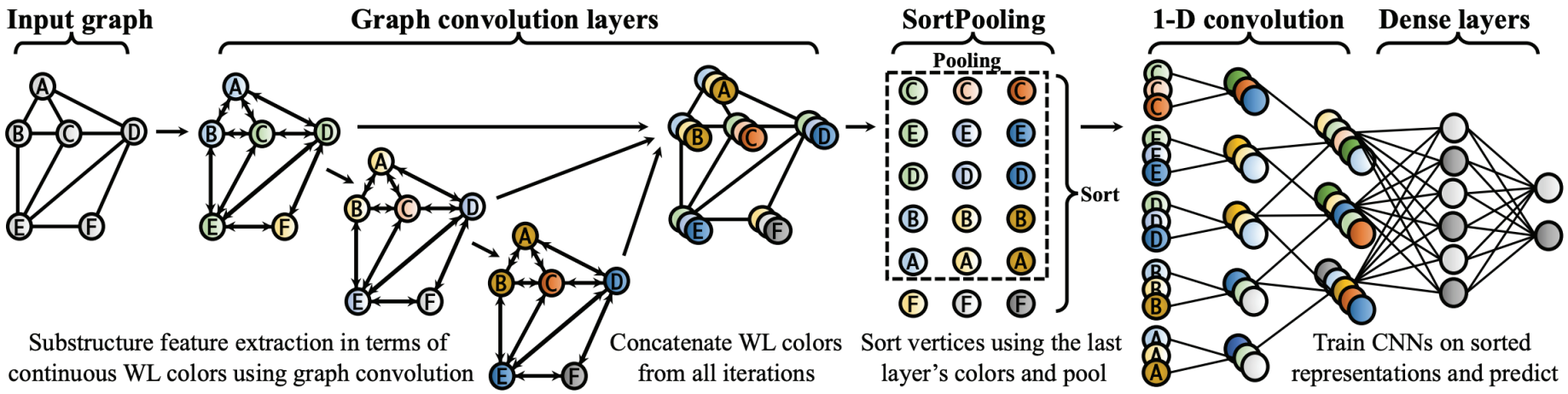


Figure 2: The overall structure of DGCNN. An input graph of arbitrary structure is first passed through multiple graph convolution layers where node information is propagated between neighbors. Then the vertex features are sorted and pooled with a SortPooling layer, and passed to traditional CNN structures to learn a predictive model. Features are visualized as colors.

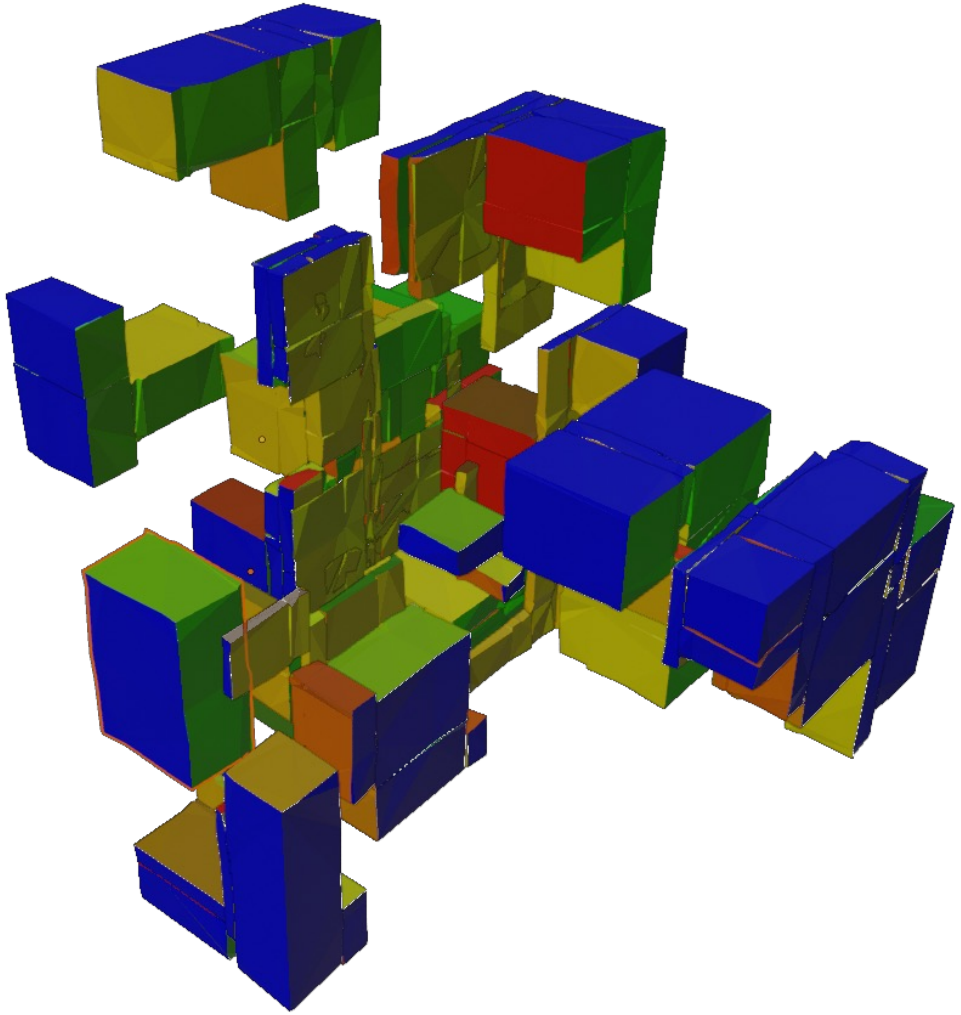
How do we train the network for our task?

- in "literature" there are training examples that are not applicable to our case
  - and there are no (big) catalogs of useful public examples

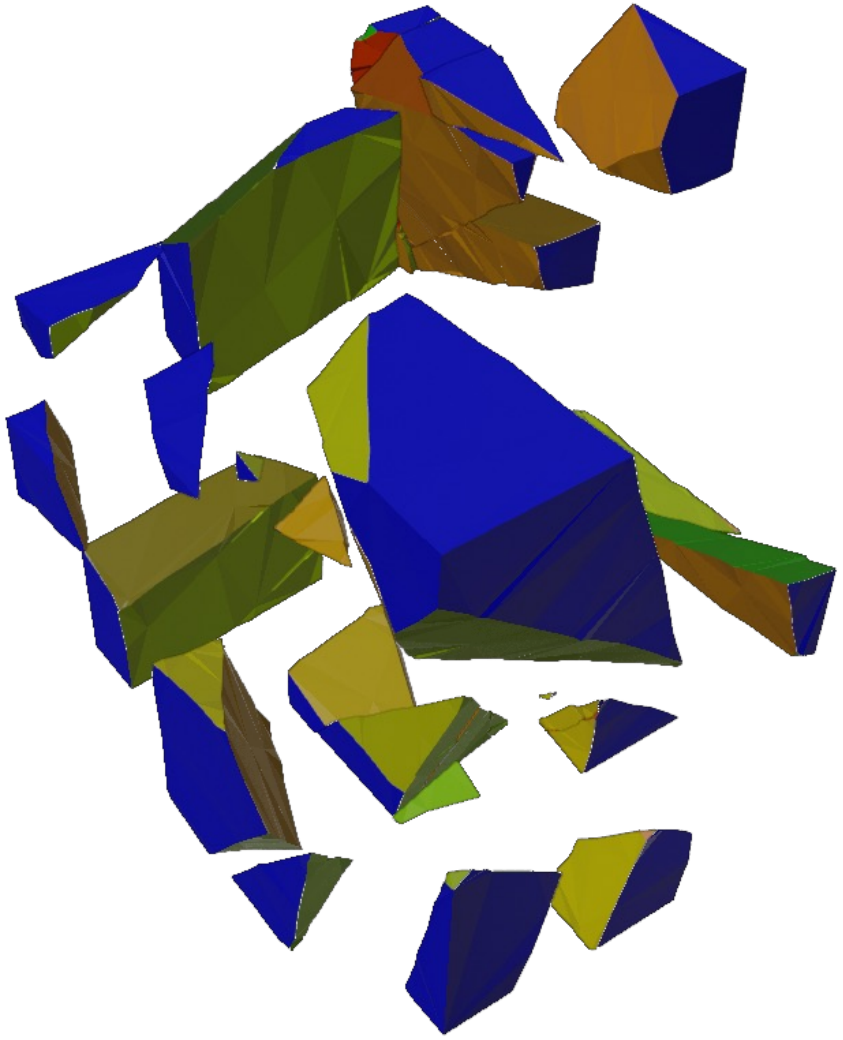
- we implemented a program that is able of building and breaking 3D objects
  - objects with a simple geometry (cubes, spheres, pyramids, ...)
  - importing 3D scans of real objects (artefact)
  - It allows us simulating aging effects

- we identified a suitable program for point sampling
  - it allows us to obtain additional information from the "geometry" (normal vectors to the surface)
  - It samples with a number of points that can be optimized ("many" is not necessarily better)
  - It allows the use of different algorithms for positioning points on the surface

Examples of artificially generated and fragmented solids (cube)

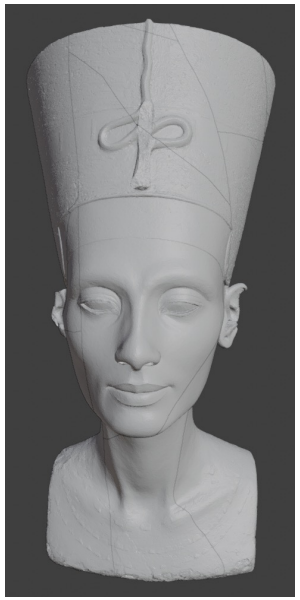


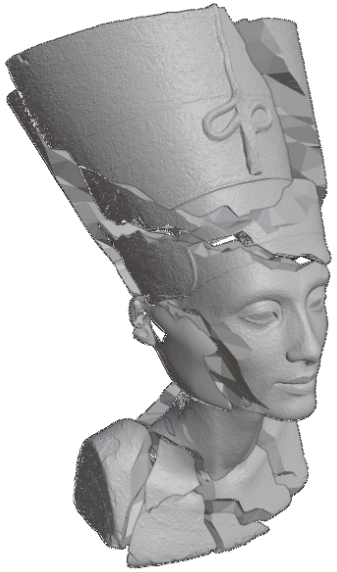
Cuts along the axes of the reference frame



Random cuts

Examples of real artefact fragmented

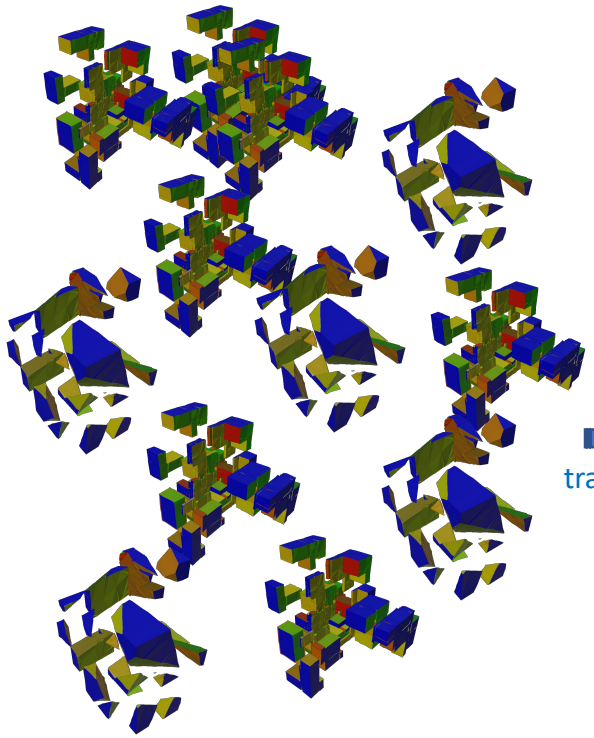


Bust in the Neues Museum in Berlin

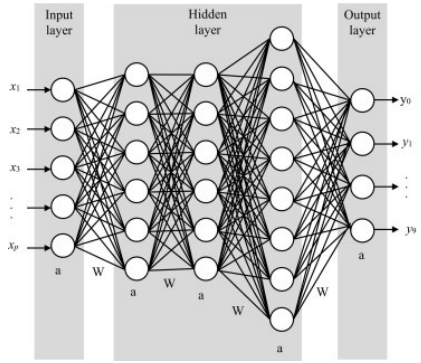

Bust in the MET Museum in NY

Train & Test



labeled examples

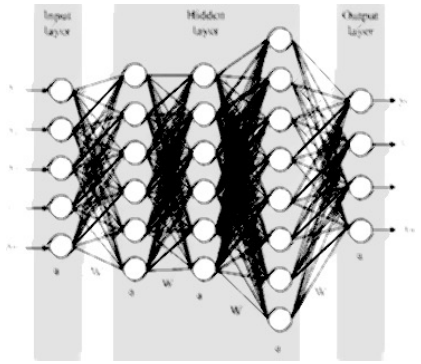
training



Classifier

?

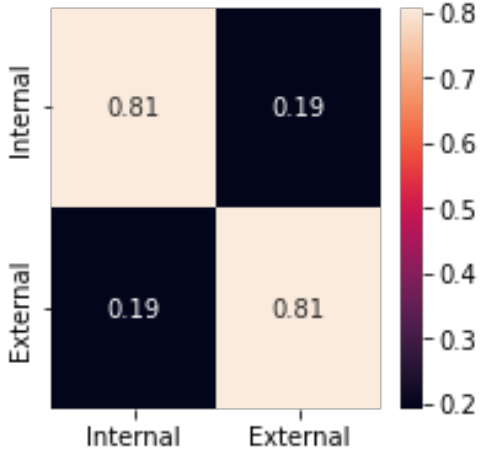
test



Trained Classifier

class external

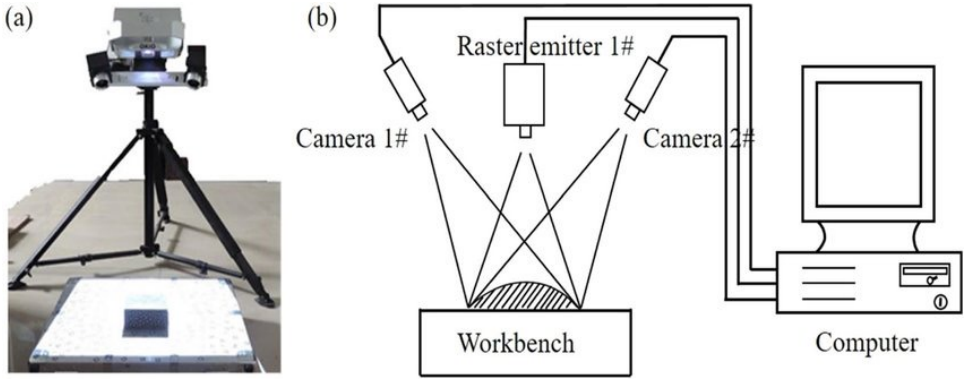
External fragment



A. Baiocchi's thesis

Thanks for your attention

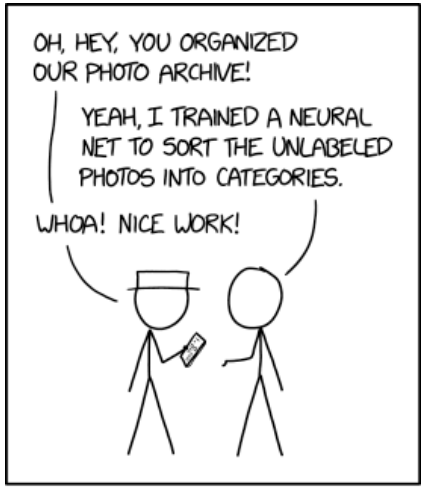
Laser scan @ INFN Rome



CHNet – Cultural Heritage Network

INFN network of laboratories working on Cultural Heritage

https://chnet.infn.it/

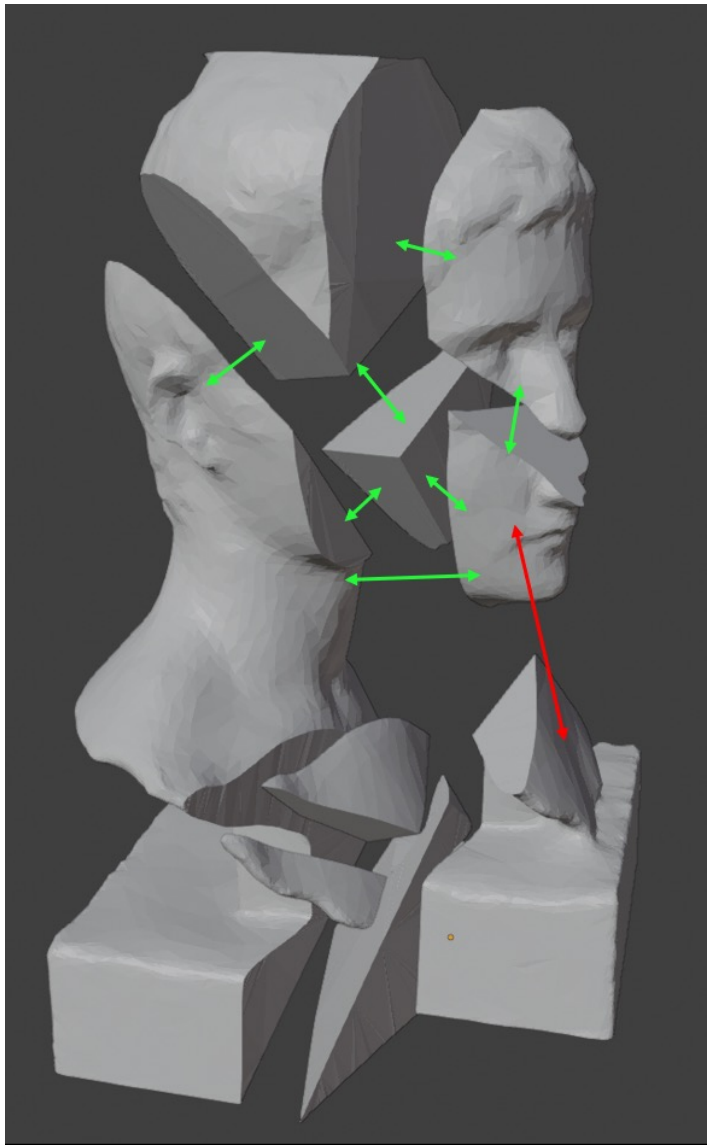


Backup - discussion

Classifier for "matching" the fragments

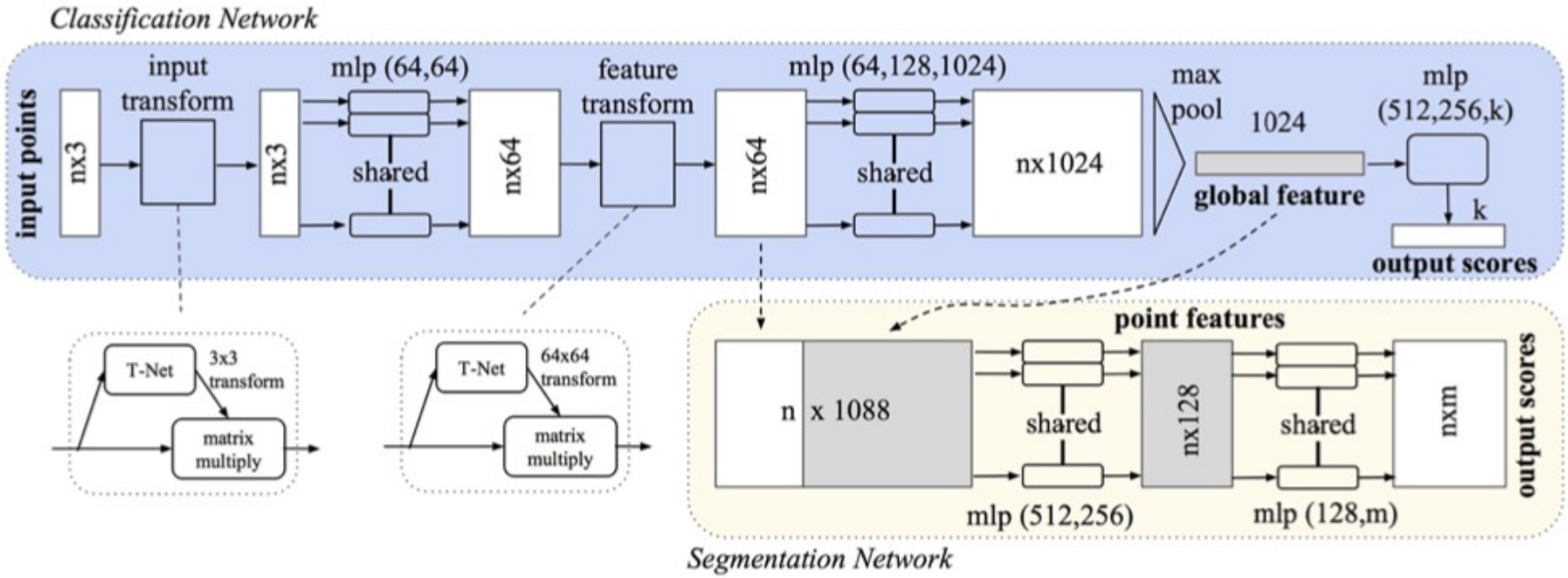
- The second step of the method we propose involves the creation of a model that starting from the fragments gives us the probability that a pair of such fragments are adjacent

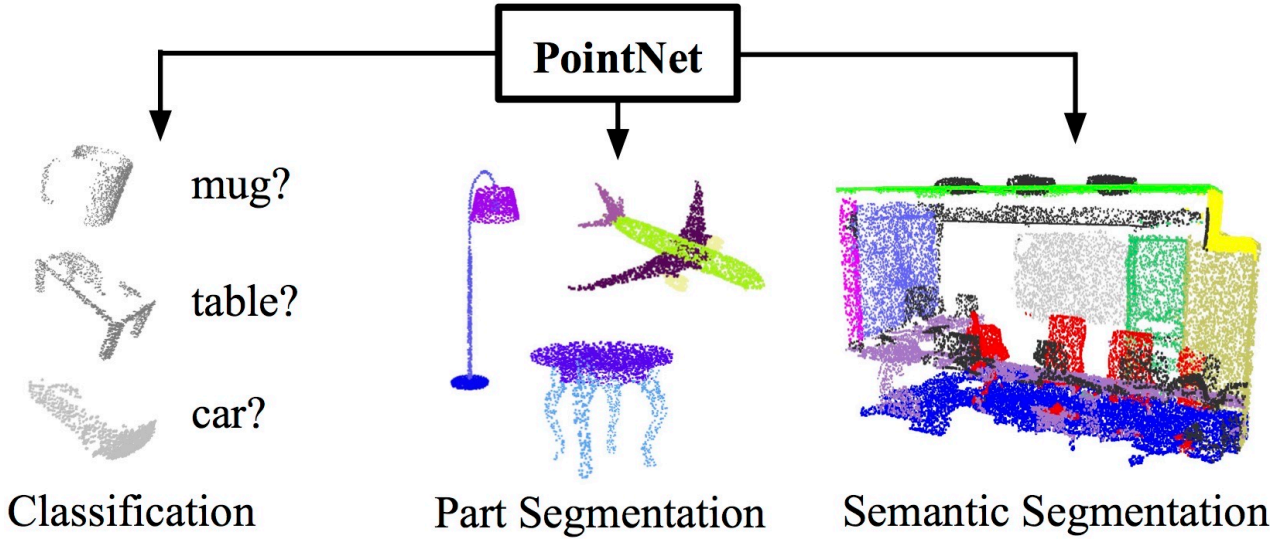
- The network model is more complex
  - two networks of the type already used are coupled in parallel, two elements are loaded to be evaluated and at the end the response of the two branches is combined
  - the training procedure is much more complex
  - preliminary attempts have been made, the results are promising but not conclusive
- Development activity is ongoing ……
  - different models for example to have an invariance under rotations



Pointnet

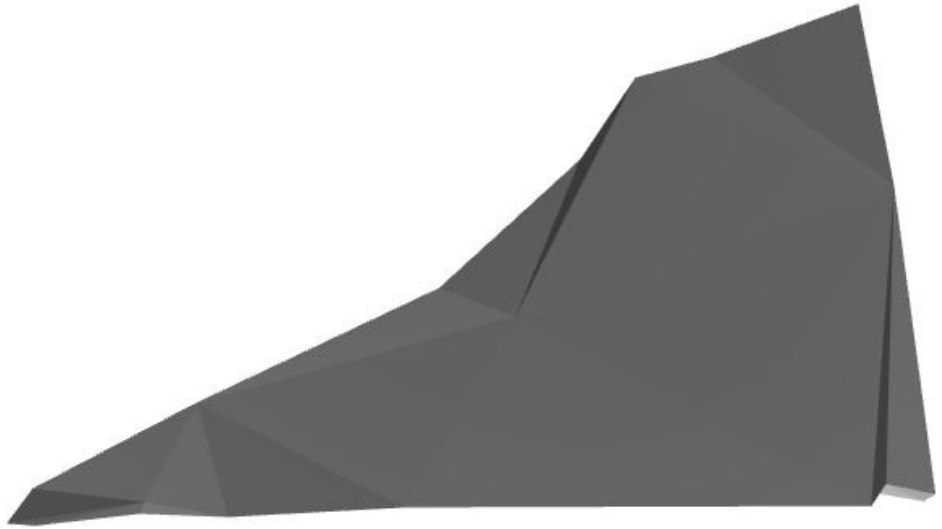
arXiv:1612.00593



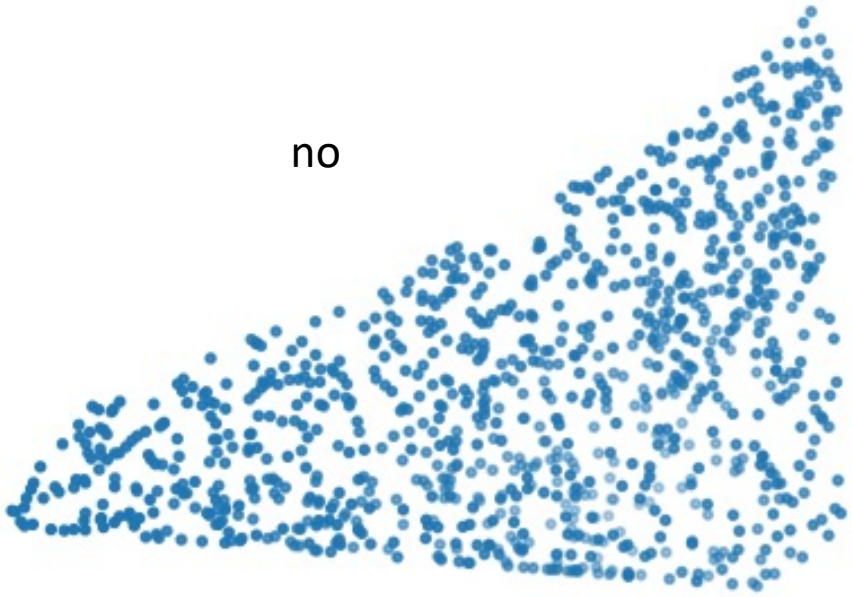


Point Cloud for an artificial fragment

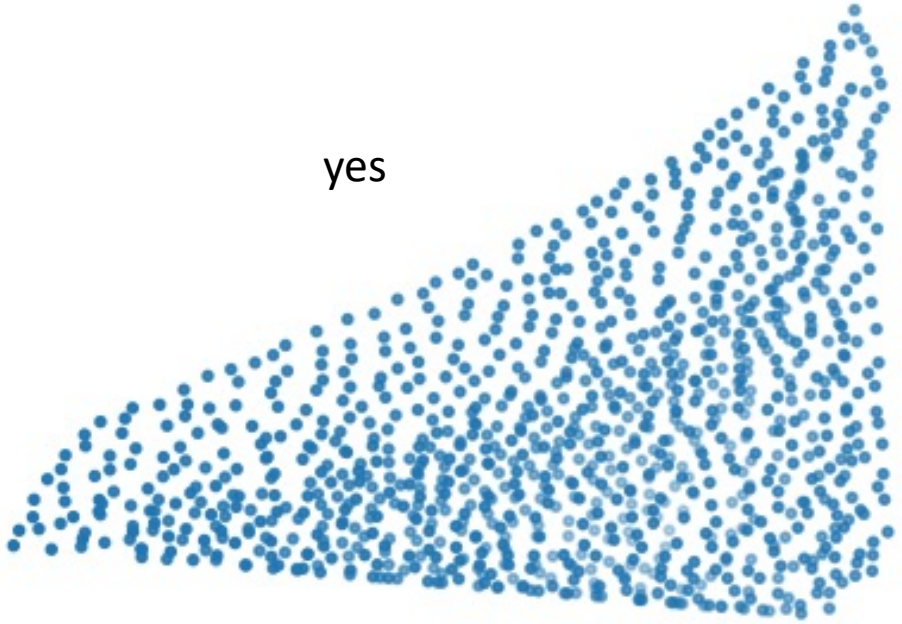
carefully choose the mode (algorithm) of the sampling to follow the profiles "correctly"



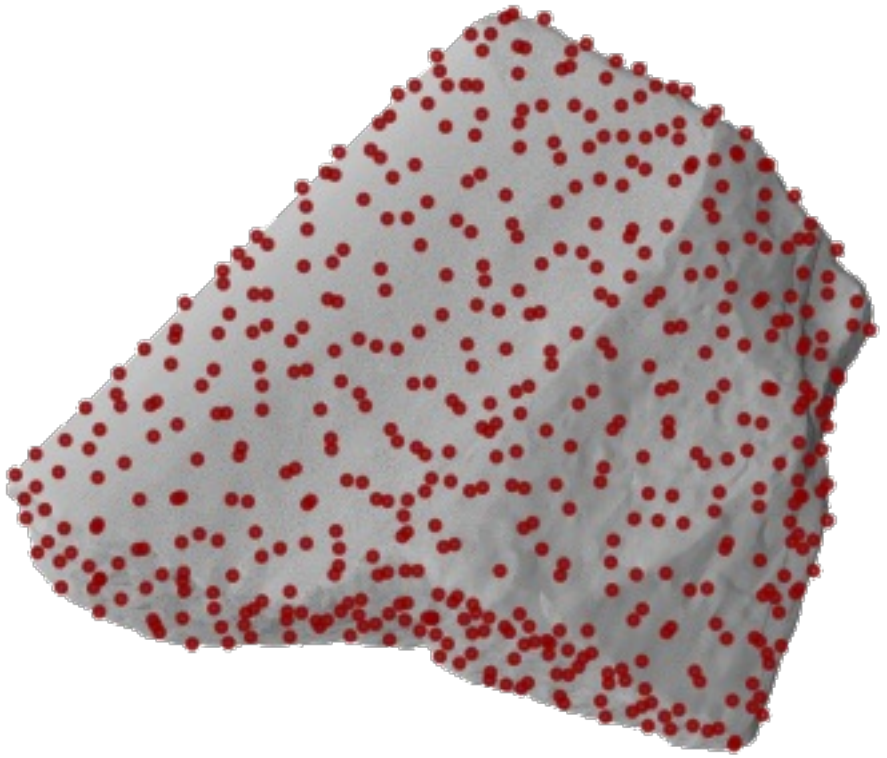
no



yes

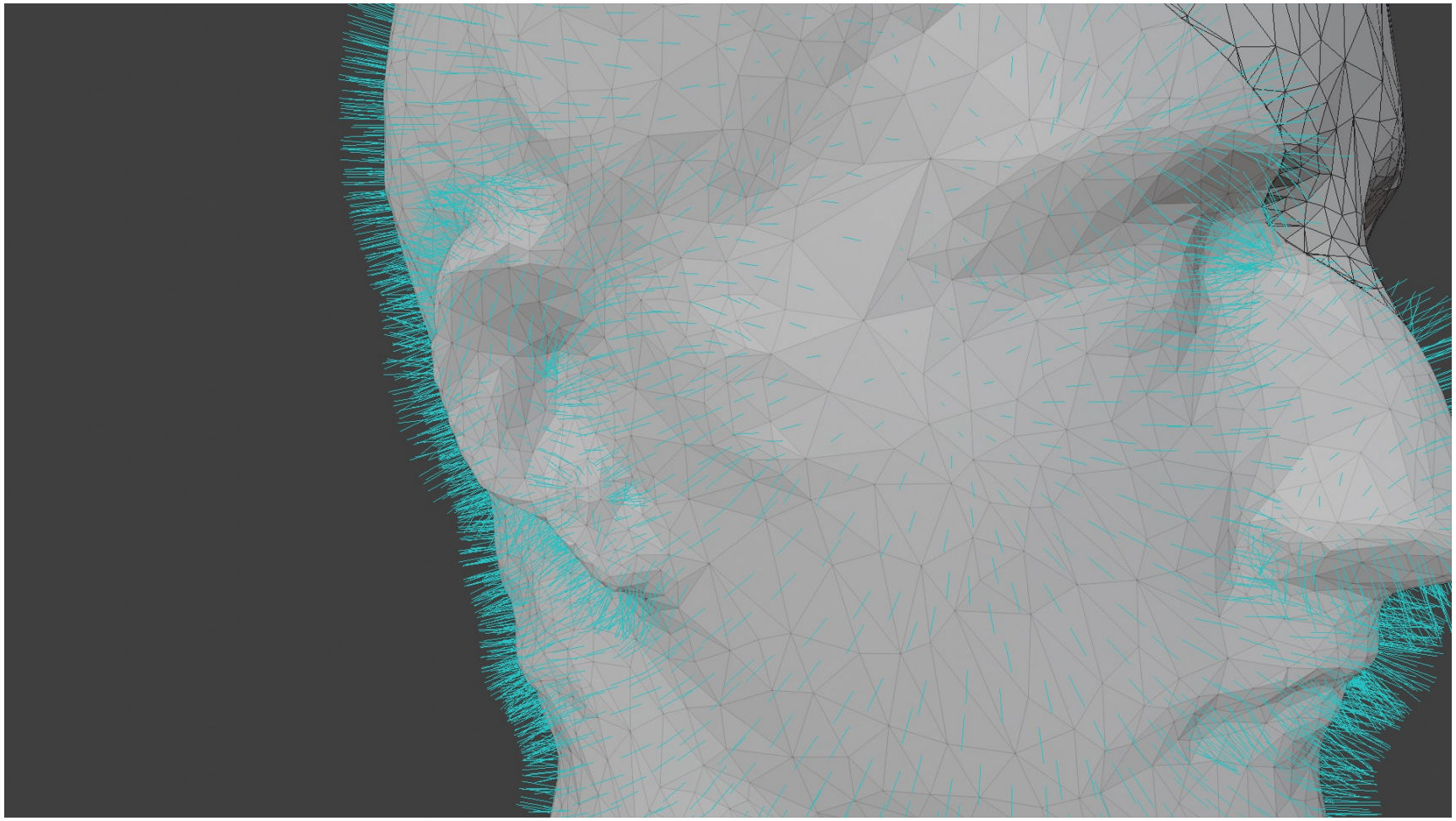


Point Cloud for a real fragment



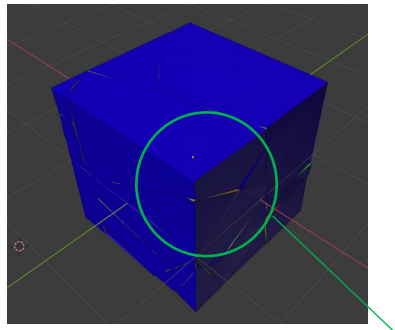
Additional information useful for networks

- We also extracted the direction perpendicular ("normal") to the surfaces of the triangles representing the surface (both for real artifact scan and for our simulated artificial object)
- Normals bring useful information related to the curvature of the surface
  - and the networks have been modified to use this information (improving the results)



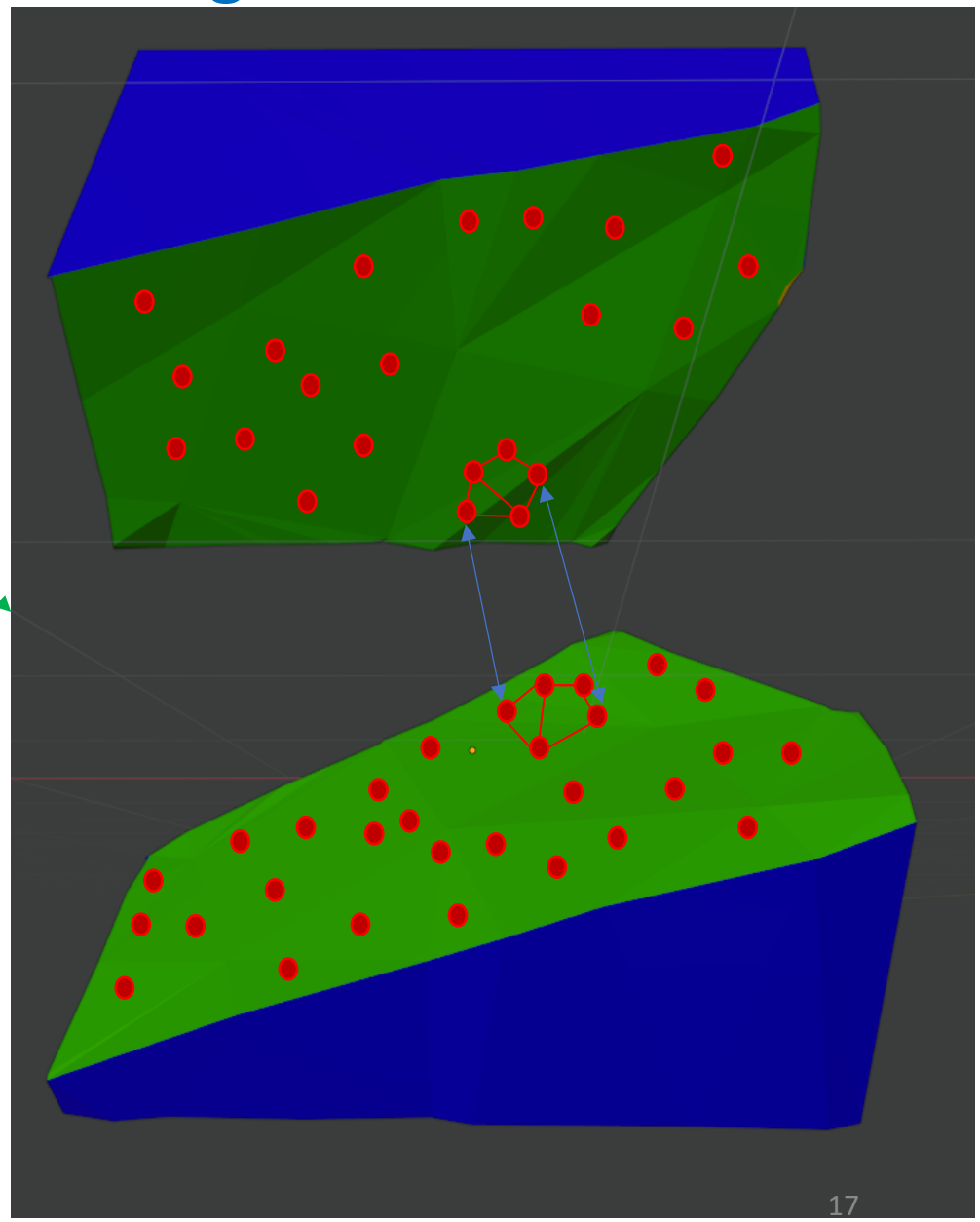
Informazioni tramite la rappresentazione di grafi

- Per ottenere la probabilità di due pezzi di essere adiacenti viene costruito - da un sottoinsieme dei punti - un grafo che ne rappresenta la topologia



- Questo viene fatto per tutti i sottoinsiemi dei due campioni che poi vengono confrontati

- Ad esempio va ottimizzata la grandezza della superficie che si utilizza per il confronto, quindi il numero di punti usati



Classification of the fragments of Xi'An's army*

- Large amount of fragments available (8000+ statues)
- Reasonable homogeneity of data (statues similar to each other)
- Presence of numerous intact statues to be used as a reference

*

H. Gao and G. Geng, "Classification of 3D Terracotta Warrior Fragments Based on Deep Learning and Template Guidance," in *IEEE Access*, vol. 8, pp. 4086-4098, 2020, doi: 10.1109/ACCESS.2019.2962791.

UNSUPERVISED SEGMENTATION FOR TERRACOTTA WARRIOR POINT CLOUD (SRG-NET)
CSAE 2021: The 5th International Conference on Computer Science and Application Engineering
October 2021 Article No.: 17Pages 1–6 https://doi.org/10.1145/3487075.3487092

Classification of the fragments of Xi'An's army*

Task: identification of 10 distinct parts of the statues (classes)

- Data preprocessing
- Step 1: Classification via Deep Learning
- Step 2: Improvement of results using the template method

*

H. Gao and G. Geng, "Classification of 3D Terracotta Warrior Fragments Based on Deep Learning and Template Guidance," in *IEEE Access*, vol. 8, pp. 4086-4098, 2020, doi: 10.1109/ACCESS.2019.2962791.

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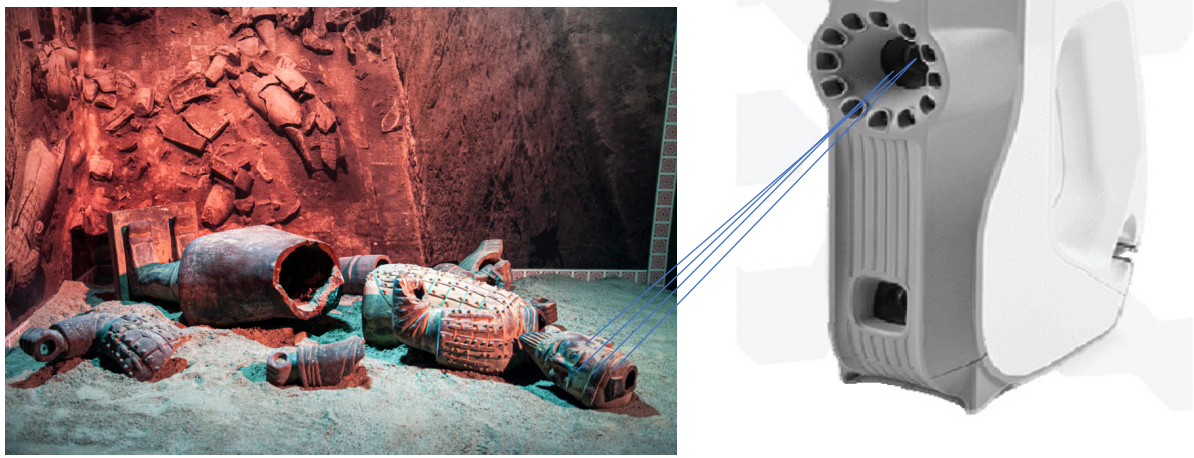
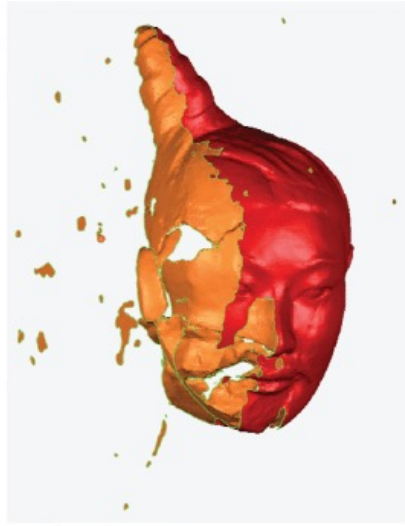
Fragments's data obtained by means of a laser scan



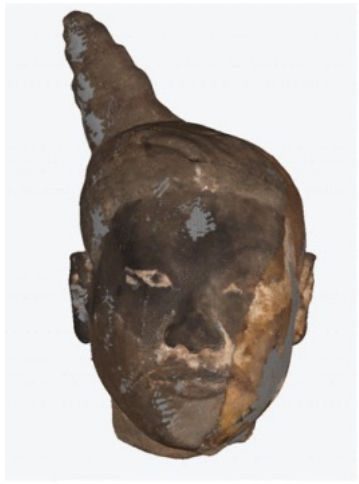
raw data

(a) Side



(b) Front

Preprocessing



(a) Front

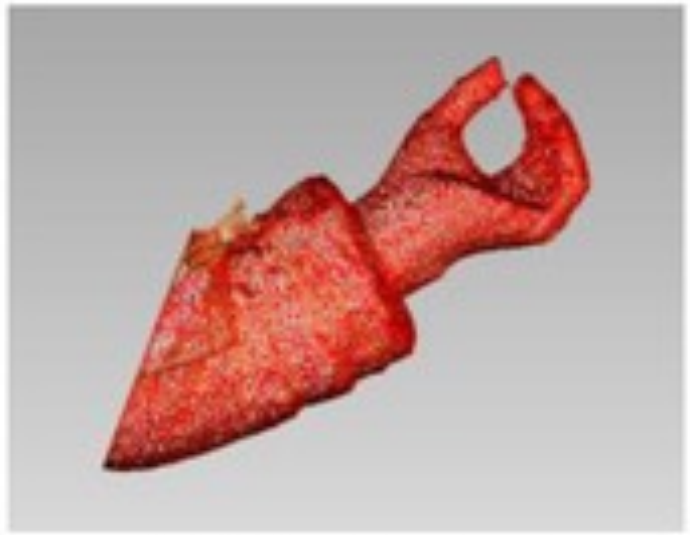
(b) Side

"calibrated" data

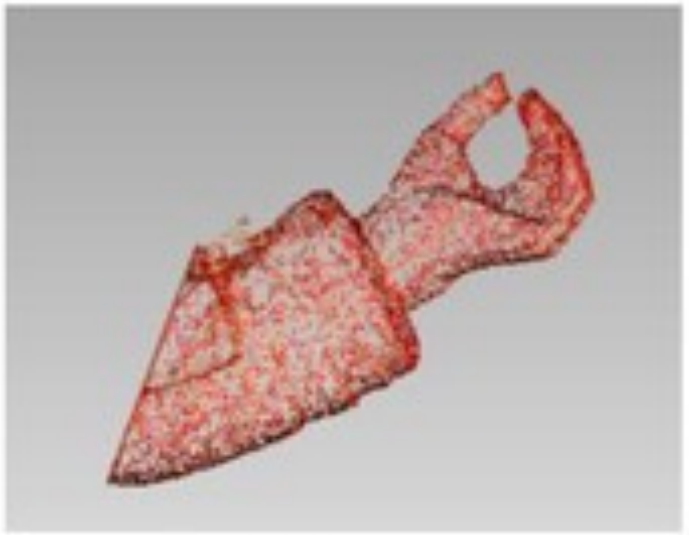
Preprocessing(I)

digitization of the fragments ➡ digitization of the fragments ➡ data augmentation*

(a) Mesh model



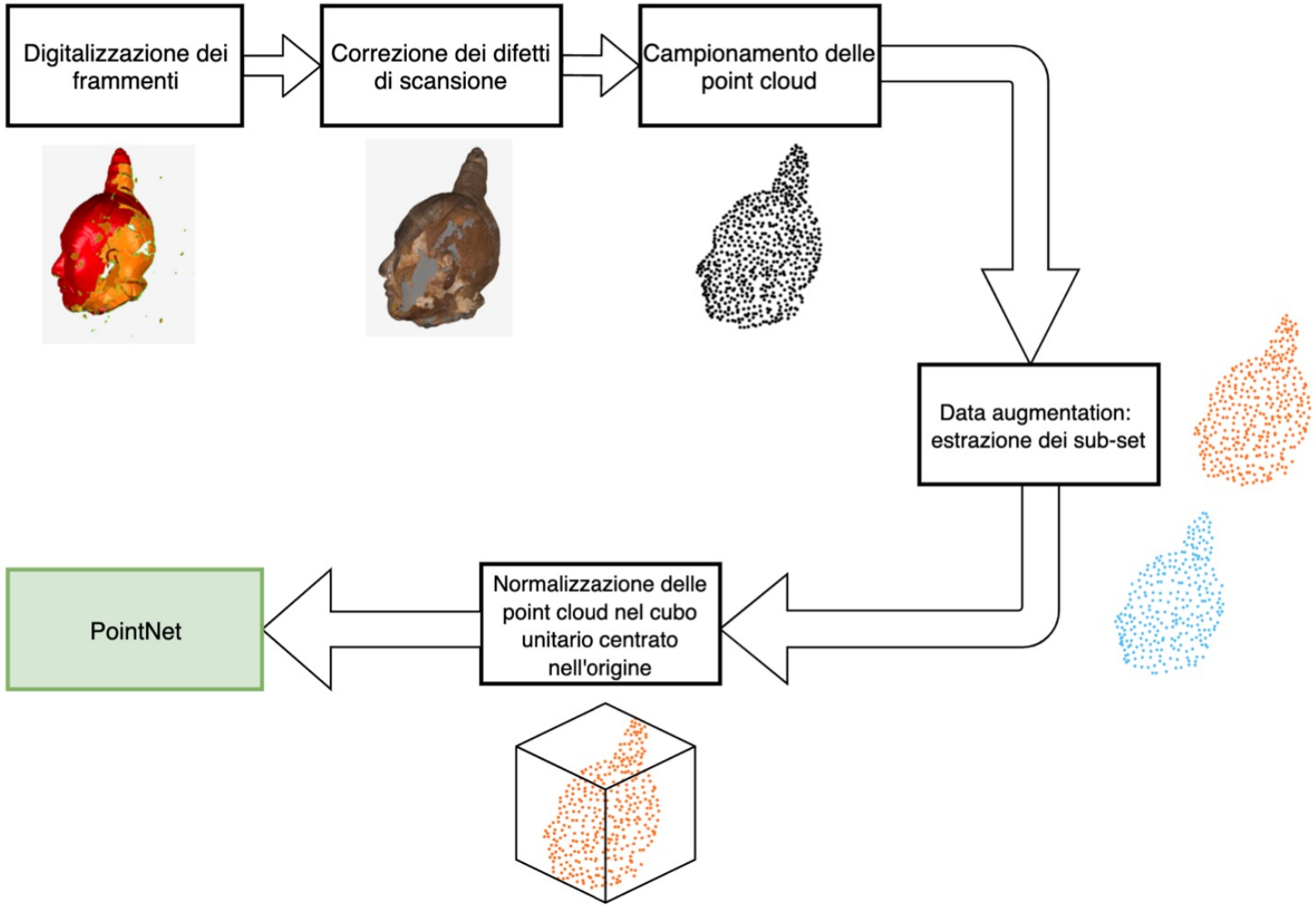
(b) Raw point model
(26923points)



(c) Sampled point model
(10769points)

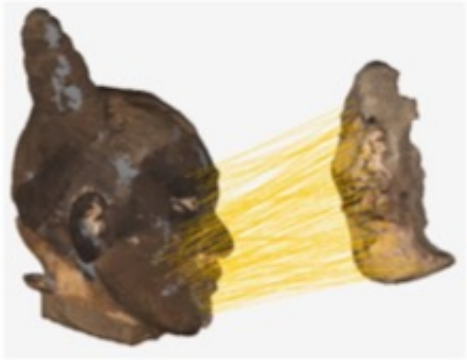
*many examples are artificially generated for network training, more on this topic later

Preprocessing



Results*

- First classification: (network model: PointNet)
  - accuracy in assigning samples to classes ~81%



- Second classification: template method
  - only for uncertain classified fragments from PointNet
  - more complex (time consuming) from the computational point of view
  - search for correspondences between points of the fragments and points on the templates
  - final overall accuracy ~91%

*

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