Synthetic Hystological Samples for Segmentation Training

A VIRTUAL SLICING METHOD ON A HYSTOLOGICAL-LIKE 3D MODEL FOR GENERATION OF IMAGE – LABEL PAIRS FOR TRAINING OF SEGMENTATION ORIENTED NEURAL NETWORK.

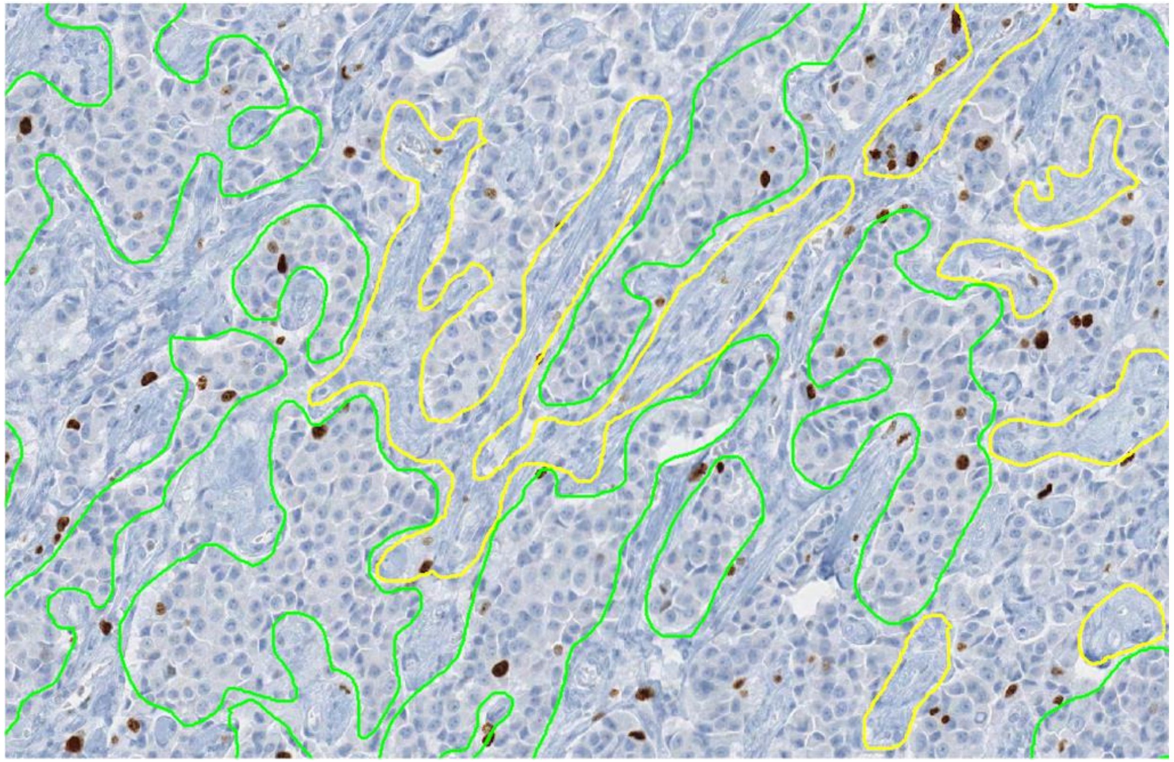
ALESSANDRO D'AGOSTINO - MASTER IN APPLIED PHYSICS UNIBO - A.Y. 2019/20

The problem

Hysto-Pathological images segmentation is a difficult operation.

It requires a labeled dataset for training or testing that it's commonly reached only through time expensive intervention by qualified experts.

This shortage of data hinders the development of new algorithms and the possibility to test existing ones.

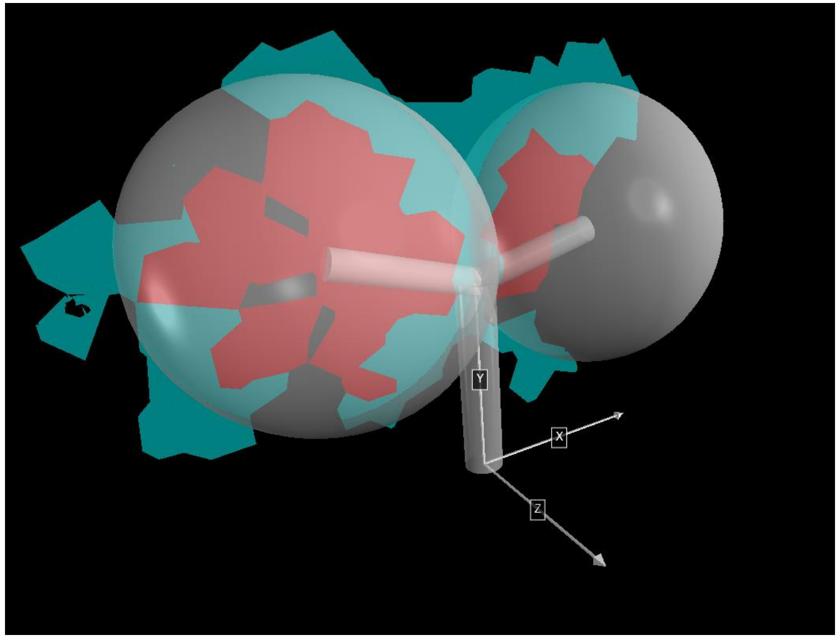


Segmentation of health and tumoral region in a pancreatic tissue sample made by a cGAN. [Link to bibliography]

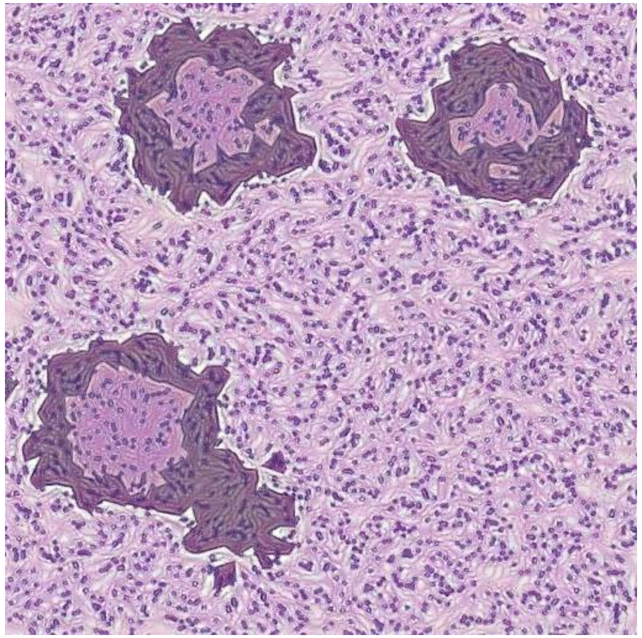
Artificial Slices Generator

Artificial generation of realistic samples could help to overcoming this problem, providing arbitrary wide datasets of images with related ground truth.

The idea is to perform virtual slicing on a 3D tissue model and recreate the slicing process.



Processing

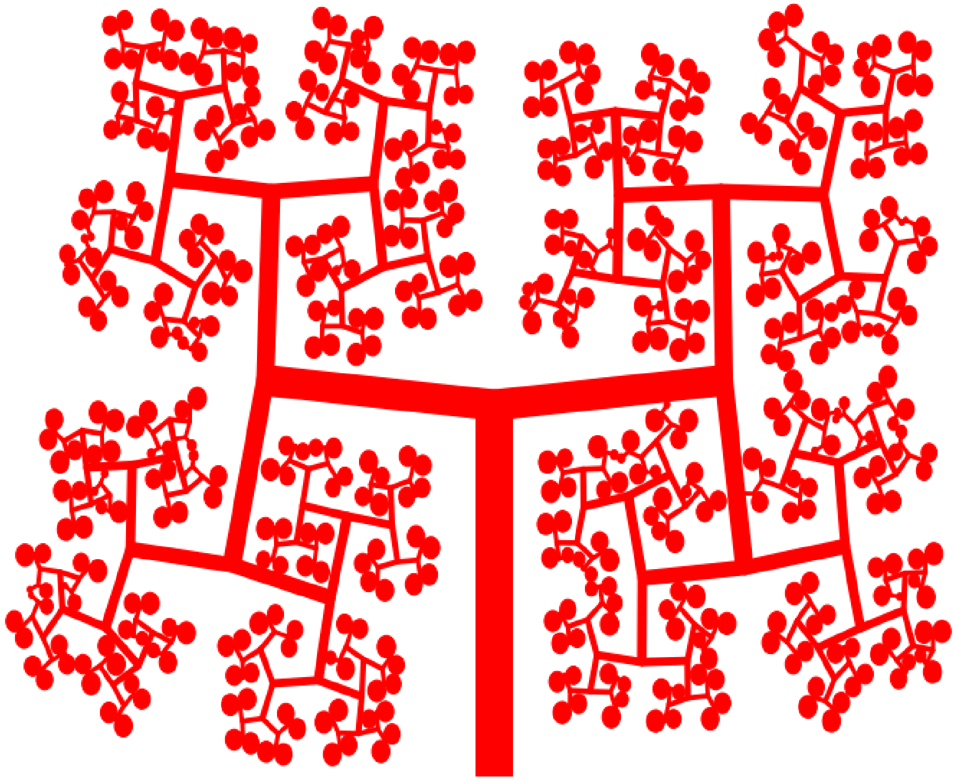


Space-Filling Iterative Structure 2D

Pancreatic tissue may be represented in first stance by a space filling iterative structure.

The succeding ramifications schematized blood vassels in glandular tissues.

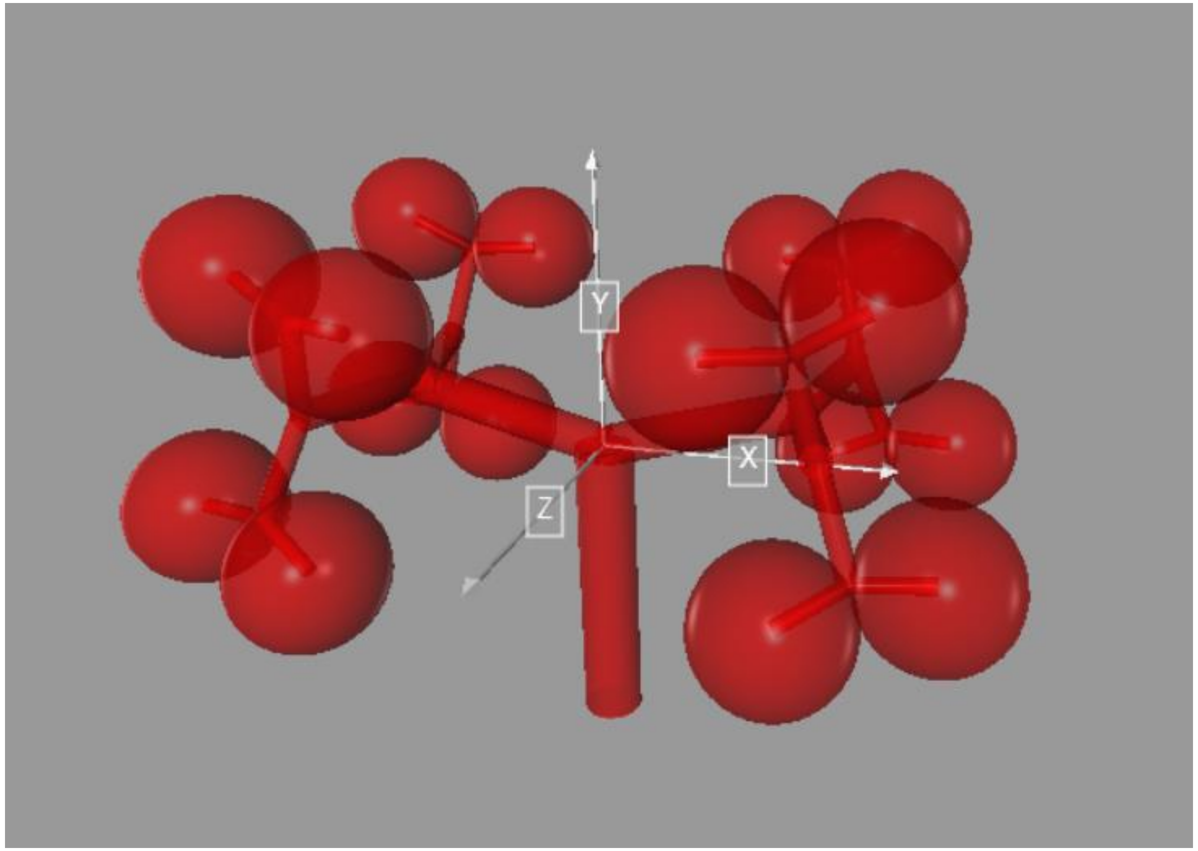
Spheres at free ends stand for glandural grapes.



Expansion to 3D Structure

Extending the geometry in 3D results in a structure representing the spatial distribution of glandural grapes in the tissue.

Quaternions were exploited for ease 3D relative orientation.



Quaternions

Quaternions are a number system that expands complex numbers in 4 dimensions:

$$\mathbf{q} = a + b\mathbf{i} + c\mathbf{j} + d\mathbf{k}$$

$$\mathbf{i}^2 = \mathbf{j}^2 = \mathbf{k}^2 = \mathbf{ijk} = -1$$

A particular subspace made of those quaternion with vanishing real part ($a = 0$) have a useful correspondence with rotations in 3D space. With this system the rotation **q** of any vector v is:

$$v' = \mathbf{q}\, v\, \mathbf{q}^{-1}$$

While the sequence of rotations **q** and **p** on a vector v is simply given by:

$$v' = \mathbf{pq}\, v\, (\mathbf{pq})^{-1}$$

Quaternions are widely used in Computer Graphic for their ease of use, respect other methods involving Euler angles or other reference system.

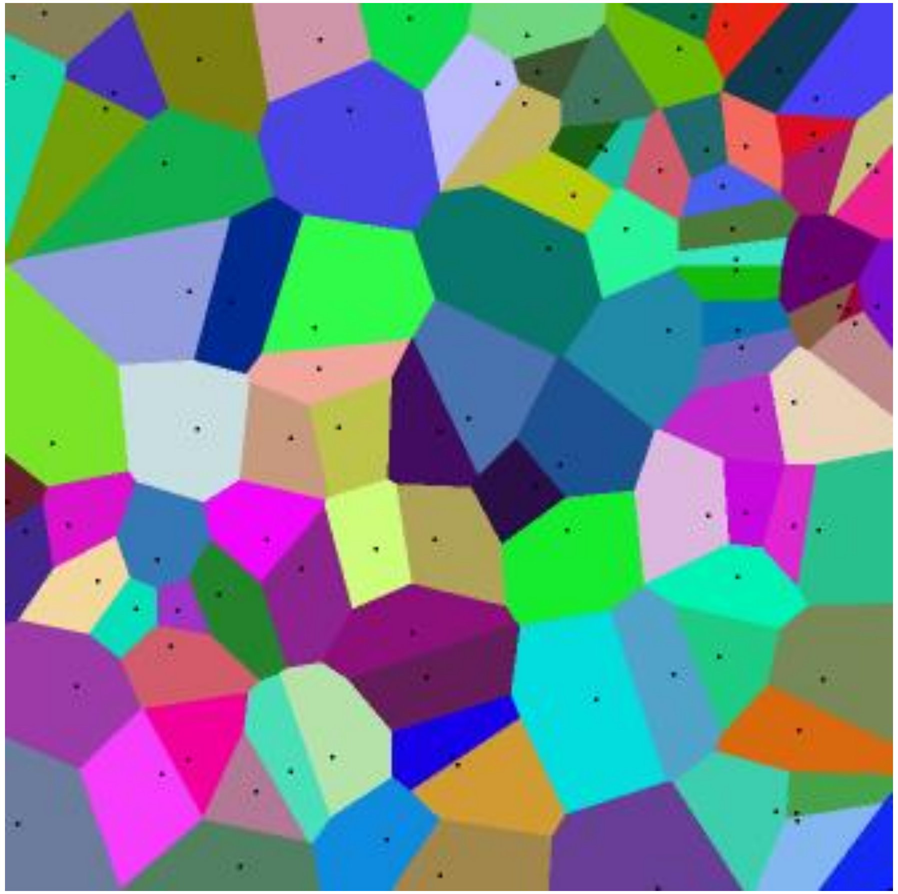
Voronoi Tassells as Cells

Cells need to be convex, with similar shape, space filling and slightly different.

A non-regular 3D Voronoi tessellation is what best suits the task.

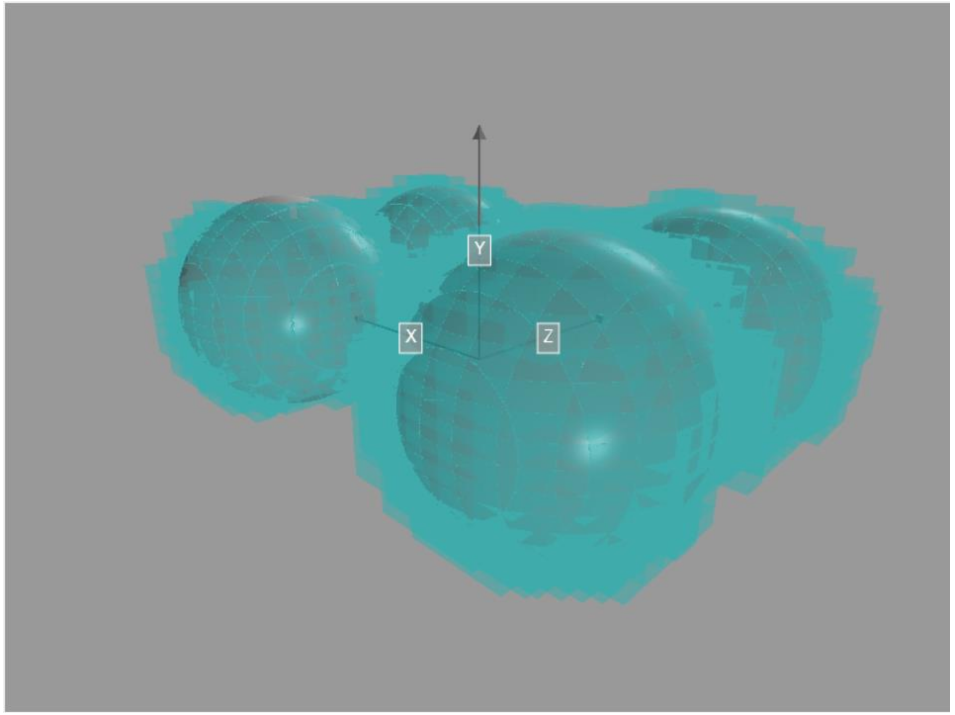
In a Voronoi tessellation the N-space is partitioned in subregions respect the proximity to the seeding points.

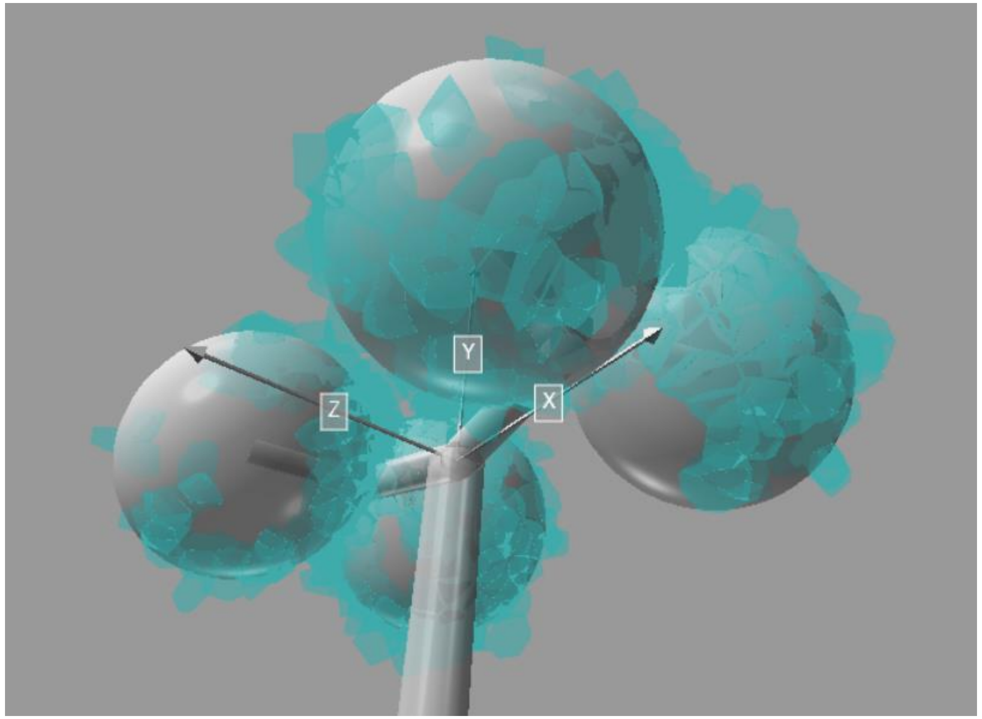
Quasi-random algorithms with low discrepancy give seeding grid for a Voronoi tessellation with the desired features.



3D Voronoi Tassells as Cells

Different quasi random number generator have been tested and the best results were given by the Saltelli Algorithm (an improved version of the Sobol sequence).

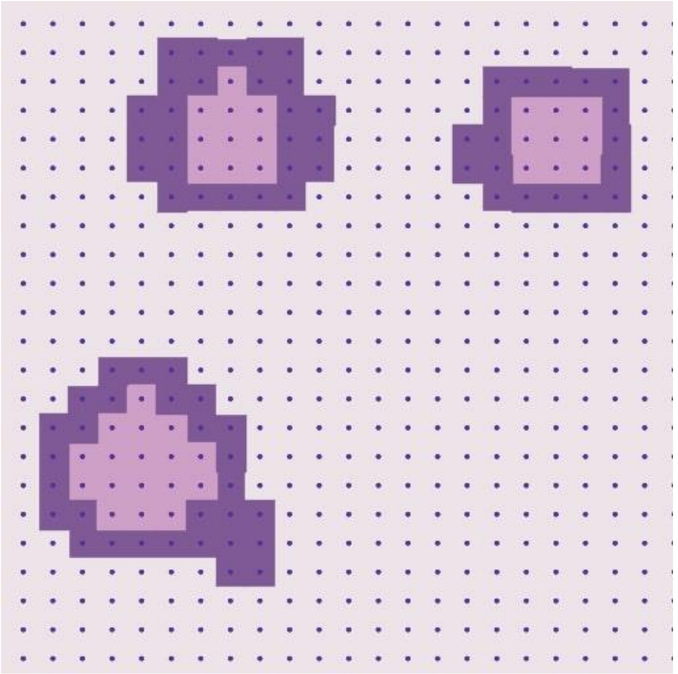


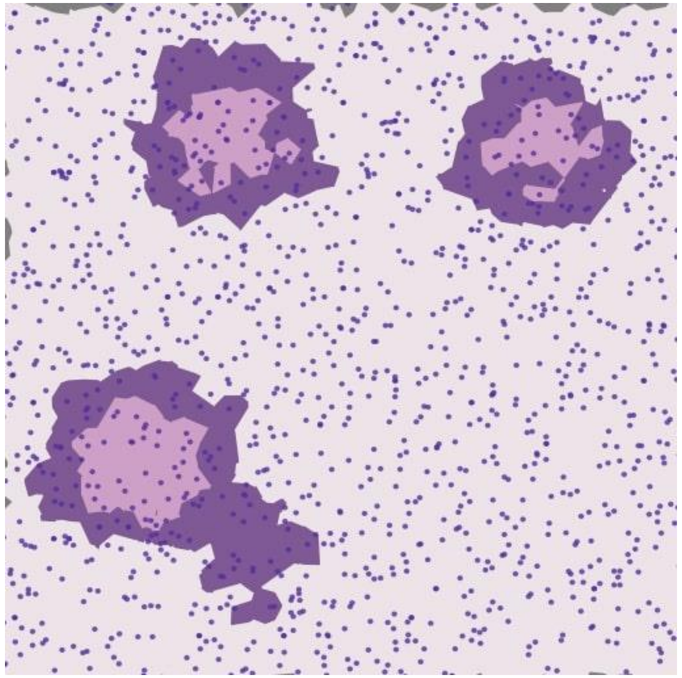


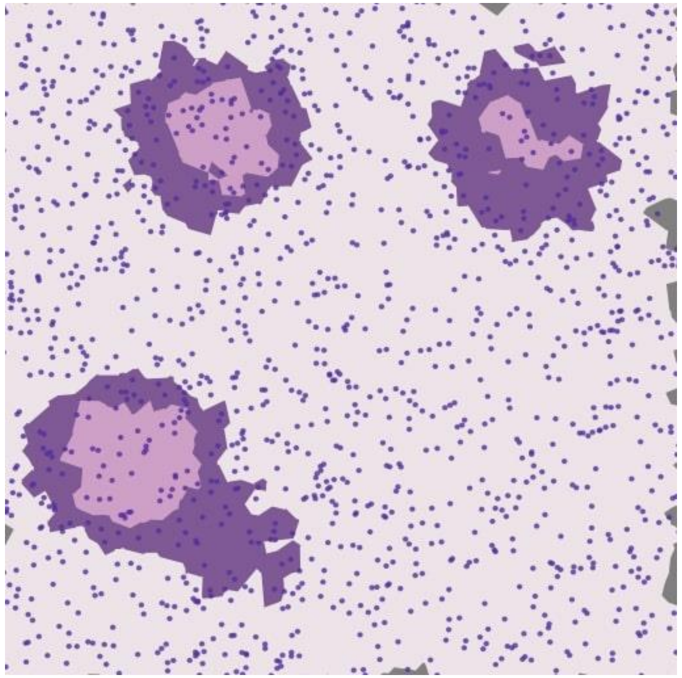
Comparison between 3D cells produced by Voronoi based on a regular grid and a quasi-random one.

Voronoi Comparison

This is a graphical comparison of three slices made on Voronoi tessellation based respectively on a regular grid, a quasi random sampled grid and a full random sampled grid.

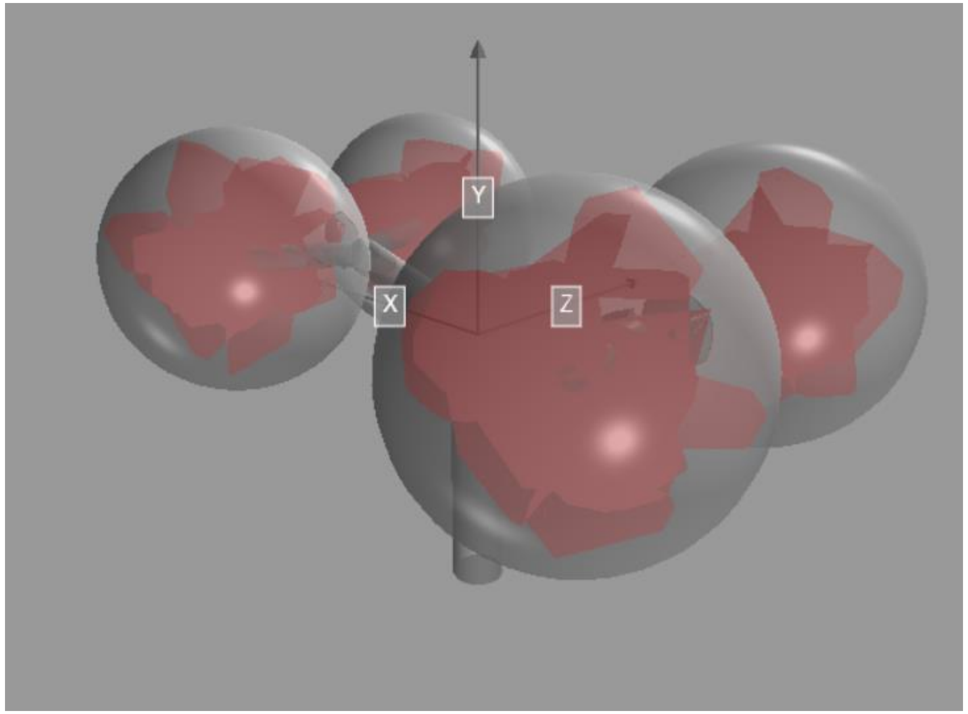


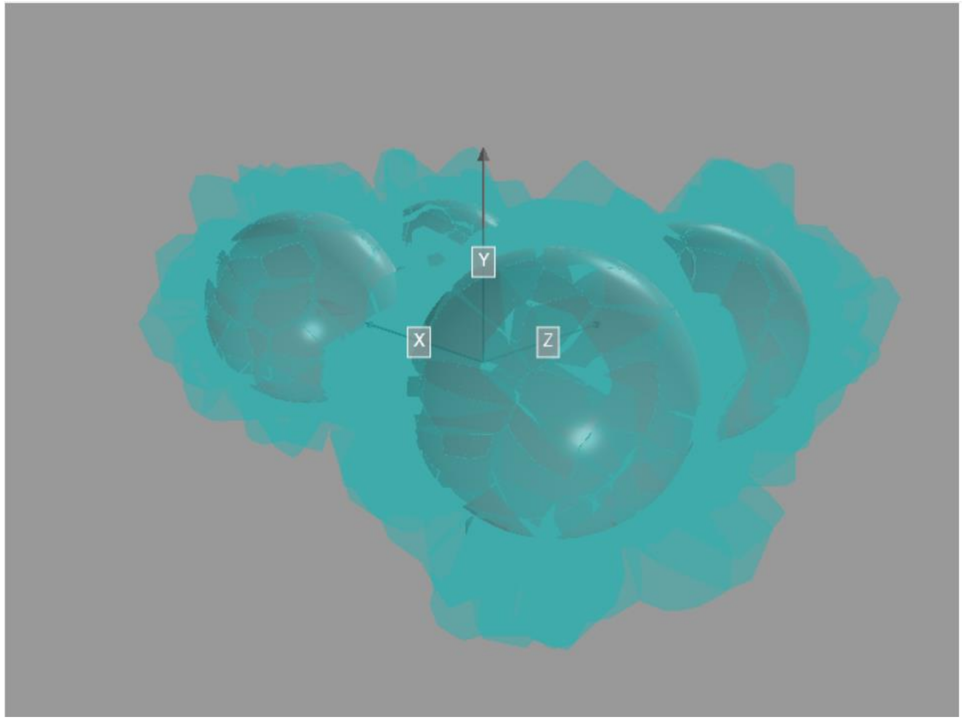




Cells Identity

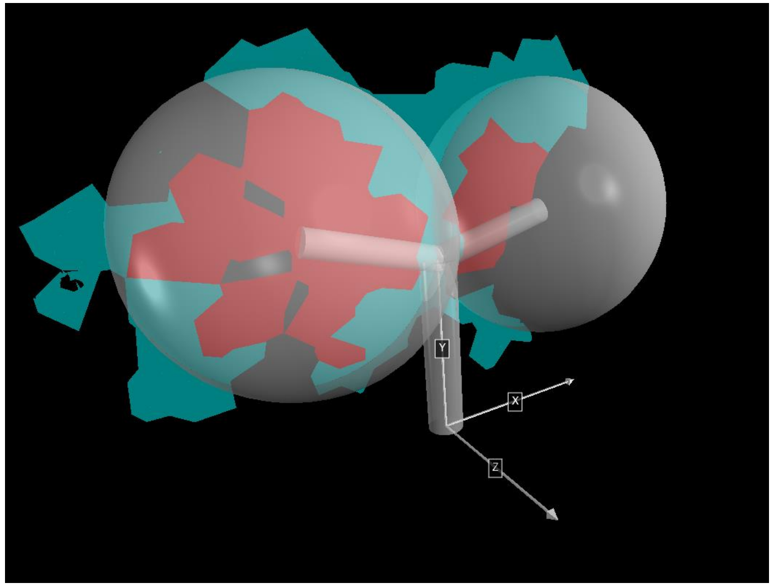
The categorization is made upon the distance of every tassel’s vertex from each free end sphere.
The division is made between internal, external and boundary tassels.
Given the amount of points to evaluate KD-Tree based algorithm were exploited for better performance.



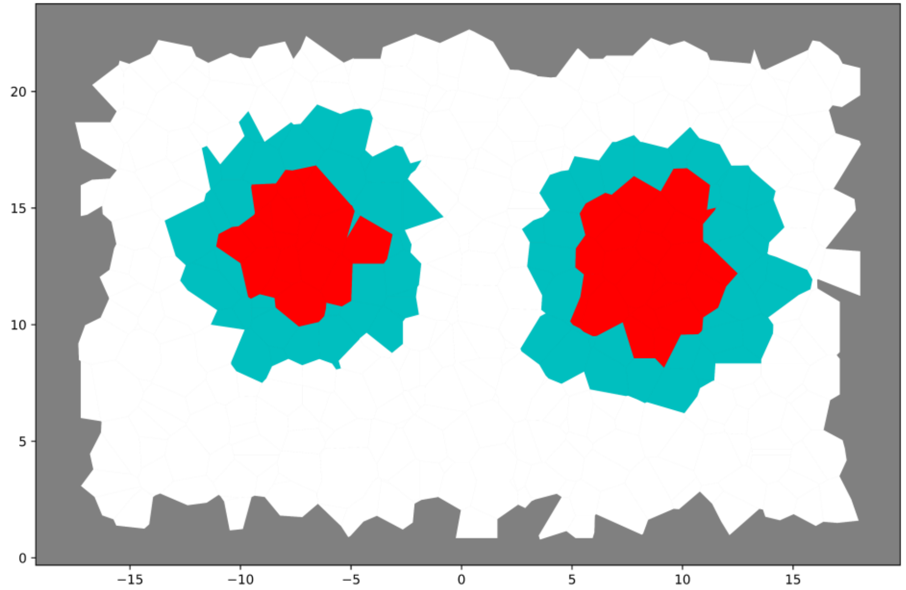


Planar Section of Polyhedrons

There is no general rule to perform the section of an arbitrary convex polyhedron, so I devised an algorithm to face the task.
Colours represent the identity: colours on the section should match the colours in the 3D structure.



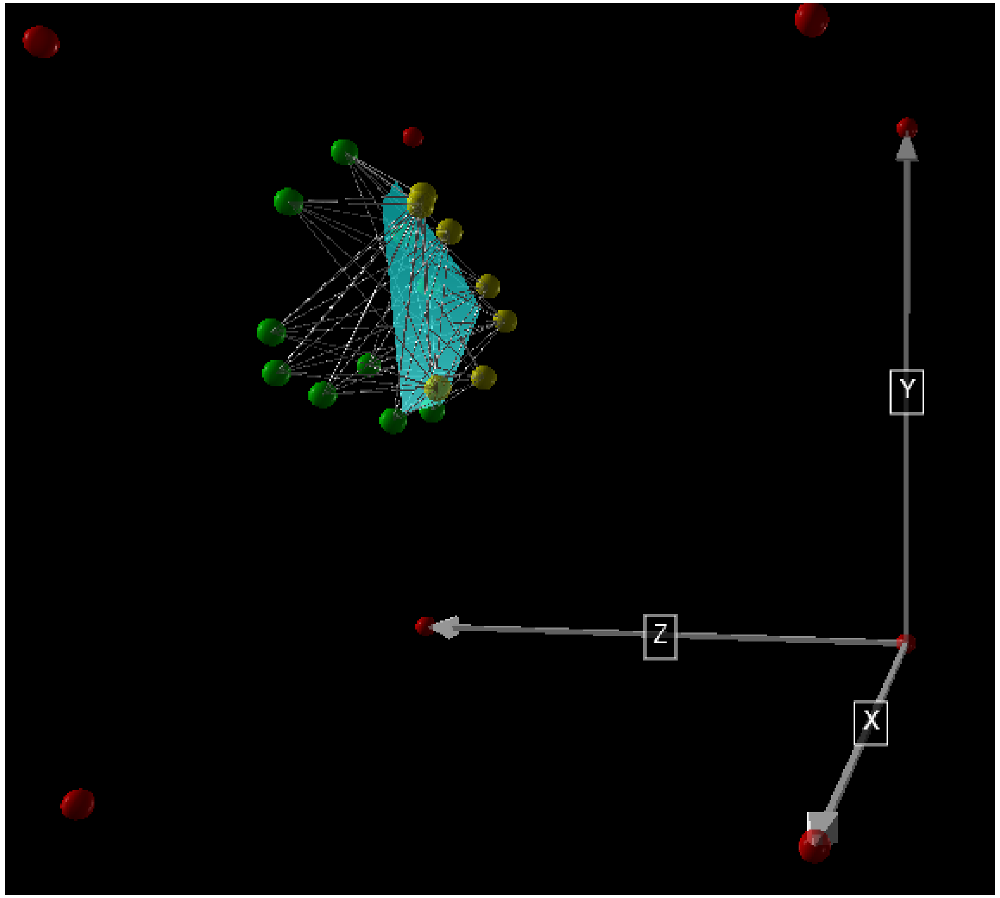
Virtual slicing



Slicing Method

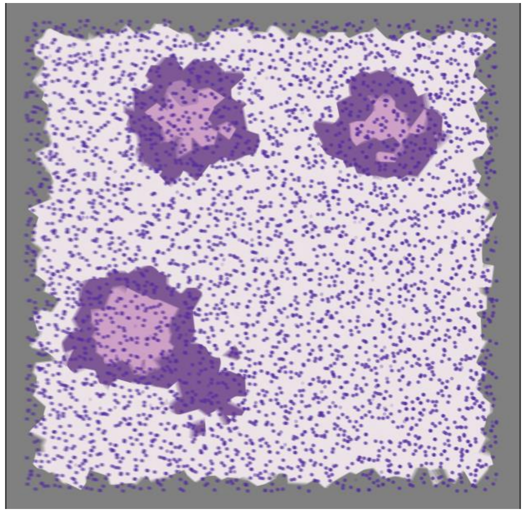
Given a convex polyhedron and the slicing plane:

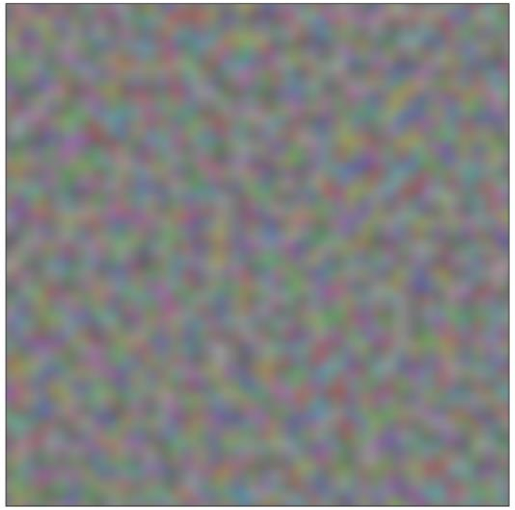
- Divide the vertex that lies to the left and the right of the plane
- Draw any possible line that cross two points from different class
- Make the intersections between the sectioning plane and all the lines
- Compute the convex hull of the intersection points

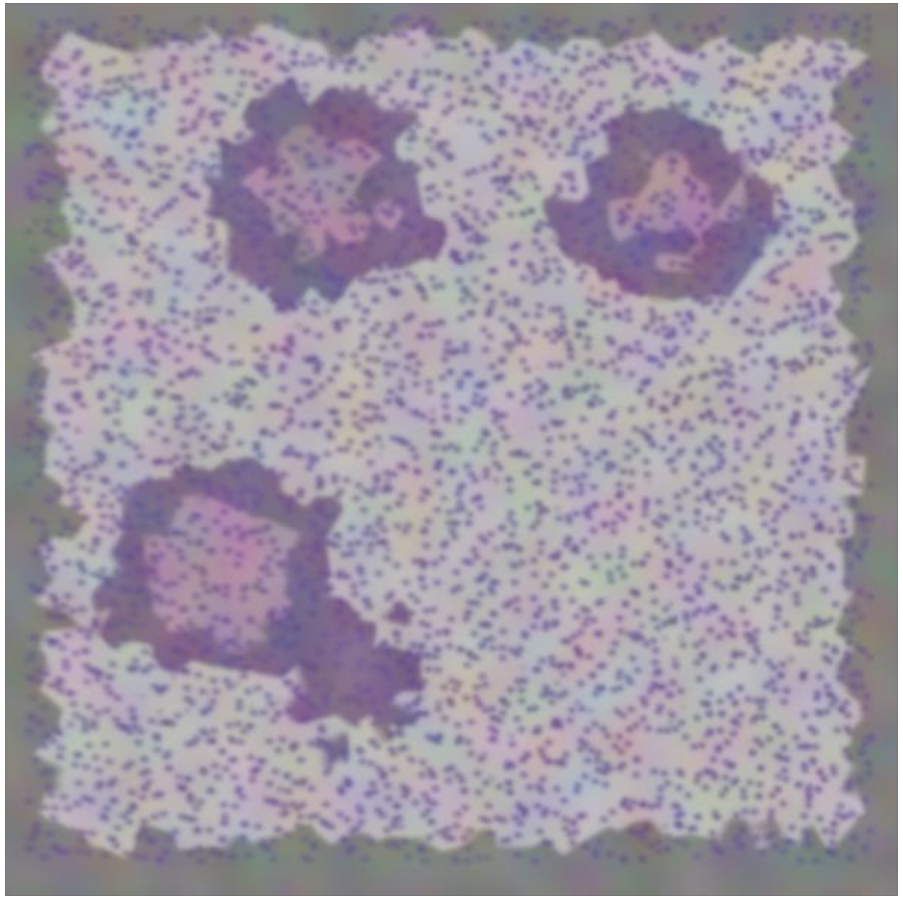


Intentional Aesthetic Refinements

- Choice of a more matching colour palette
- Addittion of projections of cells’ nuclei
- Averaging on more succeeding slices
- Application of a Perlin RGB noise



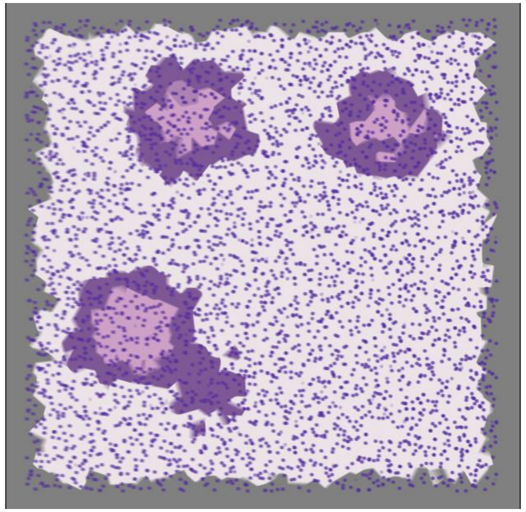


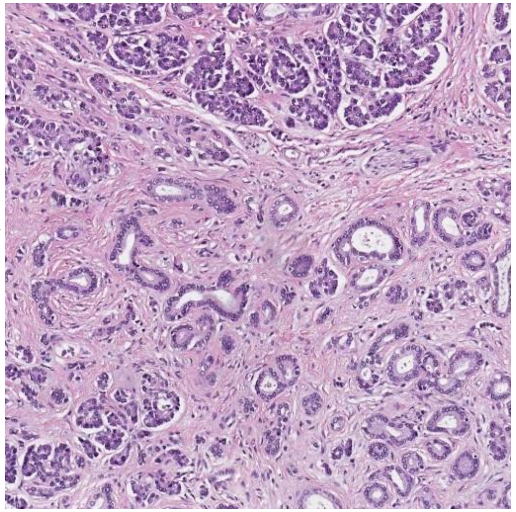


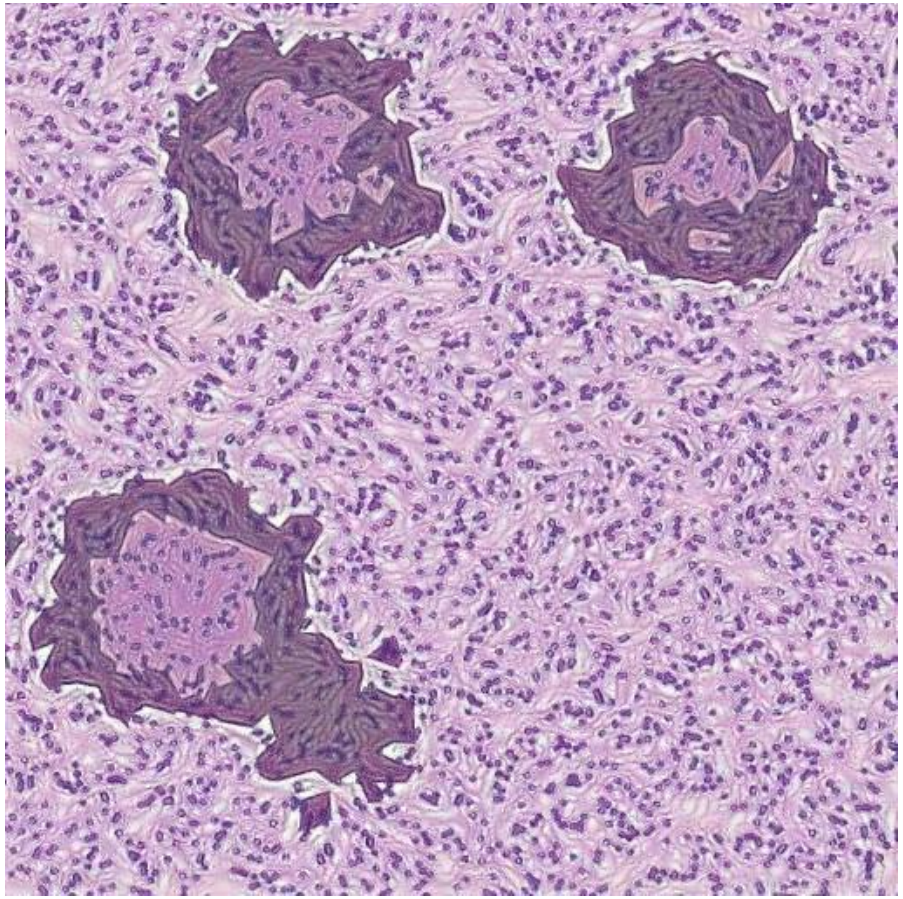
Computation Time of ~ 20 s on CPU

Style Transfer Net

Alternatively to adding a Perlin noise a style transfer NN should be exploited to give some texture to the image.
Transfering style from a real pancreas specimen.







Computation Time of ~ 7 min on GPU

Style Transfer Neural Network

Style transfer NN are able to create hybrid images, conserving the content of an image whilst implanting the visual style from another image. This type of Deep Learning instruments find interesting and funny applications in the artistic world.

Style Transfer Net informations

I used a custom version of the VGG19 network provided in a tutorial of the pytorch library. The structure is still the same, with a sequence con convolutional layers followed by a couple of fully-connected Layers.

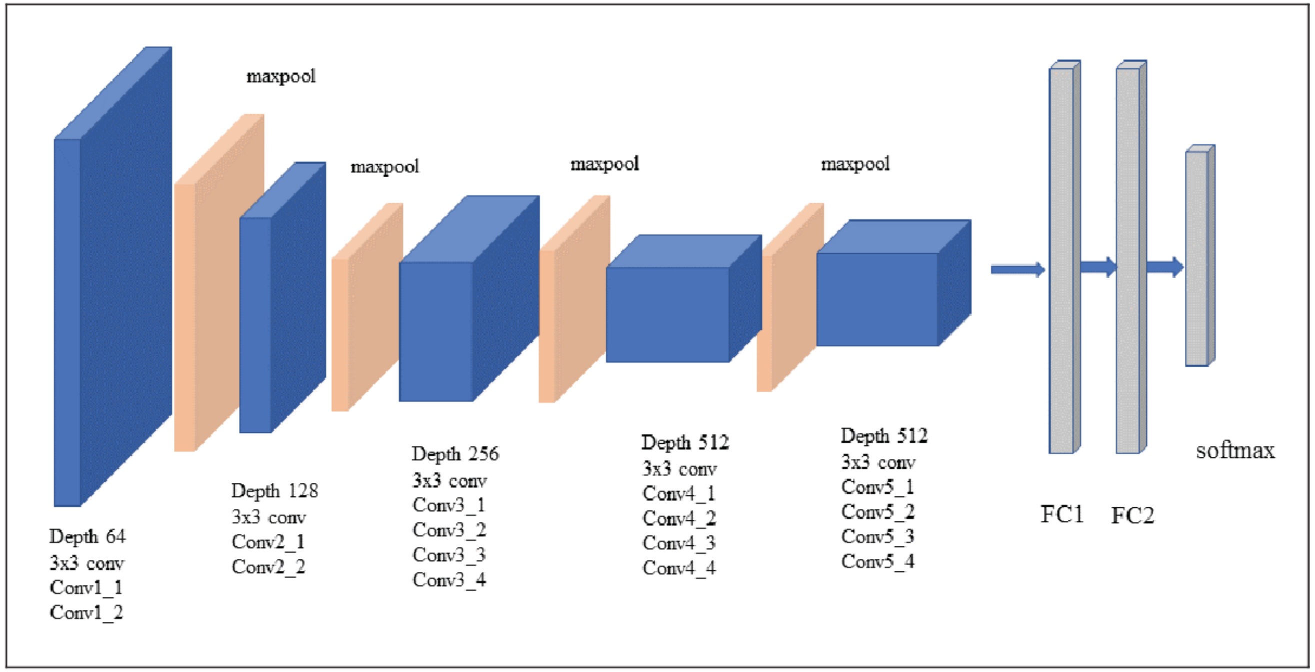


Fig. 3. VGG-19 network architecture

https://pytorch.org/tutorials/advanced/neural_style_tutorial.html

Image and Label Pair

A complete run on the pipeline results in a pair Image – Label.
This procedure may be repeated many times, providing a training dataset of arbitrary dimension.
The randomness in the slicing direction provides every time different pairs.

FOUR DIFFERENT PAIRS OF IMAGES AND RELATIVE LABELS

Next Steps

- Try applications on new types of tissues.
- Starting from a completely different geometric structure to embed in the 3D tassellation.

- Try to train a model on this data set.
- It could help detecting problematic in the images and way to improve the generation.

- Deepen the comprehension of the style transfer NN.
- The fine tuning of the network's parameters could help in the generation

Bibliography

Segmentation Article

More realistic images

Saltelli algorithm

cGAN NN