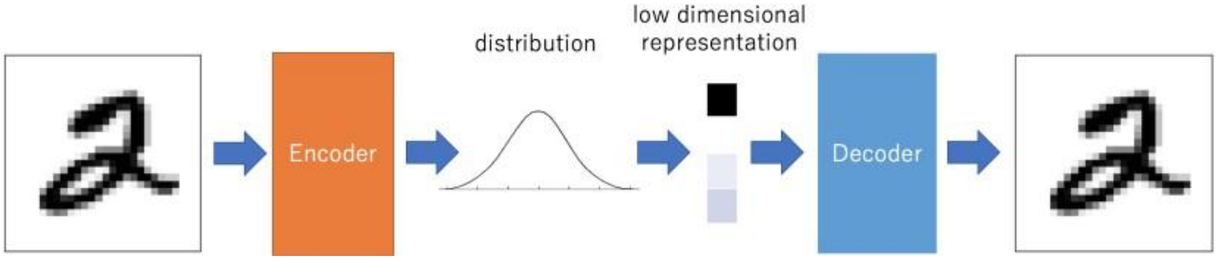
VAE for topology Optimization

Question: Can we replace the topology optimization code with a neural network that can produce new topologies?



From Markus Buehler MIT

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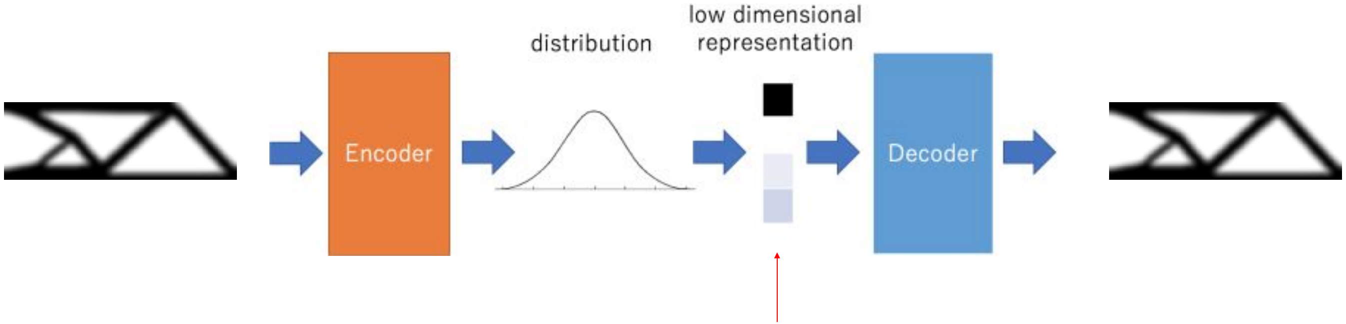
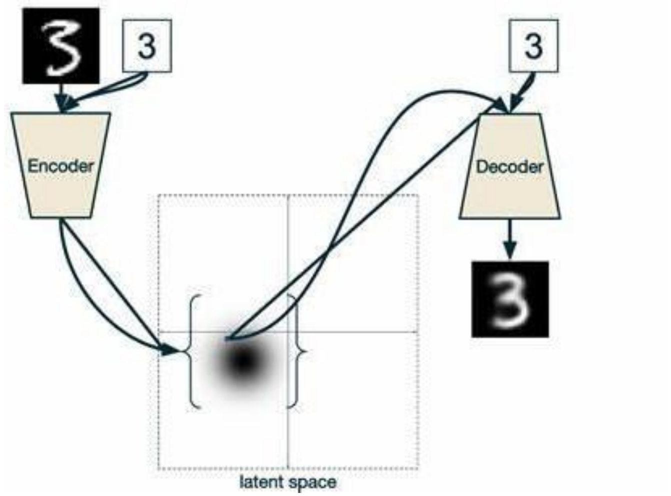


e.g. Volume fraction
…
Volume fraction and Location of force

From Markus Buehler MIT

Conditional VAE

Question: Can we condition the generation process to specific conditions (labels) such as volume fraction?



From Markus Buehler MIT

Approach

Step 1: Generate training set (large set of images generated by topology optimization code)
E.g., **images saved during optimization, for different volume fractions.**

Step 2: Set up VAE neural network

Step 3: Train

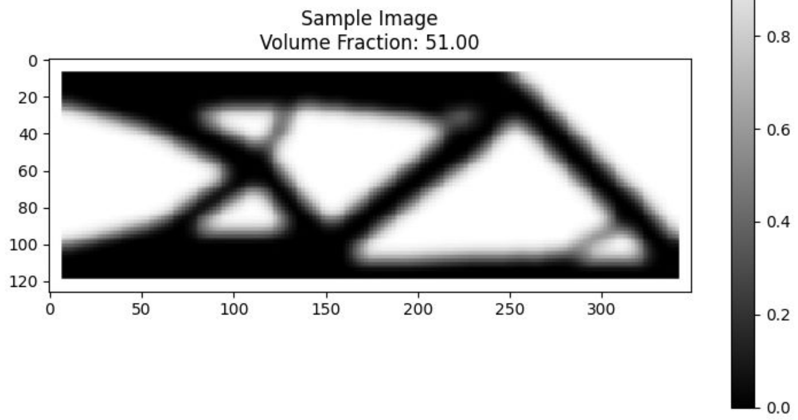
Step 4: Generate – specify label (e.g. volume fraction) – can generate volume fraction predictions that weren't part of the training set

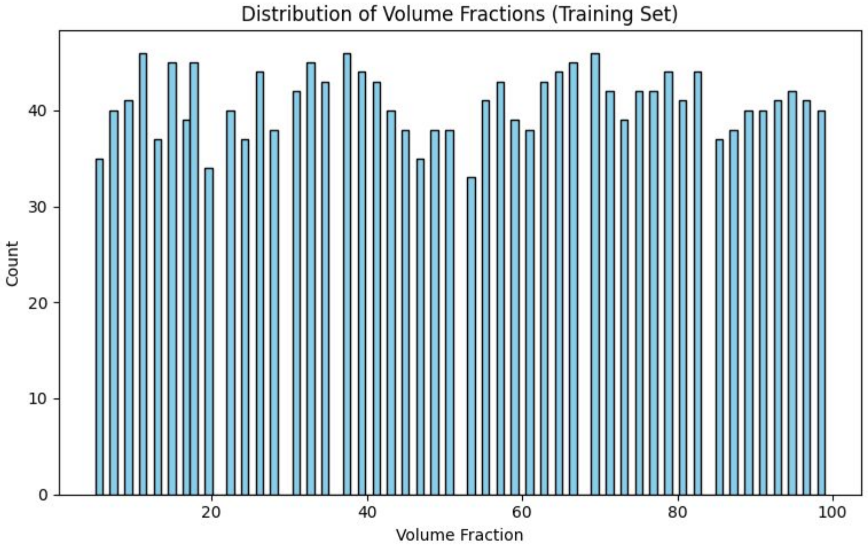
Approach

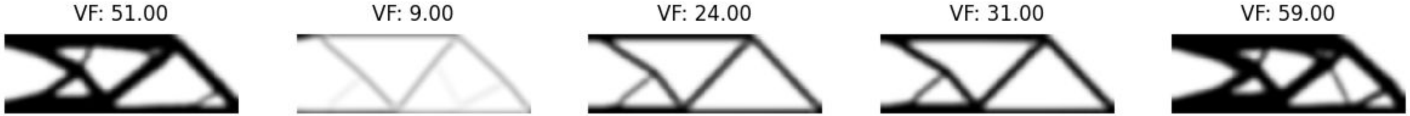
Step 1: Generate training set (large set of images generated by topology optimization code)
E.g., **images saved during optimization, for different volume fractions.**

The image data can be found at:
https://filesender.renater.fr/?s=download&token=b52ea488-8ad5-4663-8fa8-51f881041016

Load and visualize the data







Approach

Step 1: Generate training set (large set of images generated by topology optimization code)
E.g., **images saved during optimization, for different volume fractions.**

Step 2: Set up VAE neural network

```
VAE(
  (encoder): Sequential(
    (0): Linear(in_features=43975, out_features=256, bias=True)
    (1): ReLU()
    (2): Linear(in_features=256, out_features=256, bias=True)
    (3): ReLU()
  )
  (fc_mu): Linear(in_features=256, out_features=2, bias=True)
  (fc_var): Linear(in_features=256, out_features=2, bias=True)
  (decoder): Sequential(
    (0): Linear(in_features=3, out_features=256, bias=True)
    (1): ReLU()
    (2): Linear(in_features=256, out_features=256, bias=True)
    (3): ReLU()
    (4): Linear(in_features=256, out_features=43974, bias=True)
    (5): Sigmoid()
  )
)
```

Approach

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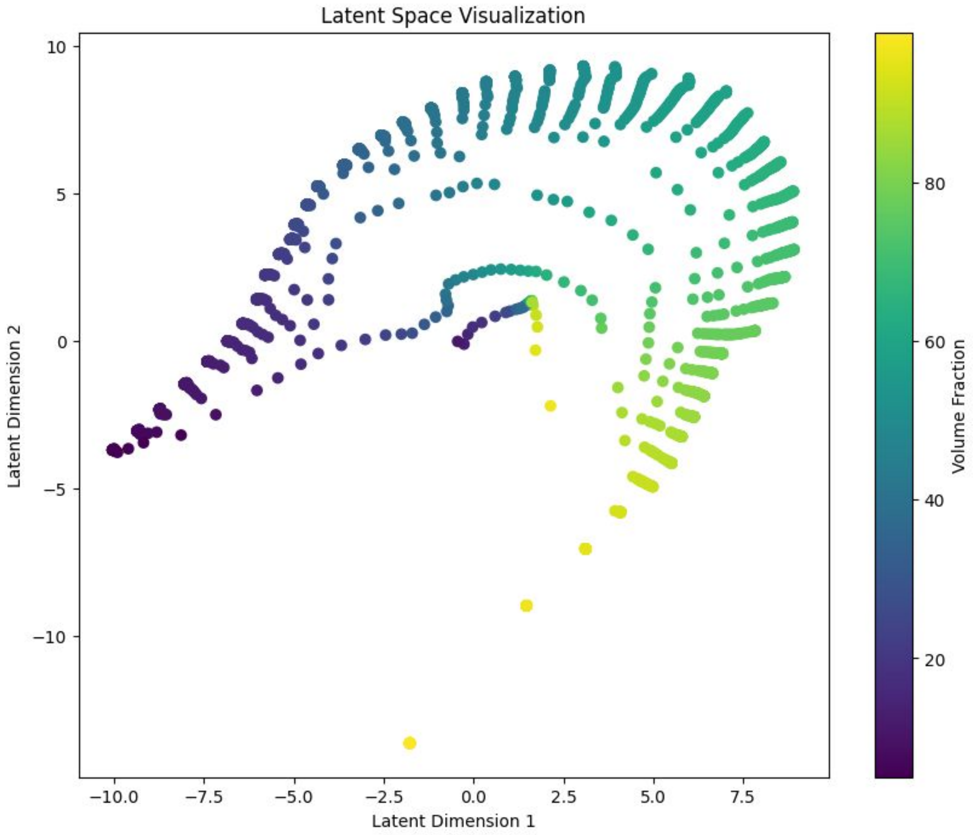
Visualize Training Data in the latent space



- The training data is encoded into compressed representation and visualized with respect to the volume fraction (label).
- The posterior distribution resembles a Gaussian Distribution.

Approach

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E.g., **images saved during optimization, for different volume fractions.**

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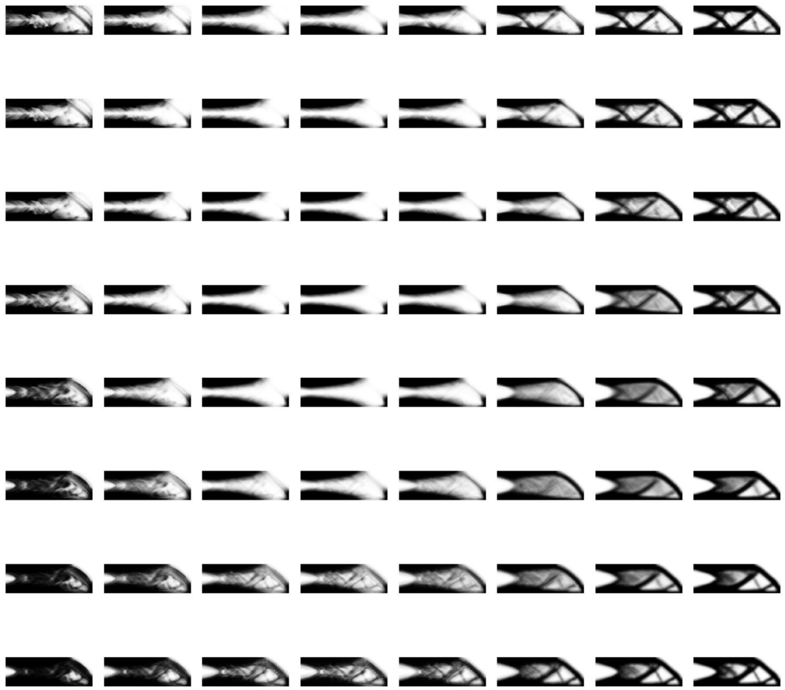
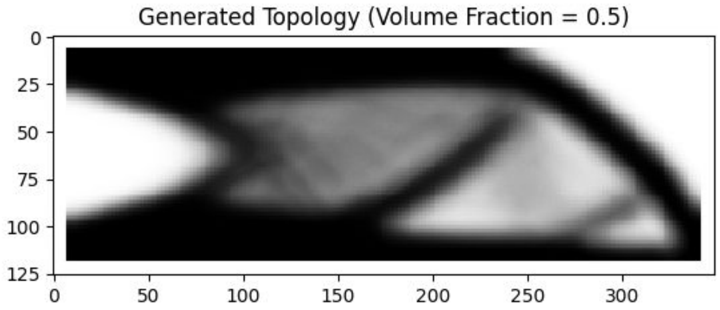
Step 4: Generate – specify label (e.g. volume fraction) – can generate volume fraction predictions that weren't part of the training set.

Generation Mode: Sample from the latent space.

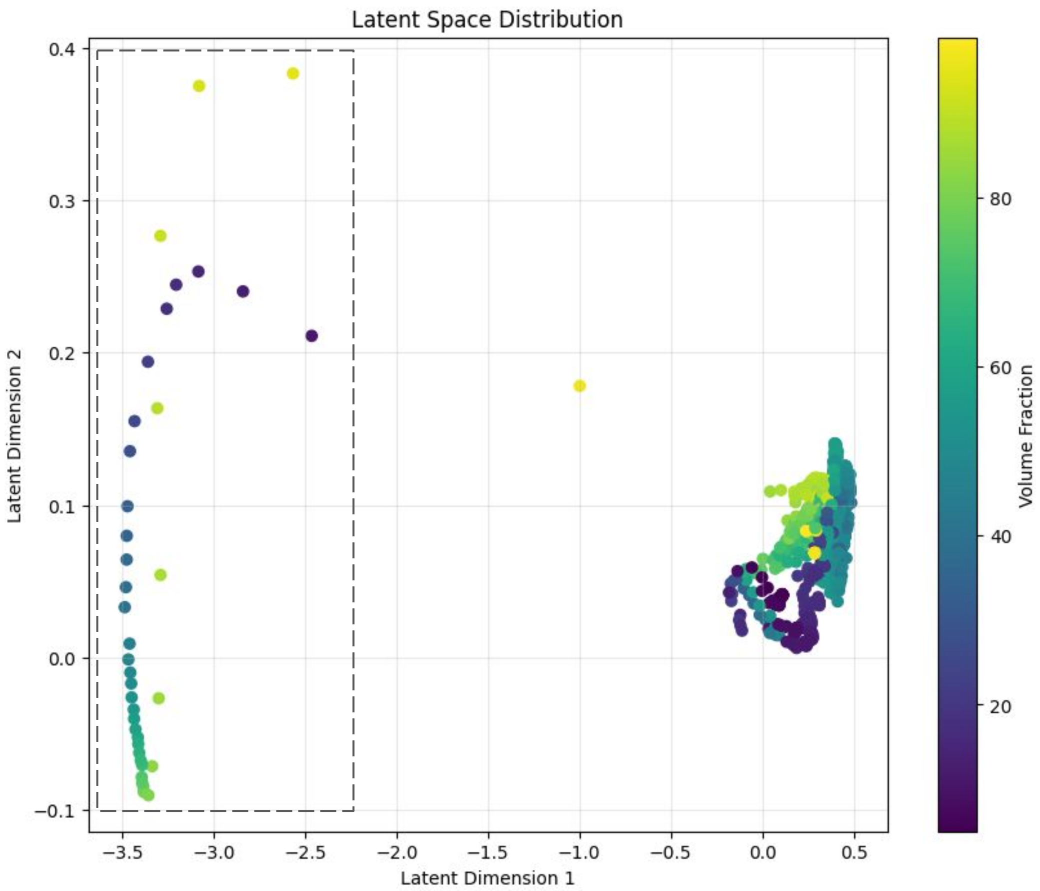
```
# Generate grid of topologies
plot_latent_space_sweep(model, condition=0.5)
```



```
# Generate single topology
topology = generate_topology(model, condition=0.5, device=device)
plt.imshow(topology, cmap='gray')
plt.title('Generated Topology (Volume Fraction = 0.5)') plt.show()
```

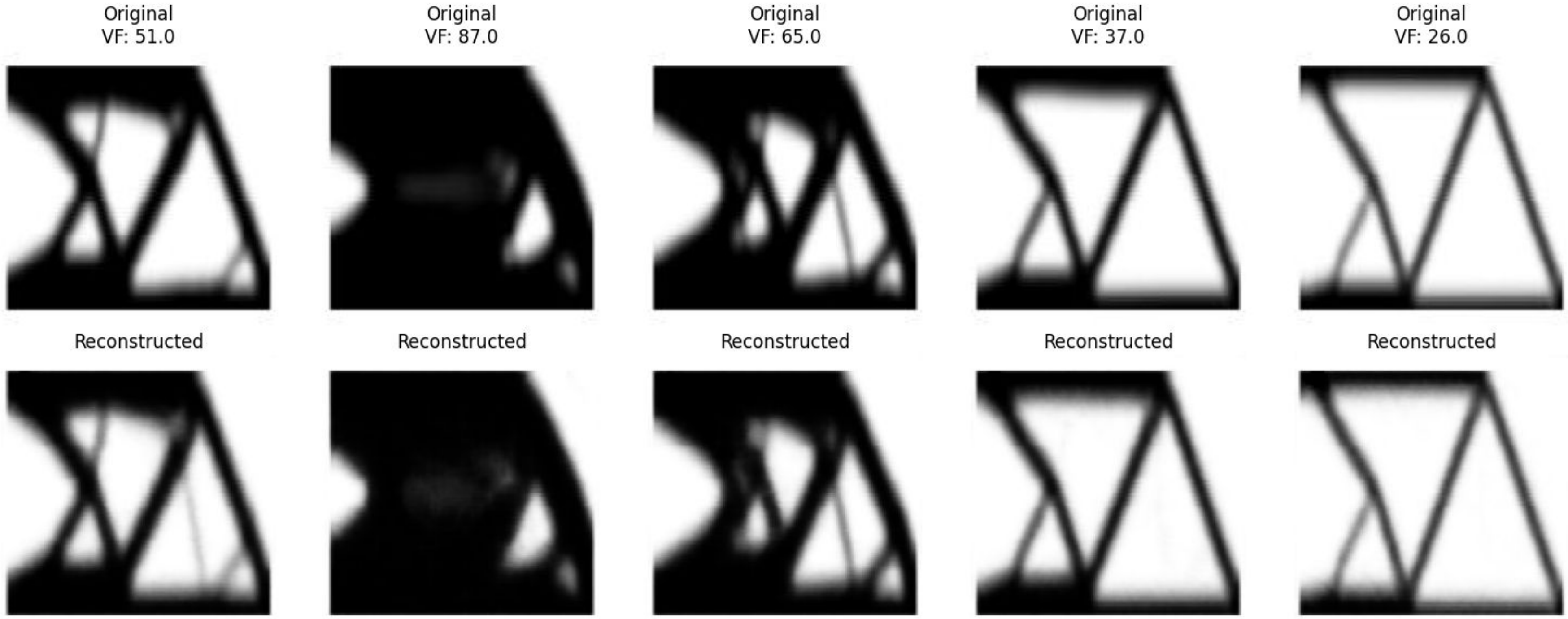


Outlier Detection

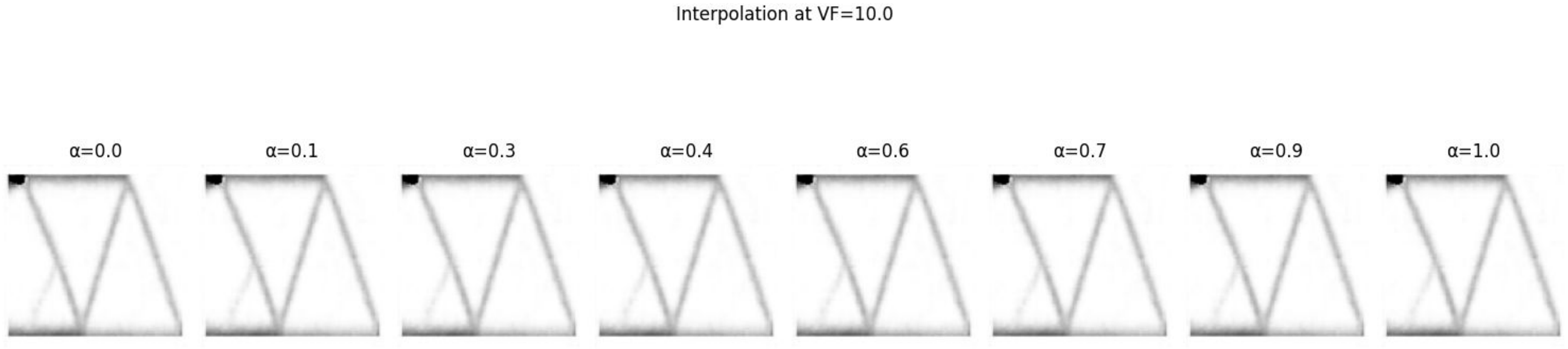


- Clustering the latent space can reveal outliers in the dataset.
- VAE can be used for outlier detection!

1. Visualizing Reconstructions...



2. Interpolating in Latent Space......



3. Generating Variations for Different Volume Fractions......