Using Generative AI Models to Design Novel Shapes

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Introduction

In order to optimize the design of complex shapes, there can be a large number of variable which can lead to difficult optimization problems. Simplifying to a smaller dimensional latent space can dramatically increase the efficiency of the optimization.

One major difficulty with this space is the lack of large quantities of data to use as a training set, which can result in poorly trained models.

Using a Generative Adversarial Network (GAN) model we seek to determine a latent space of smaller size that will make the optimization easier.

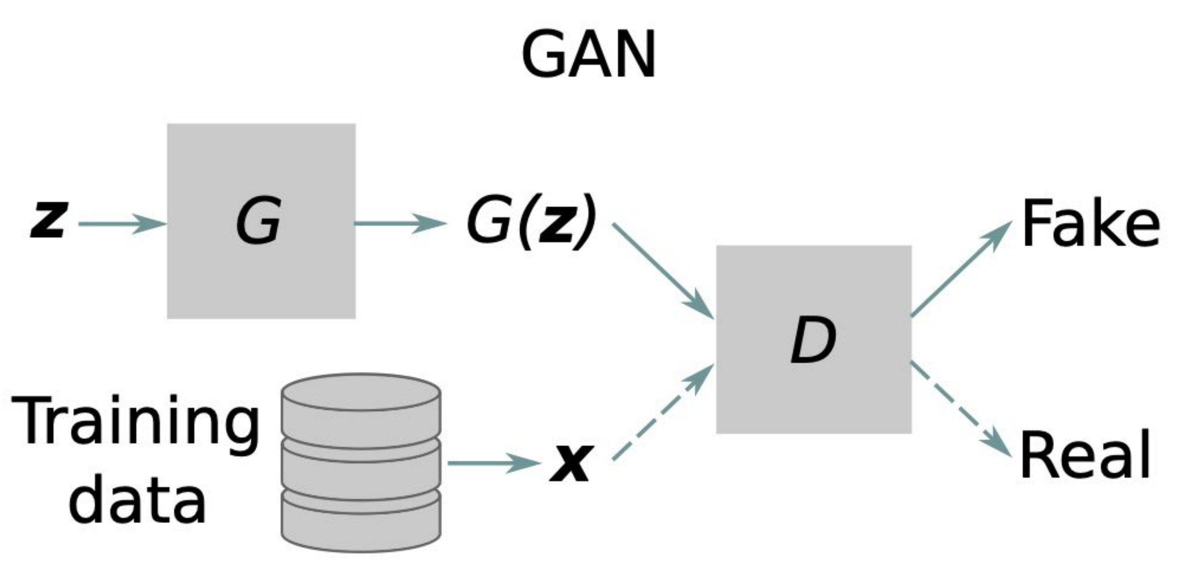

Figure 1: Outline of GAN model design

A GAN model is based on two networks, the generator (G) and the discriminator (D), which work together to convert a latent space into a design.

The role of the generator is to take the latent space along with some noise variables (Z) and convert it into a plausible design.

This generated design G(z) is then passed into the discriminator, whose role is to determine whether the generated design is real or fake.

The generator and discriminator are trained in a competitive process, with both networks refining at the same time.

Research Aims

- Design and train a GAN model to generate redox flow battery topologies
- Discover novel channel design to optimize energy density and efficiency
- Generate a training set of various topologies to use for training a GAN model

Training Data

- Use SolidWorks to create DXFs halves of predefined topologies using Design Tables
- Combine the various halves in all possible combinations using MATLAB
- Interpolate points in between all vertices to give more data for GAN model to use

Results

- Generated 6 distinct topologies with 25 variations each based on angle geometry
- Used MATLAB to generate 22,500 possible combinations of different topologies

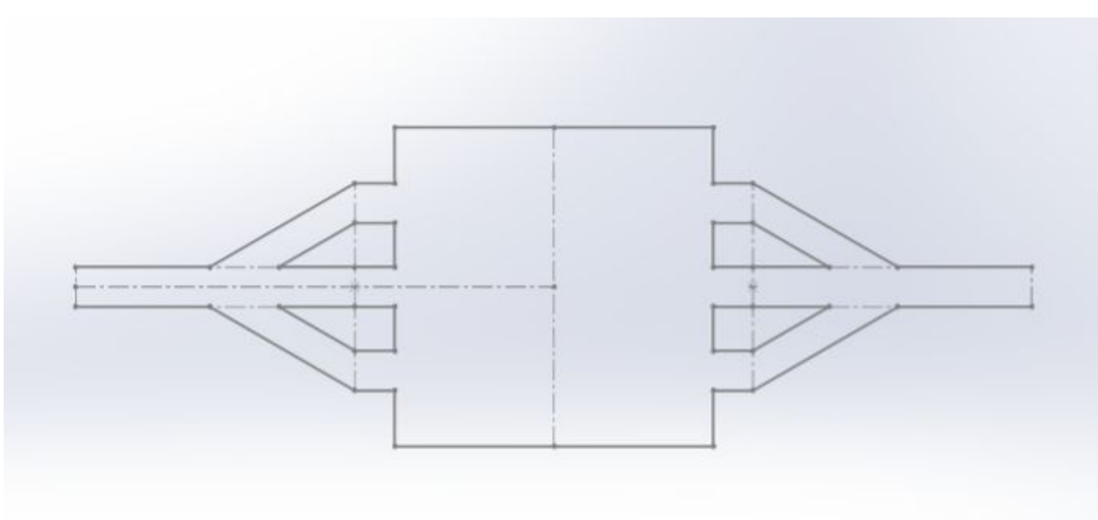

Figure 2: Example of SolidWorks design

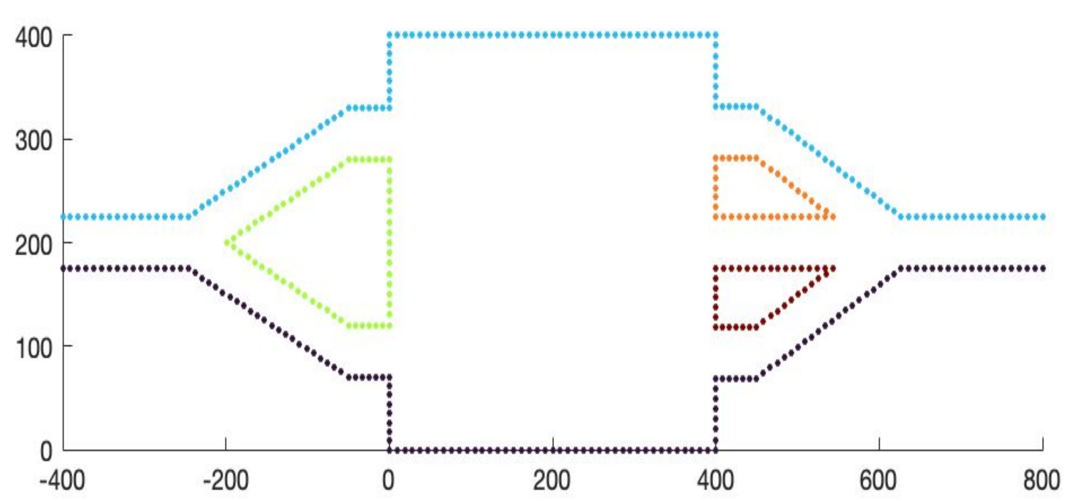

Figure 3: Example of combined redox flow manifold

GAN Design

The first milestone when designing this GAN model was to be able to generate a singular line before working out generating internal geometries.

To do this, we trained a model based on the top lines of our generated manifolds (light blue line in fig. 3).

Results

We were able to generate a line design using single point generation, and are currently in testing of a multi-point line generation GAN with varying levels of success.

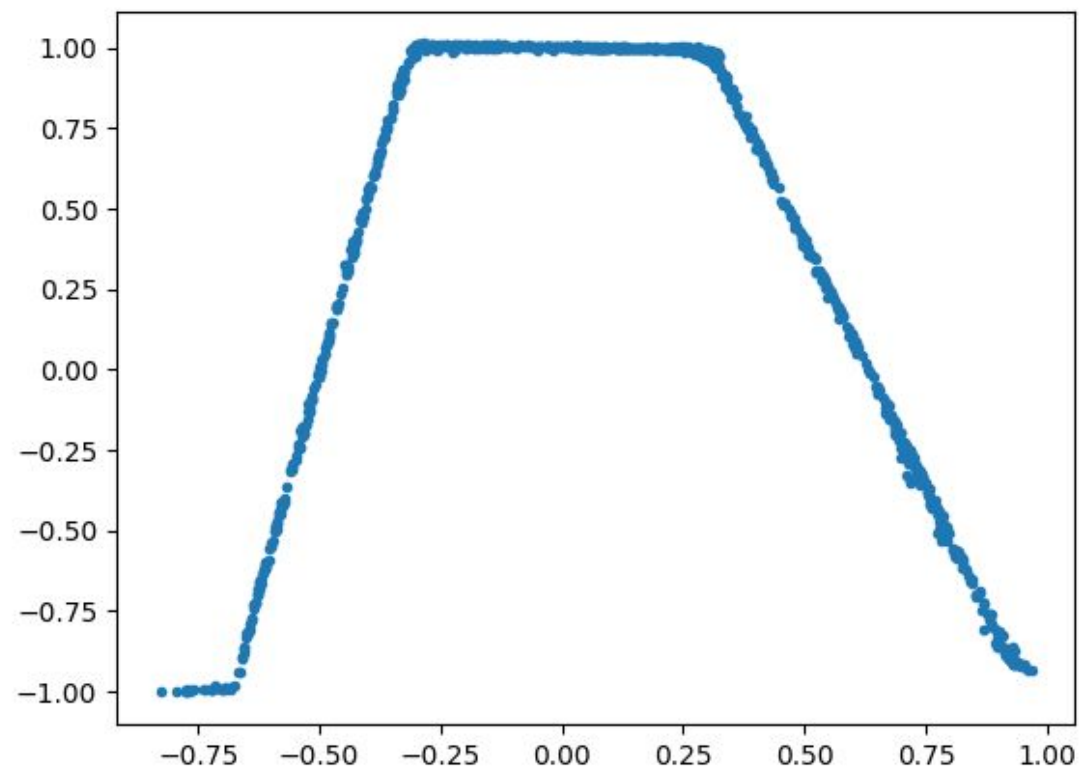

Figure 4: Example output of single point line generation

Future Steps

- Finish testing line generation with output of 1024 points
- Update GAN to be capable of generating internal geometries
- Create a bezier layer to add smoothness to the sharp edges
- Integrate bayesian optimization for discovery of new redox flow battery channel topologies

References

1. Chen, Wei & Chiu, Kevin & Fuge, Mark. (2019). Aerodynamic Design Optimization and Shape Exploration using Generative Adversarial Networks. 10.2514/6.2019-2351.
2. van Beek, Anton, et al. "Scalable adaptive batch sampling in simulation-based design with heteroscedastic noise." *Journal of Mechanical Design* 143.3 (2021): 031709.