Deep Generative Design

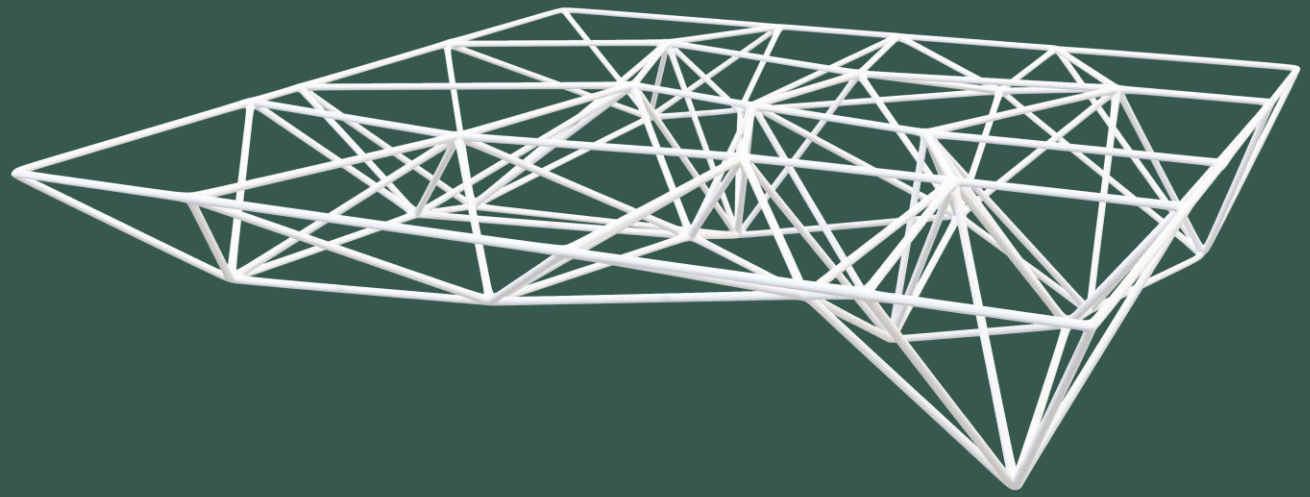
for Optimized Spatial Truss Structures with Stock Constraints

P5 – 27 June 2023

Amy Sterrenberg
4593057

DEEP GENERATIVE DESIGN

A deep learning framework for optimized spatial truss structures with stock constraints

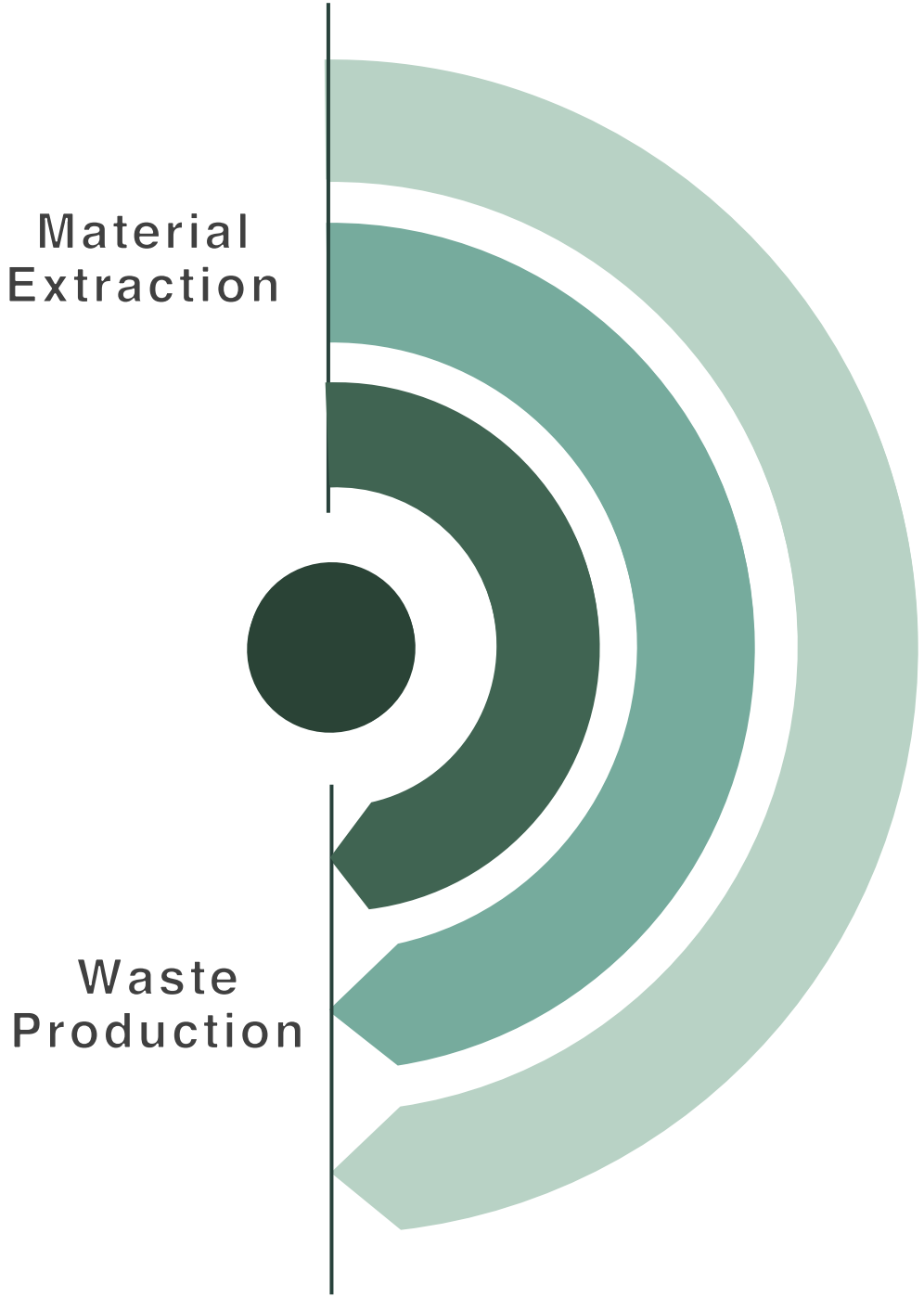


P5 – 27 June 2023
Amy Sterrenberg
4593057

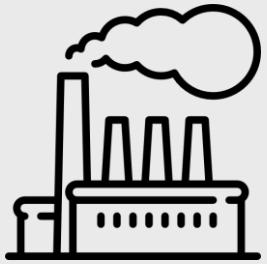
RE-USE

Bima Microlibrary By SHAU Bandung

RE-USE



RE-USE



CO2 Emissions

Energy Consumption

Waste Production

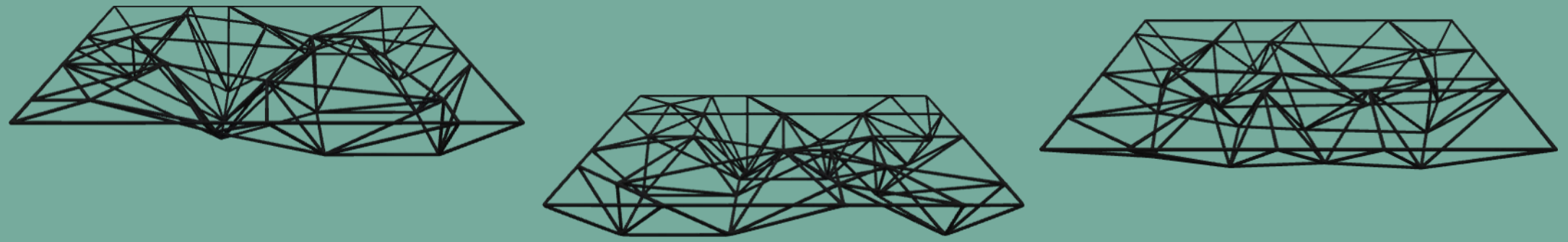
WHAT IS AI?

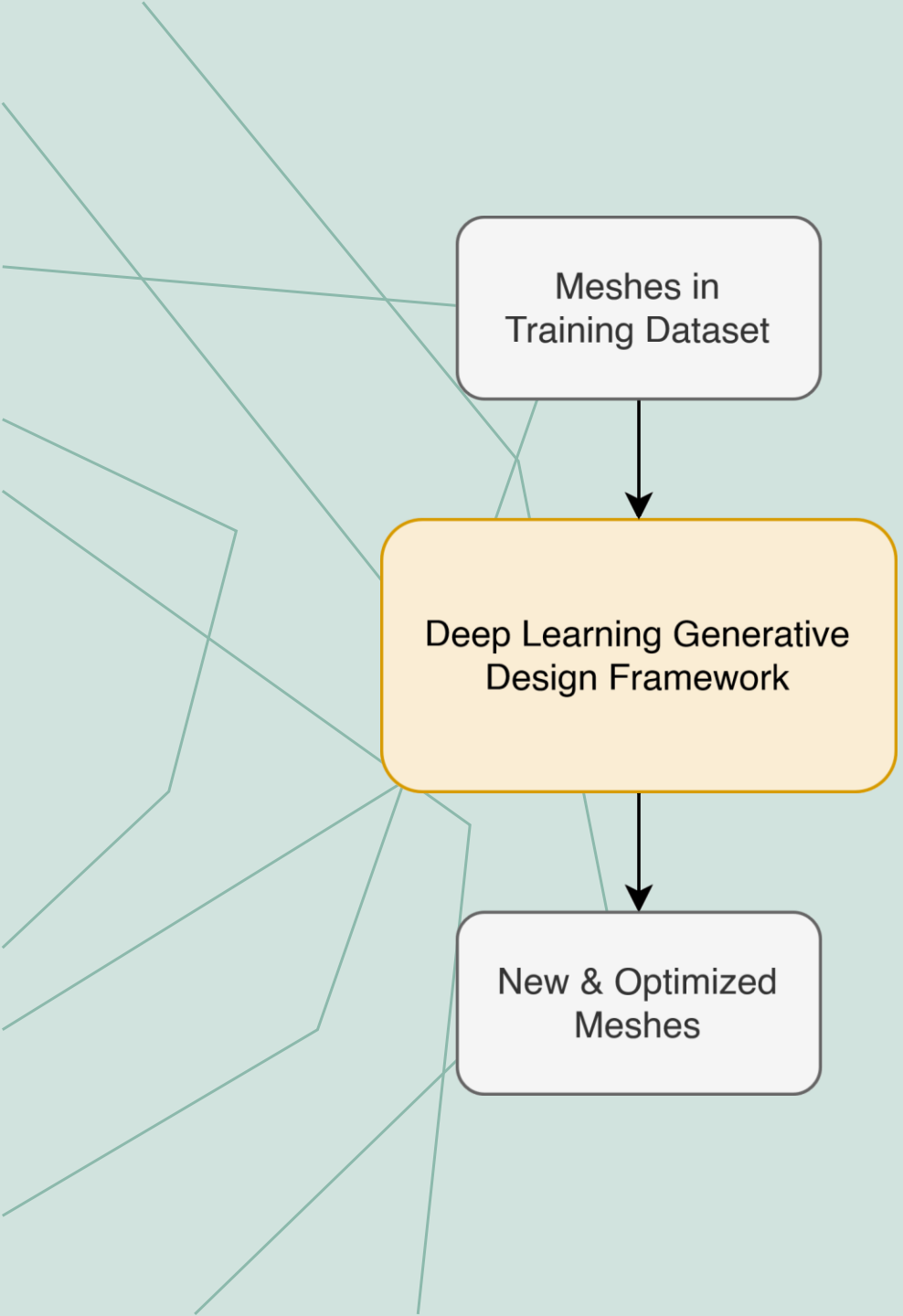
“a 3D spatial truss structure supporting a roof in a large futuristic building”

Generate

WHAT IS AI?

“a 3D spatial truss structure optimized for reusability & structural performance” **Generate**



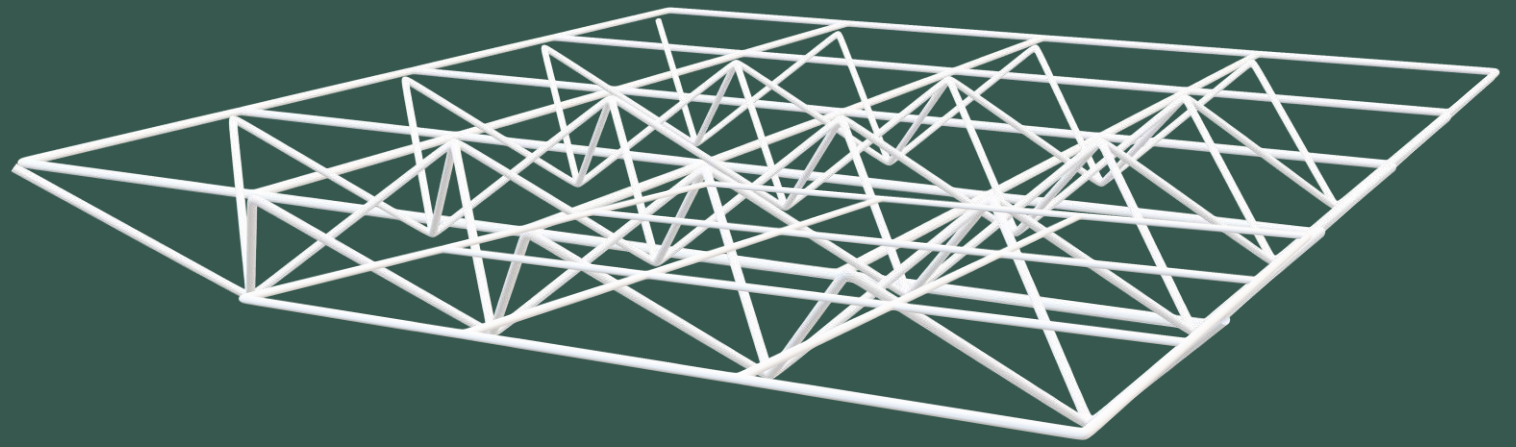


RESEARCH QUESTION

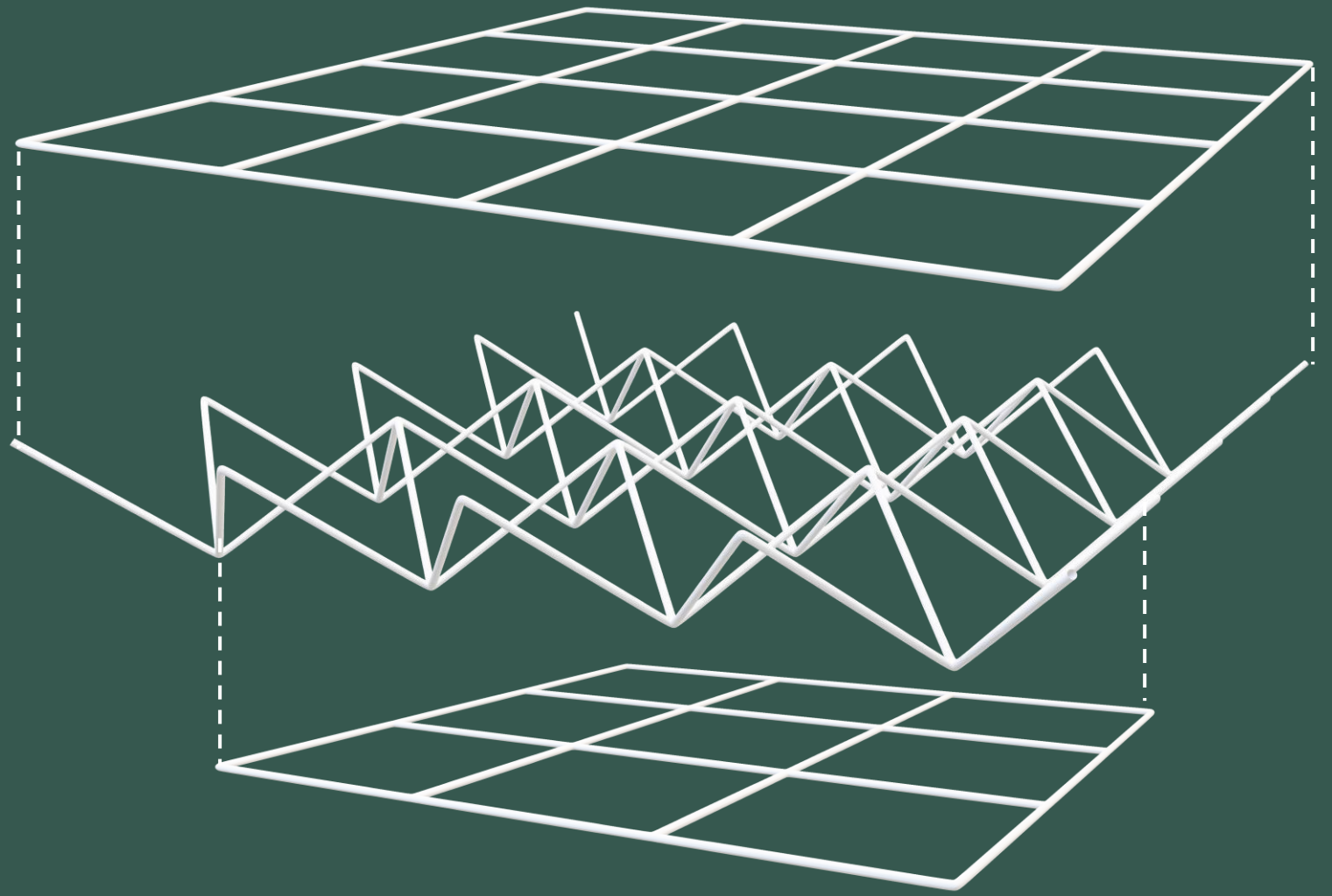
Can an **artificial intelligence (AI) based generative design framework** generate new spatial (3D) truss design solutions, with optimized structural performance, minimized material use and that consist of linear elements that closely match elements from a reusable material stock, in reference to **the training dataset**, and therefore be used as an effective tool for design exploration in early design stages of the **materially circular architectural design process?**

CASE STUDY

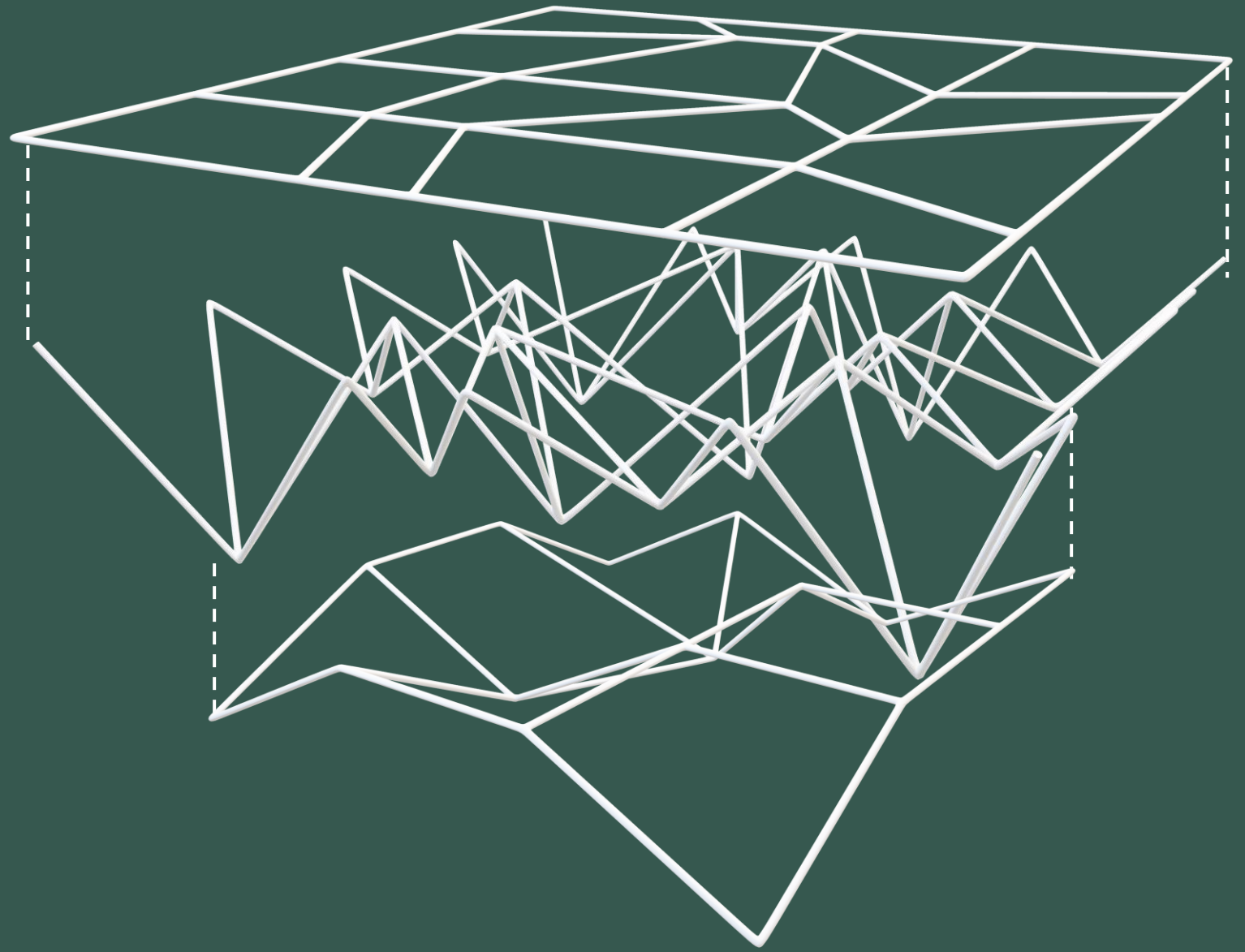
CASE STUDY



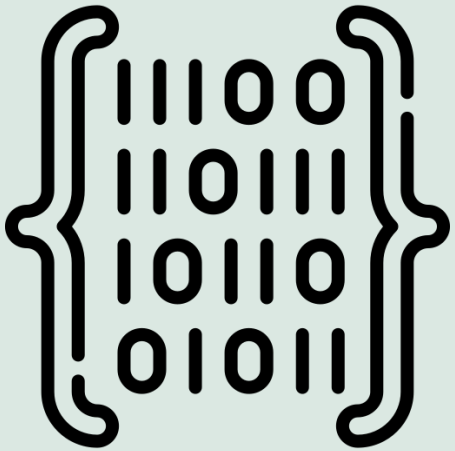
CASE STUDY



CASE STUDY

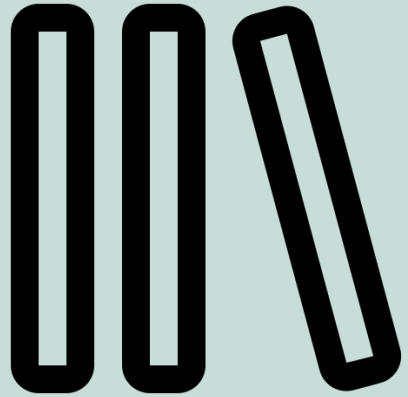


WORKFLOW



Geometry Input Dataset

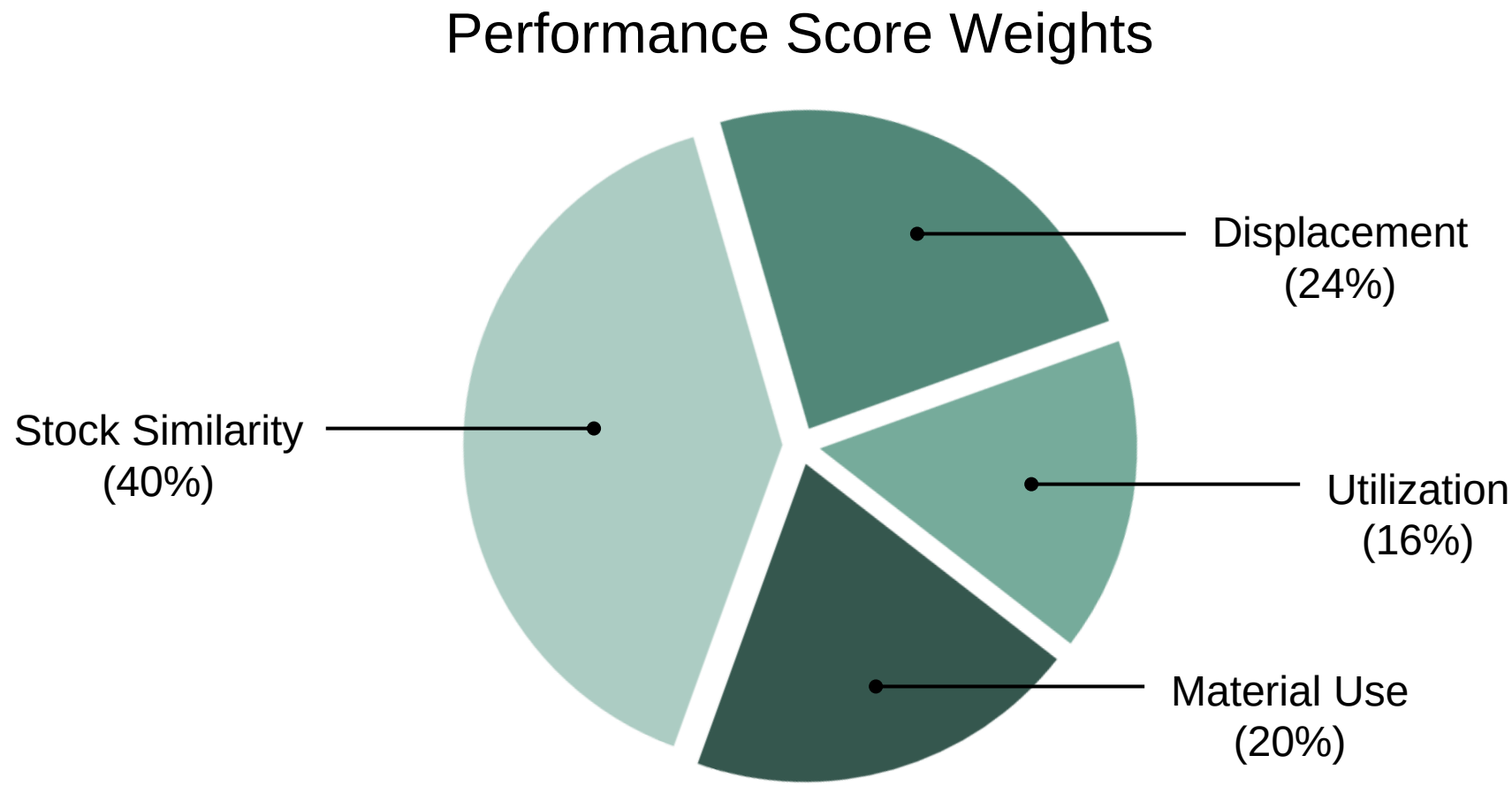
- Displacement
- Utilization
- Material Use



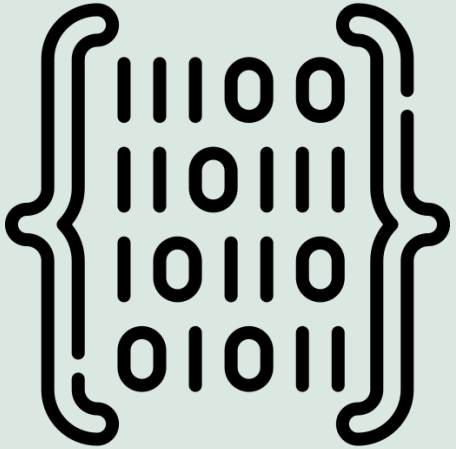
Material Stock Library

- Stock Similarity

WORKFLOW


Performance Score Weights
Displacement (24%)
Utilization (16%)
Material Use (20%)
Stock Similarity (40%)

WORKFLOW



Geometry Input Dataset

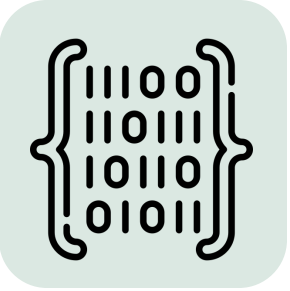
5000+ random meshes

0.78
0.54
0.63

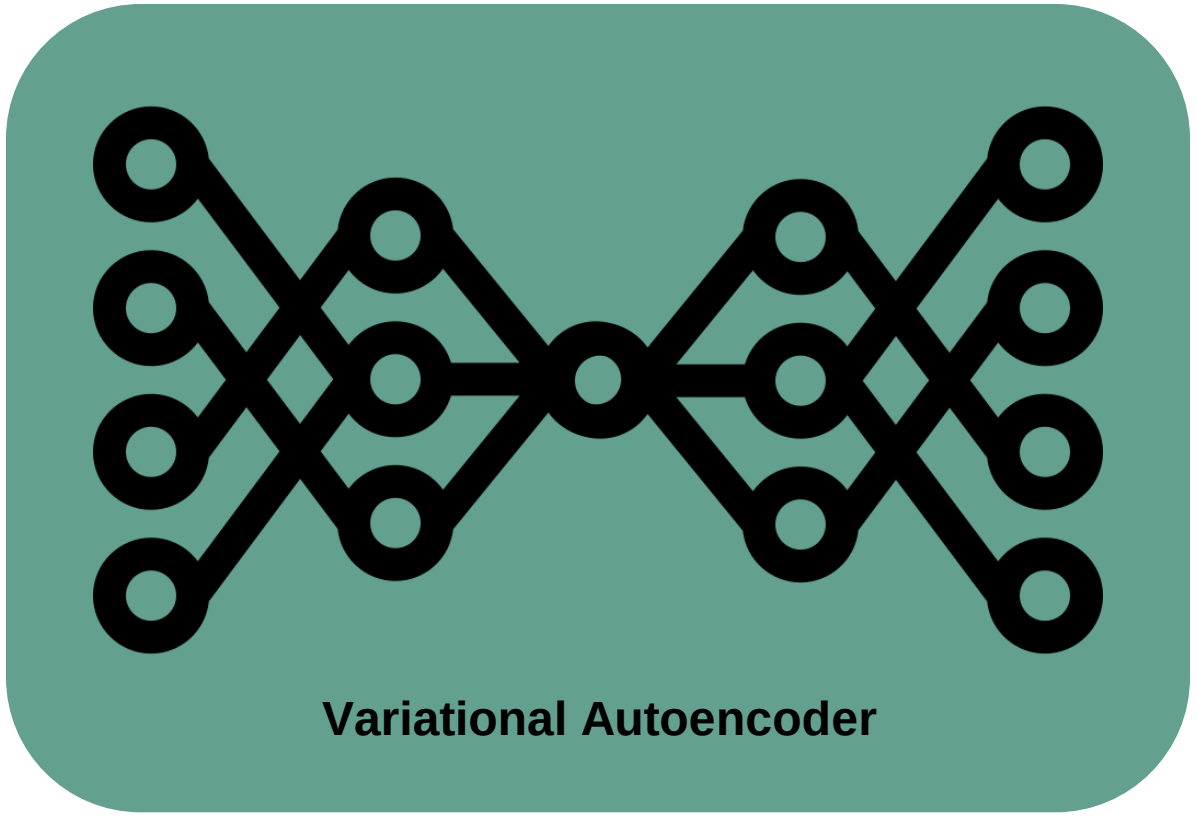
Performance Indicators

Labels for each mesh

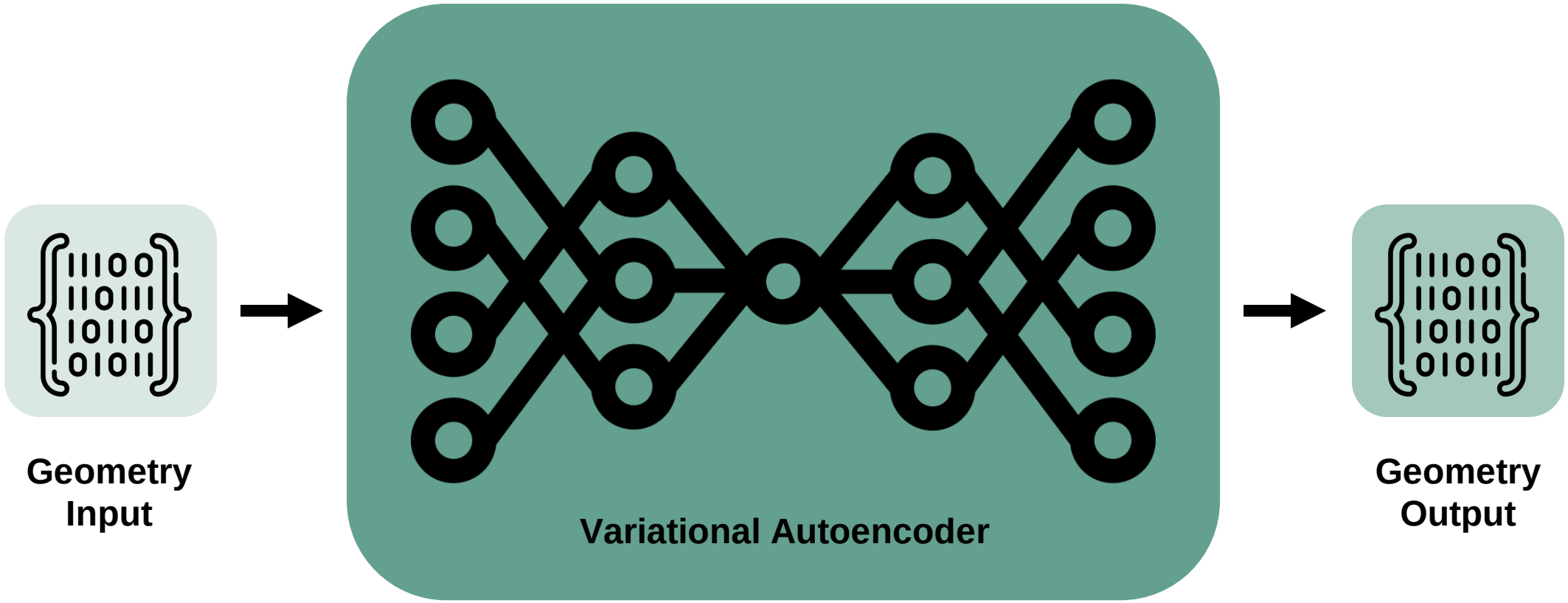
WORKFLOW



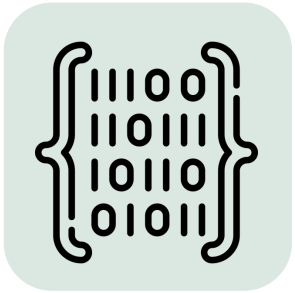
Geometry Input Dataset



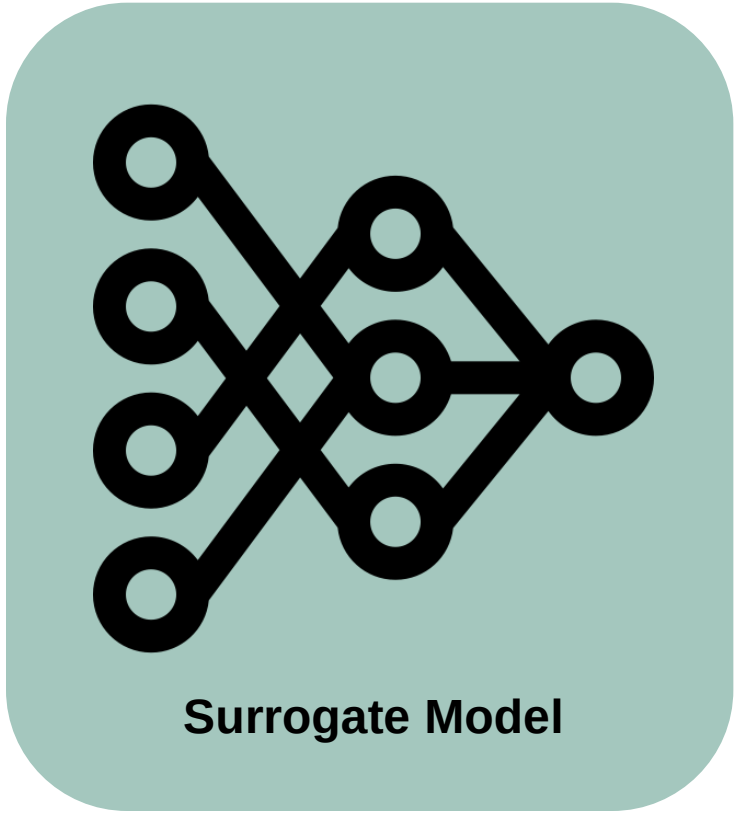
WORKFLOW



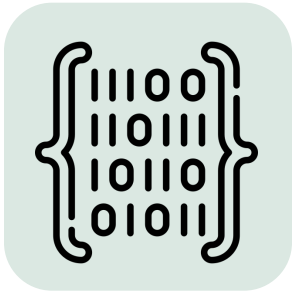
WORKFLOW



Geometry Input Dataset



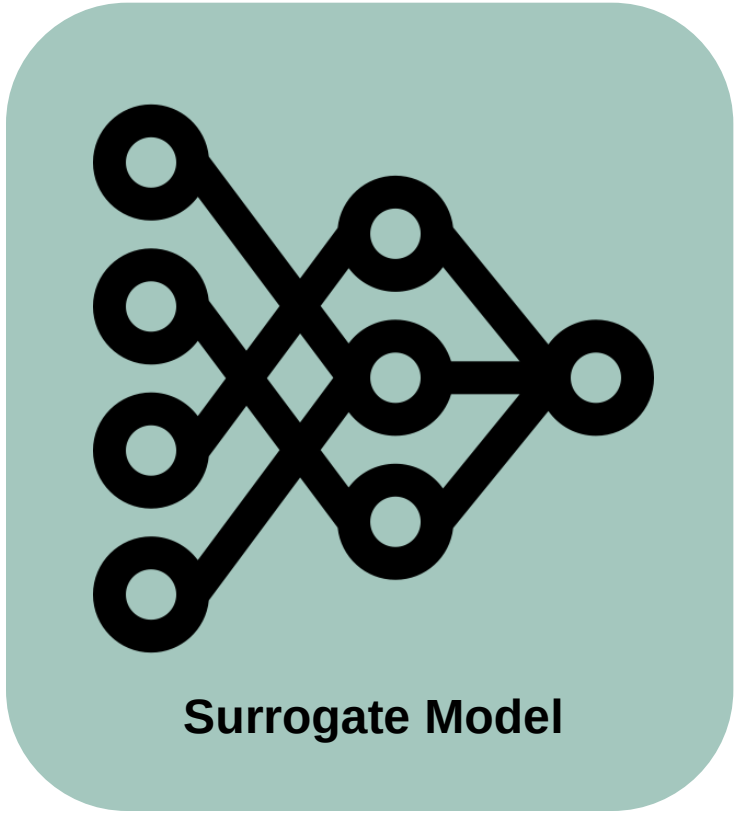
WORKFLOW



Geometry Input Dataset

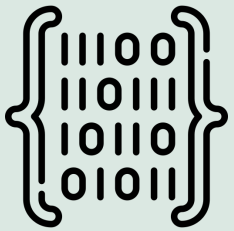
0.78

Performance Indicators



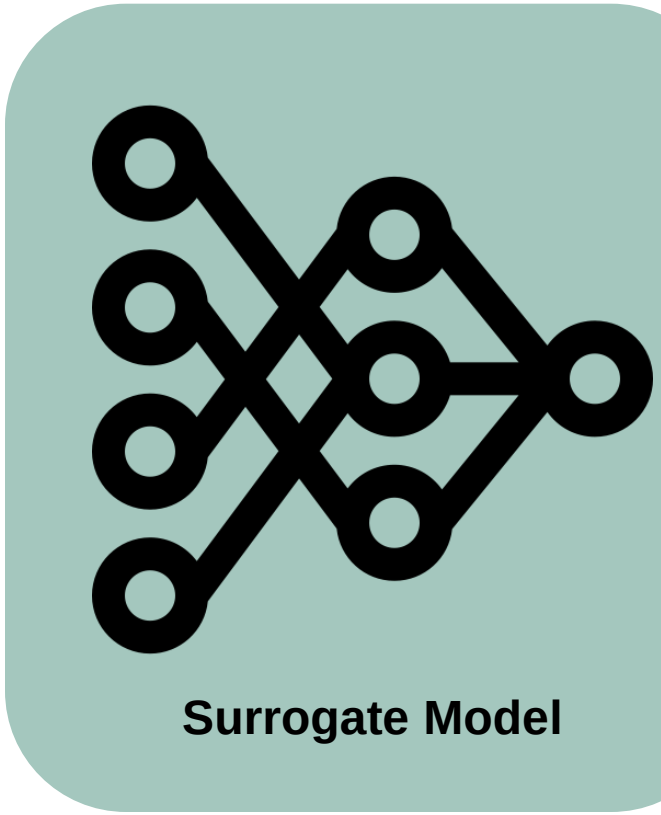
WORKFLOW

Geometry Input



0.78

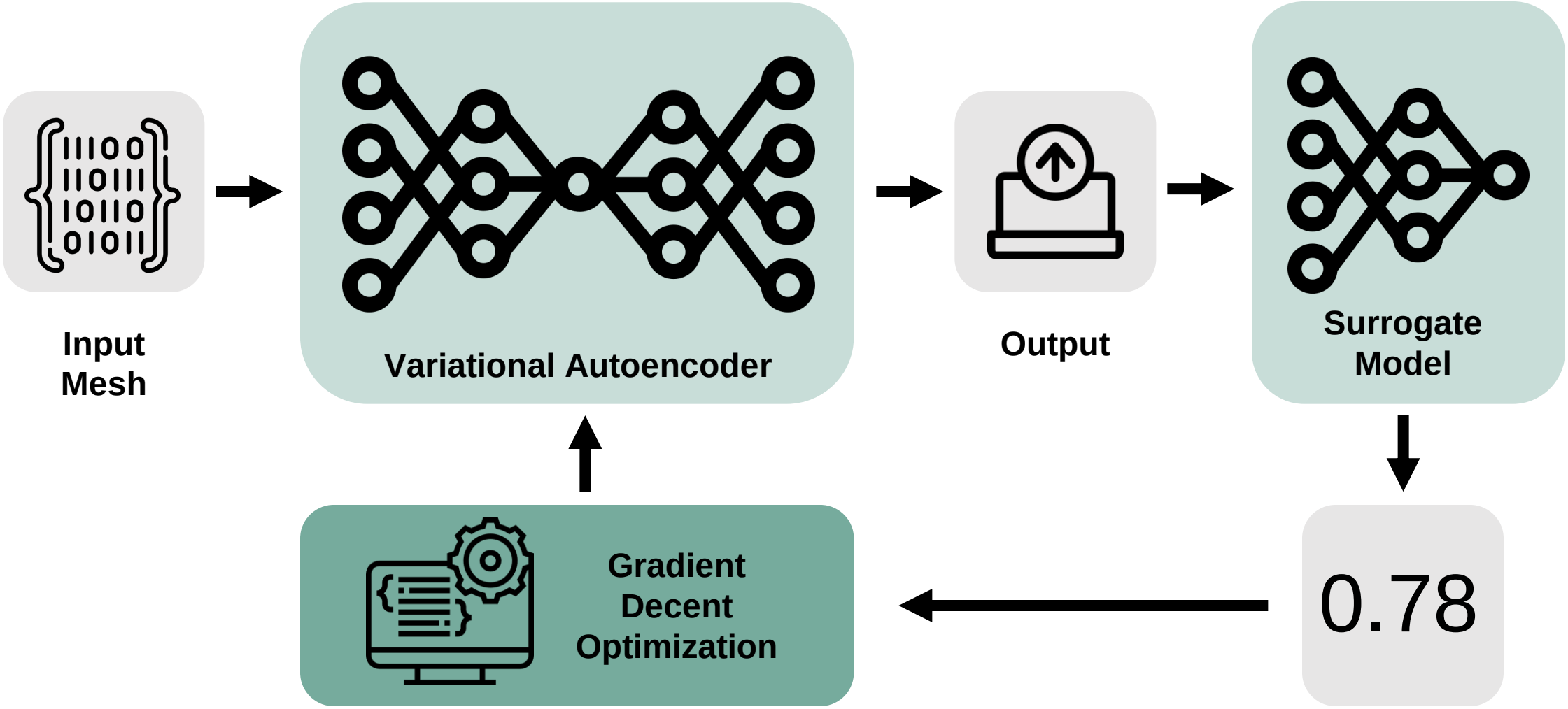
(used for training)



0.78

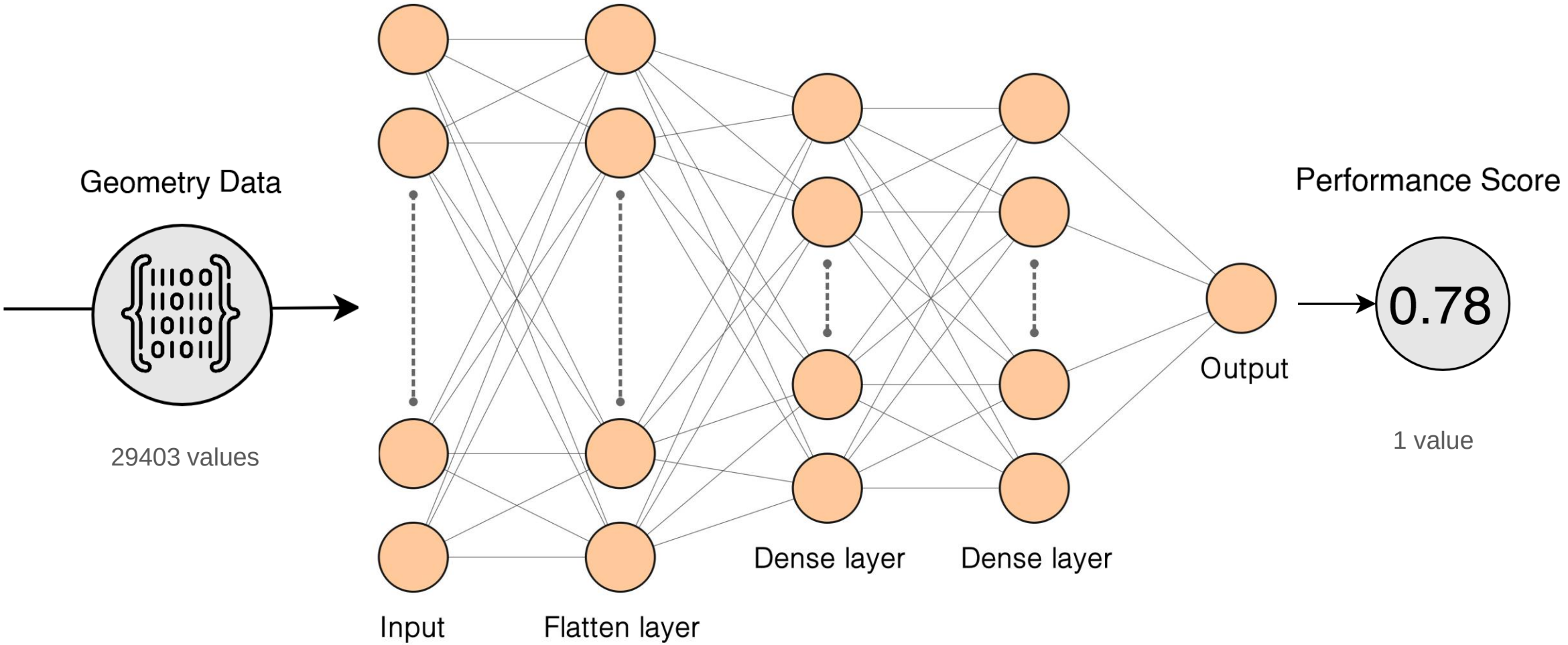
Predicted Performance Indicators

WORKFLOW

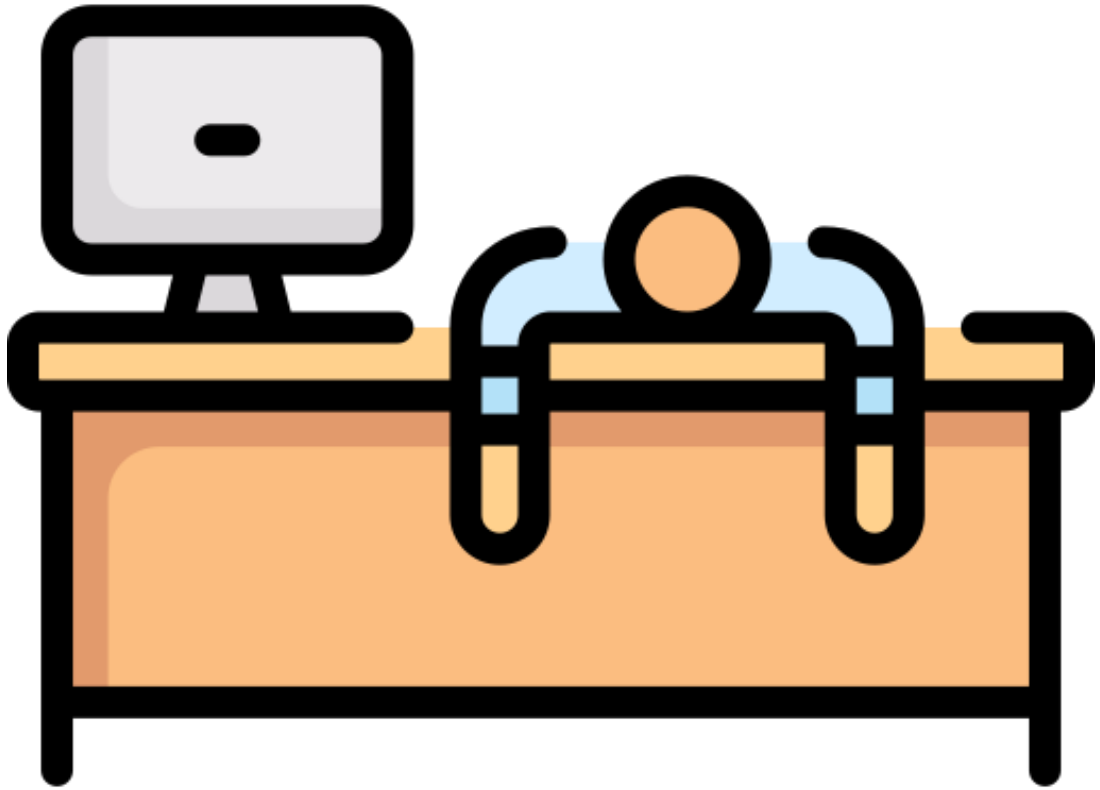

Input
Mesh
Variational Autoencoder
Output
Surrogate
Model
Gradient
Decent
Optimization
0.78
Performance
Indicator

SURROGATE MODEL

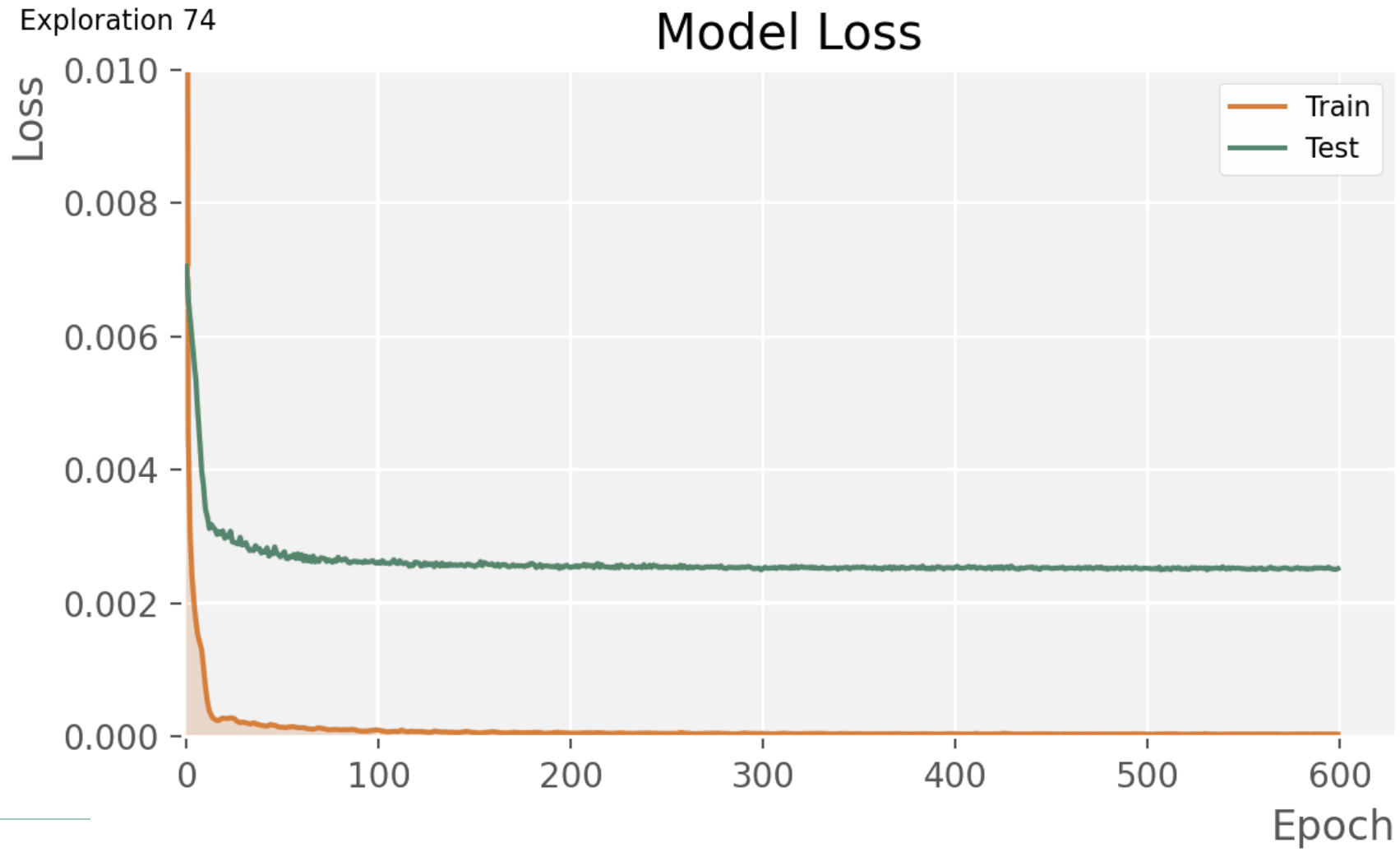
SURROGATE MODEL



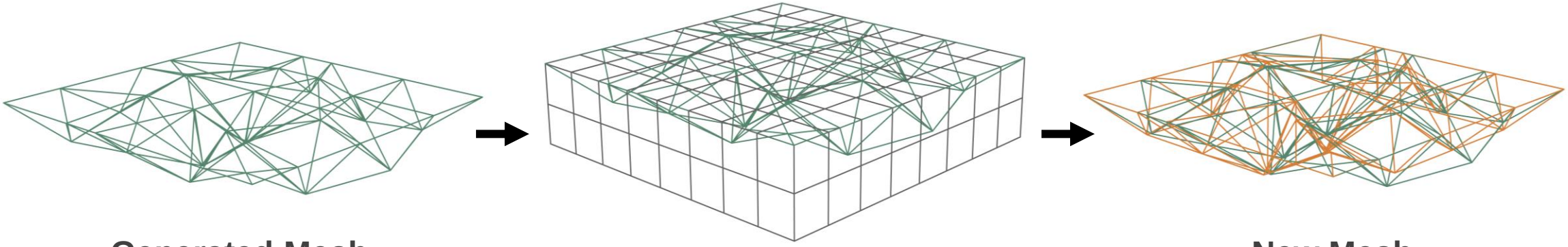
SURROGATE MODEL



SURROGATE MODEL



SURROGATE MODEL

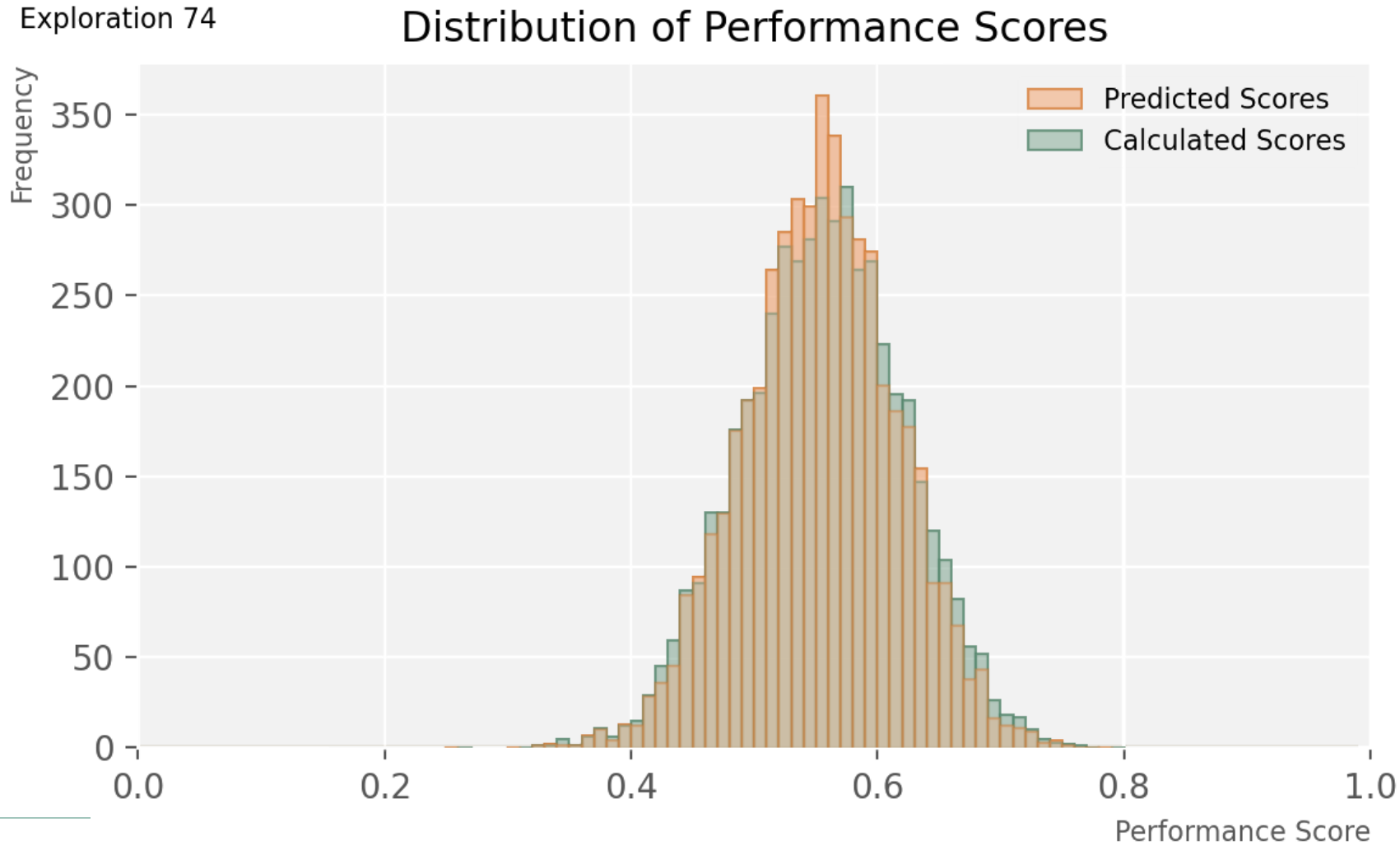


Generated Mesh
From existing dataset

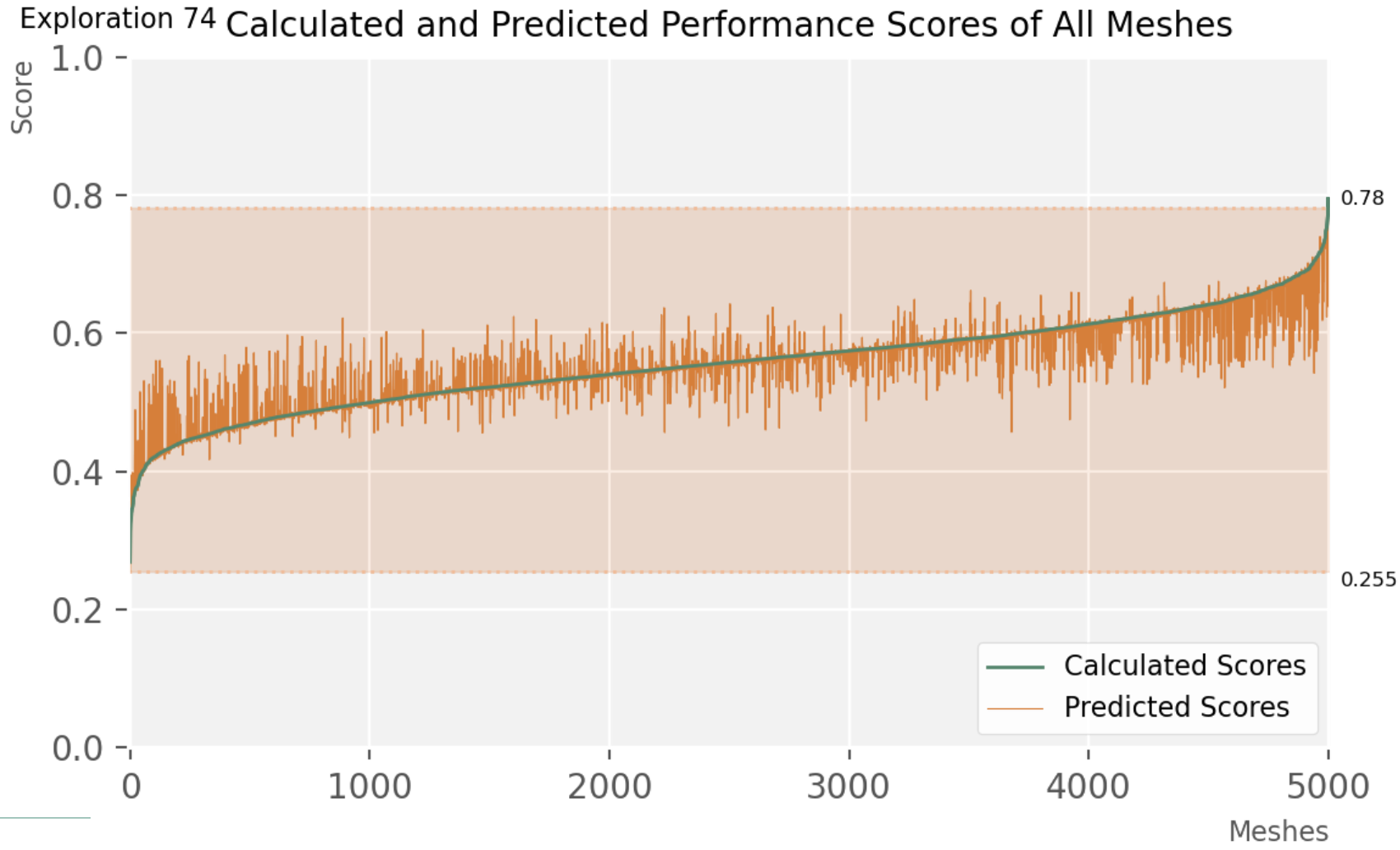
Fine Mesh Overlay
Used to create an adjacency matrix

New Mesh
With ~94% accuracy

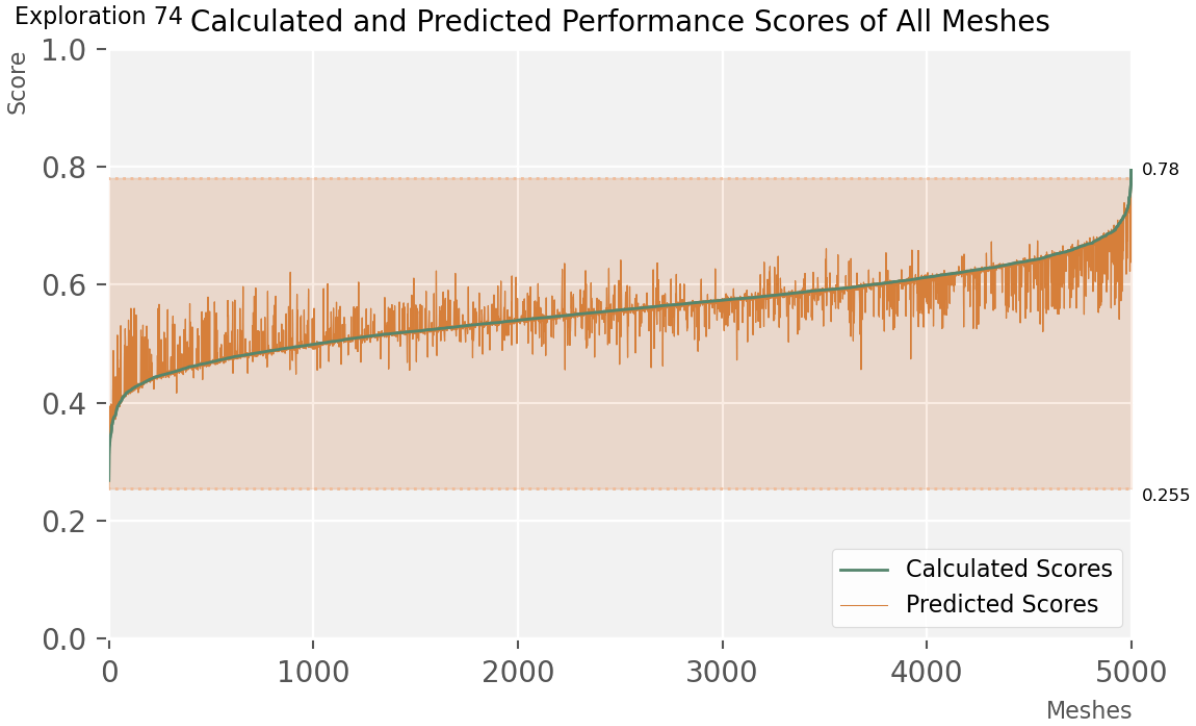
SURROGATE MODEL

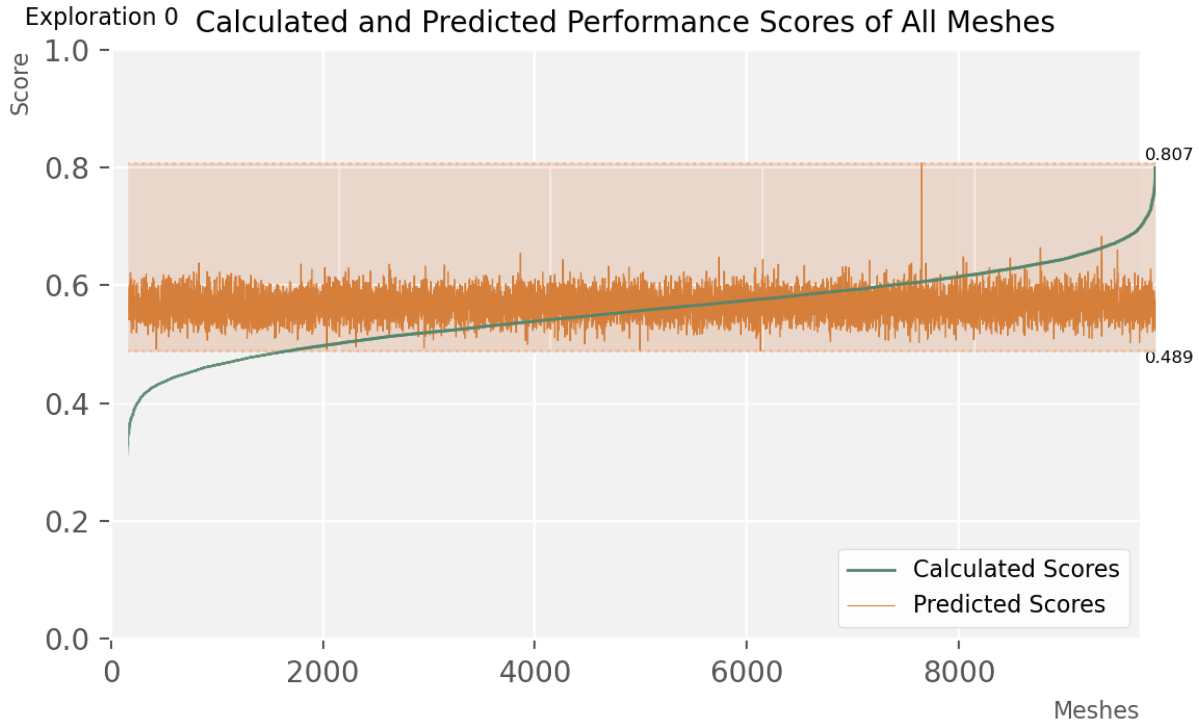


SURROGATE MODEL



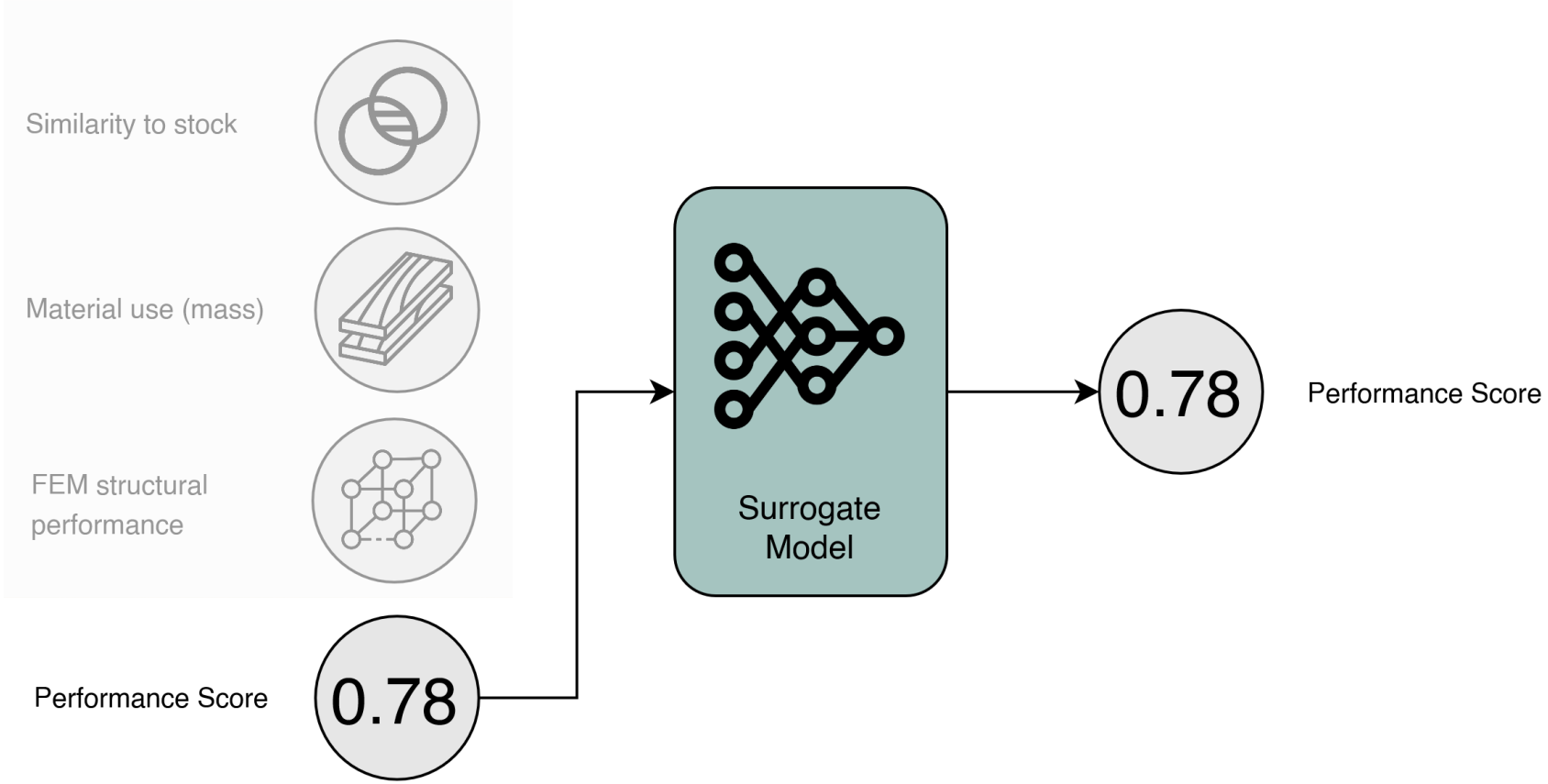
SURROGATE MODEL





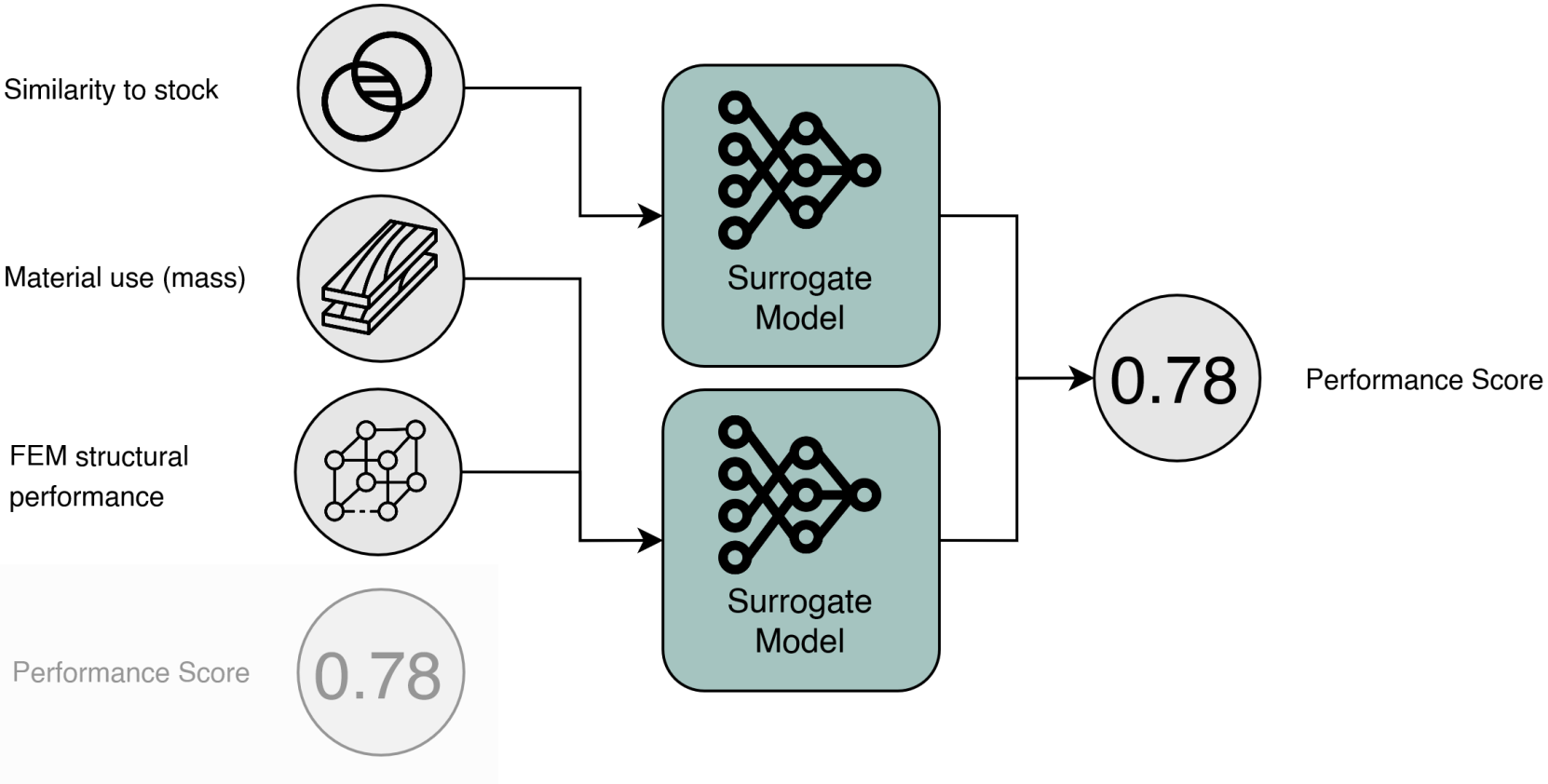
SURROGATE MODEL

Design Option 1



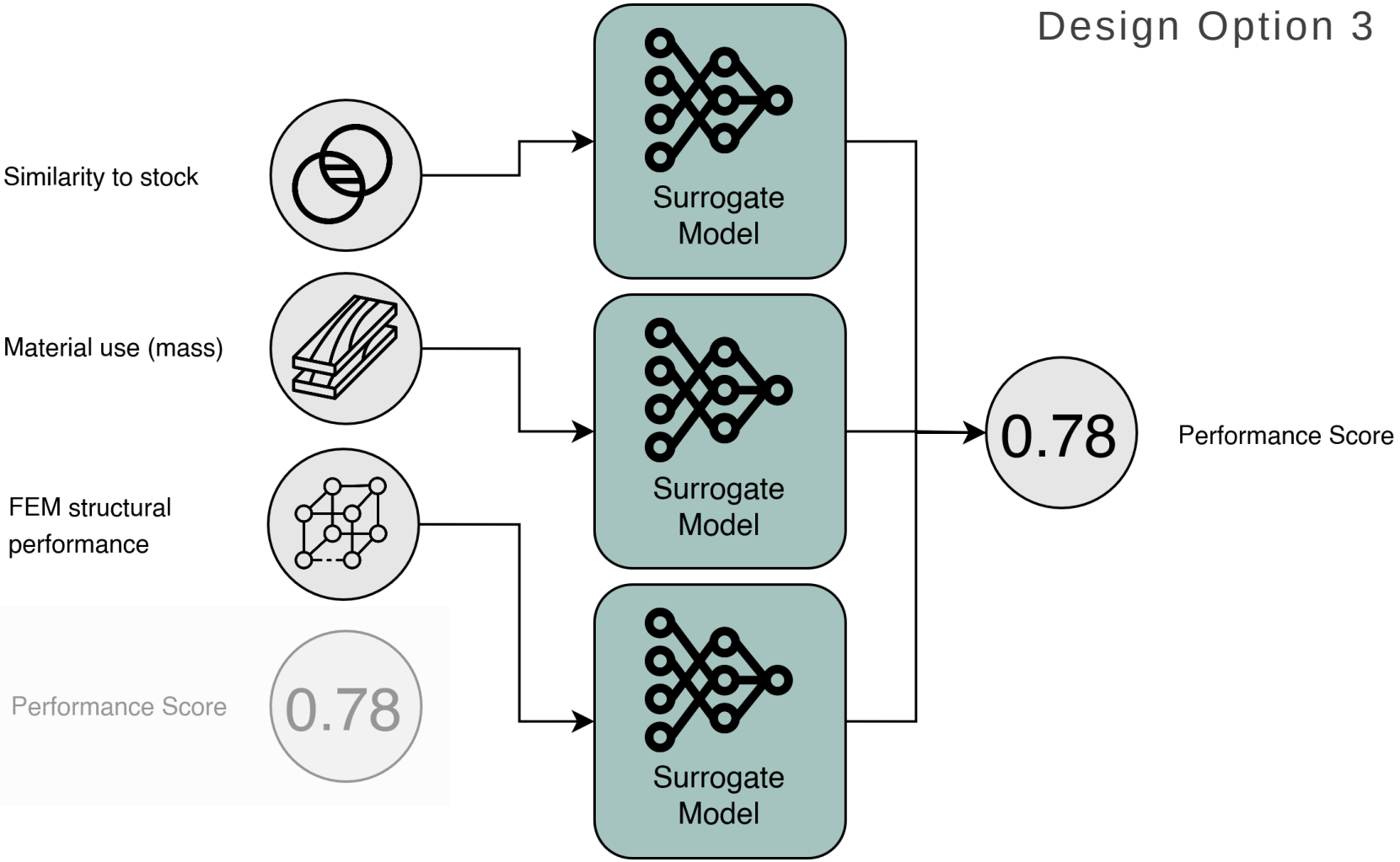
SURROGATE MODEL

Design Option 2



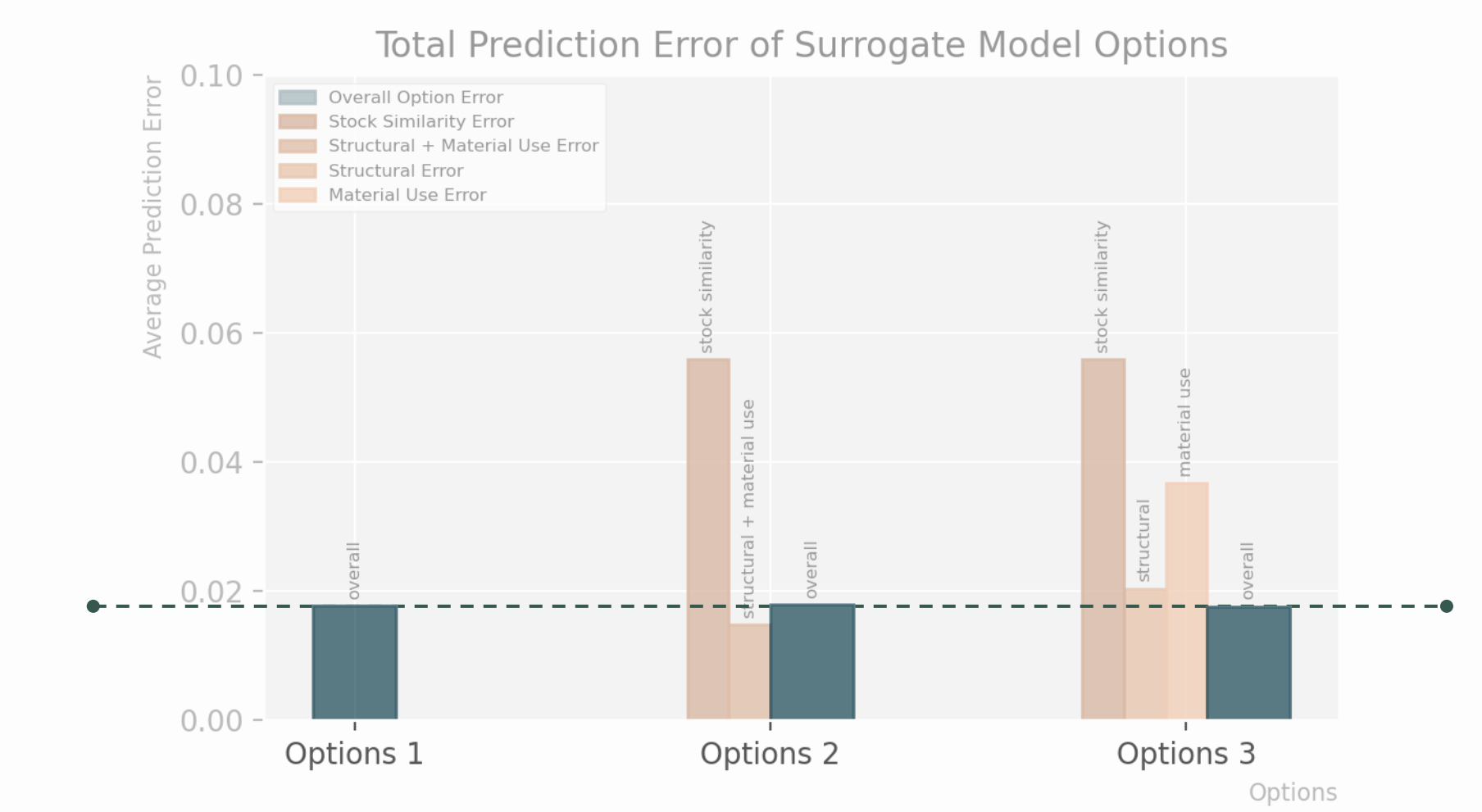
SURROGATE MODEL

Design Option 3



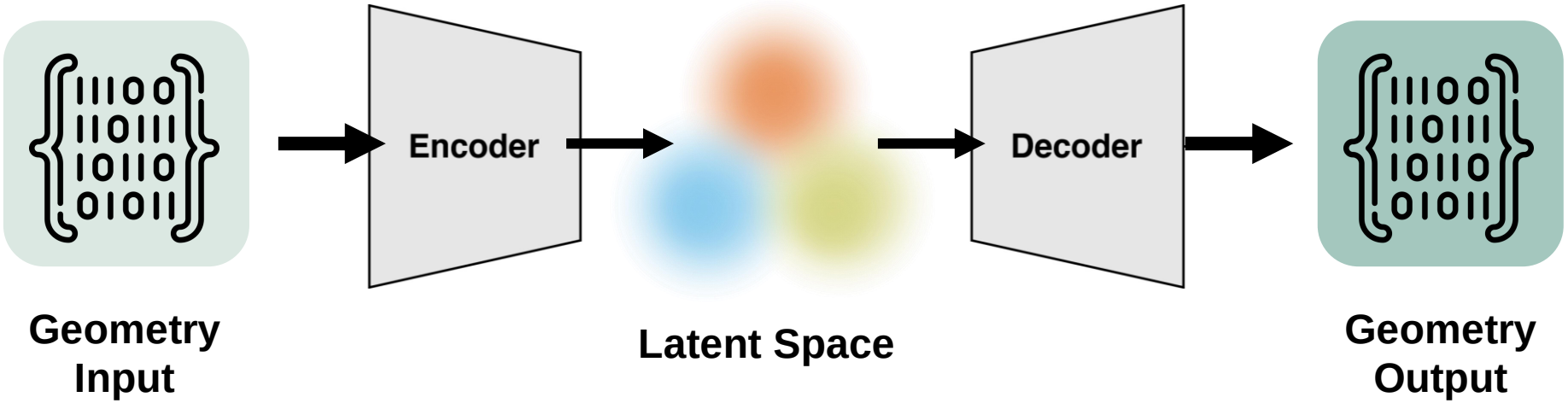
Performance Score 0.78

SURROGATE MODEL

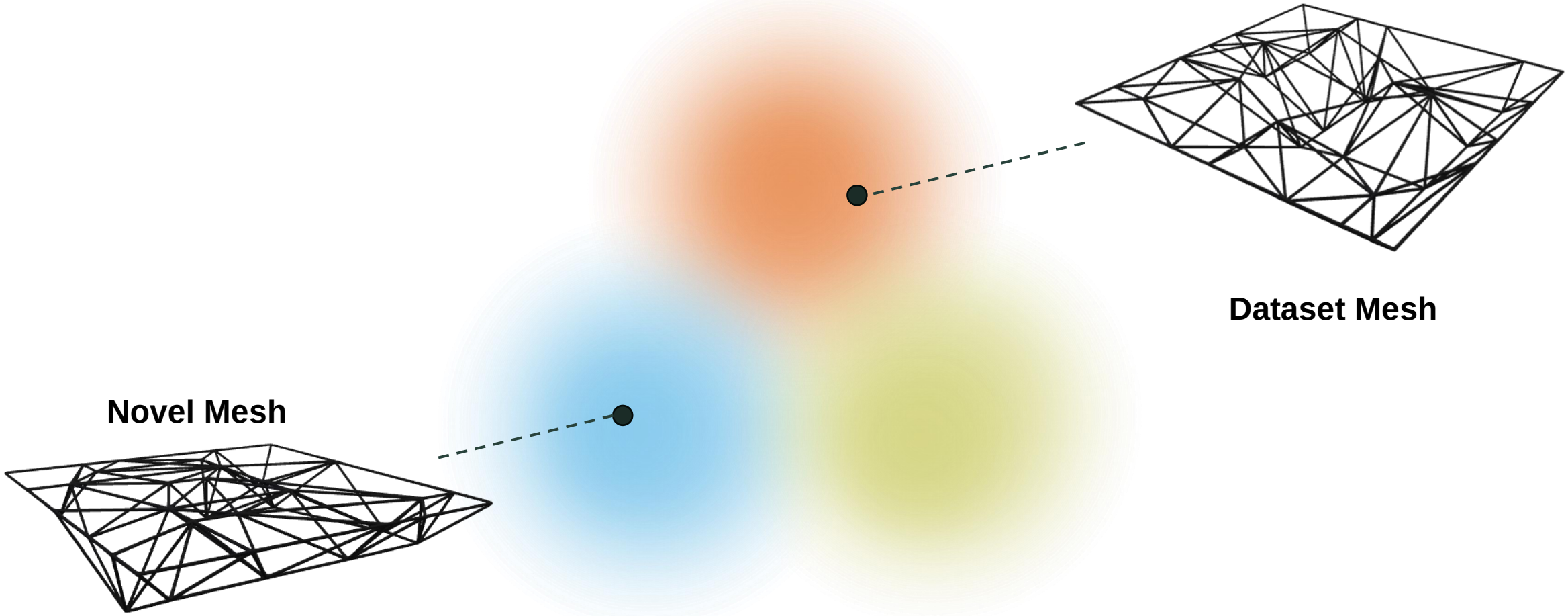


VARIATIONAL AUTOENCODER

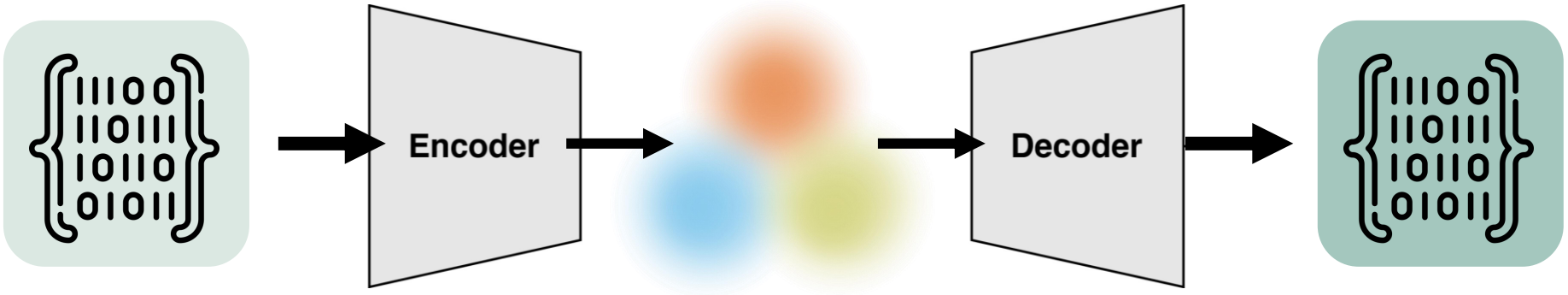
VARIATIONAL AUTOENCODER



VARIATIONAL AUTOENCODER



VARIATIONAL AUTOENCODER

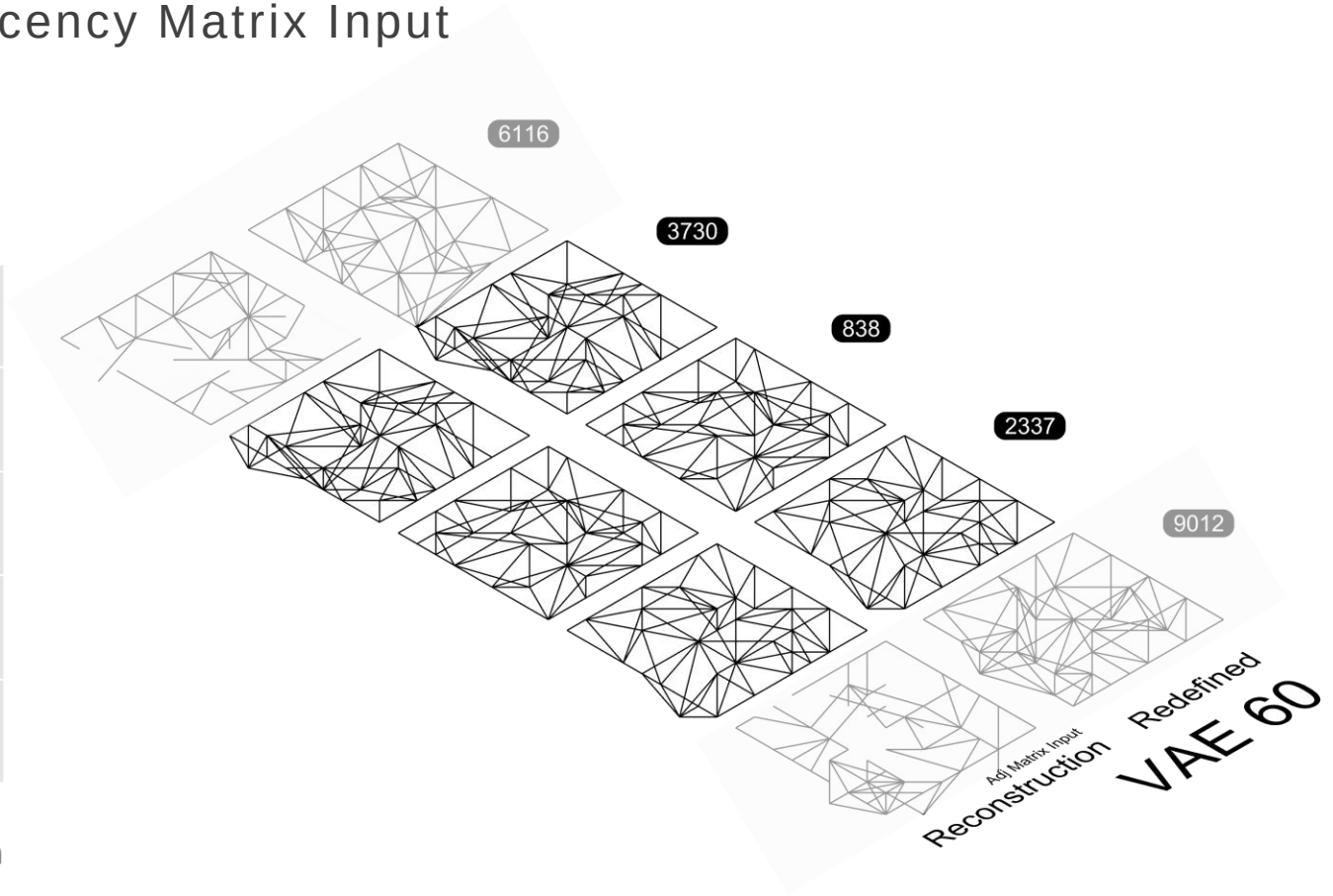


Loss type 2:
Regularization term

Loss type 1:
Reconstruction term

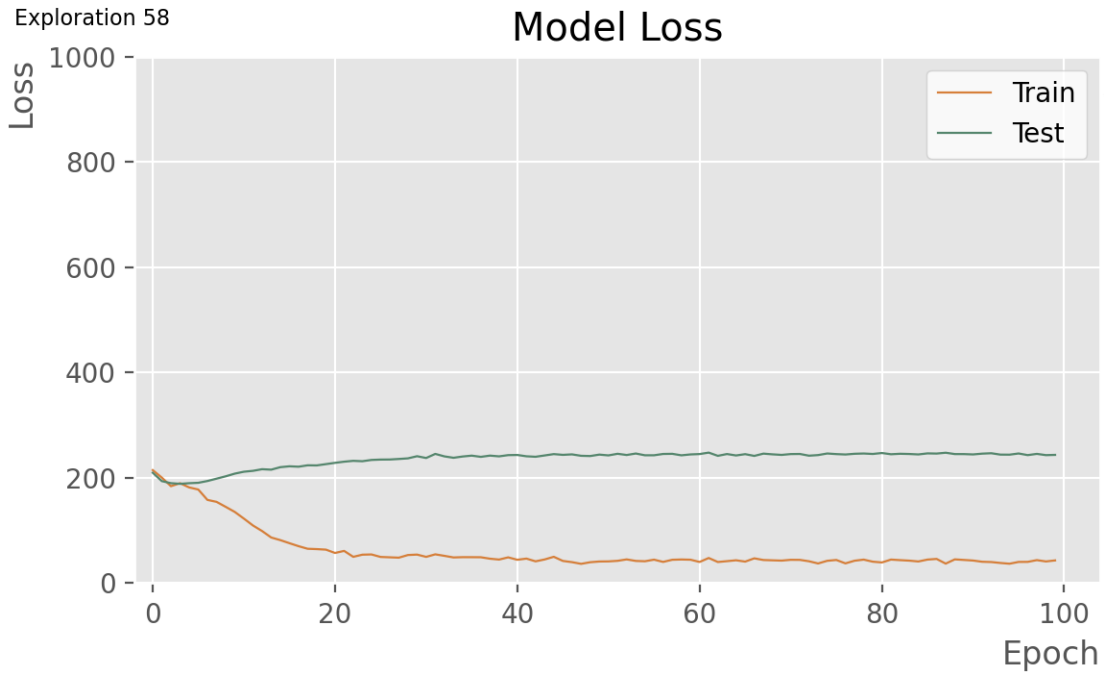
VARIATIONAL AUTOENCODER

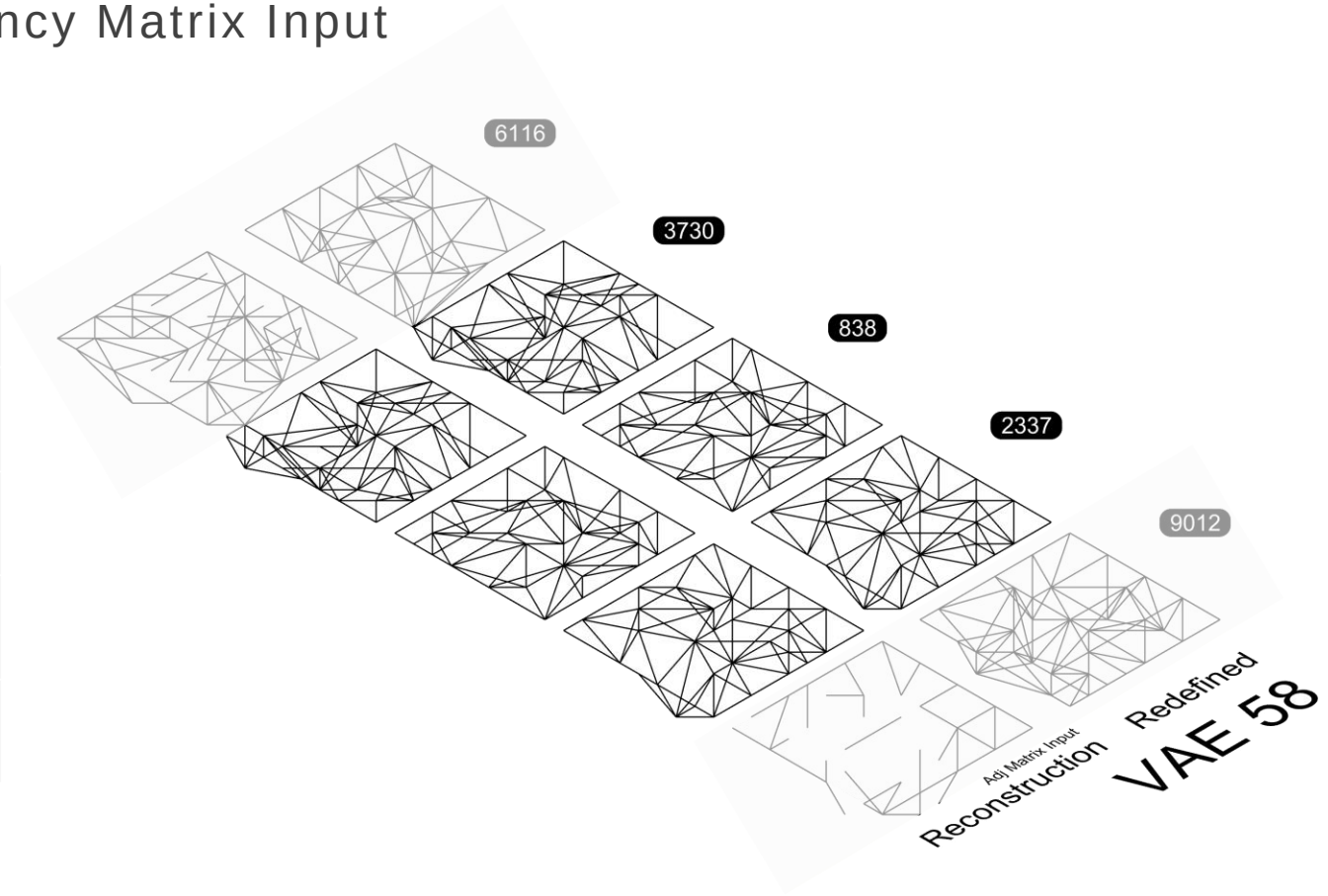
Densely-Connected VAE
Half Adjacency Matrix Input



VARIATIONAL AUTOENCODER

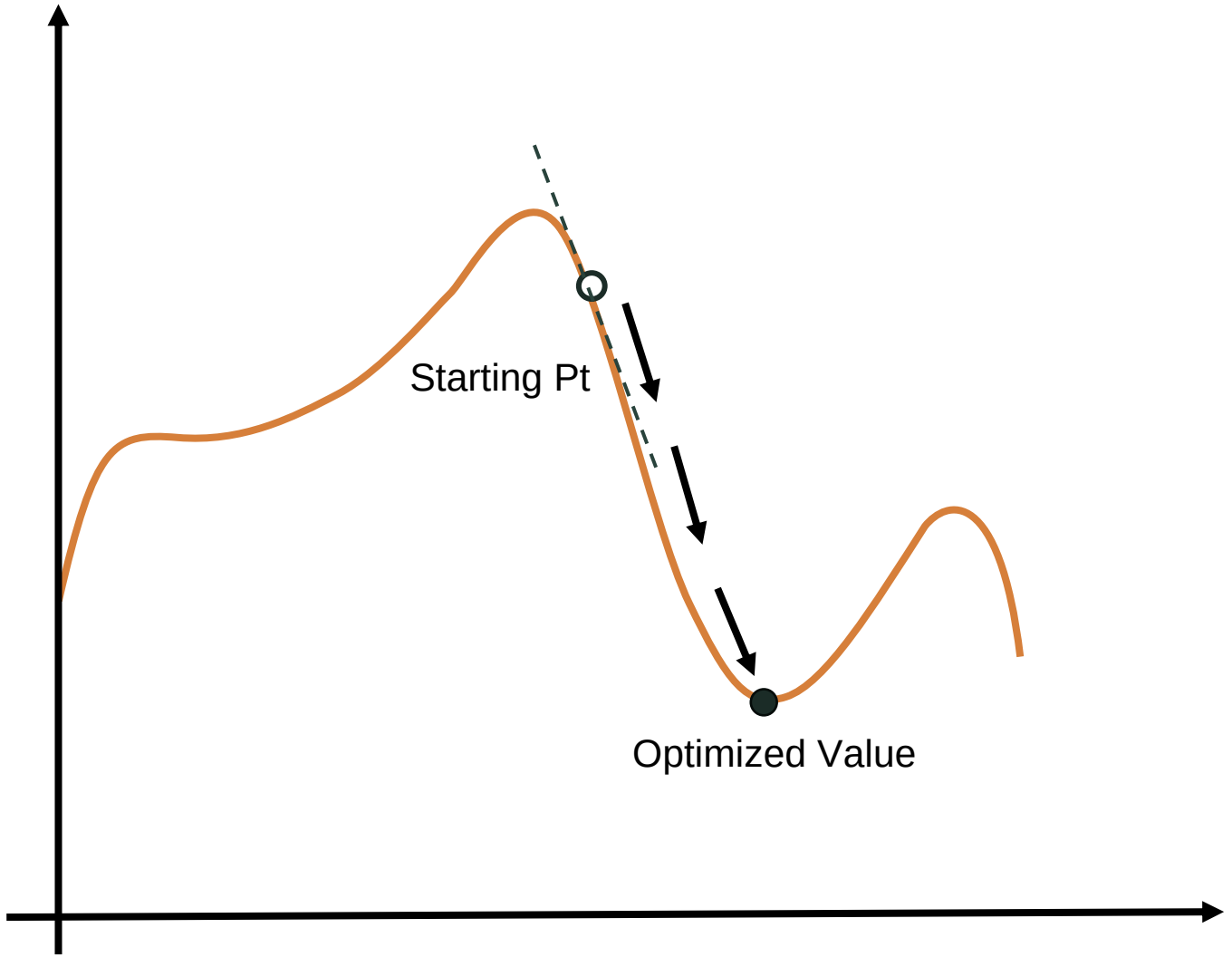
Convolutional VAE
Adjacency Matrix Input



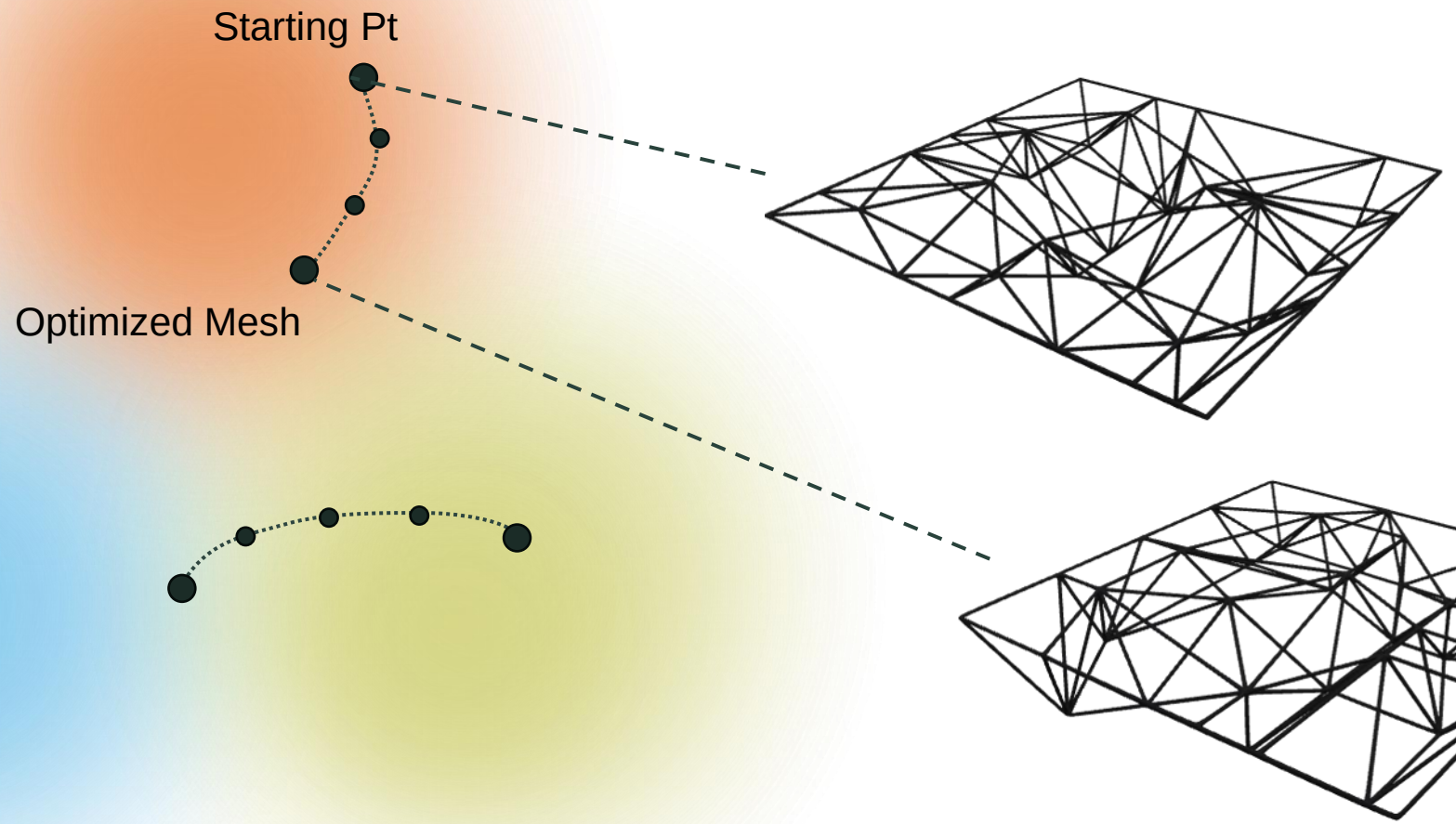


GRADIENT DESCENT ALGORITHM

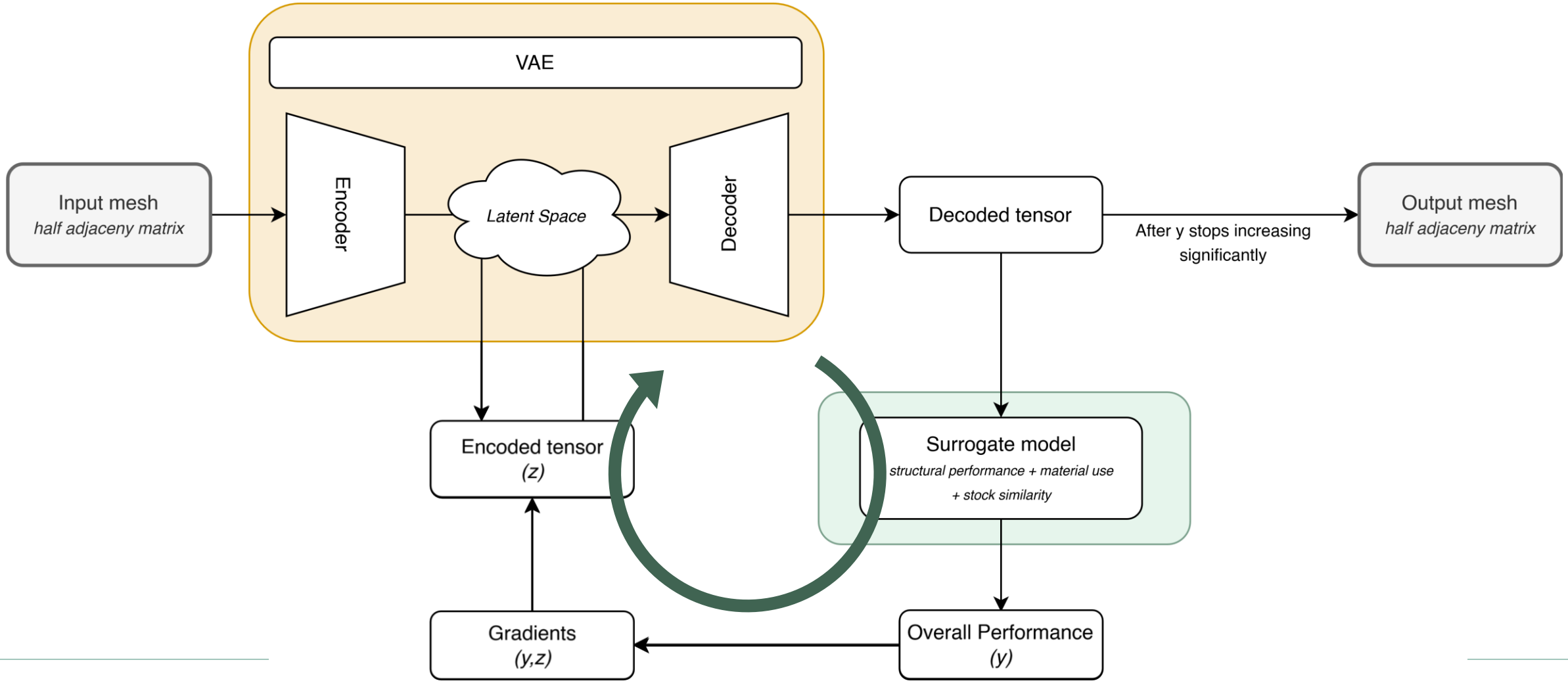
GRADIENT DESCENT



GRADIENT DESCENT

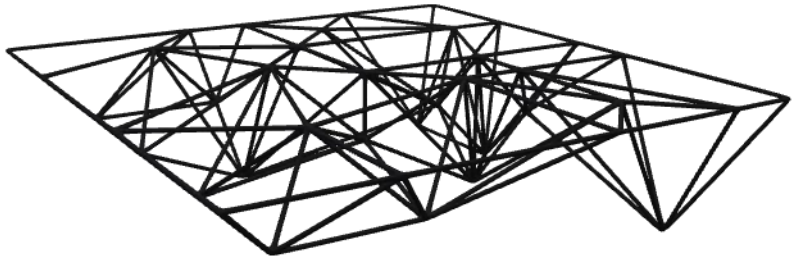


GRADIENT DESCENT

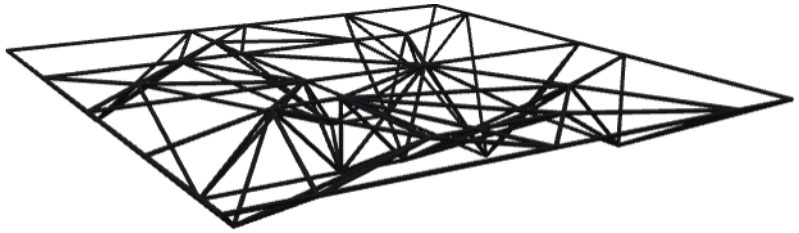


TESTED MESHES

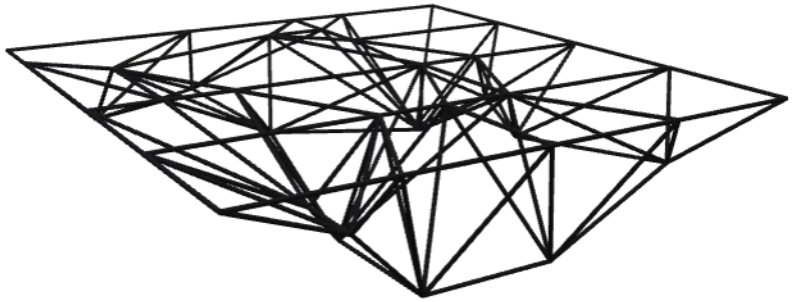
Mesh 1665



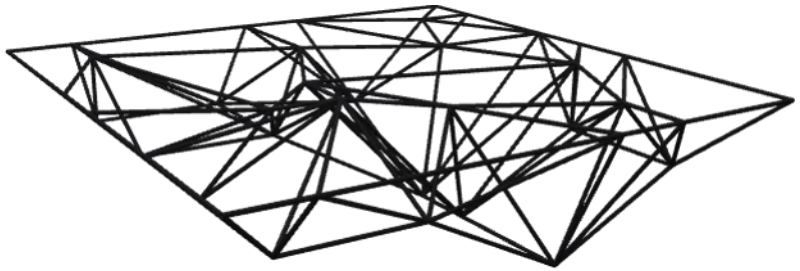
Mesh 2337



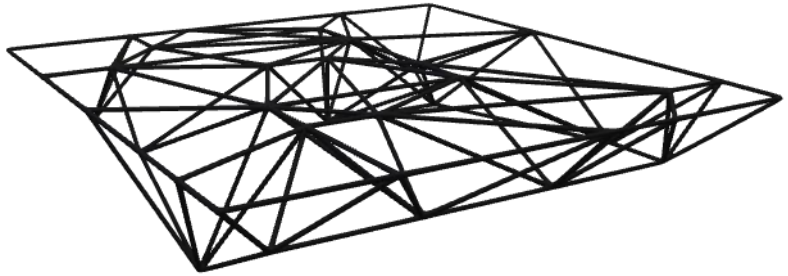
Mesh 1692



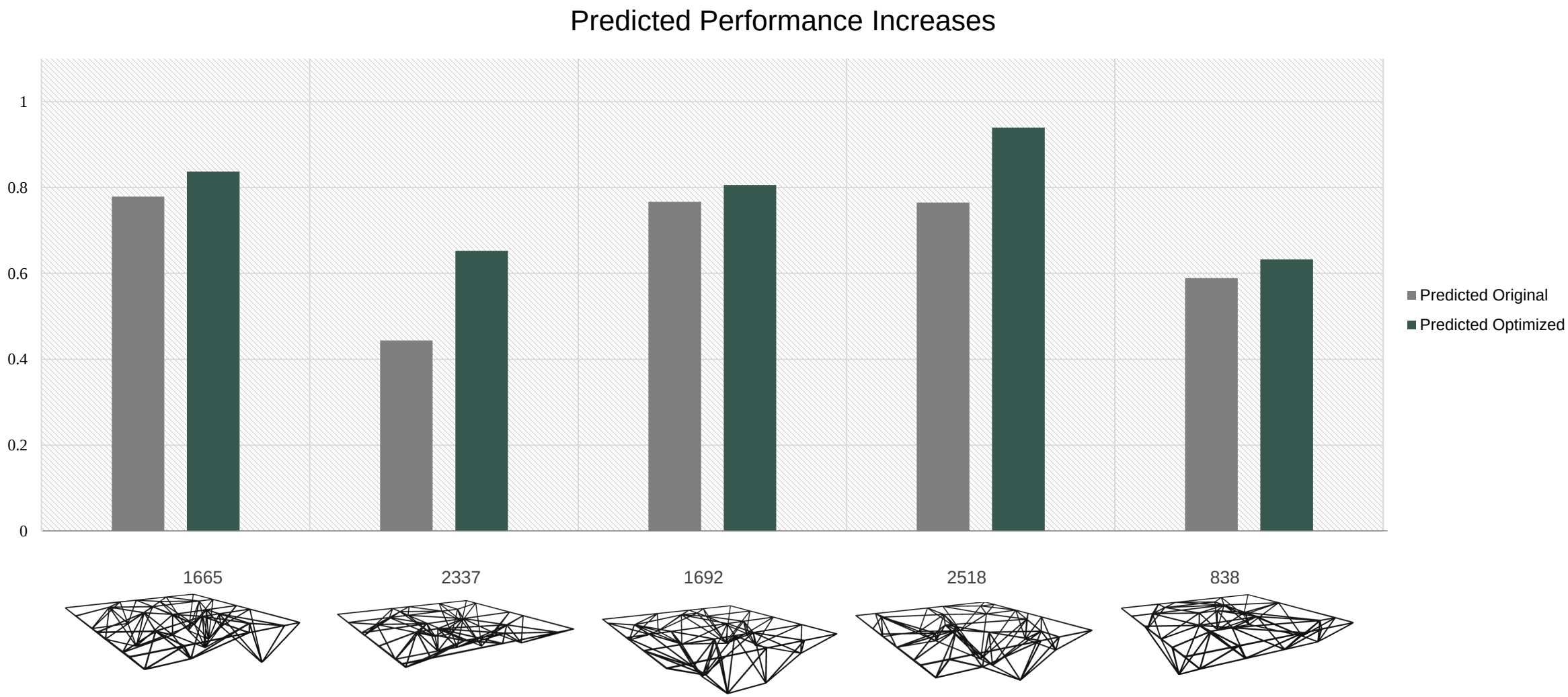
Mesh 2518



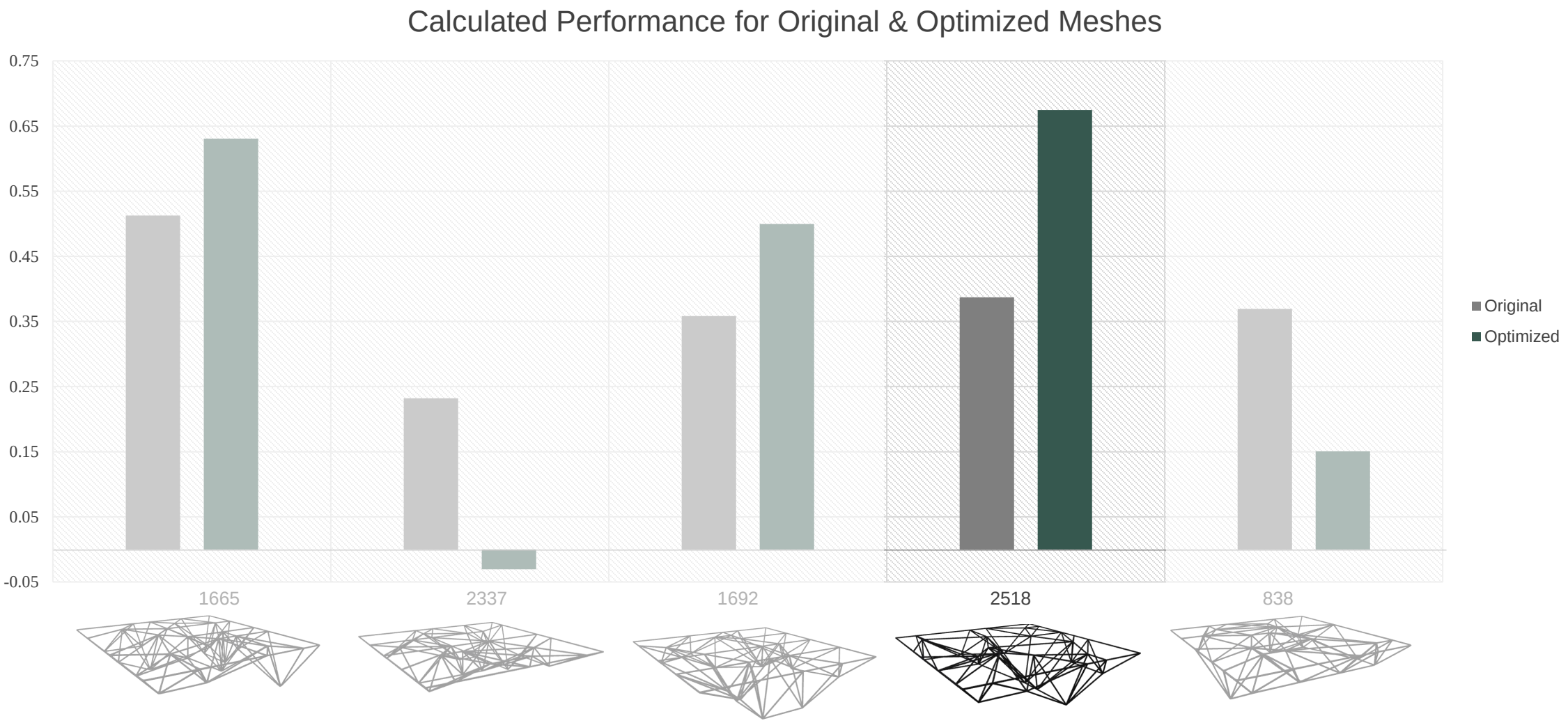
Mesh 838



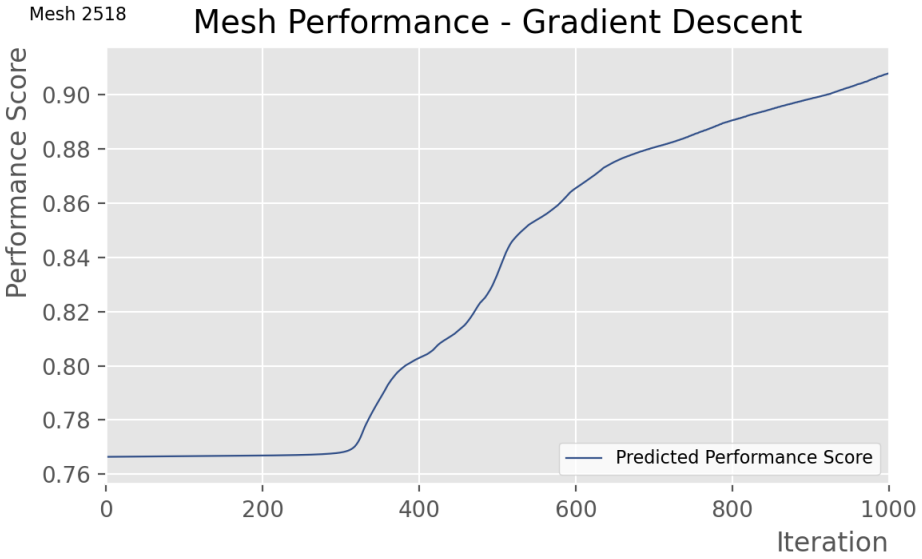
GRADIENT DESCENT

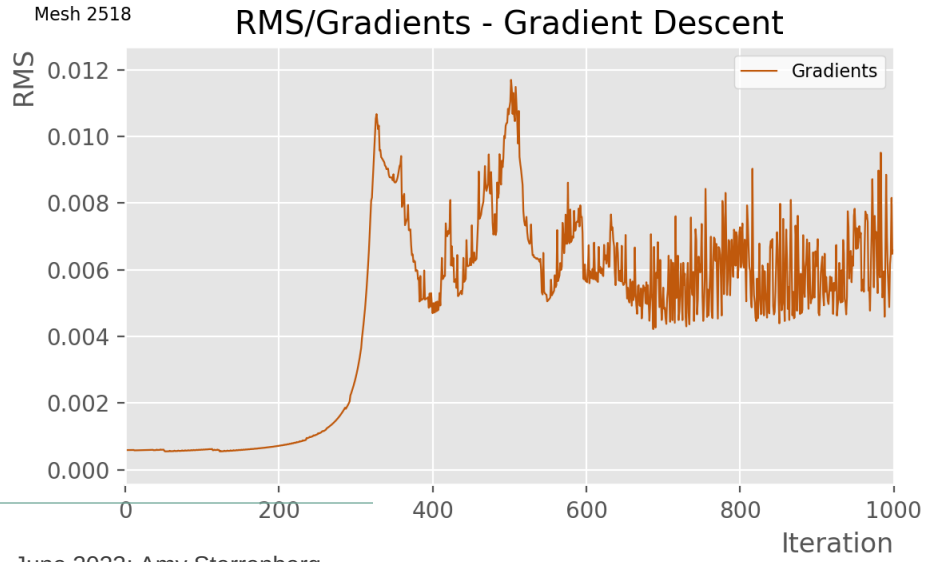


GRADIENT DESCENT

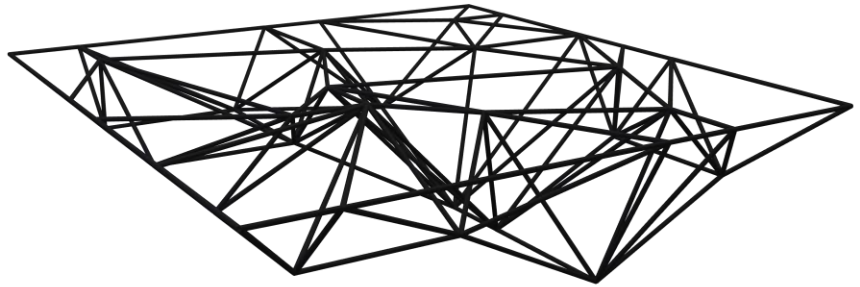


GRADIENT DESCENT

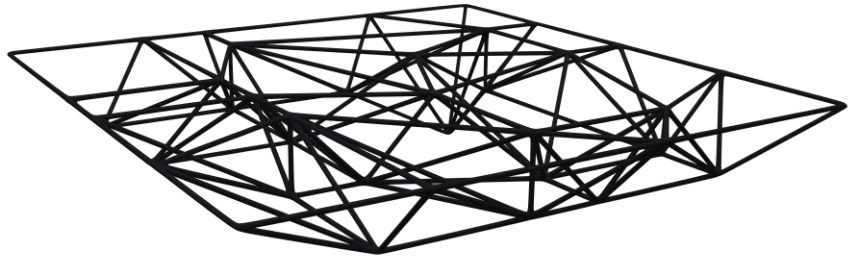




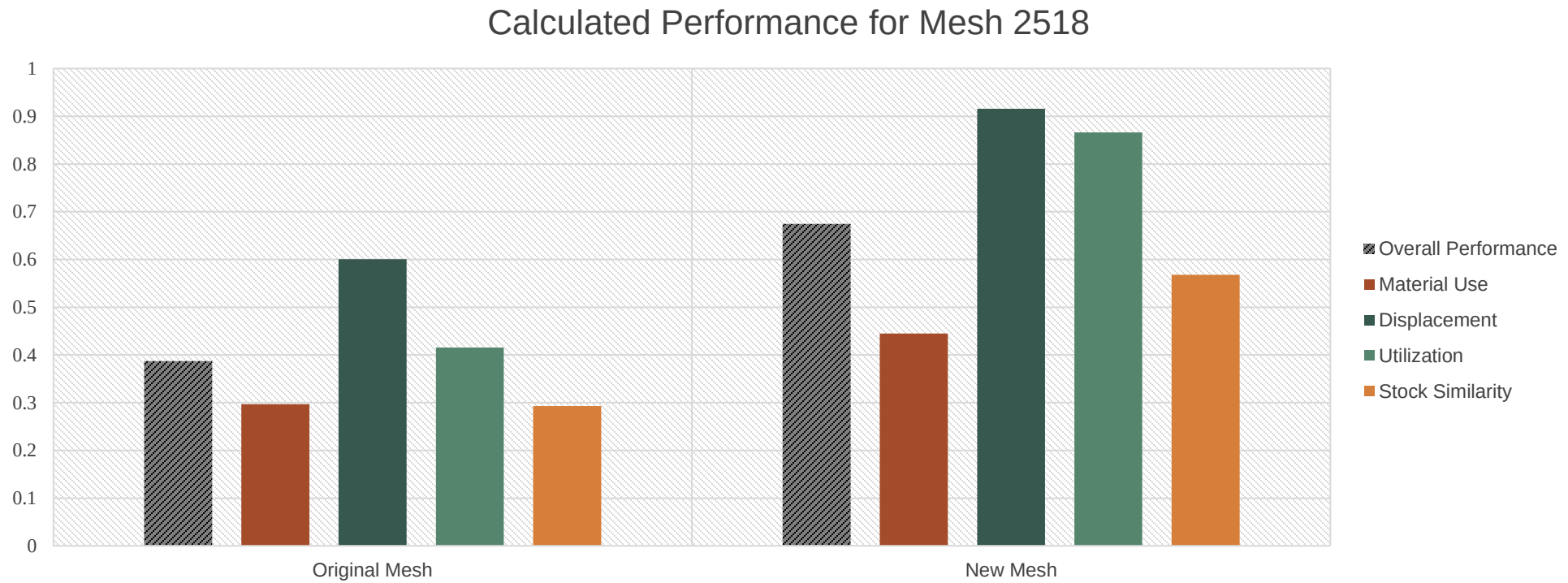
Mesh 2518
(original)



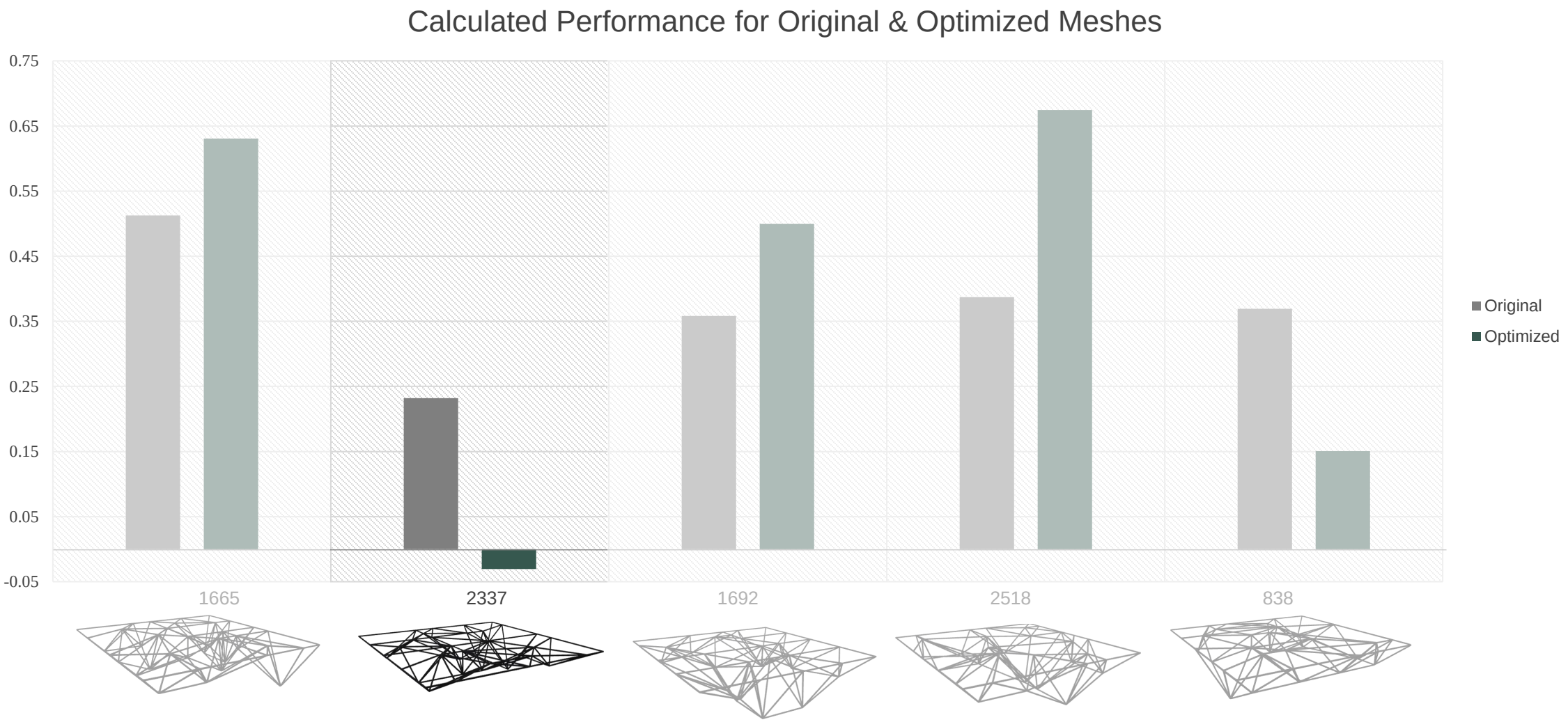
(optimized)



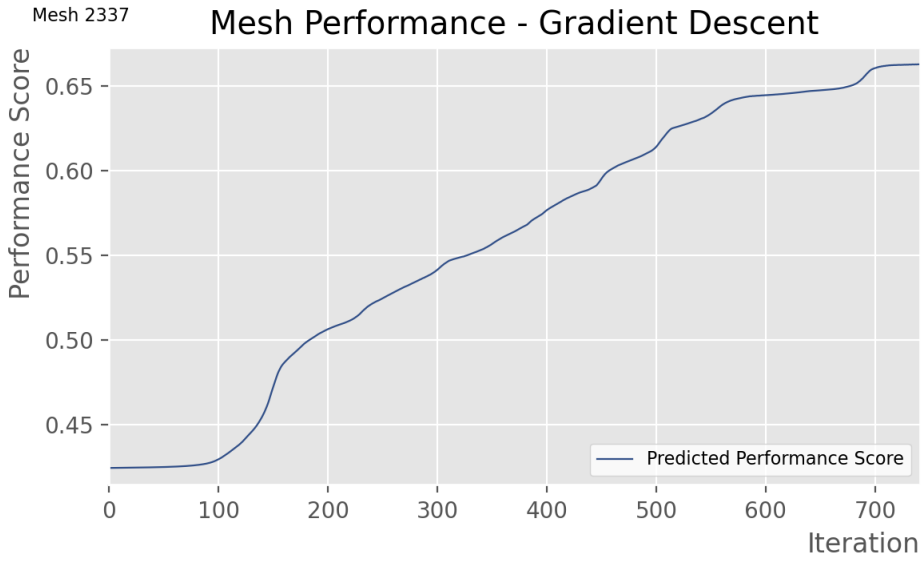
GRADIENT DESCENT

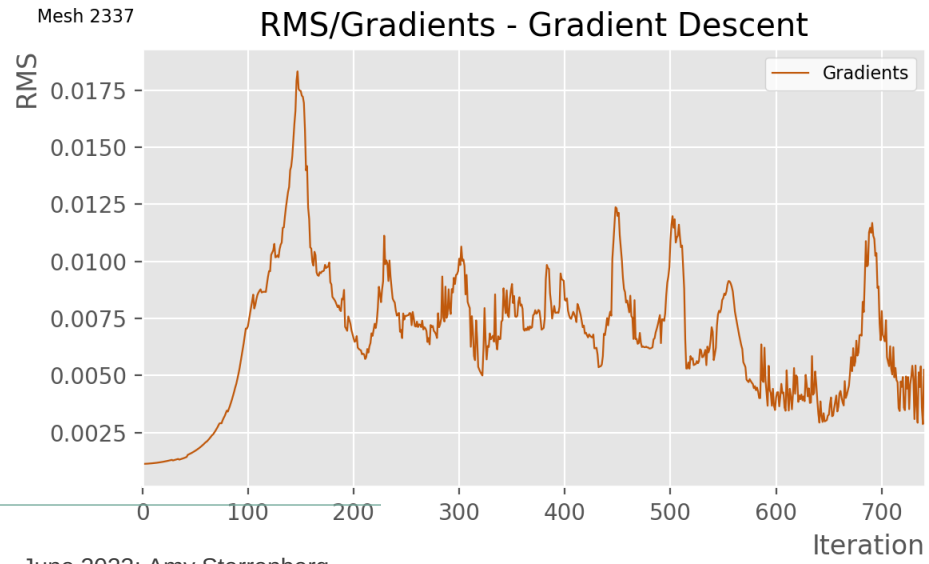


GRADIENT DESCENT

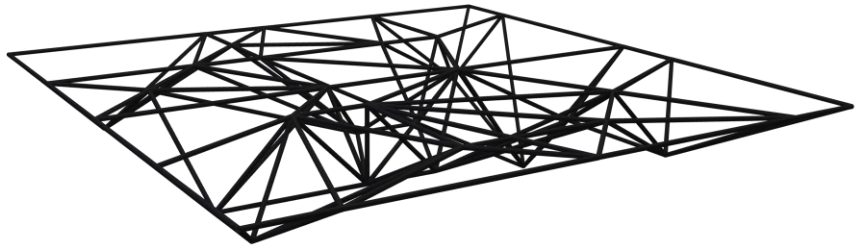


GRADIENT DESCENT

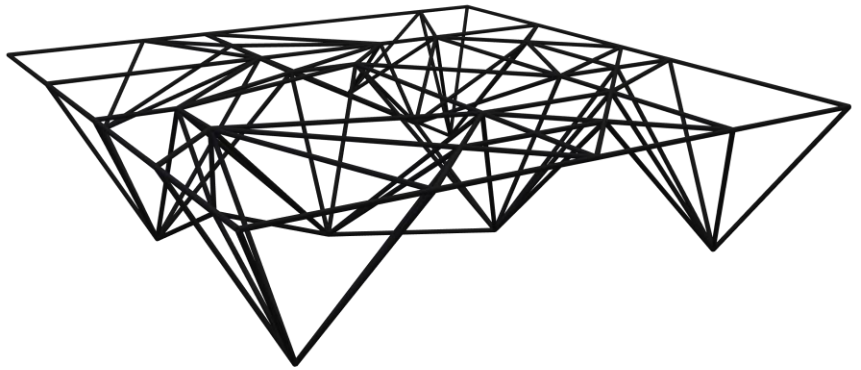




Mesh 2337
(original)

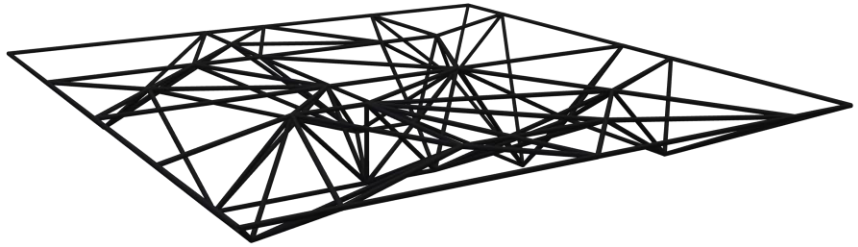


(optimized)

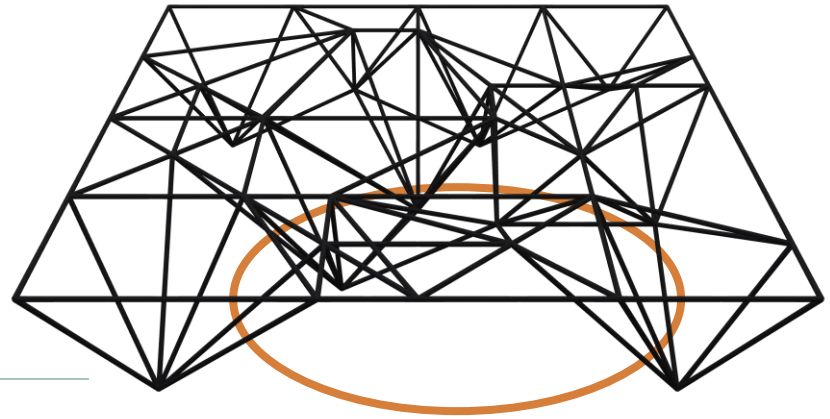


GRADIENT DESCENT

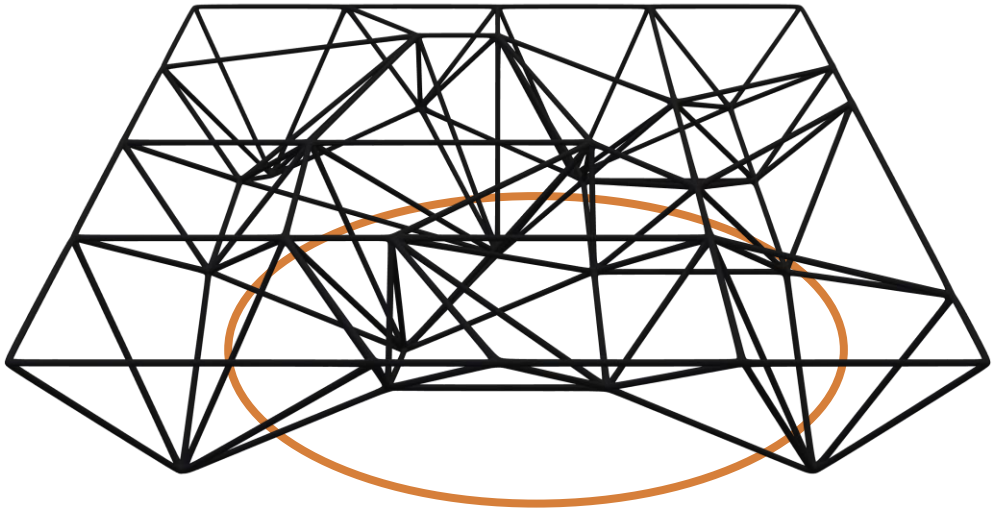
Mesh 2337
(original)



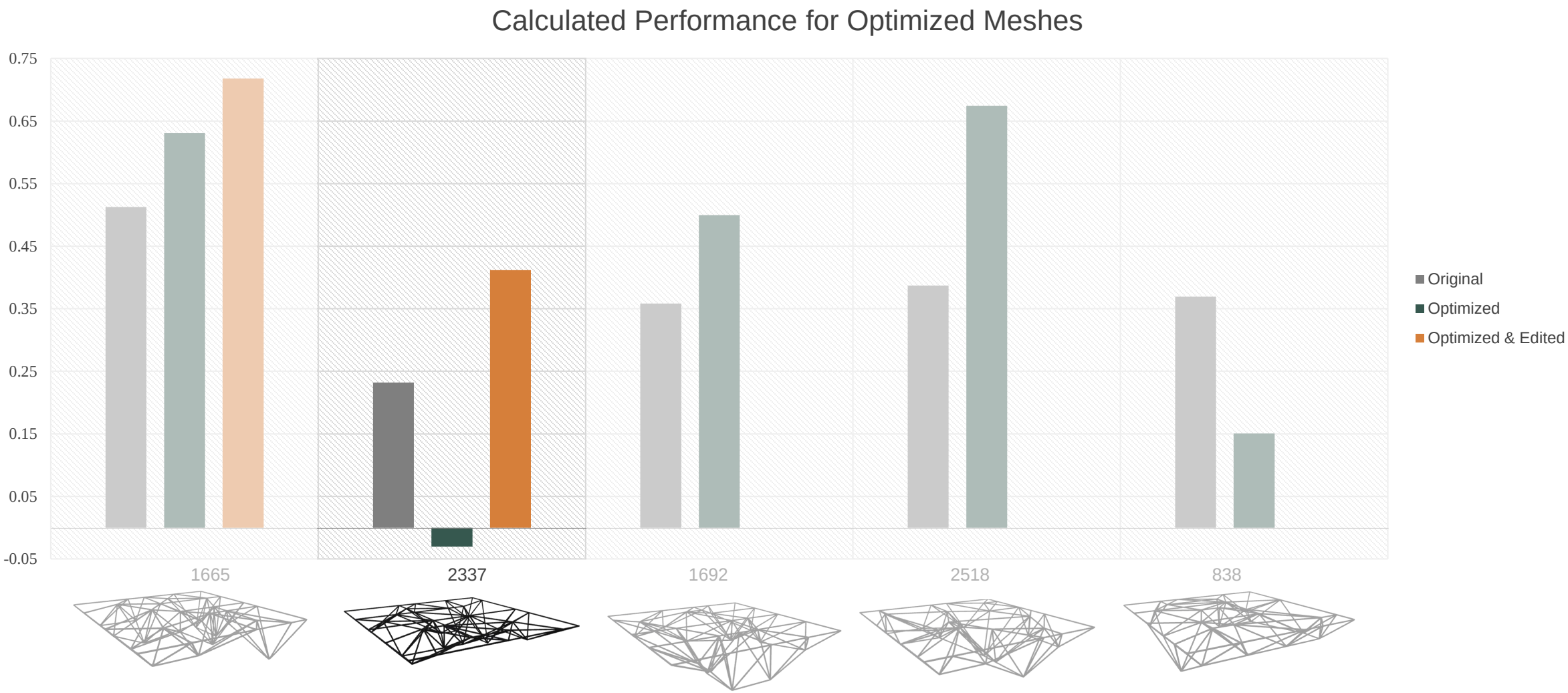
(optimized)



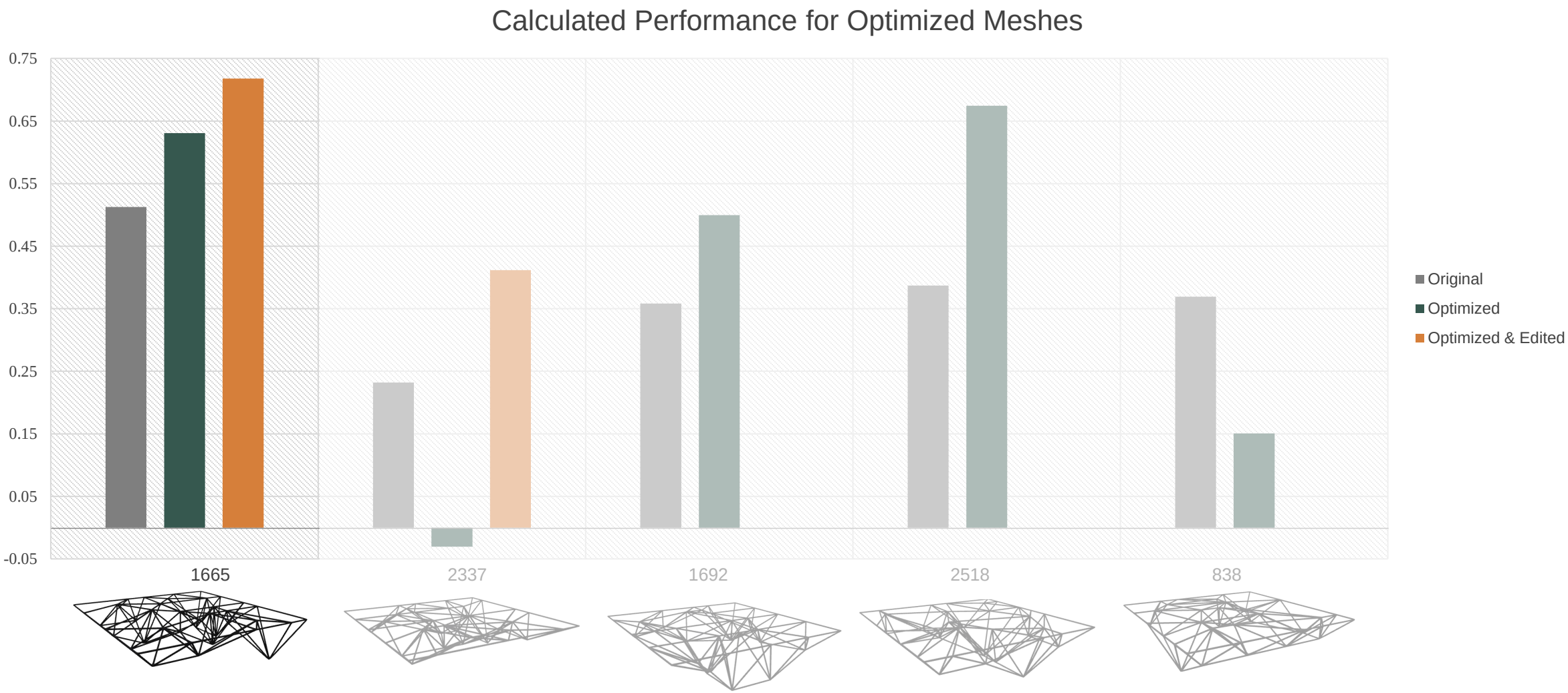
(optimized & edited)



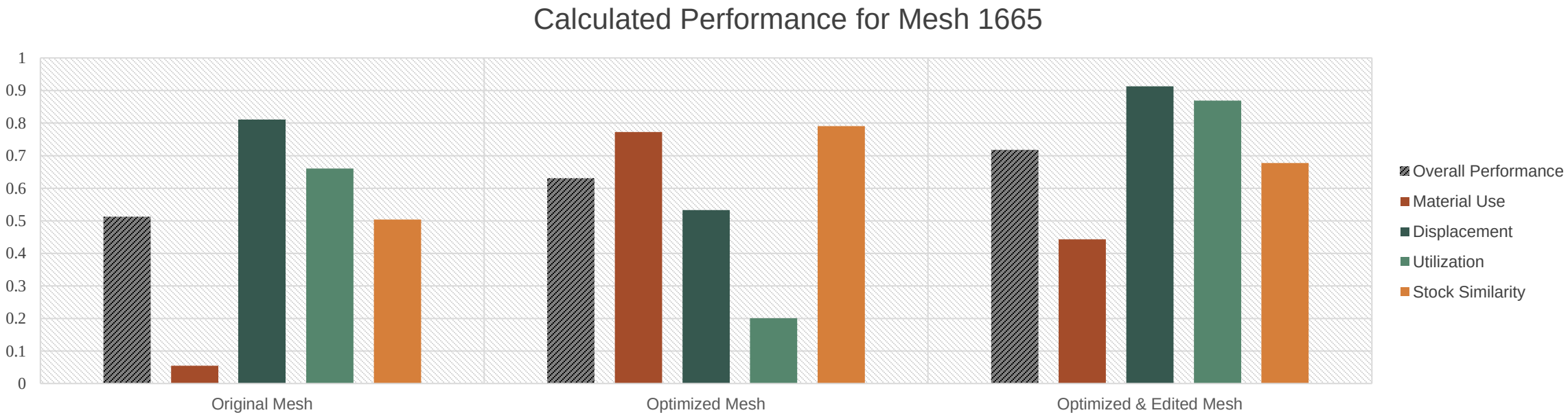
GRADIENT DESCENT

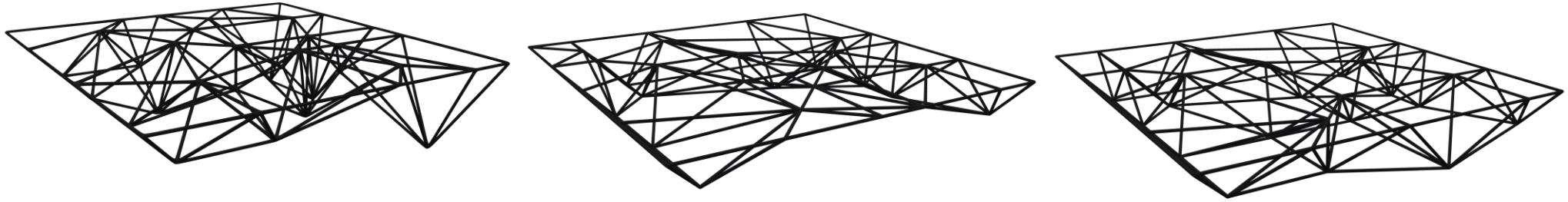


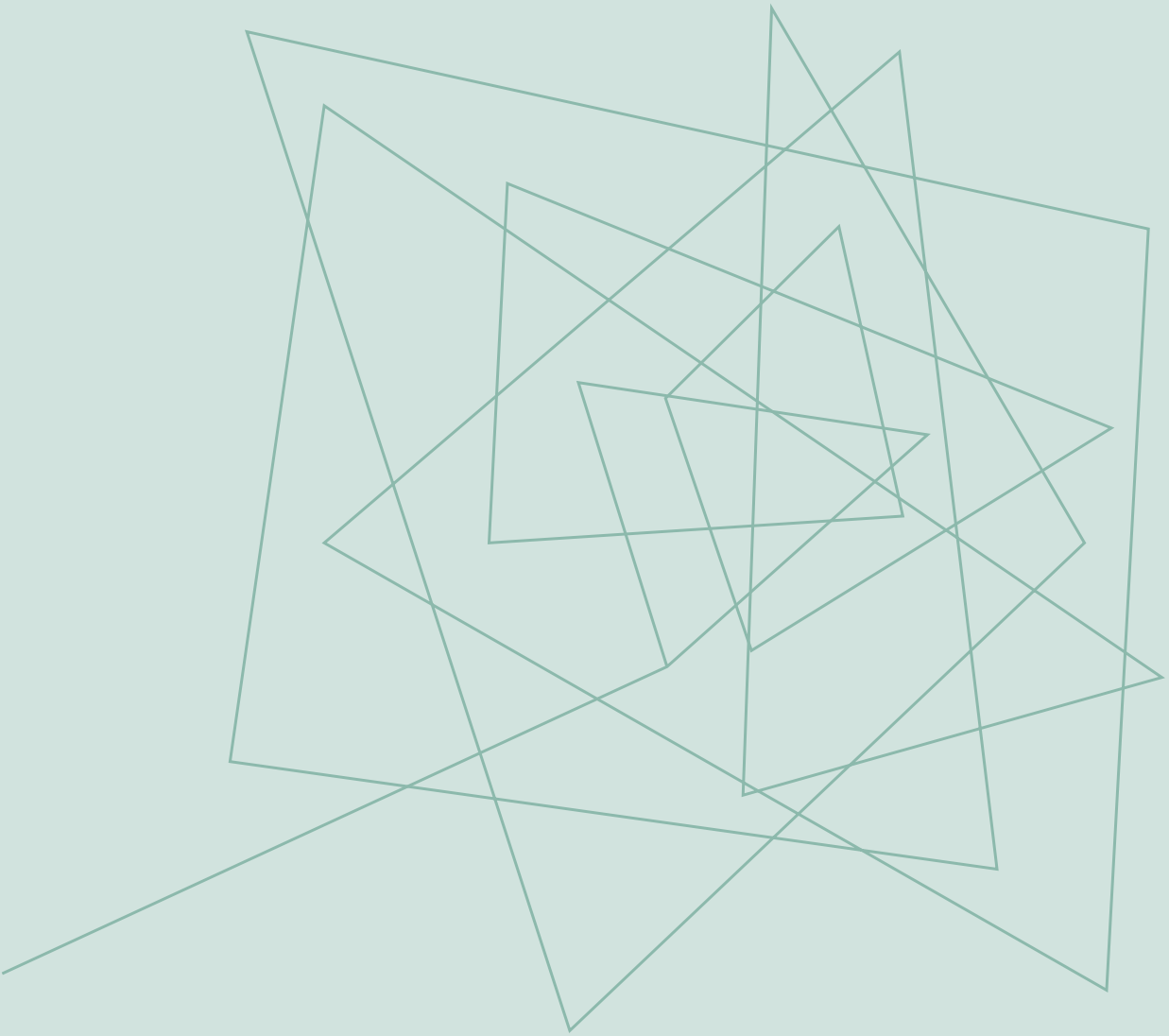
GRADIENT DESCENT



GRADIENT DESCENT

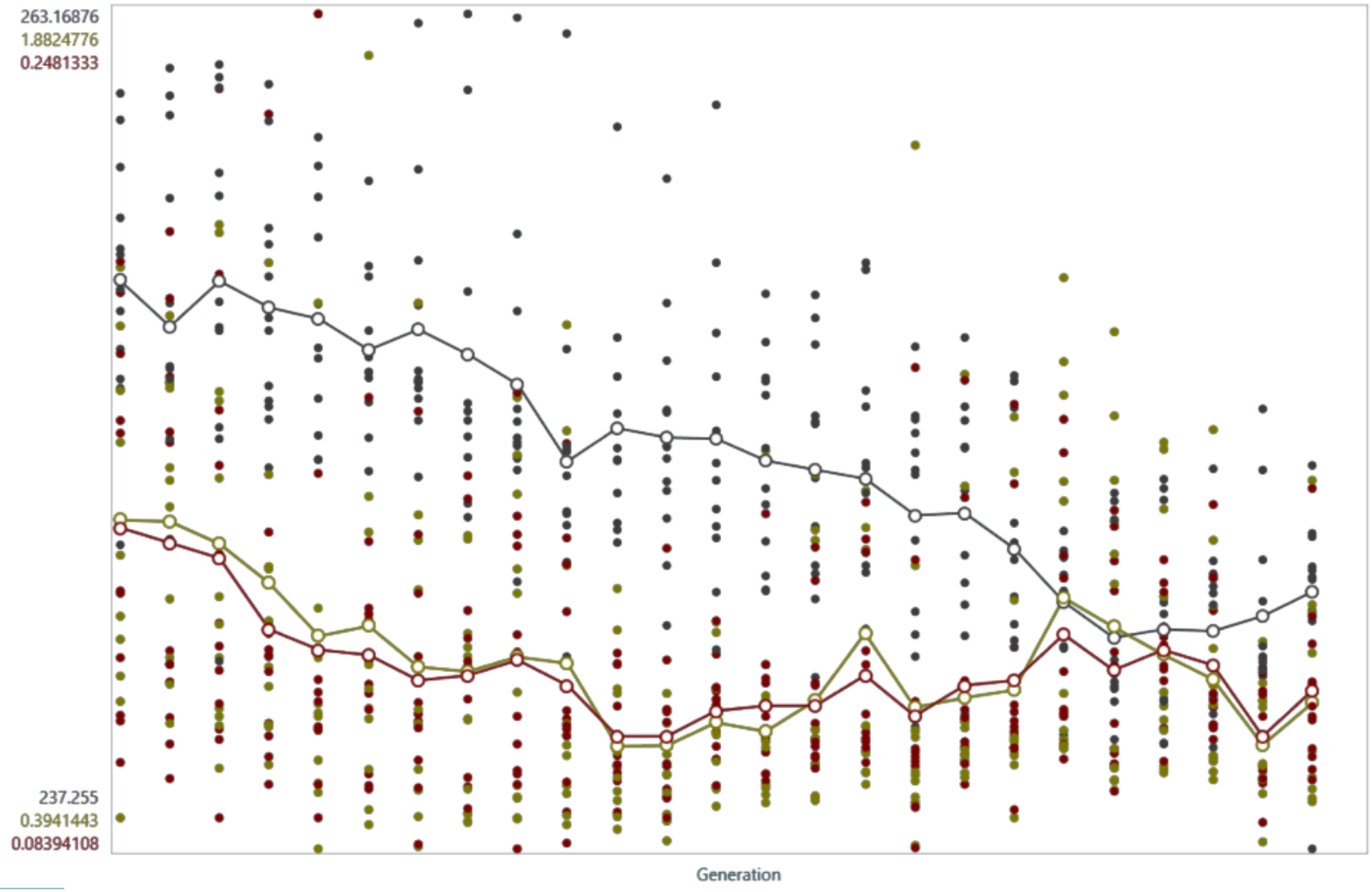




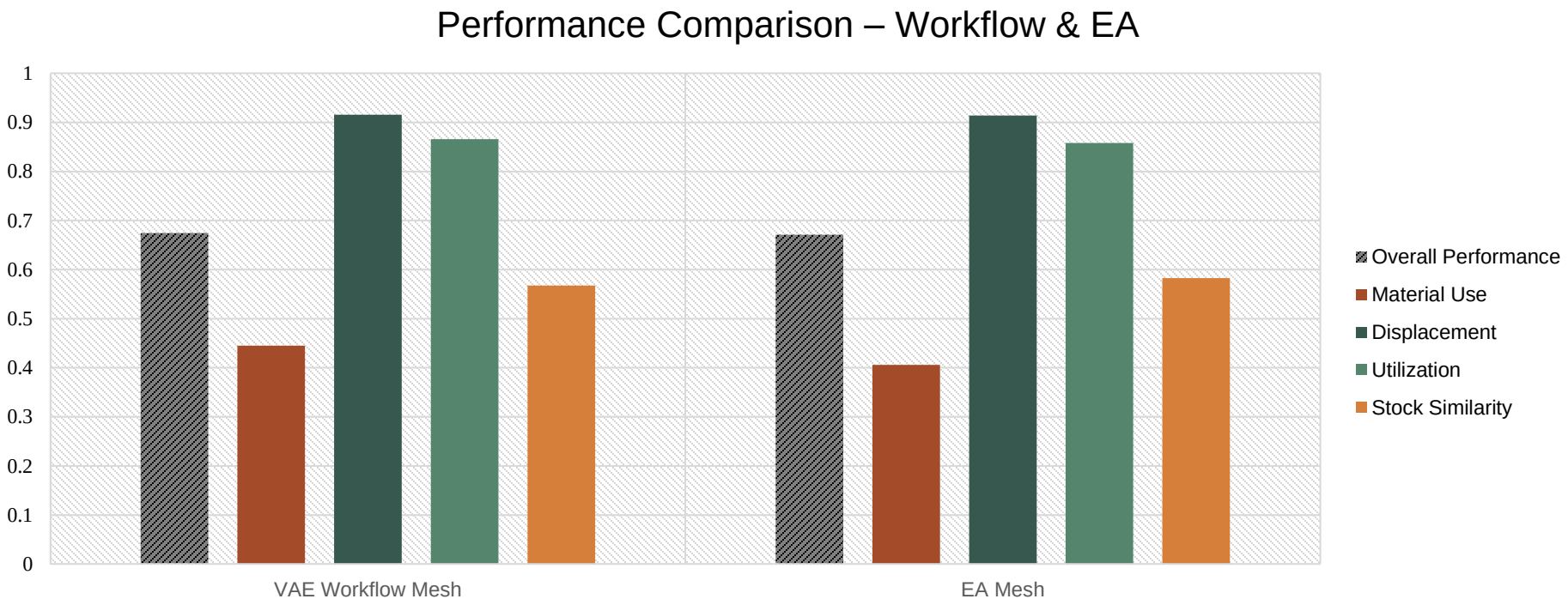


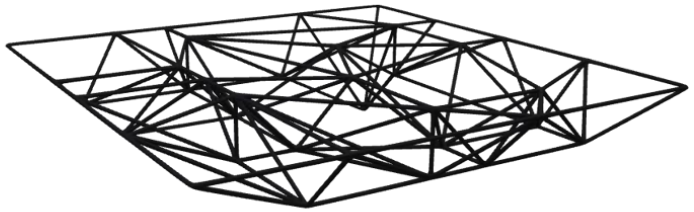
WORKFLOW PERFORMANCE COMPARISON

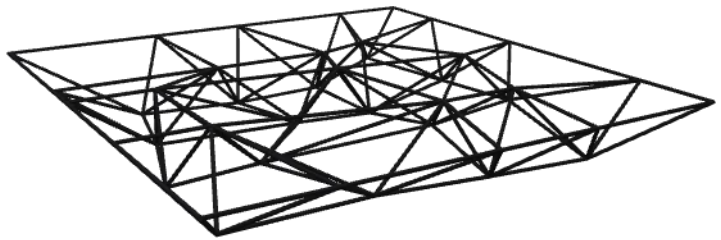
EVOLUTIONARY ALGORITHM



EVOLUTIONARY ALGORITHM







WORKFLOW IMPLEMENTATION

USE IN PRACTICE

Geometry Input Dataset

0.78

Performance Indicator

User-generated & Assignment-specific

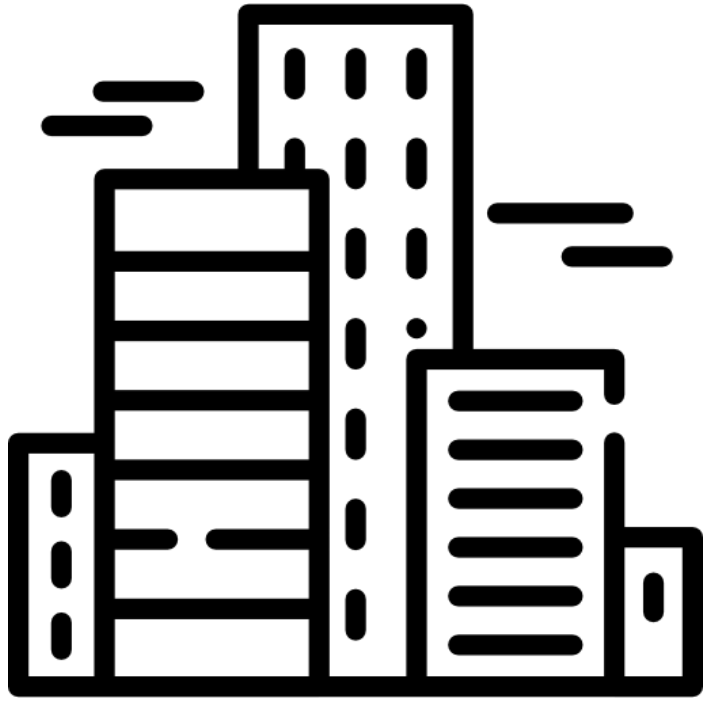
USE IN PRACTICE

Geometry Input Dataset

0.78

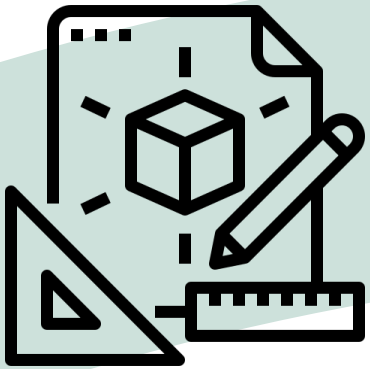
Performance Indicator

Material Stock Library



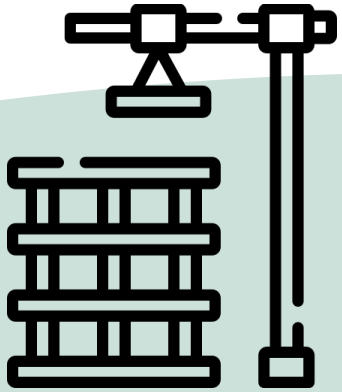
Detailed documentation on available stock, to be retrieved

BAMB



Design

Design analysis

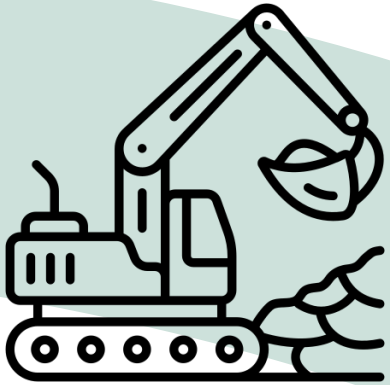


Construction

Records

Operation

Estimations and/or measurements

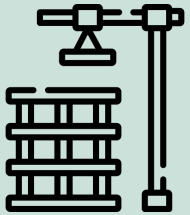


End-of-Service

Identification after demolition

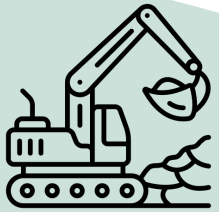
BAMB

Design



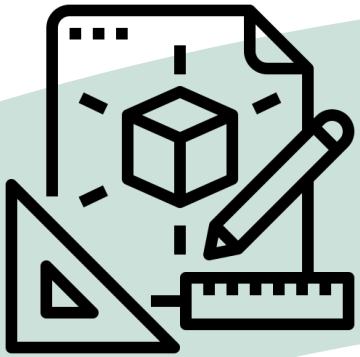
Construction

Operation

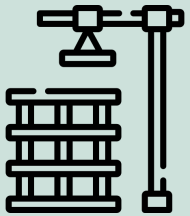


End-of-Service

BAMB

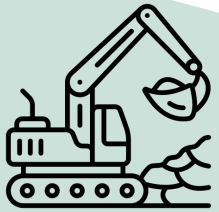


Design



Construction

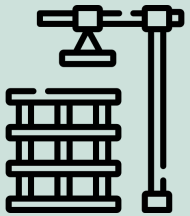
Operation



End-of-Service

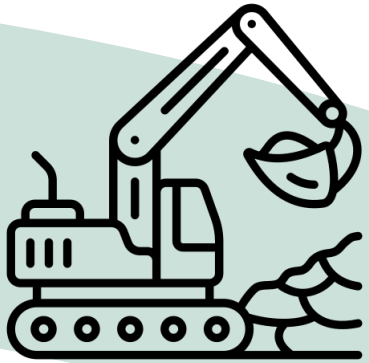
BAMB

Design



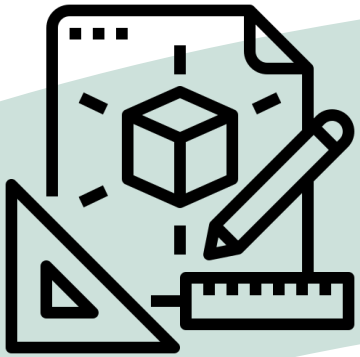
Construction

Operation

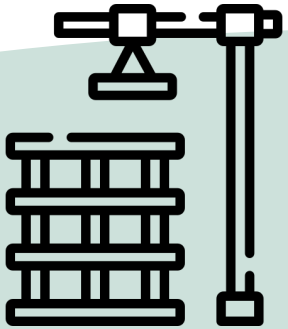


End-of-Service

BAMB

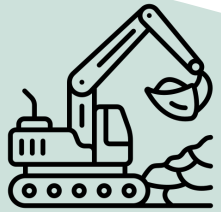


Design



Construction

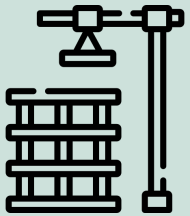
Operation



End-of-Service

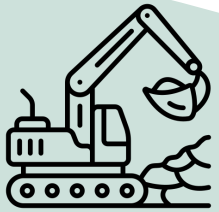
BAMB

Design



Construction

Operation



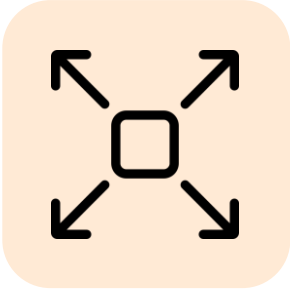
End-of-Service

Workflow in new project design

FUTURE WORK

NEXT STEPS

Improvement of the current workflow



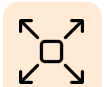
Expansion of geometry types

Expansion or addition of optimization targets

NEXT STEPS

Improvement of the current workflow

- Improve current VAE, GD, and surrogate model
- Generative Adversarial Network to replace VAE

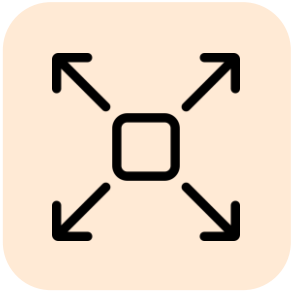


Expansion of geometry types

Expansion or addition of optimization targets

NEXT STEPS

Improvement of the current workflow



Expansion of geometry types

- More complex 3D Trusses
- Solid 3D shapes

Expansion or addition of optimization targets

NEXT STEPS

Improvement of the current workflow

Expansion of geometry types

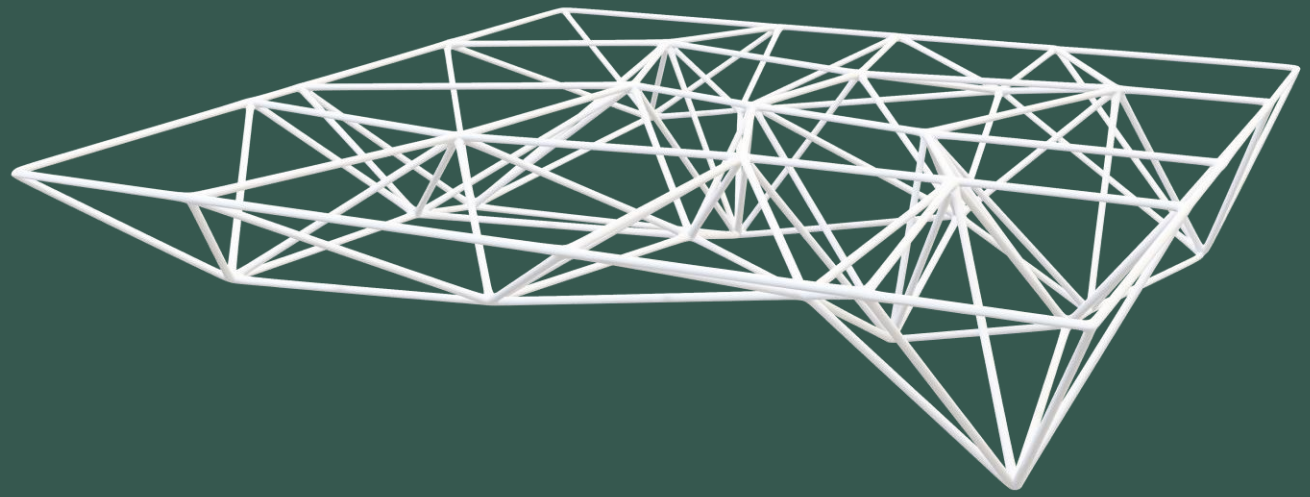
Expansion or addition of optimization targets

- Repair/Refurbishment need of elements
- Structural properties of elements
- Complexity of resulting nodes
- Aesthetics
- …

NEXT STEPS

THANK YOU

DEEP GENERATIVE DESIGN:
A deep learning framework for optimized spatial truss structures with stock constraints



P5 – 27 June 2023
Amy Sterrenberg
4593057