Latent Morphologies: Encoding Architectural Features and Decoding Their Structure through Artificial Intelligence

Citation

Permanent link
https://nrs.harvard.edu/URN-3:HUL.INSTREPOS:37372337

Terms of Use
This article was downloaded from Harvard University’s DASH repository, and is made available under the terms and conditions applicable to Other Posted Material, as set forth at http://nrs.harvard.edu/urn-3:HUL.InstRepos:dashboard.current.terms-of-use#LAA

Share Your Story
The Harvard community has made this article openly available. Please share how this access benefits you. Submit a story.

Accessibility
Latent Morphologies:
Encoding Architectural Features and Decoding their Structure through Artificial Intelligence

By

Dongyun Kim

Master of Science in Design, University of Pennsylvania, 2019
Bachelor of Architecture, Hongik University, 2017

Submitted in partial fulfillment of the requirements for the degree of

Master in Design Studies
Technology

At the Harvard University Graduate School of Design

May, 2022

Copyright © 2022 by Dongyun Kim

The author hereby grants Harvard University permission to reproduce and distribute copies of this Final Project, in whole or in part for educational purposes.

Signature of the Author

Dongyun Kim

Harvard University Graduate School of Design

Certified by

Andrew Witt

Associate Professor in Practice in Architecture
Harvard University Graduate School of Design
Latent Morphologies:
Encoding Architectural Features and Decoding Their Structure
Through Artificial Intelligence

Harvard University
Graduate School of Design
Master in Design Studies, Technology
Dongyun Kim
Advisor: Andrew Witt
Latent Morphologies: Encoding Architectural Features and Decoding Their Structure Through Artificial Intelligence

With the advent of Artificial Intelligence, new methodologies have been introduced to the architectural discipline, expanding the current possibilities of design processes. Specifically, generative models created a paradigm shift wherein, instead of spending numerous time designing the entire system for a specific task, designers allowed the overall principle and system to remain in the black box and instead focused on the desired results. These attempts, however, strongly rely on randomness and could not achieve overall controllability so those problems have hindered getting meaningful results.

This research started with building an encyclopedic architectural dataset that can represent general architecture, maintaining its variation. In addition, it explores potential applications, using Generative Adversarial Networks such as StyleGAN to find hidden patterns we cannot identify and their regularity in architectural discourse. Several statistical methodologies are utilized to understand and unveil characteristics in massive data. Especially, using the concept of encoder and decoder, latent space shows incredible possibilities, generalizing architectural features and generating their continuous morphologies which are theoretically infinite.
History of Computation in Architecture (2019)
Stanislas Chaillou

Background and Problems
Dataset Construction and Exploratory Data Analysis
Methodology I: Multi-class StyleGAN
Methodology II: Multimodal StyleGAN+CLIP
Conclusion
Cellular Automata
(John Horton Conway)

Boids
(Craig Reynolds)

L-system
(Aristid Lindenmayer)
Background and Problems

Dataset Construction and Exploratory Data Analysis
Methodology I: Multi-class StyleGAN
Methodology II: Multimodal StyleGAN+CLIP
Conclusion

On Convergence and Stability of GANs (2018)
(Mescheder et al.)

AI & Architecture: Towards a New Approach
(Stanislas Chaillou)
Background and Problems

Dataset Construction and Exploratory Data Analysis
Methodology I: Multi-class StyleGAN
Methodology II: Multimodal StyleGAN+CLIP
Conclusion

Latent Morphologies: Encoding Architectural Features and Decoding Their Structure Through Artificial Intelligence

Dongyun Kim (MDes Tech 2022'), Advisor: Andrew Witt

Algorithmic approaches


Artificial Intelligence

Re-generating Vessel (2020)  PlacemakingAI (2021)

Abstract Machine (2016)

Logistics Airport (2018)

Re-generating Vessel (2020)

PlacemakingAI (2021)
Background and Problems

Dataset Construction and Exploratory Data Analysis
Methodology I: Multi-class StyleGAN
Methodology II: Multimodal StyleGAN+CLIP

Conclusion
Background and Problems
Dataset Construction and Exploratory Data Analysis
Methodology I: Multi-class StyleGAN
Methodology II: Multimodal StyleGAN+CLIP
Conclusion

Dongyun Kim (MDes Tech 2022'), Advisor: Andrew Witt

Paradigm shift

Creating a rule
(Algorithmic approach)

Finding a pattern
(Artificial Intelligence)
Background and Problems
Dataset Construction and Exploratory Data Analysis
Methodology I: Multi-class StyleGAN
Methodology II: Multimodal StyleGAN+CLIP
Conclusion

Traversing Features (Seungho Kim, Sukyeong Cheon)
Problem I: Limitation of architecture dataset

Architectural style dataset (2014)  
(Xu et al.)

Façade dataset (2017)  
(Isola et al.)
Problem II: Limitation of controllability

Machine Hallucination (2019 - 2020)
Refik Anadol

Gan Loci (2019)
Kyle Steinfeld
Problem II: Limitation of controllability

Traditional StyleGAN architecture

A simple version of GAN architecture
Problem II: Limitation of controllability

Latent space refers to an abstract multi-dimensional space containing feature values that a human cannot interpret directly, but which encodes a meaningful internal representation of externally observed events.
Problem II: Limitation of controllability

Missing link between visual features and represented latent vector
Research Questions:

Is there an implicit rule that can create a style in architecture?
What are hidden patterns or features we cannot identify?
Is there any regularity?
Background and Problems
Dataset Construction and Exploratory Data Analysis
Methodology I: Multi-class StyleGAN
Methodology II: Multimodal StyleGAN+CLIP
Conclusion
Background and Problems

Dataset Construction and Exploratory Data Analysis
Methodology I: Multi-class StyleGAN
Methodology II: Multimodal StyleGAN + CLIP

Conclusion

Latent Morphologies: Encoding Architectural Features and Decoding Their Structure Through Artificial Intelligence

Dongyun Kim (MDes Tech 2022'), Advisor: Andrew Witt

Overall understanding
General manipulation
Specific manipulation
Dataset Construction and Exploratory Data Analysis
Dataset source

- Enough number of projects to create an encyclopedic architecture dataset
- Good quality images, descriptions, and additional data
- This platform can represent how the general architecture looks like
Dataset example
Background and Problems

Dataset Construction and Exploratory Data Analysis

Methodology I: Multi-class StyleGAN

Methodology II: Multimodal StyleGAN+CLIP

Conclusion
South Brittany's Higher School of Engineering is a microcosm the unity of which is organized around the compact, colorful central monolith from which the building's two wings radiate. The monolith contains two essential areas: the amphitheater and the cafeteria. Starting in the competition phase, the design for this central room was contributed to by artist David Saltiel. The school is part of an overall reflection by ANMA about interstitial spaces. Fostering interaction between students, teachers, researchers and staff, they are essential to the process of the school's positive synergy. Whether they enable students and faculty to isolate themselves (like the faculty council's meeting room and its terrace overlooking the entire building) or come together (like the tiered terraces of the roof), they shape the sense of the same shared place. With each place of higher education it has designed ANMA manifests its ambition to go beyond briefs, offer living space and shared venues that enable students to live and learn together. The polyvalent spaces are organized in a rationale of flows. Study cells where students may meet to work together are added to the traditional classrooms. Learning is no longer isolated but networked and connected. The concourses become public spaces connected to the city. The university thus opens onto its environment with a idea borrowed from the American campus model but applied on a French scale with constraints of density and mixed use with housing briefs. Interactions between the student city and the city of everyday life incorporate these different projects into the same rationale of urban planning.

Data analysis

Published projects are getting increased.

The projects have not published immediately after building them. It takes some time to be introduced in ArchDaily, or due to Covid.

Western-centered architecture projects

Imbalance of published project
Dataset Construction and Exploratory Data Analysis

Methodology I: Multi-class StyleGAN
Methodology II: Multimodal StyleGAN+CLIP

Conclusion
Data analysis

Distribution of published projects by area

Distribution of published projects by architect
Data analysis

Distribution of published projects by material

Distribution of published projects by color
Data analysis

A picture or image is a representation tool and a perspective that people understand when looking at the architecture.

Thus, the image is subjective, but we can understand their perspective and how they see the architecture, seeing the entire images.

Definition of a picture or image in architecture
Data analysis

High-dimensional cartography

Color-based cartography
Dataset Construction and Exploratory Data Analysis

Methodology I: Multi-class StyleGAN

Methodology II: Multimodal StyleGAN+CLIP

Conclusion

Data analysis

Circular cartography

Distribution of colors
Data analysis

PCA

t-SNE

UMAP
Data analysis

Brightness-Hue

Saturation-Hue
Data analysis

Western Culture

Northern America  Central America  South America  Western Europe  Eastern Europe  Southern Europe  Northern Europe

Asian Culture

Eastern Asia  South-eastern Asia  Western Asia  Southern Asia  Central Asia  Australia and New Zealand

African Culture

Melanesia  Middle Africa  Northern Africa  Eastern Africa  Western Africa  Southern Africa  Caribbean

Background and Problems

Dataset Construction and Exploratory Data Analysis

Methodology I: Multi-class StyleGAN
Methodology II: Multimodal StyleGAN+CLIP

Conclusion

Latent Morphologies: Encoding Architectural Features and Decoding Their Structure Through Artificial Intelligence

Dongyun Kim (MDes Tech 2022'), Advisor: Andrew Witt

Caribbean  Central America  Eastern Africa  Eastern Europe  Melanesia  Middle Africa  Northern America  Northern Europe  South Africa  South America  Southern Asia  Southern Europe  Western Africa  Western Europe  Western Asia  Australia and New Zealand  Central Asia  Central Asia  Eastern Asia  South-eastern Asia  Western Asia  Southern Asia  Central Asia  Australia and New Zealand
Methodology I: Multi-class StyleGAN
Methodology I: Multi-class StyleGAN

Traditional StyleGAN

Multi-class StyleGAN

Background and Problems
Dataset Construction and Exploratory Data Analysis
Methodology I: Multi-class StyleGAN
Methodology II: Multimodal StyleGAN+CLIP
Conclusion
Methodology I: Multi-class StyleGAN

Traditional StyleGAN

Multi-class StyleGAN
Methodology I: Multi-class StyleGAN

Multi-class latent space
Methodology I: Multi-class StyleGAN

Latent Morphologies: Encoding Architectural Features and Decoding Their Structure Through Artificial Intelligence

Background and Problems
Dataset Construction and Exploratory Data Analysis
Methodology I: Multi-class StyleGAN

Methodology II: Multimodal StyleGAN+CLIP
Conclusion
Methodology I: Multi-class StyleGAN

Original images (from ArchDaily)

Generated images by StyleGAN
Methodology I: Multi-class StyleGAN

Typology category: Public architecture

Typology category: Educational architecture
Methodology I: Multi-class StyleGAN

Same vector, but different typology category
Methodology I: Multi-class StyleGAN

Latent walk, traversing different categories
Methodology I: Multi-class StyleGAN
Methodology I: Multi-class StyleGAN

Projection of high-dimensional space
Methodology I: Multi-class StyleGAN
Methodology I: Multi-class StyleGAN

Eastern, Western, Southern, and Northern Europe
(same cultural region)

Europe, America, Asia, and Africa
(different cultural region)
Methodology I: Multi-class StyleGAN

What was effective
- It can generate diverse variations in the same class.
- It was successful to observe general architectural characteristics in the selected class and by isolating all the factors except for the class, the differences between classes were obvious.

What was lack
- It was hard to interpret the visual characteristics in a way a human can understand as well.
Methodology II: Multimodal StyleGAN+CLIP
Methodology II: Multimodal StyleGAN+CLIP

South Brittany's Higher School of Engineering is a microcosm the unity of which is organized around the compact, colorful central monolith from which the building is two wings radiate. The monolith contains two essential areas...
Methodology II: Multimodal StyleGAN+CLIP

Background and Problems
Dataset Construction and Exploratory Data Analysis
Methodology I: Multi-class StyleGAN
Methodology II: Multimodal StyleGAN+CLIP
Conclusion
Methodology II: Multimodal StyleGAN+CLIP

ArchDaily metadata in web

The main structural order is composed of beams of great expression in the longitudinal and transversal directions...

project description

pair images

ArchDaily Dataset

Text Encoder

CLIP embedding space

CLIP

visual-text representation

Image Encoder

Methodology II: Multimodal StyleGAN+CLIP
Methodology II: Multimodal StyleGAN+CLIP

Input

Image Encoder

Text Encoder

Output

Latent Morphologies: Encoding Architectural Features and Decoding Their Structure Through Artificial Intelligence

Dongyun Kim (MDes Tech 2022'), Advisor: Andrew Witt
Methodology II: Multimodal StyleGAN+CLIP

\[
\text{Loss} = \arg \min_w \mu_{\text{CLIP}}(G(w), t) + \lambda_1 \|w - \bar{w}\|_2^2 + \lambda_{\text{ID}} L_{\text{ID}}(w)
\]

For manipulation (Cosine distance)  For similarity to the input image

Generated image  Text  Updated latent vector

Original latent vector

Text Encoder

CLIP

Image Encoder

Target text  (Input text)

Update

Similarity

CLIP embedding space
Methodology II: Multimodal StyleGAN+CLIP

Pattern
- Brick elevation
- White reflective metal elevation
- Fractal pattern elevation

Properties
- Commercial building
- Old house
- Highrise building

Weather
- Sunny weather
- Snowy winter
- Rainy weather

Artist
- Picasso
- Salvador Dali
- Vincent Van Gogh

Original Image
Methodology II: Multimodal StyleGAN+CLIP

<table>
<thead>
<tr>
<th>Pattern</th>
<th>Properties</th>
<th>Weather</th>
<th>Artist</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brick elevation</td>
<td>Commercial building</td>
<td>Sunny weather</td>
<td>Picasso</td>
</tr>
<tr>
<td>White reflective metal elevation</td>
<td>Old house</td>
<td>Snowy winter</td>
<td>Salvador Dali</td>
</tr>
<tr>
<td>Fractal pattern elevation</td>
<td>Highrise building</td>
<td>Rainy weather</td>
<td>Vincent Van Gogh</td>
</tr>
</tbody>
</table>
Methodology II: Multimodal StyleGAN+CLIP

- Ghost house
- Picasso style
- Sunny weather

- High rise building
- Shrubs and trees
- Red brick elevation

- Vertical columns
- Commercial building
- Multi-story building
Methodology II: Multimodal StyleGAN+CLIP

- Ghost house
- Picasso style
- Sunny weather

- High rise building
- Shrubs and trees
- Red brick elevation

- Vertical columns
- Commercial building
- Multi-story building

Background and Problems
Dataset Construction and Exploratory Data Analysis
Methodology I: Multi-class StyleGAN
Methodology II: Multimodal StyleGAN+CLIP
Conclusion
Methodology II: Multimodal StyleGAN+CLIP

Feature manipulation in StyleGAN latent space

Height

Material

Weather
Methodology II: Multimodal StyleGAN+CLIP

Feature manipulation in StyleGAN latent space
Conclusion
Conclusion

- This research urges the architecture discipline to create and curate an architectural-centered dataset to discover and understand insights into it.

- Compared to image-only-based datasets, image-and-text-based datasets can be useful for diverse future research because it has resilient and expandable potential.
Conclusion

• The research created a tool for better understanding unstructured architectural datasets and it is a powerful way to create explicit structure in implicit structure using Neural Networks.

• Training neural network with ‘architecture-centered’ datasets (currently available models such as VQGAN+CLIP, DALL-E-2) is a general-purpose model which can be said ‘under-fitting’ to architecture, but this research proposed ‘over-fitting’ to architecture using ‘architectural encyclopedic dataset’ from ArchDaily, assuming that ArchDaily can be representatives of buildings in the world.