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

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

By

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Submitted in partial fulfillment of the requirements for the degree of

Master in Design Studies
Technology

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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
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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
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Algorithmic approaches

Artificial Intelligence

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Abstract Machine (2016)

Hyper Network (2015)
Background and Problems

Dataset Construction and Exploratory Data Analysis

Methodology I: Multi-StyleGAN

Methodology II: Multimodal StyleGAN+CLIP

Conclusion

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Background and Problems

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Creating a rule
(Algorithmic approach)

Finding a pattern
(Artificial Intelligence)

Paradigm shift
Background and Problems
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Traversing Features (Seungmook 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

Background and Problems
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Methodology I: Multi-class StyleGAN
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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.

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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
Dataset Construction and Exploratory Data Analysis
- 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
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Dataset example

Project name: School of Engineers in Bretagne
Architect: ANMA
Area(㎡): 5743
Built year: 2013
Project URL: https://www.archdaily.com/520663/school-of-engineers-in-bretagne-anma

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.

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
Data analysis

Distribution of published projects by typology

- Residential Architecture
- Cultural Architecture
- Commercial & Offices
- Hospitality Architecture
- Educational Architecture
- Interior Design
- Landscape & Urbanism
- Industrial & Infrastructure
- Refurbishment
- Healthcare Architecture
- Public Architecture
- Sports Architecture
- Mixed Use Architecture
- Religious Architecture
- Others

Distribution of published projects by subclass typology

- Houses
- Apartments
- Office Buildings
- Hotels
- Restaurants
- Hospitals
- Schools
- Renovations
- Mixed Use Architecture
- Offices
- Offices Interiors
- Institutional Buildings
- Universities
- Museums
- Stores
- Libraries
- Cafes
- Theaters
- Pools
- Apartment Interiors
- Institutions & Structures
- Kindergartens
- Public Spaces
- Restaurants & Kiosks
- Community Centers
- Cultural Architectures
- Elementary & Middle School
- Galleries
- Educational Architecture
- Landscape Architecture
- Restaurants
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

Background and Problems
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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
Data analysis

Circular cartography

Distribution of colors
Data analysis
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
Methodology I: Multi-class StyleGAN
Methodology I: Multi-class StyleGAN

Traditional StyleGAN

Multi-class StyleGAN

Background and Problems
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Methodology I: Multi-class StyleGAN

Traditional StyleGAN

Multi-class StyleGAN
Methodology I: Multi-class StyleGAN

![Multi-class latent space diagram]

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Methodology I: Multi-class StyleGAN

Multi-class latent space

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

- **Background and Problems**
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Methodology II: Multimodal StyleGAN+CLIP

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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

I₁, I₂, I₃, ..., Iₙ

T₁, T₂, T₃, ..., Tₙ

Image Encoder

visual-text representation

CLIP embedding space

CLIP

Datasets

Stadium

Sports

Church

Mexico

Sports

Rich & Stern

دعوه

Richard Rogers

Zaha Hadid

Sydney

Harvard University Graduate School of Design

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Methodology II: Multimodal StyleGAN+CLIP

Input

Image Encoder

Text Encoder

Output

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Methodology II: Multimodal StyleGAN+CLIP

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

- **StyleGAN**
  - Latent vector \((w)\)
  - Text Encoder
  - Image Encoder
  - Generated image
  - Original latent vector
  - Cosine distance
  - Text
  - For manipulation

- **CLIP**
  - Target text \((\text{Input text})\)
  - Update
  - Similarity
  - CLIP embedding space
  - Updated latent vector
  - For similarity to the input image

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### 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>
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Original Image

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**Background and Problems**

**Dataset Construction and Exploratory Data Analysis**

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**Conclusion**
Methodology II: Multimodal StyleGAN+CLIP

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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
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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

Feature manipulation in StyleGAN latent space

- Height
- Weather
- Material

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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.