

# Architectural Grayboxing using topological data

*in designing the extension of the MAXXI museum in Rome*

Tarique Ali (5498198)

Guidance /

Seyran Khademi (*Research*)  
Georg Vrachliotis (*Design*)  
Casper van Engelenburg  
(*Research + Moral*)

 **TU Delft** Delft University of Technology  
Faculty of Architecture  
and the Built Environment

Explore Lab 35

# Table of contents

Personal Fascination	05
Background	11
Problem statement	14
Research question	16
Methodology	18
Expected outcome & design idea	20
Design reflection	24
Workplan & Research diagram	26
List of figures & Bibliography	28

# Personal fascination

## Keywords

*Architectural drawings, topology, graphs, museum buildings, floor plans, machine learning, archives, space syntax, classification, mapping, nodes, network*

## 01 / Architecture and technology: An ambivalence relationship

While niched, it is not a coincidence when you find yourself among an agitated group of architects or architecture students, who keep repeating the fact that the field of Architecture and Construction is known to be out of date regarding the use of technological advancements around them in comparison to other professional fields. While architecture has become a point of departure to the argument of whether it is an art form or a public utilitarian service,<sup>1</sup> it is safe to go beyond these pedantic arguments to point out that neither of the two opposing sides have had the time to look at the process of producing architecture in itself. And this means ways in which architects can work smarter and not harder, each time, on every project. Meanwhile the field of artificial intelligence seems to be integrated in people's everyday lives more than ever, take for example the way your email client is able to segregate spam from your primary mails.

This serves as a reminder that, currently, the potential of varying software skills for each individual task might not

1

Hosey, L. (2015, November 2). *Why Architecture isn't Art (And Shouldn't be)*. Huffpost. [https://www.huffpost.com/entry/why-architecture-isnt-art-and-shouldnt-be\\_b\\_8447388?utm\\_medium=website&utm\\_source=arch-daily.com](https://www.huffpost.com/entry/why-architecture-isnt-art-and-shouldnt-be_b_8447388?utm_medium=website&utm_source=arch-daily.com)

be realized unless we learn to understand and translate the process of designing itself, to a more computational way of thinking and see where the situationally fitting tool needs to exist to make the tasks simpler or choices based more on hard data. Or at the least be discussed collectively by scholars, practitioners and students to see where it can best fit to solve problems that we hesitate to question in this day to day process of 'producing' architecture.

## 02 / A curious case of Autodesk

In response to the 2022 Nordic Open letter towards Autodesk, Iain Godwin, a former senior partner at Foster + Partners, explained how graduates are not taught to think critically about technologies nor to understand the vital economic frameworks of these tools in the process followed by designers. In its core, the 'open letter to autodesk' signed by 120 companies spread across the 4 major Nordic Architectural bodies, specifically addressed Autodesk's BIM platform, Revit, because of its lack of innovation and shortcomings in providing the right tools to aid the workflow that the designers of this generation need; Whilst charging a hefty price which the signees would rather have spent elsewhere to fill the resulting gap in the necessary tools. This brings us to the point of needing to try and democratise the tools of designing which in turn democratises the process of designing and its heavy reliance on tools from the likes of Autodesk that looks at customer expansion over innovation and the needs of its existing userbase .<sup>2</sup>

2

Robledo, A. F. (2022, October 20). *The Revit Open Letter Through the Lens of QWERTY-Nomics*. architosh. <https://architosh.com/2022/10/the-revit-open-letter-through-the-lens-of-qwerty-nomics/2/>



FIG 01 The Nordic Letter: Open Letter to Autodesk

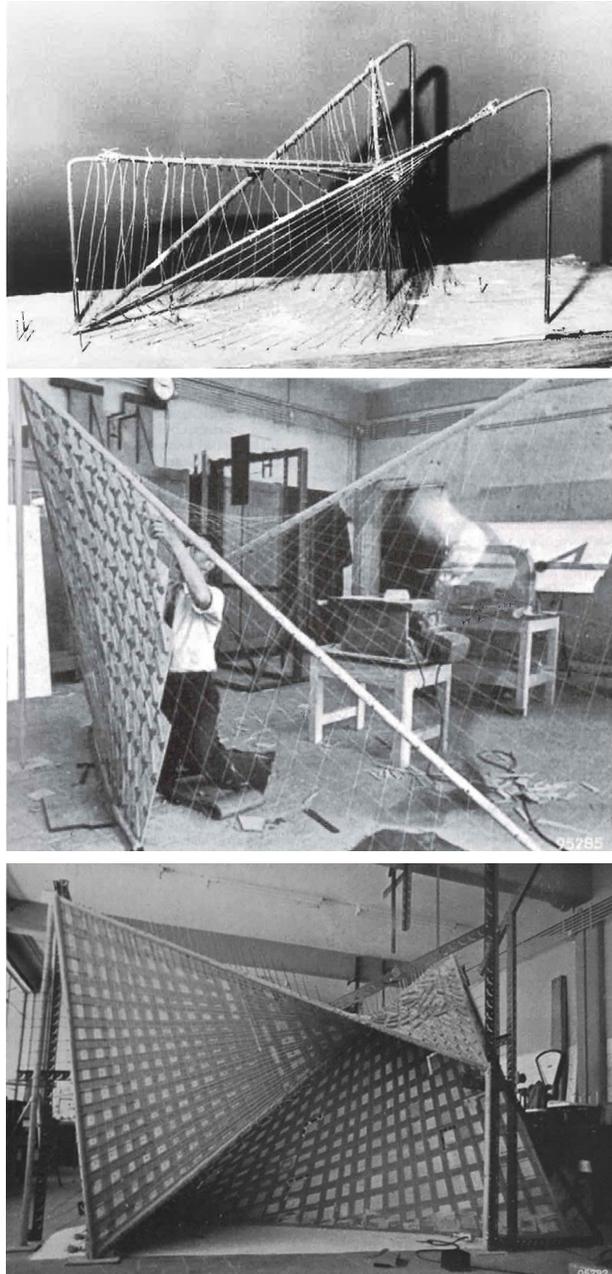


FIG 02 Iannis Xenakis and Le Corbusier's Philips Pavilion for the 1958 World's Fair, utilising mathematical models as their source of inspiration for design. *Brussels, Belgium, c.1958. Photograph. Fondation Le Corbusier / ADAGP*

### 03 / Architectural Grayboxing: Sourcebooks as blackboxes

These democratic new tools can ideally come into play in various stages of the design process. For instance, in the early conceptual stage, Andrew Witt explains about the existence of 'scientific sourcebooks' in his article titled 'Grayboxing' in the journal 'Log 43', shows us two instances during the high modernism of the 1950s and 60s where architects would adopt both the language and forms from these scientific sourcebooks as tools for design. Firstly, with crystallographic structures made of lattice packing and cells and secondly from complex mathematical surfaces and forms.<sup>3</sup> This new way of designing, relying on what one can term as blackboxes for the field of design, soon became something more tangible and interoperable between design, art and science. The ways of thinking and talking about the architectural forms were adopted from these fields, way beyond just the inspiration for the forms themselves.<sup>4</sup> And in later stages of design, this cross between disciplines comes into play when a quantitative assessment of the earlier qualitative decision making is required.

To this end, I wish to investigate the same questions posed by Moshe Safdie in 1962 when he befriended a colleague at Louis Kahn's practice Anne Tyng, who at that time approached design from the atomic, molecular and crystallographic perspective that made the form, bringing him back to think of his fascination towards the architectural DNA 'that animated design'.<sup>5</sup> What is it that constitutes the 'molecules of architectural design'? and how could that plausibly aid us in designing smarter?

<sup>3</sup>

Oubriere, J. (1999, August). *Architecture before Geometry, or the Primacy of Imagination*. *Assemblage*, 39, 94-105. <https://www.jstor.org/stable/3171261>

<sup>4</sup>

Witt, A. (2018). *Grayboxing*. *Log*, (43), 69-77. <https://www.jstor.org/stable/26588482>

<sup>5</sup>

Safdie, M. (1970). *Beyond Habitat*. Cambridge: M.I.T. Press.

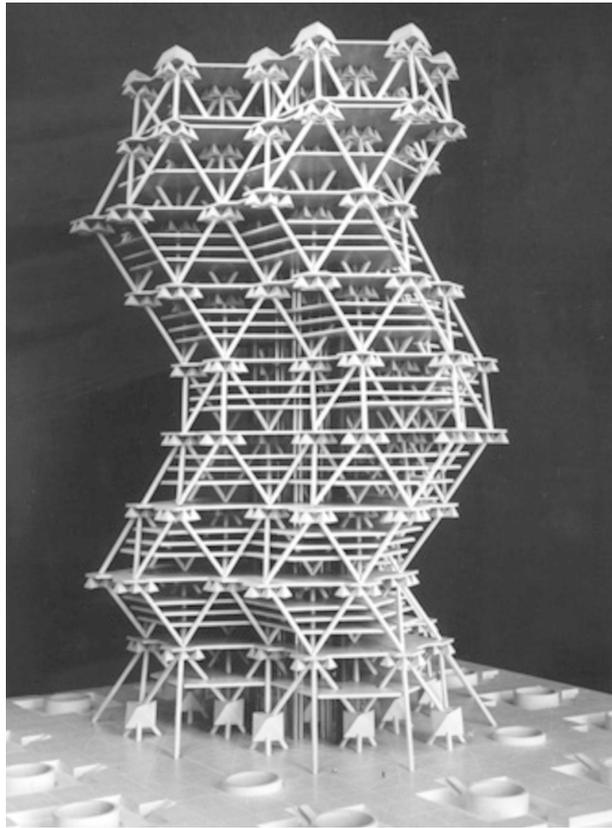


FIG 03 Anne Tyng at Louis I. Kahn's practice, Crystallographic inspiration model for City Tower, c. 1957, Philadelphia. Collection from the University of Pennsylvania and the Pennsylvania Historical and Museum Commission

## Background

For a long time the field of architecture has ignored its reliance on works that have preceded it. Existing processes of design often tend to try and reinvent the wheel each time, which can not only be time consuming but rather detrimental to the valuable insights that one can gain from existing building data.

While the current AEC fraternity can be seen knee-jerking over text to image based generative models which, while having existed for a decade now, have managed to become more mainstream with a seemingly easy to use interface and eye filling results which has had the blinding effect of being seen as the future of architectural design. In this case, one tends to forget that architecture happens to rely a lot on contextual data and spatial qualities with the likes of daylighting, materiality, spatial connections and safety, to name a few, which are overlooked by these generative/diffusion models. However, to prove that architects can utilise data from the past in aiding design decisions, this thesis wants to explore the method of topological data utilised in 'Architectural Distant Reading, Daniel Cardosos et al. (2019)' and apply it to the context of designing the extension of the MAXXI Museum in Rome, Italy.

From starting with an architectural hypothesis about museum design, the research looks to explore extraction of topological data by analysing existing designs through certain quantitative/qualitative criterias. And by creating

a process that might be able to reduce the habit of 're-inventing the wheel' each time and in some way is able to aid decision making through a spatial and functional overview of archival data. The research outcome, while hoping to aid the early design decisions, can also be vital in addressing design hypotheses that architects carry with them.



FIG 04 A midjourney render of 'Futuristic towers across the canals of Amsterdam'. Notice that context of Amsterdam canal was overlooked. Maybe the AI was smart enough to look at future floods due to climate change.

## Context ?

day light availability

site responses

safety

materiality

structural sensibility

energy considerations

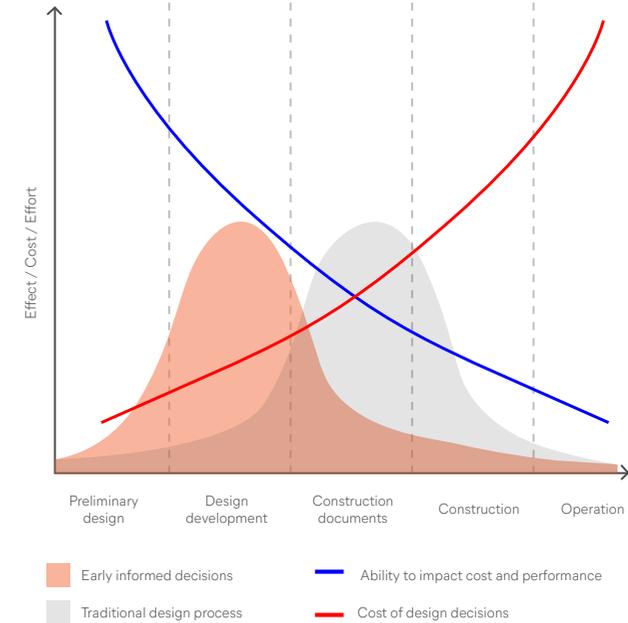
Contexts or parameters under which architectural designs are mainly based upon while shape giving. This is in no way an exhaustive list of contextual data, but rather tries to bring in light what text to image models cannot yet contribute towards architectural solutions

# Problem statement

The fast paced, ever competitive world of Architectural Design makes it hard to come together and unify in a way that can be beneficial to the field in its ability to harvest format consistency and data operability. Without having to look at the ineffectiveness that is present within the field where interoperability between softwares (Open letter to Autodesk, 2022) is an obstacle; File formats are already an early hindrance to open data standards and unification along with the lack of developments on the existing IFC (International Foundation Class) file formats that is platform neutral for the Architecture and construction industry.

From 'The New Open Minds' (TU Delft) talks', a pilot project aiming at rethinking the future foundations of design and its impact on our societies, it comes as a given that the domain of architecture needs to make the right calls at the beginning of the project to have the biggest positive impacts culturally, economically and environmentally. And through the art of vectorised visualisation, complicated data can become easy to consume.

So, looking beyond floor plans as a way of representing a building, which can lack in providing the pace in analysis and data backed approach that one might be looking for; It comes as a requisite to find an alternative knowledge representation technique that is currently missing in the field of architectural design. Which is where I believe topological graphs can be introduced to answer the questions that follow.



GRAPH 01 Stages of design vs ability to effect design ; Effort and cost in changing design decisions



FIG 05 Sarah Williams at 'The New Open Minds' talks. A focus on data action

# Research questions

How can architects effectively extract topological maps from archival drawings and learn from them, alongside their knowledgeable analysis of spatial quality to aid early stages of design-decision making ?

## Sub-questions

1. What are topological graphs ? How can they be useful to architects towards knowledge representation ?
2. How can these graphs be effectively extracted from existing architectural drawings ?
3. Why does graphical understanding of design leading to comparative analyses help us create better architectural works ? in comparison to individual qualitative plan analysis that designers are seen following today ?
4. Can the process of topological graphs be machine learnt in regards to its utilisation in varying contexts of available architectural (open or private) drawing data ?
5. In a globalised work setting, can graphs like these aid in an architect's understanding of culturally appropriate design and further help in better design decision making that are stemmed through history and culture.
6. What do the topological maps of the existing museums of Italy tell us about their changes through time or other features that can aid in design decision making ?

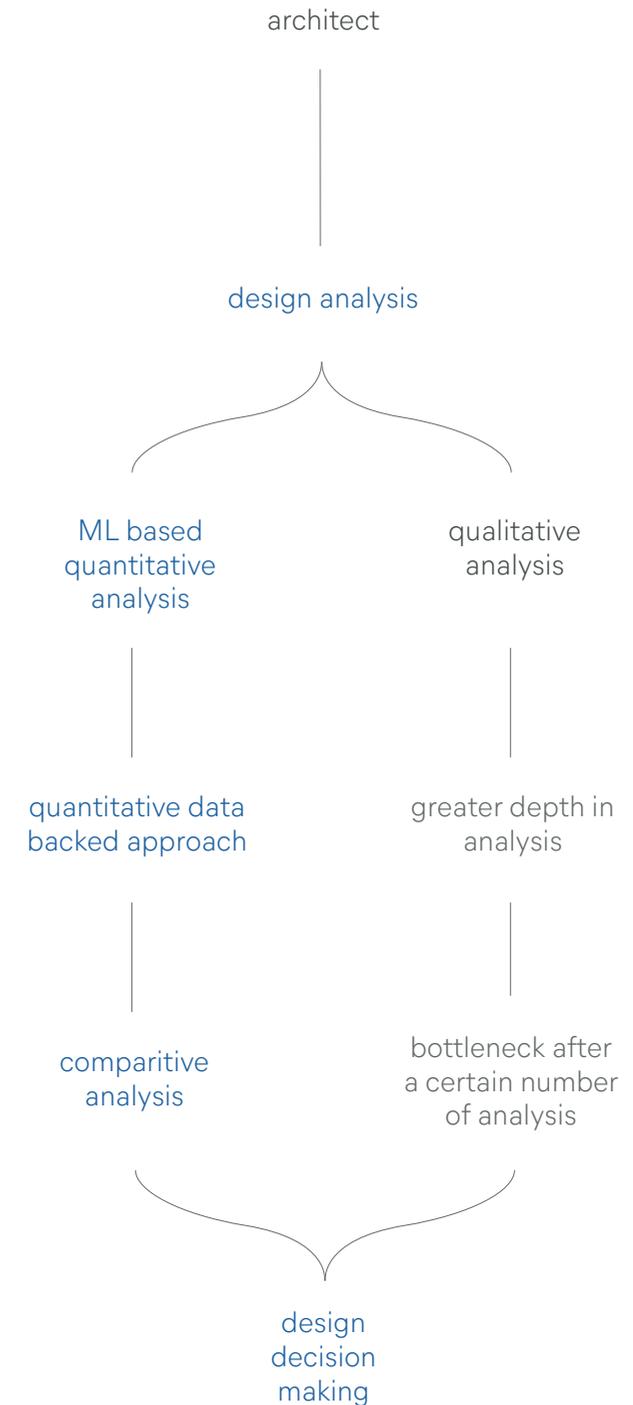


TABLE 01 Comparison between current typical ways of qualitative analysis of floorplans v. what could be possible following the research approach to be followed

# Methodology

The research takes into account the observational and derived data available through various reliable sources to conduct a mixed methodology, including but not limited to archival study, experiments and observations to arrive at a conclusion.

1. Firstly, The research will take into account the openly available and clearly documented floor plans of Italian museums across different cities from varying on-line platforms as data collection.
2. The floor plans will then require to be segmented, where state of the art (SOTA) computer vision tools and/or algorithms capable of this will be deployed. This shall be done in a way that helps us create divisions among spaces within the floorplan that need to be separated based on physical characteristics.
3. This segmented drawing will then need to be converted to their topological graphs, represented as distinct points for vertices and edges between them as connections while taking into account certain spatial qualities within them, which will be done through already available SOTA models or through algorithms either seen used in different researches or be developed on top of or from scratch.<sup>6</sup>
4. The resultant topological graphs will apply measures on graphs techniques such as node to node distances, centrality, clustering of nodes, connections per node and other features that the research will deem

6

Cecilia, F., Dalmaso, N., Mai, J., & Llach, D. C. (2019). *Architectural Distant Reading Using Machine Learning to Identify Typological Traits Across Multiple Buildings*. Hello, Culture!, 18th International Conference, CAAD Futures 2019, 206

necessary within the context for evaluation and understanding.

5. The process of feature evaluation could also be further assessed from the data in the points of the topological graphs, quantitatively, in a 3-dimensional axis map, where the evaluated criterias will guide towards conclusions from the most typical to atypical design traits seen in the dataset.
6. As a final step, the typical approach of qualitative plan analysis will be compared with the approach seen in this research to fairly estimate on where the bottlenecking happens in the orthodox approach towards drawing comparisons.

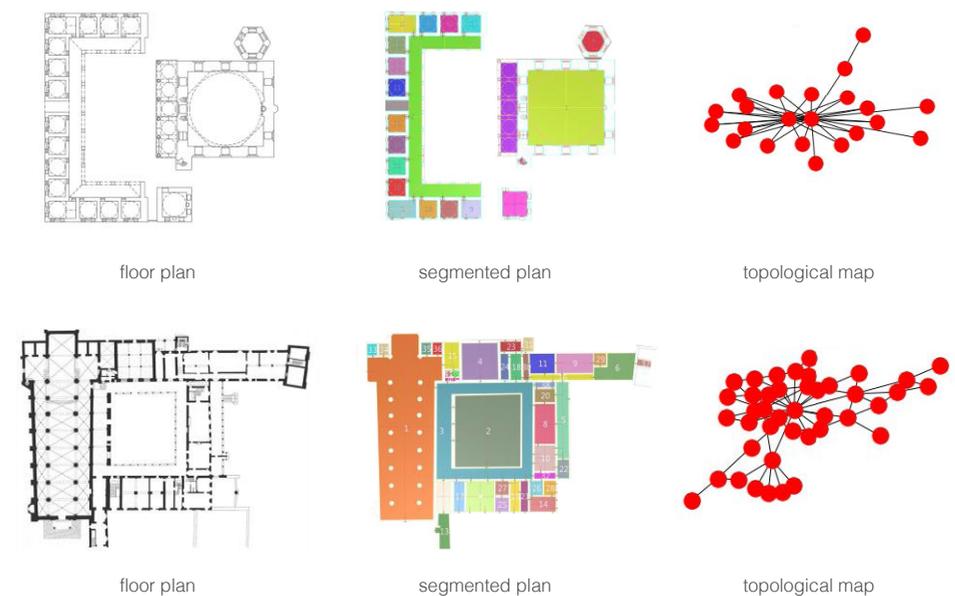


FIG 06 From Left to right and top to bottom, *The floor plan, segmentation map and topological map of Kose Husrev Pasa Camii (Turkey) and Morimondo Abbey (Italy) as seen in Architectural Distant Reading, Daniel Cardoso et al.*

# Expected outcome & design idea

The underlying spatial quality of building typologies through topological understanding can give light to how particular typologies (residential, museums, stations etc.) inherently possess familiar traits in regards to how the spaces are experienced. And while museums in our case can have a varied parameter on how it was designed beyond just the context of the site and other architectural attributes; It can also go beyond in understanding how the artworks and their historical significance can have a say while designing these spaces.

1. The process of distant reading <sup>7</sup> helps identify typological traits across multiple buildings. This aids one to compute architecture qualitatively that can stand as a stronghold to one's design decisions. While the research was primarily based on understanding religious buildings (mosques and monasteries), which primarily depend on spatial hierarchy and have a foothold when it comes to the freedom of design, we achieve what can be deemed to be the dna of museum design.
2. The research will help understand the differences seen in the context of Italy where a large majority of museums are repurposed into Renaissance structures, keeping their original footprint intact in contrast to the designs from the recent past that fall under modernism and later.

<sup>7</sup>  
Cecilia, F., Dalmaso, N., Mai, J., & Llach, D. C. (2019). *Architectural Distant Reading Using Machine Learning to Identify Typological Traits Across Multiple Buildings*. Hello, Culture!, 18th International Conference, CAAD Futures 2019, 204

3. The methodology of data preparation of the museum typology in the context of Italy will provide a deep dive into how these buildings have always been designed and how it can be related back to the MAXXI extension in Rome, the topological understanding of the examples will aid in better spatial positioning of the programs when designing a building that holds cultural coherence to the society it exists in.
4. And finally the extension of MAXXI will play host to science, architecture and artificial intelligence as displays, while the architectural quality of the space will be decrypted from the parent museum by ZHA from 2010, a larger deep dive into the 'needs' rather than the 'wants' of a museum will be explored to reach the final design pedagogy.

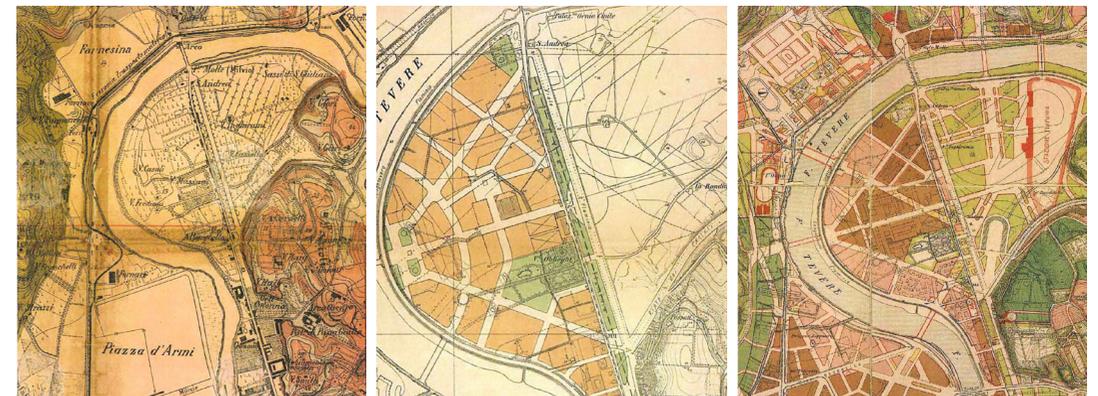


FIG 07 From left to right: A. Tellini, Geological map of area around Rome, 1893. Region right of Tiber River. E. Sanjust di Teulada, Master Plan of Rome, 1909 and Piano Regolatore 1931 - Particolare dell'area Flaminia

# Design reflection

The MAXXI extension project is focused to be grounded under the foundations of sustainability, inclusion and innovation. The 'Grande' project is to foster an extension to the Zaha Hadid designed museum to include a research hub fostering the dialogue between art, architecture, science and artificial intelligence. The proposal also includes targeting a centre for excellence for contemporary art installation, alongside other training, educational and storage/archival spaces.

But through the dialogue on where the museum stands in the current society in aiding knowledge and being able to bring people out of their homes, we need to question ourselves few of the following

1. How do museums not become superfluous in the era of bingeing ? Can they dare to become spaces that challenge the likes of netflix ?<sup>8</sup>
2. How does one design for AI and machine learning ? how do you spatialise what you do not see ? and how do you convey through the design the things necessary for the visitors to not only learn what AI means but to see it for what it is and not as what the general public see it as being a threat to humans. Designing for 'Explainable AI' is the goal.
3. How can museums go back to being institutes that invoke learning rather than becoming spaces that are trying to educate. People do not want to be educated (Gen Z?), they want to learn.

8

Figueiredo, S. M., Yegenoglu, H., & Zardini, M. (Eds.). (2018). *The architecture museum effect* (OASE #99 ed.). Nai010 Publishers.

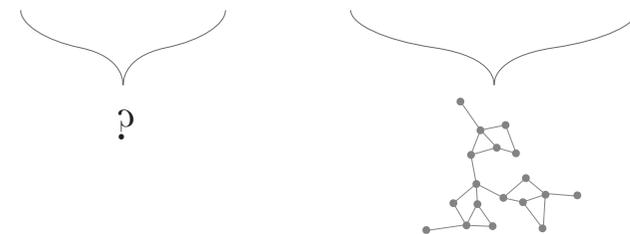
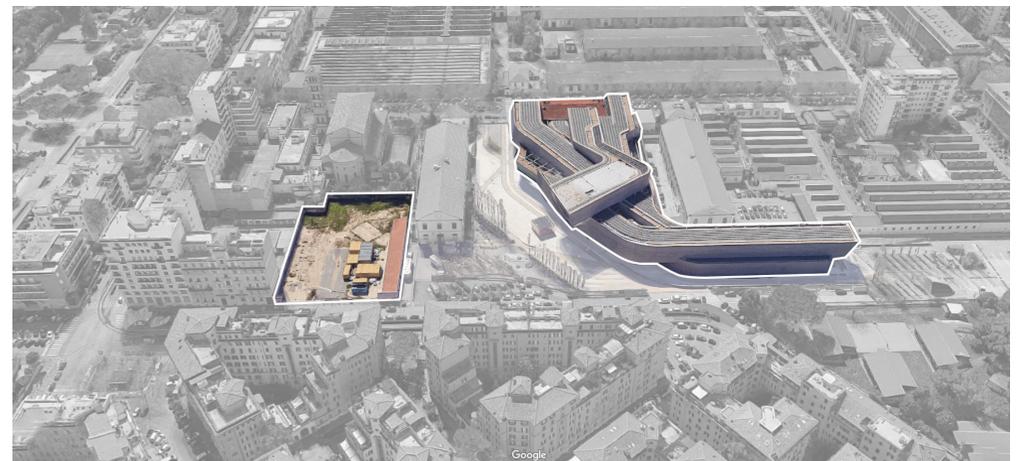
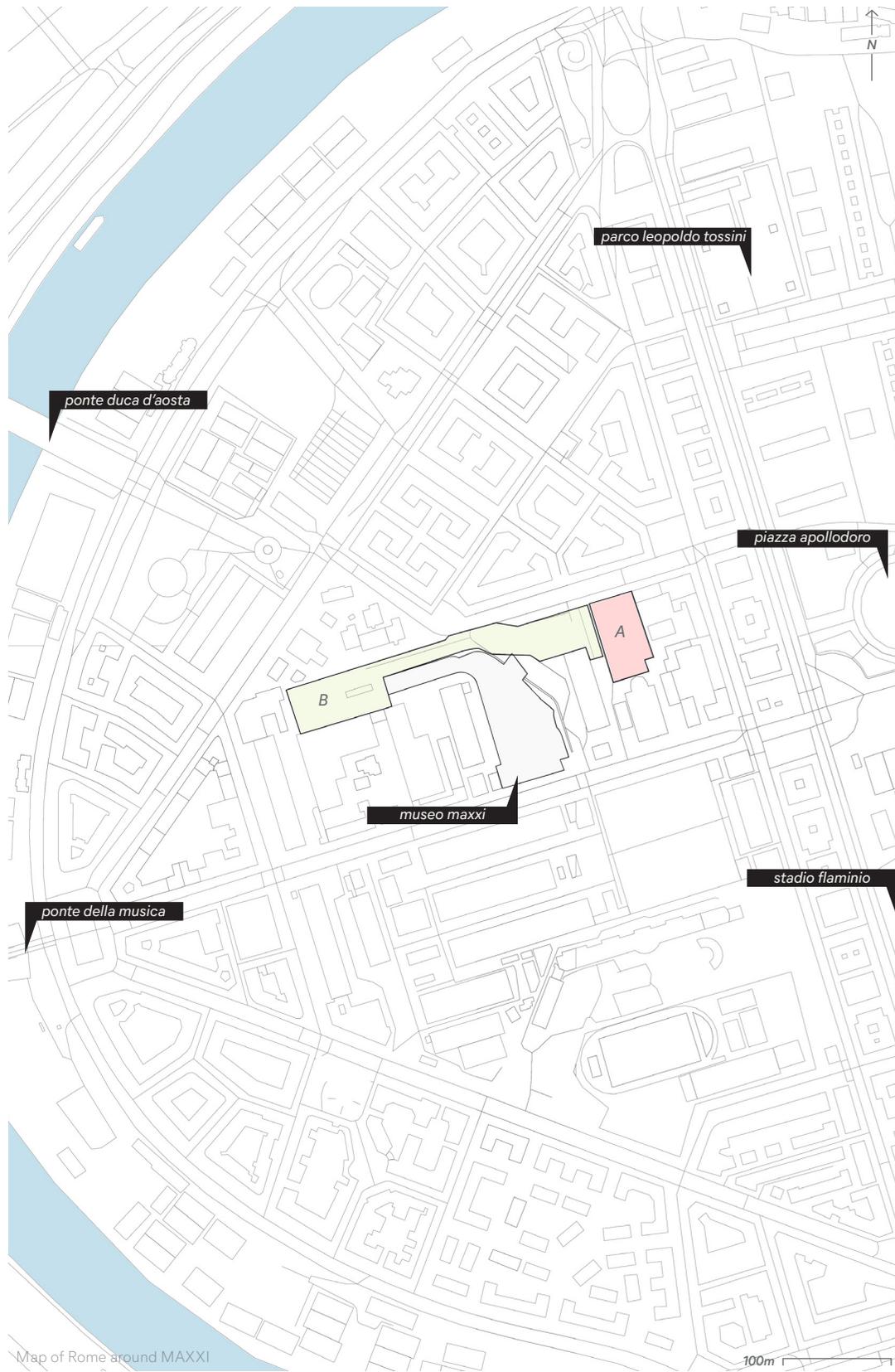
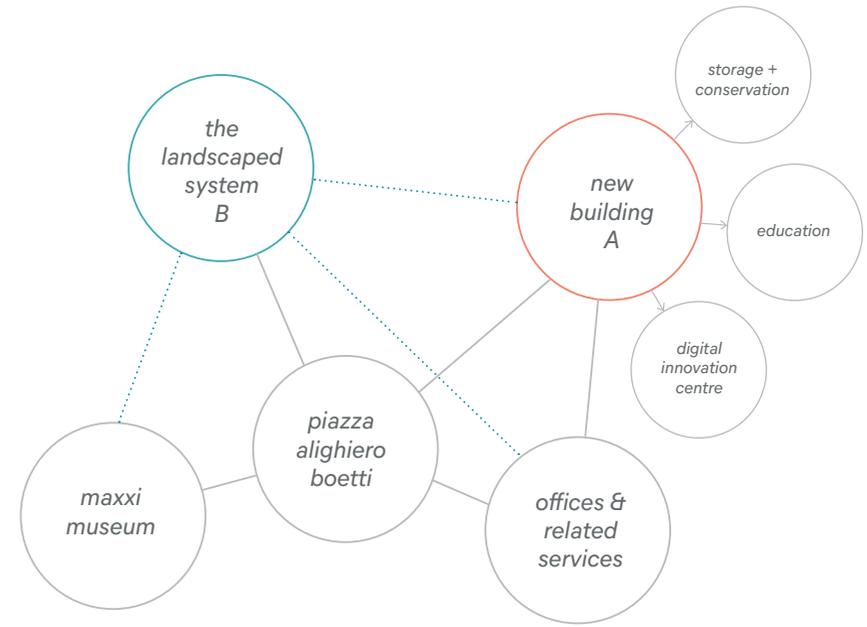


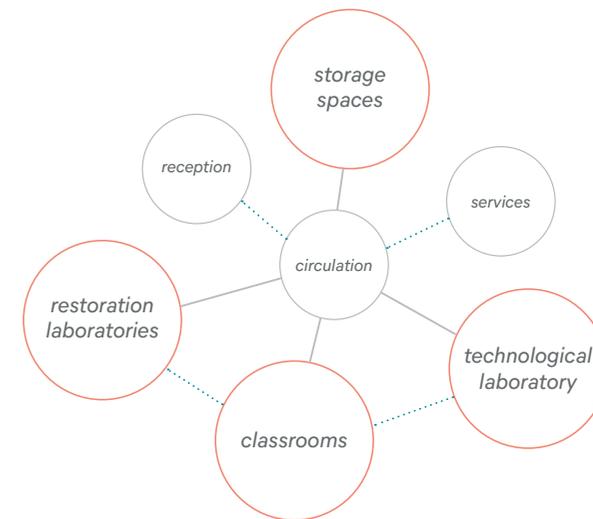
FIG 08 From top to bottom: The aerial view of the neighborhood of MAXXI. The museum and the plot for building A and the museum with its speculative graphic version of a topological map



Map of Rome around MAXXI



IDEOGRAM 01 Relation between the existing Museum and new project



IDEOGRAM 02 Requirements for building A on plan

# Probable limitations

1. While the study can seem rather automatic to the eye, the tangible efforts to the data preparation can be extremely time consuming, which is why an understanding of readily readable or easily pre-processable plans (or how one might archive them) can play as an important study
2. Time constraints will only possibly lead to a limited data set of plans within the single typology of study, i.e. museums in this case of the design thesis.
3. The study might not look into scoring architecture through machine intelligence, so the boundaries of what is statistical and what components are actually intelligent might be tested

# Workplan

## P1: November 2022

1. *Research Plan*
2. *Preliminary research update*
3. *Design idea and masterplan*

## P2: January 2023

1. *Final Research paper*
2. *Graduation plan*
3. *Research outcome for design*
4. *Masterplan and programme stacking*
5. *Design draft*

## P3

1. *Design presentation*
2. *Preliminary detailed design*
3. *Preliminary building engineering solutions*
4. *Facade fragments*
5. *Research correlations to design*

## P4

1. *Formal design presentation*
2. *Site drawings*
3. *Plans, sections and elevations*
4. *Facade fragments and details*
5. *Final architectonic and social relevance*

## P5

1. *Final thesis presentation*
2. *Research reflection*

# Research plan diagram



## 01 Drawings

Collection of floor plans of museums from major Italian cities. A mix of renovated and newly built projects, ranging from untouched, renovated interiors and completely altered interiors



## 02 Extraction

State of the art models, algorithms and scripts will have to be worked on to be able to standardise this process. Along with understanding what exact features need to be taken into consideration



## 03 Configurations

The topological map of the floor plans are then extracted as nodes and edges. The edges showing the level of connections and/or adjacencies and the nodes carrying other information



## 04 Mapping

The nodes/rooms can then be possibly be compared in 3-dimensional space about their features and unique details for awareness. This step could alternatively be approached visually



## 05 Paralleling

Understanding the requirements of the design brief coupled with the research extracting design features of Italian museums with the topology of the MAXXI museum providing insights



## 06 Grayboxing

The act of reaching a design conclusion backed with hard data from the step of 'paralleling' will be used to design. The term grayboxing here is to bring light towards this new process of designing



## 07 Designing

The final step is to take the grayboxed design into a final design output with its materiality and humane atmospheres of design, towards materiality and social purpose. Design through research!



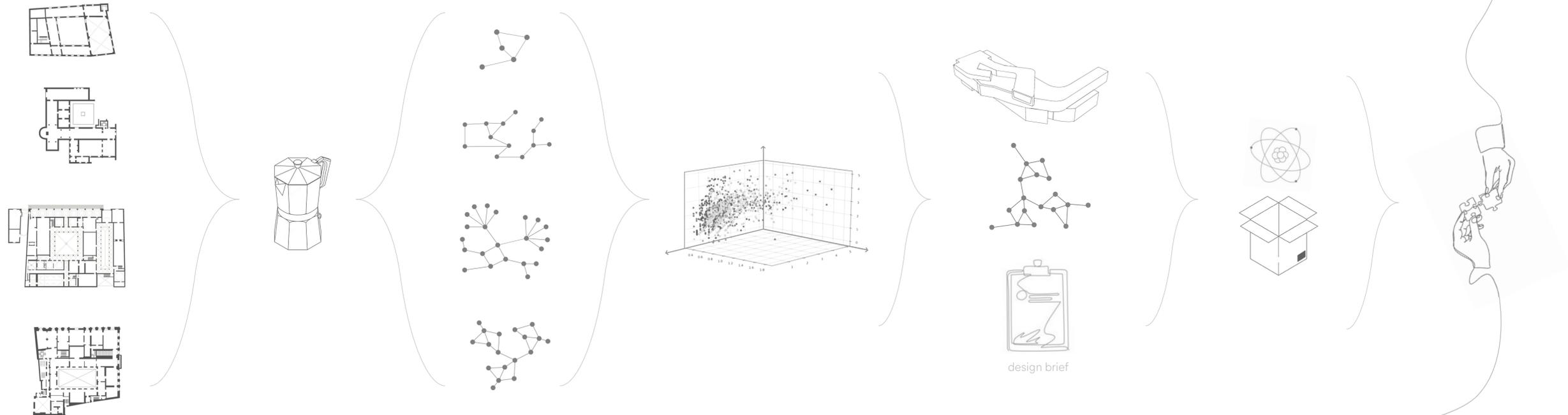
P1

P2

P3

P4

P5

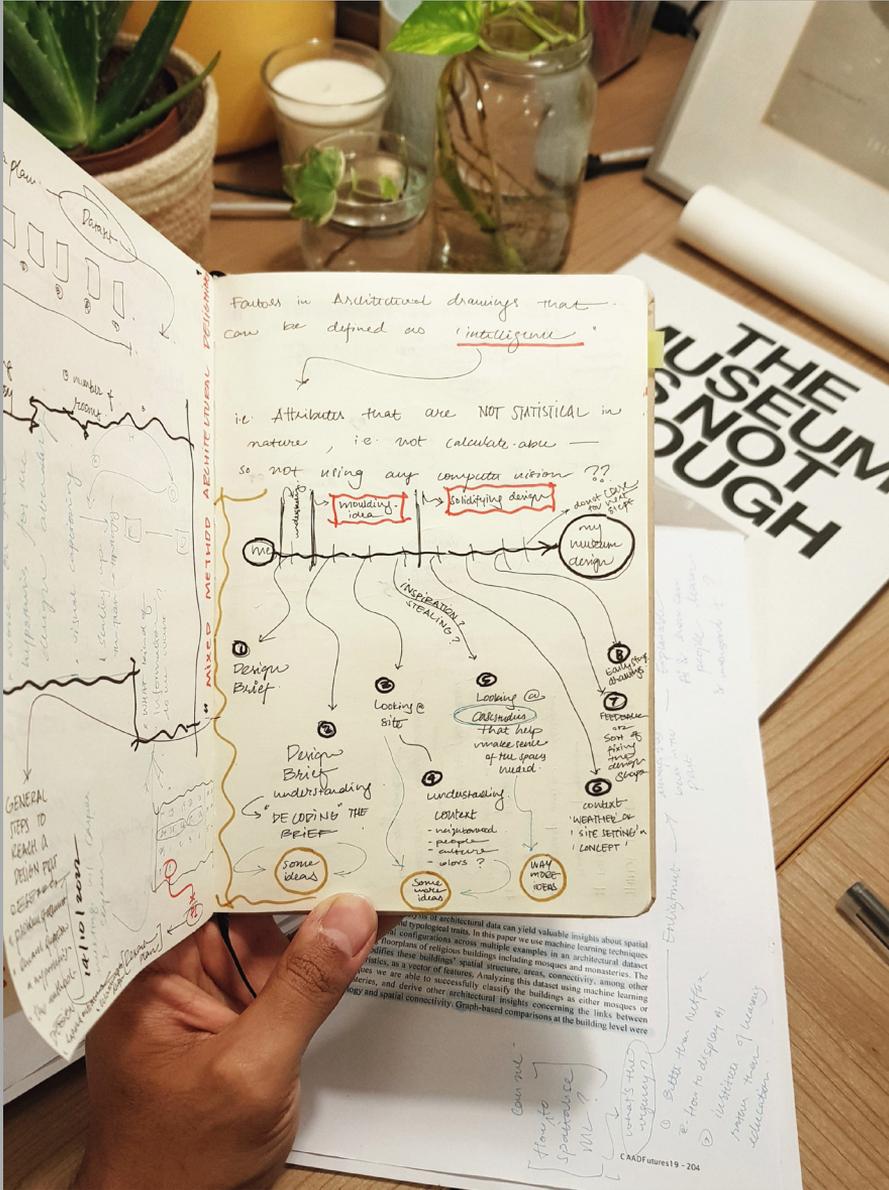


# List of figures

1. FIG 01 The Nordic Letter: Open Letter to Autodesk from <https://the-nordic-letter.com/>
2. FIG 02 Iannis Xenakis and Le Corbusier's Philips Pavilion for the 1958 World's Fair, utilising mathematical models as their source of inspiration for design. Brussels, Belgium, c.1958. Photograph. Fondation Le Corbusier / ADAGP via <https://drawingmatter.org/the-philips-pavilion-models-as-structural-expression/>
3. FIG 03 Anne Tyng at Louis I. Kahn's practice, Crystallographic inspiration model for City Tower, c. 1957, Philadelphia. Collection from the University of Pennsylvania and the Pennsylvania Historical and Museum Commission
4. FIG 04 A midjourney render of 'Futuristic towers across the canals of Amsterdam'. Crated on [midjourney.com](https://midjourney.com)
5. FIG 05 Sarah Williams at 'The New Open Minds' talks. A focus on data action, specifically talking about building teams, ground truthing, sharing data and visualising data
6. FIG 06 From Left to right and top to bottom, *The floor plan, segmentation map and topological map of Kose Husrev Pasa Camii (Turkey) and Morimondo Abbey (Italy) as seen in Architectural Distant Reading, Daniel Cardoso et al.*
7. FIG 07 From left to right: A. Tellini, Geological map of area around Rome, 1893. Region right of Tiber River. E. Sanjust di teulada, MasterPlan of Rome, 1909 and Piano Regolatore 1931 - Particolare dell'area Flaminia
8. FIG 08 From top to bottom: The aerial view of the neighborhood of MAXXI. The museum and the plot for building A and the museum with its speculative graphic version of a topological map

# Bibliography

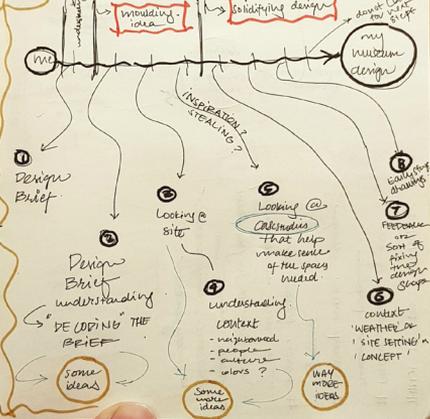
1. Cecilia, Ferrando, Niccolo Dalmasso, Jiawei Mai, and Daniel C. Llach. 2019. "Architectural Distant Reading Using Machine Learning to Identify Typological Traits Across Multiple Buildings." Hello, Culture! 18th International Conference, CAAD Futures 2019:204-217.
2. Cicek, Asli, Jantje Engels, and Maarten Liefoghe, eds. 2022. Oase 111: Staging the Museum. N.p.: NAI Uitgevers / Publishers Stichting.
3. Dalmasso, Nic. 2019. "ML-architectural-analysis." <https://github.com/c0deLab/ML-architectural-analytics>.
4. Figueiredo, Sergio M., Hüsnü Yegenoglu, and Mirko Zardini, eds. 2018. The architecture museum effect. OASE #99 ed. N.p.: Nai010 Publishers.
5. Hosey, Lance. 2015. "Why Architecture isn't Art (And Shouldn't be)." Huffpost. [https://www.huffpost.com/entry/why-architecture-isnt-art-and-shouldnt-be\\_b\\_8447388?utm\\_medium=website&utm\\_source=archdaily.com](https://www.huffpost.com/entry/why-architecture-isnt-art-and-shouldnt-be_b_8447388?utm_medium=website&utm_source=archdaily.com).
6. The New Open Minds, Talks + Workshops. 2022. TU Delft, Netherlands.
7. "Open letter to Autodesk." 2022. To Andrew Anagnost, President and Chief Executive Officer, Autodesk. <https://the-nordic-letter.com/>.
8. Robledo, Anthony F. 2022. "The Revit Open Letter Through the Lens of QWERTY-Nomics." architosh. <https://architosh.com/2022/10/the-revit-open-letter-through-the-lens-of-qwerty-nomics/2/>.
9. Safdie, Moshe. 1970. Beyond Habitat. N.p.: Cambridge: M.I.T. Press.
10. Witt, Andrew. 2018. "Grayboxing." Log, no. 43, 69-77. <https://www.jstor.org/stable/26588482>.



Factors in Architectural drawings that can be defined as intelligence

i.e. Attributes that are NOT STATISTICAL in nature, i.e. not calculable - so not using any computer vision??

plan  
Demost  
0 number of  
hearts  
visual copying  
1 scaling up  
non-plan - approx  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60  
61  
62  
63  
64  
65  
66  
67  
68  
69  
70  
71  
72  
73  
74  
75  
76  
77  
78  
79  
80  
81  
82  
83  
84  
85  
86  
87  
88  
89  
90  
91  
92  
93  
94  
95  
96  
97  
98  
99  
100



THE MUSEUM IS NOT ENOUGH

Enlightenment -> ...

Can ML -> ...

How to reproduce ML? ...

What's the ...

① Better than ...

② ...

③ ...

④ ...

⑤ ...

⑥ ...

⑦ ...

⑧ ...

⑨ ...

⑩ ...

⑪ ...

⑫ ...

⑬ ...

⑭ ...

⑮ ...

⑯ ...

⑰ ...

⑱ ...

⑲ ...

⑳ ...

㉑ ...

㉒ ...

㉓ ...

㉔ ...

㉕ ...

㉖ ...

㉗ ...

㉘ ...

㉙ ...

㉚ ...

㉛ ...

㉜ ...

㉝ ...

㉞ ...

㉟ ...

㊱ ...

㊲ ...

㊳ ...

㊴ ...

㊵ ...

㊶ ...

㊷ ...

㊸ ...

㊹ ...

㊺ ...

㊻ ...

㊼ ...

㊽ ...

㊾ ...

㊿ ...