FLOOR PLAN GENERATION

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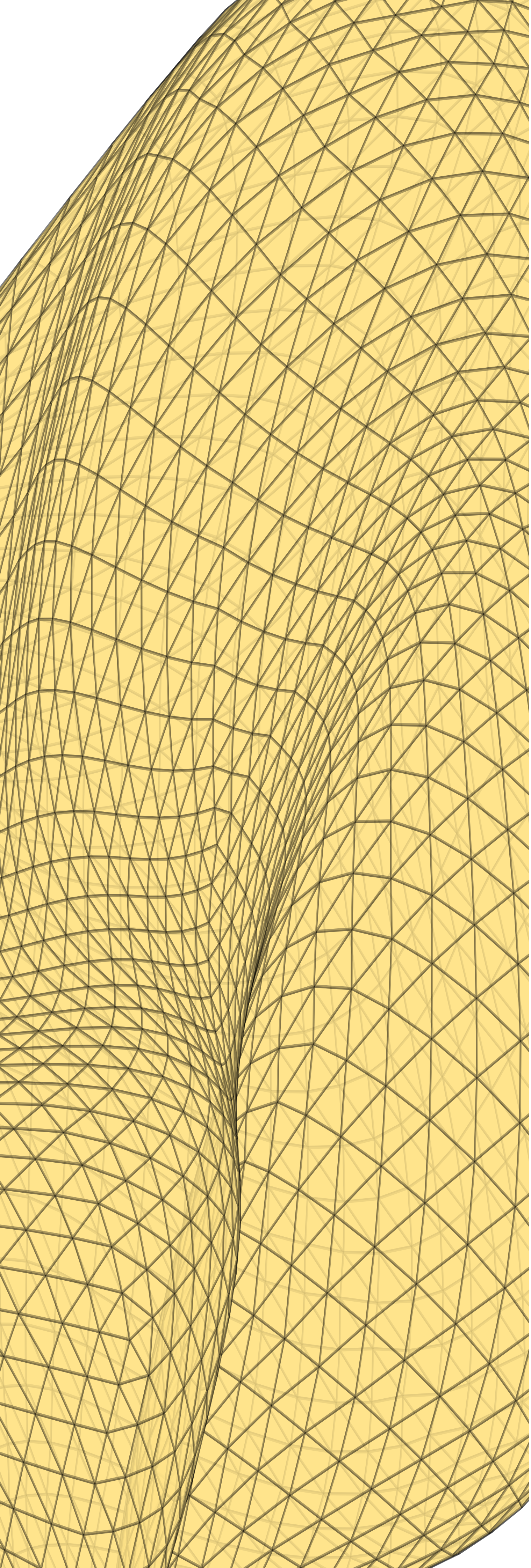
Contents



Introduction

The increasing application of computer science in a wide variety of industries has become reality since the vulgarization of technology and the facilitated access by the broad public. The applications are as diverse as the underlying mechanisms and range from simple code-based optimizations to simulations in every direction to fully digitized frameworks. That scientific fields such as natural, structural, economic and engineering sciences benefit from increasing digitization is fairly natural and may be easily explained by the relevance of mathematical modeling, computational simulations, and the need for significant calculating power, but this interaction is far less intuitive when one considers the example of the artistic or humanistic fields. This report examines the interaction between computer science and the field of architecture, which is situated intermediate between science and art. In particular, it examines the topic of automatic floor plan generation as a starting point for exploring applications such as simulation, analysis, data manipulation, and machine learning based on the generated data. Each of these topics has been extensively researched by the academic world in the past few years and therefore provides extensive documentation of scientific reports. This explains why this work is largely based on third party work, but attempts to bring the individual topics together in a relevant way to create a workflow that can potentially provide new insights. Due to the significant amount of existing research and information, a extensive state of the art and thoroughly reading of relevant research is essential.
In addition, a significant emphasis is placed on the interaction of computer-based algorithms and the inherent creativity of the architectural profession, which has proven difficult to combine with digital means. Thus, this is neither a purely scientific work nor an exclusively experimental investigation, but rather the structured documentation of a problematic investigation with sensitive consideration of interdisciplinary aspects.

Abstract

This project tries to intervene in the architectural design process by applying different prediction models in order to pre-select certain volumetrics based on user-defined properties. To achieve this, several steps with different software library and algorithm application are needed, since the domains to be obtained vary from geometric to environmental simulations. First, the focus is on the parametric generation of an apartment floor plan using Python, Blender's Sverchok and various algorithms such as Voronoi Diagrams, KD-Trees and Genetic Algorithms. After generating a manifold spatial configuration, it can be analyzed from a variety of geometric aspects using the Python library Topologic. It is important that these two steps are in constant feedback exchange to combine geometric data with spatial analysis evaluation and to save the information in a file format appropriate for the data. These formats can vary from simple CSV files to database formats or graph data.

Furthermore, the evaluation stage can be complemented by physical and environmental analyses such as the application of light and radiation based simulation using Radiance, Vi-Suite, Honeybee and OpenStudio. It is also possible to perform a simulation of the energy performance of the architectural object using Energy+, Vi-Suite-Energy and OpenStudio's core component.

The evaluated geometric synthetic data can then be used as training data for a machine learning model after adapting the data shape with Pandas using SciKit-learn, Tensorflow or Pytorch.

Whether it will be a CNN, GAN or simpler algorithms like Random Forest will be determined based on the data properties. The last step concerns the reconstruction of the data in geometric form into a three-dimensional model, which will eventually be extended, enhanced, stored and displayed in a common open source BIM format such as IFC using IFCOpenshell, BlenderBIM, Topologic, Opencascade and Homemaker.

Special attention will be paid to the consistent use of python-based libraries to ensure the best possible compatibility of the individual software interactions. Furthermore, for didactic, ideological and compatibility reasons, only open source projects will be employed. During the execution of the individual steps, possible problems, suggestions, solutions, proposals for improvement and, just as important, ideas for further research of the topic are noted, which are described in detail in the following report.

This project tries to explore an unconventional approach in the connection between architectural generative design, spatial and environmental simulation in combination with machine learning.

Framework

This report is part of a long line of research on the interaction between machine learning and architectural design. The following project was developed in the framework of the Architecture and Design Studio at the Université libre de Bruxelles, which is characterized by an openness to new technologies in connection with architecture. The studio's focus is to raise interdisciplinary questions between technology, research and architecture that can be freely developed without having to remain in their limited domains.

The aim is to develop hypotheses about the future of architecture, taking into account all areas that may be of interest in terms of the design process of the project. In every aspect of the project development, it is important to take into account the analysis of new scientific knowledge and to explore the achievements of current science. Yet, it is also important to base experiments on inventions that have emerged throughout history.

This studio is not primarily about inventing novel objects, but rather to deepen the study of a given topic with all existing publications and research in order to formulate a relevant research hypothesis. The goal is then to begin a process of experimentation accompanied by meticulous documentations. The goal of this process is to find answers to the questions raised in the preliminary stage. In this way, the experimentation cycle will advance the research and may possibly lead to a concrete solution, but in any case will raise a new set of questions that can be pursued subsequently.

The operation of the studio is closely linked to the FabLab of the Faculty of Architecture, providing access to many tools for designing and experimenting. This space will also act as a library of skills acquired by each individual, and thus the emergence of collective knowledge. As a result of the restructuring around the Covid 19 pandemic, the workshop has become a paperless studio, which means that the visual representations and research objects are mostly digital.

Hypothesis

The use of intelligent neural networks and models trained through machine learning to optimize traditionally manual processes has become the norm nowadays. Machine learning is no longer limited to computer science, but extends to any domain as long as a database to be analyzed is involved or can be created. It is therefore not surprising that learning models have also found their way into architectural optimization.

However, the application of machine learning in architecture is wide-ranging and can be useful in any project development process. For example, intelligent parametrization can help find the adequate shape even before a concrete project is modeled, a mechanical analysis of the existing conditions and framework can be helpful to determine an approximate volumetry. Furthermore, it is possible to generate through intelligent algorithms the partitioning of the internal space and thus propose several adapted plans, which can lead to a qualitatively enhanced experience for the occupants. This optimization is not limited to the two-dimensional space and can therefore provide suggestions for optimal circulation or optimization of daylight incidence throughout the building. Besides the conceptual phase, it is equally possible to optimize the BIM model through various machine learning algorithms. All these processes are no longer visions of the future, but rather have become the norm, although often automated and therefore not directly visible. This report will mainly focus on the application of pretrained models, pseudo intelligent and evolutionary algorithms in the conceptual phase to attempt to automatize the generation of floor-plans in order to obtain an optimized plan through subsequent steps.

Premise of this work is the assumption that there is a direct re-

lationship between external conditions such as space connections, solar radiation, shading, humidity, wind flow, heat formation, soil conditions, air quality, pedestrian circulation or traffic congestion and the occupant's perceived quality of living.
The main hypothesis treated in this report addresses whether and to what extent learning algorithms can simplify, accelerate, and/or optimize the architectural design process. Is the increasing application of intelligent architecture considered purposeful or will traditional values be lost? Is the automation of processes traditionally performed by humans again just an idealized label or are there tangible benefits for both clients and architects? Furthermore, this thesis will investigate to what extent it is possible to perform a complete workflow from generation to simulation, analysis, prediction and back to generation without resorting to proprietary software and thus describe a step towards the democratization of architecture and its digital tools.

State of the Art

Since this project deals with diverse topics, the collection of previous works is accordingly divided into hierarchical subgroups. First, the role and emergence of computational design with parametric, generative and algorithmic design as subgroups should be considered. Its origins go back to 1960, when Sutherland's SKETCHPAD software was a major step towards the automation of architectural drawings and the digital parameterization of the relationships between individual geometric units. In the following years, several individual approaches to building information modeling inspired by important computational design conferences developed. With the establishment of various computer-aided design software, the way to visual programming interfaces was paved and with it the access to parametric and generative design tools for the masses. In this work, the geometric parametric tools apart from backend python coding will focus on the visual interface of the Sverchok addon for the three-dimensional processing software blender, which makes use of various python libraries. The first goal of this work, the automatic generation of synthetic floorplans, is as a topic widely researched and this with many very diverse tools, which can be roughly divided into simple algorithms, intelligent algorithms and machine learning enhanced algorithms. The group of simple algorithms is subdivided into geometric space partitioning by Voronoi diagrams and its derivatives like Delaunay triangulation, Lloyd's Algorithm, Orthogonal Voronoi Diagram and weighted Voronoi Diagrams. Also mentioned are aproximating schemes for subdivision such as Cutmull-Clark and interpolating ones such as Butterly subdivision Surfaces. Kdimensional trees, originally from the family of such algorithms, differ from the previous ones, despite the essential similarities, by a subdivision of input vertices as opposed to polygons, which thus allows a sensitive control over control points. The method of slicing tree structure forms the connection between point and area oriented subdivision. Another method of simple algorithms is the shape grammar methodology which allows rule based geometry generation and thus space for variation in defined limits. This topic has gone through many variations such as the CGA shape or parametric shape grammar and is recognized as a programming language in its own right through successful simulation of turing machines. Far enough away from these methods to define themselves as a group of their own are physics solver based methods like attraction force models or MagnetizingFPG algorithm to some degree. In this paper, however, we will mainly focus on the latest and more interesting topology based method developed by Wassim jabi. Topologic is not a layout generation method but rather an opencascade based geometry processor that processes non-manifold topologies and thus reduces the architectural spaces to simple cells and cell complexes. This method allows layout generation by combining the above mentioned methods and paves the way to a simple geometry to file workflow. Furthermore, topologic's boundary representation method facilitates environmental simulations for the subsequent plan evaluation stages. However, by far the most significant advantage of using topologic is the analytical approach to continuous space and relations awareness, which allows the arbitrary addition of apertures such as doors and windows, as well as the graph generation of various topological parameters and last but not least an interface to common BIM file types such as IFC, BREP and JSON.

More important in the literature of floorplan generation than the mentioned approaches are intelligent methods like evolutionary algorithms since the 1990s. These are input populations that go through biology-inspired mechanisms such as reproduction, mutation, recombination, and selection through fitness evolutionary phases, resulting in an optimization of the fitness function. Evolutionary algorithms can be combined with simple geometric methods by means of goal definition and can also be used for optimization by means of evaluation analyses. Computational intelligence also includes machine learning and neural networks, which are by far the most widely used methods in the field of automated floorplan generation. However, the above methods differ drastically from artificial neural network applications in that the latter are based on the learning of features in defined training datasets. In the context of plan generation, these datasets are real plans designed by humans. Thus, the computer generated floor plans resemble the input drawings but leave room for differentiation which is limited by the learning process based on existing plans or evaluation based on suitably defined examples.

Process

This work is an experimentally exploratory approach, meaning the primary goal is not to achieve an optimized process, but rather to critically analyze the individual steps. Thus, by repeatedly questioning the method, insights can be gained that will be beneficial in the following phases. Moreover, an essential focus lies on answering the formulated questions presented in the hypothesis, which means that the individual steps should be reected on several layers in order to gain not only technical, but also moral, ethical, and social insights.

First, the topic of parametric automated plan generation must be addressed in depth. In today's world, artificial intelligence is used as a kind of selling point, a solution to all complex problems, which raises the question of whether this assessment is truthful, or is this term simply associated with idealized solutions? Once

these questions are answered and a concrete concept has emerged from the abstract term, it becomes possible to think about connections between architecture and machine learning that simplify existing design processes, blueprints, simulations or constructive procedures.
Just as important as a clear understanding of the subject matter an in-depth review of the available libraries and their functions, in order to create a customized network diagram covering the interactions. The open source community, through platforms such as Github, Gitlab, and OSArch-community, provides an appropriate and direct exchange with developers and interested individuals and a complete understanding of the functions and procedures, as well as, in most cases, detailed documentation. With the help of various forums and exchanges with developers, it is possible to gain a comprehensive understanding of the software in question in a relatively short period of time, thus advancing the ideas of the project.

Objectives

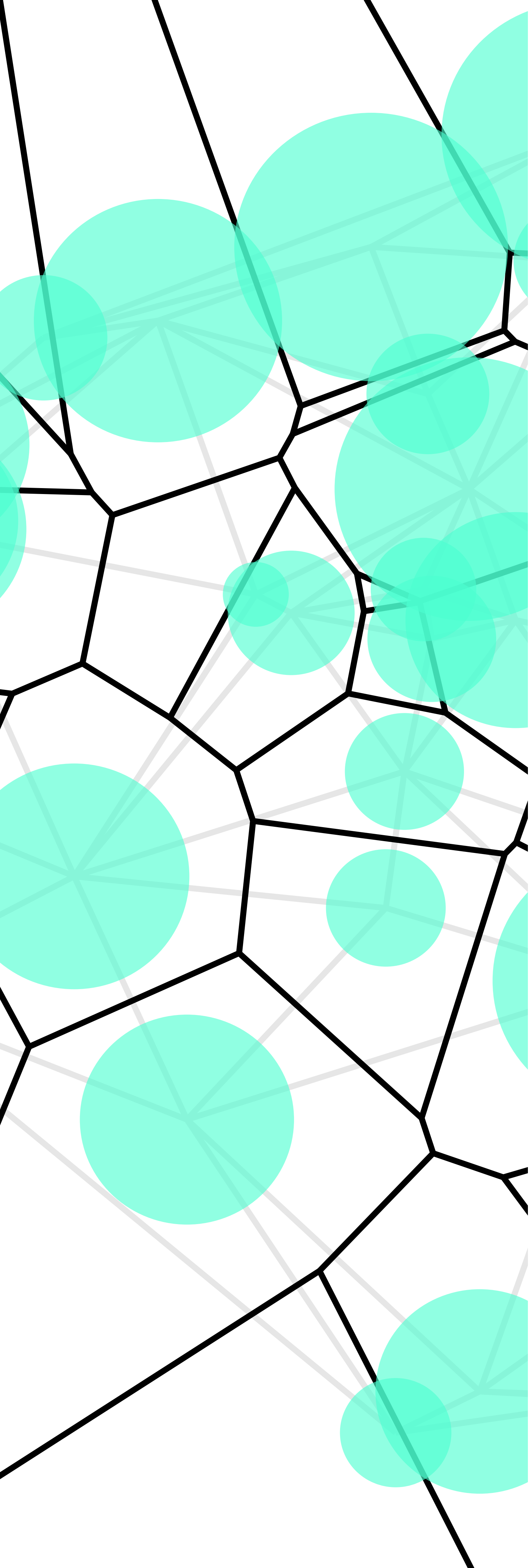
The experimental freedom explained above also leads to flexibility in terms of the defined aims. In general, there are objectives for each stage, but this does not mean that a step has failed if they turn out differently than expected or formulated in advance. Thus, the stage of parametric generation has as a desired result the generation of synthetically generated models that can be constrained by certain parameters. These can be the number of living rooms, the number of residents, the area, the volume or the shape of the floor plan. The end result of this phase should be a database of the different geometries that describes each situation as accurately as possible while still requiring a minimum amount of points. In the next stage, the simulations would generate new evaluation values that could be added to the geometric database. Further, the next stage is to train a model that describes the relationship between the individual values as accurately as possible by means of a graph. Finally, the last stage is to provide an accurate visualization of the predicted scenario.

Roadmap

- [ ] Information Gathering
  - [ ] Search Resources
    - [ ] Code Repositories
    - [ ] Academic Papers
    - [ ] Books / Reports / Articles
    - [ ] Student Works
  - [ ] Create Bibliography
  - [ ] Adequate Software
    - [ ] Code Documentation
    - [ ] Explanatory Resources
- [ ] Geometric Generation
  - [ ] Available Methods
    - [ ] Algorithms

      - ☐ Evolutionary Generation
      - ☐ KD-Tree
      - ☐ Pulga Physics
      - ☐ Shape Grammar
      - ☐ Shape Packing
      - ☐ Orthogonal Convex Hull
      - ☐ Voronoi
      - ☐ Orthogonal Voronoi
      - ☐ Lloyd
      - ☐ Delaunay
      - ☐ Power Diagram
      - ☐ Polygon Division
      - ☐ Recursive Subdivision
      - ☐ Recursive Bisection
      - ☐ Recursive Angled Bisection
      - ☐ Surface Population
      - ☐ Point Cloud
    - ☐ Machine Learning
      - ☐ CNN
      - ☐ GAN
      - ☐ Random Forest
  - ☐ Parametric Generation
    - ☐ Sverchok
    - ☐ Grasshopper
  - ☐ Evaluation
    - ☐ Data Set Search
    - ☐ Comparison
    - ☐ Esthetic Verification
    - ☐ Functional Verification
    - ☐ Ideological Verification
      - ☐ A Pattern Language
- ☐ Simulations / Analysis
  - ☐ Familiarization
    - ☐ Environmental
      - ☐ Energy
        - ☐ Energy+
        - ☐ Openstudio-Energy
        - ☐ Ladybug
        - ☐ Vi-Energy
      - ☐ Lightning
        - ☐ Radiance
        - ☐ HoneyBee
        - ☐ Openstudio
        - ☐ Vi-Radiance
      - ☐ Air
    - ☐ Spatial

        - ☐ TopologicPY
        - ☐ IFC
        - ☐ Blender BIM
      - ☐ Structural
    - ☐ Usage
    - ☐ Data Type Examination
    - ☐ Verification
- ☐ Data Manipulation
    - ☐ Database Types
    - ☐ Data Preparation
- ☐ Machine Learning
    - ☐ Methods
- ☐ Visualization
    - ☐ Back Feeding
    - ☐ Geometry Viewer
- ☐ Pertinence Study
    - ☐ Usage Application

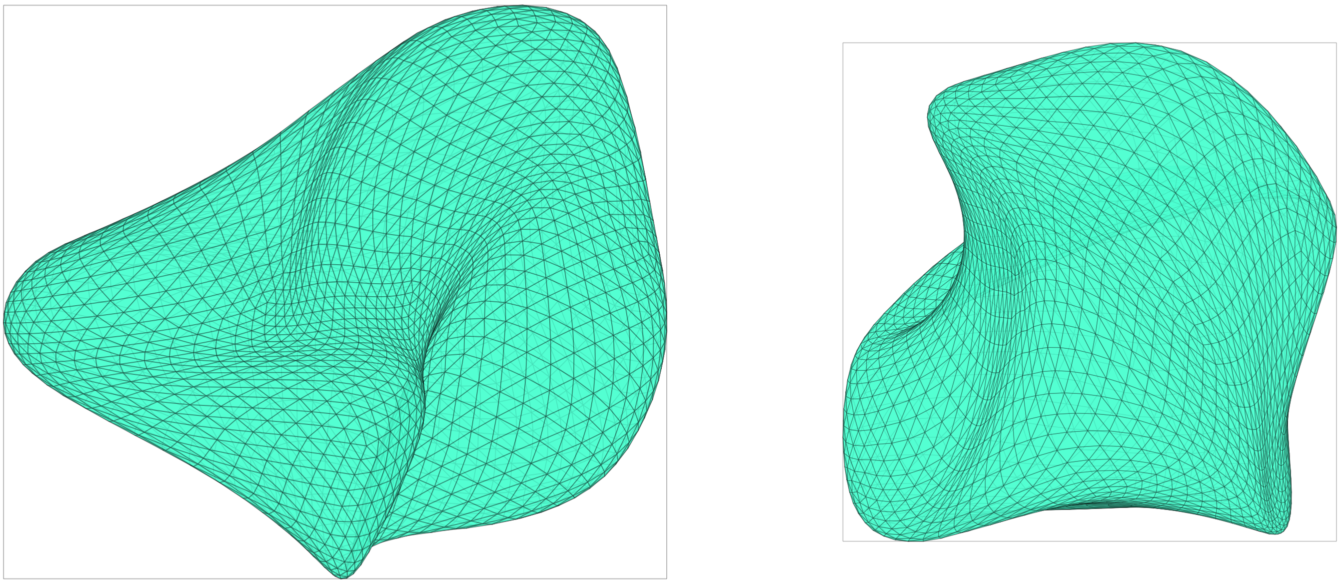


Layout Generation

The first stage of this work deals with the automated generation of different apartment layouts using different geometry processing software. An alternative to the generation approach is the acquisition of existing architectural datasets provided by real estate and research groups. Advantages of reality-based datasets are the certainty of architectural feasibility and construction of the individual plans, but disadvantages are a conservative approach in creative terms and a high risk of traditional bias due to the predominance of local and traditionally influenced architectural methods. Therefore, this experimental phase is primarily concerned with testing different floorplan generation methods and their derivatives as well as their possible combination. Simple algorithms like voronoi diagrams, intelligent methods like evolutionary algorithms and data driven approaches like neural networks are explained and evaluated by different experiments. Criteria for the evaluation are simplicity in the construction process, computing power, time and memory, integration and interaction with used software, purity of the generated geometry, degree of readiness for the simulation stage, simplicity of the layout for data storage but above all spatial quality, creativity in form finding and feasibility. After experimentation, the most appropriate method or combination of algorithms for the following steps is selected and an appropriate set of different layouts is generated. In order to increase the variation in the synthetic dataset, results from different methods can be mixed, but they must not deviate from the generally defined quality level. Furthermore, it is a requirement to understand the functionality of the algorithms sufficiently to allow slight adaptations and combinations with other functions and to achieve variation in the individual applications. In general, simplicity is preferred to complexity, creativity to ordinariness and variation to repetition.

Genetic Algorithm

The Genetic Algorithm developed by Holland and De Jong is an optimization model based on Darwin's natural selection-based theory of evolution in biology. Its operation is based on biological mechanisms such as crossover, recombination, mutation and selection by fitness evaluation acting on a population of defined size. Due to their mode of operation, genetic algorithms and their derivatives are particularly adaptable and offer a parallelization of the solution finding. However, for optimal application, the right parameters have to be set, such as crossover and mutation rate, population size, iterations and fitness boost. These parameters are problem-dependent and there is a risk of an undesired and non-optimized result if the starting conditions are set incorrectly. The construction of an evolutive algorithm begins with the determination of the variable function to be optimized, which consists of an unlimited number of components and has a tendency towards zero. After the framework conditions of the algorithm have been defined, the variables to be varied must also be determined, whereby it is important to ensure a proportional relationship between parameter variance and fitness evaluation function. In Figure 27, the surface area of the X- and Y-dimensional bounding box of an irregular three-dimensional body was defined as the fitness function. The population of the genetic algorithm acts on the three Eulerian rotation axes of the body and thus achieves a minimization of the Z-section of the irregular shape by iterative mutation and fitness evaluation.

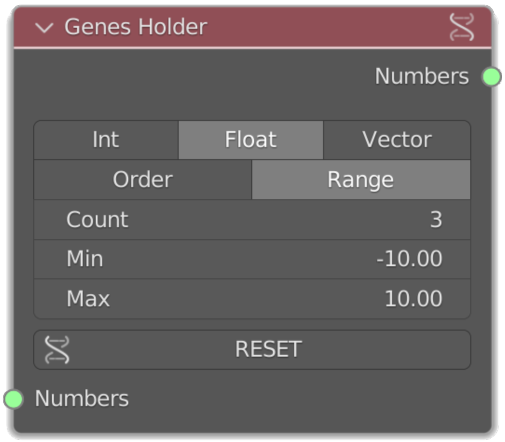


(a)

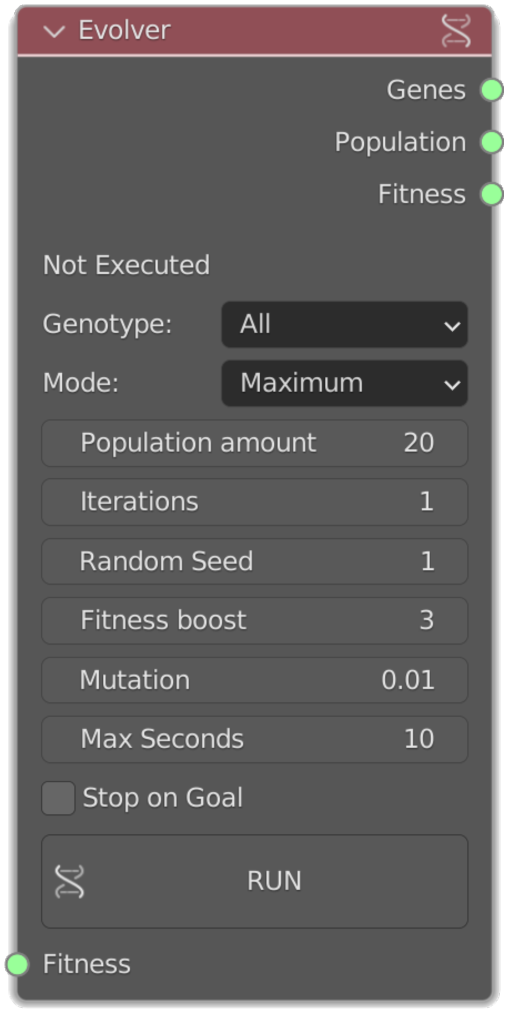
(b)

Figure 1: (a) blah (b) blah

With increasing iterations and an increase of the population number, the optimum is progressively approached, but the question arises how such a method works theoretically and how it proves itself on more complex problems? In Python there are several established evolutionary algorithm libraries with different integration mechanisms ranging from native python implementation to Keras and Pytorch or even scikit-learn integration. Since this work is primarily focused on generation and manipulation of visual and three-dimensional entities, the python natieve Blender implementation of the sverchok Genes solver was chosen as the experimentation tool. This provides a seamless integration into a visual scripting environment and thanks to sverchok's Blender integration, Blender's features such as the variety of available export file formats can be easily used.



(a)



(b)

Figure 2: (a) blah (b) blah

In order to test the floorplan-layout-generation capabilities of the evolution algorithm in Blender, different rectangles with defined X and Y sizes are first generated parametrically, each of these space representations being anchored by its origin location and rotation in two-dimensional space. The shape of each unit remains constant and represents the space sizes of the different apartment components. However, the lacolization and orientation of these modules remains free and is defined as a population parameter.

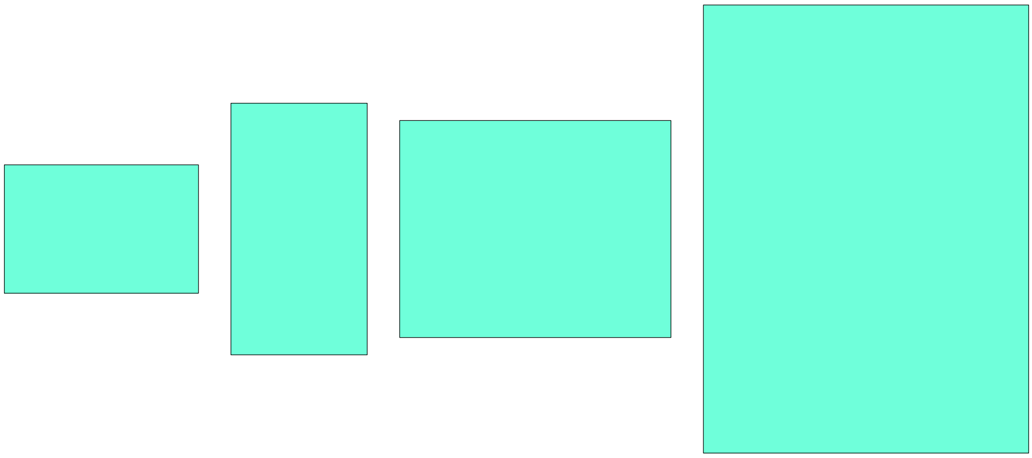
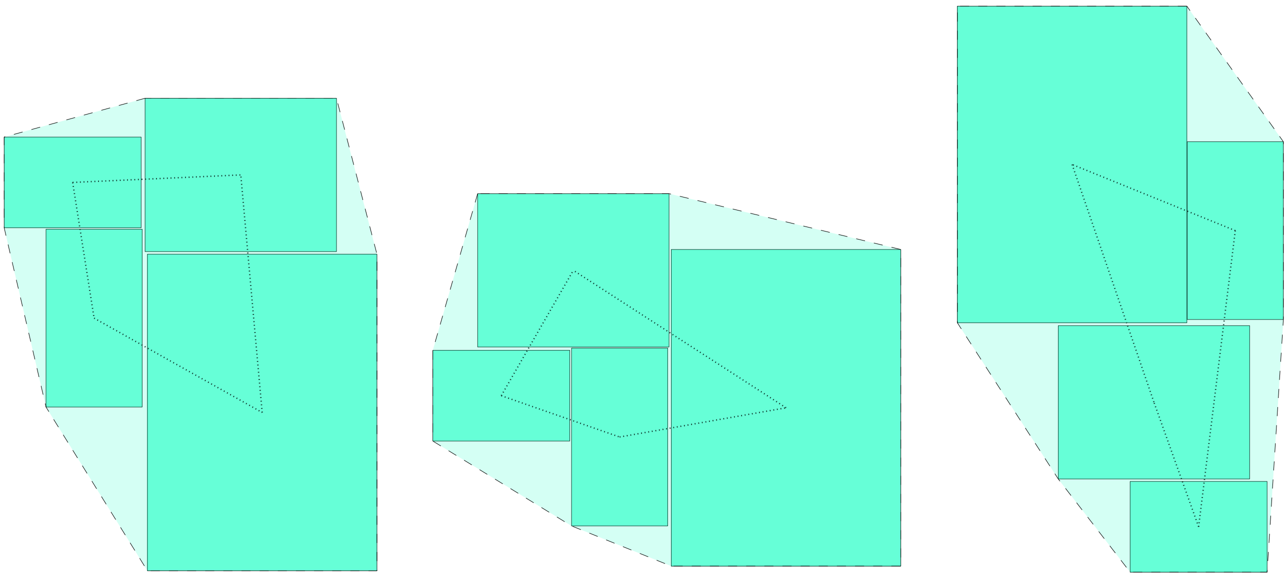


Figure 3: test

The fitness function is composed of the total length of the path of the UV connection of the individual rectangle origins, added to the total area of the two-dimensional convex hull with respect to the Z-axis of the overall geometry. Thus, the smaller distance between the individual units is rewarded in parallel by the total area and the individual distance of the center points, while also avoiding the overlap of the individual rectangles. This is achieved by an irradiation function which evaluates the number of geometries formed by a constant check of the boolean intersection to see whether the total number increases. If this is the case, a defined irradiation variable is added to the fitness function. The population size is set to 500, the fitness boost to 5, the mutation rate to 0.3 with an iteration of 5.



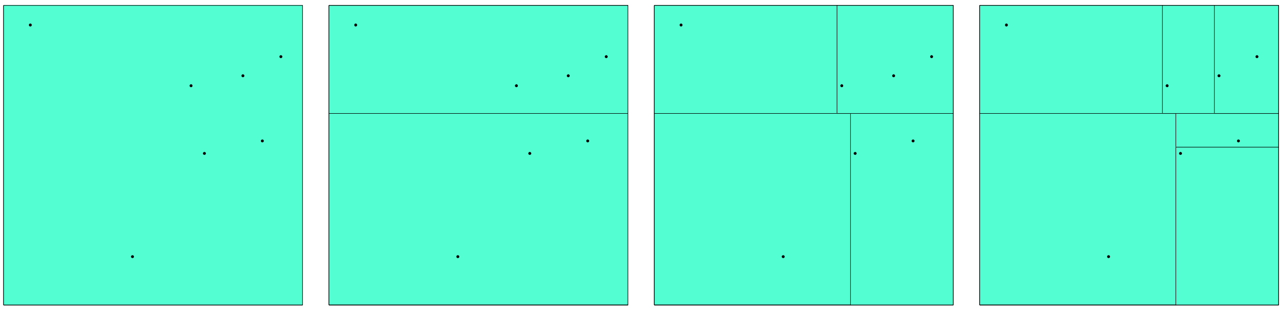
(a) (b) (c)

Figure 4: (a) blah (b) blah (c) blah

The different results generated parametrically by changing the random seed of the algorithm give random results with an amazing variance. Advantages of this method are the possibility of parameterization during the execution of the algorithm, a parallelization of the optimization, the possibility of defining different spatial relations by multipliers, the adaptability of the framework conditions and a variability of the obtained results. However, the main disadvantage is the constant distance between the spaces, which complicates the generation of boundary representation geometries and thus the complexity with respect to later environmental simulations or topological analyses. Furthermore, this increases the impurity of the geometry files to be stored. Possible solutions to this problem are a change of the framework and an extension of the irradiation function due to the overlap of the single units, which could integrate the size of the overlap surface. Furthermore, it would be possible to implement a second method that could lead to the cleanup of the overall geometry, but there is a risk of altering the basic geometry by causing alternating angles.

K-D Tree

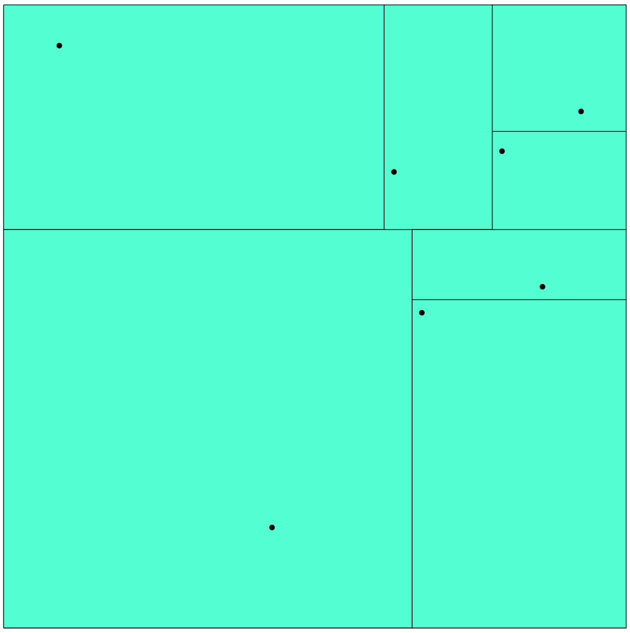
The k-dimensional tree data structure is a space partitioning primarily used in computer science for search algorithms and thus belongs to the family of binary space partitioning trees. It is the partitioning of pointclouds in a k-dimensional space. In this work I will limit myself to the two-dimensional space, since the floorplan layout can be described sufficiently in this dimension. In such a data structure, the dataset is divided into branches by nodes and branches, creating successive levels. Each of these branches leads to a leaf, which carries the coordinates of exactly one point.



(a) (b) (c) (d)

Figure 5: (a) blah (b) blah (c) blah (d) blah

The functionality of such a data tree can vary, but the basic principles remain the same and can be implemented in a simple way in python without using external libraries, building the tree from the root upwards. First, the entire set of data points is considered and a sorting axis is determined based on the depth of the points. After these points have been sorted according to the axis, the node point is determined. This is located on the median of the point list and determines the coordinates of the subarea, which in the following step divides the point list into two child lists. The orientation axis of this intersection is also determined by the depth of the dataset to be split. If the data set to be divided consists of only one point, the leaf of the tree is reached and the iteration is terminated at this node. Thus, by repeating these steps, the complete tree is created using the logarithm.



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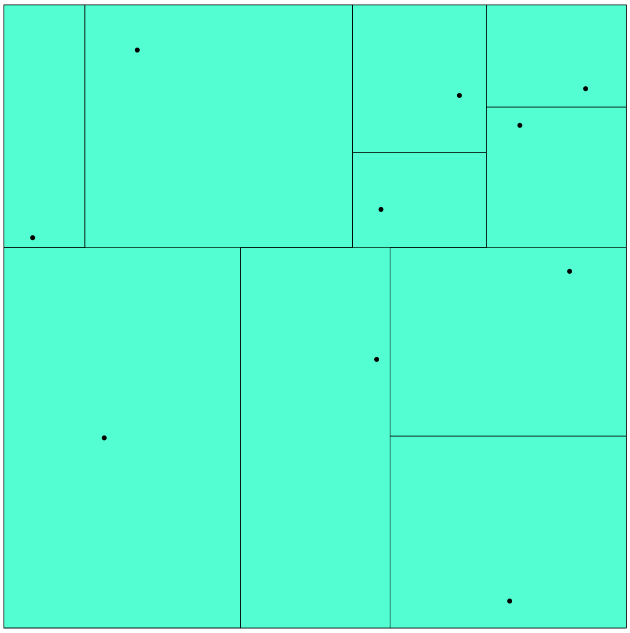
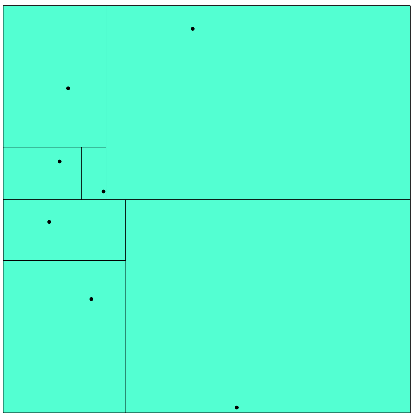


(b)

Figure 6: (a) blah (b) blah

In Blender's Sverchok, creating a spatial K-d tree partition is relatively simple and requires only list manipulation, mathematical operators, slicing planes and loops. The points to be split and the corresponding planar area can be freely defined and are described in the examples shown by X and Y size defined rectangles and randomly selected points on this area. To avoid too small sheet spaces, a minimum distance between these points is defined. The number of these points is unlimited and can be defined accordingly, whereby their number determines the number of spaces of the floorplan.



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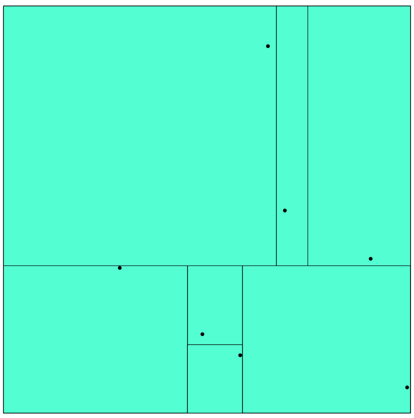

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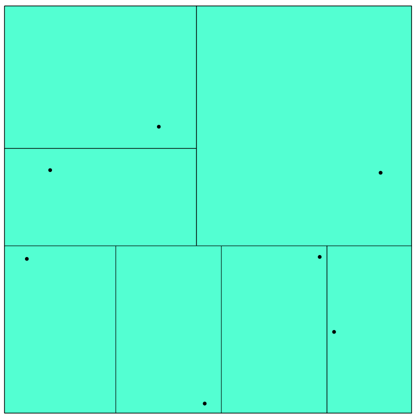
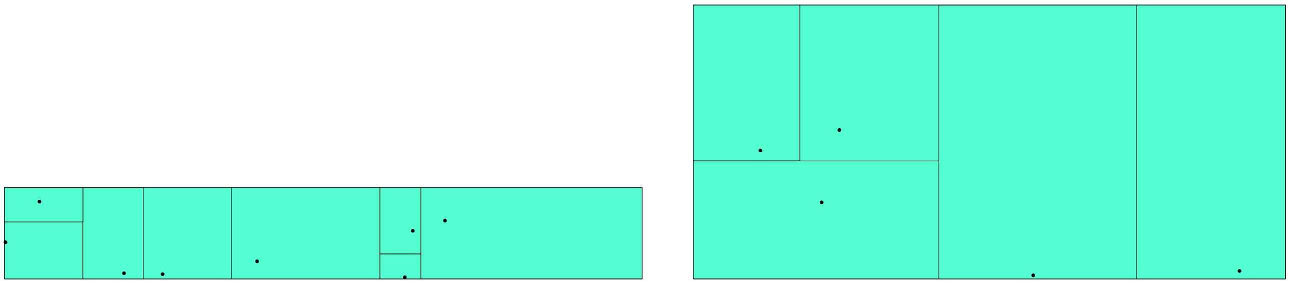


(c)

Figure 7: (a) blah (b) blah (c) blah

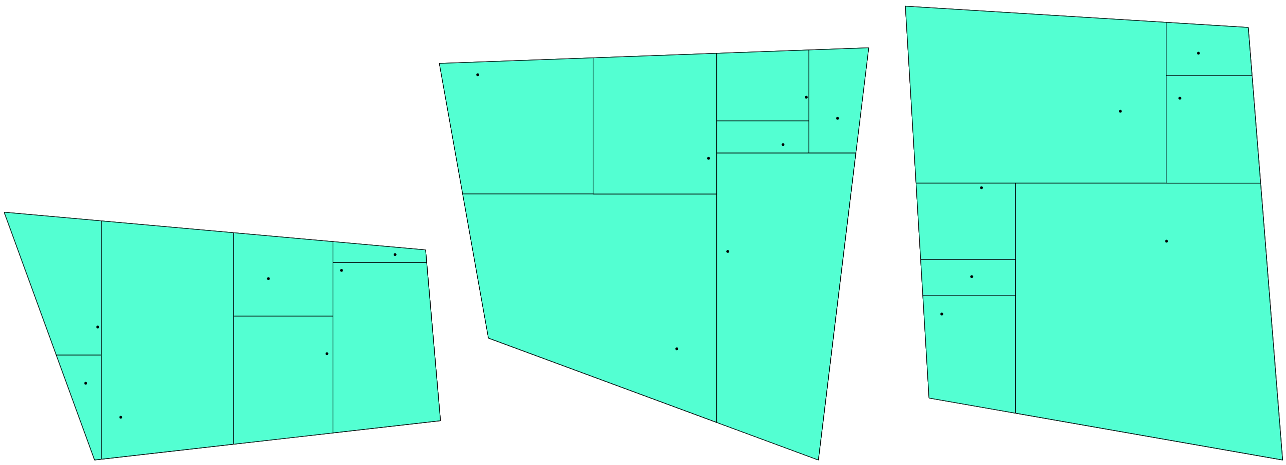
The main advantages of the described method are its speed and simplicity, the generation of natively connected units which simplify the export to boundary condition geometries, the possibility to parameterize the generation process, the determination of localizations of the individual spaces and the choice of the underlying volumetry of the contours of the plan.



(a) (b)

Figure 8: (a) blah (b) blah (c) blah

The outlines of the individual shapes can assume any shape of the rectangles and are thus adaptable to the different frame conditions. Furthermore, it is possible without problems to determine more complex shapes as input geometries, from deformed rectangles to irregular polygons. However, this method also has its drawbacks, such as the difficulty of generating composite apartments in which individual units protrude beyond the floorplan contour as isolated shapes. Thus, it becomes complicated to generate shapes such as terraced garages or irregular facades.



(a) (b) (c)

Figure 9: (a) blah (b) blah

KD-Tree and Genetic Algorithm

A possible combination between the k-dimensional space partitioning method and the evolutionary algorithm could be to optimize the variables of space contour, space number, but especially the point coordinates with a user defined fitness function according to the desired results. Such a combination would optimize the floorplan generation according to the objectives, but it would not solve the above mentioned problems.

Voronoi Diagram

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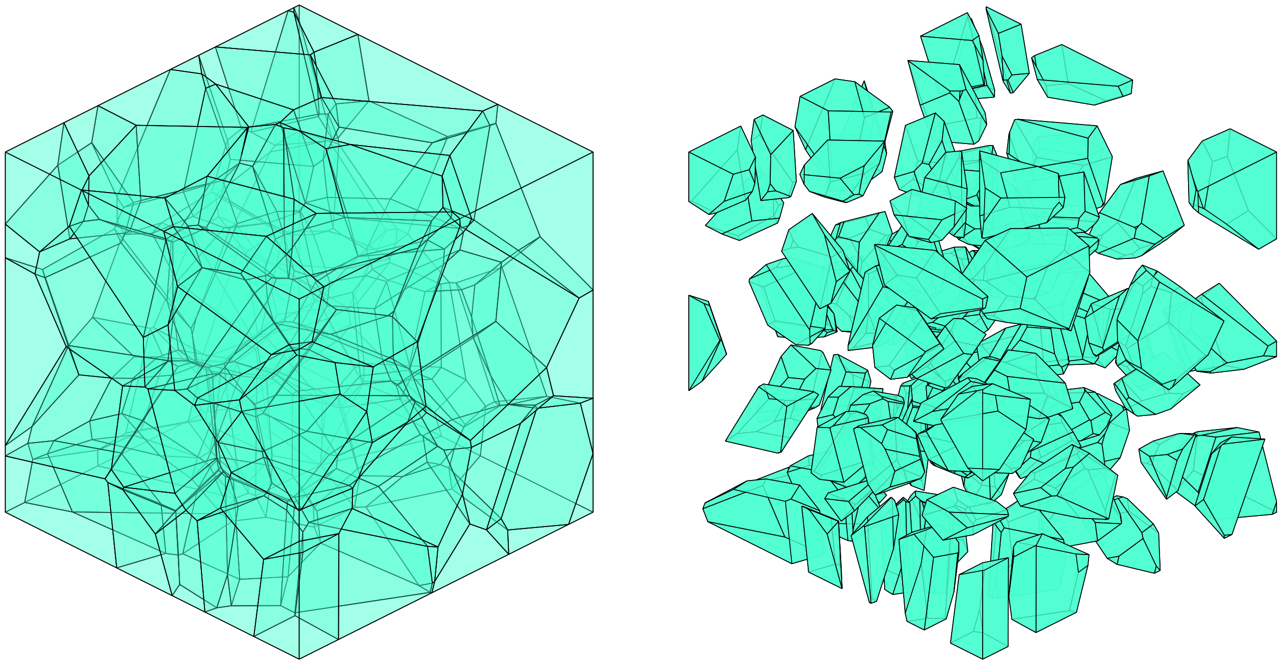

(a) (b)

Figure 10: (a) blah (b) blah (c) blah

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Delaunay Triangulation

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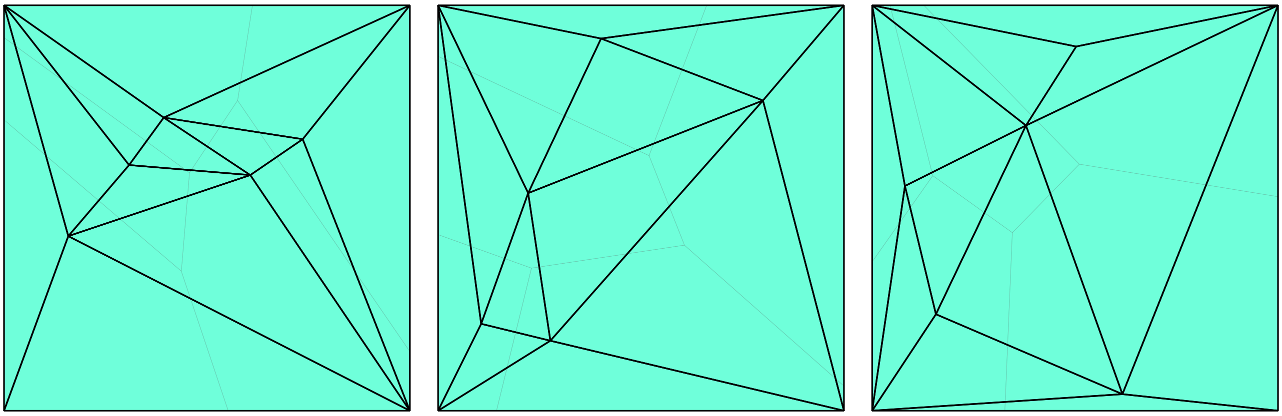

(a) (b) (c)

Figure 11: (a) blah (b) blah (c) blah

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Lloyd's Algorithm

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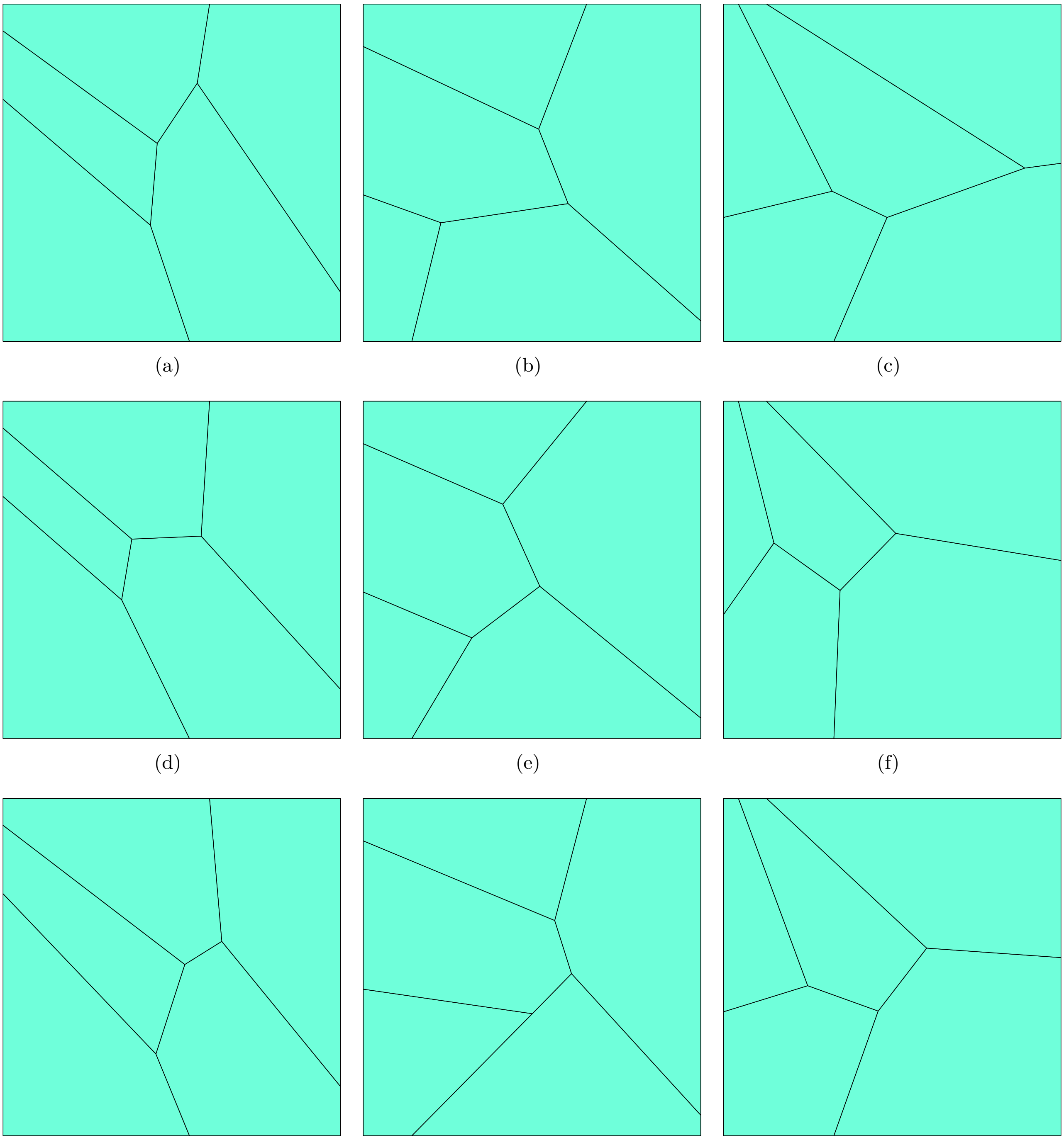

(a) (b) (c) (d) (e) (f) (g) (h) (i)

Figure 12: (a) blah (b) blah (c) blah (d) blah (e) blah (f) blah (g) blah (h) blah (i) blah

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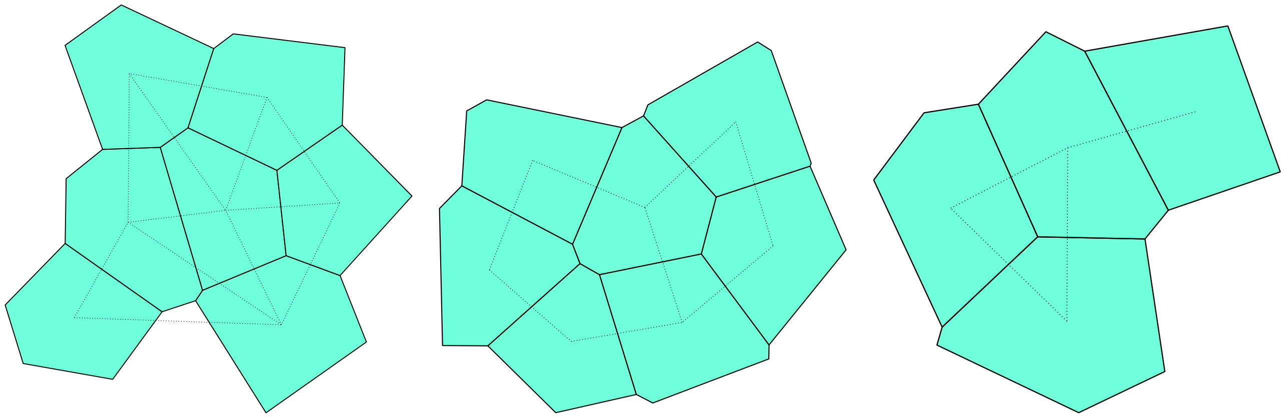

(a) (b) (c)

Figure 13: (a) blah (b) blah (c) blah

Laguerre-Voronoi

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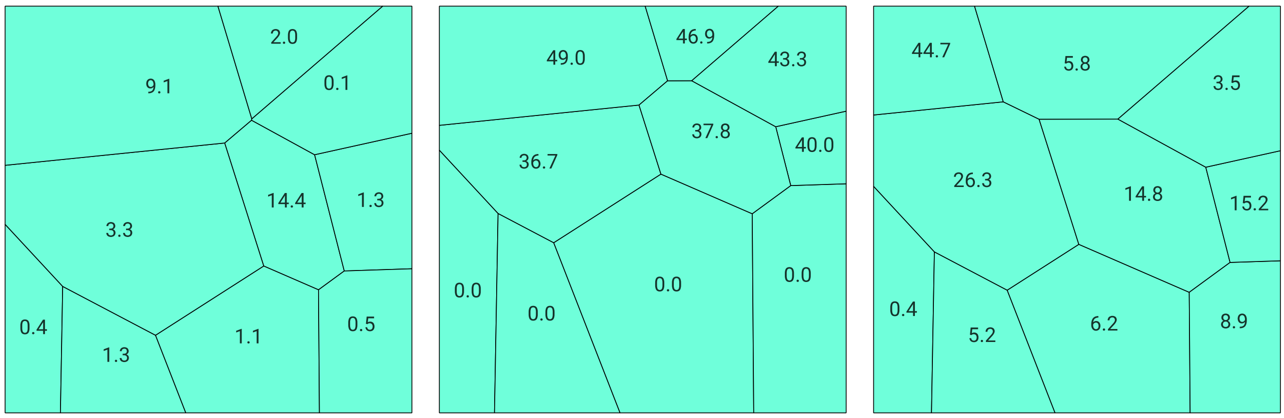

(a) (b) (c)

Figure 14: (a) blah (b) blah (c) blah

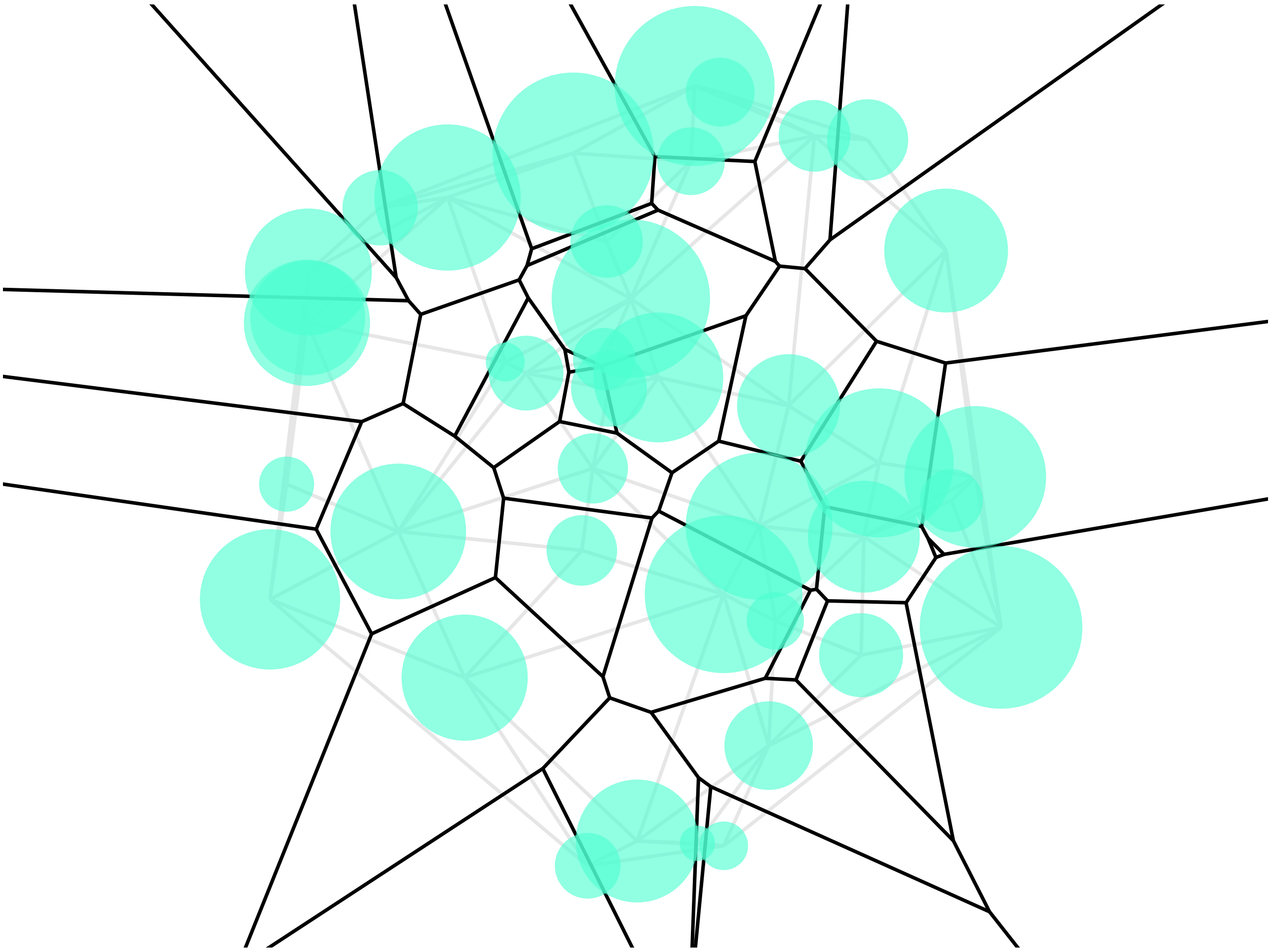

Figure 15: test

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Orthogonal Voronoi Diagram

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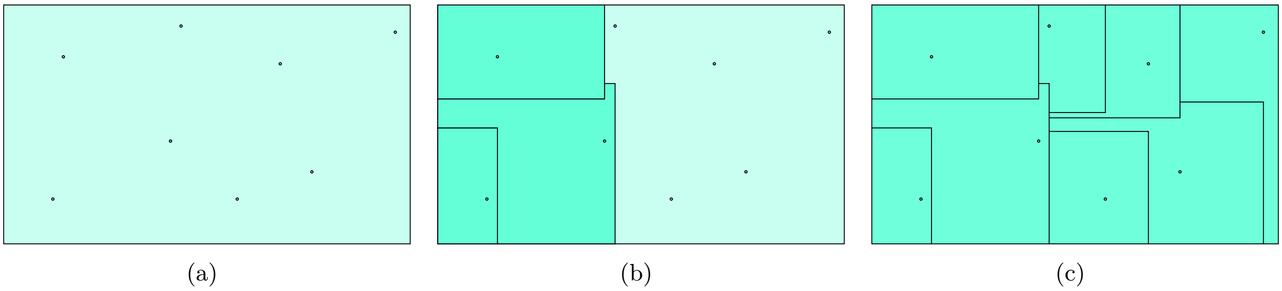

Figure 16: (a) blah (b) blah (c) blah

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Convex Hull

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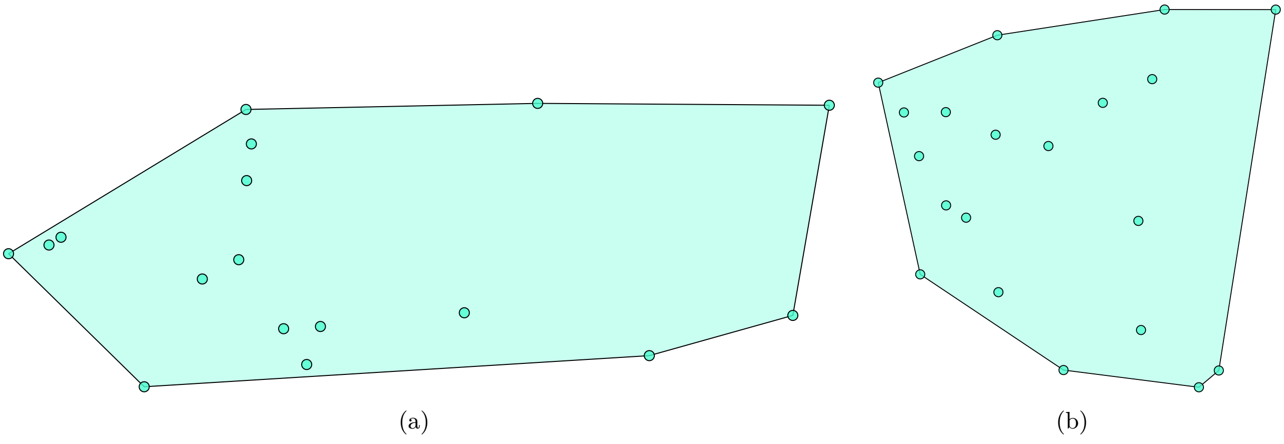

Figure 17: (a) blah (b) blah

Orthogonal Convex Hull

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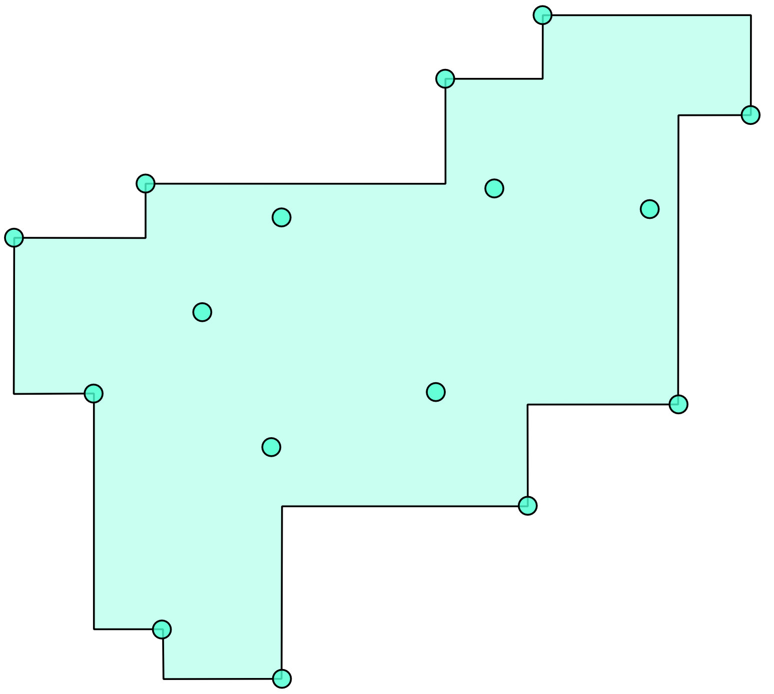

Figure 18: test

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Recursive Subdivision

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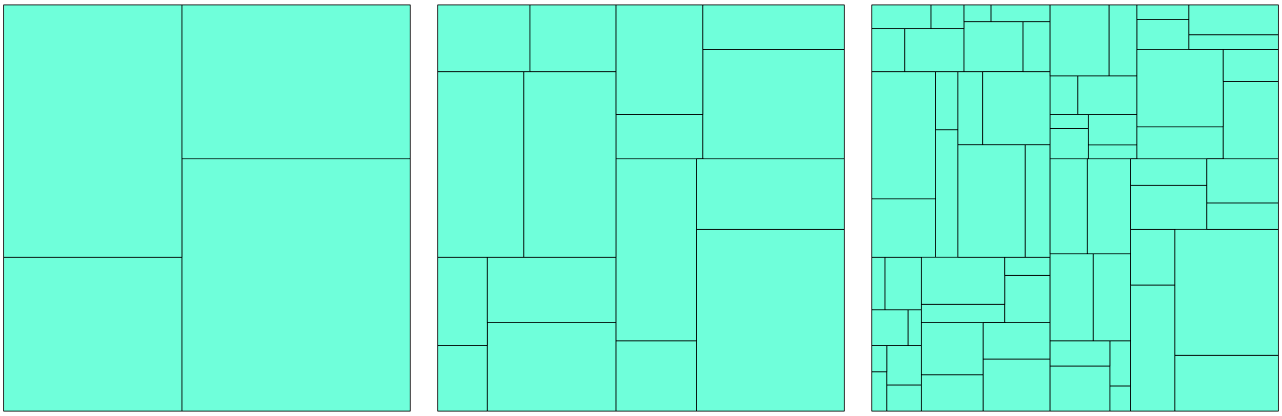

(a) (b) (c)

Figure 19: (a) blah (b) blah (c) blah

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Bent Bisection

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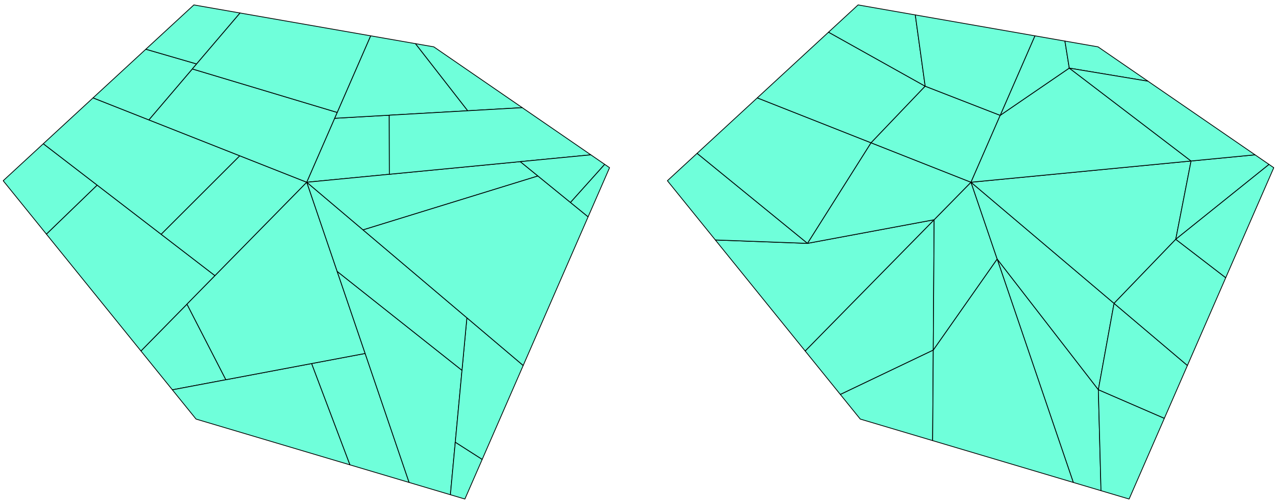

(a) (b)

Figure 20: (a) blah (b) blah

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Shape Grammar

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Topologic

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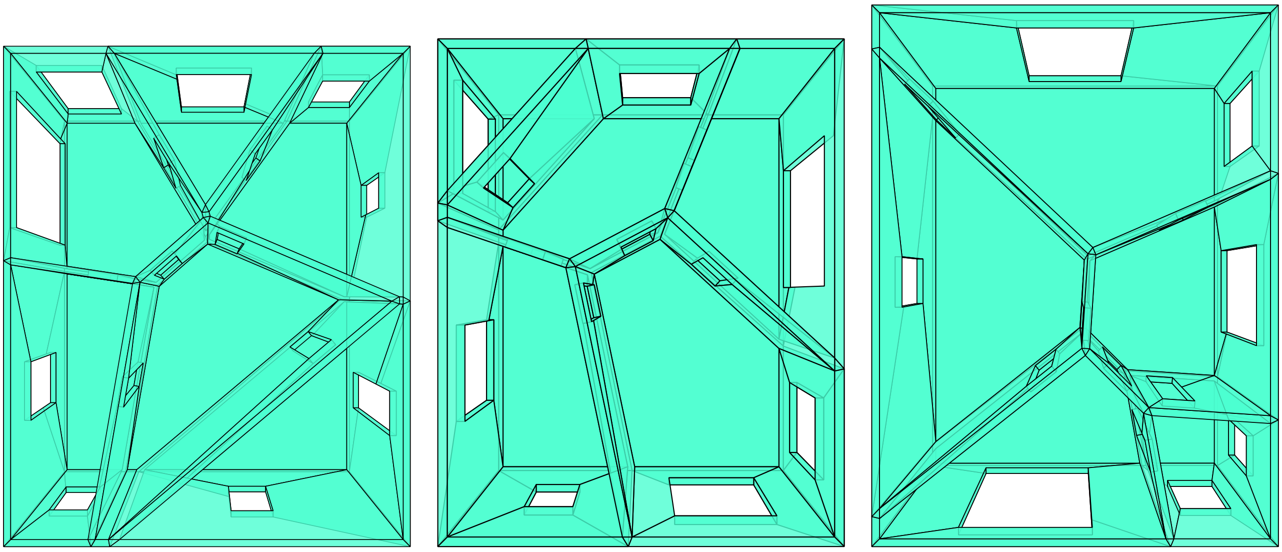

(a) (b) (c)

Figure 21: (a) blah (b) blah (c) blah

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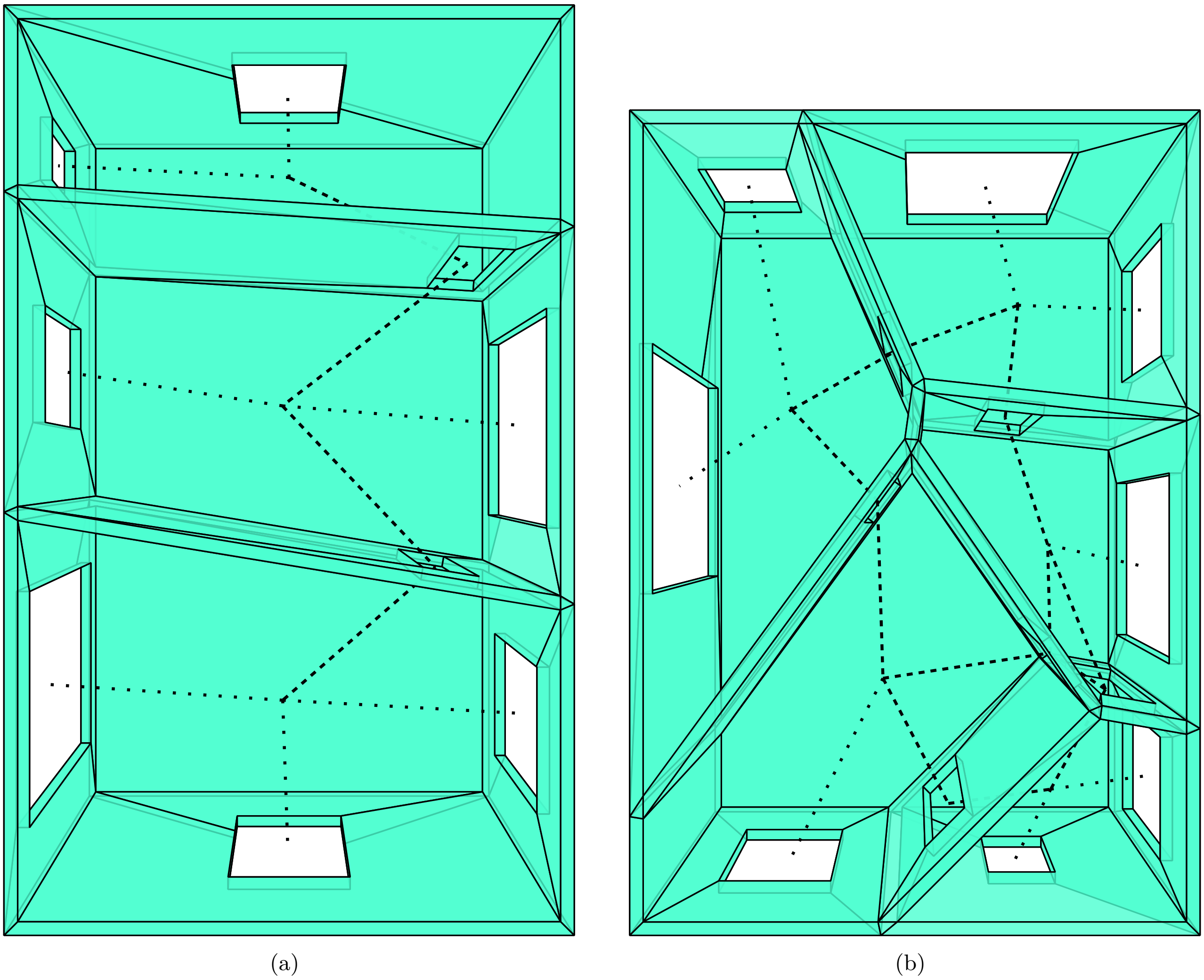

Figure 22: (a) blah (b) blah

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Shape Packing

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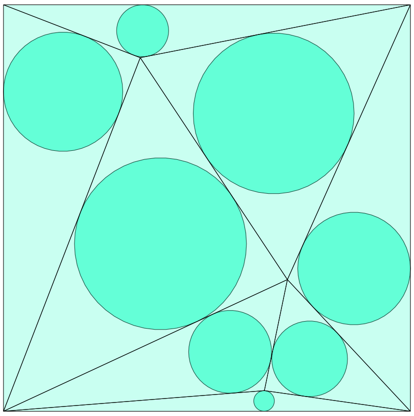
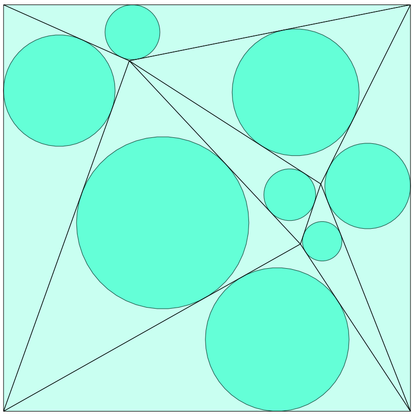
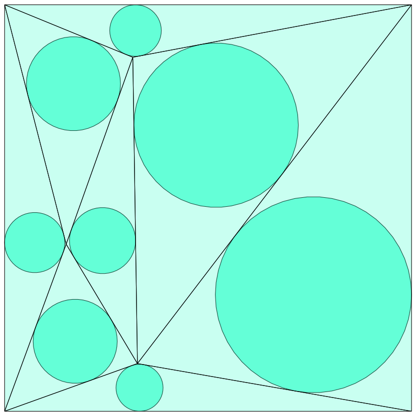


(a)



(b)



(c)

Figure 23: (a) blah (b) blah (c) blah

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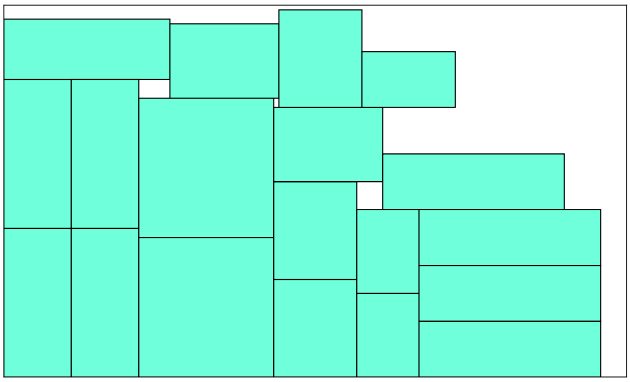
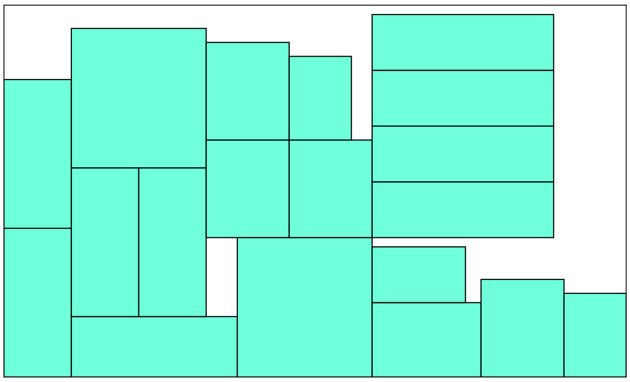


(a)



(b)

Figure 24: (a) blah (b) blah

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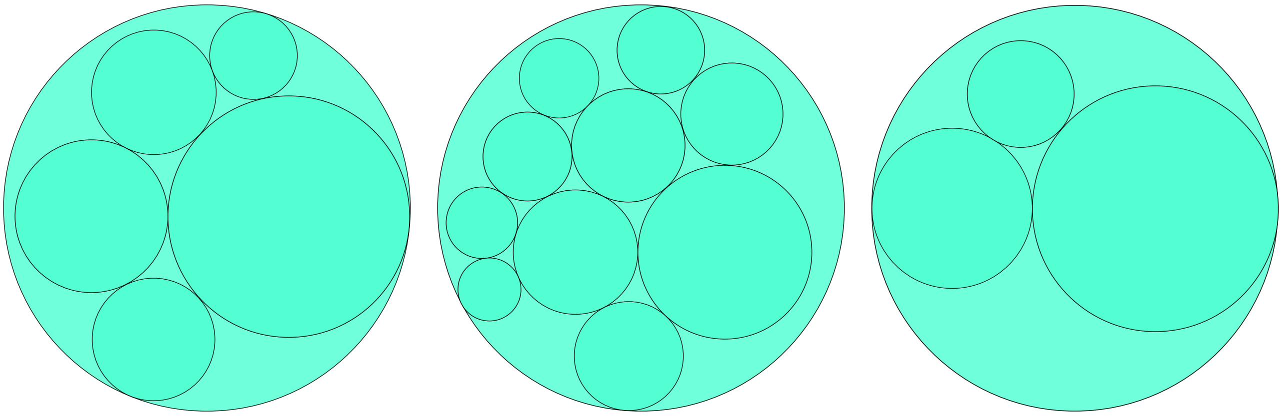

(a) (b) (c)

Figure 25: (a) blah (b) blah (c) blah

Physics Solver

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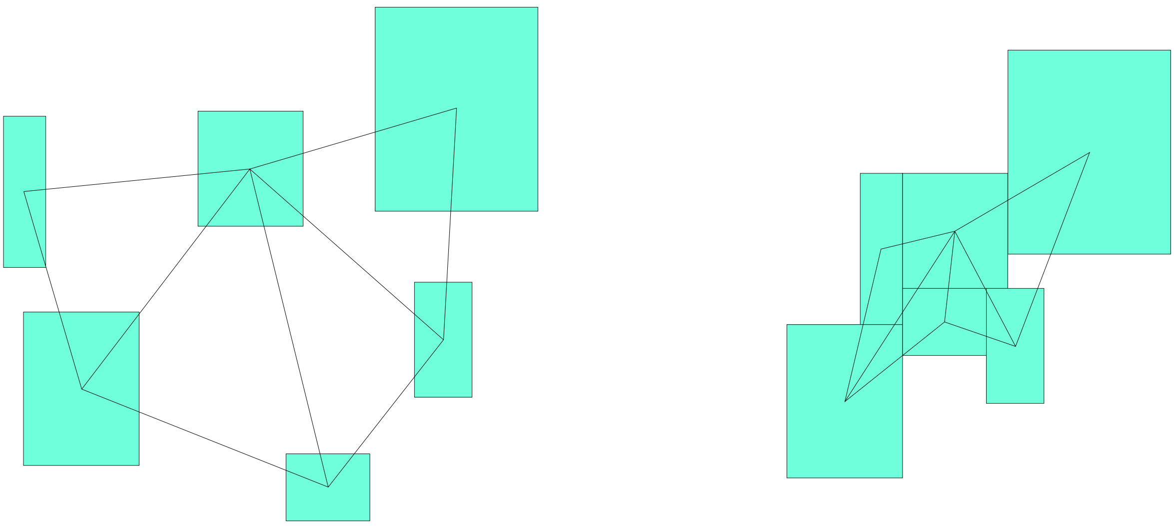

(a) (b)

Figure 26: (a) blah (b) blah

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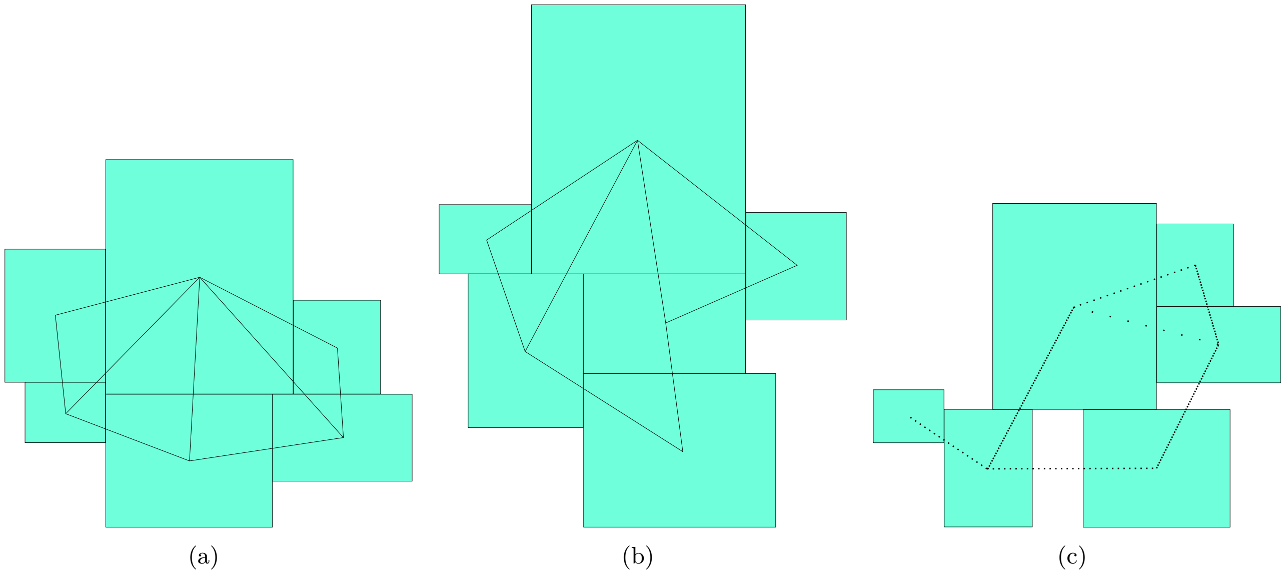

Figure 27: (a) blah (b) blah (c) blah

Physics Solver and Genetic Algorithm

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Data Driven Approaches

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Method of Choice

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Analysis

The first stage of this work deals with the automated generation of different apartment layouts using different geometry processing software. An alternative to the generation approach is the acquisition of existing architectural datasets provided by real estate and research groups. Advantages of reality-based datasets are the certainty of architectural feasibility and construction of the individual plans, but disadvantages are a conservative approach in creative terms and a high risk of traditional bias due to the predominance of local and traditionally influenced architectural methods. Therefore, this experimental phase is primarily concerned with testing different floorplan generation methods and their derivatives as well as their possible combination. Simple algorithms like voronoi diagrams, intelligent methods like evolutionary algorithms and data driven approaches like neural networks are explained and evaluated by different experiments. Criteria for the evaluation are simplicity in the construction process, computing power, time and memory, integration and interaction with used software, purity of the generated geometry, degree of readiness for the simulation stage, simplicity of the layout for data storage but above all spatial quality, creativity in form finding and feasibility. After experimentation, the most appropriate method or combination of algorithms for the following steps is selected and an appropriate set of different layouts is generated. In order to increase the variation in the synthetic dataset, results from different methods can be mixed, but they must not deviate from the generally defined quality level. Furthermore, it is a requirement to understand the functionality of the algorithms sufficiently to allow slight adaptations and combinations with other functions and to achieve variation in the individual applications. In general, simplicity is preferred to complexity, creativity to ordinariness and variation to repetition.

Topologic

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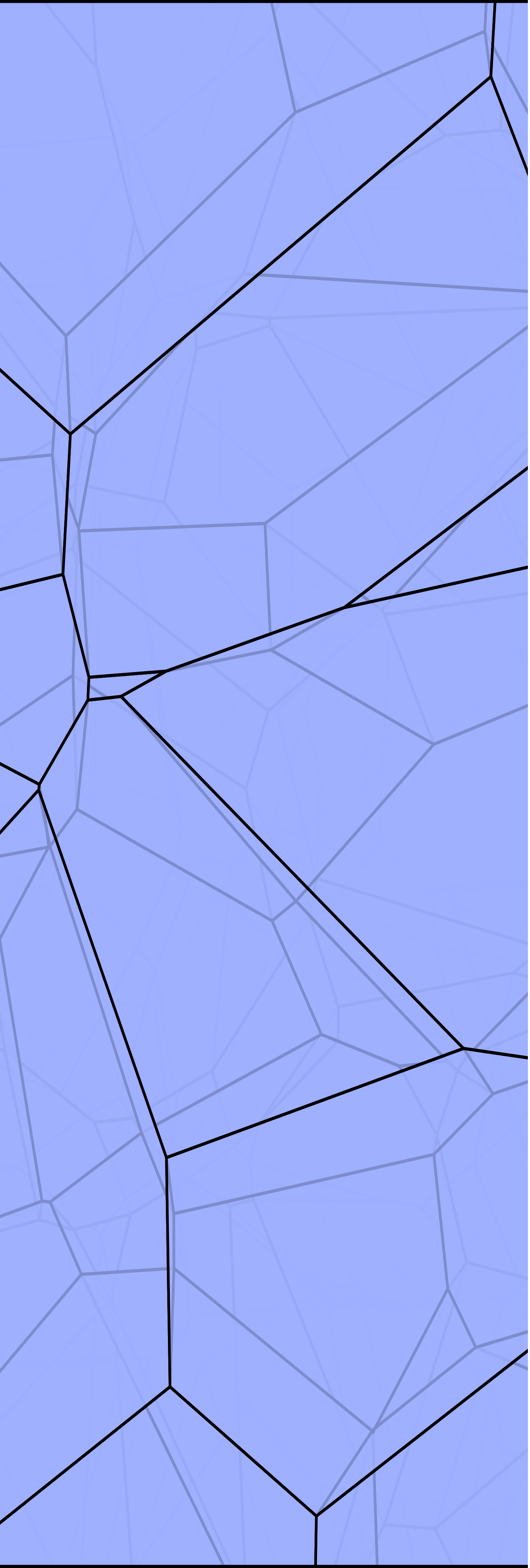

Data

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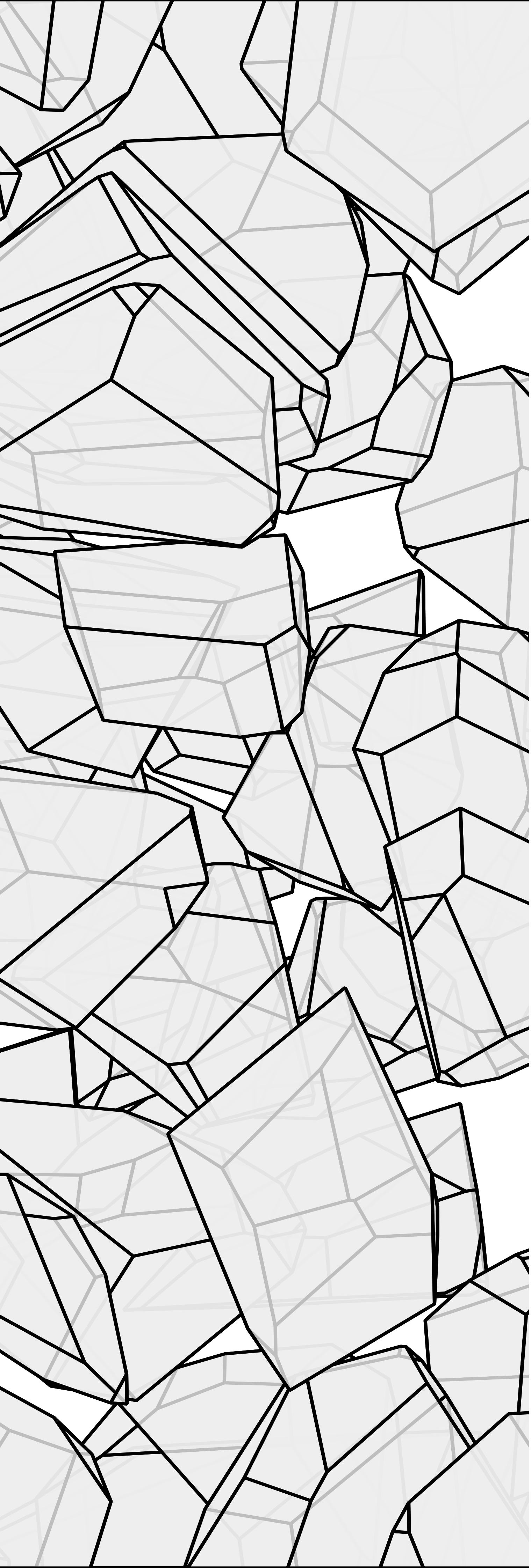
Learning

The first stage of this work deals with the automated generation of different apartment layouts using different geometry processing software. An alternative to the generation approach is the acquisition of existing architectural datasets provided by real estate and research groups. Advantages of reality-based datasets are the certainty of architectural feasibility and construction of the individual plans, but disadvantages are a conservative approach in creative terms and a high risk of traditional bias due to the predominance of local and traditionally influenced architectural methods. Therefore, this experimental phase is primarily concerned with testing different floorplan generation methods and their derivatives as well as their possible combination. Simple algorithms like voronoi diagrams, intelligent methods like evolutionary algorithms and data driven approaches like neural networks are explained and evaluated by different experiments. Criteria for the evaluation are simplicity in the construction process, computing power, time and memory, integration and interaction with used software, purity of the generated geometry, degree of readiness for the simulation stage, simplicity of the layout for data storage but above all spatial quality, creativity in form finding and feasibility. After experimentation, the most appropriate method or combination of algorithms for the following steps is selected and an appropriate set of different layouts is generated. In order to increase the variation in the synthetic dataset, results from different methods can be mixed, but they must not deviate from the generally defined quality level. Furthermore, it is a requirement to understand the functionality of the algorithms sufficiently to allow slight adaptations and combinations with other functions and to achieve variation in the individual applications. In general, simplicity is preferred to complexity, creativity to ordinariness and variation to repetition.



Conclusion

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Discussion

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Further Readings

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Future Works

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Used Software

Geometry Manipulation

Blender (Version 3.2) [Computer Software]. (1994). Retrieved from https://www.blender.org

SciPy (Version 1.8.0) [Computer Software]. (2001). Retrieved from https://scipy.org/

Sverchok (Version 1.1.0) [Computer Software]. (2012). Retrieved from https://github.com/nortikin/sverchok

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IfcOpenShell (Version 220330) [Computer Software]. (2011). Retrieved from https://blenderbim.org

Simulation

Topologic (Version 0.6.0) [Computer Software]. (2014). Retrieved from https://topologic.app

Radiance (Version 5.3) [Computer Software]. (1985). Retrieved from https://www.radiance-online.org

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OpenFOAM (Version 9) [Computer Software]. (2004). Retrieved from https://openfoam.org

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Tools

Numpy (Version 1.22.3) [Computer Software]. (1995). Retrieved from https://numpy.org/

Pandas (Version 1.4.2) [Computer Software]. (2008). Retrieved from https://pandas.pydata.org/

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