Evolutionary Analysis for Building Efficiency

inventing generative tools for diagramming spatial relationships

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_abstract

This project attempts to utilize generative software in order to create an analytical system intended to enhance order and efficiency within groups of complexly inter-connected architectural programs. The focus of the research involves developing a parametric definition that can diagrammatically arrange spatial volumes. These volumes represent the various building functions (programs) in terms of square footage. The driving condition for these experiments is adjacency. The theory is that if two functions in a building need to be connected, they should be adjacent to one another. The degree of adjacency is here viewed as the distance between the centers of programmatic masses. The relationship between programs is scored as a numerical value, the lower the value, the closer the programs, the better the score. The resulting model contains all programs, arranged within a larger volumetric container. This container represents the building shell. Each arrangement represents an 'individual' iteration. The tool will automatically create individuals and store their information in groups or 'generations'. The evolutionary process improves the proximity score over the course of many generations. The resulting diagrams produced autonomously by the computer are sorted, and the fittest results can be examined and refined in sharp contrast to less fit ones, informing the design process. This type of approach can offer a much wider range of explorations in a very short window of time than conventionally possible.

_rationale

Emerging Parametric technologies are creating new possibilities for design processes at many stages. Generally it is seen primarily as an engine to drive formal exploration and renderings. Its implications however can be larger, and it is possible to employ it at many stages in the design process in more abstract ways. During the initial design stage, much of what is explored involves theoretical concept and parti diagramming. If the concepts can be distilled to their limiting parameters, then it is possible to begin including parametric analysis. This type of analysis can allow designers to develop a much wider range of options in a much shorter time frame. This study intends to explore the ability of evolutionary parametric modeling as a diagram-building tool. For a building to be efficient it must meet the needs of it occupants. The needs of the occupants are determined by a complex relationship of programmatic and physical situations. These situations can be measured and used as metric data; which can be translated into parameters.

_directive

This research explores using Parametric NURBS modeling tools Rhinoceros and parametric plug in Grasshopper, with Galapagos evolutionary problem solving, to create an analytical planning tool. The tool can be used to create a three dimensional diagram of building programs (parti diagram). The purpose of this project is to attempt to create new ways of further utilizing evolutionary algorithms and physics modeling to aid designers and reduce inefficiencies in buildings and in the design process. The system can be used to aid in the massing of buildings that have inherently complex spatial relationships. Rapid iteration through the application of an easily manipulated algorithmic tool can save firms time and money. This type of approach also offers a unique system of analysis that can create an incredibly extensive range of unique and otherwise unexplored solutions when faced with problems in developing complex order for spatial relationships.

_test

A series of generic tests help to demonstrate how the system works and where to refine it. This test was run with nine programs. Those are broken into three groups represented by three color groups. The groups want to be adjacent to the others in their own group. The site is for square blocks. There are four storeys to be occupied. the definition drawn here represents that scenario.

_conclusions

The tool can be applied in a wide variety of situations in the early design phases. It can give designers metric data to inform their process and justify their decisions. The adaptability of the tool is critical to its usefulness. It has been simplified in terms of the scripting to a large degree but could perhaps still be refined to produce faster results. One observation from the experiments however is that the best way to save time is by sacrificing certain amounts flexibility. The more customizable the tool becomes, the more complex the calculation. There are of course many ways to achieve similar results within the structure of the parametric tools, so this is just one solution to a problem that can be answered in many ways. Evolutionary algorithms allow the computer to independently handle time consuming iterative work. The ideal situation for the tool involves a combination of parametric operations with evolutionary solving. Then the tool becomes more like a partner or double for the designer. Creating the range for the results is the task of the designer, and the narrower the range, the more meaningful results are. In other words, narrowing the field where variables can occur creates more pertinent results. The end results of this definition are diagrammatic, so they serve as a source of information that can be observed as metric data then incorporated into design. It could be expanded into a more literal space, with doors and windows etc., and the results could become more directly applicable to building design in the later stages. In general, the evolutionary modeling methods could be utilized on a much wider range of situations. Here research explored adjacency but any parameter or combination of parameters could be driving the modeling process. The parametric and evolutionary tools can accelerate the iterative process and produce meaningful, purely data-driven results.

_additional sources

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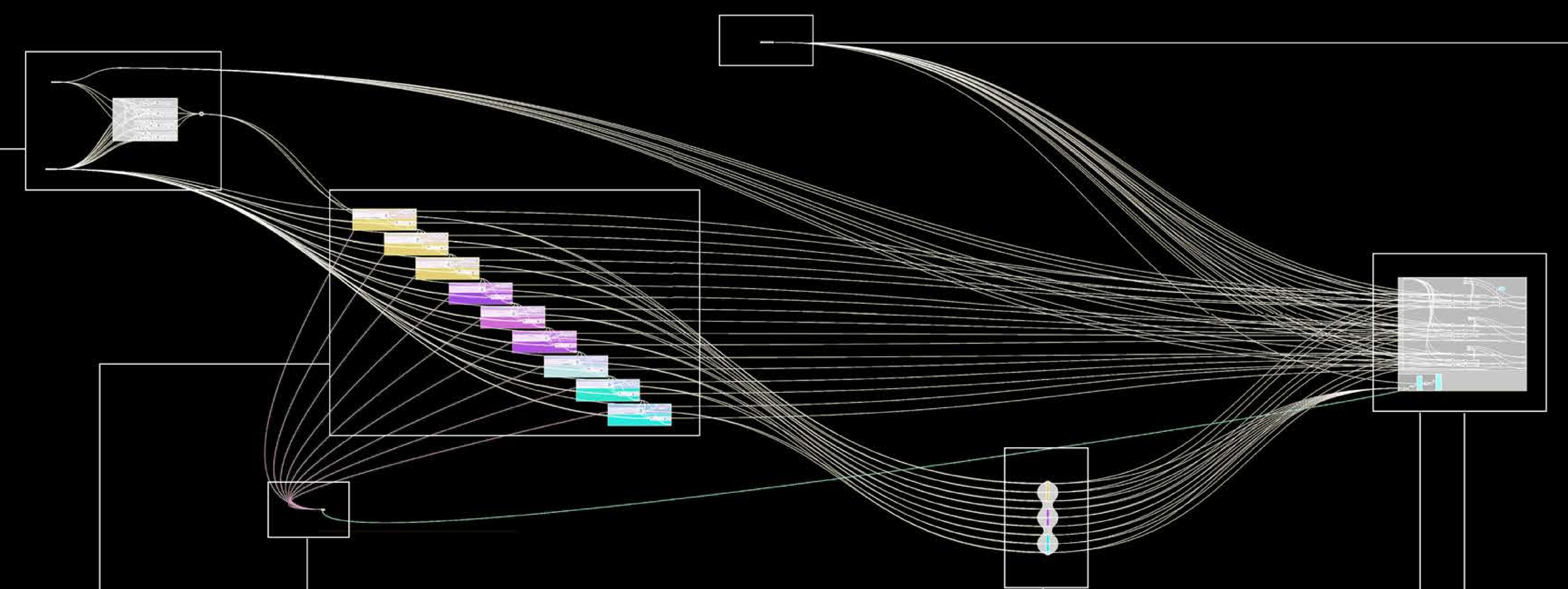
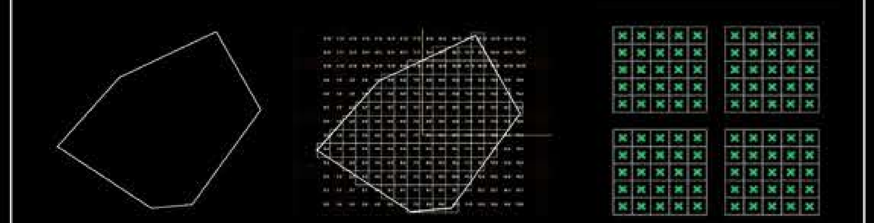


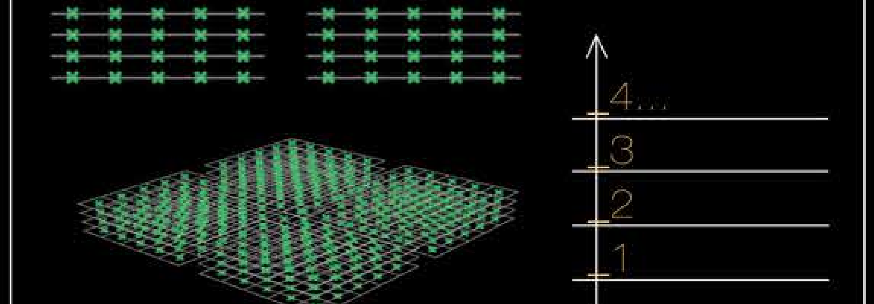
_establish site specific initial geometry

The starting parameters are customizable. the user sets up a grid that the spaces are built within. The number of cells and size of cells can be set to a specific coarsenes. The program can also build the grid inside of a two dimensional site outline to further refine the end results.



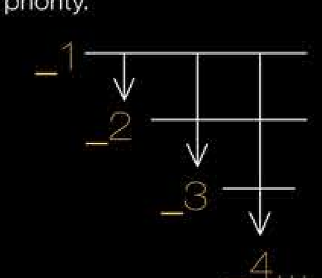
_offset levels

To account for multiple storeys the grid can be offset vertically any number of times, floor to floor height is adjustable.



_assign hierarchy of spaces with list order

When the program activates, the order of the list of program elements is the order of importance. The first element dominates the second, which dominates the third and so on. This is applied when the spaces are divided and reassigned, the dominate one always takes priority.



_assign square footage to each space

The volume of each space is set on number sliders.

_set origin locations for individual program elements

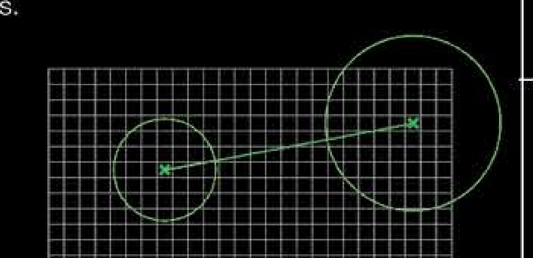
The various program elements are located with points. Grid cell spaces are filled in using these points as centers. The points snap to cell corners on the pre-established grid. Their position can be moved on the grids in x, y , and z directions.

_use galapagos evolutionary problem solving : make iterative generations

The genome collection is made up of all the origin location sliders. It will automatically rearrange the programs ecah time.

_create lines between origins

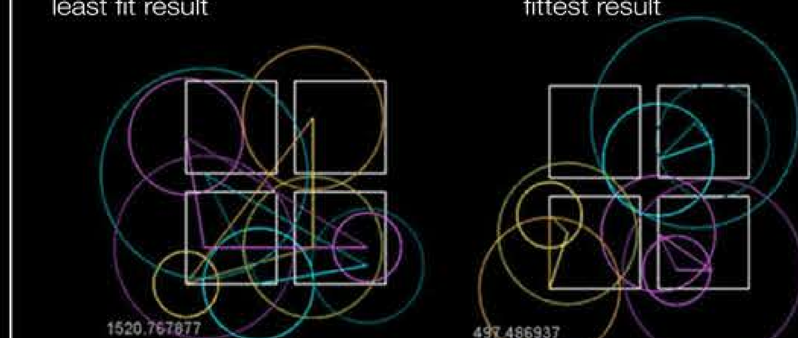
A line connecting origin points is established for every adjacency requirement based on the spreadsheet combinations. These lines are the distance between the programs" centers. A lower value indicates a closer proximity and a more adjacent situation. These lines will determine fitness.



_add up total distance of all interconnecting origins: shortest overall distance = fittest results

The lines that connect origins are mass added and can be weighed in terms of importance by multiplying the distance by a factor relative to others. The use of galapagos allows for a variety of potentiall useful results. The reward system can create attraction and repulsion though manipulating the fitnness. Galapagos will attempt to minimize the number over generations.

least fit result | fittest result



_visualize 3d spaces

The areas inside the circles are translated into squares on the grid and extruded into cubes that give 3D presence to the diagram.

_record results and animate

All the iterations are recorded in sequence and sorted based on fitness score. The results can be exported as animation.

least fit result

fittest result