Non-Geeks Guide to Optimizing Daily Workflows with Generative Design

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Introduction
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2008 – 2014 BIM Manager
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Learning Objectives

• Discover potential workflows for optimization
• Learn how to compose Dynamo graphs ready for Generative Design in Revit
• Learn how to implement Generative Design to optimize repetitive tasks
• Learn how to adapt given examples to custom needs
Why Non-Geek?

NO PYTHON SCRIPTING

LIMITED DESIGNSCRIPT USE

CODE BLOCK

"Just because we are lazy"; >

NO THIRD-PARTY PACKAGES REQUIRED

EASY TO FOLLOW TEMPLATE
Key Concepts
Algorithm
[æl.ɡə.ri.ðəm]

a set of mathematical instructions or rules that, especially if given to a computer, will help to calculate an answer to a problem

Source: Cambridge Dictionary
Generative Design

[ˈdʒenərətɪv dɪˈzaɪn]

a process that uses iteration to refine the potential solutions to a problem against certain metrics and constraints.

Generative Design

Link
Machine Learning

computer algorithms that improve automatically through experience.

Machine Learning
Generative Design Workflow
Generative Design Workflow

Link
**Try, Learn, Repeat**

- **Goal** Sank as many ships as possible
- **Design Space** Grid of cells with two coordinates
- **Strategy**
  - Pick a cell (Generate)
  - Wait for result (Evaluate)
  - Decide next move (Evolve)
- **Winning Criterion**
  - Maximize sank ships
  - Maximize hits
  - Minimize attempts

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Surrogate Model

• **Abstract representation of a real problem**
  - It is the result of the initial analysis
  - It helps focusing on the key features
  - It supports the visualization of parts

Image Source towardsdatascience.com – Einstein in Oxford 1933
Generative Design in Revit

Create logic in Dynamo & export to GD
Launch GD in Revit and create study
Explore outcomes
Select “Best in Class”
Adopt solution in Revit
Dynamo Graphs for GD

INPUTS & VARIABLES
• Number/Integer slider, Boolean or Revit Selection nodes
• Check “Is Input” for each input node
• Rename nodes to a unique name

OUTPUTS & METRICS
• Only Watch nodes with a Number value
• Check “Is Output” for each output node
• Rename nodes to a unique name
Dynamo Graphs for GD

INTERACTION WITH REVIT

• Generation can only be executed with Dynamo code
• All references to Revit data should be stored in a `Data.Remember` node
• `Data.Gate` node will create or modify elements in Revit when you select “Create Revit Elements”

DISPLAY

• The geometry for the different options in the study will be displayed as in the Dynamo Graph when it was exported
• It is highly recommended to colour the geometry with codes for visual comparison
Applications
01 Pick Apartment
Problem Statement

Find the option from a list that has the most favourable combination of price, area, number of rooms, management costs, energy costs, most recent construction, on an intermediate level, with a lift and possibly with furniture.

To finalize the selection there is need to examine the pictures, visit the apartment and evaluate the surroundings, etc.
01 Pick Apartment | Problem Statement

• Inputs / Constraints
  o The catalog with all characteristics of the apartments

• Variables
  o The index of the apartment

• Objectives
  o Price/Costs [-]
  o Area [+]
  o Rooms [+]
  o Year of Construction [+]
  o Intermediate level 2-6 [+]
  o Lift Y/N [+]
  o Furniture Y/N [+]


01 Pick Apartment | Process Diagram
01 Pick Apartment | Similar applications

- Selection of equipment types/models
- Selection of Cross-Sections
- Selection of Materials
02 Can I park here?
02 Can I park here? | Problem Statement

Optimize the position of the car inside a parking bay so the driver’s door can open, the vehicle is inside the designated area, and there are no clashes.
02 Can I park here?

**Problem Statement**

- **Inputs / Constraints**
  - Car size
  - Parking bay shape & dimensions
  - Obstacles (i.e. walls, columns, etc.)
  - Neighbouring parking bays
  - Distances allowances

- **Variables**
  - Driver’s door opening angle
  - Density of the grid of origin points
  - Origin point
  - Rotation angle

- **Objectives**
  - Intersection with neighbours [-]
  - Clashes with obstacles [-]
  - Area inside parking bay [+]
02 Can I park here? | Process Diagram
02 Can I park here? | Study in action
02 Can I park here? | Similar applications

- Logistics planning
- Building outline in plot
- Tree planting in urban environments
03 Shape arrangement
Problem Statement

Find an arrangement of any number of shapes with any number of sides so that there are no overlaps, and the result is esthetically pleasing whilst compact.
03 Shape arrangement | Problem Statement

- **Inputs / Constraints**
  - The geometrical shapes

- **Variables**
  - The order/sequence in which the shapes are processed
  - The side used to connect the next shape
  - The parameter along the side used as anchor point for the following shape

- **Objectives**
  - Bounding Box Area [-]
  - Overlapping Area [-]
  - Perimeter [-]
  - Perimeter over Area [-]
03 Shape arrangement | Process Diagram
03 Shape arrangement | Study in action
03 Shape arrangement | Similar applications

- Tile / façade patterns
- Floor planning
- Site layout
04 Floor Tiles Pattern
Reducing waste on site is one of the priorities to achieve a greener construction industry. By optimizing the pattern and location, less time and material will be required.
**Problem Statement**

- **Inputs / Constraints**
  - Tile size (Width/Length)
  - Joint size
  - Overlap
  - Minimum cut size
  - Floor geometry

- **Variables**
  - Angle
  - Origin of the first tile

- **Objectives**
  - Number of tiles [-]
  - % Completed tiles [+]
  - % Non-compliant cuts [-]
04 Floor Tiles Pattern | Study in action
04 Floor Tiles Pattern | Similar applications

- Wall & façade panels
- Archives & warehouse layout
- Open office/ classroom design
05 Bathroom Layout
Bathroom elements have clear needs of space and use area, as well as relationship with other plumbing elements and walls. However, there is no single option so computer and designer should work hand by hand in finding the best solution for each situation.
05 Bathroom Layout | Problem Statement

- **Inputs / Constraints**
  - Type of fixtures
  - Size of fixtures
  - Space geometry and conditions (i.e. doors, windows…)

- **Variables**
  - Permutation (order of the fixtures)
  - Origin point
  - Distance between fixtures

- **Objectives**
  - % Fixtures geometry outside boundary [-]
  - Element clashes [-]
  - % Free use area [+]
  - % Use area outside boundary [-]
  - Distance to waste pipe [-]
  - Perimeter curves < 200mm long [-]
05 Bathroom Layout | Study in action
05 Bathroom Layout | Similar applications

- Interior design
- Warehouse layout
- Planting plan
- Site planning
- Factory layout
06 Scope Boxes for Masterplan
Find the orientation and distribution of scope boxes that covers an entire site with the maximum dimensions compatible with the title block and scale factor, minimizing the areas out of scope and total number of drawing sheets.
06 Scope Boxes for Masterplan

Problem Statement

• Inputs / Constraints
  o The site boundary
  o The scale factor and the available plot dimensions of the title block
  o Overlap factor

• Variables
  o Rotation angle
  o Fixed Height / Width

• Objectives
  o Site Area covered [+]
  o Number of Scope Boxes [-]
  o Out of scope area [-]
  o Dimensions within maximum allowed [+]

06 Scope Boxes for Masterplan | Process Diagram

[Diagram with process steps and calculations for generating scope boxes in a masterplan process]
06 Scope Boxes for Masterplan | Study in action
06 Scope Boxes for Masterplan | Similar applications

- Parceling
- Site planning
- Façades
Inputs

- Only selection inputs can be changed from the Generative Design “Create Study” dialog

Variables

- Narrow down the potential values to get meaningful results (repeat the studies as necessary)
- Use normalized values when possible (i.e. 0-1)
Metrics / Objectives

- Explicit in the code name if the objective is to be maximized or minimized
- Use normalized values (% or 0-1) so the study is valid for different use cases and options are easy to compare
- Some users like to combine all outputs into a value weighting each of them with a coefficient

Study Settings

- Balance between population size and number of generations
- Seed introduces randomness, it can be left at its default value
Graph

- Use grouping and colouring to explain the process
- Identify the portions of the graph used for Inputs, Variables, Objectives and Visualization

Documentation & Sharing

- For others to run the GD study, share the DYN file and Dependencies folder created in the AEC Generative Design folder in your Documents folder
- Highly recommended to add a video, process diagram and instructions
Resources
Resources

GENERATIVE DESIGN PRIMER

https://www.generativedesign.org

AUTODESK UNIVERSITY 2020

- Generative Design in Revit for Workspace Layout - Tomasz Fudala
- Using Generative Design and Machine Learning for Faster Analysis Feedback - Varvara Toulkeridou
- Generative Design at Hogwarts: Using Tech Instead of Magic - Jacob Small
- Generative Design für Revit in der Praxis - Lejla Secerbegovic
- Diseño Generativo en Revit para todos los públicos - Raquel Bascones Recio
- Generative Design—Daylighting and CFD: A Practical Application for a Nonprofit - Luc Wing
- Generative Design of Landforms with Dynamo in Civil 3D - Andreas Luka

DYNAMO FORUM & BLOG

https://forum.dynamobim.com/
https://dynamobim.org/blog/

PRODUCT HELP

Product help
Release notes