From Design Automation to Generative Design in AEC

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Computational Design & Engineering
About me

- Computational Design & Engineering
- Passionate about Generative Design in AEC
- +5 years at Autodesk
- Previous experience in structural engineering
- DJ QuSe @ Autodesk Events 😊

@BIM4Struc

www.linkedin.com/in/dietervermeulen

www.youtube.com/user/RevitbeyondBIM

www.facebook.com/quse.dj

www.revitbeyondbim.wordpress.com

www.autodesk.typepad.com/bimtoolbox/

AU Online Profile
DEMOGRAPHIC CHANGES
Number of Cities X2

200,000 people/day

About 13,000 buildings/day
3,600 MORE BUILDINGS PER DAY
DESIGNS TODAY
TRADITIONAL DESIGN PROCESS
GENERATIVE DESIGN PROCESS
Generative design is a methodology and a process more than a singular product or tool.
Accelerating Growth in AEC Technology

ERA OF DOCUMENTATION
- Hand Drawings
- CAD

ERA OF OPTIMIZATION
- BIM
- Parametricism
- Algorithmic Modeling
- Interoperability

ERA OF CONNECTION
- AI BIM
- Photogrammetry
- Parametricism
- Generative Design
- Robotic Construction
- Internet Of Things

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Generative Design in Architecture Gives Designers More Options… Faster
What level of design progression?
Cases

**Conceptual Tower Mass**  **Structure Waste Optimization**  **Light Distribution**
More Cases

Tower Crane Positioning

Urban Planning

Parking Layout
Traditional Design
Sketching
Computer Aided Drafting
PARAMETRIC DESIGN

Designer/engineer uses computer as passive machine

one human + one computer = limited design
PARAMETRIC MODELING
Parametric Modeling

\[ a = 2 \]

\[ b = 1 \]

\[ a - b = c \]
Parametric Modeling

\[ a = 2 \]

\[ b = 1 \]

\[ a - b = c \]

\[ f(x) \]
Parametric Modeling

\[ a = \]

\[ b = \]

\[ a - b = \]
Conceptual Tower Mass – Design Model

Create Geometry
Assign Parametric Constraints
Modify Parameters
Document the Idea
Conceptual Tower Mass – Design Model
Parametric Modeling with Autodesk Revit
input  design automation  output
Dynamo
Ecosystem to increase capabilities

Difficult

Expressive Power

REVIT

REVIT API

DYNAMO
Dynamo to simplify things

**PROGRAMMING**

```csharp
void getParameterInfoInDocument(Document document, Element element)
{
    // Format the prompt information string.
    String prompt = "Choose parameter in selected Elements: [n]"
    StringBuilder sb = new StringBuilder(prompt);
    // Iterate element's parameters.
    foreach (Parameter param in element.Parameters)
    { ...
    }
    // Display the user action information.
    MessageBox.Show("utch", prompt, MessageBoxButton.OK);
}

string GetParameterInfoInDocument(Parameter param, Document document)
{
    string format = param.Definition.Name == "" ? "" : param.Definition.Name;
    // Use consistent content if the parameter name is stored according to the storage type
    switch (param.StorageType)
    { ...
    }
    case StorageType.String:
    { ...
    }
    case StorageType.ElementId:
    { ... }
    case StorageType.Integer:
    { ... }
    case StorageType.Decimal:
    { ... }
    case StorageType.Boolean:
    { ... }
    case StorageType.Enumeration:
    { ... }
    case StorageType.Double:
    { ... }
    case StorageType.Object:
    { ... }
    default:
    { ...
    }
    return defValue;
}
```

**VISUAL SCRIPTING**

Select Model Element

- Select
- Element

Element: 296833

Parameter Name: var[](.)

Result: 2.68072498291346
Dynamo offers more benefits

- Provide simple, coherent, and capable programming tools for people who make things
- Foster a collaborative design computation ecosystem
- Share tools within teams and across disciplines
- Generate sophisticated designs from simple data
- Automate repetitive tasks
Conceptual Tower Mass - Automated Placement
Design Automation with Revit and Dynamo Player
Cut Openings in Structural Walls
Design Automation with Revit and Dynamo

Thanks for contributing:
Jesper Wallaert, AB Clausen, Denmark
Light Placement Automation
Design automation with Revit and Dynamo
Façade Panels with Mathematical Influence

Design Automation with Revit and Dynamo Player
Computational Modeling
Computational Modeling Process

1. DATA INPUT
2. GENERATE
3. ANALYZE
4. EXPLORE
5. INTEGRATE
Conceptual Tower Mass with Computational Modeling

Get Boundaries  →  Generate Geometry  →  Analyze & Evaluate  →  Model Integration

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Conceptual Tower Mass
Computational Modeling with Revit and Dynamo
Steel Diagrid Waste Evaluation

System Definition → Automate Structural Design → Cut Length Optimization → Integration of Results
Steel Diagrid Waste Evaluation
Computational Modeling with Revit and Dynamo
Generative Design
one human + computational algorithms + computing power = 100s to 1000s of design options
Generative Design Process

DATA INPUT
VARIABLES CONSTRAINTS

GENERATE
OPTIONS

ANALYZE
METRICS

RANK
SCORING

EVOLVE
EXPLORE

VISUALIZATION
INTEGRATED CHAMPION

INTEGRATE

Refinery

Public Beta Project for Generative Design in AEC

- Explore and optimize designs
- Uses NSGA-II optimization algorithm
  Learn more here: https://www.iitk.ac.in/kangal/Deb_NSGA-II.pdf
- Advanced results display
- Syncing selected option back to Dynamo
- More information and beta access: www.autodesk.com/solutions/refinery-beta
Types of studies | Generation Methods

4 Types

Randomize

Cross Product

Optimize

Like This

Inputs

Design Space

Outcome

5 Designs # defined by user

5 x 3 = 15 Designs
User defines sampling density

3 x 6 = 18 Designs
User defines population size and number of generations

5 Designs # defined by user
OPTION GENERATION
Option Generation Process
Conceptual Tower Mass Randomization

Get Boundaries → Computational Model → Generate Options → Model Integration
Conceptual Tower Mass Randomization

Option Generation with Dynamo and Refinery
CRANE POSITION OPTIMIZATION
Crane Position Randomization

Create Design Model  ->  Crane Position Analysis  ->  Randomization of Options  ->  Send to Design Model
Crane Position Analysis

Flowchart Approach

1. Revit Building Components
   - Define distance between element and crane

2. Lift Capacity Table
   - Define element weight based on category
   - Lookup crane capacity per element depending on its distance

3. Truck
   - Lookup crane capacity for truck distance

4. Distance < Max crane range
   - Yes
   - Weight < Crane load depending on range
     - Yes
     - Weight < Max crane load for truck position
       - Yes
       - Liftable
       - No
       - Liftable but Truck Issue
   - No
   - Unreachable
   - Non-Liftable
   - No
   - Liftable
Crane Position Randomization
Option Generation with Dynamo and Refinery
DESIGN OPTIMIZATION
Conceptual Tower Mass Optimization

Data and Constraints → Define Computational Model → Optimization Champion Selection → Integrate in design

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Conceptual Tower Mass Optimization

Optimization with Refinery
Light Distribution Optimization

Data & Constraints

Generate

Analyze & Ranking

Evolve Explore Results
Light Distribution Optimization

Design Optimization with Revit, Dynamo and Refinery

Special thanks for contributing:
Jared Linden, Hoare Lea, UK
Radu Gidei, Matterlab, UK
Spatial Truss Optimization

Design Optimization with Dynamo, DynaShape and Refinery

- Search for the best spatial truss configuration with
  - Maximal Platform Area
  - Minimal Deformation
  - Minimal Structure Weight

- by changing the geometry inputs for
  - Width and length of platform
  - Start depth of the truss
  - End depth of the truss
  - Truss divisions
Spatial Truss Optimization

Geometry Definition ➔ Deformation Analysis ➔ Results Evaluation ➔ Optimization in Refinery

DYNAMO

Outputs

Deformation Score ➔ 2.89
Material Score ➔ 1552.98
Platform Area ➔ 189

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AUTODESK
Spatial Truss Optimization
Design Optimization with Dynamo, DynaShape and Refinery
Shop Layout Planning

Optimize the ratio of shop and storage area of a liquor store
Parking Layout Optimization
Objective of the Optimization

- Layout of main roads, secondary roads
- Number of parking spots
- Assignment of accessible spots
- Concentration of spots for electrical vehicles
- Green zones
- Walking distances to payment terminals
Parking Layout Optimization

Process
Parking Layout Optimization

Data & Constraints → Analysis & Ranking → Layout Option Generation → Optimization of EV spots and terminals
Parking Layout Optimization

Computational Model

Parking In- & Outlet Selection

Road Settings
Parking Layout Optimization

Option Generation of Possible Layouts
Parking Layout Optimization

Optimization of spots for electrical vehicles
Parking Layout Optimization

Optimization of payment terminals position
Alternative Site Selection

Script is generically useable
Urban Planning
Urban Planning

Data and Constraints ➔ Computational Model ➔ Optimization of Solutions ➔ Generate model
Urban Planning
Computational Model with Dynamo

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Urban Planning
Optimization with Refinery
Design Technology Progression

**TRADITIONAL DESIGN**
- Recording Decisions

**PARAMETRIC DESIGN**
- Associating Geometry

**GENERATIVE DESIGN**
- Describing Goals + Constraints

**Computer-Aided Drafting**

**Parametric Modeling**

**Design Automation**

**Computational Modeling**

**Option Generation**

**Design Optimization**

**AutoCAD**

**Revit**

**Dynamo**

**Refinery**

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What level of design progression?

You know what to do! 👊
https://refineryprimer.dynamobim.org/

Welcome

Welcome to the Refinery Primer, which aims to introduce AEC practitioners of all experience levels to an exciting new approach to design using generative design workflows.
The full presentation with embedded videos will be available for download on this link after November 18th, 2019