Connecting people and algorithms
Generative Design for informed decisions

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Data Analyst | @linkedin.com/in/erikforsberg
Sofia Malmsten

Sofia is graduated from Chalmers University of Technology with a Master in Architecture and Urban design and a Bachelor of science in Architecture and Engineering. With a background in programming and architecture she combines algorithms and design logics in order to investigate wide design scopes and enable data driven decisions.

Sofia is a consultant for Bonava, developing tools and processes for Parametric and Generative Design.
Erik Forsberg

Erik has a bachelor degree in Architecture and Engineering from Chalmers University of Technology. He is currently studying a MCs in Complex Adaptive Systems and writing his master thesis at the Department of Physics where he wants to explore the possibilities that machine learning can open in architecture. Erik is interested in the way big quantities of data can be processed and used to understand what, how and why we build.

Erik is a consultant at Bonava, developing tools and processes for parametric- and generative design.
About the speakers

Anita Apele

*BIM Specialist, graduated from Riga Technical University with Master degree in Architecture. Professional experience as an architect in residential field now is now brought to building information modelling, with the goal to eliminate as many mundane tasks as possible and implement best practices in the organization.*
AGENDA

INTRODUCTION
• Introduction to Bonava

VDC AT BONAVA
• Introduction to VDC
• Bonava Parts
• Bonava Building System
• VDC Software

GENERATIVE DESIGN
• Introduction to Generative Design
• Applied on Single Family Housing
• Applied on Multi Family Housing

CONCLUSIONS
• Our Generative Design journey
• Lessons learned

NEXT STEPS
• Agenda 2030
• Science based targets
• Connecting people and algorithms
An introduction to Bonava
Who we are

- Bonava is a leading residential development company in northern Europe
- Bonava has been creating homes and neighbourhoods since the 1930’s
- We operate in eight countries around the Baltic Sea

Homes in Production: 9,732 by the end of 2019
Started and sold homes: 50,000 since 2009
Coworkers: 2,300 in eight markets
What we do

Vision
We create happy neighbourhoods where people have the highest quality of life

Mission
We challenge ourselves every day to change the housing game, creating better homes and lives for the many
Bonava is active across the whole value chain

1. Land purchase
2. Project development (design and planning)
3. Marketing and sales
4. Project execution
5. Handing over keys
6. Customer service
Virtual Design and Construction at Bonava
VDC at Bonava
Bonava Parts

A Bonava Part is:

**Key Element**
that we use in all processes - modelling, cost calculation, production, purchasing and visualization

**Pre-defined component**
it is designed and described in detail to be reused in as many projects as possible

A Bonava Part contains:

**Technical and functional specifications**
such as measurements, materials, weight and classification

**Bonava Part ID**
a unique identifier
Building System

A Building System is:

a Collection
of Bonava Parts

A Building System contains:

a Description
a complete description of coordinated technical solutions that enables execution of design and production phases of the Building Projects.
“The parts are defined - what varies is how they are combined.”
Generative Design
Data driven design process

Outcome driven

Traditional Design process

Generative Design process
Bonava develops single family housing projects in Sweden and in Germany. The houses themselves are defined as Bonava Parts - a good prerequisite for generative design.
The Early Stages workflow

Setup
10011
11001
01010

Generate

Evaluate

Select
Setup
Choose and formalize rules & constraints
Building System
Single Family Housing
Site development
A case for Generative Design

Setup
1. Bonava part
2. Plot
3. Restrictions & requirements

Generate
- Generative design scripts
- Layout 1
- Layout 2
- Layout ...
- Layout n-1
- Layout n

Evaluate
1. Evaluation 1
2. Evaluation 2
3. Evaluation ...
4. Evaluation n-1
5. Evaluation n

Select
- Chosen alternative
Building system rules

Codified requirements for Bonava Parts

0, 250 or 450 mm vertical height difference

No horizontal displacement

One type 3-6 houses in a row
Site rules

Codified requirements for Bonava Parts

- No horizontal displacement
- 0 or 250 or 450 mm
- 7-10 m
- 5-7 m
- Minimum street length
Site rules

Codified requirements for Bonava Parts

0 or 250 or 450 mm

No horizontal displacement

5-7 m
Algorithms
Algorithms

Algorithms for site exploitation

1. Generative zones and existing streets
Algorithms

Algorithms for site exploitation

1. Generative zones and existing streets

2. Subdivision
   Voronoi, Boundary offset or grids
Algorithms
Algorithms for site exploitation

1. Generative zones and existing streets
2. Subdivision
   Voronoi, Boundary offset or grids
3. House placement- Bonava Parts
Algorithms

Algorithms for site exploitation

1. Generative zones and existing streets
2. Subdivision
   Voronoi, Boundary offset or grids
3. House placement- Bonava Parts
4. Access point connections
Algorithms
Algorithms for site exploitation

1. Generative zones and existing streets
2. Subdivision
   Voronoi, Boundary offset or grids
3. House placement - Bonava Parts
4. Access point connections
5. Minimal spanning tree
Generate
Enrich initial design proposals with algorithms
Skogsbo

Two house types were used together with different street network configurations. The output was a wide range of neighborhood designs.
We explore thousands of design alternatives
Evaluate

Compare multiple design alternatives
Identify goals

- Number of houses
- Ground data
- Parkings
- Sunny terraces
- Street data
- Green Factor
Translated into metrics
Neighbourhood profiles

Number of houses: 48
Cut: 8932 m³
Fill: 7003 m³
Mass balance: 1923 m³
Street area: 5700 m²
Green area: 18213 m²

Houses: 48
Carports: 48

House types:

Plot utilization ratio: 0.24
Neighbourhood profiles

#261

Houses: 89
Carports: 0

House types

Plot utilization ratio: 0.43

Neighbourhood values

<table>
<thead>
<tr>
<th>Number of houses</th>
<th>89</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cut</td>
<td>12342 m3</td>
</tr>
<tr>
<td>Fill</td>
<td>6232 m3</td>
</tr>
<tr>
<td>Mass balance</td>
<td>6018 m3</td>
</tr>
<tr>
<td>Street area</td>
<td>4232 m2</td>
</tr>
<tr>
<td>Green area</td>
<td>15123 m2</td>
</tr>
</tbody>
</table>

Terrace orientations

- NE
- E
- SE
- S
- SW
- W
- NW
- N
Neighbourhood profiles

Number of houses: 46
Cut: 8245 m³
Fill: 5341 m³
Mass balance: 2904 m³
Street area: 4751 m²
Green area: 19465 m²

Houses: 46
Carports: 46
Plot utilization ratio: 0.22

Terrace orientations

Neighbourhood values

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of houses</td>
<td>46</td>
</tr>
<tr>
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<td>8245 m³</td>
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<tr>
<td>Street area</td>
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</tr>
<tr>
<td>Green area</td>
<td>19465 m²</td>
</tr>
</tbody>
</table>

Graphs showing various data distributions for the neighbourhood.
Design explorer

Open source web-based evaluation tool
Design explorer
Open source web-based evaluation tool

**Ground work**
- Cut
- Fill
- Mass balance (Mb)
- Number of each house type (A-F)
- Number of pair/row/free standing houses
- Number of carports
- Total number of houses
- BTA (net area)

**House Data**
- Street area [m²]
- Street inclination
- Street dimension

**Street Data**
- Front yard length
- Backyard length
- Green Area (common areas)

**Green Area**
- Number of terraces towards S, SW, W etc.

**Terrace Orientation**
- Parallel Axes Diagram
- Capability Parameters
- Design explorer
- Open source web-based evaluation tool
Disciplines and preferences

Schematic examples

Cost calculator

Sales and marketing

Procurement
Traditional workflow
From discipline to discipline

- Development manager
- Design team and manager
- Cost calculator
- Procurement (Strategic and operational)
- Head of production
- Site manager
- Sales and marketing
- Customer service

- Investment idea
- Decision to buy land
- Control real estate
- Start of development
- Pre-sales start decision
- Project and sales start decision
- Construction start
Informed decisions...

Setup

10011
11001
01010

Generate

Decision to buy land

Control Real Estate

Start of development

Evaluation

Pre-sales start decision

Final design

Project and sales start decision

Construction start
...before land acquisition

Set Up
10011
11001
01010
Generate
Evaluation
Final Design

- Investment Idea
- Decision to buy land
- Control Real Estate
Select
Integrate a generative design process into Revit

SetUp  Generate  Evaluate  Select
10011  11001  01010
Data flow

Bonava Parts
Bonava Parts

Rhino.Inside Revit
Algorithms in Rhino, Grasshopper and in C#

Data storage + visualization
MongoDB: Converted geometry to JSON
Azure or AWS for further storage
Visualization: Design explorer

Dynamo scripts
For importing the selected solution
Import To Revit
Bonava develops multi-family houses in all markets. Unlike the case for single family housing, the multi-family houses are not defined as just one single Bonava Part. Instead, it consists of several Bonava Parts in different scales.
Two perspectives

From the outside

From the inside

VS
Combining Bonava Parts

Interior perspective

<table>
<thead>
<tr>
<th>Bonava Part IDs</th>
</tr>
</thead>
<tbody>
<tr>
<td>SE_191022_010</td>
</tr>
<tr>
<td>SE_201012_002</td>
</tr>
<tr>
<td>SE_200121_002</td>
</tr>
<tr>
<td>SE_200230_001</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
</tr>
<tr>
<td>Perimeter</td>
</tr>
<tr>
<td>Capacity</td>
</tr>
</tbody>
</table>

- 17% Area
- 33% Perimeter
- 28% Capacity
Combining Bonava Parts

Interior perspective

BATHROOM DATA

Bonava Part IDs

SE_191022_010

Parameters

<table>
<thead>
<tr>
<th></th>
<th>Area</th>
<th>Perimeter</th>
<th>Persons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
<td>17 %</td>
<td>33 %</td>
<td>28 %</td>
</tr>
</tbody>
</table>
Combining Bonava Parts

Interior perspective

LIVING UNIT DATA

Living Unit data

Room
Area
Perimeter
Façade Length

Bonava Part IDs

SE_191022_010
SE_201012_002
SE_200121_002
SE_200230_001
SE_190612_009
SE_180103_020
For big Data Sets

**Living Unit 3151**

- Room Area: 2 | 55 m²
- Part IDs:
  - SE_171024_003
  - SE_191016_012
  - SE_200124_049
  - SE_200326_009
  - SE_200325_008

**Living Unit 618**

- Room Area: 5 | 84 m²
- Part IDs:
  - SE_171024_003
  - SE_200124_049
  - SE_200325_001
  - SE_200325_008
  - SE_200325_008

**Living Unit 771**

- Room Area: 3 | 62 m²
- Part IDs:
  - SE_171024_003
  - SE_200325_008
  - SE_200325_001
  - SE_200325_008
  - SE_200325_008

**Living Unit 1652**

- Room Area: 2 | 51 m²
- Part IDs:
  - SE_171024_003
  - SE_191016_012
  - SE_200124_049
  - SE_200326_009
  - SE_200325_008

**Living Unit 158**

- Room Area: 2 | 43 m²
- Part IDs:
  - SE_171024_003
  - SE_200325_008
  - SE_200325_001
  - SE_200325_008

**Living Unit 78**

- Room Area: 3 | 59 m²
- Part IDs:
  - SE_171024_003
  - SE_200525_008
  - SE_200124_049
  - SE_200325_001
  - SE_200325_008

*This work is in progress and the material shows a schematic representation of living units. Discrepancies in data and spatial configurations may occur.*
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Auto complete

Exterior perspective
Conclusions
Our generative design journey

2017
- Standardisation
- Modularisation
- Content generation, families etc. in Revit

2018
- Automatization
- Scripts for simplifying modelling and correcting mistakes

2019
- Option Generation for Single family housing

2020
- Genetic algorithms for design optimization

Future
- Constantly learning from previous experiences
- Giving the user more relevant and accessible information earlier on
Lessons learned

Design
- Boosted creativity
- Faster
- Not the final solution
- Quantifiable soft values

Communication
- Holistic perspective
- Number supported

Technology
- Customized code (BU and project)
- Constantly evolving
- Common sense is hard to program ;-)

;->
Next steps
Sustainability goals

1. NO POVERTY
2. ZERO HUNGER
3. GOOD HEALTH AND WELL-BEING
4. QUALITY EDUCATION
5. GENDER EQUALITY
6. CLEAN WATER AND SANITATION
7. AFFORDABLE AND CLEAN ENERGY
8. DECENT WORK AND ECONOMIC GROWTH
9. INDUSTRY, INNOVATION AND INFRASTRUCTURE
10. REDUCED INEQUALITIES
11. SUSTAINABLE CITIES AND COMMUNITIES
12. RESPONSIBLE CONSUMPTION AND PRODUCTION
13. CLIMATE ACTION
14. LIFE BELOW WATER
15. LIFE ON LAND
16. PEACE, JUSTICE AND STRONG INSTITUTIONS
17. PARTNERSHIPS FOR THE GOALS
Quantifying sustainability

To reduce environmental impact
Quantifying sustainability

To reduce environmental impact
Quantifying sustainability

To reduce environmental impact
Future steps
Evolving the human-machine interaction

Evaluate and store priorities → Evolve alternatives → Human-computer interface
Evil robot?

Good to have digital assistant?
Connecting people with algorithms