Parametric BIM

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What is parametric modelling?

Types of parametric modelling

Is BIM parametric?

Parametric BIM workflows

Current Research
What is parametric modelling?

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The future

Some tools

Some history

Benefits of parametric modelling

Drawbacks of parametric modelling
Scenario

- The Killian Roof

- Created by Axel Killian for a GenerativeComponents tutorial in 2005
The Killian Roof

- Four parametric modelling systems
  - GenerativeComponents
  - Grasshopper
  - Dynamo
  - Houdini
Killian Roof

• GenerativeComponents (GC)
Killian Roof

• Grasshopper
Killian Roof

- Dynamo
Killian Roof

- Houdini
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Benefits of parametric modelling

Drawbacks of parametric modelling
History of Parametric Design

• Three historic examples

• The Fish (Vila Olimpica), 1992
  – Gehry Architects

• Waterloo Station, 1993
  – Nicholas Grimshaw and Partners

• City Hall, 2002
  – Fosters and Partners
The Olympic Fish

– Barcelona, 1990 - 1992
– Gehry

• Model was parametrically generated using CATIA software

• Design and constriction all coordinated through digital ‘BIM’ model
Waterloo Station

- Nicolas Grimshaw and Partners

- Train shed roof with tapering span, consisting of 36 three-pin bowstring arches

- The roof structure was parametrically modelled using GC

http://www.architectureweek.com/2001/0919/tools_1-1.html
City Hall

• Example
  – City Hall, London, 1998 - 2002
  – Foster + Partners

• Performance driven design process using GC

• Main axis orientated towards the midday sun, thereby minimizing solar gain


http://www.fosterandpartners.com/media/Projects/1027/development/img6.jpg
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Benefits of parametric modelling

Drawbacks of parametric modelling
Benefits of parametric modelling

• There are two fundamental benefits

• **Complexity**
  – Generate complex models
  – Rationalize geometry

• **Speed**
  – Generate big models
  – Generate model variants
Complexity

• You want to model something that is really hard using explicit modelling

• Usually, this will also involve rationalize the geometry to some extent

• Example
  – Waterloo Station, London, 1993
  – Nicolas Grimshaw and

http://www.architectureweek.com/2001/0919/tools_1-1.html
Speed

• You want to automate the generation of big models

• You may need to respond to unforeseen changes

• You may want to generate lots of model variants

• Example
  – City Hall, London, 2002
  – Foster + Partners

http://www.fosterandpartners.com/media/Projects/1027/development/img6.jpg
Beyond parametrics

• Some types of problems need more complex types of solvers

• For example, optimization routines might be needed
  – Museo Soumaya, Mexico, 2011
  – FR-EE / Fernando Romero Enterprise
  – Gehry Technologies

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Drawbacks of parametric modelling

- More demanding to build
- More demanding to comprehend
- More demanding to modify
- More demanding to manage
- More demanding to execute


http://rhinobim.com/profile/RickSmith
Drawbacks of parametric modelling

• More demanding to build
  – For big parametric models, a lot of upfront work is required to build it

• More demanding to comprehend

• More demanding to modify

• More demanding to manage

• More demanding to execute

https://rbrodiegh.wordpress.com/category/professor-nick-senske/
Drawbacks of parametric modelling

• More demanding to build

• More demanding to comprehend
  – For big parametric models, it is difficult for others to understand how it works

• More demanding to modify

• More demanding to manage

• More demanding to execute
Drawbacks of parametric modelling

• More demanding to build

• More demanding to comprehend

• More demanding to modify
  – For big parametric models, it is easy to make changes that break the logic in the model

• More demanding to manage

• More demanding to execute

http://www.3dcadworld.com/the-failed-promise-of-parametric-cad/
Drawbacks of parametric modelling

• More demanding to build

• More demanding to comprehend

• More demanding to modify

• More demanding to manage
  – For big parametric models, it is easy to accidently change parameters without realizing it

• More demanding to execute
Drawbacks of parametric modelling

- More demanding to build
- More demanding to comprehend
- More demanding to modify
- More demanding to manage
- More demanding to execute
  - For big parametric models, the update process can be slow, making it less responsive
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A generalized model

• All parametric modelling tools can be mapped into a common model

• The model is like a flow diagram, called a Directed Acyclic Graph (DAG)

• It is easy to calculate the order of execution
  – i.e. the operation nodes can be topologically sorted
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A generalized model

Iteration – they key differentiator

A taxonomy of parametric modelling approaches
Iteration

• Existing parametric tools support iteration in different ways
  – No iteration
  – Single operation iteration
  – Multi-operation iteration
Multi-Operation Iteration

• Not everything can be achieved in one operation
  – For example, replace each four sided polygon with diagonal struts.

• Multi-operation iteration is extremely powerful
Conditional Multi-Operation Iteration

• Task is to generate a tower
  – Input: the form of the tower
  – Generate:
    • the floor plates
    • the façade grid

• Plot Ratio Constraint
  – Define a site plot ratio
  – Add floors until plot ratio is reached
FAR Tower

- Task is to generate a tower
  - Input: the form of the tower
  - Generate:
    - the floor plates
    - the façade grid

- Plot Ratio Constraint
  - Define a site plot ratio
  - Add floors until plot ratio is reached
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A generalized model

Iteration – the key differentiator

A taxonomy of parametric modelling approaches
Four types of parametric modelling

• There exist four types of parametric modelling

• They differ in how the support iteration

  – Object modelling
  – Associative modelling
  – Dataflow modelling
  – Procedural modelling
The parametric hill

- As you go up-hill, the level of parametric gets more advance
The parametric hill

- As you go up-hill, the level of parametric gets more advance
  - Object modelling is at the bottom of the hill
  - Procedural modelling is at the top of the hill
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How parametric are BIM systems?

How parametric should BIM systems be?
How parametric are BIM systems?

• The FAR Tower cannot be modelled parametrically in any of the BIM applications
  
  – ArchiCAD
  – Revit
  – ...
  
  – (Yes – with scripting, it is possible... )
How parametric are BIM systems?

- BIM systems only support associative modelling
- In general, they do not support multi-operation iteration
  - ArchiCAD
  - Revit
Local versus global

- Associative modelling may create relationships that are either local or global
  - Local:
    Relationships are created between adjacent elements
  - Global:
    Relationships are created between non-adjacent elements
Local versus global

• ArchiCAD supports local associative relationships

• It does not support global associative relationships

Local versus global

• Revit supports both local and global associative relationships

• Global associative relationships are defined as constraints
  – Dimension constraints
  – Alignment constraints

• Satisfying constraints requires the use of constraint solvers
  – Similar to Feature Based Modelling
Adaptive Components

• Revit has something called Adaptive Components

• This also comes from Feature Based Modelling
  – When you designate underconstrained geometry as adaptive, you specify the geometric elements allowed to change.


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How parametric should BIM systems be?

• BIM systems focus on the design development and construction documentation

• These types of BIM model are BIG!

• This conflicts with parametric modelling
How parametric should BIM systems be?

- Do you *really* want more parametrics in your BIM system?
  - More demanding to build
  - More demanding to comprehend
  - More demanding to modify
  - More demanding to manage
  - More demanding to execute
How parametric should BIM systems be?

• Revit supports associative parametric modelling with global relationships
  – It gets some of the benefits
  – But it also gets plenty of drawbacks

Autodesk_Revit_2015_Model_Performance_Technical_Note.pdf
How parametric should BIM systems be?

- Using constraint solvers can further exacerbate these drawbacks
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Current Research
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| Coupling parametric systems  |
| to BIM systems               |
| Tightly coupled workflows    |
| Loosely coupled workflows    |
| Recent developments          |
Parametric to BIM: P2B

• Linking parametric tools with BIM
  – We call it ‘P2B’

• For the couple approach there are currently two ways:
  – Tightly coupled workflows
  – Loosely coupled workflows
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- Coupling parametric systems to BIM systems
- Tightly coupled workflows
- Loosely coupled workflows
- Recent developments
P2B Tightly Coupled

• Parametric tools communicates with the BIM system via an API

• Examples for ArchiCAD:
  – GH to ArchiCAD Connection

• Examples for Revit:
  – Dynamo
  – Hummingbird / WhiteFeet
  – Chameleon
  – LMnt
  – Case Apps (?)
P2B Tightly Coupled

- Currently, this is the more popular approach
- BUT...
  - Only works with one BIM system
    - It is not workflow agnostic
    - Collaboration is more difficult
Dynamo

• Visual Programming tool by AutoDesk

• Dynamo <-> Revit
  
  – Can instantiate BIM elements in Revit through the API

ArchiCAD Connection

• Visual Programming plugin by Graphisoft

• Grasshopper <-> ArchiCAD
  
  – Can instantiate BIM elements in ArchiCAD through the API

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P2B Loosely Coupled

• Parametric tools communicates with the BIM application via a neutral file format
  – IFC

• Example:
  – Geometry Gym
  Grasshopper -> IFC -> BIM
  Jon Mirtschin

GH: Grasshopper
Dy: Dynamo
GC: Generative Components
Hou: Houdini
HW: Hummingbird/WhiteFeet
Ch: Chameleon
Lt: LMnt
GG: Geometry Gym
P2B Loosely Coupled

• Has key advantages...
  
  – It is workflow agnostic and therefore support collaborations better
  
  – File formats are developed by standards organizations and support improves over time
P2B Loosely Coupled

• Currently, the best example of this is Geometry Gym
  – Plugin for IFC
  – Developed by

• BUT...
  – It is hard work!

https://geometrygym.wordpress.com/
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Coupling parametric systems to BIM systems

Tightly coupled workflows

Loosely coupled workflows

Recent developments
New Workflow Tools....

• This morning you saw the Flux.io demonstration

  – Link tools through the cloud
  – Many other benefits
    • Allows you to collaborate with others
    • Allows you to encapsulate complexity
    • Allows you to manage change
New BIM Tools....

• Rhino BIM plugins for explicit modelling
  – Generate geometry in GH
  – Merge with Rhino BIM
  – Export to IFC
  – Import to BIM System
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Current Research
Current Research

• Möbius
  http://mobius.design-automation.net/

• A research project to develop a procedural modelling tool in the browser

• Capable of integrating into BIM workflows using IFC