48-624 Parametric Modeling

Fall Semester 2017 Mini A1 • 6 units • Tuesdays + Thursdays 1.30–2:50pm (CFA 317)

Open to upper-year undergraduate and graduate students

Prerequisite: At least Junior standing.

Instructors: Ramesh Krishnamurti • ramesh@cmu.edu

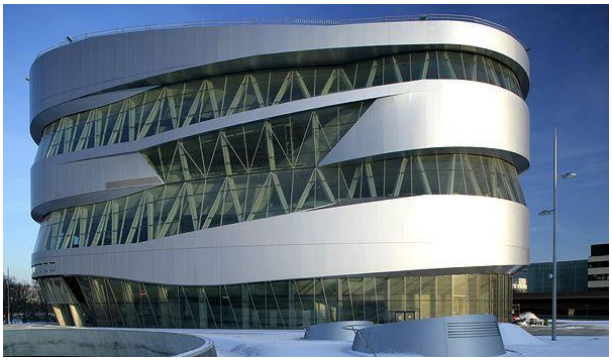
Noreen Saeed • nsaeed@andrew.cmu.edu

Office Hours: TBD

Syllabus

Motivation

Geometry is at the very core of architectural design—from the very early conceptual form finding to the more detailed assembly and construction. In practice, architecture designers are showing an increasing interest in being able to compute and fabricate non-simple and sometimes intricate geometric forms.



(*Right*) Mercedes Benz museum, UN Studio, Stuttgart

Contemporary approaches to modeling architectural geometry are computational—this is reflected in designers wanting much more parametric control over the generative process; in turn, this enhances the efficiency with which they can navigate design variations, analyze design artifacts and explore design manifestations.

(*Right*) Roof of the Olympic Stadium in Munich, Germany [A minimal surface]

Constructing geometry parametrically and computationally poses challenges for the designer—especially for those with little formal geometry training; more so—when required to tackle evolving issues between complex geometry and architecture. There is a compelling and emerging need to better understand concepts that support geometric constructions—to develop (new) computational schemes that can intelligently or ably assist designers in managing geometry data and propagating designs.

(*Right*) London City Hall by Norman Foster and Partners

Course objective

This course is to prepare students for modeling architectural geometry through development of parametric schemes for architecture applications. This course supplies the basis of understanding parametric geometric construction mechanisms.

Learning outcomes

In this course students will:

- Understand the core structures and workflows of parametric modeling
- Manipulate complex data flows toward desired design outcomes
- Apply elementary algorithmic thinking to design problems
- Model complex forms and relationships using geometric concepts and parametric tools
- Become familiar with program flow and geometry manipulation in Rhino
- Possess the critical skills necessary to question the limits and biases of a software interface
- Have begun to develop a sensibility for generative modeling uniquely your own.

Course description

This is a half-semester introduction to parametric modeling with no prerequisites.

The course consists of lectures (on Tuesdays), computer cluster instruction (on Tuesdays and Thursdays), and assignments.

In this course we will introduce:

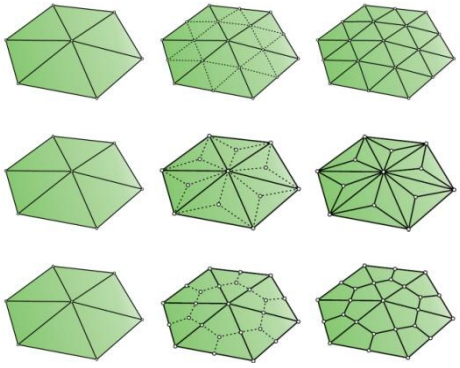
- *Elements of parametric design and design patterns*
  The structure of parametric design processes, their characteristics and reusable parametric design approaches
- *Fundamental concepts of geometric modeling:*
  Spatial coordinates, projections, Boolean operations, formal transformations, freeform surface creation, surface development and deformations aimed at architecture applications, discretization and meshing, digital prototyping and geometry reconstruction. Lectures will focus on concepts in computational geometry that can be applied to parametric architectural geometry modeling.
- *Parametric modeling techniques and tools:*
  Tools that are available to model design parametrically will be introduced in this class to illustrate the construction of geometrical relationships among complex shapes. The lectures will focus on hands-on techniques that can be applied to the design process, to extend the efficiency and productivity of work during the process.

For practical reasons, the course uses *Rhinoceros 5* ® and *Grasshopper* ® and may also use some of the following plug-ins in the parametric modeling environment: *Hoopsnake*, *Weaverbird*, [*Kangaroo*, *Firefly*, *gHowl*, *Galapagos*, *Geometry Gym* and *Karamba*.]

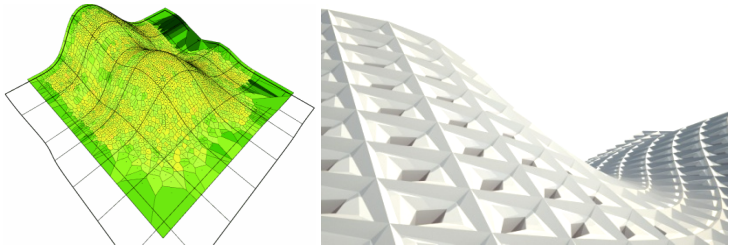
Course topics

The topics covered are:

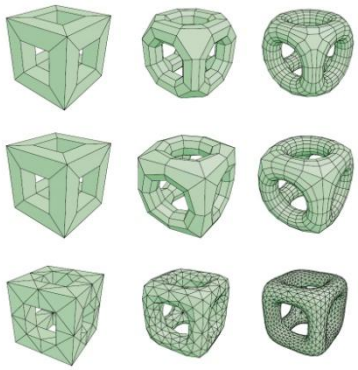
Basics of geometric modeling: coordinates and transformations
Surface Construction: Freeform curves to surfaces
Surface Development: surface offsets, sweeping and evolutions
Deformations
Discretization: Converting surfaces to meshes
Further applications: Digital Prototyping and Geometry Reconstruction
Other topics



Surface refinements

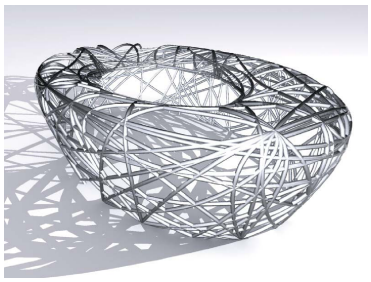


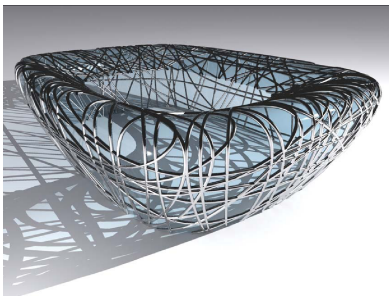
Tessellations



Subdivisions

Relationship definition file for Bird's Nest pattern generations





Reference texts and readings

There is no textbook for the course. The following are useful resources.

- Arturo Tedeschi. *AAD – Algorithms-Aided Design*. Len Penseur Publisher, 2014.
- Robert Woodbury. *Elements of Parametric Design*. Routeledge, 2010.
- Helmut Pottmann, Andreas Asperl, Michael Hofer, and Axel Kilian. *Architectural Geometry*. Bentley Institute Press, 2007.
- Wassim Jabi. *Parametric Design for Architecture*. Lawrence King Publishing, 2013.

- Rajaa Issa, *Essential Mathematics for Computational Design – Third Edition*. http://www.rhino3d.com/download/rhino/5.0/EssentialMathematicsThirdEdition/
- Andrew Payne & Rajaa Issa, *The Grasshopper Primer – Third Edition* https://modelab.is/download/grasshopper-primer-third-edition-2/#pkg_10515_57c89cfd7be4d
- Zubin Khabazi, *Generative Algorithms*. https://labdigifab.files.wordpress.com/2014/03/generative-algorithms.pdf

Other books and readings will be added to this list.

Online resources

- GH Gateway >> for access to tutorials, videos, and other resources
- GH Forum >> for answers to specific GH questions from the GH community
- Grasshopper Primer >> great reference material to have on hand
- Lynda >> great video tutorials on all things digital. Sign in through CMU for free access

Canvas

All course material will be on Canvas

We will use Canvas for additional class discussion.

Course requirements

Three modeling assignments.

Grading

Grades are based on three assignments with the two higher scored assignments weighted at **35%** each and the third at **30%**. However, there may be **bonus points** associated with each assignment. Students will receive feedback on each assignment.

Grades are based on the following scheme:

A: 90% and over **B:** 80-89% **C:** 70-79% **D:** 60-69% **R:** < 60%

Students are not graded on a curve.

Prerequisite

At least Junior standing.

Policies

All university academic and student policies as set out in http://www.cmu.edu/graduate/policies/ and https://www.cmu.edu/policies/student-and-student-life/index.html apply to this course.

Specifically:

- You are expected to be on time at all lecture and lab sessions.
- Please backup your work in the cloud. We cannot accept hardware failure as a valid excuse.
- You may not copy code without citation. Copying code without citation is plagiarism.
- Late work may result in a reduced grade.
- Email should only be used for crucial queries and concerns. Please direct software related questions to Piazza or to Pedro during office/lab sessions.

Accommodations for students with disabilities

If you have a disability and have an accommodations letter from the Disability Resources office, I encourage you to discuss your accommodations and needs with me as early in the semester as possible. I will work with you to ensure that accommodations are provided as appropriate. If you suspect that you may have a disability and would benefit from accommodations but are not yet registered with the Office of Disability Resources, I encourage you to contact them at access@andrew.cmu.edu.

Student well-being and support

Carnegie Mellon University is deeply committed to creating a healthy and safe campus community including one that is free from all forms of sexual and relationship violence. To that end, University Health Services, the Office of Community Standards & Integrity, and the Office of Title IX Initiatives have partnered to expand their educational efforts for graduate students in this domain. There is an educational opportunity for all graduate students at Carnegie Mellon that reflects its commitment to sexual assault and relationship violence prevention as well as to your overall safety:

> **Haven Plus** for Graduate Students. For more information follow the link: https://shib.everfi.net/login/default.aspx?id=CarnegieMellonHavenPlus

Additionally, it is important to take care of yourself and try as best as possible to reduce, preferably avoid, stress. Maintain a healthy lifestyle by eating well, exercising, getting sufficient sleep and taking some time to relax. All of us benefit from support during times of struggle. There are many helpful resources available to all students on campus. Asking for support sooner rather than later is more often helpful.

If you or anyone you know is experiencing academic stress, difficult life events, or feelings like anxiety or depression, we strongly encourage you to seek support. Counseling and Psychological Services (CaPS) is here to help: call 412-268-2922 and visit their website at http://www.cmu.edu/counseling/.

Consider reaching out to a friend, faculty or family member you trust for help getting connected to the support that can help. If you or someone you know is feeling suicidal or in danger of self-harm, call someone immediately, day or night:

> **CaPS**: 412-268-2922
>
> **Re:solve Crisis Network**: 888-796-8226

If the situation is life threatening, call the police:

> **On campus**: CMU Police: 412-268-2323
>
> **Off campus**: 911

If you have questions about this or your coursework, please let us know **Student well-being and support**

Carnegie Mellon University is deeply committed to creating a healthy and safe campus community including one that is free from all forms of sexual and relationship violence. To that end, University Health Services, the Office of Community Standards & Integrity, and the Office of Title IX Initiatives have partnered to expand their educational efforts for graduate students in this domain. There is an educational opportunity for all graduate students at Carnegie Mellon that reflects its commitment to sexual assault and relationship violence prevention as well as to your overall safety:

Haven Plus for Graduate Students. For more information follow the link:

https://shib.everfi.net/login/default.aspx?id=CarnegieMellonHavenPlus

Additionally, it is important to take care of yourself and try as best as possible to reduce, preferably avoid, stress. Do your best to maintain a healthy lifestyle by eating well, exercising, getting sufficient sleep and taking some time to relax. All of us benefit from support during times of struggle. This will help you achieve your goals and cope with stress. There are many helpful resources available to all students on campus. Asking for support sooner rather than later is more often helpful.

If you or anyone you know is experiencing academic stress, difficult life events, or feelings like anxiety or depression, we strongly encourage you to seek support. Counseling and Psychological Services (CaPS) is here to help: call 412-268-2922 and visit their website at http://www.cmu.edu/counseling/.

Consider reaching out to a friend, faculty or family member you trust for help getting connected to the support that can help. If you or someone you know is feeling suicidal or in danger of self-harm, call someone immediately, day or night:

CaPS: 412-268-2922

Re:solve Crisis Network: 888-796-8226

If the situation is life threatening, call the police:

On campus: CMU Police: 412-268-2323

Off campus: 911

If you have questions about this or your coursework, please let us know.

Course Schedule*

* Schedule subject to change

Week	Lecture • computer lab • lab challenge	Assignment
1 **Introduction** 08/28/18 08/30/18	course presentation introduction to parametric modeling interface, components and connections basic data structure and data matching 2d-attractors	
2 **Coordinate systems and curves** 09/04/18 09/06/18	coordinate systems • points, vectors + panes • curves generated by functions and interpolation list manipulations math components to generate curves interrupted hyperboloid with lines paraboloid from grid British Museum roof structure	Assignment 1 out
3 **NURBS curves** 09/11/18 09/13/18	NURBS curves • transformations curve division and curve guiding geometry • transformations • surface generation Butterfly curve Skyscraper	
4 **NURBS surfaces and analysis** 09/18/18 09/20/18	NURBS surface • domain, mapping and division surface division and mapping projection and sectioning surfaces adaptive structure and grid waffle structure	Assignment 1 due Assignment 2 out
5 **Morphing** 09/25/18 09/27/18	Deformations Surface components (subsurface) Morphing Advanced diagrid Adaptive components	
6 **Meshes** 10/02/18 10/04/18	Mesh and mesh division tree manipulation generating meshes dividing meshes (+Weaverbird) creating components from mesh division	Assignment 2 due Assignment 3 out

7 **Recursion and Loops** 10/09/18 10/11/18	Recursion vs loops Fractals Loops (Hoopsnake) Fractals and other algorithms Managing flows in GH (conditionals, gates and filters) combining existing modules structural grids	
8 10/16/18 10/18/18	**READING PERIOD** (NO Course Meetings)	Assignment 3 due