ADVANCED COMPUTATIONAL DESIGN METHODS

INSTRUCTOR
WANG Zhenfei zhenfeiwang@cuhk.edu.hk

ISSUE

Traditional architectural design methods face limitations compared to digital approaches. Digital design methods have revolutionized architecture by enhancing precision, creativity, and efficiency. Advanced tools enable architects to create complex, sustainable, and optimized projects. These methods improve collaboration among stakeholders, reduce errors, and streamline project timelines. Digital simulations allow for performance analysis, ensuring energy efficiency and structural integrity. As architecture embraces smart cities and innovative materials, digital design becomes essential in pushing boundaries while meeting functional and aesthetic demands. Ultimately, it bridges imagination and reality, shaping the future of built environments.

DESCRIPTION

Digital design is a computational approach where architectural elements are defined by algorithmic relationships and parameters rather than fixed forms. Using tools like Grasshopper (Rhino), Dynamo (Revit), or Python scripting, architects manipulate variables (e.g., dimensions, environmental data, material constraints) to generate adaptable, complex geometries. This method enables data-driven, iterative design that responds dynamically to changes. Digital design allows architects to explore complex geometries that would be nearly impossible to draft manually, pushing the boundaries of creativity.

This course aims to give students an overview of advanced digital design methods, explores the transformative role of computational tools in architectural design, bridging mathematical principles, algorithmic thinking, and practical applications. Through 12 lectures and hands-on workshops, students will learn to harness digital tools like Grasshopper, Kangaroo, Wallacei and other parametric plugins to generate innovative, performance-driven designs.

IMPACT AND SUSTAINABILITY

This course equips students with advanced computational design skills that bridge mathematics, digital tools, and architectural innovation. Through hands-on learning, students will:

1. Master Mathematical Principles
   Apply geometry, topology, and algorithms to generate unique architectural solutions.
2. Develop Digital Proficiency
   Gain expertise in Grasshopper, Ladybug, Kangaroo, and Wallacei for parametric modeling, environmental analysis, physics-based simulations, and multi-objective optimization.
3. Connect Theory to Design
   Translate architectural challenges—structural efficiency, environmental performance, spatial organization—into mathematical frameworks for computational problem-solving.
4. Quantify Research into Design Parameters
   Convert qualitative research (e.g., solar studies, user behavior) into quantifiable inputs for algorithmic design processes.
5. Build Custom Computational Workflows
   Construct personalized digital toolkits combining mathematical models, geometric operations, and performance criteria to generate iterative prototypes.

COURSE SYLLABUS

PHASE 1 FOUNDATIONS OF COMPUTATIONAL DESIGN

Focus: Introduction to parametric thinking, Grasshopper workflows, and environmental analysis.

Key Concepts:
1. Mathematical principles in design (geometry, data structures)
2. Solar analysis and performance-driven shading strategies

Task 1: Design a parametric shading device responding to environmental data (sun path, radiation).

PHASE 2 PHYSICS-BASED FORM-FINDING

Focus: Kangaroo Physics for dynamic relaxation and material behaviors.

Key Concepts:
1. Particle springs, force simulations, and tensile structures
2. Mathematical optimization of structural efficiency

Task 2: Create a pavilion design using Kangaroo for form-finding and stability.

PHASE 3 EVOLUTIONARY OPTIMIZATION

Focus: Wallacei for multi-objective optimization design solutions.

Key Concepts:
1. Genetic algorithms and Pareto fronts
2. Balancing competing design goals (e.g., cost, energy use, aesthetics)

Task 3: Develop a small-scale architectural project optimized via Wallacei.

METHODS

This course employs a rigorous weekly schedule combining lectures and practical workshops to systematically develop students' computational design expertise. Each week's sessions build foundational knowledge in three critical areas: (1) digital tools (Rhino, Grasshopper, and specialized plugins), (2) essential mathematical principles underlying parametric systems, and (3) contemporary computational methodologies transforming architectural practice.

The curriculum features three carefully sequenced design assignments that progress from fundamental skills to advanced applications. Students will apply computational concepts to solve real architectural challenges, integrating parametric modelling, environmental analysis (using tools like Ladybug), and performance optimization techniques. This scaffolded approach ensures theoretical knowledge translates directly into practical design capabilities.

Through this integrated learning model, students develop both technical proficiency and critical thinking skills needed to evaluate when and how to implement computational strategies. The course emphasizes professional workflows, preparing students to create designs that simultaneously address aesthetic, functional, and sustainability requirements - mirroring the complex demands of contemporary architectural practice.

DELIVERABLES

Three Individual Projects (Digital Submission)
Each project submission must include:
1. Project Description: Clear statement of design objectives and computational approach
2. Design Documentation: Professional-quality renderings, plans, sections, and analytical diagrams
3. Technical Files: Fully annotated Grasshopper scripts demonstrating parametric logic
4. Process Documentation: Evolution sketches showing design iterations and optimization

Computational Design Project Book (Printed/Digital)
A comprehensive publication featuring:
1. Project Portfolio: High-quality visual documentation of all three projects
2. Methodology Breakdown: Detailed explanations of implemented computational strategies
3. Technical Analysis: Diagrams deconstructing parametric systems and algorithms
4. Critical Reflection: Evaluation of successes, challenges, and lessons learned
5. Code Appendix: Key Grasshopper definitions with functional annotations

Evaluation Criteria:
1. Technical mastery of computational tools
2. Integration of parametric methods in design solutions
3. Quality of visual communication
4. Depth of methodological documentation
5. Innovation in computational application

All deliverables must demonstrate professional presentation standards suitable for academic review and portfolio inclusion.

LEARNING OUTCOMES

1. Ability to demonstrate competency in computational design tools (Rhino, Grasshopper, Ladybug, Kangaroo, Wallacei) to generate, analyse, and optimize architectural solutions.
2. Ability to develop architectural designs that harmonize aesthetic intent with technical performance through computational methods.
3. Ability to Employ diverse media—digital models, diagrams, data visualizations, and drawings—to effectively communicate design concepts across all project phases.
4. Understanding of the core principles of computational design, including parametric logic, algorithmic thinking, and performance-driven workflows.
5. Understanding of how mathematical principles (geometric transformations, parametric equations, topology, and optimization algorithms) inform computational design processes and architectural decision-making. Apply these concepts to generate structurally efficient, functionally responsive, and aesthetically compelling design solutions.

ASSESSMENT SCHEME

SPECIFIC ASSESSMENT

1. Individual Project 1 (25%)
2. Individual Project 2 (25%)
3. Individual Project 3 (25%)
4. Project Book (15%)
5. Final Quiz (10%)

Total: 100%

COURSE FORMAT

Teaching Days

1. Students must attend for F2F teaching during these teaching hours.
   Teaching Day: Thursday 09:30am – 12:15pm
   Teaching Venue: SB LT2

REQUIRED READINGS

1. Architectural Geometry
   Helmut Pottmann / Andreas Asperl / Michael Hofer / Axel Kilian, 2007, Bentley Institute Press
2. Digital Culture in Architecture: An Introduction for the Design Professions
   Antoine Picon, 2010, Birkhäuser Architecture

OTHER REFERENCES

1. Origins of Form
   Williams, Christopher, 1995, Taylor Trade Publishing
2. Informal
   Cecil Balmond, 2002, Prestel

IMPORTANT NOTE TO STUDENTS

Expectations for Professional Conduct
The motto of The Chinese University of Hong Kong (CUHK) is "Through learning and temperance to virtue". This motto places equal emphasis on the intellectual and moral education of students.
In addition to pursuing academic excellence, students of CUHK are expected to maintain and uphold the highest standard of integrity and honesty in their academic and personal lives, respect the rights of others and abide by the law. More information on Postgraduate studies can be found in the PG Student Handbook. https://www.gs.cuhk.edu.hk/

Attendance
Class attendance is required in all courses. For an excused absence, the instructor must be notified and presented with documentation of illness or personal matter. Please note: **Three (3)** or more unexcused absences may result in a failing grade for the course.

Academic Honesty
The Chinese University of Hong Kong places very high importance on honesty in academic work submitted by students and adopts a policy of zero tolerance on academic dishonesty

Attention is drawn to University policy and regulations on honesty in academic work, and to the disciplinary guidelines and procedures applicable to breaches of such policy and regulations. Details may be found at: http://www.cuhk.edu.hk/policy/academichonesty/.

With each assignment, students may be required to submit a statement that they are aware of these policies, regulations, guidelines and procedures.

Third-Party Assistance
All intellectual work essential to the design project must be completed by the student and cannot, under any circumstance, be outsourced to a third party (including, but not limited to a company, consultant, alumni, and/or friend).

In the design studio context, students may utilize external resources, such as printing services for presentation materials, and/or laser cutting and 3D printing services for prototyping purposes. Use of such third-party services constitutes non-intellectual work done by others. It is only permitted with prior written consent from the studio tutor and acknowledgment of such work done by the third party.

Assistance from other students or friends for aspects of project production also constitutes non-intellectual work done by others; this is allowed only if declared and acknowledged in a written statement attached to any such work that has received assistance.

Under all circumstances, students must declare all work done by others by completing the school's designated form before assessment. This form must include a detailed explanation of the third party's identity (name and relationship to the student), when and how they were utilized, and the specific tasks they performed in the project. The completed form, signed by the student, must be endorsed by the tutor and presented during the final review. The school will collect and retain this form for record-keeping purposes.

Failure to follow this code of conduct may be considered a case of academic dishonesty, to be reviewed by a disciplinary board, and possible failure of the course.

Artificial Intelligence
Students may use some AI tools in some learning activities and/or assessments on the condition that they make explicit acknowledgement and proper citations of the input from AI tools.

Acknowledging support from AI tools
Students are required to acknowledge all functional uses of an AI tool and cite it when they paraphrase, quote, or incorporate into their own work any content (whether it is text, image, data, or other format) that was created by it.

I. An example of acknowledgement
'I acknowledge the use of (name of AI tool – e.g. ChatGPT (https://chat.openai.com/) to (specify the support, e.g. plan my essay, generate some ideas for the content, ask for examples of data collection instruments, get the dates of historical events, etc.).

II. An example of citation
OpenAI. (2023). *ChatGPT* (Mar 20 version). https://chat.openai.com/chat

(Students are reminded that due to the rapid developments of AI tools, some citation formats may be updated regularly.)

III. An example of including texts generated by an AI tool in their work
"The following text was generated by an AI tool/language model (ChatGPT):"
[Insert the text generated by ChatGPT here.]

IV. An example of including texts generated by an AI tool and the prompts that were used to elicit the text from the AI tool
"[The prompt], as generated by an AI language model (ChatGPT):" [Insert the text generated by ChatGPT in response to the prompt.]

Students are reminded to learn and use the AI tools responsibly and ethically and be aware of the limitations.

Improper/unauthorized use of AI tools in learning activities and assessments will constitute acts of academic dishonesty which will be handled in accordance with the University's Procedures for Handling Cases of Academic Dishonesty.

Students are reminded to clarify with the course teacher and obtain permission if necessary when in doubt.

Students may refer to Approach 3 of the CUHK 'Use of Artificial Intelligence tools in Teaching, Learning and Assessments' – A Guide for Students.

Student Work
Submission of studio documentation must be complete and correctly formatted. Missing or incomplete submission of the documentation folder will result in the grade for the course being withheld. This will prevent registration for the following term or delay graduation. In addition, a grade deduction of *one letter grade* will be made.

Term 1: 1 September 2025 (Monday) – 29 November 2025 (Saturday)

WEEK 1		
04.09	**INTRODUCTION**	Course Introduction and Lecture
WEEK 2		
11.09	**GEOMETRY & GRASSHOPPER**	Lecture and In-class Workshop
WEEK 3		
18.09	**GEOMETRY & GRASSHOPPER**	Lecture, In-class Workshop and Individual Task 1
WEEK 4		
25.09	**GEOMETRY & GRASSHOPPER + LADYBUG**	Lecture, In-class Workshop and Individual Task 1
WEEK 5		
02.10	**GEOMETRY & GRASSHOPPER + LADYBUG**	Lecture, In-class Workshop and Individual Task 1
WEEK 6		
09.10	**GEOMETRY&KANGAROO PHYSICS**	Lecture, In-class Workshop
WEEK 7		
16.10	**GEOMETRY&KANGAROO PHYSICS**	Lecture, In-class Workshop and Individual Task 2
WEEK 8		
23.10	**GEOMETRY&KANGAROO PHYSICS**	Lecture, In-class Workshop and Individual Task 2
WEEK 9		
30.10	**GEOMETRY&KANGAROO PHYSICS**	Lecture, In-class Workshop and Individual Task 2
WEEK 10		
06.11	**WALLACEI**	Lecture, In-class Workshop
WEEK 11		
13.11	**WALLACEI**	Lecture, In-class Workshop and Individual Task 3
WEEK 12		
20.11	**WALLACEI**	Lecture, In-class Workshop and Individual Task 3
WEEK 13		
27.11	**PRESENTATION**	Presentation of Task 3

Grade	Descriptor	Criteria	Points
A	Excellent	Comprehensively excellent performance on all aspects of the design intention, development, technical resolution and presentation. Achieving all learning outcomes with distinction.	4
A-	Very Good	Generally outstanding performance on the design intention, development, technical resolution and presentation. Achieving all learning outcomes with merit.	3.7
B+	Good	Substantial performance on the design intention, development, technical resolution and presentation. Achieving all learning outcomes satisfactorily.	3.3
B			3
B-			2.7
C+	Fair	Fair performance on the design intention, development, technical resolution and presentation. Achieving all learning outcomes at a passing standard.	2.3
C			2
C-			1.7
D+	Pass	Barely satisfactory performance on the design intention, development, technical resolution and presentation. Achieving all learning outcomes at a barely satisfactory standard.	1.3
D			1
F	Failure	Unsatisfactory performance on the design intention, development, technical resolution and presentation. Not achieving all learning outcomes.	0

Written Feedback to Students

Term: ______________________ **Grade:** ______________

Course Code: ______________________

Review: ______________________

Tutor: ______________________

Student Name: ______________________

Student ID: ______________________

Feedback from Tutor:

Achievements:
Challenges: