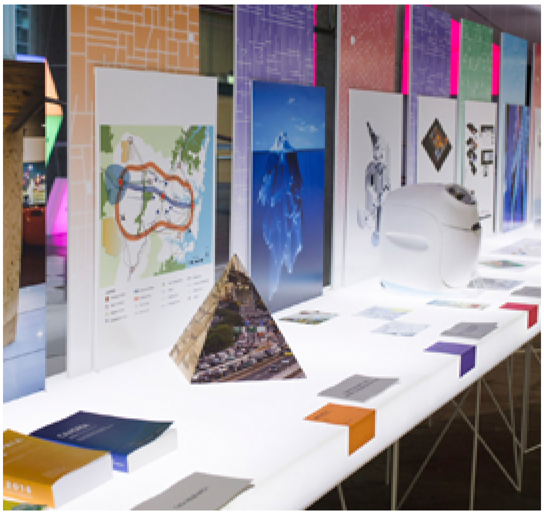
UNSW SYDNEY | Australia's Global University

Built Environment

3+ Abbreviated Course Outline – T1

CODE1150
Computational Design Studio I (Fundamentals)

Cristina Ramos



Disclaimer

This abbreviated course outline is indicative of the outcomes, delivery and assessment. While Course Learning Outcomes will remain constant, other details may be subject to change. The full and most accurate course outline will be available in Moodle.

1. COURSE STAFF

Course Convenor	Cristina Ramos
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2. COURSE DETAILS

Credit Points: 6 UoC

Learning Activity	Hours per week
Lecture	1
Tutorial	1
Studio	3
Online learning activity	1

Description

Computational Design I (Fundamentals)' is the first of four Computational Design courses that introduce students to Computational Design. In this course, students will develop and apply fundamental skills in visual programming languages, and apply fundamental mathematical concepts to inform computational design methods. Students will produce innovative geometries that shape the form, space and detail of architectural environments via digital fabrication techniques, 3D printing and laser cutting. Students will also demonstrate knowledge of computational design as a system that connects design to fabrication and apply digital fabrication skills to inform their own design practice. Theoretical knowledge will be introduced falling under the following broad concepts: Topological Architectures, Influenced Architectures, Dynamics and Motion, Generative Forms, Parametric Design, Evolving Architectures, Digital Fabrication, Digital Manipulation, Digital Optimization and Performance. Students will participate to weekly laboratory-based activities to experiment with and develop complex geometries. The students performance will be evaluated with respect to their progressive explorations and findings developed in preparation for or during the studio activities.

Program Learning Outcomes (PLOs)

The Computational Design Program Learning Outcomes addressed in this course are:

1. Synthesise interdisciplinary knowledge of cultural, natural, and technological systems in local and global contexts.
2. Apply interdisciplinary knowledge using computational design thinking and methods to built environment challenges.
3. Critically analyse complex environmental conditions through digital technologies and computational methods.
4. Apply computational design knowledge and skills for professional work and, or further learning.
5. Practice the ethical application of digital and computational technologies in and for the design of the built environment.

Course Learning Outcomes (CLOs) with Alignment to PLOs and Assessment

CLO #	CLO Statement	PLO #	Related Assessment
CLO 1	Apply fundamental skills in a visual programming language interface.	4	Assessments 2,3
CLO 2	Apply fundamental mathematical concepts that inform computational design methods.	2	Assessments 1,2,3
CLO 3	Demonstrate knowledge of computational design as a system that connects design to fabrication.	1	Assessments 1,2,3
CLO 4	Apply digital fabrication skills for their own design projects and professional work.	4	Assessments 2,3

3. ASSESSMENT

Assessment Task	Weight	Course Learning Outcomes Assessed	Due Date
1. Assessment 1: Scripting and Fabrication of Flat and Single Curvature Surfaces: – Felix Candela's work Report – Model 1: Simplified Geometry – Model 2: Finger Joints – Model 3: Living Hinges	25%	CLO 1 / CLO 2 / CLO 3	Week 2/3/4/5
2. Assessment 2: Scripting and Fabrication of Double Curvature Surfaces: – Model 4: Double Curvature Shell – Model 5: Waffle – Model 6: Perforated Shell	35%	CLO 1 / CLO 2 / CLO 3	W 6/7/8
3. Assessment 3: Scripting Fabrication Systems based on Meshes: – Model 7: Rods and Nodes – Model 8: Substructure and Plates – Model 9: Plates with Tabs	40%	CLO 1 / CLO 2 / CLO 3 / CLO 4	W 9/10
Exhibition	-	CLO 4	W 10

4. WEEKLY COURSE SCHEDULE

Week	Topic	Activity	Related CLO
Week 1	Introduction to the course CODE 1150. Introduction to Grasshopper. Felix Candela: Selection of Works	• Lecture: Course Organization: Objectives and expectations; Structure of the course; Weekly submissions and Assessments; Exhibition. The key themes that will be addressed during the course are presented: Introduction to Parametric Design and Digital Fabrication; Félix Candela's concrete thin-shells.	CLO 1 CLO 2 CLO 3

		• Tutorial: This first tutorial is a general introduction to Grasshopper, including: User Interface; Communication Rhino-GH; Radial menu; Canvas organization; Parameters and Components; Object State and Wires. • Studio: Students will select one of Candela's works presented in the lecture. In the studio students will have time to research about it, exploring the geometry behind the shell and creating a report with sketches, pictures and text. All the concepts and techniques learned in the lectures and tutorials will be then applied to that specific geometry in the studio, creating a collection of variations based on the same original shape.	
Week 2	Numbers, Functions and Curves. Creating and Transforming Geometries	• Lecture: This lecture presents the essential elements in geometry, offering a strong base to understand the 2D and 3D space and the direct relationship between maths and geometry. Includes: Main type of numbers used in parametric design: Reals, Integers and Booleans; Basic elements in geometry: Point, Vector and Plane; Functions and Variables translated into Curves; The Coordinate System and its 6 transformations. In Grasshopper we will see the Mathematical Operators, their types and applications (Mathematical; Conditional and Boolean); as well as different ways to create basic elements (point, vector, plane), curves, surfaces and solids, and how to transform them (move, rotate, mirror, orient). • Tutorial: Parametric Definition of a Simple Geometry: In this first GH definition, a simple parametric geometry is designed based on basic elements and transformations. We will start in 2D to move then to 3D. The concept of 'function' and 'variable' is reinforced showing how different numeric values are translated into modifications in the geometry. • Studio: The concepts learned in the lecture and tutorial will be applied to develop a variation of Candela's thin-shell: a simplification of the geometry in Flat Surfaces.	CLO 1 CLO 2 CLO 3
Week 3	Intersections and Tolerances. Data Management I: Lists, Sets and Domains	• Lecture: In this lecture mathematical intersections: curve-curve; surface-curve; surface-surface are presented. Students will learn that mathematical and physical intersections in grasshopper return points and curves that don't actually trim the objects, and how to use them to split then the geometry in parts. Other ways to trim/join curves, surfaces and solids are also presented, as well as the importance of tolerances in fabrication. Students will be introduced to the concept of 'Lists', learning several ways to construct them; visualization of the order of the items within a list; how data matching between lists works and ways to modify that relationships; list management (extract, insert and remove items; reorganize, divide and join lists); and sets. Domains will be used to organize and visualize	CLO 1 CLO 2 CLO 3

		objects within a list by length, area, volume, etc by assigning colours. • Tutorial: Finger Joints: In the second tutorial we will learn to create linear joints to connect discrete flat elements. The concepts of 'lists', 'intersections' and 'orient objects' are applied in this activity. • Studio: The GH script developed in the previous studio is going to be reviewed and recreated using lists; and then finger joints will be applied to create the connections between the flat surfaces. A new variation of the thin-shell will be manufactured in wood using the laser cutters.	
Week 4	Simple Curvature Surfaces. Ruled and Developable Surfaces. Rationalization I	• Lecture: Fabrication of complex continuous surfaces (with application, for example, in facades) requires a deep understanding of the geometry behind them. Not all the shapes can be unrolled in a flat sheet allowing for fabrication. And also, the subdivision method used to create the pieces, can potentially simplify the fabrication process. 1. In this lecture we will study the types of ruled surfaces, which one of them are developable, and we will go further, in this case, with the simple curvature ones (cylindrical and conical surfaces; right and oblique; of revolution and no revolution). The intersection of a plane with a simple curvature surface generates different types of curves depending on the orientation of the plane in relation to the axis of the surface. We will see the best way to cut the different shapes to achieve the simplest subdivision pattern. • Tutorial: Living Hinges: In this tutorial students will develop a script to unroll a simple curvature surface into a flat sheet for fabrication. Creating a collection of strategic cuts in the direction of the generatrix, the rigid sheet will be transformed into a flexible element able to recreate the original shape. • Studio: The concepts learned in the lecture and tutorial are applied to develop a new variation of Candela's thin-shell: a simplification of the geometry in Simple Curvature Surfaces. It will be materialized into a scale-model in wood using the laser cutter.	CLO 1 CLO 2 CLO 3
Week 5	Double Curvature Surfaces. Double Ruled Surfaces. Rationalization II	• Lecture: This lecture complements the previous one. In this case it is focused on Double Curvature Surfaces (sphere; ellipsoid; toroid; paraboloid; hyperboloid). Although these geometries are not developable in a flat sheet; some of them, the ones that are based on rules (paraboloid and hyperboloid), can be easily transformed into developable shapes. The student will learn the subdivision method to achieve that transformation. 2. The intersection between a double curvature surface and a plane generates different types of curves depending on the orientation of the plane in relation to the axis of the surface. We will see the best way to cut the different shapes to achieve the simplest and optimal subdivision pattern.	CLO 1 CLO 2 CLO 3

		• Tutorial: Continuous Double Curvature Shell: In this tutorial students will develop a double curvature network surface (parabolic hyperboloid) in two different ways: based on a collection of straight lines (rules), and based on a collection of parabolas. The shape will be then cut with the proper planes to achieve different effects on the boundary. • Studio: Based on the concepts learned in the lecture and the tutorial, the original Double Curvature Surface of Candela's Thin-Shell is parametrically modelled. This digital model needs to be accurate and faithful to the original Candela's shape, as it will be the base to develop all the following digital and physical models using different fabrication techniques.	
Week 6	Data Management II: Trees	• Lecture: GH organizes the data hierarchically, and in the same way that a list is a collection of organized items; a tree is a collection of organized lists. In this lecture students will be introduced to the concept of 'Trees', learning how to construct/deconstruct them; how to visualize the structure of a tree (param viewer; tree statistics); and modify it (flatten; graft; simplify; trim; flip matrix) and manage the date inside the tree (extract and remove branches and items, divide a tree). This will give the students the ability to manage the data efficiently in more complex scripts, required as we advanced in the course. • Tutorial: Waffle: Using the script of the previous tutorial, the Double Curvature Surface is sliced by a collection of planes in the most efficient way, that is to say, obtaining the simplest curves. The model is transformed into a waffle structure. Crossing ribs will be connected with cross lap joints. 'Intersections', 'tolerances', 'tree' and 'orient' concepts are reinforced through this activity. • Studio: The fabrication technique learned in the tutorial is applied to develop a new variation of Candela's Thin-Shell: a Waffle structure. The original shape defined at Model4 will be used as starting point. The variables can be modified to achieve an interesting version of the geometry, and then it will be sliced by the collection of planes that returns the elements with maximum curvature in both directions; and by the collection of planes that returns the elements with non-curvature. One of these models will be fabricated in wood and acrylic using the laser cutter. The pieces for fabrication will be labelled at the cross-lap joints for assembly instructions.	CLO 1 CLO 2 CLO 3
Week 7	Subdivision Methods and Patterns. Analysis and Evaluation of Points, Curves and Surfaces. Attractor Points.	• Lecture: This lecture introduces students to the analysis and evaluation of points (distance; closest point/points), curves (curve closest point; curve proximity; evaluate curve; point on curve) and surfaces (surface closest point; evaluate surface, surface curvature) are presented. The concept of 'reparametrize' a curve and a surface is reinforced with numerical and geometrical examples, and its relevance in any subdivision process is explained.	CLO 1 CLO 2 CLO 3

		Different subdivision methods and patterns to populate the surface are presented. (projection, grids, etc.) • Tutorial: Perforated Shell: Using Model4 as a base, in this tutorial we will explore different ways to subdivide a surface using a collection of different patterns. The concept of “projection” is reinforced in this task. The centre point of the cells created on the surface will be used as a reference to apply two different attractor points that will allow to control and modify a couple of parameters in the shell (permeability, height, etc.) • Studio: The concepts learned in the lecture and tutorial are applied to develop a new variation of Candela’s Thin-Shell: a Perforated Shell. It will be materialized in a 3D printed scale-model.	
Week 8	Normal Vector and Tangent Plane to a Surface. Meshes and Topology.	• Lecture: The concepts of Normal Vector and Tangent Plane to a surface in a point are explained, as well as its relevance at any panelization process. The lecture introduces ‘Meshes’, explaining their anatomy based on vertex and faces with direction; how to construct and deconstruct them and the importance of the order of the vertices to avoid non-manifold meshes. The concept of ‘Topology’ is also presented, showing that the same collection of points can be connected in many different ways, creating different topologies; while a set of points can be moved without changing the order in which they are connected, creating a new mesh with the same topology. We will see the difference between Mesh and NURBS and when can be useful to change from one to the other. Operations with meshes will be also explained. • Tutorial: Rods and Nodes: In this tutorial a triangulated mesh is created using as a base the main curves of Model4 (2 collections of parabolas/ 2 collections of straight lines). The edges of that mesh will be the axes of a new model composed by rods and nodes. Rods are generated using extruded profiles and nodes are groups of hollow elements embracing the bars that intersect at the same common point. Tolerances are required to make fit the elements between them when fabricated. Bars are grouped by lengths and a domain function will be used to visually classified them with colors. Nodes are labelled at each endpoint with the number of the corresponding rod. • Studio: The fabrication technique learned in the tutorial is applied to develop a new variation of Candela’s Thin-Shell: a Rods and Nodes Structure. The original shape defined at Model4 will be used as starting point. The variables can be modified to achieve an interesting version of the geometry. The model will be fabricated using bamboo skewers for the rods and the nodes will be 3D printed in PLA.	CLO 1 CLO 2 CLO 3
Week 9	Guest Lecturer: Researcher in Parametric Design	• Lecture: This lecture introduces students to research in Parametric Design and gives an overview of Advanced Digital Fabrication Techniques including	CLO 1 CLO 2 CLO 3

	and Digital Fabrication	CNC milling and robot fabrication. Machinery, materials and fabrication processes are presented. The most relevant examples of digital fabrication in architecture and design are presented • Tutorial: Substructure + Plates: In this tutorial, the concepts of 'mesh', 'panelization', 'oriented profiles' and 'orient surface' are reinforced. The mesh developed in the previous tutorial (T7) is used here to create a construction system based on a substructure and a collection of plates. The edges of the mesh will be transformed into oriented 'T' profiles in which the panels sit. The design of the panels can be modified by using attractor points. • Studio: The fabrication technique learned in the tutorial is applied to develop a new variation of Candela's Thin-Shell: a Substructure with Panels. After modifying the general shape of the surface, the mesh developed at Model7 can be used as starting point. The model will be fabricated using the 3D printer to create the substructure, and the panels can be cut in clear acrylic with the laser cutter, or printed in clear PLA.	
Week 10	Guest Lecturer: Professional Senior Computational Designer	• Lecture: In this lecture, a professional from industry specialized in parametric design, is invited to present his research and work using digital fabrication on a building scale. The rationalization of the surface to transform a complex geometry into buildable elements; the fabrication system used; issues during the assembly process; and solutions adopted will be explained. This lecture will showcase how the techniques learned during the semester are applied to real installations and buildings. • Tutorial: Plates with Tabs: This tutorial combines the techniques of 'plates' with 'ribs' to generate the tabs, creating a different fabrication system where the pieces are connected by their lateral faces to each other, generating the surface without any substructure. The concepts of 'tree', 'mesh' and 'unfold surface' are reinforced. The triangulated mesh developed at T7, it is used as starting point of this activity. The edges are used to create labelled duplicated tabs, and each one of them is assigned to one of the two triangular panels that share the edge. Each panel must be linked and merged with the three tabs located in its perimeter. The panels are unfolded, oriented and distributed in a planar sheet for fabrication. • Studio: The fabrication technique learned in the tutorial is applied to develop a new variation of Candela's Thin-Shell: Plates with Tabs. After modifying the general shape of the surface, the triangulated mesh developed at Model7 can be used as starting point. The model will be fabricated in a thin sheet of metal, using the laser cutter. The pieces will be connected by their lateral tabs using metallic pin joints.	CLO 1 CLO 2 CLO 3 CLO 4