DIGITAL DESIGN
INTRODUCTION

NURBS

Meshes

Subdivision Surfaces

T-Splines

Parameters and Generative Design

Algorithms and Scripted Design
**NURBS (NON-UNIFORM RATIONAL BASIS SPLINE)**

Nurbs are mathematical models of forms

- ex: perfect spheres

vector-based: geometrical definitions of surfaces

- ex: \((x - x_0)^2 + (y - y_0)^2 + (z - z_0)^2 = r^2\)
- ex: \(y = y_0 + r \sin \theta \sin \varphi \quad (0 \leq \theta \leq 2\pi \text{ and } 0 \leq \varphi \leq \pi)\)

- can be simple or extremely complicated though the use of control points, weights, and knots

- can take any shape without a large amount of information, as the computer calculates the shapes (and partial derivatives)

- can be smooth continuous curves

- must obey particular Cartesian geometry laws, meaning it is not possible to create holes or branches

- ex: Yas Hotel exterior form - Asymptote Architects
Meshes are many discrete data points connected by polygons

raster-based: collection of points defined close enough to describe a surface

formed of vertices, edges, faces

often triangulated

by definition, not a smooth or continuous surface

can describe any geometry, including those with holes, handles, or branches

much less precise than any other method

ex: a land survey of locations and elevations

ex: LIDAR point clouds serving as vertices for forming triangles with near-points
**Subdivision Surfaces**

Subdivision surfaces attempt to approximate smooth surfaces by creating increasing numbers of edges and polygons.

Refine a raw shape into a more smooth shape.

New surface points are interpolated (on the surface) or approximated (off the surface).

Tend to be smoother than meshes as they have smaller polygons, but are not continuous.
**T-SPLINES**

T-Splines are a superset of NURBS formed when rows of control points are allowed to terminate (rather than continue across the surface). This allows for the opportunity to combine the benefits of NURBS and subdivision surfaces, defining edges where systems can meet smoothly without gaps (as opposed to other systems).
PARAMETERS AND GENERATIVE DESIGN

relating a particular measurable quantity to another

ex: the length of one element with its width
ex: the height of one element with its orientation

allows for using the calculation abilities of the computer to make unique pieces that fit as a set of elements

ex: a set of components of varying lengths and widths, each to be assembled numerically to create a unified wall system

allows for changing individual parameters and changing many other quantities simultaneously

ex: Mobile Art Pavilion by Zaha Hadid
ALGORITHMS AND SCRIPTED DESIGN

the idea of using a computer for its calculation abilities as a means of design, rather than using the computer as a drafting tool

leverages the processing power of the computer to solve the design problem

requires determining which factors are relevant and how the design should react to them

ex: Q1, ThyssenKrupp Quarter Essen / JSWD Architekten + Chaix & Morel et Associés
WWW.YOUTUBE.COM/WATCH?v=bws0oU1zKzk

0:00 explain concept
4:00 software demonstration
6:00 milling demonstration
CNC Milling

Milling refers to the processing of metals, wood, or plastics by machining with a milling tool. CNC machines can mill material in a 2D or 3D fashion.

Milling is a subtractive process in which a material is cut down to a certain shape and size defined by a 3D program.

A CNC machine allows for a material to be cut down precisely to a certain shape and size as defined by the design created on a computer modeling program.

Different milling bits can be used to create a various amount of cuts and are chosen depending on surface finish, precision, or speed.

Because CNC milling is subtractive process, it has the tendency to have a large amount of waste- especially when milling material in the 3D process.
CNC Axes

The more axes the machine has the greater amount of movement it has for milling the material.

1 Axis - X axis = Left and Right

2 Axis - Y axis = Back and forward

3 Axis - Z axis = Up and Down

4 Axis - A axis = Clockwise and counterclockwise rotation (horizontal plane)

5 Axis - C axis = Clockwise and counterclockwise rotation (vertical plane)

http://www.youtube.com/watch?v=kGCZUO_E0AU
**Kerfing Wood Using the CNC Machines**

Kerf refers to the width of cut a sawblade makes when it’s cut through wood.

Kerf cutting is making many kerf cuts (cuts the width of your sawblade) along a piece of wood.

Making kerf cuts can be done on a table saw but using a CNC machine to make the cuts can allow you to easily create more intricate and precise kerf cuts.

One example of this is the zipshape chair by students from the Hamburg school for timber technology.
Laser Cutting

Laser cutting was first introduced as a cutting method in the 1970s.

A laser cutter cuts materials on a 2D plane.

It cuts objects by heating them in a precise area, (the area the laser is projected on) in a very short amount of time.

At the same time the material is being heated, a process gas blows the heated material downwards causing it to cut.

Wood laser cut in certain ways can allow wood to bend more easily.
Laser Cutting (continued)

By adjusting the speed and power settings of the laser, the laser is able to cut or engrave a number of different materials and thicknesses effectively.

Although laser cutting can only cut on a 2D plane, adjusting the speed and power settings of the laser allows the laser to cut to different depths in a material as the laser moves allowing it to create depth.

Having the potential to burn what it is cutting if the power and speed are set incorrectly.
3D Printing

3D printing unlike CNC milling is an additive process. It involves creating a solid object by layering thin slices of material including plastic, metal and ceramic.

There are 3 main types of 3D printers used commonly today:

1. Printers that print with fine powder or Laser Sintering
2. Printers that print with resin or Stereo Lithography
3. Printers that print by extruding plastic or Fused Deposition Modeling (FDM)
**Laser Sintering**

Two major parts:

A “build box”

Contains a smooth, thin bed of finely ground material such as pulverized stainless steel or powdered plastic.

The printing head

Contains either a heat source, such as a laser or an electron beam, that melts the powdered material or jets a spray binder over the powder in a precise pattern.

The binder functions as a glue for the material as an object is built.

The printer layers powder over and over again binding the areas part of the model with heat.

After many layers of powder and binding, the model is taken out of the printer and cleaned.

http://www.youtube.com/watch?v=sFpSxX0SzhY&list=PLISUnI-s8ALPDHwXcN3fuPKKrXUbc9CNRg&feature=player_detailpage

Or (longer video)

http://blog.themakestore.com/2013/09/the-3-types-of-3d-printing/
Stereo Lithography is made in a pool of liquid resin

The liquid resin is originally at room temperature making it liquid at the beginning of the process.

As printing begins, a laser draws the shape of the design in the resin causing it to harden.

The model is then pulled up out of the resin by just a fraction and the next layer is drawn by the laser.

This process is repeated until the model is finished.

http://blog.themakestore.com/2013/09/the-3-types-of-3d-printing/
**FUSED DEPOSITION MODELING**

The plastic comes as strands of filament that are usually a standard 1.75 millimeters or 3 millimeters in width.

Available in many different colors.

Usually comes on a spool that is attached to the printer and attached to a gear.

A gear pulls the piece of filament through the print head.

Just before it is extruded by the pointed nozzle, the filament passes through a heated tube and liquefies.

The nozzle deposits it in ultra-fine lines generally about 0.1 millimeters across.

The plastic solidifies quickly, sealing together layers.

http://www.youtube.com/watch?v=bpcwBQKUqK4
**Benefits of Digital Fabrication**

Digital fabrication allows people to cut things that were before almost impossible to cut.

It is allowing for pieces of furniture and other forms of design to be produced easily, quickly and precisely.

Can create cut the same piece over and over again very quickly if need be.

Nonstandard design

Mass customization

People can easily customize objects from furniture to cell phone cases to toys and much more.
STRATEGIES IN DIGITAL FABRICATION
INTRO

Digital fabrication: a way of making that uses digital data to control a fabrication process. Relies on computer driven machine tools to cut parts.

“Architecture continually informs and is informed by its modes of representation and construction, perhaps never more so than now, when digital media and emerging technologies are rapidly expanding what we conceive to be formally, spatially, and materially possible.” –Lisa Iwamoto

Types of digital fabrication techniques/strategies:

- Sectioning
- Tessellating
- Folding
- Contouring
- Forming

Modern architecture has been described as **NEW MATERIALS = NEW FORMS.**

In this case **NEW TECHNOLOGIES & TECHNIQUES APPLIED TO MATERIALS = NEW FORMS.**
SECTIONING

Sectioning: plans and sections (orthographic projections)

Sectioning uses a series of profiles, the edges of which follow lines of surface geometry instead of constructing the surface itself.

Sectional assemblies can produce both surface and structure.

Sectioning construction techniques:

1. Sectional ribbing (dunescape installation SHoP architects)
2. Lamination or parallel stacking (Mafoombey winning contest entry Helsinki 2005 by Martti Kalliala, Eas Ruskeepaa with Martin Lukasczyk)
3. Waffle Grid: Metropol Parasol (J. Mayer H. Architects)

In the case of parallel stacking the frequency of the sections required to approximate the increasingly varied surfaces increases, sometimes resulting in a visual intensification of material.

By using edge profiles to describe surface through implied visual continuities, architects have taken advantage of sectioning – both to merge and perceptually elevate the relationship of form with material tectonic.
TESSELLATING

Tessellation is a collection of pieces that fit together without gaps to form a plane or surface. Tessellation can be virtually any shape so long as they puzzle together in tight formation.

Digital technologies afford greater variation and modulation through nonstandard manufacturing, even as they provide an inherent economy of means. Working digitally enables movement from one representational format to another.

For example, from digital model to vector line file to manufacturing method. This series of translation allows for a more fluid fabrication process and reducing the labor associated.

“M.C. Escher”

Tessellation offers a way to build smooth form using sheet material.

Depending on the resolution of tessellation approximated surfaces can be smooth and precise, or faceted and crude.

When evaluating tessellation strategies, if the aim is to calibrate the initial form with a constructional system, one may better determine the size and resolution of the tiles relative to overall geometry and design intention, and with regard to final building materials and fabrication process.

Ex: Helios house by Office dA and Johnston Marklee & Associates. 2006-07

Ex: SHoP Architects, 290 Mulberry Street New York, 2007
FOLDING

Folding turns a flat surface into a three-dimensional one.

Folding is materially economical, visually appealing, and effective at multiple scales. A technique for making forms and creating structure with geometry.

Planar material properties when folds are introduced:

Gain stiffness and rigidity

Can span distance

Can often be self supporting

The operation of folding material is also a generative design tool that has gained currency in digital-fabrication processes. Folding expands the three-dimensional vocabulary of surface by naturally producing deformation and inflection. Digital tools enable subtle and complex geometric modulations, affording the ability to both incorporate and smooth over difference. The structural stiffness produced by introducing folds into material is another significant advantage of the technique.

Ex: In-out curtain, Iwamoto Scott, 2005

Ex: Digital Origami, University of Technology, Sydney / Chris Bosse, 2007
Contouring is a technique that reshapes this surface and creates a three dimensional relief by removing successive layers of material. It is a subtractive process.

Construction materials typically come as sheets and examples include stone slabs, plywood, particleboard, mdf, gypsum board, and cast composites among other.

Digital fabrication has enabled architects to transcend the idea that carving resides exclusively in traditional handcraft practice.

Contouring is a material and time intensive process and material waste is inherent in the process.

Ted video Gregg Lynn @ 17:30 min http://www.ted.com/talks/greg_lynn_on_organic_design.html

Ex:

Greg lynn, prettygoodlife.Com showroom, stockholm, sweden, 2000

Design 306 , erwin hauer and enrique rosado, 2005

Door with a peephole , williamsonwilliamson, 2004
FORMING

Forming - generating multiple parts from a small number of molds or forms. It follows that the most common uses for this technology are mass produced products.

Benefits include flexibility in material choices with different mechanical properties & colors.

In buildings this translates to architectural components, such as hardware, façade panels, and window mullions.

Though forming processes are never digital in themselves, digital fabrication has created new possibilities for conceiving and designing customizable formwork.

Ex.

P_wall, andrew kudless/matsys 2006
Further Resources

Digital fabrications :architectural and material techniques / Lisa Iwamoto
Published by Princeton Architectural Press 2009
37 East Seventh Street, New York, NY 10003

Material Strategies in Digital Fabrication / Christopher Beorkrem
Published by Routledge 2013
731 Third Avenue, New York NY 10017

Zip Chair - http://www.designboom.com/design/imm-cologne-09-preview-zipshape-by-schindleralmerton/

Nested Table - http://synthesis-dna.com/nested-table/

Ripples Bench - http://www.horm.it/project/ripples/#lang=en#prettyPhoto[1]/


Cork 3D Chair - http://danielmichalik.com/danielmichalik.com/furniture/

Laser Sintering - http://www.youtube.com/watch?v=dIPxeX05qjY&list=PLISUNd8APDMHwZ1v3f6pKKKxUbc9CNRp&feature=player_detailpage


Fused Deposition Modeling- http://www.youtube.com/watch?v=hpwBQRUqK4


Digital Processes: Planning Design Production
by Moritz Hauschild & Rüdiger Karzel