3D Design and Prototyping

ITP 415x (2 Units)

Spring 2014

USC Viterbi School of Engineering

Objective

Explore the range of 3D printing and Prototyping technologies, and their application in modern industrial, design, and creative fields. Overview of 3D design and modeling techniques for modern Rapid Prototyping and Additive Manufacturing applications. Develop a complete 3D modeling project from initial concept to finished printed model.

Concepts

Explore the range of prototyping technologies, base materials, and how the application of emerging tools and technologies impacts the production process. Learn 3D modeling and design techniques for manufacturing and product development. Understand successful modeling methodologies, topologies for exporting to printing, measurement techniques, and how to work within manufacturing tolerances. Explore modeling software and modeling techniques, including traditional 3D modeling, procedural modeling, image-based modeling, and photogrammetry. Build precise and printable 3D models to meet product development needs.

Prerequisites

No prerequisite

Instructor	Lance S. Winkel
Contacting the Instructor	Email Address: winkel@usc.edu Telephone: 213.740.9956
Office Hours	Office Hours and location. OHE 530 H. Hours TBD
Lab Assistants	TBD
Lecture	1.5 hours per week
Lab	1.5 hours per week

Required Textbooks

Manufacturing Processes for Design Professionals by Rob Thompson
Hardcover: 528 pages, ISBN-10: 0500513759, ISBN-13: 978-0500513750

Website

Class materials are posted on the USC Blackboard website. https://blackboard.usc.edu/

Grading

14 weekly progress checks, 10 points each = 140 points
Initial Product Design = 20 points
Finished Product Model (prior to 3D printing) = 20 points
Final Project / Presentation / Physical Model = 50 points
Final Exam = 50 points
Total = 230 points

Grading Scale

A 100-93
A- 92-90
B+ 89-87
B 86-83
B- 82-80
C+ 79-77
C 76-73
C- 72-70
D+ 69-67
D 66-65
F 64 or below

Policies

Projects: All projects and weekly assignments are due at the start of class and are considered late 1⁄2 hour after class begins. Only one project or assignment may be turned in late. All other late projects will NOT be accepted unless pre-approved by the instructor. With the instructor's approval, on time projects may be redone for additional credit but must be turned in by the following class session. The final project may not be turned in late.
Before logging off a computer, students must ensure that they have emailed or saved projects created during the class or lab session. Any work saved to the computer will be erased after restarting the computer. ITP is not responsible for any work lost.
ITP offers Open Lab use for all students enrolled in ITP classes. These open labs are held beginning the second week of classes through the last week of classes. Please contact your instructor for specific times and days for the current semester.

Incomplete and Missing Grades

Excerpts for this section have been taken from the University Grading Handbook, located at http://www.usc.edu/dept/ARR/grades/gradinghandbook/index.html. Please see the link for more details on this and any other grading concerns.

A grade of Missing Grade (MG) "should only be assigned in unique or unusual situations… for those cases in which a student does not complete work for the course before the semester ends. All missing grades must be resolved by the instructor through the Correction of Grade Process. One calendar year is allowed to resolve a MG. If an MG is not resolved [within] one year the grade is changed to [Unofficial Withdrawal] UW and will be calculated into the grade point average a zero grade points.

A grade of Incomplete (IN) "is assigned when work is no completed because of documented illness or other 'emergency' **occurring after the twelfth week** of the semester (or 12th week equivalency for any course scheduled for less than 15 weeks)."

Academic Integrity

USC seeks to maintain an optimal learning environment. General principles of academic honesty include the concept of respect for the intellectual property of others, the expectation that individual work will be submitted unless otherwise allowed by an instructor, and the obligations both to protect one's own academic work from misuse by others as well as to avoid using another's work as one's own. All students are expected to understand and abide by these principles. *Scampus,* the Student Guidebook, contains the Student Conduct Code in Section 11.00, while the recommended sanctions are located in Appendix A: http://www.usc.edu/dept/publications/SCAMPUS/gov/. Students will be referred to the Office of Student Judicial Affairs and Community Standards for further review, should there be any suspicion of academic dishonesty. The Review process can be found at: http://www.usc.edu/student-affairs/SJACS/.

Students with Disabilities

Any student requesting academic accommodations based on a disability is required to register with Disability Services and Programs (DSP) each semester. A letter of verification for approved accommodations can be obtained from DSP. Please be sure the letter is delivered to your course instructor (or TA) as early in the semester as possible. DSP is located in STU 301 and is open from 8:30am to 5:00pm, Monday through Friday. Website and contact information for DSP http://sait.usc.edu/academicsupport/centerprograms/dsp/home_index.html (213) 740-0776 (Phone), (213) 740-6948 (TDD only), (213) 740-8216 (FAX) ability@usc.edu

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Course Outline

Week 1 – 3D Modeling Principles

- Survey of students and 3D animation experience
- Overview of course plan and objectives
- Sample work
- Review fundamentals of 3D modeling (polygons and NURBS)

Reading

Reference Slides

Manufacturing Processes for Design Professionals, Chapter One

Assignment/Project

Project 1 - Reference: Produce or procure a design schematic or blueprint for a complex object (mechanical part, gear, piston head, multi-part tool) to serve as a resource in class. Find or shoot proportional reference images of the object (top, front, side, comparative scale if using two objects). Bring the object, a ruler, and digital image files for next class. Due week 2.

Week 2 – Basic Modeling (Polygons)

- Understanding 3D geometry
- WYSIWYG Modeling.
- Modeling workflows for Polygons
- Additive vs. Subtractive Tools
- Components types and considerations. Best practices for modeling with polygons

Reading

Reference Slides

Manufacturing Processes for Design Professionals, Chapter Two

Assignment/Project

Project 1 - Introduction to Modeling: Set up the scene work area with grids, guides, and image planes. Begin by plotting key areas of complexity with measurement stand-ins. Using the proportional reference images; model the simple object as accurately as possible. Pay close attention to screw threading, mounting points, articulation points, and other details, etc. Due week 3.

Week 3 – Intermediate Modeling (NURBS)

- Understanding NURBS
- NURBS Surfaces advantages
- Curve and surface construction
- Clean, uniform, and non-uniform topology. Rebuilding strategies.

- NURBS component types and considerations. Best practices for modeling with NURBS

Reading

Reference Slides

Manufacturing Processes for Design Professionals, Chapter Three

Assignment

Project 2 – NURBS: Setup the scene work area as per week 2. Build the exact same object from Project 1 using only NURBS geometry. The parts can be assembled from NURBS curves or from NURBS surface primitives, but should achieve the same level of physical detail as was produced for the polygon version. Pay close attention to curved verses flat surfaces, complex contours, and completely filling any gaps in the structure. Due week 4.

Week 4 – Advanced Modeling (Hybrid Poly/NURBS Modeling)

- Modeling workflows for NURBS and Polygons
- Conversion techniques
- NURBS to Polygons
- Polygons to NURBS
- Subdivision surfaces
- Best practices
- Preserving UV texturing coordinates throughout conversion

Reading

Reference Slides

Manufacturing Processes for Design Professionals, Chapter Four

Assignment

Project 2 B – Final cleanup and assembly: Use the most advantageous geometries from Project 1 and Project 2, as well as NURBS to Polygon conversion tools, and cleanup techniques. Assemble the master part in its entirety with no overlapping UV texture coordinates as a single uniform mesh object. Texture coordinates should look clean and make sense. Mesh should have uniform polygons and be manifold. Due week 5.

Week 5 – Modeling for design and production

- Moving Parts and Articulation
- Form and function
- Visualizing the assembly process

Reading

Reference Slides

Manufacturing Processes for Design Professionals, Chapter Five

Assignment

Project 3 – Brainstorming and Concept: Design three unique parts or objects. Begin by identifying the purpose and function of the object. (Ex: automobile brake assembly, gas cap and tank line assembly, socket wrench, complex door hinge, etc.) There should be something unique about the object's function or a significant deviation from a conventional approach. Also, the designs should contain moving part, or articulation, or some form of interlocking pieces that will normally require post fabrication assembly.

Top, front, side, and relative scale. Due week 6.

Week 6 – Modeling for manufacturing

- Broad overview of manufacturing techniques
- Molding, sculpting, lathing, lofting, welding, cutting, drilling, gluing, etc.
- How manufacturing impacts design

Reading

Reference Slides

Manufacturing Processes for Design Professionals, Chapter Six

Assignment

Project 3 – Previsualizing the design: Model a rough block-in of each part. These are fast and low detailed models, but should contain enough information and detail to describe form, function, silhouette, and help identify potential manufacturing and fabrication contingencies. Also include a rough outline of the manufacturing procedures that would be typical for mass production. Due week 7.

Week 7 – 3D Design Fundamentals

- Examples of successful production workflows:
    - Prominent Designers
    - Franchises
    - Success stories
    - Design failures and lessons learned
- Influence of pop culture and media
- Rules, regulations, and safety

Reading

Reference Slides

Manufacturing Processes for Design Professionals, Chapter Seven

Assignment

Project 3 – Final Design: Based on critique of the proposed design and previsualization models, pick one specific design to serve as the basis for the remainder of the course. Make necessary design changes. Add embellishments and style, resolve any lingering design concerns, and render it as series of scaled orthographic (top, front, side) profile images. Additionally, design a packaging, carriage, holster, or other interacting accessory that can fit or be fitted to the chosen designed product. Due week 8.

Week 8 – Starting a Production

- Early decision making criteria
- Balancing artistic or entrepreneurial vision against production reality
    - Visualizing manufacturing (scale, cost, complexity to build, waste)
    - Visualizing usability (some assembly required, ergonomics, stability, context of use)
    - Packaging, print, waste, and potential distribution complexities

Reading

Reference Slides

Manufacturing Processes for Design Professionals, Chapter Eight

Assignment

Project 4 – Building the product: Incorporate changes as necessary to the design to support assembly and rough packaging strategies. Fix any remaining design problems. Begin manufacturing of the project. Rough in the model structure using polygons or NURBS curve wire frames. Due week 9.

Week 9 – Measurements and Scale

- Tolerances (accuracy in 3D, structural strength, surface smoothness)
- Initial scene set-up (how scenes scale effects accuracy, how workflow effects software decisions)
- Roughing in the model
- Complex angles
- Fundamental geometric concepts and measurement

Reading

Reference Slides

Manufacturing Processes for Design Professionals, Chapter Nine

Assignment

Project 4 – Building the product: Based on critique in class, adjust the design as necessary. Loft and extrude all NURBS structures, and fully wireframing all polygon surfaces. Due week 10.

Week 10 – Modeling to fit a master part

- Creating a part negative
- Bolts, Fasteners
- Interfacing and support
- Structure
- Range of motion
- Order of assembly

Reading

Reference Slides

Manufacturing Processes for Design Professionals, Chapter Ten

Assignment

Project 4 – Building the product: Accurately model and close up any points of articulation or areas where separate parts contact. Remove overlap. Close up gaps. Due week 11.

Week 11 – Prototyping and Printing Technologies

- Selective Laser Sintering (SLS)
- Direct Metal Laser Sintering (DMLS)
- Fused Deposition Modeling (FDM)
- Stereolithography (SLA)
- Laminated Object Manufacturing (LOM)
- Electron Beam Melting (EBM)

- 3D Printing (3DP)

Reading

Reference Slides

Manufacturing Processes for Design Professionals, Chapter Eleven

Assignment

Project 4 – Critique: In class critique of model files. Based off of critique, clean up and refine any last changes to the product. Due week 12.

Week 12 – Print Materials

- Detailing
- Printing Resolutions and Tolerances
- Materials Properties (Temperature, Flexibility, Strength, Brittleness)
- Injection Molding
- Projection Manufacturing
- Terms and standards for injection molding systems

Reading

Reference Slides

Manufacturing Processes for Design Professionals, Chapter Twelve

Assignment

Project 4 – Conversion and Printing: Convert all parts into triangulated, planar, manifold, airtight meshes. Export to SLA format for final printing. Upload to online print service web site for sample cost confirmation. Due week 13.

Week 13 – Manufacturing and Molding

- Workflows for printing
- Software and Drivers
- Formats for Printing (SLA, OBJ, CAD, etc.)
- Cleanup and airtight modeling
- Post and Export

Reading

Reference Slides

Manufacturing Processes for Design Professionals, Chapter Thirteen

Assignment

Project 5 – Visualization: Using the completed model to build a demonstration reel of either the assembly or operation of the designed device. Due for presentation along with finished printed parts Week 15.

Week 14 – Processing, Cleanup, and 3D Printing

- Print Lab setup
- Loading models and arranging print stage
- Printing
- Removing support material
- Special topics

Reading

Reference Slides

Manufacturing Processes for Design Professionals, Chapter Fourteen

Assignment

Project 5 – Visualization: Cleanup and refine any remaining work. Presentations in class Week 15.

Week 15 – Presentations and Review

- Individual Final Project Presentations
- Final exam Q and A during last half of class.

Reading

Reference Slides

Manufacturing Processes for Design Professionals, Chapter Fifteen

Assignment

Critiques and Presentations in class.

Final Exam/Project

- Final Exam will be multiple choice. Details and study guide will be available week 15 and on Blackboard. All materials will be provided.
- Bring a pencil.

Date, Time, and Place

According to the final exam schedule

Final Project:

Due: In Class Week 15

Required Materials:

- Finished printed model prototype
- Finished 3D files and digital materials
- Power point presentation documenting and summarizing the design process to date. Include the following information for discussion:
    - Concept designs
    - Primarily challenges encountered throughout the class and the project
    - Breakdown of the planned manufacturing process, materials to be used, and technologies involved if the prototype were to go into production. Illustrations, diagrams, and any other organizational information are encouraged.

Grading:

- Model print cleanliness and quality - 15
- Model printed detail - 15
- Presentation - 20