CSC293 CS Improves 3D Printed Manufacturing

Introduction

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URCS
Outline

Software Development Tools

3D Printed Manufacturing

Technology

Administrivia
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Basic Tools

Developing software can be a very simple process with limited tools

- Input: Source Code (typed is using an text editor)
- Output: Binary (generated using a compiler)
- Debugger
Sophistication

- Integrated Development Environment (IDEs)
  - Frontend for editor + compiler + debugger
- Version Control
  - Track changes
  - Prototype features
  - Coordinate development
- Issue Tracker
  - Report and track bugs
- Continuous Integration
  - Test software after every change
- Documentation Generators
The scale of software systems

- Google, around 2 billion lines of code
- Windows Kernel, around 50 million lines of code
- Linux, around 28 million lines of code
  - 4,000+ developers in 2020
  - 1,730 organizations since 2007

Google Is 2 Billion Lines of Code—And It's All in One Place

Linux in 2020

Linux Kernel History Report 2020
Next generation?

- Code writing assistance
  - LLMs
  - Other techniques
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3D Printing

- Sometimes called *additive manufacturing*, the creation of physical objects by laying down materials in layers
  - Fused Deposition Modeling (FDM)
  - Stereolithography (SLA)
  - Selective Laser Sintering (SLS)
  - Multi Jet Fusion (MJF)
3D Modeling (Solid Modeling)

- Create a digital representation of a 3D object
- One method: Constructive Solid Geometry (CSG)
  - Primitive objects (Lines, Cubes, Spheres, etc.)
  - Boolean operations (Union, Subtraction, Intersection, etc.)
- OpenSCAD

Figure by User:Zottie - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=263170
Another method: Boundary Representations (B-reps)
- Faces, Edges, Vertices
- Boolean operations + Others
- Most Computer Aided Design (CAD) packages
- Check out cadquery, a Python 3D modelling library

Many others!

The history of solid modeling has strong Rochester connections, check out the Production Automation Project.
Figure by Freeformer, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=3854978
A 3D model represents a continuous object

A *mesh* is a discretization of the object into (usually) triangles

Common file formats: STL, 3MF

Most CAD tools that are used to design can also produce meshes

Figure by User:LaurensvanLieshout - File:STL-file.jpg, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=34722631
Mesh to G-Code

- A mesh needs to be “sliced” into layers, and commands to move the print head for each layer need to be generated
  - The program is called a slicer
- Akin to the compilation step for programs
- End result is G(eometry)-Code, a set of commands originally intended for robots
  - Also used by automated CNC machines
G-code to Printed Object

- A printer "firmware" then converts G-code commands to motion plans
- Then, generates actual signals to drive motors, heat/cool plastic, etc.
- Popular open source firmware: Marlin, Klipper
The widespread availability of 3D printers allows the creation of physical objects that can be completely defined digitally.

- “Download an object”

But usually also incorporate other off-the-shelf components:

- Fasteners (nuts, bolts, gears, etc.)
- Extrusions
- Electronics
Examples

- FLATBURN: the open source city scanner
  - https://github.com/MIT-Senseable-City-Lab/OSCS
- Gondola PlottyBot
- PUMA Opensource Research-Grade Microscope
  - https://github.com/TadPath/PUMA
- Stealthburner 3D printer head
- Voron 3D printers
Artifacts

- CAD files
- STL files
- Bill of Materials (BOM)
- Assembly Manuals
Goals for the Projects

To develop technologies that improve the process of creating these 3D printing manufactured objects.
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Science, Engineering, Technology?

- Science: body of knowledge
- Engineering: "application" of knowledge
  - Under this definition, can paradoxically precede science
- Technology?
Examples of Technology

- Fire
- Wheel
- Printing press
- Electronic, Digital Computing
- Internet
In this course, we will treat *technology* as synonymous with *tool*, with the understanding that technologies differ from tools primarily in that:

- enables us to do things we couldn’t do before
- improves some metric (time, cost, labour, precision, accuracy, etc.) at least 10x on existing tasks
Humans and Technology

- Note: *not* societal implications of technology
- How do we, as individuals, use technology and/or are affected by it?
  - From perspective of developers of technology
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What we will do in this course

- Read about technology development, esp. computer-science related
  - How do we identify the need for tools based on computing?
  - What impact do computing technologies have?
- Software development “in-the-large”
  - Apply everything you have learnt in your degree so far
  - Gain experience in all software development-related tasks!
- All activities above in the context of 3D Printed Manufacturing
- What we will not do: original research
People

- **Instructor:** Dr. Sreepathi Pai
  - E-mail: sree@cs.rochester.edu
  - Office: Wegmans Hall 3409
  - Office Hours: TBD

- **TAs:**
  - There are no TAs in this course.
Places

- Class: Hylan 203
  - M, W 900–1015
- Lab: Gavett 312
  - F 940–1055
- Course Website
  - https://cs.rochester.edu/~sree/courses/csc-293/fall-2023/
- Blackboard
  - Announcements, Discussions
- GitHub
  - Project development
• This course requires a lot of reading!
  • Material will be released weekly
  • Some online, some in Library
Grading

This is a project-based course with 100% of the grade from activities related to the project.

Activities include:

- Reading
- Writing
- Coding/Programming
- Presentations, Demonstrations
Academic Honesty

- Unless explicitly *disallowed*:
  - you may show your code to other students
  - you may use external code (with credit)
  - you may jointly code with fellow students
- You may discuss, brainstorm, etc. with your fellow students
- If in doubt, ask the instructor
- You are permitted (and expected) to make your assignments on GitHub (or similar sites) public

All violations of academic honesty will be dealt with strictly as per UR’s Academic Honesty Policy.
Course Goals

- Major: Learn to develop (computer-science-based) technology
- Minor: Learn 3D Printing