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Introduction to Computer Aided Design and Manufacturing

Workshop TIM THE BEAVER

Department of Mechanical Engineering
Massachusetts Institute of Technology

Outline

- Mechanical Product Design Overview
  - Design Procedure
  - Case Study
  - CAD Software
- Manufacturing Process Overview
  - Types of manufacturing techniques
  - How is this part made
- Rapid Prototyping
  - 3D Printing Process Capability and Limitation
  - 3D Printed Part Showcase

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Mechanical Product Design

- Approaching the Design Problem
  - Understand problem description and background
  - Obtain project requirements
  - Translate to engineering specification
  - Identify potential challenges and plan for time and resources
- Preliminary Design
  - Perform functional decomposition
  - Brainstorm for concept generation
  - Make design selection benchmark solutions
- Detailed Design
  - Create model with CAD software
  - Perform engineering analysis on design
  - Select components for purchase

Mechanical Product Design

- Manufacturing
  - Create engineering drawing for fabrication
  - Manufacture components based on bill of material
  - Assembly
- Control and Electronics
  - Identify using scenario
  - Implement embedded system
  - Program to control algorithm
- Testing and Verification
  - Conduct tests for functionality
  - Measure system parameter for meeting specification

Reiterate many, many times if not done properly! (not shown here)

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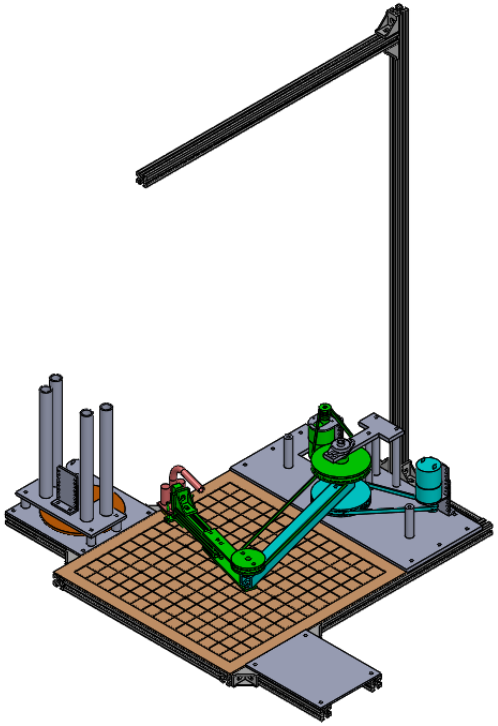
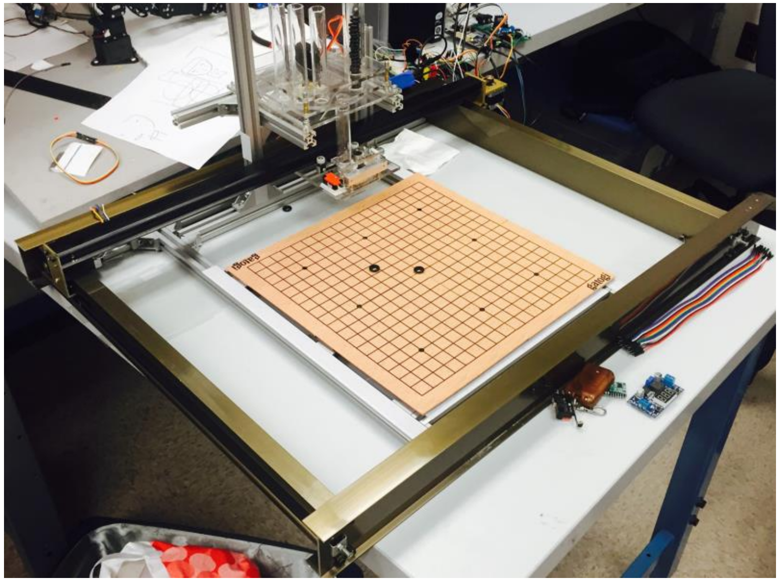
GoBang Winner Design Example





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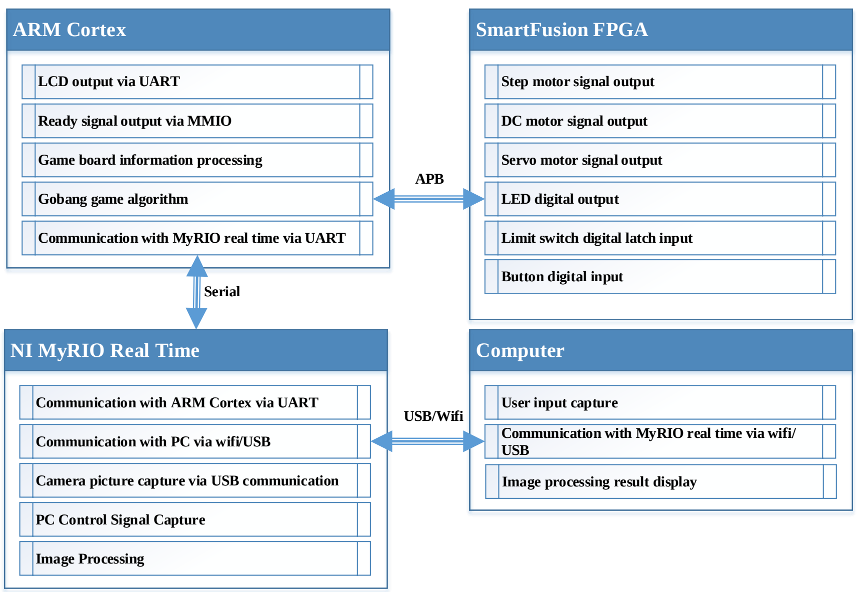
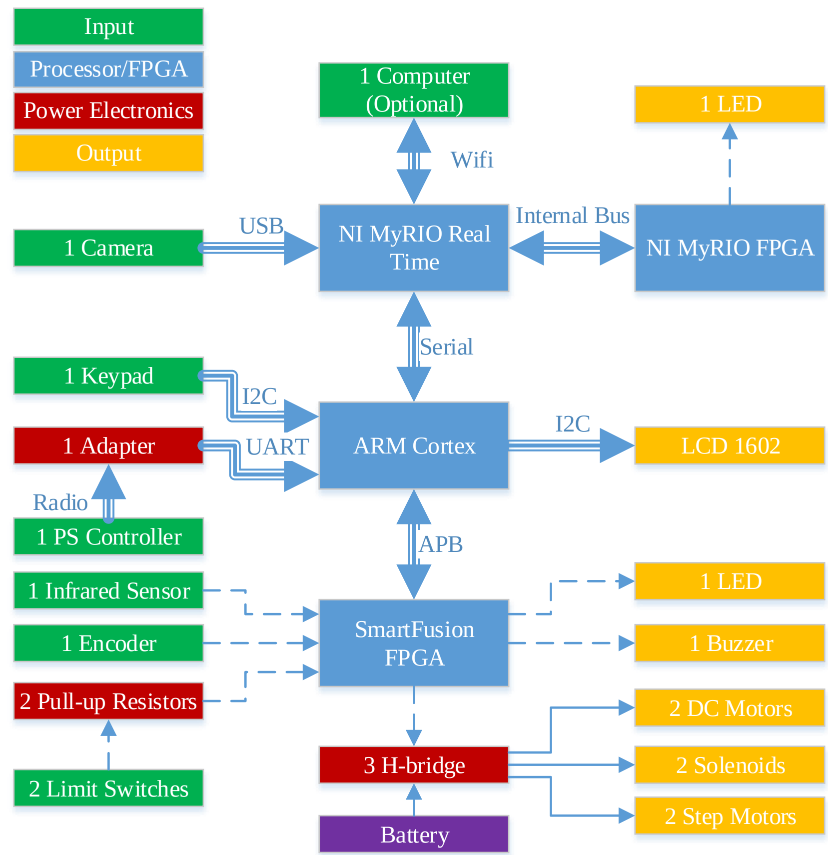
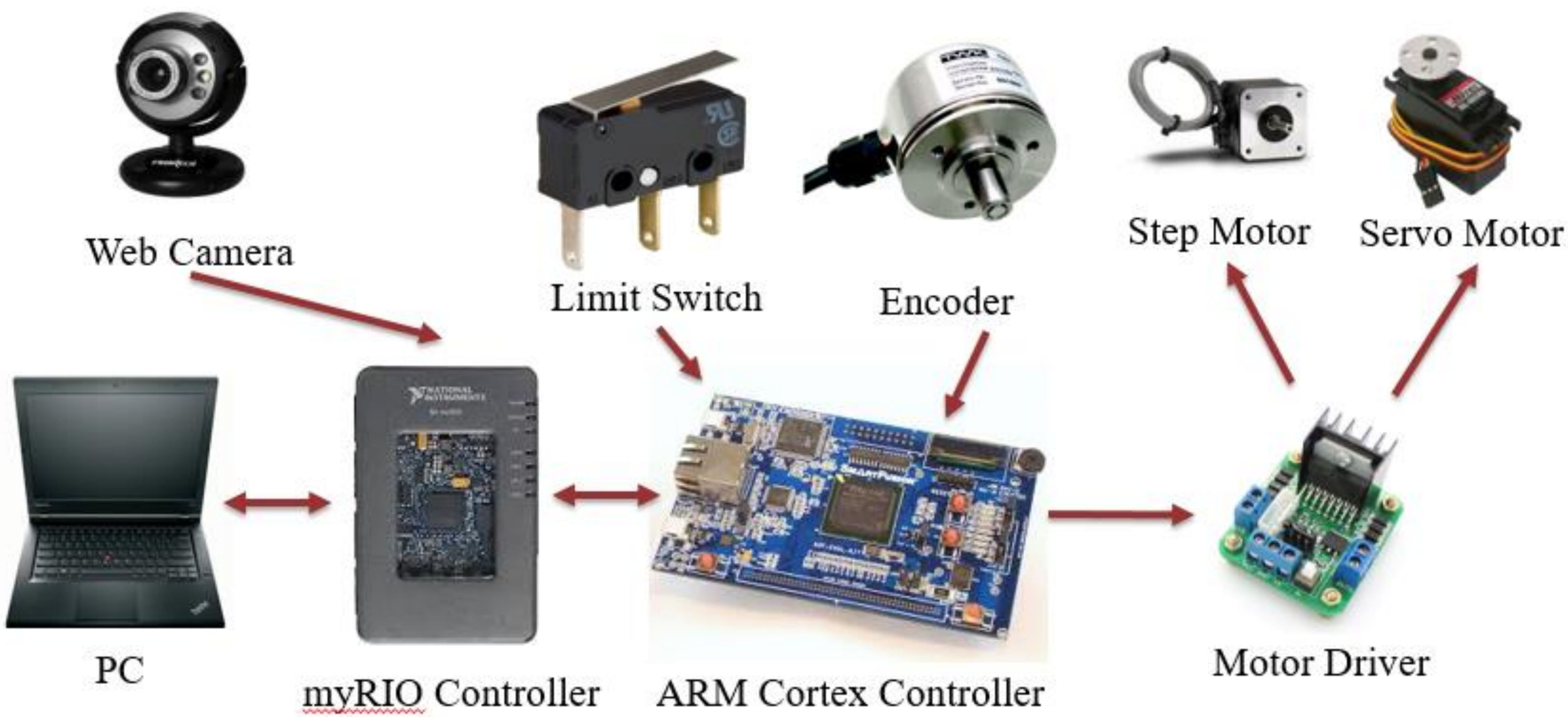
Functional Decomposition

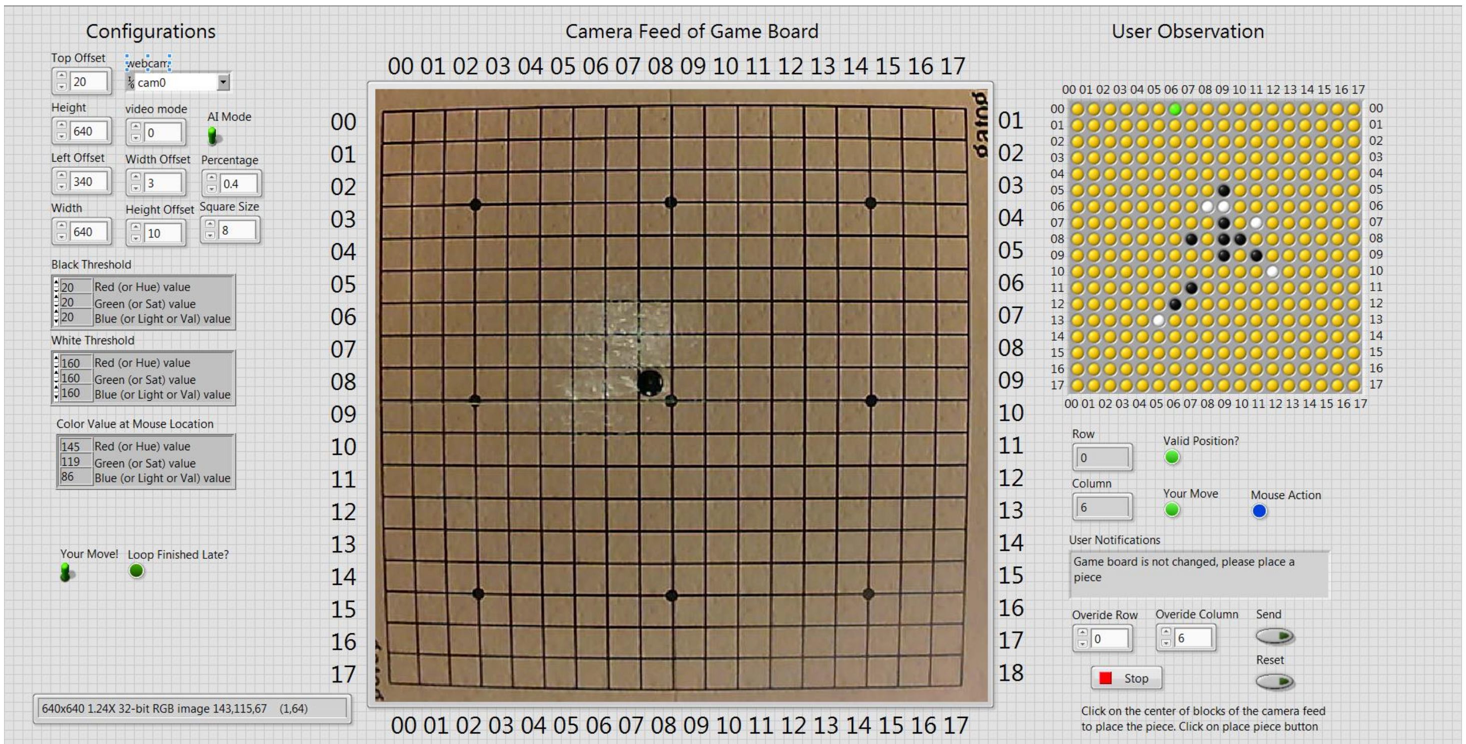




Electrical Components



LabVIEW Visualization



Project Demo

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Computer Aided Design Software

- Purpose of CAD/CAM
  - CAD software helps mechanical designer to manage complex design
  - Computer Aided Manufacturing (CAM) automates the manufacturing process

- Types
  - Mechanical Design: **Solidworks/OnShape**, UG NX, Catia, Creo/ProE, AutoCAD, SketchUp, etc.
  - Industrial Design: Rhino. Etc.
  - Animation: 3ds Max, Maya, etc.

Manufacturing Processes

- Manufacturing is a very broad area of Mechanical Engineering
  - Manufacturing process development
  - Quality control
  - Mass production
  - Design for manufacturing and assembly
  - Assembly line automation
  - …
- We care about quality, cost, rate, flexibility
- We give some basic introduction to manufacturing process

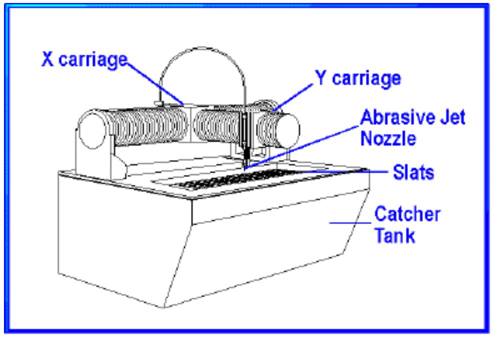
Mechanisms of Geometry Formation

- 1. Subtractive
  - Blanking- shearing, punching..
  - Machining -turning, milling, boring, reaming…
  - Grinding- surface, cylindrical, honing…
  - Erosion- water jet, abrasive water jet, slurries..
  - Melting/Vaporization- EDM, laser cutting…
  - Dissolution- plasmas, ECM, solvents…

fast → slow
recycle → destroy
coarse → fine

Lathe

Mill



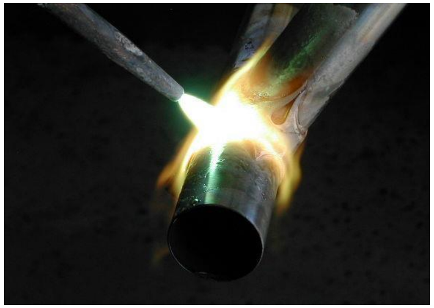
Water Jet

Mechanisms of Geometry Formation

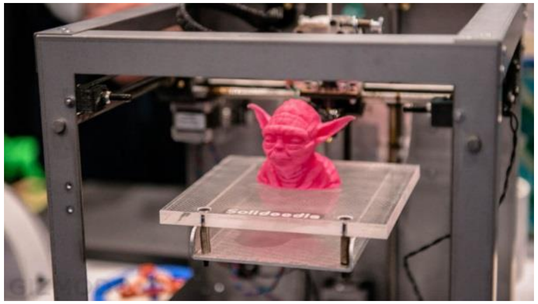
- 2. Additive
  - Assembly - manual, automated, robotic..
  - Joining - mechanical, adhesives, welding, brazing..
  - Composites layup- hand lay-up, tape lay-up, filament winding..
  - Additive manufacturing- 3D printing, stereo lithography…
  - Surface & Thin Film Processes-
  - Liquids - coatings, painting, printing, plating…
  - Gases/vapor/atomic scale- CVD, PVD, sputtering

coarse

fine



Welding

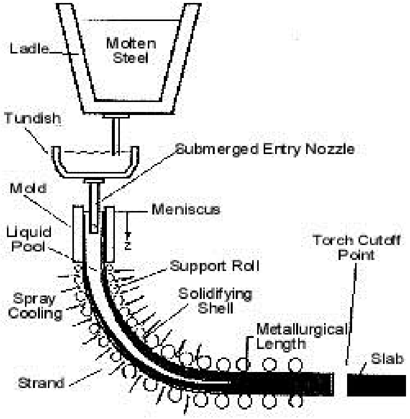


3D Printing

Mechanisms of Geometry Formation

- 3. Continuous
  - Pushing
    - Metals extrusion
    - Plastics extrusion
    - Continuous casting
  - Pulling
    - Pultrusion of composites
    - Crystal pulling (Czochralski process)
    - String ribbon process (Ely Sachs)

Extruded Parts

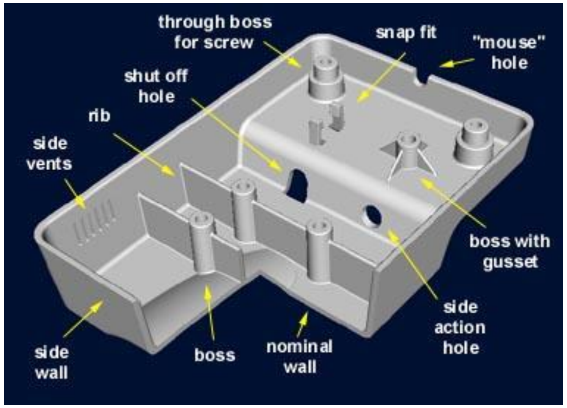


Continuous Casting

Mechanisms of Geometry Formation

- 4. Net Shape
  - Solids: metal forming, powders, others
  - Liquids: casting, injection molding, others
  - Mixtures: infiltration, Viscoelastics, others
  - Forming: vacuum, compression

Forging

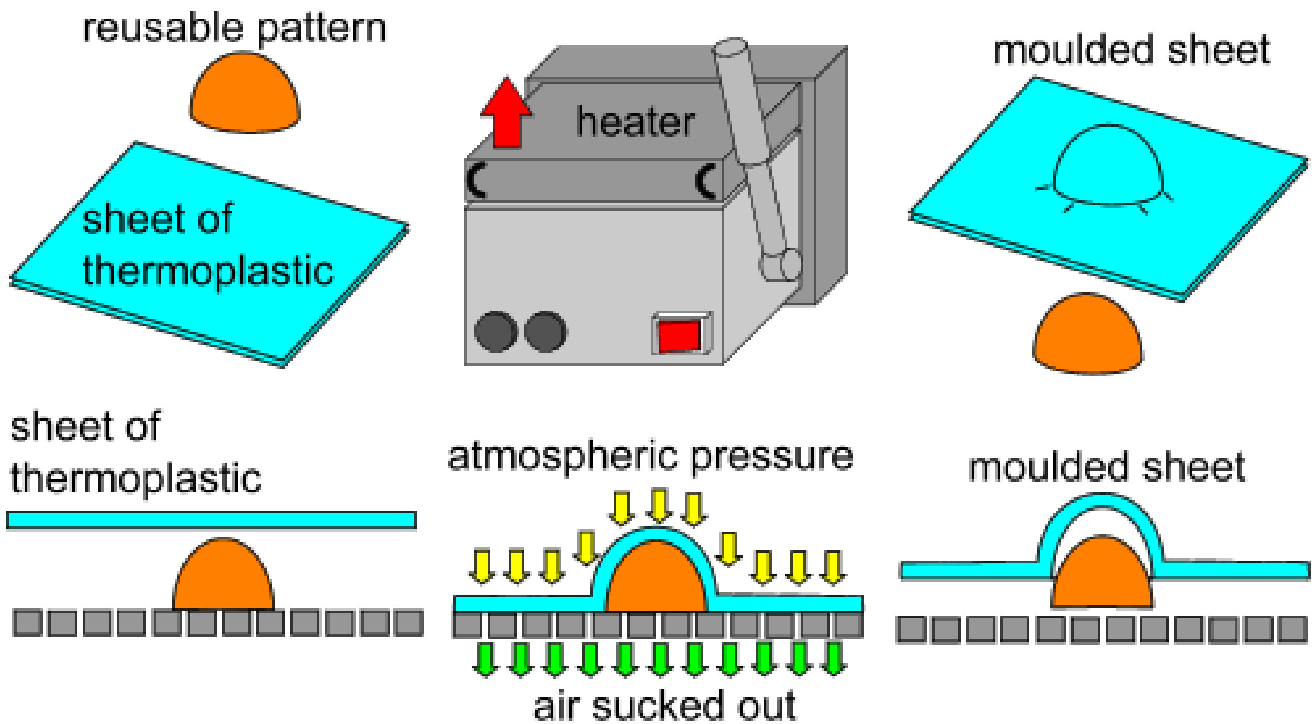


Injection Molding

Metal Casting

Mechanisms of Geometry Formation

- Vacuum plastic forming



How Its Made

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Fabrication Facilities at MIT

- On-campus machine and tools at Makerworks
  - 3D printing (ABS)
  - Laser cutting (acrylic, paper, wood)
  - Water jet (aluminum, steel)
  - CNC mill and lathe (aluminum, steel)
  - Bandsaw, drill press and hand tools
- Off-campus option
  - PortoLabs (expensive)

MW Makerworks ME

Vendors and Idea Generation

- Mechanical Components
  - McMaster (recommended)
  - Misumi and SDP/SI
- Electronics
  - Pololu and Sparkfun (off the shelf robotics solution)
  - Amazon and Ebay (general product)
  - Digikey and Mouser (PCB component, connector)
- Embedded System Implementation Examples
  - Instructables and NI case studies

Additive Manufacturing

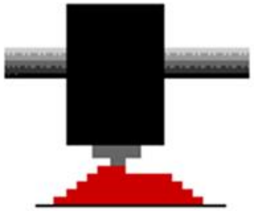
Additive Manufacturing (AM) refers to a process by which digital 3D design data is used to build up a component in layers by depositing material.

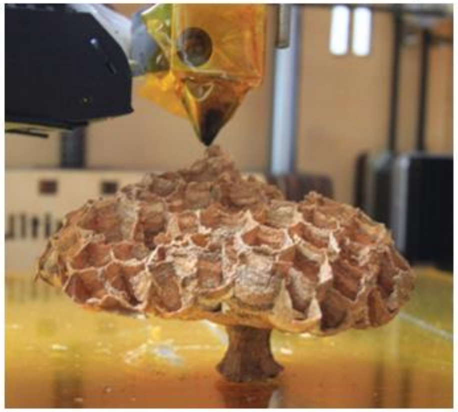
The term **'3D printing'** is increasingly used as a synonym for AM. However, the latter is more accurate in that it describes a professional production technique which is clearly distinguished from conventional methods of material removal.

Additive Versus Subtractive

Material subtraction (removal)
"top-down"

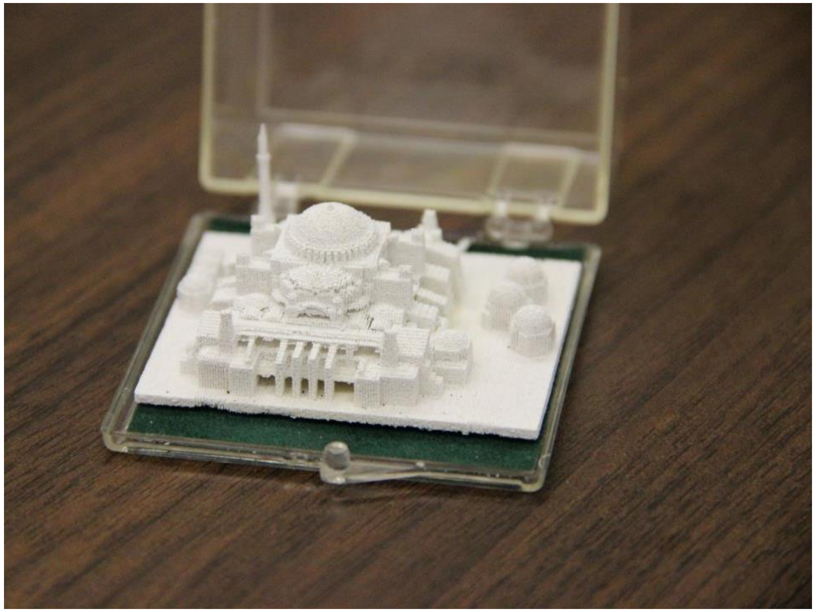
Material addition
"bottom-up"





3D Printing at MIT

MIT 3D printer v1.1



The Dome

Why 3D Printing

- Fast Prototyping
- Complex Geometries
- Multiple Materials
- Enhanced Performance (e.g., weight, flexibility, strength, thermal management, etc)
- Low-volume manufacturing → market testing, product differentiation, *personalization*
- Increased supply chain efficiency, reduced inventory

Complex Part

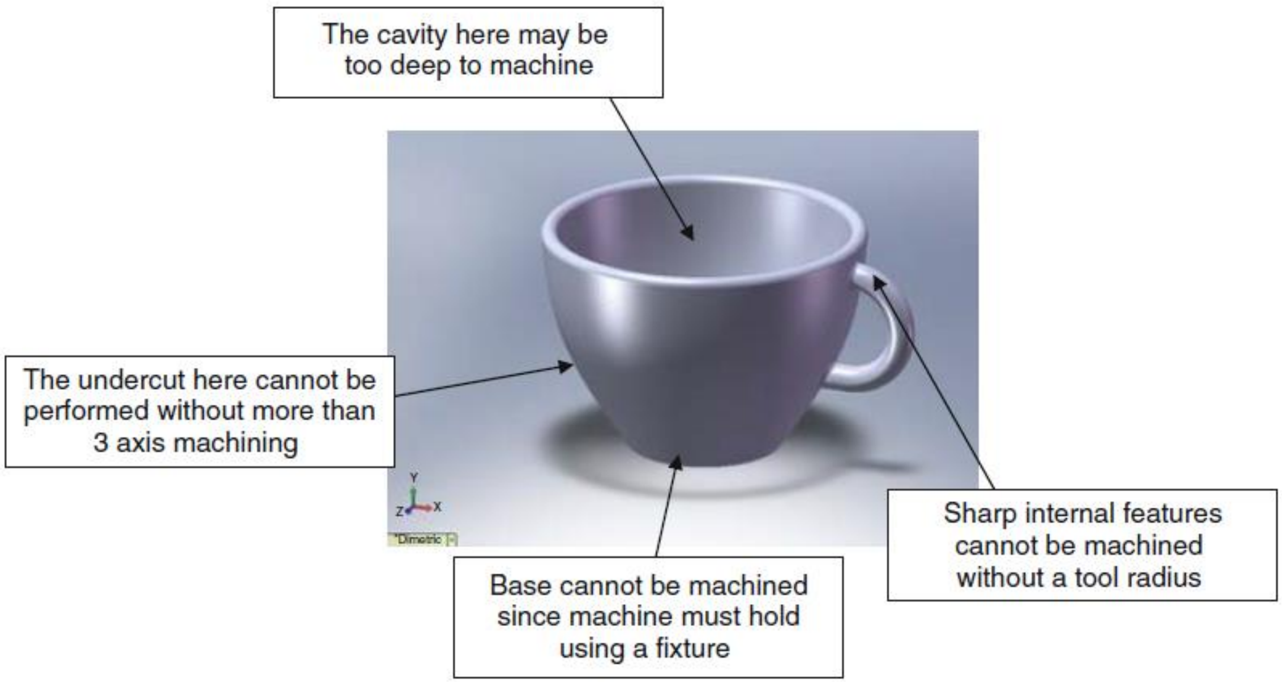
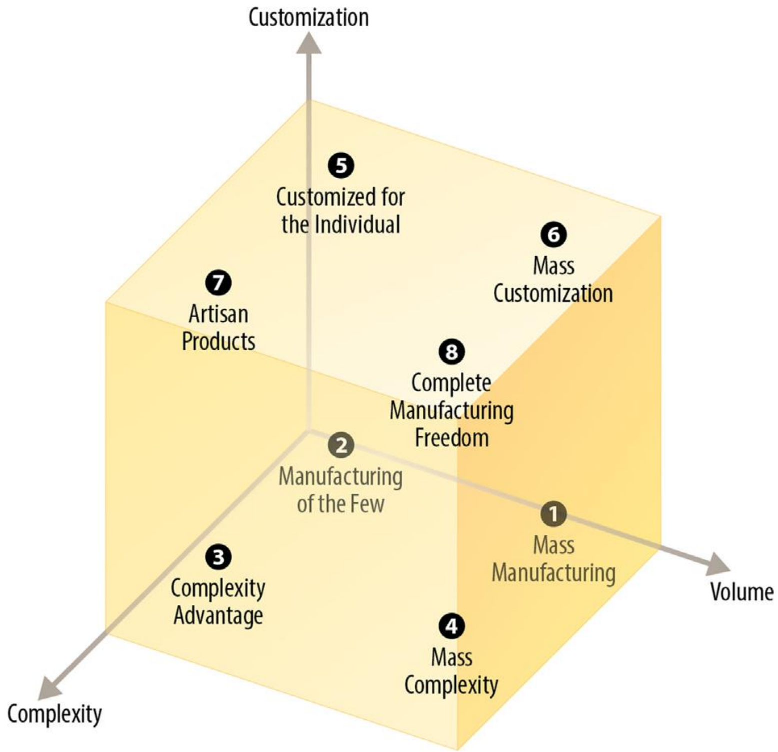


Fig. 1.3 Features that represent problems using CNC machining

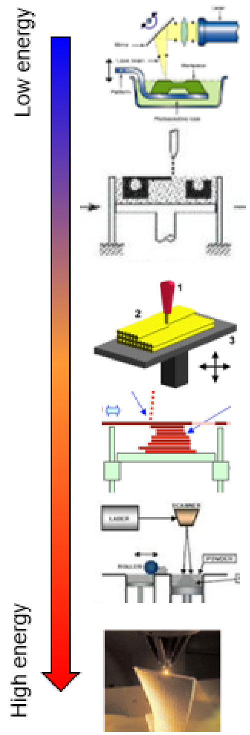
Characteristic of 3D Printing



Complexity, Volume, Customization Plot

Types of Additive Manufacturing

The 7 AM methods (from ASTM F42)



- **Vat photopolymerization** (→ SLA): material is cured by light-activated polymerization.
- Material jetting (→ Objet): droplets of build material are jetted to form an object.
- Binder jetting (→ 3DP): liquid bonding agent is jetted to join powder materials.
- **Material extrusion (→ FDM)**: material is selectively dispensed through a nozzle and solidifies.
- Sheet lamination (→ LOM): sheets are bonded to form an object.
- **Powder bed fusion (→ SLS/SLM)**: energy (typically a laser or electron beam) is used to selectively fuse regions of a powder bed.
- Directed energy deposition (→ LENS): focused thermal energy is used to fuse materials by melting as deposition occurs.

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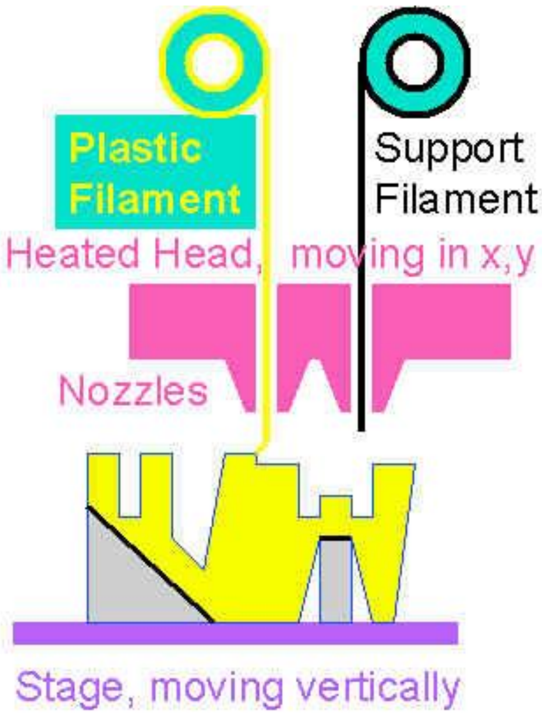
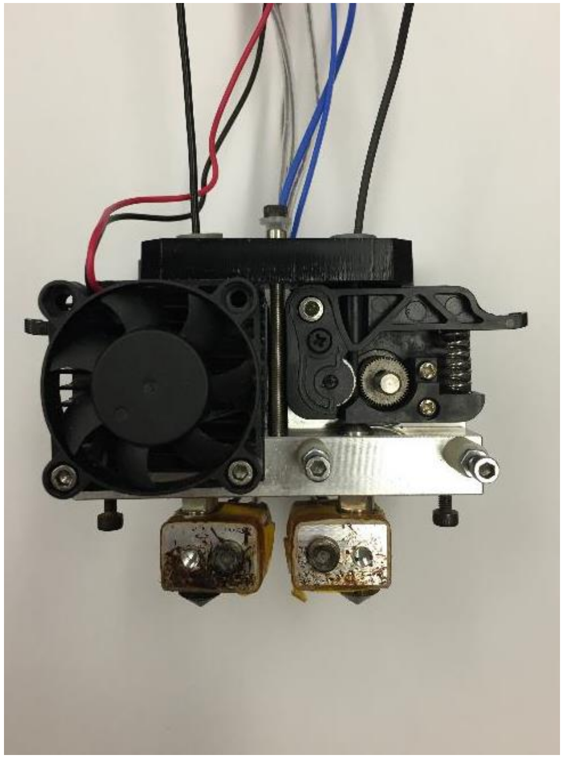
Fused Deposition Modeling (FDM)



Nozzle Diagram



Extrusion Nozzle

3D Printing Design Consideration

- Size of Part
- Component Strength
- Geometric Tolerance (Oversizing)
- Supporting Structure Removal
- Material Selection
- Process and Machine Capability

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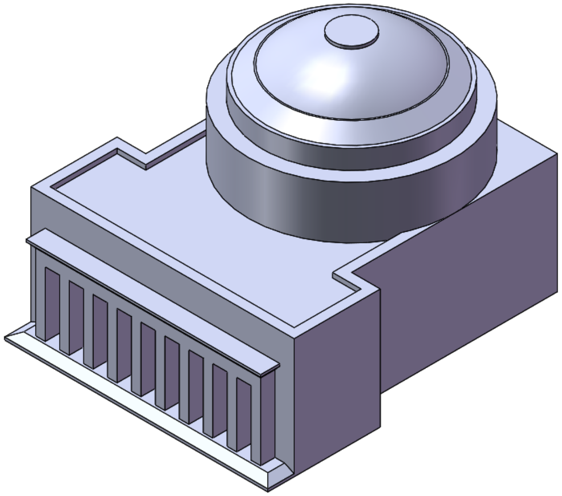
Showcase: MIT Dome Model

MIT Dome



Simplified CAD Model

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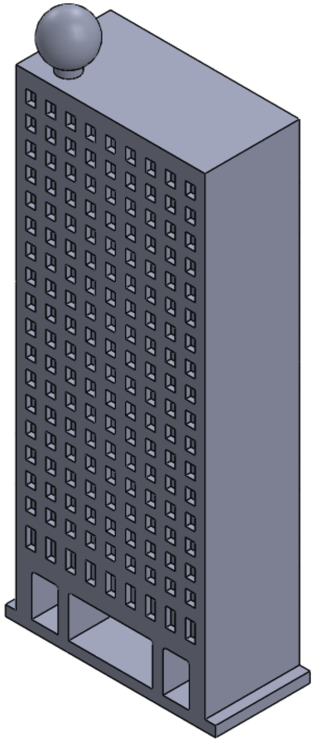
Homework: Model MIT Green Building

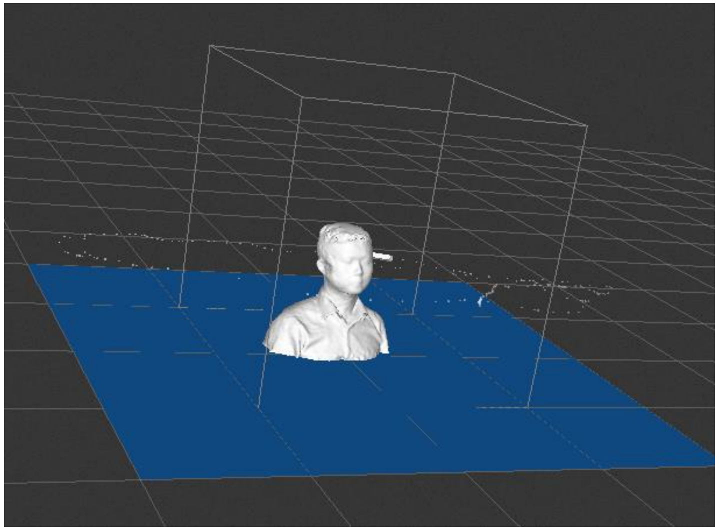
MIT Green Building



Simplified CAD Model

3D Scanning with Kinect and Skanect

$30 Kinect



Skanect (free for 5000 polygons)

3D Printing of Self Portrait

- Duo nozzle setup for support and structure
- Can do PLA, ABS, HIPS (support) and etc.

	PLA	ABS
Performance	• Higher strength • Higher rigidity • Stronger layer bond	• Higher impact resistance • Higher flexibility • Higher temperature resistance (higher Tg)
Quality	• Sharper details (features, corners, surfaces)	
Process	• Lower warping • Better odor • Less particle emissions	• Lower risk of jamming

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Thank You!