3D Printing: A new era has started, hasn't it?

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Presentation Outline

- **What is 3D Printing?**
  - The basic concepts

- **What do we have today?**
  - Current technologies on the market

- **Are you ready to own a 3D Printer?**
  - Some practical issues you may not know yet

- **How would 3D Printing change our lives?**
  - Designer
  - Manufacturer
  - Consumer
What is “3D Printing”?  

- Also known as:
  
  Rapid Prototyping (RP), Additive Manufacturing (AM), Direct Digital Manufacturing (DDM), Layered Manufacturing, and Freeform Fabrication.

- It can be the smallest unit of a “Manufacturing Enterprise”!

![Diagram showing the process from CAD Model to Physical Object through a 3-D Printer.](image-url)
Four Technical Aspects of 3D Printing

#1. Additive Manufacturing Process

#2. Layered Manufacturing Process

#3. Freeform Manufacturing Process

#4. Direct Manufacturing Process
Tech #1. Additive Manufacturing Process

Categories of Manufacturing Processes:

1. Formative (Compressive):
   - Shape transformation processes
     e.g., casting, mold injection, forging, extrusion...

2. Subtractive:
   - Material removal processes
     e.g., milling, turning, drilling, grinding,...

3. Additive:
   - Material adding processes
     e.g., welding, assembly, and 3D Printing
Tech #2. Layered Manufacturing Process

- Additively develop the cross sections layer by layer to build up the three dimensional object.

Diagram showing the process from Geometric Model to Physical Prototype via Layered Manufacturing.
Tech #3. Freeform Manufacturing Process

- The **additive process** allows the workpiece to form **any shape** that is geometrically possible.
  - Not constrained by **tool size or direction** like in CNC M/C
  - Creates complex shape (even assembly) directly, which is not possible by using any single conventional process

- **Example**: Hand-Crank Fan  
  Cubical Gearbox

http://www.extrudehone.com  
http://www.geoinformatics.com/blog/online-articles/large-format-and-3d-printers
Tech #4. Direct Manufacturing Process

- Directly from CAD model to physical output
  - No misinterpretation from blueprint
  - No programming/translation of NC codes
  - No tool selection, fixture design, etc.
  - No inventory of special tooling
What do we have today?

- Current technologies on the market
Development of 3D Printing Technologies

- **Brief History:**
  - **1970’s:** Pioneer research on manufacturing applications
  - **Late 1980’s:** Early commercial system ready
  - **~today:** Hundreds of options on the market

- **Taxonomy** by means of material formation
  - **Liquid Solidification:** SLA, SGC
  - **Powder Sintering:** SLS, EBM
  - **Layer Adhesion:** LOM, 3DP
  - **Fused Deposition:** 3D Welding, FDM
  - **Mixed Type:** Recursive Masking and Deposit Process
3D Printing Equipment at UTSA

- Mechanical Engineering Department
  - Dimension SST 1200
    (FDM Technology, by Dimension Inc.)

- Interactive Technology Experience Center (iTEC)
  - Z Printer 450
    (3DP Technology, by Z Corp.)
FDM: Fused Deposition Modeling

- Method: Direct deposition
- Material: Thermoplastic filament
3DP: 3-Dimensional Printing

- Method: Adhesive deposition
  (Post-process: Heated drying)
- Material: Powder mixture

RP System: 3DP

Fig. 7. Three dimensional printing.

Picture: Castle Island Co., http://home.att.net/~castleisland/
RP System: SLA

SLA: Stereolithography Apparatus
- Method: Selective laser scanning
- Material: Liquid photopolymer

Diagram of SLA process:
- Laser
- Elevator
- Lenses
- X-Y scanning mirror
- Laser beam
- Vat
- Liquid photopolymer
- Sweeper
- Layered part
- Build platform

Copyright © 2008 CustomPartNet
RP System: SGC

SGC: Solid Ground Curing
- Method: Masked UV light exposure
- Material: Liquid photopolymer

Picture: Castle Island Co., http://home.att.net/~castleisland/

Fig. 4. Solid ground curing.
RP System: SLS

SLS: Selective Laser Sintering
- Material: Thermoplastic powder (mixed with metallic, ceramic powder, etc.)

3D Systems, Inc.
RP System: EBM

EBM: Electron Beam Melting
- Method: Selective electron beam scanning
- Material: Metal (mostly titanium alloy)

http://www.calraminc.com/services.htm
Direct Metal Deposition

- Produces metal parts
- Suitable for large objects

Direct Metal Deposition
- Method: Laser, Arc, or Hybrid
- Material: Metal Powder


http://www.youtube.com/watch?v=iLndYWw5_y8
RP System: LOM

- Method: Selective laser scanning
- Material: Paper with adhesive

LOM: Laminated Object Manufacturing

http://www.designinsite.dk/htm sider/pb0055.htm
3D Printing Becoming More Affordable

- Many DIY kits are less than $1,000 now.

Prusa Mendel
http://Reprap.org

Makerbot
http://makerbot.com

Botmill Glider
http://botmill.com

Printrbot
http://3dprinter.net
2013 is the year of small 3D printers!

- List of small printers: [http://www.3ders.org/pricecompare/3dprinters/](http://www.3ders.org/pricecompare/3dprinters/)

RoBo 3D “ABS+PLA Model” $699
“PLA Model” $599

Makibox
3D Printing
$200
Presentation Outline

The Development

3D Printing Today

In the New World

Are you ready to own a 3D Printer?

- Some practical issues you may not know yet
Some Facts about Using 3DP

- **Benefits of 3DP**
  - Freeform, direct, efficient, and quite accurate

- **Limitations**
  - Not always “Rapid”
    - *FDM process takes 10-30 hours + 4-8 hours post-process*
  - Not always “Freeform”
    - Thin or stretched structures may not be feasible
    - Surfaces at certain angle can be rough
  - Not always “Direct”
    - Still involves some setups and post-processing
    - Not always strong enough for functional use
  - Not always “Economic”
    - Materials, accessories, & supporting equipment/personnel
3D Printing at SMS Lab

- **Dimension SST 1200**
  - Build size: 10”x10”x12”
  - Material: ABS Plastic

<table>
<thead>
<tr>
<th>Material Type</th>
<th>Liquifier Temp (°C)</th>
<th>Build Speed (cm/sec)</th>
<th>Notched Izod Impact Strength Average (J/m)</th>
<th>Peak Flexural Stress (MPa)</th>
<th>Flexural Module Average (GPa)</th>
<th>Peak Tensile Stress Average (MPa)</th>
<th>Tensile Modulus Average (GPa)</th>
<th>Break Elongation Average (%)</th>
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</thead>
<tbody>
<tr>
<td>ABS FDM</td>
<td>290</td>
<td>5.08</td>
<td>114.8</td>
<td>34.3</td>
<td>1.21</td>
<td>21.6</td>
<td>1.64</td>
<td>3.18</td>
</tr>
<tr>
<td>Polycarbonate FDM</td>
<td>340</td>
<td>5.08</td>
<td>100.4</td>
<td>76.3</td>
<td>1.46</td>
<td>52.6</td>
<td>1.96</td>
<td>3.6</td>
</tr>
<tr>
<td>ABS Injection Molded</td>
<td>-</td>
<td>-</td>
<td>133.4</td>
<td>62.1</td>
<td>2.21</td>
<td>30.3</td>
<td>1.86</td>
<td>50-95</td>
</tr>
<tr>
<td>Polycarbonate Injection Molded</td>
<td>-</td>
<td>-</td>
<td>640.5</td>
<td>93.1</td>
<td>2.31</td>
<td>65.5</td>
<td>2.48</td>
<td>120</td>
</tr>
</tbody>
</table>

Strzelec and Vavreck, 2005 ASEE Annual Conference
CAD Model: *.STL File Format

- **STL**: STereoLithography
  - A surface model composed with **triangular facets**
  - Advantage: **Simple format**
  - Disadvantage: **File size vs. resolution**
    - Hard to model/modify directly

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**Important**: Check “**resolution**” while exporting a CAD design into a STL file!

- Using “low resolution” may result in rough surface.

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Senior Design, ME/UTSA, Fall 2011 ➔
Problems with 3D Printing

- **Volumetric Errors**
  - Roughness of layering
  - Delicate details
  - Resolution of STL Files

- **Impact of Orientation**
  - Build time
  - Support Material
  - Strength (ABS “string”)
  - Geometry (roughness)

- **Material trapping**
  - Enclosed or narrow areas
Operational Issues

- Setting up a job on computer
  - CAD model checking, setting orientation, etc.
- Physical preparation of a print job
  - Cartridges, base plates, nozzles, etc.
- Post-processing and cleaning
- Maintenance of 3D printers
A Check Sheet for Our Students

- **Size of your design**
  - SST: 10”x10”x12”
  - Always specify the unit

- **Required strength**
  - It’s just ABS plastic

- **Thickness and fine features**
  - Layer thickness is 0.01”
  - No thinner than 0.04” (1mm)
  - Holes no smaller than 0.07”
  - Thin, out-stretched features may not be made
  - Allow open channels to remove support material
  - Check STL file resolution

- **Manufacturability**
  - Allow clearance for assembly
  - Do not expect perfect shapes
  - Consider feasibility for future

- **Lead time**
  - Printing: 10~30 hrs
  - Post processing: 2~8 hrs

- **Cost**
  - Save material if possible
  - Divide long/big parts into smaller pieces
  - Reduce chance of reprint

(Designed for Dimension SST)
Presentation Outline

The Development

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In the New World

How would 3D Printing change our lives?

- Designer
- Manufacturer
- Consumer
My vision in 1996…

Buy shoes? Order shoes? Or build shoes!

Parametric Design Library

CAD Model

Rapid Prototyping

Customer

3D Scanner

Final Product
For Designers

The design paradigm is shifting!

- **Direct & Freeform**: Pushing the frontier of manufacturability
- **Integrated Design**: Eliminates welding, assembly, & even wiring!
- **Parametric Product Design**: Mass customization!


Object_Gear_Box.mp4
For Manufacturer

- More and better **materials** for direct functional use
  - Some machines work with more than 100 types of material, including *reinforced plastic, soft (rubber like), transparent, conductive, thermal resistant*, … and so on.

- **Multi-material** Printing

- **Embedded** Circuits

- **Larger** and **Faster** processes

MIT accelerates multi-material 3D printing software


This machine prints:
- **4mx2mx1m**
- 26,560 nozzles; 600 dip
- printing speed 75s / layer
- layer thickness 300 mm
An Example: 3D Printed Car

“3-D Printed Car Is as Strong as Steel, Half the Weight, and Nearing Production”

Engineer Jim Kor and his design for the Urbee 2.

http://www.wired.com/autopia/2013/02/3d-printed-car/

“3D Printing Industry Will Reach $3.1 Billion Worldwide by 2016”

What else?
Impact on Logistics and Inventory

Logistics Specialist inventories supplies in a storeroom aboard the aircraft carrier USS George H.W. Bush

http://en.wikipedia.org/wiki/Logistics
NASA Plans to 3D Print Spacecraft in Orbit

- Sending equipment to outer space is not easy and not cheap!

What crazy scientists have been doing...

World's first **chocolate** printer
*University of Exeter*

Inkjets print **living cells** in 3-D
*Msnbc.msn.com*

The printed future of Christmas **dinner**
*BBC.co.uk*

Scientists use 3D printer to make new **bones**: How?
*cbsnews.com*

Wake Forest invents ink jet **organ** printer
*NOVA*

Turkey and celery square, anyone?
There are more…

3D Printing in Biotechnology - ASME at MIT

http://asme/scripts.mit.edu/home/asme-blog/3d-printing-in-biotechnology/

An Artificial Ear has been developed by scientists using a 3D printer and cells from a sheep.

http://www.thetimes.co.uk, 7/31/2013

UPS launches 3D printing in San Diego, expanding to more US cities soon

http://www.theverge.com, 8/1/2013

Dreambox, a 3D printing vending machine at Berkeley.

www.3dreambox.com

http://asme/scripts.mit.edu/home/asme-blog/3d-printing-in-biotechnology/
You can have one, too.

“Zeus 3D copier and printer does it all in one”

The world of 3D scanning and printing is about to get simplified immensely with the Zeus, an all-in-one 3D machine. "The process is fairly simple. You place an object inside Zeus, the machine scans it, and then creates a copy. You can also load your own 3D files for printing.”

“The $2,500 machine has a fax function, which may seem like a curious feature at first glance. It allows for the sending of a design from one Zeus printer to another.”

Finally, for Educators

- Yahoo Japan develops voice search engine connected to 3D printer
  

Video: Sep. 2013
Special Needs Education School for the visually impaired
http://www.youtube.com/watch?v=xQx6YeoKVwU
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