Direct Digital Manufacturing:
Challenges and Potential

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Overview

• Defining “Direct Digital Manufacturing” or DDM
• The growing industry in Ohio you may not have noticed
• Broad overview of DDM technologies
• Applications of DDM
• Potential and Research Challenges
  – Materials development
  – Process modeling
  – Product design
  – Education
What is “Direct Digital Manufacturing”?

• Any of a variety of manufacturing technologies that enable 3D physical parts to be created directly from CAD or other data files using computer-controlled additive or subtractive techniques

• Other names
  – Solid freeform fabrication
  – 3D printing
  – Rapid prototyping
A little history...

• First DDM techniques emerged in the mid 1980s
  – First version of Windows in 1985, MacOS 1984
• Largely a novelty for many years
  – Artistic endeavors
  – Prototypes
  – Architectural models
• Emerging as a tool for manufacturing parts for real products
Direct Digital Manufacturing in Ohio

- This is a bigger industry than you might think....

- Some companies in Ohio doing this kind of work:
  - 3D Technical Services - Franklin
  - Aerosport Modeling and Design - Canal Winchester
  - Astro Model - Eastlake
  - Bastek - Vandalia
  - Cam-Lem - Cleveland
  - DRS Industries - Holland
  - EWI - Columbus
  - Ferriot - Akron
  - Kovatch Casting - Uniontown
  - Laser Reproductions - Gahanna
  - Leyshon Miller Industries - Cambridge
  - MDF Tool Corp. - Cleveland
  - Morris Technologies - Cincinnati
  - RapidScan - Vandalia
  - SelectTech - Miamisburg
  - The Technology House - Solon
  - Thogus - Avon Lake
  - Toledo Molding & Die - Toledo
  - Toledo Prototype - Toledo
DDM Technologies

At least 25 different processes, mostly in two main groups

- Laser initiated processes
  - Start with a thin layer of material (usually powder or resin)
  - Laser fuses or crosslinks material in bed
  - Add another thin layer of material and repeat
  - Examples
    • Stereolithography
    • Selective laser sintering

- Deposition processes
  - Material deposited in successive thin layers from a “print head”
  - The “ink” may be:
    • Melted polymer
    • Dense suspension of particles (metal, ceramic, or polymer)
  - Examples
    • Fused deposition modeling
    • Robocasting
    • Multijet modeling
DDM Technologies

• Wide range of system costs
  – High end: $750,000
    • Large build areas (up to 18 ft$^3$)
    • Can be high resolution
  – Low end: <$1,000
    • Home-made kits
    • Low resolution
DDM Technologies

• Each technology good for a few applications
  – None optimized for more than about 6 different materials

• Several DDM technologies required for a complex system with many different kinds of parts

• All of them are relatively slow - if you need a million of a part
  – It would take a LONG time
  – It would cost far more than with more traditional technologies
What Is It Good For?

• No part specific tooling required
  – Largest cost with most traditional manufacturing technologies
• Energy efficient
• Low material waste

• Great for...
  – Custom, unique parts
  – Small production runs (100s to even 1000s)
  – Complex geometry

• Some common applications today
  – Developing tooling for traditional manufacturing
  – Prototyping
  – Jewelry design
  – Models
  – Custom fit medical devices
  – MANY unique and small production run plastic parts
  – Potential for the future...
What else COULD you do?

• Custom design of UAVs

• USAF has identified 1500 parts for the next generation joint strike fighter to be made using DDM

• Unfortunately, imagination is NOT the only limitation right now...
Challenges

• Few materials optimized for any process
  – Example: for commercial fused deposition modeling systems, you can use...
    • ABS
    • Polycarbonate
    • Ultem
    • Polyphenylsulfone

• No process design rules
  – Limited understanding of how adjusting system parameters will impact part properties
  – Either use factory settings, or trial-and-error
  – Some commercial systems have very limited ability to adjust

• No product design rules
  – Properties of final part often depend on how layers are put down
  – Opportunity for low density, honeycomb type structures

• No educational infrastructure
  – A few short courses
  – One book in print

Challenges = Opportunities for Research that Makes an Impact!
Materials Development for DDM

• Composites
  – Demonstrated with some success in the lab
  – Even less understanding of process/property relationships
  – Example below for Fused deposition modeling
    • Nylon with chopped carbon microfiber used to make airfoil

• Nanotechnology and functional or “Smart” materials
  – Anti-microbial coating?
  – Enhanced mechanical strength?
  – Greater thermal conductivity?
  – Embedded devices?
  – ???
Process Design Rules

• Limited understanding of relationship between
  – Process parameters
  – Materials properties
  – Part properties

• Consider stereolithography process parameters:
  – Laser wavelength
  – Laser intensity
  – Exposure time of resin to laser
  – Optical properties of resin
  – Resin chemistry
  – Resin additives/fillers
  – Resin temperature
  – Resin thermal properties
  – Environment temperature
  – Resin layer thickness
  – Post process curing
  – Others?

How do these impact the properties of the final part/material?

Without this knowledge, materials development is VERY difficult!!!
Product Design Rules

• DDM enables novel designs
  – Complex geometries
  – Lightweight, honeycomb structures

• How the part is “sliced” impacts its properties
DDM Education

• Growth of DDM requires engineers, technicians, and scientists with training in the field
• Let’s make a quick comparison between DDM and injection molding

Injection Molding
• Books listed on Amazon.com: >1000
• College courses in Ohio: >10

DDM
• Books listed on Amazon.com: 1
• College courses in Ohio: used in 2-3, not a major topic in any
Conclusions

• The era of direct digital manufacturing is arriving!
  – Rapidly growing industry
  – Potential for huge growth – many manufacturing jobs!!

• Challenges = Research Opportunities
  – Materials development
  – Process and product design rules
  – Education