3D Printing

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We will be sharing our research in the form of a video. This video will be formatted similar to a talk show/news program, with one group member being a host/news anchor while the other members make appearances to share their specific research subtopics.

Types of 3D Printing - Nadine

- Stereolithography
    - Uses plastic
    - Excels at producing parts with lots of details and a smooth surface
    - This method of 3D printing is widely used in the medical industry and common applications include anatomical models and microfluidics
    - This method was the original industrial 3D printing process
- Selective Laser Sintering (SLS)
    - A method of 3D printing that melts together nylon-based powders into plastics.
    - It is used to prototype designs that will be injection molded.
    - Creations made by SLS are durable, suitable for function testing and can support living hinges and snap-fits.
- PolyJet
    - Uses plastic
    - Can fabricate parts with multiple properties, such as colors and materials.
    - Can be used for prototyping elastomeric or overmolded parts.
- Digital Light Processing (DLP)
    - Cures liquid resin using a digital light projector screen.
    - Can image entire layer of what's being built all at once, meaning faster build speeds
    - It is frequently used for rapid prototyping
- Fused Deposition Modeling (FDM)
    - Uses plastic
    - It is an additive manufacturing where layers of material are fused together.
    - The material is melted and then poured on layer by layer.
    - It is the simplest way to achieve 3D printing, and is cheap and fairly efficient.
    - Dominates the market.
- Direct Metal Laser Sintering (DMLS)

    - Used to reduce metal, multi-part assemblies into one component or into a few light-weight parts with internal channels or hollowed out features.
    - Is viable for both prototyping and production, and use in the medical field.
- Electron Beam Melting (EBM)
    - Metal printing technology.
    - Uses an electron beam controlled by electromagnetic coils to melt metal powder.
- *Sources:*
    - https://www.protolabs.com/resources/blog/types-of-3d-printing/
    - https://smallbiztrends.com/2021/07/what-is-3d-printing.html

Sustainability - Aeriana

- Where are we currently at with sustainability in 3D printing?
    - The concept of sustainability in 3D printing is still young, but it is gaining in popularity.
    - Big money has yet to start chasing sustainability in 3D printing.
- Recyclability in FDM printing
    - Recyclable material in 3D printing
        - Metal
        - Plastic
            - HDPE, PETE, PVC, LDPE, PP, PS, and more.
    - Ways to recycle in 3D printing
        - Machines
            - The Refabricator
            - The Filabot
            - 3devo
        - Do it yourself with HDPE
- *Sources:*
    - https://www.nasa.gov/mission_pages/centers/marshall/combination-3d-printer-will-recycle-plastic-in-space.html
    - https://www.azom.com/article.aspx?ArticleID=8114
    - https://3devo.com/filament-makers/
    - https://3devo.com/blog/recycling-plastics/
    - https://all3dp.com/2/hdpe-3d-printing-material-all-you-need-to-know/

Benefits - Avery

What are the benefits of incorporating 3D printing in business?

- Recyclability if you use the proper plastics + equipment (The filabot-recycler, the Refabricator-in space)
- Creation and Proof of Concept

    - Boost a company's start-up by being able to present the product/concept to investors and future customers without wasting money.
    - The prototyping process is made easier, and can significantly accelerate your whole product development.
    - As a small company, you will be able to develop your project without wasting time and money.
- Proof of concept
    - "...50% of the respondents see the use of 3D printing inside their business as a competitive advantage," ("Top 3D Printing Benefits for Small Businesses").
- Rapid prototyping
- Minimal waste
    - There has been a greater force on businesses to progress into an environmentally conscious mindset
- Inexpensive
- Competitive Advantage
    - Older companies are slow to change, giving start-ups an advantage when incorporating 3D printing
- *Sources:*
    - "Top 3D Printing Benefits for Small Businesses." *Sculpteo*, https://www.sculpteo.com/en/3d-learning-hub/3d-printing-business/3d-printing-benefits-for-small-businesses/.
    - Long, Liz. "How 3D Printing Can Benefit Your Business." *Forbes*, 1 March 2018, https://www.forbes.com/sites/lizlong/2018/03/01/how-3d-printing-can-benefit-your-business/?sh=3d57ae52636c.
    - Dale, Joshua. "Six Benefits of 3D Printing." *hh global*, https://www.hhglobal.com/about/blog/3d-printing.

Challenges - Avery

What are some relevant challenges and limitations to 3D printing?

- Time-consuming
- Equipment cost
- Issue of recyclability and impact on environment
- *Sources:*
    - https://ttconsultants.com/3d-printing-limitations/
    - 10 of the Biggest Challenges in Scaling Additive Manufacturing for Production in 2020

Improvements- Will Li

- Make the printers smaller and lighter
- Cheaper cost of supplies (current total cost is $450 for all colors)

- Improve quality of the prints by adjusting/leveling the bed and nozzle distance
- Self organizing different colors in the printer systems
    - You have to manually add your own plastic colors, versus a regular printer which manages its own colors
- Nozzle temp checker
    - Currently the nozzle gets hot, which can melt the top of tall plastic projects as they're being printed
- Use different materials to build different things that have complex functions (ex: printing could be used to build new organs in the future)
- Ability to adjust speed of printing based on project needs
- A fan or water resistant layer to reduce overheating/damaging
- Make using colors less expensive by mixing colors together during printing to make new hues
- *Sources:*
    - https://www.machinedesign.com/3d-printing-cad/article/21127585/eight-tips-for-improving-3d-print-quality
    - www.hp.com

Examples and Uses of 3D Printing - Jacob

- 3D printed houses
    - Can be printed in one day
    - No waste
    - Costs less
    - Have solid size being with some at 1,500 square feet
    - Different kinds and many can be made anywhere
    - Made in 1 single day
- 3D printed spare parts

Cost Reduction
Shorter Lead Time
Accuracy
Easy Storage

- 3D printed tools

These tools used in almost every industry
Materials like Metal and Polyamide used
Shorten lead time
Cost reduction
Optimize existing tools
Create custom tools

- 3D printed organs

    - Printing isn't difficult part, finding the right materials
    - Viable option
    - Use patients own tissues
    - Use cells to reproduce tissues
    - Not close to mass use
- Hero Forge
    - 3D printed figurines
- Prototyping
- *Sources:*
    - https://www.3dsourced.com/guides/3d-printed-house-2/
    - https://all3dp.com/2/3d-printed-house-cost/
    - https://www.heroforge.com/?gclid=CjwKCAjwkvWKBhB4EiwA-GHjFooTFPe9mVY-3t23c9UV0K7GQCEZ79LfGYqp1NjyOODdkkbmTx4q3hoCwAoQAvD_BwE
    - https://www.forbes.com/sites/amitchowdhry/2013/10/08/what-can-3d-printing-do-here-are-6-creative-examples/?sh=4f4430bc5491
    - 3D Printed Organs: Current Research and How They Will Work | 3D Print Start Point (3dstartpoint.com)
    - https://3dgence.com/3dnews/3d-printing-of-spare-parts-4-advantages/

Time: ~3 - 3:30 min
Hi, folks! Tonight, we are talking about 3D printing. We will be hearing from a lot of researchers on the topic tonight, including me, your favorite host, Felix-Nadine.

The 3D printing industry has grown a lot over the past few years, and there are now a multitude of methods and materials that can be used to create something through 3D printing. I'm here to give you a brief overview of most of the methods, the materials they use, and what they are most used for.

To start us off, Stereolithography is a 3D printing process that uses plastic, and excels at producing parts with lots of details and a smooth surface. This method of 3D printing is widely used in the medical industry and common applications include anatomical models and microfluidics. A fun fact about Stereolithography is that this method was the original industrial 3D printing process.

The PolyJet method also uses plastic, and can fabricate parts with multiple properties, such as colors and materials. It can be used for prototyping elastomeric or over-molded parts.

Fused Deposition Modeling (FDM) is yet another plastic-using method, and is an additive manufacturing process where layers of material are fused together. It is the simplest way to achieve 3D printing and is both cheap and fairly efficient, meaning it can be used for many things. It is most likely because of this that FDM dominates the market.

Selective Laser Sintering (SLS) is a method of 3D printing that melts together nylon-based powders into plastics. It is used to prototype designs that will be injection molded. Creations made by SLS are durable, suitable for function testing and can support living hinges and snap-fits.

Digital Light Processing (DLP) is a method that cures liquid resin using a digital light projector screen. It can image an entire layer of what's being built all at once, meaning faster build speeds. It is frequently used for rapid prototyping.

Direct Metal Laser Sintering (DMLS) is used to reduce metal, multi-part assemblies into one component or into a few light-weight parts with internal channels or hollowed out features. It's viable for both prototyping and production, and is frequently used in the medical field.

Electron Beam Melting (EBM) is metal printing technology as well. It uses an electron beam controlled by electromagnetic coils to melt metal powder. EBM is used in a lot of industries, including aerospace, automotive, defense, petrochemical, and medical.

I know that's a lot to process but we're gonna move right along, so next up is the challenges and benefits of 3D printing by researcher Avery Finkle.

Questions:

Time: 3:25 + 1:28 = abt 4:53 minutes
Challenges/Benefits:

- **Felix-Nadine:** "What are some challenges people may run into with 3D printing?"
    - As much as 3D printing prides itself to be environmentally conscious when discussing its minimal waste, there is still room for improvement regarding its effect on the people directly involved in the process. Health hazards of 3D printing are constantly being researched. These hazards vary depending on the type of printer and the materials used.
    - A hazard can occur when particles and other harmful chemicals get released into the air. It is common for people to breathe in these particles or chemicals which is very alarming. Skin contact with harmful materials can also be dangerous.
    - We can look at desktop 3D printers as a specific example. Most famously, stereolithography and Fused deposition modeling (FDM) have been adapted and refined into desktop 3D printers that are more affordable and easier to use. Recent studies by Illinois Institute of Technology discuss desktop 3D printers and their ultrafine particle emissions. The study tested a few samples and estimated ultrafine particle emissions ranged from 20 billion particles per minute to about 200 billion particles per minute. Human inhalation of these particles can lead to serious harm. When inhaled, the particles penetrate to our lungs, cause irritation, and can possibly reach our brain. This can cause serious neurologic, stomach and heart conditions to take place.
    - While discussing these studies, it is important to recall that 3D printing is a relatively **new technology** which, in turn, means new research will continuously be discovered and more data such as this will be available. Not only will the major health risks related to this process be further examined, but also possible solutions and better alternatives could be uncovered in the near future.
    - Shifting in the direction of printing in industries driven by mass serial production, an obstacle for adoption is its **slow production speed**. Many current industrial 3D printers still lag behind traditional machine equipment in terms of speed and efficiency.
    - There is also a lack of industry-wide standards when it comes to additive manufacturing. Although 3D printing has been around for more than 30 years, the manufacturing world began to recognise it as a production

method only recently. For this reason, the industry has just begun to develop production-relevant and industry-wide standards. Two core benefits of standardisation for 3D printing are ensuring consistency and meeting regulatory standards. In more detail, this means producing parts of high quality that follow a repeatable process each time, meaning 3D printing has to be reliable to avoid additional costs and error, as well as, achieving quality assurance and product certification.
    - This goes along with the lack of understanding and expertise in additive manufacturing which can hopefully be resolved over time.
- **Felix-Nadine**: “From what you mentioned, in summary, it sounds like there are health hazards to be aware of in 3D printing, along with challenges related to implementing additive manufacturing into businesses.”
- **Avery**: “Yes, correct. It will take some more time before 3D printing will be a sufficient replacement for traditional manufacturing.”
- **Felix-Nadine**: “After hearing about those challenges, let’s now explore the benefits that can be found in this process.”
    - 3D printing has stepped into a bigger role in businesses, small and large, over the past few years. As society has attracted more awareness to being eco-friendly, there has been a greater force on businesses to progress into an environmentally conscious mindset. Incorporating 3D printing into companies is a great start. Additive manufacturing dramatically reduces the production of scrap waste — sometimes by as much as 90 percent compared to conventional manufacturing
    - Another benefit of 3D manufacturing is that the costs and potential for low order volumes make it ideal for testing new materials and prototyping. Using 3D printing gives a business the liberty to be creative and make their innovations physical. This is a huge benefit for start-up companies, who now have the opportunity to present their product or concept to investors and future customers without wasting as much money. 3D printing can significantly accelerate a product’s whole development.
    - Each year, Sculpteo launches its annual survey to collect data about the additive manufacturing world, calling it The State of 3D Printing. The State of 3D Printing in 2019 states, “50% of the respondents see the use of 3D printing inside their business as a competitive advantage,” (cite).

That’s a lot of new information to absorb, but very thought-provoking. Thanks Avery!

Next up, researcher Aeriana Brentlinger, to talk about sustainability.

Time: ~4:15 min
Sustainability:

- Where are we currently at with sustainability in 3D printing?
    - The concept of sustainability in 3D printing is still fairly young, and it is still being researched. But the processes we have found so far to make 3D printing sustainable are very cool.
- What are some of those cool processes?
    - Well, sustainability in 3D printing comes from recyclability. FDM printing is a 3D printing process that is particularly easy to make recyclable. FDM printing uses filament, which is essentially the "ink" for the 3D printer. The filament is made of plastic, which is where recyclability comes in. Filament can be made by melting down and extruding plastic into a thin, string-like shape that you then guide onto spools so it's ready to be used in printing. The extrusion process is like making plastic spaghetti noodles.
- Ooo, spaghetti. What types of plastics can you do this with?
    - Plastics that can be melted down like this include PETE, HDPE, PVC, LDPE, PS plastics, and more, making the materials easy to get a hold of. What's more, the plastics can be melted and re-melted multiple times, this includes after they have been 3D printed. This allows you to melt 3D printed parts to make filament to make more 3D printed parts.
- What are some instances of this being done?
    - This cycle is being used in many ways, including in space. The Refabricator, built by *Tethers Unlimited, Inc.*, is a machine that is both a 3D printer and a recycler. It allows the user to print, melt, and extrude, which means that with one machine, users can recycle obsolete 3D printed parts to create new objects, like tools. This is particularly advantageous in space where self-sustainable cycles are vastly important due to a shortage of easily accessible supplies.
    - There are a variety of other machines that also facilitate the melting and extruding process, including the Filabot machine, and different filament makers by 3devo. These machines can help users recycle and produce their own 3D printing materials in their own homes. A common way to do this is with HDPE, or *high density polyethylene* plastic. HDPE plastic is a widespread recyclable plastic found in all sorts of household items including milk containers, soda bottles, corrosion-resistant pipes, liquid-permeable membranes used in biology settings, and lumber made out of recycled plastic. HDPE plastic is a thermoplastic polymer made from ethylene; it's super strong yet light enough to float, and it has a high strength to density ratio. Another characteristic is that it is food-grade, so it can be used to make food containers and lids. Industrial medical supply makers have also been experimenting with making more invasive *medical* objects from 3D

printed HDPE plastic, such as bone replacements. It's strength and lightness make this ideal, and its sustainability drives cost down and accessibility up.

- It's neat that you can use common household plastics for 3D printing.
    - It really is! The melting and extruding process also allows you to mix plastics, creating custom filament to fit more specialized needs.
    - Recycling plastics this way keeps them in rotation which benefits both the user and the planet.
    - *pause*
    - Aside from plastic as a 3D printing material, you also have metal, which is likewise highly recyclable because--like plastic--you can melt it down and reuse it.
    - *pause*
    - Again, the technology for sustainable 3D printing is still in early stages, but mass sustainability is coming. Unfortunately, big companies haven't started chasing it yet, and many of them don't see the value in it. It will probably take new companies to get things to change, but once we start chasing sustainability in 3D printing, the results will be wild.
- What kind of results are you anticipating?
    - Well, the ability to distribute sustainable 3D printing technologies will likely alleviate some of the pain points in current distribution.
    - For example, many people in Africa have phones but do not have microscopes; 3D printing allows you to print a microscope that works in tandem with a smartphone, which means anywhere that has a smartphone and a 3D printer can have a microscope, too.
    - New sustainable 3D printing technologies allow you to produce these sorts of amazing things at much less cost, both material-wise and environmentally.
    - Like I said, the results of sustainability will be wild. :)
- That does sound wild! Well, thank you for that, Aeriana.

Thanks Aeriana! Our next researcher is Jacob Statman, here to talk about the uses of

3D printing.

Time: ~1:30 min

Examples:

- What are real world examples of 3D printing?

3D printed organs are a new invention that might revolutionize medicine.

- Printing isn't difficult part, finding the right materials
- Viable option
- Use patients own tissues
- Use cells to reproduce tissues

    - Not close to mass use

Although it is not the solution right now it easily could in the near future and can help save millions of lives if successful.

Another example, 3D printed houses are being used across the world and can even be seen as a great alternative for buying/building a new home.

    - Can be printed in one day
    - No waste
    - Costs less
    - Have solid size being with some at 1,500 square feet
    - Different kinds and many can be made anywhere

These can be viable options for many people as some houses are $4,000 to build the structure of an actual house.

That's very interesting. Thanks Jacob!

Will Li is our final researcher, here to talk about possible and future improvements to 3D printing and its processes.

Time: ~4:15 min

Improvements:

- **What are some ways we can improve 3D printing?**
    - The impression of improvements in 3d printing are still improving to this day.
    - First, we think that making the printers smaller will reduce the weight. By this happening we can't really make big projects, however at least you would still be able to get small prototypes done plus, you can also bring it places with you like your office or your friends house with the benefit of its lightweight.
    - Which leads into my next point which is to make the supplies cheaper, like to build the printer itself, as well as the colors. The current total cost of all the color filaments combined is $450. And a small 3d printer itself costs around $200. Something else that will be practical would be self organizing colors in the system. Right now we have to manually add our plastic color filaments and that is time consuming and could mess up the process of the printing, but if it can be like ink printers where they just switch colors and manage its own colors, then later we would just have to replace the plastic after the filament runs out, that would make the final product turn out better than if we have to change the colors and mess up the printing process by leaving extra scabs that are not intended.
- **Is there any way to make the coloring supplies cheaper?**

    - Yes! If we could mix cheap colors together by melting both plastics then mixing it together to create another color so we don't have to buy specific colored plastic filaments, it would definitely reduce the cost of the supplies. For example if we mix white and red, that will make pink and so we won't need to buy an additional pink plastic filament.
- **Since this is similar to a computer, do you think there should be any fans or coolers built into it?**
    - Yes! I call it the nozzle temperature checker / cooler. So currently the nozzle gets hot which can melt the top of tall plastic projects as they are being printed, so with a system built into the 3d printer that will tell you the exact temperature it is or could have some kind of a fan or cooling system built into it just like your Personal Computer, would be great and will prevent from overheating and make a more improved / longer lasting system.
- **Based on what was said by the previous researcher, can you tell me more about 3d printed organs?**
    - Ok, So the next thing that might benefit the future is 3D printing with non toxic materials--like HDPE plastic--with this it can print new organs that function and that can save someone's life for a bit longer until the actual organ arrives or maybe even longer if it can be permanent. Examples include kidneys, heart and so on… An interesting fact I found is that they have already begun to experiment with this process by growing bladders so I found this interesting as well.
- **That's really neat.**
- **What do you think about the current speed at which one can 3D print?**
    - As of right now the speed is generally stable, but having an adjustable switch or something similar to speed up the process or slow down the process of printing based on specific project needs. This can be beneficial, say if you don't need this prototype finished until 3 days later then you can go slow, but if for example you need to print an organ fast or some kind of emergency or rushed projects, then there's a switch that will make the machine work faster and hopefully accurate.
    - While there are clearly improvements to be made, the research for 3D printing is on the right track, and innovations are continuous. Thank you.

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