Printing and Physical Output

Learning Goals

- Understand …
  - Available printing technologies
  - Advantages and disadvantages of different technologies
  - How to create 2D and 3D objects from a computer
- Know
  - How paper can be part of the user interfaces
  - The basics steps for 3D printing

Paper: Printing and Printers

- What to print?
  - Text, graphics, photos, books, objects
- On what to print?
  - Paper, special paper, cardboard, t-Shirt, …
- Where to print?
- How much to print?

- Total cost of ownership
  - dependent on usage/user profile
  - printer price (often insignificant compared to other cost)
  - materials (e.g. paper, ink, toner, energy)
  - maintenance (e.g. changing of paper in a ticket machine)

Paper: Printing and Printers

printing on paper

- Hardware
  - Print technology e.g. laser, dot-matrix, ink-jet, thermo
  - Media size and type, e.g. paper A4, CD, card board, envelops
  - Media handling, e.g. paper container, rolls and cutting
  - Speed – e.g. pages/minute, characters per second, sq ft/h
  - Resolution – typically dpi (dots per inch)
  - Colors
  - Connectivity e.g. network, WLAN, BT, USB, …
  - Size, weight, noise, …
- Software
  - Printer driver
  - Printer language, e.g. PS (postscript), HPGL (Hewlett-Packard Graphics Language, plotter), PCL (printer command language), GDI (Graphical Device Interface)
  - Libraries to create printed documents, e.g. FPDF, Apache PDFbox, OpenPDF

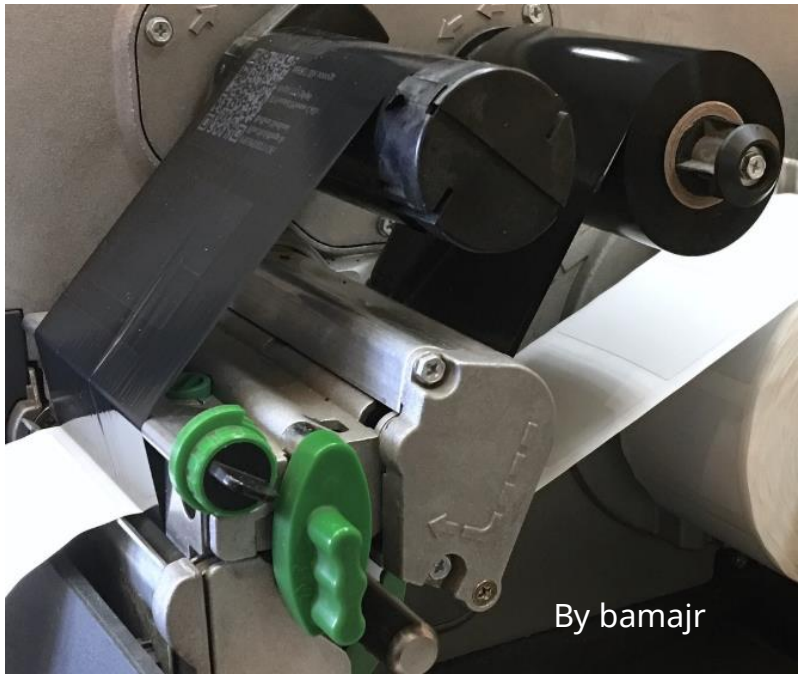
```php
<?php
require('fpdf/fpdf.php');

$pdf = new FPDF();
$pdf->AddPage();
$pdf->SetFont('Arial','B',16);
$pdf->Cell(40,10,'Hello World!');
$pdf->Output();
?>
```

FPDF example, https://ourcodeworld.com/

Paper: selected technologies

printing on paper

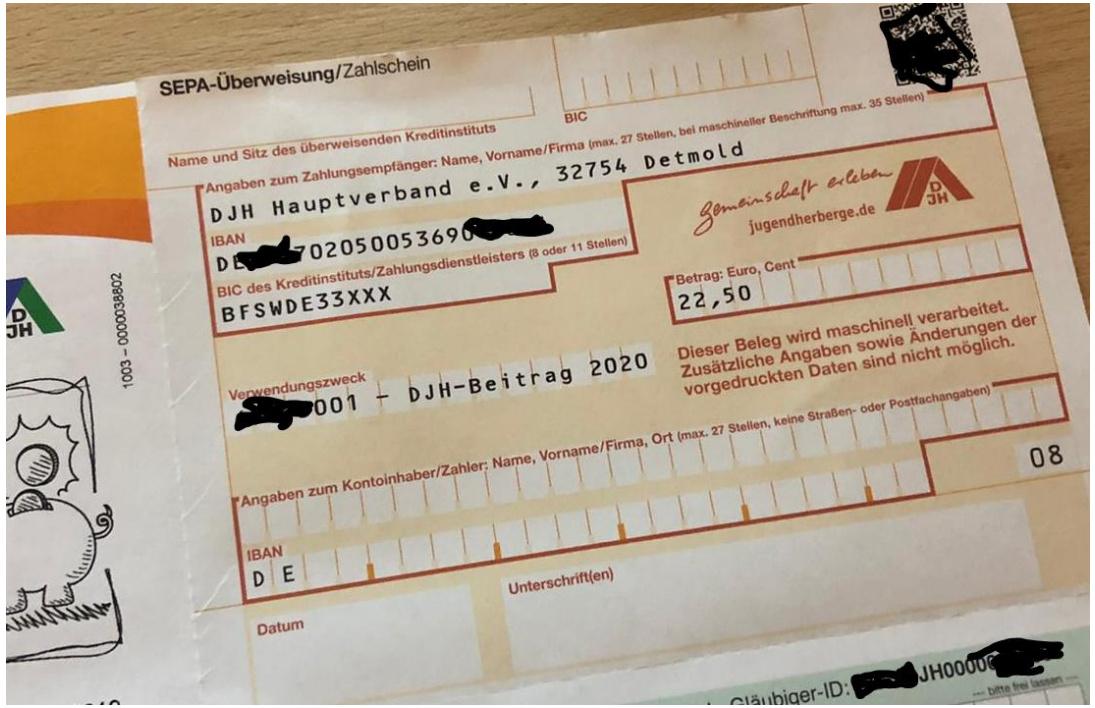
- Laser (black/white and color)
  - creating documents
  - office use
  - high resolution
- Plotter
  - Big drawings, posters
  - Endless printing
- Dot-matrix
  - Point of sale, Ticket printers
  - Multiple copies (e.g. carbon copy slip for credit card payment)
- Thermo printer
  - Point of sale, Ticket printers
  - Mobile printers



Paper: selected technologies

printing on paper

- Paperless office has not yet happened!
- Advances in technology makes it easier to use paper as interaction media
  - (fast) printing as output mechanism
  - Scanning as input mechanism
- Printing for reading, marking, commenting
- Paper as a temporary interface
  - Multi-step process, e.g.
    - print out a check list on paper
    - user interacts with the checklist on paper
    - scan & recognize interaction and create a database entry
  - for specific scenarios this can be a state of the art solution



2D output

On further materials

- Printing on different material (e.g. printing labels on a a DVD or printing on plastic sheets)
- Photo output on different materials, photo books
- **cutting plotter** (foil, stickers, paper), e.g. Brother ScanNCut
- Laser cutter for different materials such as paper, cardboard, wood, plastic, metal
- Engraving (laser, mechanical CNC)
- Sewing machine (fabric, stitching)

By O gerlach

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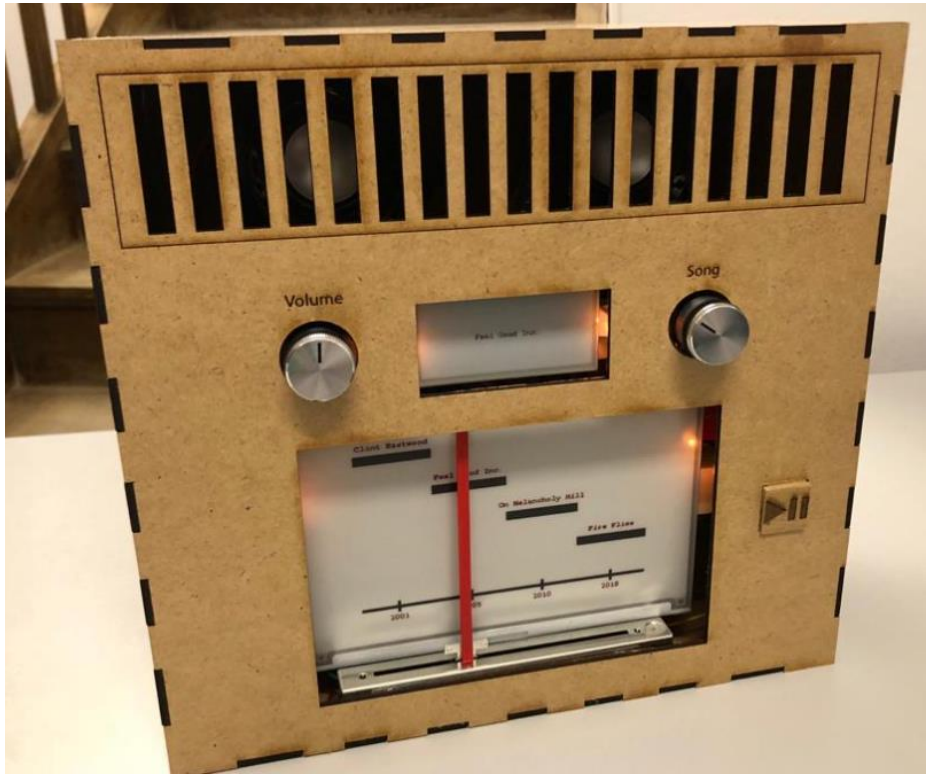

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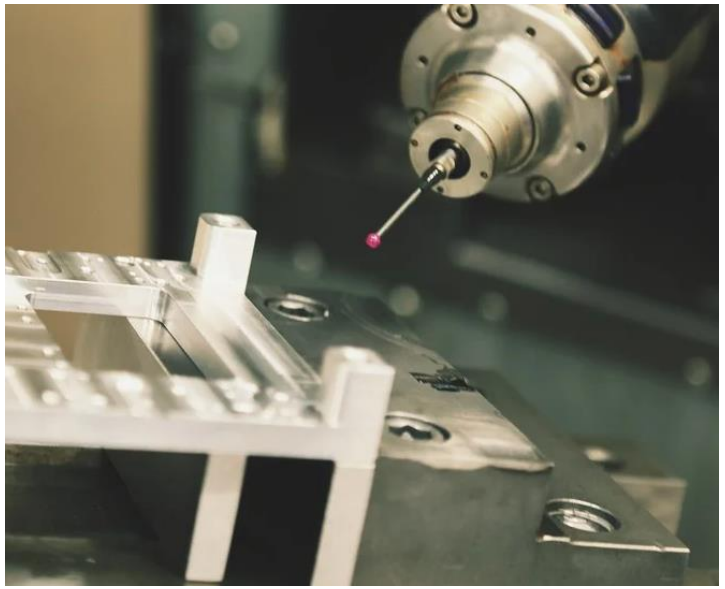
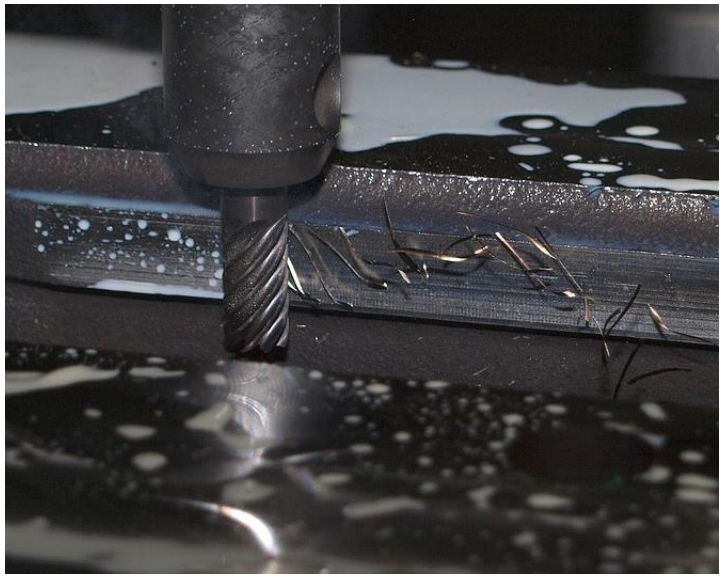
Creating Objects

“printing” things

- Subtractive, 3D
  - **CNC Milling**
  - Taking the material away to make the object
- Additive, 3D
  - 3D Printing
  - Building the object from material (e.g. layer by layer)
- Building from 2D parts
  - Laser cutting and assembly
  - Cutting sheets with connectors





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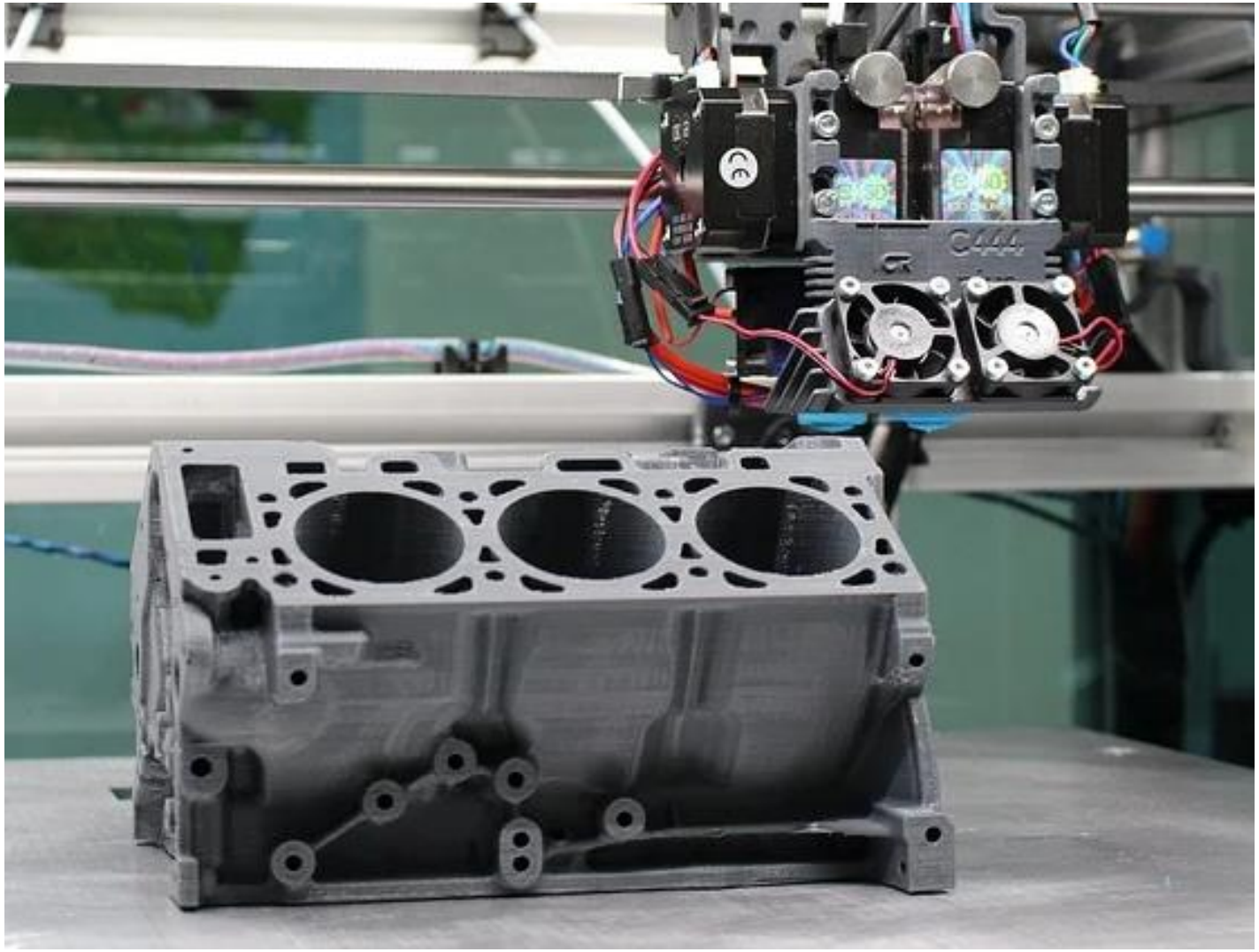
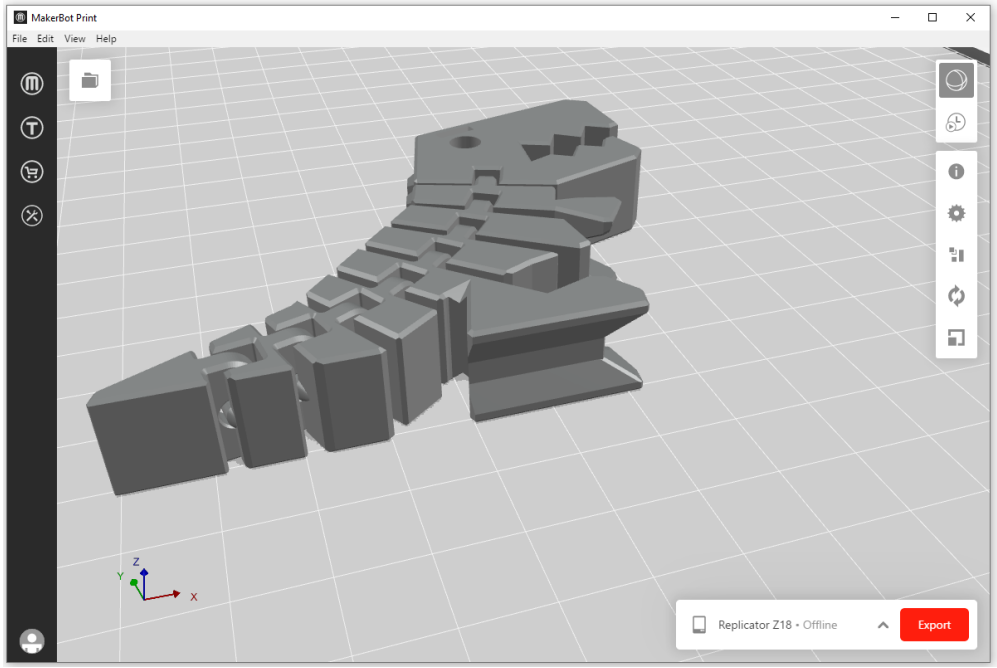


3D Printing Basics

From Idea to Objects – typical steps

- Create a Digital 3D Model
  - Scan from a real object
  - Model with a CAD / design software
  - E.g. Files in STL, OBJ, AMF, 3MF format
- Slice up the model into layers
  - Layer thickness is property of the printer (e.g. 0.1 mm)
  - Slicer or Slicing software
  - Create a representation that can be printed on a 3D printer (e.g. G code)
- Print layer by layer the object
  - Printing materials: object and if required support
  - Printing materials: metal, plastic, starch, …, chocolate
  - Support material will be removed



DrLex CC https://www.thingiverse.com/thing:2738211

More on 3D Printing

FORUM | INTERACTION TECHNOLOGIES

Envisioning, designing, and implementing the user interface require a comprehensive understanding of interaction technologies. In this forum we scout trends and discuss new technologies with the potential to influence interaction design. — **Albrecht Schmidt, Editor**

3D Printing for Human-Computer Interaction

Stefanie Mueller, MIT CSAIL

In the past five years, personal fabrication has become a major research area in human-computer interaction (HCI), with many new contributions every year. In this article, I explain one of its core technologies, 3D printing, with the goal of helping interested researchers get started. For a survey and roadmap of open research directions, please refer to [1] and to the corresponding website (http://hcie.csail.mit.edu/fabpub/), which provides a list of all the research papers published in the field.

3D PRINTING TECHNOLOGIES AND MATERIALS

A common misconception is that 3D printing is limited to the plastic extrusion process seen on today's popular consumer devices such as the MakerBot. In this process, plastic is extruded through a hot nozzle and deposited voxel by voxel (a physical pixel), layer by layer onto a build platform until the 3D object is complete. This is called *fused deposition modeling* (FDM).

The reason FDM technology entered the consumer market first is that its patents expired first: 3D printing is a technology developed in the 1980s with a variety of different processes and materials. In 2009 the first FDM patent ran out; only a few months later, the MakerBot Cubcake CNC appeared on the market. However, many more advanced technologies still have active patents and thus right now are available only in industry.

Another recently expired patent is that of *stereolithography* 3D printing, a process used, for example, in the Form2 3D printers. A liquid resin is poured into a tank. Then a laser (SLA 3D printing) or a projector (DLP 3D printing) selectively shines light onto the resin, which hardens it in these locations. Many other 3D-printing techniques will be available for startups soon. For instance, in inkjet 3D printing, an inkjet head releases a binder that selectively hardens powder in a powder bed. At the end of the process, users remove the object in a process that resembles an archaeological excavation. Metal printing works similarly: A laser selectively melts and fuses metal powder in a powder bed. Finally, layered-object manufacturing (LOM) can process materials that cannot be extruded, bound, or sintered. It takes entire sheets of material, such as a roll of fabric, cuts each sheet into a shape using a laser or other cutting device, and then stacks each layer to create the 3D object. Many more processes and materials exist (Figure 1), from machines that 3D print with felt to create entirely soft objects such as Teddybears, to 3D printers that can print glass.

The words *3D printing* and *additive manufacturing* are often used interchangeably; however, they are not the same. 3D printing is a subcategory of additive manufacturing. Additive manufacturing is any process that creates objects by iteratively adding material until the object is finished. 3D printing is a specific additive manufacturing process in that it has full control over the placement of every voxel in the 3D object, which lends it unlimited degrees of freedom and thus unlimited complexity in the objects it can build. This makes it a very powerful tool.

Insights

- → Research on personal fabrication technologies such as 3D printing is increasingly contributing to the field of HCI.
- → Plastic is perceived to be the most common material for 3D printing, but the use of materials such as fabric, metal, and glass is now possible in industry.
- → Despite 3D printing's enormous potential, speed, especially for high-fidelity detailed prints, remains a limiting factor.

THE PROCESS FOR CREATING PHYSICAL OBJECTS USING 3D PRINTING

The traditional workflow consists of three steps: 3D modeling, slicing (preparing a model for fabrication), and 3D printing.

3D modeling. There are many different 3D editors with different modeling processes. The most accessible ones for novice users, such as TinkerCAD, use a process called *solid modeling*, in which users combine primitive shapes, such as cubes and spheres, and use Boolean operations, such as intersect, join, and subtract, to create a 3D model.

Other editors, such as SketchUp, use a process called *surface modeling*, in which users manipulate the faces, edges, and vertices of a 3D model. This allows for more expressive free-form shapes but, there is a drawback: Users can accidentally create invalid geometry, for instance, by creating a hole in the surface geometry, which goes against the watertight requirement of 3D printing (i.e., the geometry needs to be "manifold"). In solid modeling, water-tightness is always guaranteed, as it is an inherent property of the modeling process. Many tools exist to help analyze 3D models for defects and repair them for 3D printing, either as additional plugins for 3D editors such as the SketchUp Manifold plugin, or as separate programs, the most popular one being Autodesk Meshmixer.

Slicing. To prepare a model for 3D printing, users have to open the 3D model in a separate program called a *slicer*. Preparing a model for 3D printing includes steps such as generating the support material that is printed below the model geometry that has nothing underneath it (called an *overhang*), splitting the model into layers that the 3D printer will print one at a time, and selecting the materials with which the object will be printed. Each of these attributes has additional parameters. For instance, there are different types of support structures for different use cases: Each layer consists of not only a height but also a number of outlines (so-called *shells*) and the percentage of *infill*, a honeycomb pattern used inside the object instead of solid infill to save printing time. The slicer typically imports the 3D model in .stl file format (but other formats, such as the recently developed .amf, exist). For most 3D editors that do not have an .stl export built in, there are additional plugins that can be installed (e.g., Sketchup provides an .stl extension plugin).

Fabrication. The slicer exports instructions to the 3D printer in so-called G-Code, which is the machine language for 3D printers. G-Code tells the print head where to move, how much material to extrude along the way, and how fast to move. Similar commands exist for leveling the print bed, warming up the extruder nozzles, and other parts of the printing process. Regular users will not have contact with low-level G-Code; however, many HCI research projects such as WirePrint [4] (Figure 2) leverage custom G-Code commands for their applications. Before printing, users typically must load the right materials into the 3D printer and level the printing platform to be the right distance from the extruder nozzle. However, more and more of these routines are becoming automated to make the process easier (e.g., via auto-leveling of the print bed).

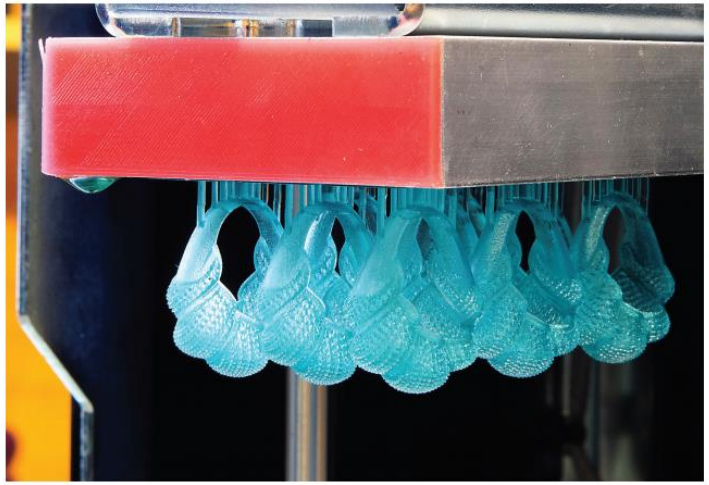


IMAGE BY MIRIENE GIFFELLA

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Mueller, S. (2017). 3D printing for human-computer interaction. interactions, 24(5), 76-79.

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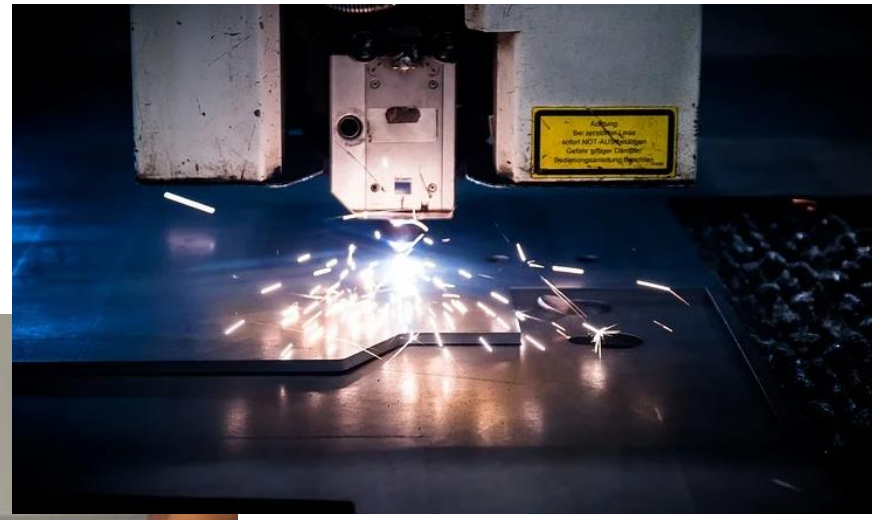

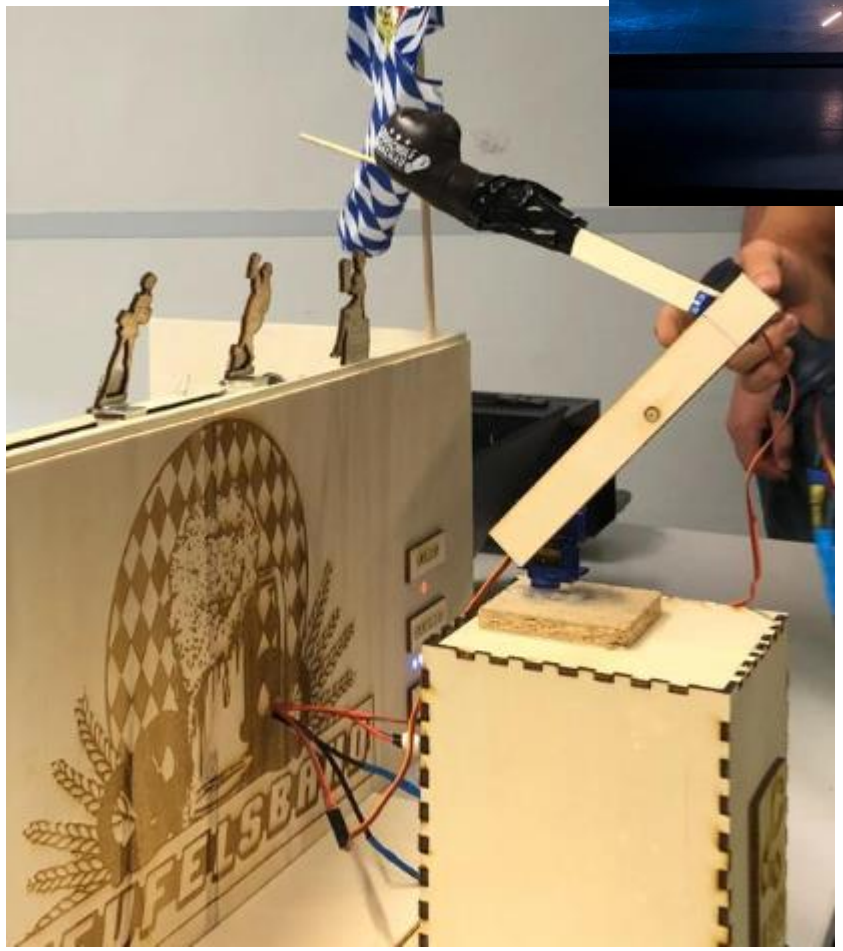

Did you understand this block?

Can you answer these questions?

- What can a dot matrix printer do, that as laser printer can not?
- Discuss what different printing technologies are good for?
- What are cutting plotters used for?
- How can you use a laser cutter for creating 3D objects?
- What are the typical steps for creating a printed 3D object?
- How can paper be a part of a user interface design? In which use cases would this make sense?

References

- Mueller, S. (2017). 3D printing for human-computer interaction. interactions, 24(5), 76-79.

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