Working Title: Supporting Library Operational Needs with In-House 3D Printing

Author(s): Kymberly Anne Goodson & Scott McAvoy

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Keywords: 3D printing, 3D scanning, library infrastructure, furniture, equipment, maintenance, repair, library spaces, facilities, how to

Purpose – The paper offers a how-to look at 3D printing a variety of items to address internal or facilities-related issues in a library setting using the library's existing 3D printing technology and expertise.

Design/methodology/approach – Intended to support others in doing so, the paper details several scenarios in which in-house 3D scanning and printing produced unique or valuable outcomes with facilities-related issues, as well the process that led to successful solutions.

Findings – N/A

Research limitations/implications – N/A

Practical implications – The paper offers how-to instructions for other libraries wishing to explore the use of its existing 3D printing technologies for internal, facilities-, or operations-related needs.

Originality/value – The article complements a 2019 one by author Kymberly Goodson in *Library Hi Tech News* which offered a case study on UC San Diego Library staff use of its 3D printing technology to develop unique solutions to a variety of facilities-related challenges, which in turn was based on a poster the author presented at the June 2019 American Library Association conference in Washington, DC.

Biographical Statements

Kymberly Goodson (kgoodson@ucsd.edu) currently serves as Program Director for the UC San Diego Library's Spaces, Lending, & Access Program, which manages services including user technology and equipment, digital media services, learning space design and functionality, circulation, billing, reserves, building hours, user feedback initiatives, and selected outreach to students.

Scott McAvoy (smcavoy@ucsd.edu) runs the UC San Diego Library's Digital Media Lab, offering 3D printing, 3D modeling, 3D scanning, and virtual reality as user services. Scott has over a decade of experience in 3D design and fabrication, he puts this experience to use helping students and researchers to design and build custom functional parts.

Introduction

The UC San Diego Library's Spaces, Lending, & Access (SLA) program oversees many aspects of user spaces, furnishings, technology, and equipment, as well as the Library's Digital Media Lab, which operates a popular 3D printing service for the campus community. In 2019, program staff brainstormed the idea to utilize existing 3D printing to address facilities-related challenges they encountered in managing the library's public spaces. This experience was first shared in a poster presented at the June 2019 American Library Association conference, followed by a more detailed article in *Library Hi Tech News* (2019, Vol. 36 Issue 9, p1-5, 5p; DOI: 10.1108/LHTN-08-2019-0056). The purpose, benefits, and challenges of the initiative were shared, along with details on several early examples of our facilities-related 3D prints including light switch covers, cord management solutions, brackets, tabletop electrical outlet inserts, chair levelers, knobs, and more.

Because of the timeliness and potential widespread value of the approach, the *Computers in Libraries* editor invited a complementary article on this unique application of technology offered in many types of libraries. This article offers instructional details for several 3D printed examples, with the hope of inspiring even those not currently skilled with or working in digital media to consider 3D printing for internal library applications.

How-to Examples

Intended to spark brainstorming about applications in the reader's library context, presented below are four challenges encountered at the UC San Diego (UCSD) Library which led to 3D printing of facilities- or operations-related items. The examples and their related processes range from simplest to most complex.

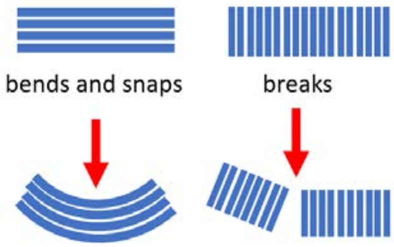
1) Entry Level: Finding and Printing Needed Parts from Existing Models

The recent explosion of 3D technologies triggered a widespread movement toward open access 3D printable models. Creators have made millions of items freely available through websites like thingiverse and myminifactory. While one can find curious and ephemeral items, practical items for the workplace such as doorstops, pencil holders, and cubicle hooks are often also available.

While models are created through many different programs and databases, an additional program, which varies according to the make of one's 3D printer, is needed to prepare the original file for 3D printing. This "slicing" program translates the model's volumetric data into discrete machine movements to be read by the 3D printer. Program settings determine the quality of the print, its strength and weight, and the length of the print.

Most consumer 3D printers use fused deposition modeling (FDM) technology. Much like a hot glue gun, these printers feed plastic filament into a hot nozzle, which smears thin layers on a flat plane. 3D volume is built as these layers stack on top of each other. This system requires additional planning, as the orientation of these layers can impact the strength of the printed piece (Figure 1), and the need to provide additional support for sharp overhangs may result in poor surface quality. For items needing manual cleanup, smooth the 3D printed piece after using steel files or silicon carbide autobody sand paper; the more common garnet sandpaper, used for wood, often crumbles against the harder plastic of a 3D print.

Figure 1: Orientation of a 3D print impacts the resulting item's flexibility and strength



As an example, steps below outline how to 3D print a lens cap for one of our lendable cameras from an existing model.

Supplies Needed

- Any 3D printer
- Computer with internet access
- 3D print slicing software (like Cura)

1. Search thingiverse.com for "DSLR lens cap," noting descriptive language to match specific lens models
2. Select an appropriate item from the results (we chose a Nikon camera lens cap https://www.thingiverse.com/thing:1782703)
3. Click 'download all files'
4. Import file into 3D print slicer program (example here uses Cura)
5. Adjust orientation and settings, including:
    - o Resolution (thickness of each layer)
    - o Infill (density of filler pattern on inside solid pieces)
    - o Supports (to enable additional support material, if required by geometry)

Figure 2: The three-piece lens cap, 3D printed on a Prusa MK3

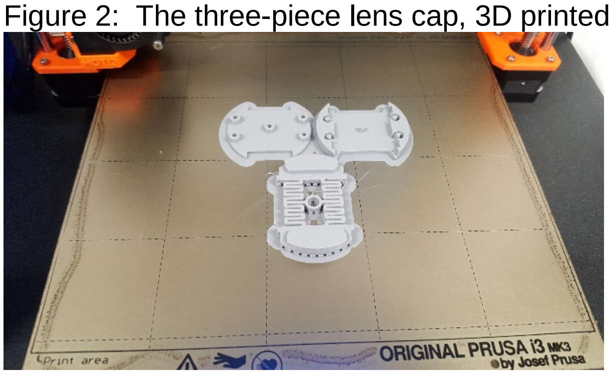


Figure 3: Assembled 3D printed lens cap

2) Intermediate Level: 2.5D Modelling of a Needed Piece

The UCSD Library offers a popular Shared Puzzle Program, through which rotating puzzles are placed in the public space for completion by library visitors. Over time, puzzle pieces invariably go missing. Additionally, some users take a puzzle piece early in the completion process to ensure they will have the final piece when the time is right. Rather than discard puzzles with missing pieces, we design and 3D print replacement pieces.

Many simple parts, such as a missing puzzle piece, can be designed using only 2D graphics. When a 3D object like a puzzle piece has no overhangs, and all features project upwards from a flat shape, it is referred to as a 2.5D shape. Such objects are easier to design than 3D objects, and can be made using 2D image processing programs. For example, Adobe Photoshop offers 3D extrusion functionality (the ability to add thickness to a 2D shape). Some 3D printing slicers, like Cura, will also read common image files like .jpg and .png and allow the user to extrude (add depth/thickness) to a specified dimension. This same workflow can be used to create physical signage and even braille plaques.

In this example, a missing piece from a Coca-Cola-themed puzzle provides the opportunity to employ simple 2.5D design processes.

Supplies Needed

- Any 3D printer
- Computer with internet access
- Paper and pencil
- Calipers (recommended) or ruler
- Camera
- 3D print slicing software (like Cura)

1. Photograph the gap from the missing puzzle piece from straight on, so no perspective warp is produced
2. Note the scale, measuring the longest dimension of the gap (26mm long)
3. Measure the depth/thickness of the cardboard puzzle (1.6mm thick)
4. In Photoshop, PowerPoint, or another image editor, use a brush or line tool to trace the outline of the missing piece and fill the shape in black (see Figure 4)

5. Place the black shape on a white background and save it as an image (.png or .jpg)
6. Import the image into Cura, setting base value to zero, to isolate the shape from the image's white background (see Figure 5)
7. Adjust the sizing to the appropriate scale
8. Slice the model into layers using the 'prepare' button
9. Export the project as a .gcode file, which details the needed machine movements
10. Sand and trim edges of the new piece to fit the puzzle space, manually finishing it to achieve the perfect fit
11. If desired, paint the finished piece to match the puzzle's image (see Figure 6)

Figure 4: Puzzle with missing piece and outline of missing piece in Photoshop

Figure 5: Scaling of puzzle piece in Cura

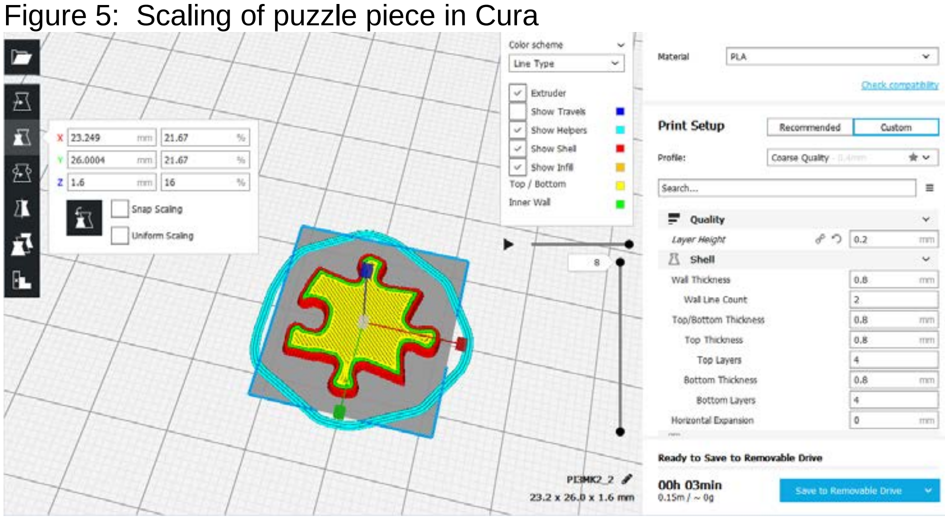


Figure 6: Completed 3D printed puzzle piece inserted into puzzle

3) Intermediate Level: Replicating an Existing Item

The UCSD Library's Special Collections department uses typewriters to create labels. Over decades of use, plastic typewriter pieces have become brittle and prone to damage, though staff have found it difficult to procure replacement parts. In this instance, the flap which weights the paper against the roller snapped off (see Figure 7). When functional, it's held against the roller by small cylindrical tabs (pegs) pressed into holes on either side. One of these pegs broke off (see Figure 9), leaving the flap to hang at an angle and preventing the paper from moving. Staff used measurements from the working side of the flap (see Figure 8) to replicate the measurements for the broken side. The T-shaped extrusion provides an anchor to hold the new peg, as the break made it difficult to match the springy mechanical properties of the original tab.

Figure 7: A typewriter used by the UCSD Library's Special Collections department

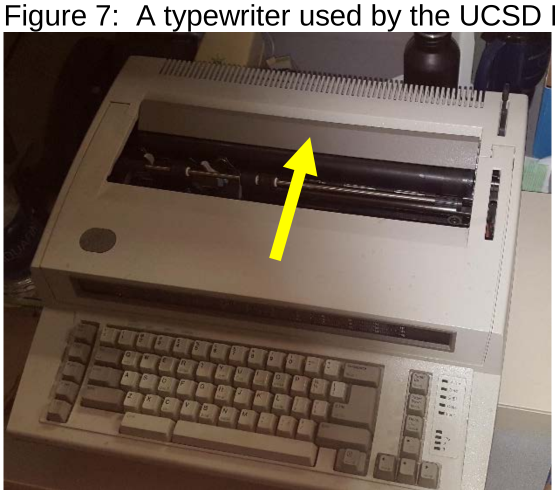


Figure 8: Intact side of weighted flap with existing, undamaged peg

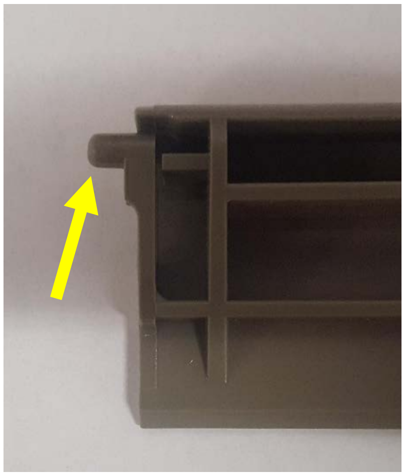
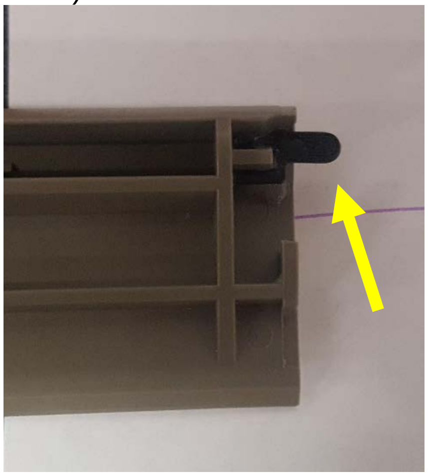


Figure 9: Damaged side of weighted flap with missing peg replaced by new 3D printed peg (in black)



Steps below show how this process took trained staff 15 minutes to make the typewriter functional again: 10 minutes to design, 3 minutes waiting for the printer to heat up, and 2 minutes to print.

Supplies Needed

- Any 3D printer
- Computer with 3D CAD software
- Paper and pencil
- Calipers (recommended) or ruler

1. Inspect the piece and determine necessary functionality
   - In this case, the peg needed to keep the flap in place and allow it to rotate
   - Staff determined the bend/spring of the tab wasn't essential and simplified the piece to shed that functionality
2. Note and sketch measurements of relevant features (see Figure 10)
   - Necessary features included the length of the peg, how far it protruded beyond the side of the flap, and the thickness of the T-shaped section to which the peg would attach, to cut a notch over which the new peg would slide

3. Begin CAD modeling once the concept and measurements are determined
    - o Draw the same lines from your sketch *to scale* within CAD software, where flat shapes are given depth and round shapes are revolved
4. Refine the form and 3D print
    - o As the piece was so small and lacking clean surface area to keep it on the 3D printer build plate, the bottom third of the peg was trimmed away to leave a flat surface (Figure 11).

Figure 10: Sketch of intact peg to mirror missing peg on opposite side

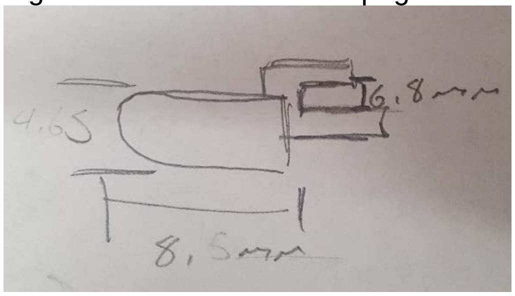
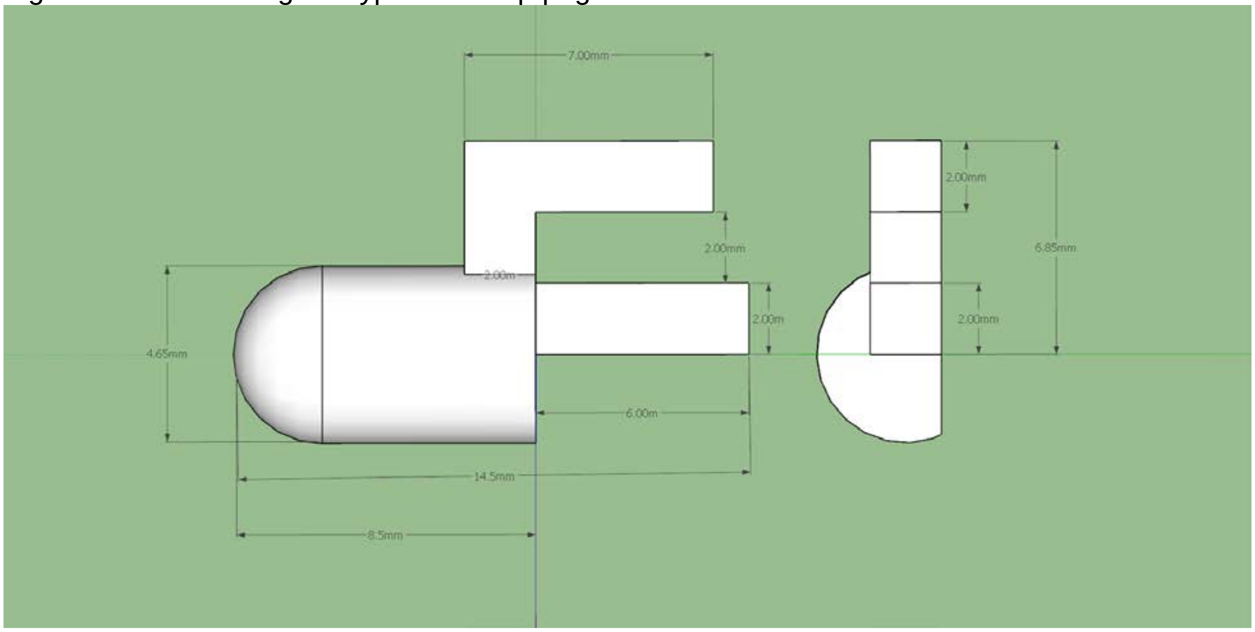


Figure 11: CAD-designed typewriter flap peg



4) Expert Level: Designing and Prototyping a New Piece from Scratch

In some instances, one can imagine the need for a particular type of item, but no such piece exists in the marketplace or is reasonably available for purchase. In these cases, the UCSD Library's facilities-related staff collaborated with the Library's Digital Media Lab staff to brainstorm sketches of items to fulfill the need. Multiple design considerations must be taken into account to design a custom part from scratch. Because endless solutions might be applied to any circumstance, the challenge is to identify a simple and effective solution. Utilizing any resources readily at hand. Instead of measuring an existing piece or known area, one measures the space the needed item will occupy, along with anything that will fit to it.

Readily available standard parts, conceived in new ways, can sometimes prove more effective than a 3D print. Inventory available resources, apply creative thinking, and design around existing tools or supplies, wherever possible. For example, if something needs to attach firmly to a wall stud, find an appropriate screw and design around that form. No 3D print will perform better at fastening something to a wooden stud than a standard steel screw. Similarly, a project requiring complex objects to be held tightly to something may benefit from zip ties. It's much easier to design and print an item that anchors zip ties to an object than to engineer an equally strong and flexible locking mechanism from 3D printed parts.

Two instances requiring items to be made from scratch have arisen since publication of the *Library Hi Tech News* article. This example details fabrication of a new scrap paper bin for a high-volume Swingline hole punch (see Figure 12). Because the broken bin is missing, no existing model is available for replication.

Supplies Needed

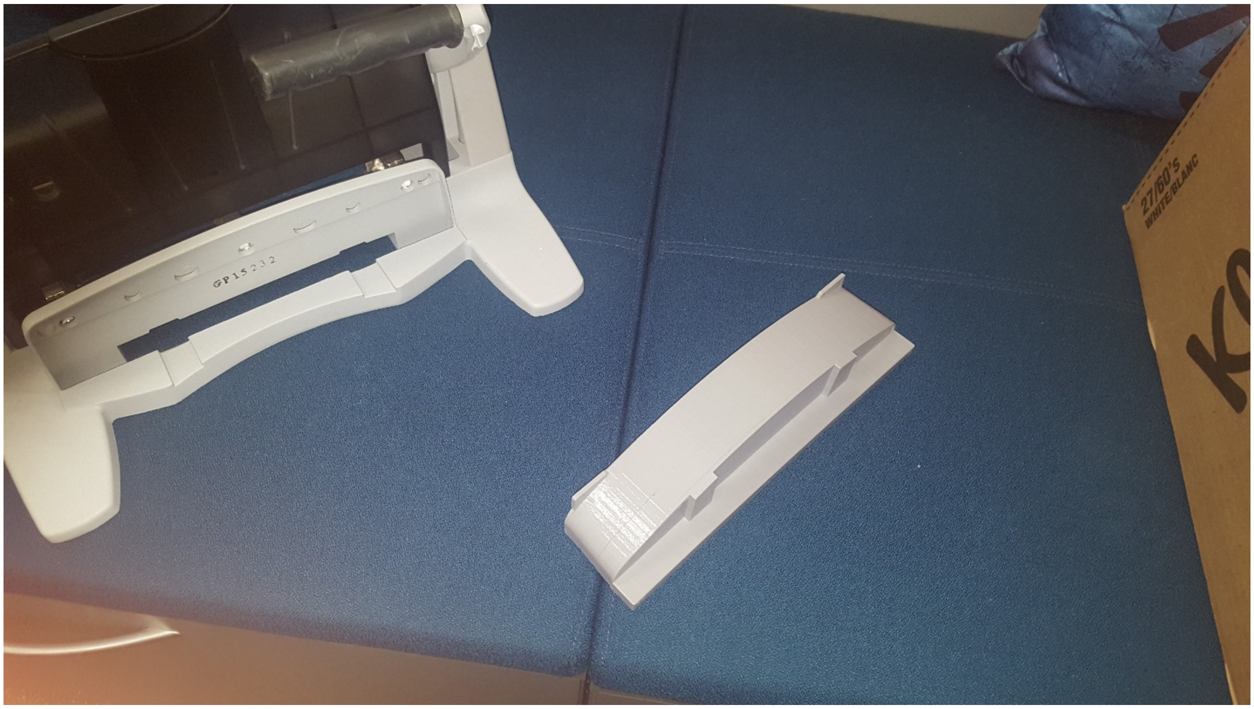
- Any 3D printer
- Computer with 3D CAD software
- Paper and pencil
- Calipers (recommended) or ruler
- Readily available standard parts (screws, zip ties, rubber bands…)

1. Examine the item
2. Note necessary features and measurements in a rough sketch, using measurements left in the gap from the previous, now absent bin to design the new one
3. Abandon complex or unnecessary features inessential to the new item's functionality, such as a latching mechanism, in this instance
4. Sketch a prototype, and model it in CAD
5. Expecting multiple prototype revisions, first 3D print sections of the model that need to fit perfectly
    - In this case, the two bottom grooves and curves on the far side were expected to require additional adjustment, so these pieces were printed separately, waiting to print the full bin only after adequate fit was achieved with these key pieces
6. Tweak and test individual components until they fit satisfactorily, then print the whole bin
7. Manually smooth parts, where needed
    - Little finishing was needed in this instance

Figure 12: Unaltered Swingline 3-hole punch

Figure 13: A 3D printed, simplified scrap paper bin, optimized for function and 3D printability

Figure 14: 3D printed scrap paper bin (bottom view), conforming to the shape of the bin holder



Conclusion

With the right tools, available software, and introductory knowledge of 3D printing, even a novice with digital media can begin to explore 3D printing. Once inspired, and armed with a need on which to experiment, those without such experience can leverage their library's in-house experts to achieve a successful outcome. Whether a library maintains a facilities unit or not, those interested in expanding use of existing 3D printing infrastructure beyond supporting the pursuits of library users, can look for a staff member eager to learn or employ these technologies in a new way to benefit the organization. Public libraries might take advantage of library volunteers, including teens, who may be enthusiastic about utilizing these technologies. Those in academic settings can utilize library student workers. Another option is to seek out students from engineering or related departments on campus for temporary or permanent library employment specifically for this purpose. In the UC San Diego Library context, most engineering students are trained to perform many of these tasks by their sophomore year of college, and object replication and reverse engineering can provide useful hands-on practice for them.

Once items have been made, staff can add their prepared models to online repositories like thingiverse for their own future use or for use by others who might find them useful.

The authors hope that this primer and the examples illustrated here inspire and enable others to consider new ways to take advantage of their library's existing 3D printing technology. Additionally, they hope it helps expand the number and type of library staff mindful of opportunities presented by 3D printing and skilled in applying it to applications internal to the library, to complement the ways in which library's offer 3D printing to support the academic work or other pursuits of those in their user communities. This outcome materialized at the UC San Diego Library when its Safety & Security director initiated a collaboration with Digital Media Lab staff. After learning of 3D printing for various internal purposes, she hoped to use 3D printing to design a custom template for mounting intercom receivers on horizontal desk surfaces, rather than on vertical walls, the mounting approach typically used for intercoms, which is enabled out of the box. As seen in the examples presented here, a little creative thinking can result in novel solutions to difficult, unique, and sometimes long-unresolved problems with library infrastructure.