Spring 5-1-2017

The Intersection of Manufacturing Technologies and School Music Programs

Leslie Prunier
University of Connecticut, leslie.prunier@uconn.edu

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May 2017

Advisors: Julian Norato, Diane Van Scoter, James Jackson

I. Abstract

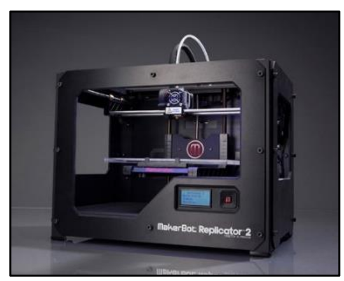
The objective of this project is to design and manufacture a musical instrument, a marching baritone horn, out of plastic. It is constructed out of both PVC pipe and 3D-printed components. Utilizing this project's documentation, a high school student could use a 3D printer and other basic tools to make their own musical instrument for a fraction of the cost of purchasing one. This documentation will produce a horn tuned in the key of B flat with one functioning valve, and suggestions for future work to make the other two valves functional as well.

II. Table of Contents

VIII. Introduction

The baritone horn is a brass instrument, most simply described as a cross between a trumpet and a tuba. Like most brass instruments it consists of a series of tubing, the length of which can be altered by pressing valves with the fingers. The specific length of tubing, combined with the method of "buzzing" into the mouthpiece to generate sound waves, is what determines the pitch that comes out of the bell of the horn. I intend to use additive manufacturing, a process which creates an object by "adding" material instead of subtracting, unlike fabrication methods such as cutting and drilling. With 3D printing, a type of additive manufacturing, a 3D printer will create physical pieces of the baritone by melting a plastic filament, then extruding it through a nozzle that moves in precise patterns. The plastic solidifies after passing through the extruder nozzle to form a cross-section of the part, and then more layers are added until a finished piece is formed. This type of additive manufacturing is called Fused Deposition Modeling (FDM).

Yamaha marching baritone horn [1]



MakerBot Replicator 2 3D Printer [2]

A number of plastic musical instruments are currently available on the market, and they are cheaper than traditionally manufactured metal or wood instruments, but they are not created through 3D printing. Companies such as pBone, Allora, and Tromba sell plastic trombones [3-5]. Trombones are relatively easy to manufacture compared to other musical instruments because they do not contain valves. Allora and Tromba also sell plastic trumpets, which contain metal valves. This research explores a musical instrument that is not currently made of plastic by any major manufacturer. The total material

cost of this experimental horn is under $50, which is significantly lower than a new beginner-level baritone that costs approximately $2000 [6].

IV. Equipment

The instrument was designed with accessibility in mind. The goal is for a high school student with typical resources to be able to manufacture it at a low cost. As such, the required tools and materials can be found in a standard technology education classroom, or purchased at low cost at a local store or online. A detailed list of required PVC parts can be found in Appendix A.

Material List
PVC pipe and fittings (various sizes)
PVC 2-part cement
PLA 3D printer filament
Superglue/Gorilla Glue
2-inch metal springs

Tool List
FDM 3D Printer
PVC ratchet cutters
Hacksaw
Wood file
Drill
Spade drill bit set
Deburring tool
Vise

V. Methods

The instrument was created through an iterative process of modeling, making, and testing. It is split up into two main parts, the simple tubing and the complex valve section.

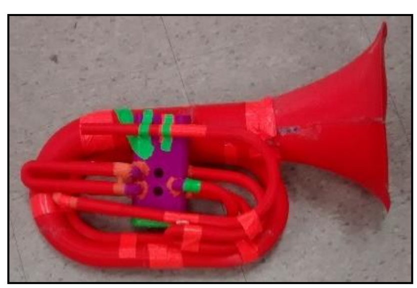
Step 1. Create accurate computer model of original metal instrument

Step 2. Adjust model to optimize for 3D printing

- 2.1. Thicken tube walls
- 2.2. Split bell into segments

Step 3. 3D-print model → testing

Metal baritone horn (Step 1)



3D-printed baritone (Step 3)

Step 4. Tubing

4.1. Replicate basic shape out of heat-molded PVC → testing

4.2. Replicate basic shape out of PVC joints → testing

Heat-molded PVC (Step 4.1)

PVC joint assembly (Step 4.2)

Step 5. Valves

5.1. Re-model to fit inside a PVC tube

5.2. Assemble single straight joint → testing

5.3. Assemble single angled joint with tuning tube → testing

5.4. Assemble multi-valve joint with 3 tuning tubes → testing

Step 6. Combine tubing and valves

Single straight PVC joint (Step 5.2)

Single angled joint with tuning tube (Step 5.3)

Unfinished multi-valve joint (Step 5.4)

Multi-valve joint with 3 tuning tubes (Step 5.4)

VI. Results

- 3D-printed components cannot be used for the full horn because of air leakage and poor rigidity
  - Future work in using non-3D-printed parts for the 1st and 3rd valve slides is predicted to create a fully functional horn
- Air leakage at joints is the biggest obstacle to creating a functional instrument
  - PVC components and cement help mitigate this issue
- A resin-based 3D printer (Formlabs Form1+) was used to create a smoother valve with higher tolerances, but this difference was found to be negligible compared to other factors in sound production
- Researching methods to construct the bell out of a more rigid material could result in greater sound projection
- Design of a 3D-printable jig could greatly aid the construction process

Final Product

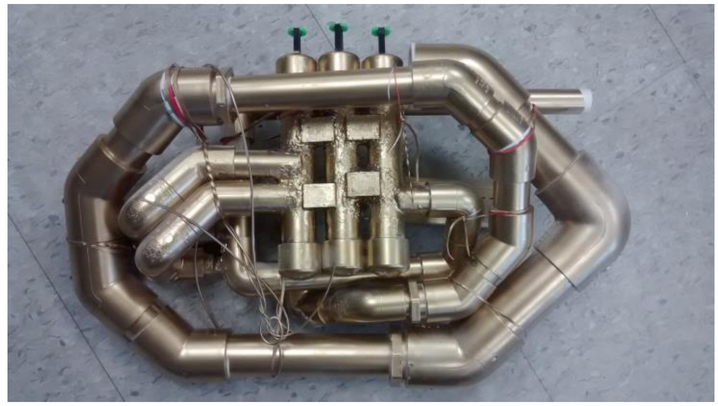
Appendix A – Parts List

Item	Size (Nominal)	Unit Price	Qty	TOTAL
90° elbow[1]	½”	$0.32	11	$3.52
45° elbow[1]	½”	$0.54	5	$2.70
45° elbow[1]	¾”	$0.96	4	$3.84
45° elbow[1]	1”	$1.09	4	$4.36
90° elbow[1]	1 ¼”	$1.67	1	$1.67
45° elbow[1]	1 ¼”	$1.38	2	$2.76
Reducer bushing[1]	¾ x ½”	$0.54	1	$0.54
Reducer bushing[1]	1 x ¾”	$0.86	1	$0.86
Reducer bushing[1]	1 ¼ x 1”	$1.38	1	$1.38
Socket cap[1]	¾”	$0.59	6	$3.54
Pipe (5’ length)[2]	½”	$2.13	1	$2.13
Pipe (5’ length)[2]	¾”	$3.07	2	$6.14
Pipe (5’ length)[2]	1”	$4.50	1	$4.50
Pipe (2’ length)[2]	1 ¼”	$4.46	1	$4.46
All pipe and fittings are PVC Schedule 40 [1] - Home Depot retail price [2] - Lowe’s retail price			**TOTAL:**	**$42.40**

STL Files	
tube1	valve_stem
tube23 (print x2)	valve1
valve_connector	valve2
valve_stopper (print x9)	valve3

Appendix B – Assembly

Front View



Back View

Top View

Bottom View

Left View

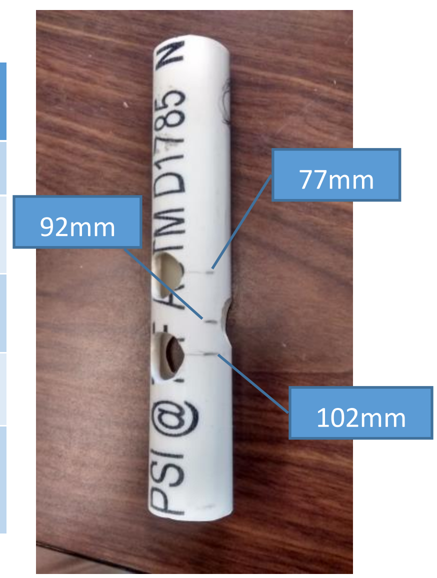
Right View

Valve Detail

Valve Casing Hole Locations (mm)

	Valve 1	Valve 2	Valve 3
Front	77 102	77 102	92
Right	92	102	77 102
Left	102	92	102

Measure from top of valve casing
Front/left/right holes spaced 120° apart
Use 9/16" spade drill bit



1st valve
Front and right holes visible.

Appendix C – References

[1] "YBH-301M Bb Marching Baritone." Yamaha. Yamaha Corporation of America. From http://usa.yamaha.com/products/musical-instruments/winds/marchingbrass/baritones/ybh-301m/?mode=model

[2] "MakerBot Replicator 2 Desktop 3D Printer." MakerBot. MakerBot Industries LLC. From https://store.makerbot.com/replicator2.html

[3] "Allora Brass Instruments." Woodwind & Brasswind. From http://www.wwbw.com/Allora,Brass-Instruments.wwbw

[4] pBone Plastic Trombone: The World's Best Selling Trombone. pBone Plastic Trombone. From http://www.pbone.co.uk/

[5] Tromba. Tromba Instruments. From http://trombainstruments.com/

[6] "Baritone Horns." Woodwind & Brasswind. From http://www.wwbw.com/Baritone-Horns-Brass-Instruments.wwbw