Alternative Methods for Cost Effective Diffusion

Zachery L'Italien
Visual and Performing Arts
Michigan Technological University
Houghton, MI, USA
zolitali@mtu.edu

Henry Ashburn
Visual and Performing Arts
Michigan Technological University
Houghton, MI, USA
hwashbur@mtu.edu

Abstract

Acoustic diffusion is a necessary element in the realm of room acoustics; with its high commercial cost, it can be hard for a sound designer to afford a sufficient amount to treat their personal studio. This paper addresses this situation for the DIY community to offer alternative methods to effectively and efficiently create diffusors with a much smaller overall cost.

The methods that are examined throughout this paper will revolve around the use of 3D printing, an increasingly more common mode of production in households, as well as the use of closed cell and spray foam to mold around/inside of the 3D printed diffusor segments. This paper will analyze the cost, time, and overall diffusive efficacy of the production methods mentioned.

Keywords—diffusion; cost efficacy; 3D Printing; CNC; construction

1. Introduction

The interaction between the surfaces of a room and the sound waves that propagate through the air within the room are of great interest to those who care about the acoustic properties of the room they use for work. Because, sound waves generally travel in a straight line, reflections of sound waves between the square walls of a standard rectangular room can make this room a poor listening or recording environment. to correct this, two common types of treatment are done to rooms : absorption, which is the treatment of walls, or diffusion, which is the addition of objects in the room to alter the sound waves in a positive manner.

Absorption occurs when sound waves interact with any physical object, as sound is absorbed into porous surfaces and converted into heat energy. Knowing the properties of various objects and materials we can create objects that absorb sound more efficiently and accurately than random objects [1]. Common materials used in these passive absorbers are open cell foam, fabrics, and carpet. Active absorbers include diaphragms or membranes that use volumes of air to absorb the sound [2].

Diffusion also occurs when sound waves interact with physical objects, but instead, the sound waves are reflected and redistributed back into the room at different angles. This is especially useful when treating a rectangular room, as the diffusion helps break up the sound waves — allowing the listener to hear both the initial sound wave, as well as the reflections from the diffusion. Diffusion is a form of sound wave scattering, but diffusion aims for an equal energy dispersion of a broader frequency range [3]. There are many types of diffusor designs that are commonly used and recreated, but the most common designs include quadratic residue diffusors (QRD), primitive root diffusors (PRD), and polycylindrical (poly) diffusors.

Many DIY project studio owners have acoustically less-than-desirable rooms, which could be improved with proper diffusion or absorption treatment. Unfortunately, most diffusion products on the market are costly, but we believe that there is an alternative method to create efficient and cost effective diffusors that could be offered to the DIY community. Our approach is to utilize common products in combination with the increasingly available production method of 3D printing to form a diffusor that can be replicated multiple times and used in a room to improve the acoustics.

2. Related Work

In acoustics one of the most beneficial uses of 3D printing is in product prototyping. AcousticsFirst — a company that focuses in room treatment solutions — uses 3D printing as an alternative to the costlier process of making a mold for researching a new product, as it is quick and much more cost effective. Before printing their prototype they use 3D modeling and computer generated particle physics modeling in order to analyze the theoretical diffusion.

Another example of (deleted text) the possibilities of 3D printing in producing diffusors is the model by thingiverse.com user bkubicek who creates diffusors using a consumer-grade 3D printer. Unfortunately, the cost and time is about 16 days and about $180 for a one square meter diffusor which is too costly for most DIY consumers.

3. System Model

Project studio owners often have tight budgets, but want to work in a good sounding room, but most acoustic treatments are expensive to buy in sufficient quantity. For example, (deleted text) one of the most inexpensive diffusor in the consumer market is the Auralex T'Fusor with a price of $65 for a 2'x2' unit. These prices continue to increase with size and model type and material.

This graphic should come later.

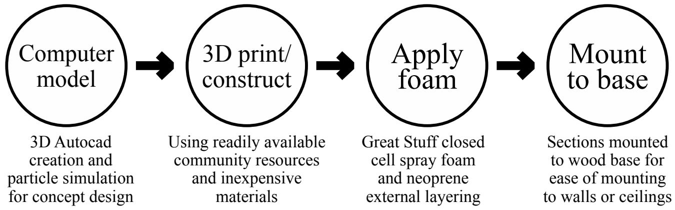


Figure 1: Process for diffusor creation

In our model we want to create a diffusor that works with a similar effective frequency range and similar dispersion as the T'Fusor but at a lower cost. We can assume that 3D printing is becoming increasingly more accessible to home users due to decreased cost and ease of use. Resources are becoming increasingly more available in communities as libraries and makerspaces are including them in their services [4]. We are also assuming that studio owners wish to save money by creating their own diffusors. There are also materials available in the consumer market that can be repurposed to make inexpensive diffusors.

The following paragraph and graphic should not be here, but in section 4.

Mathematically, we assume that the quadratic residue sequence supports the design goals of QRD [5]. We also apply the idea that reflections on a cylinder will reflect at 120º off of the angle of incidence [1].

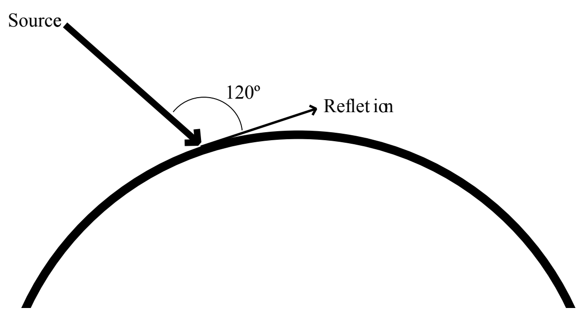


Figure 2: Reflection off of a cylinder

Our QRD model will shape wire mesh into a firm base, and then attach foam to it.. The foam samples that we will be using in our model will be a foam used for poker tables, and a neoprene sample. A car headliner foam was considered, but was deemed too absorptive in our tests. See appendix A.2 to view links to purchase the materials used in this research.

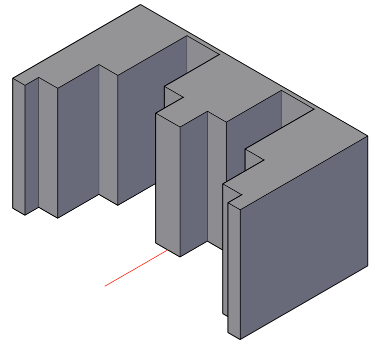


Figure 3: QRD mold

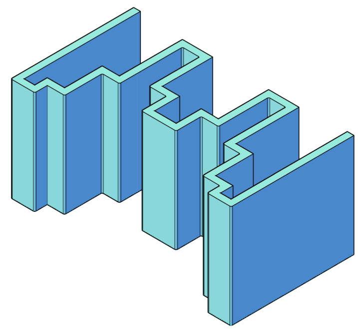


Figure 4: QRD foam diffusor

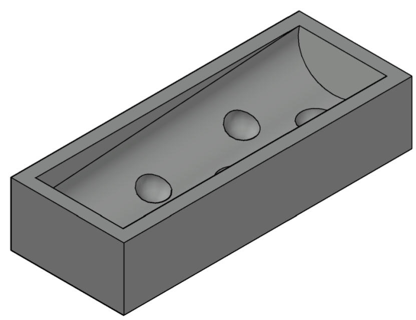


Figure 5: Polycylindrical mold

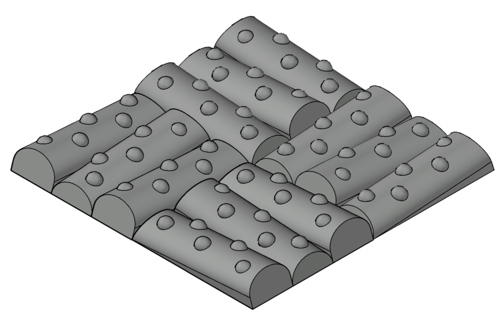


Figure 6: Polycylindrical diffusor

4. Solution

We created an alternative diffusor design based on a polycylindrical shape, (see figures 5 and 6) which is not presently found on the market (deleted text). This diffusor takes the typically two dimensional dispersion of a polycylindrical diffusor and expands the dispersion to three dimensions. The arrangement that we use includes cylinders tilted at various angles along the base of the cylinder as well as a non-perpendicular herringbone pattern.

The mold for a single cylinder of this diffuser can be 3D printed for about $65 to $80 using ABS filament.

The QRD model that was created is a well known design that is commonly used in the industry. The design is based on mathematical calculations based on the quadratic residue sequence [5]. This model proves to be acoustically effective but is more expensive (deleted text). Many common manufacturers in room acoustics include this diffusor type in their product lines.

5. Analysis

Below, is a rough cost comparison of the construction of the two diffusors. These costs are based on average costs of the material that we (deleted text) researched. The mold will be constructed from an ABS filament and printed by university services. The paint (deleted text) is fireguard E84. The spray foam (deleted text) used in the creation of the polycylindrical diffusors is a generic, high expansion insulation foam. The prices listed are the prices of the material cost for the creation of one diffusor. The luan is to simplify ceiling and wall mounting.

	Type 1 Poly	**Type 2 QRD**	**Cost per Sq. Ft.**
Mold Cost	$65.00	$20.00	
Spray Foam	$4.50		12 oz. can
Foam Sheet		$24.00	$1.80 - $2.40
Wire Mesh		$12.00	$1.14
Paint	$1.00	$1.00	$0.25
Luan Mount	$1.50	$1.50	$0.38
Number of Molds	1	1	
Number of diffusers	10	10	
Total Cost	$135.00	$405.00	

Table 1: Cost analysis of the creation of ten diffusors using one mold

The creation of our diffusors will be much cheaper than the traditional diffusors on the market. If the price of 10 Auralex T'Fusors is compared with the costs shown above, our models are (deleted text) a much cheaper option. Compared to purchasing 10 T'Fusors, (deleted text) 10 DIY QRD diffusors would save the user $515. while the the polycylindrical model, would save (deleted text) $405.

6. Simulation and Experimentation

The effects of the three foams are shown below in a reverb chamber. Each of the foams were tested individually. The sample sizes in m^2 are as follows: white foam, 0.852; black neoprene, 1.24; headliner foam, 2.78.

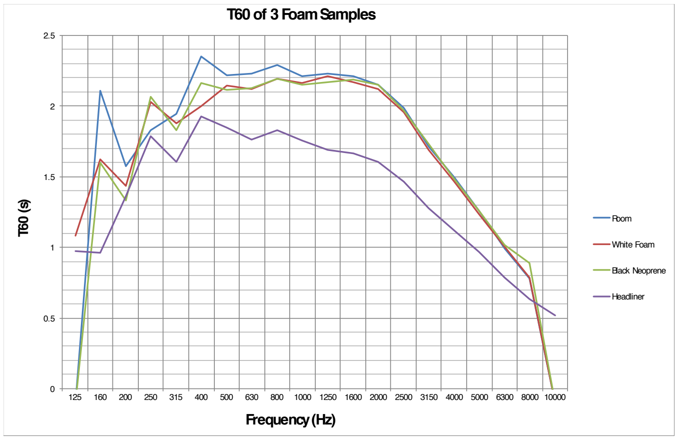


Figure 7: T60 of foam samples

The white foam sample and neoprene sample had the least effect on the reverberant field, so we used those those in our diffusor model.

Simulations of our work on the polycylindrical diffusor are in Appendix A.1 which compared our original model and revised model. In our revised model the sound field is shown to be much more diffuse. To accomplish this, we have added small spheres to the surface of each polycylindrical section, along with slight angles at each of the bases.

7. Future Work

Moving forward, we will continue to experiment with designs that are potentially cheaper and disperse sound over a greater frequency range. We will continue to accept suggestions of materials that are easily accessible in the consumer market. Testing of the diffusive properties and absorption coefficients of the initial diffusor designs will give us a better understanding of how effective our molds are with respect to time and durability.

8. Conclusions

To this point, (deleted text) the polycylindrical model — if acoustically successful — will be cheaper to construct in large quantities. Due to the modularization and repetitive nature of the polycylindrical diffusor, the 2' x 2' diffusor can be constructed from one mold that is 1/12 of the total size, keeping the cost of 3D printing minimal. It should be noted that the 3D printer used for cost predictions and mold construction is a large-scale Fortus 400mc, and not the more common Lulzbot. While the Fortus 3D printer has proven acceptable in terms of cost and time, our methods for diffusor construction may not be viable for (deleted text) household printing. Nonetheless, this is not an insurmountable barrier. The overall construction time needed to create your own diffusors may be longer, but the end cost will be significantly lower.

References

[1] E. Smith, "Practical Guidelines for Constructing Accurate Acoustical Spaces," *Acoustics 101*, vol. 3, Jul. 2004.

[2] A. F. Everest, *Sound studio construction on a budget*. New York: McGraw-Hill Companies, The, 1996.

[3] P. Newell, *Recording studio design*, 2nd ed. Amsterdam: Elsevier/Focal Press, 2007.

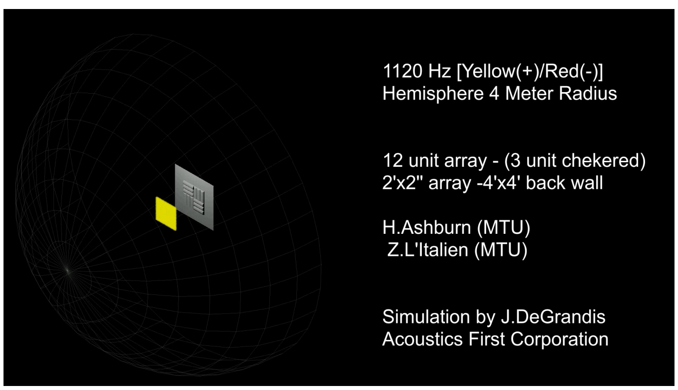
[4] "4 ways 3D printing is becoming more accessible," 2017. [Online]. Available: http://redstack.com.au/support/blog_posts/4-ways-3d-printing-is-becoming-more-accessible. Accessed: Jan. 25, 2017.

[5] T. Perry, "The Lean Optimization of Acoustic Diffusers: Design by Artificial Evolution, Time Domain Simulation and Fractals," University of Victoria - Faculty of Engineering, 2011.

[6] J. DeGrandis, "Particle simulations advance insight into diffusion device design, efficiency, diffuse field development and propagation," *Proceedings of Meetings on Acoustics*, vol. 23, May 2015.

Appendix A

A.1 Computer simulations



Video Courtesy of James DeGrandis

he video above shows our first model of the polycylindrical diffusor.

Video Courtesy of James DeGrandis

The video above shows the revision to our first model of the polycylindrical diffusor.

A.2 Foams and other materials used

1. Craft Foam Hi Dense Closed Cell Upholstery Auto Interior Poker 1/4"x 22"x 60"

   https://www.amazon.com/Craft-dense-Closed-Upholstery-Interior/dp/B01INZWXRQ/

2.Neoprene Foam Sheet – High quality, ¼" thick, 80"x24"

   http://www.foambymail.com/NE/neoprene-foam-sheets.html

3. GREAT STUFF™ Gaps & Cracks Insulating Foam Sealant http://greatstuff.dow.com/product/gaps-and-cracks.htm
4. GREAT STUFF™ Big Gap Filler http://greatstuff.dow.com/product/big-gap-filler.htm
5. GREAT STUFF™ Window & Door Insulating Foam Sealant http://greatstuff.dow.com/product/window-and-door.htm
6. 1/4 Inch Mesh 24 Inch Tall x 5 Feet Long Hardware Cloth https://www.amazon.com/Inch-Mesh-Tall-Hardware-Cloth/dp/B000BWY7UQ/
7. BANFIRE INTUMESCENT FIRE RETARDANT PAINT (ASTM E84) - 1 GALLON http://shop.rdrtechnologies.com/product-p/bf-frp-1g.htm?gclid=CMfi--Kt69ECFUWewAodfN8LUA