Sycamore Seed - Inspired Fan Blade for a Portable Air Purification System

Problem

- Air pollution accounts for more than 1 in 8 deaths worldwide, making it the second largest risk factor for early death [1,2].
- Air pollution is a significant burden on lower-income communities [3].
- Exposure to polluted air is associated with a range of structural and functional brain alterations in children [4].
- A significant portion of the world's vulnerable population lacks access to costly integrated air filtration systems [5].
- Standard air filters used in these systems are non-biodegradable and add to the world's constantly growing landfills [6].

Engineering Goal

Develop a sustainable, portable air purifier that is energy efficient and uses a biodegradable filter.

Filter Design

Bio Breeze Filter (developed in the previous year)

Snake Plant Cellulose Fiber + Granular Activated Carbon + Coconut Fiber (GAC).

Snake Plant fiber extraction process

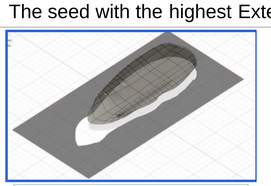
Fan Blade Design

Method 1: Generalized Seed Model –

- 28 Sycamore seeds were studied.
- A longer *Falling Time* indicates a more efficient seed
- Calculated geometrical features by analyzing 2D images of the seeds.

Coefficients:	Estimate	Std. Error	T Value	P value
(Intercept)	2.615	3.523	0.742	0.467
Weight	-0.069	0.016	-4.201	< 0.001 ***
Leading Edge Thickness	1.288	0.923	1.395	0.179
Major Axis Length	-0.001	0.002	-0.594	0.560
Minor Axis Length	-0.004	0.010	-0.431	0.671
Solidity	-8.020	6.071	-1.321	0.202
Extent	6.505	3.061	2.125	0.046 *
Perimeter	0.002	0.002	0.987	0.336
Circularity	7.508	8.156	0.921	0.369

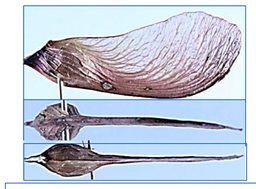
- The regression analysis showed that the feature *Extent* had a significant positive correlation with the *Falling Time*.
- The seed with the highest Extent was chosen to be modeled.



Mask of the seed with the highest *Extent* in AutoDesk

Sycamore Seed Fan blade (Method 1)

Method 2: Specific Seed Model

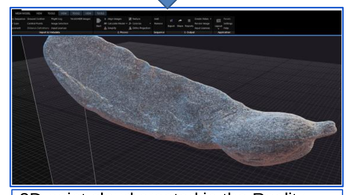


Sycamore seed

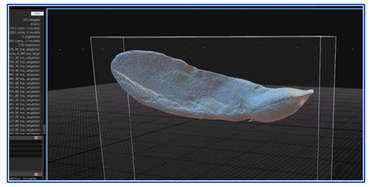
Polymer clay replica of Sycamore seed

DC Stepper motor- programmed to rotate by 3° per step

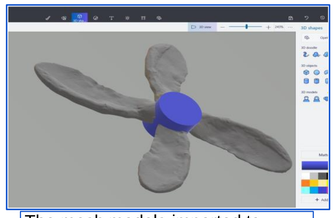
The photobox used to take pictures of the clay model in 360 degrees (left). Examples of the model images taken at various points during its rotation (right).



3D point cloud created in the Reality Capture software using photogrammetry.



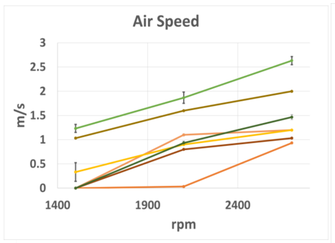
Mesh model created from the point cloud in Reality Capture.

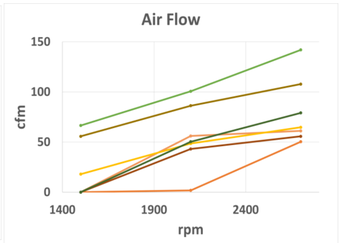


The mesh models imported to the Paint 3D software to create the fans.

Air Flow Velocity Experiment

Air flow was measured above the fan blades at 3 different RPM levels using an Anemometer (3 trials).

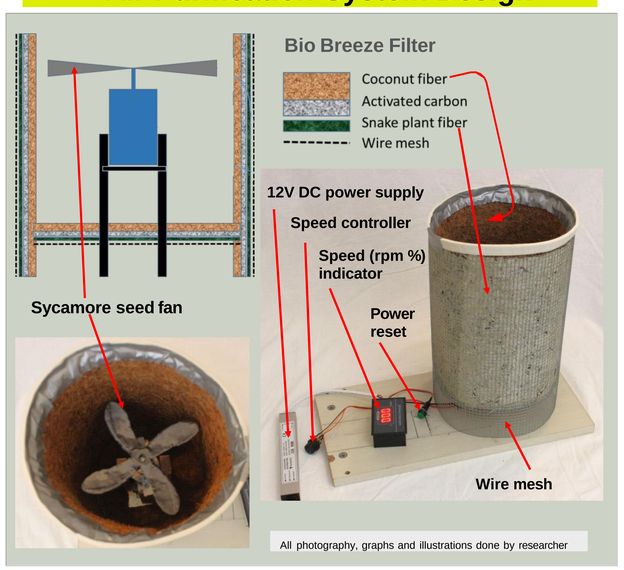




Sycamore 4 - method 1 · Sycamore 2 - method 2 · Standard 4 - method 2 · Angled Sycamore 2 - method2 · Standard 2 - method 2 · Angled Sycamore 4 - method 2 · Sycamore 4 - method 2

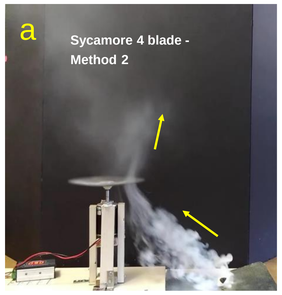
Results indicate that the Sycamore 4 blade seed model based on the 3D clay replica of the seed (method 2) is the optimal design.

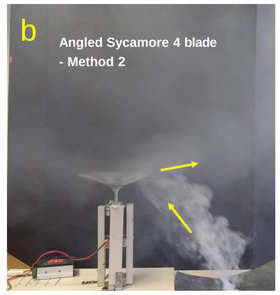
Air Purification System Design

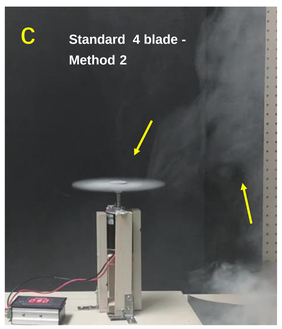


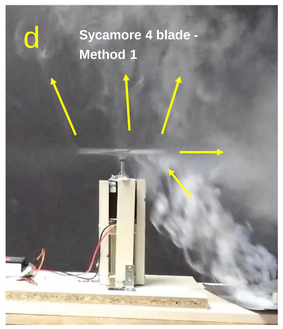
All photography, graphs and illustrations done by researcher

Air Flow Pattern Experiment







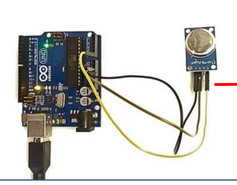


Ideal flow pattern is seen in the Method 2 Sycamore 4 blade fan (a), without much turbulence.

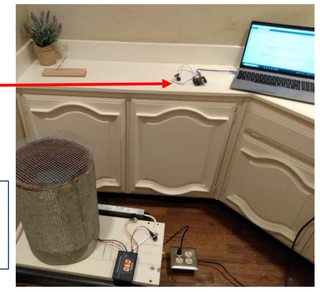
References

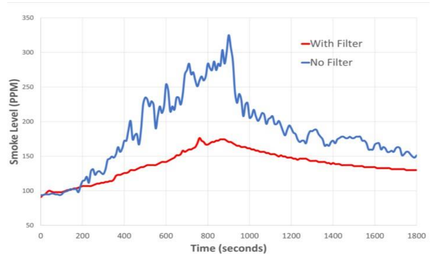
1. Health Effects Institute. State of Global Air 2024. Special Report.Boston, MA:Health Effects Institute. ISSN 2578-6873
2. Domingo, Nina G. G., et al. One Earth 7.2 (2024): 325-35.
3. Rentschler, Jun, and Nadezda Leonova. Nature Communications 14.1 (2023): 4432.
4. Beckwith, T. et al. PLOS ONE. Edited by E. Bartolini, 15(1) 2020, p. e0228092.
5. Currie J et al. Am Econ Rev. 2015 Feb;105(2):678-709
6. US Environmental Protection Agency, Facts and Figures on Materials, Wastes, and Recycling.

Purification Efficiency Experiment

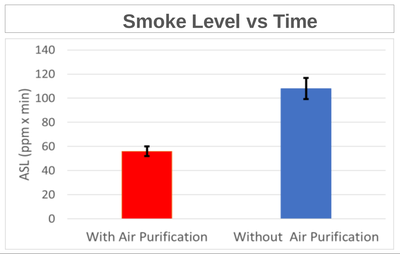


Smoke detector system: Sensor (MQ-135), Arduino Board and Laptop





smoke levels remain significantly lower with the purification unit.



Based on the accumulated smoke level, the efficiency of the air purification system is 48%.

Accumulated Smoke Level with and without Air Purification (3 trials)

Discussion

- **Sycamore 4 Blade fan from Method 2 was more effective and suitable for the air purification system** – produced the highest air speed and air flow and had the best flow pattern,
- Sycamore 4 Blade (Method 2) had an efficiency of 48% within 30 minutes, confirming the air circulation ability of the fan blade in the system.
- In an initial attempt to make the fan blade photos of the Sycamore seed were used. However, this was unsuccessful as the thinnest part of the seed was not detected by the Reality Capture software. Use of a laser or high- resolution scanning technology may help.
- Previous project showed that combination of all three biodegradable material (Snake Plant Fibers + GAC) was the most efficient (81%), and Snake Plant fiber filter alone had the highest efficiency of any filter test independently (67%).
- **In conclusion, the combination of the Method 2 Sycamore 4 Blade fan and the Bio Breeze combination filter in an air purification system has the potential to be implemented as a high efficiency air purifier.**

Future Directions

- Use Computational Fluid Dynamics simulations to further improve the blade design.
- Experiments to evaluate the effect of the pitch and the number of fan blades on the efficiency of air purification
- Explore ways to reduce noise
- Different purifier architectures (currently a cylindrical design) can be explored to investigate the its effect on the purification efficiency.
- Since the fan requires only 30W to operate solar power could be an option.
- A smoke detector could be employed to automatically power on/off the fan when a threshold of smoke level is reached.