Choose Your Own Adventure

How Computer Fan Speed Affects Noise Volume and Spectral Distribution

Denis Koush
ME 105

Hi I’m Denis, and I did my “Choose Your Own Adventure” experiment on computer fan noise because of a few things I had noticed when I adjust the cooling fan speeds.

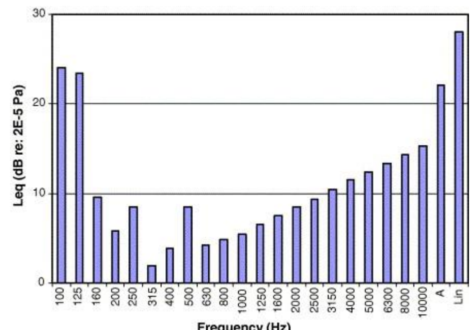
[Word Count: 1042 + text in slides]

Objective

Context: I often adjust my computer's fan speed if I notice my CPU heating up too much. However, the fans get drastically lowder beyond some speed threshold, (>65%). I want to know where exactly that threshold is, how steeply returns diminish, and whether some sound frequencies get louder disproportionately (I've heard that sometimes a transition to turbulent flow causes high pitched whining)

Objective

- Research Question: How does computer fan speed affect noise volume and its spectral distribution?
- Explore the relationship between fan speed and noise characteristics.
- Prior study: [Experimental study of the noise emission of personal computer cooling fans - ScienceDirect]



My experiment aims to answer the research question: How does computer fan speed affect noise volume and its spectral distribution? Understanding this relationship can have practical implications, such as improving the design of quieter, more efficient cooling systems for personal computers.

To explore this, I examined how noise characteristics—like overall loudness and the distribution of frequencies—change with varying fan speeds.

My research builds on prior studies, such as one published on ScienceDirect titled "Experimental study of the noise emission of personal computer cooling fans." That study focused on noise measurement and provided a solid theoretical foundation for analyzing fan noise, with a note of the effect of fan blade harmonics, but my approach dives deeper into frequency-based insights using spectrograms and volume trends of my particular PC rather than a lab setup.

By combining this prior knowledge with experimental data, I aim to provide both practical insights and a better understanding of the physical phenomena underlying fan noise.

Methods

So, how exactly will I achieve this?

Experimental Setup

- Equipment: Microphone, fan, soundproofing materials, data recording setup.
- Procedure:
  1. Measure noise at various fan speeds (100% to 0%).
  2. Short 5-second recordings minimize interruptions.
  3. Analyze volume and spectral data using Python scripts.
- Challenges: Soundproofing, ambient noise interference.

Here’s an overview of the experimental setup and procedure:
For the equipment, I used a microphone to record noise, a standard computer fan, clothes(red) as soundproofing materials to reduce external noise interference, and a data recording setup to automate the process.
The procedure involved measuring noise at fan speeds ranging from 100% down to 0%. I made short 5-second recordings at each speed to minimize the impact of occasional interruptions or loud ambient sounds.
The collected data was analyzed using custom Python scripts to calculate both the average noise volume and its spectral distribution.
A significant challenge was soundproofing the setup to isolate fan noise from ambient noise, such as air conditioning or other background sounds. While soundproofing reduced some interference, ambient noise still posed issues, especially at lower fan speeds.

*point out and describe each component
This method allowed me to collect clean, repeatable data while addressing the limitations posed by noise interference.

Analysis

So, what were the data processing methods I used to derive insights from the recorded audio.

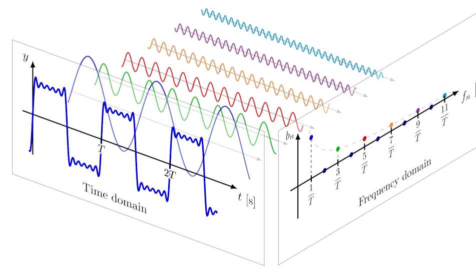
Data Processing

- Volume: Average volume calculated from recordings.
- Spectral Analysis: FFT applied to determine frequency distribution.
- Uncertainty:
  - High precision due to a large dataset.
  - Challenges with lower fan speeds due to ambient noise.

$$L = 20 \cdot log(\ P_r\ )$$

Decibel Conversion

$$\hat{f}(\xi) = \int_{-\infty}^{\infty} f(x)\, e^{-2\pi i \xi x}\, dx$$



Volume analysis: For each recording, I calculated the average noise volume. This gave me a clear view of how the noise level changes as the fan speed varies.

Spectral Analysis: Using Fast Fourier Transform (FFT) with python, I analyzed the frequency distribution of the noise. This allowed me to identify the dominant frequencies and their harmonics, which are key to understanding the tonal characteristics of fan noise at different speeds.

Uncertainty: The large dataset provided high precision in results, reducing uncertainty significantly. However, challenges arose with recordings at lower fan speeds where ambient noise made it harder to isolate fan-generated noise. This prompted further calibration and soundproofing to minimize errors.

Uncertainties

- Measurement uncertainty for microphone
- Propagation for decibel equation
- Nearly identical calculations for spectral power
- The largest source of uncertainty would be external/ambient noise, but this was mitigated

16 bit wav file measurement uncertainty:
$\Delta P = 0.5 * 2\text{^}8\, mV/Pa = 0.128\, dB/V$

Volume equation: $20 * log_{10}(P)$

Volume uncertainty at 100% fan speed

$= \sqrt{\left(\frac{\partial}{\partial P}(20 * log_{10}(P)) * \Delta P\right)^2}$

$= \frac{20}{ln(10) * P}\Delta P$

$= 0.2216\, V * 0.128\, dB/V$

=0.028 dB

Key uncertainties: namely just the the microphone measurement uncertainty and its propagation.

Microphone Sensitivity: Minor variations, especially at low volumes, introduce some uncertainty.
Decibel Conversion: Logarithmic calculations can amplify small errors but were carefully managed.
Spectral Power: Repeated calculations showed high consistency, ensuring reliable frequency data.

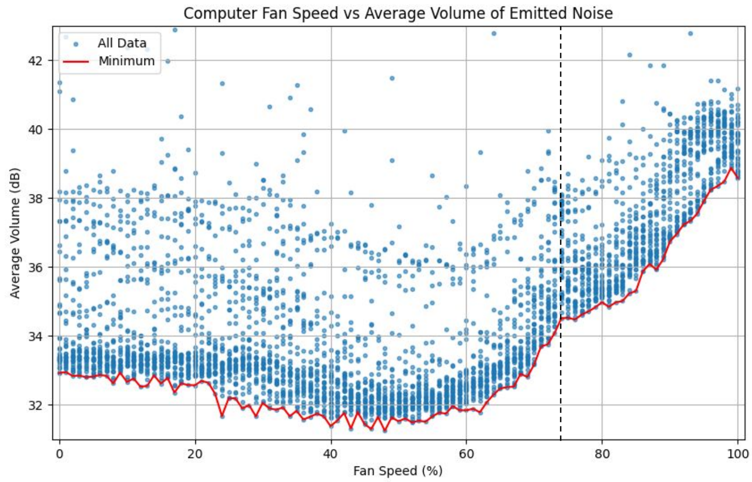
Overall, uncertainties were minimal and did not significantly impact the conclusions. The largest source of uncertainty would be external/ambient noise, but in the next slide I will discuss how this was circumvented.

Results

Let’s have a look at the results.

Volume vs. Fan Speed

- Taking the minimal average volume per fan speed to be representative.
- Linear relationship until fan volume drops below ambient noise (~65%).
- Small lip around 75%
- Calibrated microphone zero at 30.07 ± 0.018 dB



Speaker Notes:

This graph shows the relationship between fan speed and the noise volume measured in decibels.

I am taking the minimum average volume at each fan speed to be representative of the noise from the computer fans, since the recorded noise cannot be any quieter than the fan noise alone. Any louder noises are taken to be coming from surroundings, like passing cars or ambient sound like AC.

The data reveals a roughly linear increase in noise volume starting from about 60% fan speed. This aligns well with the research question by demonstrating how fan speed directly affects noise levels.

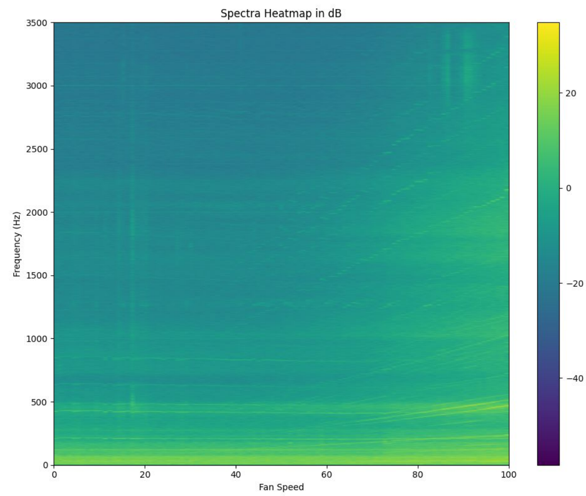
There's a notable dip in the trend around 70–75% fan speed. Interestingly, I've noticed an audible increase in volume in that same range during personal use, which is why I've kept my fan speed around 65% for better sound comfort. This dip could reflect a resonance effect or a subtle shift in how the fan blades interact with airflow.

Another observation is that the noise levels between 20–65% fan speed are unexpectedly lower than at 0% fan speed. Through testing, I discovered that this is due to a small motherboard fan, which my software cannot control. When the main fans slow down, cooling efficiency drops, and the motherboard fan gradually kicks in to compensate, increasing the noise.

baseline for interpreting the data.

Spectrogram Analysis

- Higher frequencies become louder above ~70% speed.
- Diagonal frequency streaks indicate blade rotation harmonics.
- Potential improvements?



This plot showcases the spectral distribution of the recorded noise as a function of fan speed.
High-Frequency Trends: Above ~70% fan speed, higher frequencies disproportionately increase in volume. This correlates with the previous plot, and suggests that faster fan speeds amplify certain tones more than others. Namely:
Harmonic Patterns: The frequency streaks observed in the spectrogram correspond to fan blade rotation and their harmonics, providing clues about the physical behavior of the fan at high speeds.

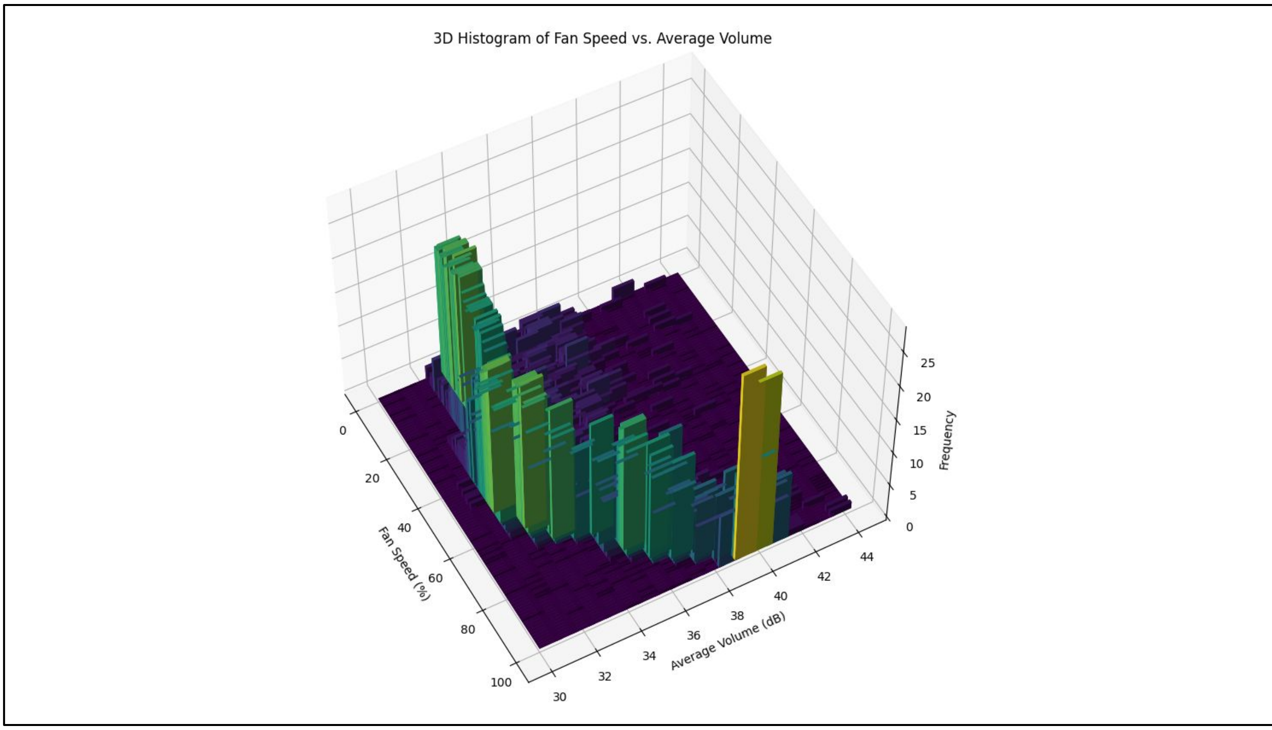
Higher fan speeds result in fan blades moving through the air at higher frequencies, causing proportionally higher noise frequencies.

These findings link fan speed to its spectral fingerprint, showing how noise characteristics evolve with speed.

A few improvements that could be made include: identifying multiple representative recordings per fan speed and taking their average spectra for a clearer spectral heat map. Also, finding a way to control (or just disconnecting) the one fan that my software cannot control, giving a more true-to-life representation of fan speed vs noise.

Questions?

Thank you for listening. Any questions?



3D histogram, to hopefully give a better overview of the distribution of the average volumes.

There was too much code to be included in this appendix, it will be attached as a zip file on Canvas

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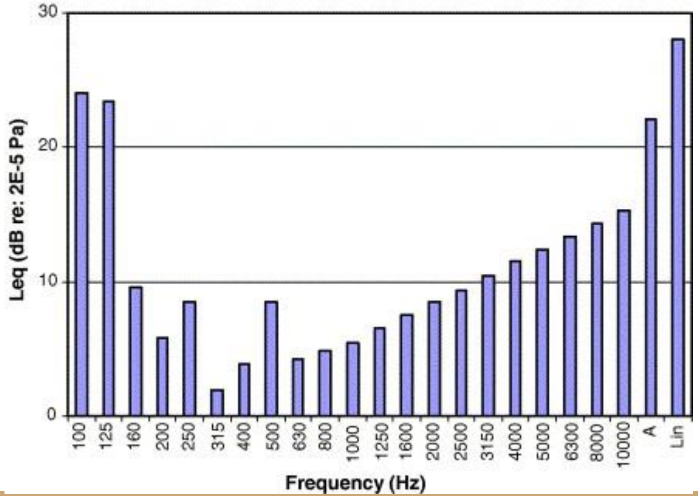

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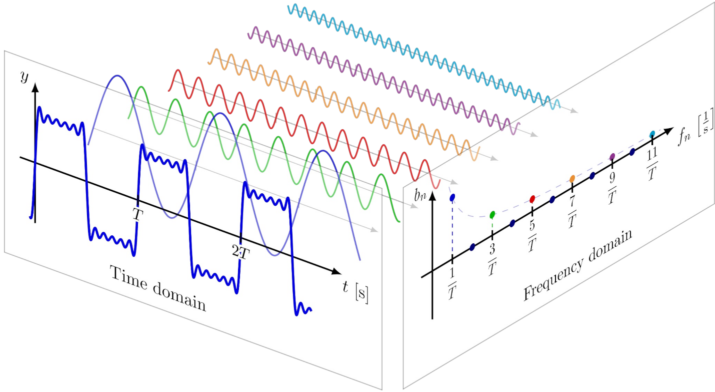

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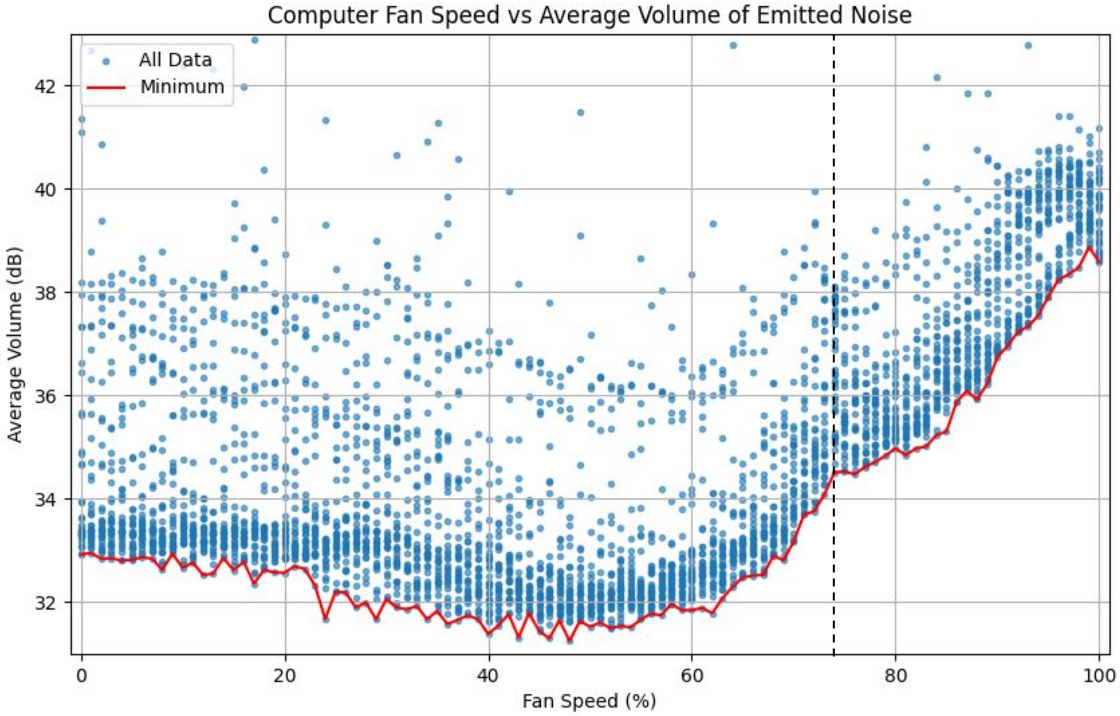

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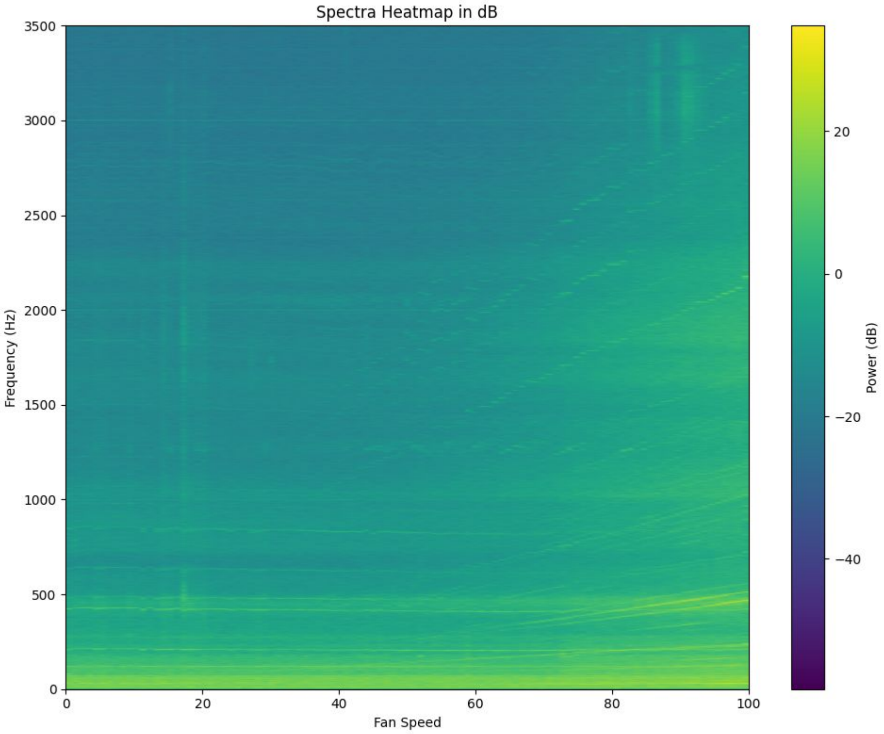
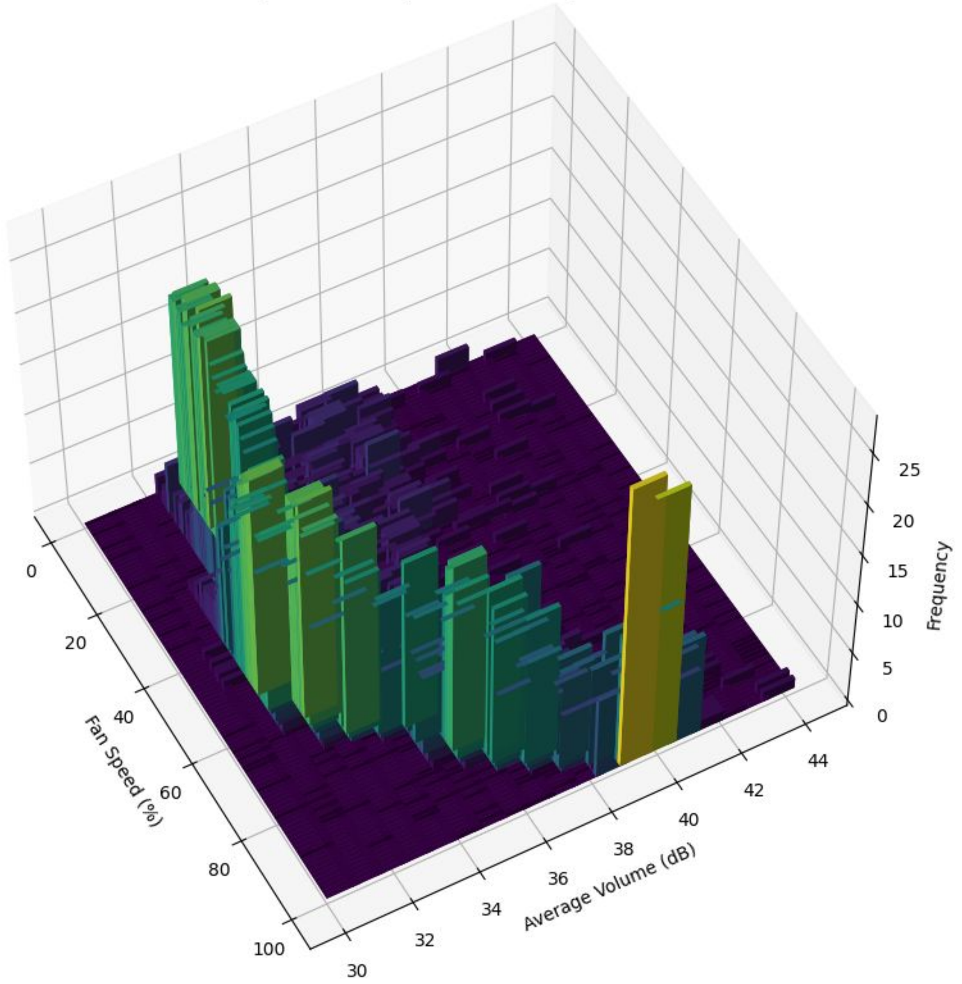


Questions?

3D Histogram of Fan Speed vs. Average Volume



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