Undergraduate Thesis Prospectus

Automatic Plant Watering System Based On Plant Generated Ultrasonic Sounds
(technical research project in electrical engineering)

Dislike your recorded voice? It's not you: How signal filters alter the way women sound and perpetuate gender bias
(sociotechnical research project)

by

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May 10, 2024

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On my honor as a university student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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General Research Problem

How can technological bias against women be remedied?

Implicit technological bias in society occurs because we live in a "default male society", where the idea that men are a default person and women are an outlier perpetuates everyone's daily life. Criado-Perez in her 2019 publication Invisible Women: Data Bias in a World Designed for Men, states that "the result of this deeply male-dominated culture is that the male experience…has come to be seen as universal, while the female experience…is seen as niche". This cultural idea results in anything from "[male] STEM managers…demonstrating implicit in-group gender favoritism in their hiring decisions" (Friedmann 2022) to low "awareness that conventional [cardiovascular disease] risk factors…impact women differently than men" resulting in women receiving "missed and delayed diagnoses of heart disease" (Johnson 2021). This shows that technology and knowledge meant to benefit lives instead reflect the implicit biases of creators and reinforce those cultural beliefs.

Automatic Plant Watering System Based on Plant Generated Ultrasonic Sounds

How can noise at higher frequencies be filtered out without affecting the sensor's ability to correctly read the desired audio information within the same range?

My capstone project is a plant care system that utilizes sensors and a website interface to display sensor information and help plant owners give the best care to their plants. This project is being advised on by Adam Barnes in the electrical engineering department, and being worked on with Audrey Swart, Alex Morris, and Sophia DeCleene. The core piece of our project centers around the processing of ultrasonic signals produced by dry plants. The ultrasonic range of sound waves is slightly higher than the human hearing range, and when a plant is dry, air bubbles in the stem are created and subsequently pop, resulting in a high frequency clicking sound (Khait

2023). The tracking and logging of these sounds can inform an owner on if their plant needs water before the plant begins to show physical signs of distress.

Ultrasonic sounds can also be created by things like buzzing household electronics. A sensor cannot distinguish between sources at the same frequency, so filtering is required to achieve the desired outcome. Our project aims to solve this problem using a two microphone setup, where one microphone is pointed towards the plant and one is pointed away. The difference between the two incoming sounds is just the plant signals and accounts for if the plant microphone picks up any additional high frequency noise. This "spectral subtraction technique" is currently used in some enhanced speech enhancement applications (Nasr 2018).

Another noise filtering technology is a group of techniques called adaptive algorithms. They work by sending the filtered output signal back through a feedback loop where the system can compare the new input signal to the previous output signal and determine if the ratio of frequencies being attenuated needs to be adjusted (Sudhakar 2023). Although this capstone project is applying these filtering concepts to plant care, the ability to easily implement these more advanced filtering methods can have a major impact on sound filtering of the human voice.

This project automates plant care by alerting owners if a plant needs watering and provides a way for the user to automatically water the plant hands free through a button on a website interface.

Dislike your recorded voice? It's not you: How signal filters alter the way women sound and perpetuate gender bias

How are advocates of gender equality striving to mitigate discriminatory biases associated with gender distinctions in the human voice?

In the 1920's voice technology was booming due to the widespread use of the radio (Steinberg 1927). Sound filter designs at the time were limited to mostly analog circuits, which work by filtering out a specific range of frequencies. Recording technology was designed to account for the majority of speakers, who were men, and since women naturally speak at higher frequencies, this past design choice has resulted in decades of encoded gender bias (Steinberg 1927).

Brent Lorenz, a designer for Texas Instruments, wrote an article for the EEtimes explaining why wideband voice technologies are uncommon. Wideband systems require more processing power to reach a wider range of frequencies (Lorenz 2007). Present day industry designers are more inclined to stick with the "Trade-offs in both processing horsepower and the bandwidth required" that the industry has historically made instead of those needed for more equal voice processing (Lorenz 2007).

Allison Smith of Yoga & Voice trains women to speak "like a grown-up" by "entreat[ing] women to talk lower [and] talk slower" so they can be more successful at work. Her reasoning for her work is that "men [have] an undisputed air of authority" due to their "naturally lower tone", and women should emulate this to achieve the same gravitas (Smith, n.d.). She does not mention workplace voice biases that filtering perpetuates. Her business success relies on teaching women to change how they present themselves, not the environment they are presenting in.

The Design Justice Network fights against discriminatory biases and for a design process that includes diverse viewpoints so that developments benefit everyone. Their third core principle is "prioritiz[ing] design's impact on the community over the intentions of the designer", which introduces an idea that a design which reinforces implicit bias is not blameless because a

designer did not intend their technology to be biased, because the real impact of a technology is more important than the original intentions (DJN, n.d.).

The Internet & Television Association, a trade association representing many U.S. broadband companies, lobbies for larger ranges of unlicensed spectrum which allow “portions of spectrum open to any use by anyone, as long as devices follow certain technological rules” (NCTA, n.d.). They state that “unlicensed bands offer the most room to innovate, lowering barriers to entry for new technology” (NCTA, n.d.). This could incentivize companies to pursue wideband technologies, making inclusive tech the norm, as opposed to an add on.

DPAO Microphones is a company founded in 1992 that sells condenser microphones to professional markets(DPAO, n.d.). On their website, they provide information about sound filtering for their customers. One article is Facts About Speech Intelligibility, which states that “a speech spectrum is either high-pass or low-pass filtered” (DPAO, n.d.). Most traditional speech filters are low-pass because higher frequencies are considered undesirable noise. Low pass filters cut out all sound past a certain frequency, and sound near the cut off frequency can drop in intelligibility. DPAO also states that when the cutoff frequency is at “1kHz, the intelligibility is already less than 40%” (DPAO, n.d.). They provide this to inform customers of the benefits of their microphones to increase sales, but another consequence is that consumers become more informed about how recording technologies work with different voices.

Criado-Perez found that Google's version of voice recognition software was 70% more likely to understand a man than a woman (Criado-Perez 2019). Bolton also found that multiple digital data processing methods affected women’s voices differently than men’s, resulting in less understandable women's speech through VoIP (Bolton 2022). Steinberg also acknowledged that women’s consonants especially tend to occur at a higher frequency (Steinberg 1927).

References

Bolton, M. L. (2022). Preliminary evidence of sexual bias in voice over internet protocol audio compression. In M. Kurosu (Ed.), Human-Computer Interaction. Technological Innovation (Vol. 13303, pp. 227–237). Springer International Publishing. doi.org/10.1007/978-3-031-05409-9_17

Criado-Perez, C. (2019). Invisible women: Data bias in a world designed for men. Abrams Press.

DJN (n.d.). Read the principles. Design Justice Network. designjustice.org/read-the-principles

DPAO (n.d.). Fact about speech intelligibility. (n.d.). DPAO Microphones. www.dpamicrophones.com/mic-university/facts-about-speech-intelligibility

Friedmann, E., & Efrat-Treister, D. (2023). Gender bias in stem hiring: Implicit in-group gender favoritism among men managers. *Gender & Society*, 37(1), 32–64. doi.org/10.1177/08912432221137910

Johnson, G. M. (2021). Algorithmic bias: On the implicit biases of social technology. *Synthese*, *198*(10), 9941–9961. doi.org/10.1007/s11229-020-02696-y

Johnson, H. M., Gorre, C. E., Friedrich-Karnik, A., & Gulati, M. (2021). Addressing the bias in cardiovascular care: Missed & delayed diagnosis of cardiovascular disease in women. *American Journal of Preventive Cardiology*, *8*, 100299. doi.org/10.1016/j.ajpc.2021.100299

Khait, I., Lewin-Epstein, O., Sharon, R., Saban, K., Goldstein, R., Anikster, Y., Zeron, Y., Agassy, C., Nizan, S., Sharabi, G., Perelman, R., Boonman, A., Sade, N., Yovel, Y., & Hadany, L. (2023). Sounds emitted by plants under stress are airborne and informative. *Cell*, *186*(7), 1328-1336.e10. doi.org/10.1016/j.cell.2023.03.009

Lorenz, B. (2007). Wideband vs. Narrowband VoIP Codecs. EE Times.

Nasr, M. A., Abd-Elnaby, M., El-Fishawy, A. S., El-Rabaie, S., & Abd El-Samie, F. E. (2018). Efficient implementation of adaptive wiener filter for pitch detection from noisy speech signals. *Menoufia Journal of Electronic Engineering Research*, *27*(1), 109–126. doi.org/10.21608/mjeer.2018.64399

NCTA (n.d.). Internet and Television Association. Future of wi-fi | ncta—The internet & television association www.ncta.com/positions/spectrum-wifi

Smith, A. (n.d.). How to talk like a grown woman. Yoga & Voice www.yogaandvoice.com/2021/06/04/how-to-talk-like-a-grown-woman

Steinberg, J. (1927). Understanding Women. *Bell Laboratories Record*.

Venkata Sudhakar, M., Prabhu Charan, M., Naga Pranai, G., Harika, L., & Yamini, P. (2023). Audio signal noise cancellation with adaptive filter techniques. *Materials Today: Proceedings*, *80*, 2956–2963. doi.org/10.1016/j.matpr.2021.07.080