Sonification Techniques and Fibonacci Series

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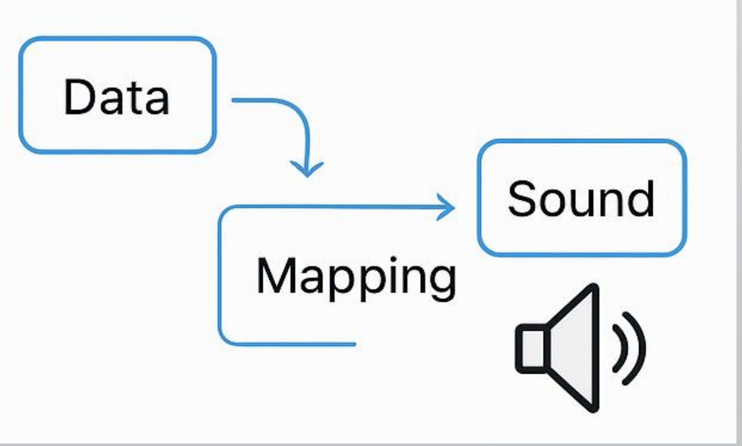
Contents

Introduction to Sonification

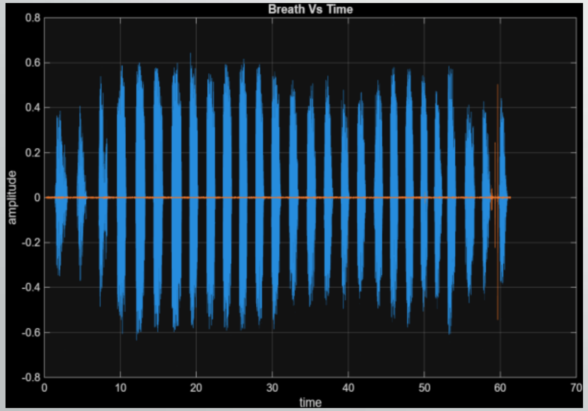
- Conversion of data into sound for analysis and perception.
- Mainly used when visual patterns are hard to interpret; sound can help detect anomalies.
- <u>Different Techniques</u>:
  - **Parameter Mapping Sonification**: Map data parameters (frequency, amplitude, etc.) to sound parameters (pitch, volume, timbre).
  - Audification → speed up data so it becomes audible (used in seismic/EEG).
  - Model-Based Sonification (MBS) → treat data as a "physical object" that produces sound when interacted with. (Ex. Virtual bell)
  - Musification → map data into structured music (scales, chords).
- <u>Applications</u>:
  - Automotive
  - Aerospace
  - Medical
  - Gesture-controlled Music, stock market analysis, etc.
  - novel interfaces for visually impaired people

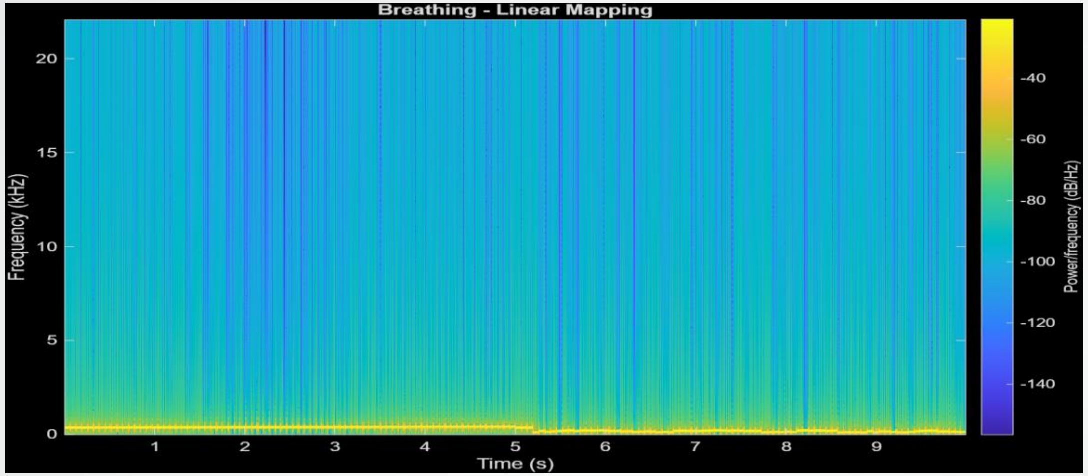


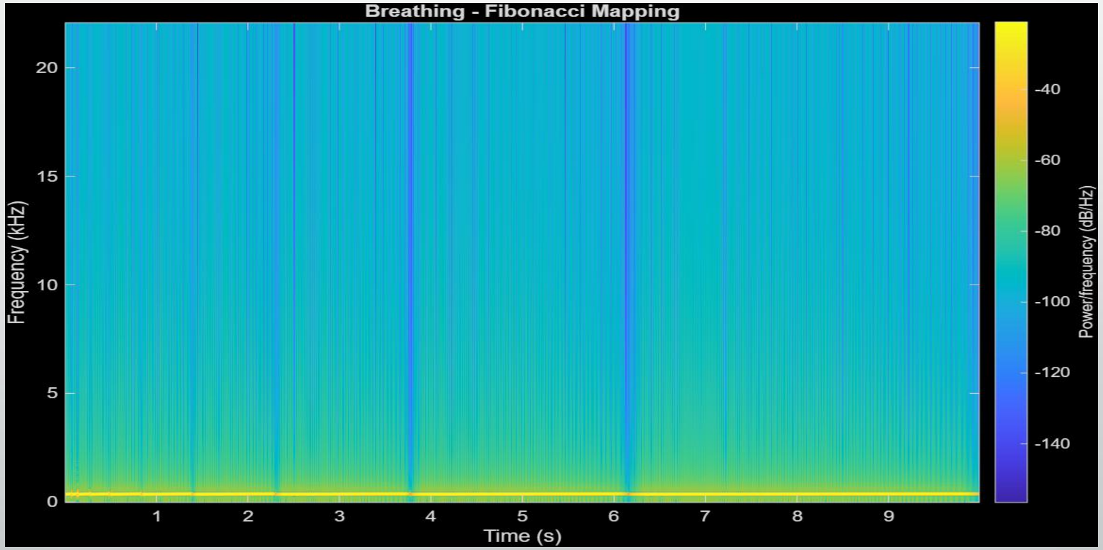
Breathing

Spectrograms

Phone Recorder







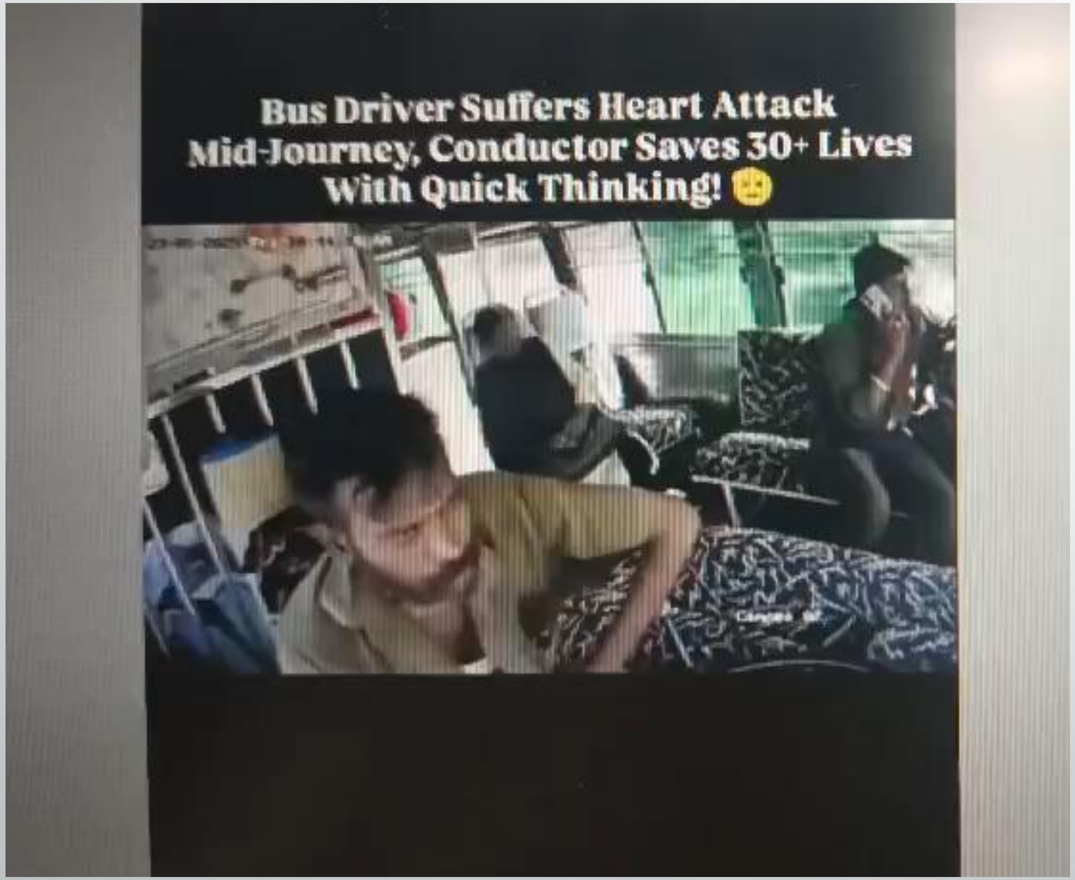
Sonification

Linear

Fibonacci

Van Kerrebroeck B and Maes P-J (2021) A Breathing Sonification System to Reduce Stress During the COVID-19 Pandemic. Front. Psychol. 12:623110. doi: 10.3389/fpsyg.2021.623110

Automotive Application: Motivation



Odisha Bytes

Odisha Driver’s Quick Action Saved Over 40 Lives Moments Before Succumbing To Cardiac Arrest

Bhubaneswar: Showing his presence of mind and quick action, a bus driver saved the lives of more than 40 passengers onboard after...

1 day ago

Hindustan Times

KSRTC bus driver saves passengers while suffering fatal heart attack in Bengaluru: Report | Bengaluru

A KSRTC driver died after suffering a heart attack while driving. He safely stopped the bus, ensuring passengers' safety before collapsing.

1 month ago

The Indian Express

PMPML bus driver suffers heart attack while driving, police administers CPR helping save his life

As the passengers screamed for help, the constables entered the car and pulled the driver onto the curb with the help of other passengers ... A...

26 Aug 2025

India Today

Video: Rajasthan driver passes steering to helper, collapses, then dies

Satish Rao, a bus driver on the Jodhpur–Indore route, suffered a fatal heart attack. His quick decision to hand over control to a colleague...

29 Aug 2025

Existing Solutions

Ref: https://www.netradyne.com/in

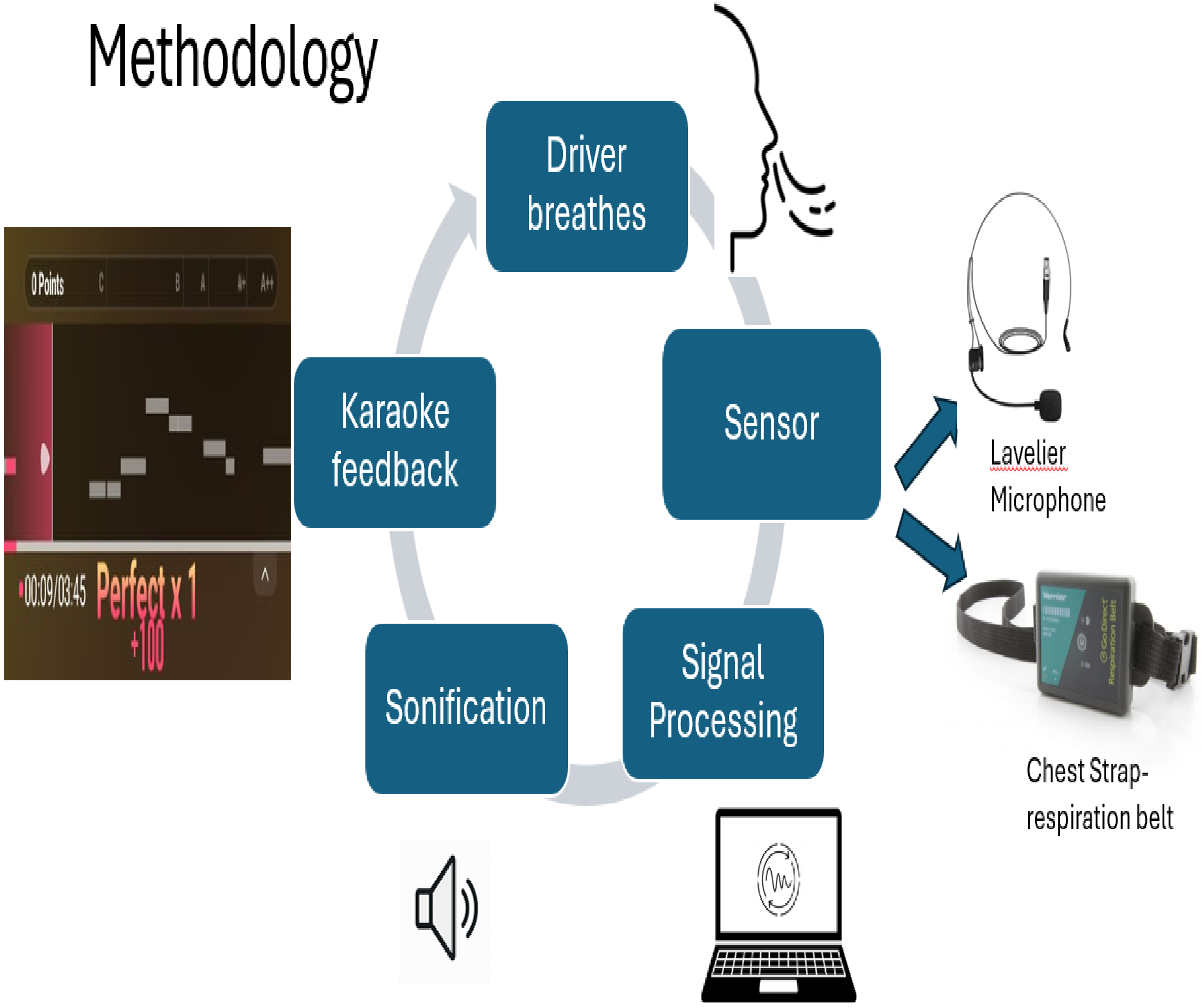
Breathing Sonification for Early Detection of Driver Fatigue and Cardiorespiratory Stress

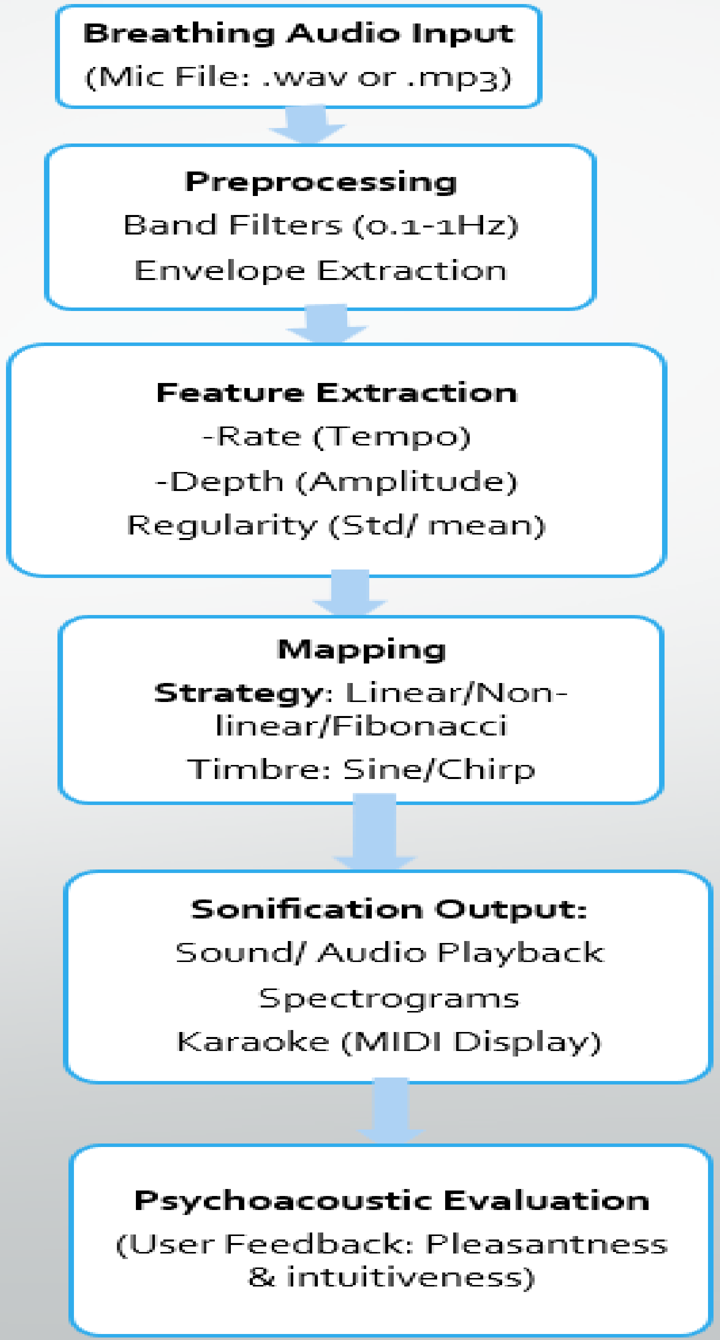
- **Single physiological signal (breathing)** can reveal multiple risk conditions:
  - Early fatigue and drowsiness (irregular, shallow breathing).
  - Stress and panic (short, fast, arrhythmic breathing).
  - Impending cardiac problems (changes in respiration pattern, apnea events, or coupled HR irregularities).
- “Normal values (eupnea) range from 12 breaths/min to 20 breaths/min in adults” (Ref [2])

Objective & Scope

- Develop interactive Real-time Live-Demo
- Compare Fibonacci, Linear and Non-linear Mappings by
  - **Signal/spectral Metrics:** Analyzing the audio signal itself for clarity and distinctness.(computed from simulated breath patterns)
  - **Subjective Ratings:** Gathering user feedback on which mapping feels more intuitive and pleasant.

Methodology

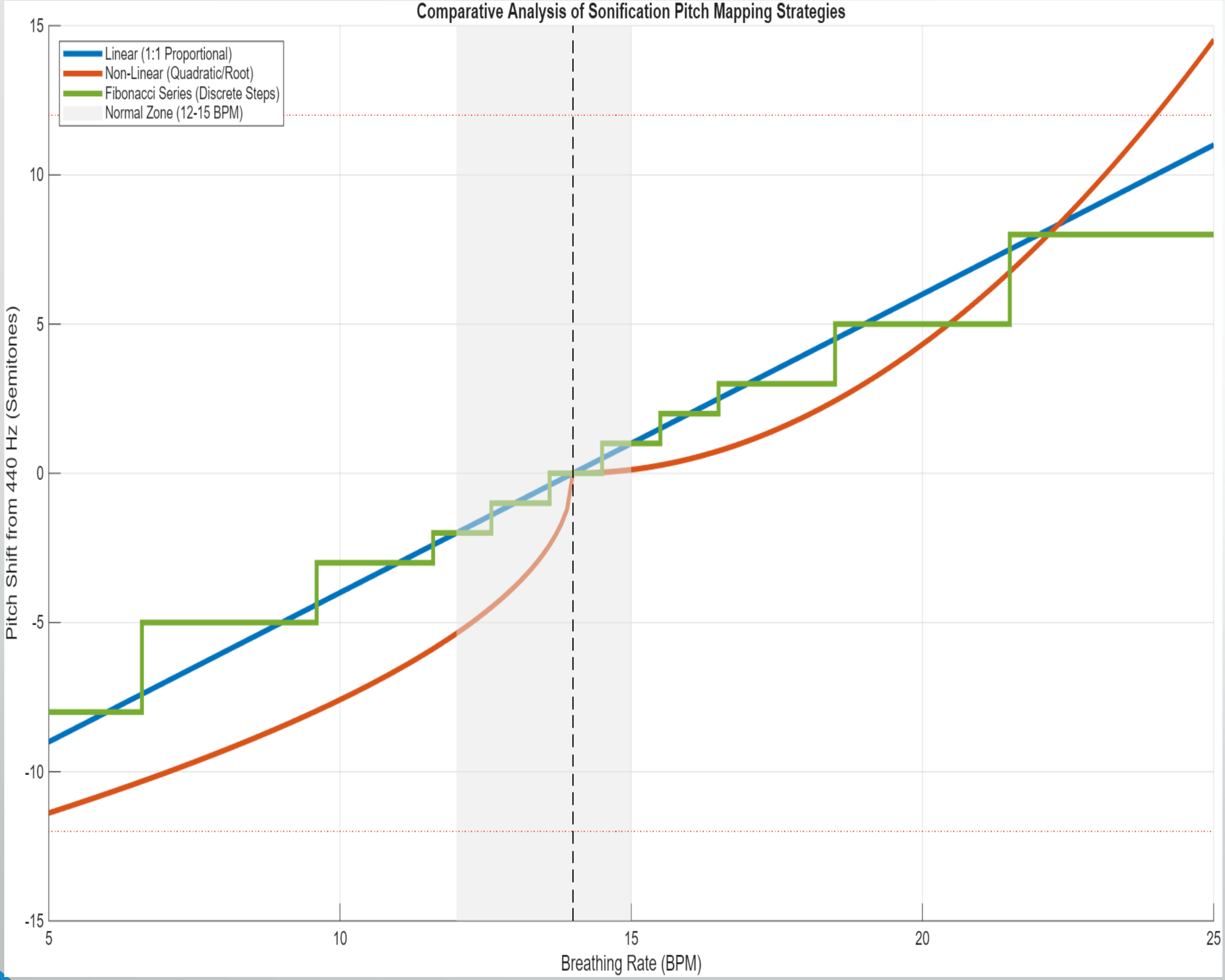




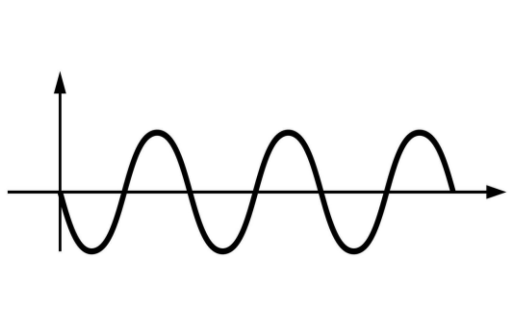
Parameter Mapping strategy

Input Range	Driver State	Linear Mapping	Non-linear	Fibonacci Series	Perceptual result
BPM ~ 14	Normal	Shift ~0	Shift ~0	Shift~0	**Neutral**, unobtrusive tone (A4)
BPM < 14	Fatigue/ Drowsiness	Shift= Deviation*1	Shift=-12 * [abs(Deviation/10)^0.5]	Shift=Fibonacci_interval *Deviation	**Pitch drops** sharply (warning)
BOM > 14	Stress	Shift= Deviation*1	Shift=12 * [(deviation/10)^2]	Shift=Fibonacci_interval *(-1)*Deviation	**Pitch rises** sharply (warning)

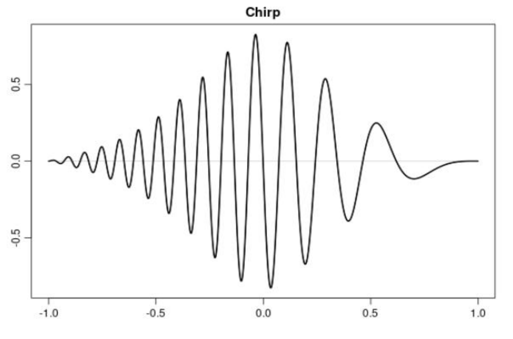
Parameter Mapping strategy



Timbre

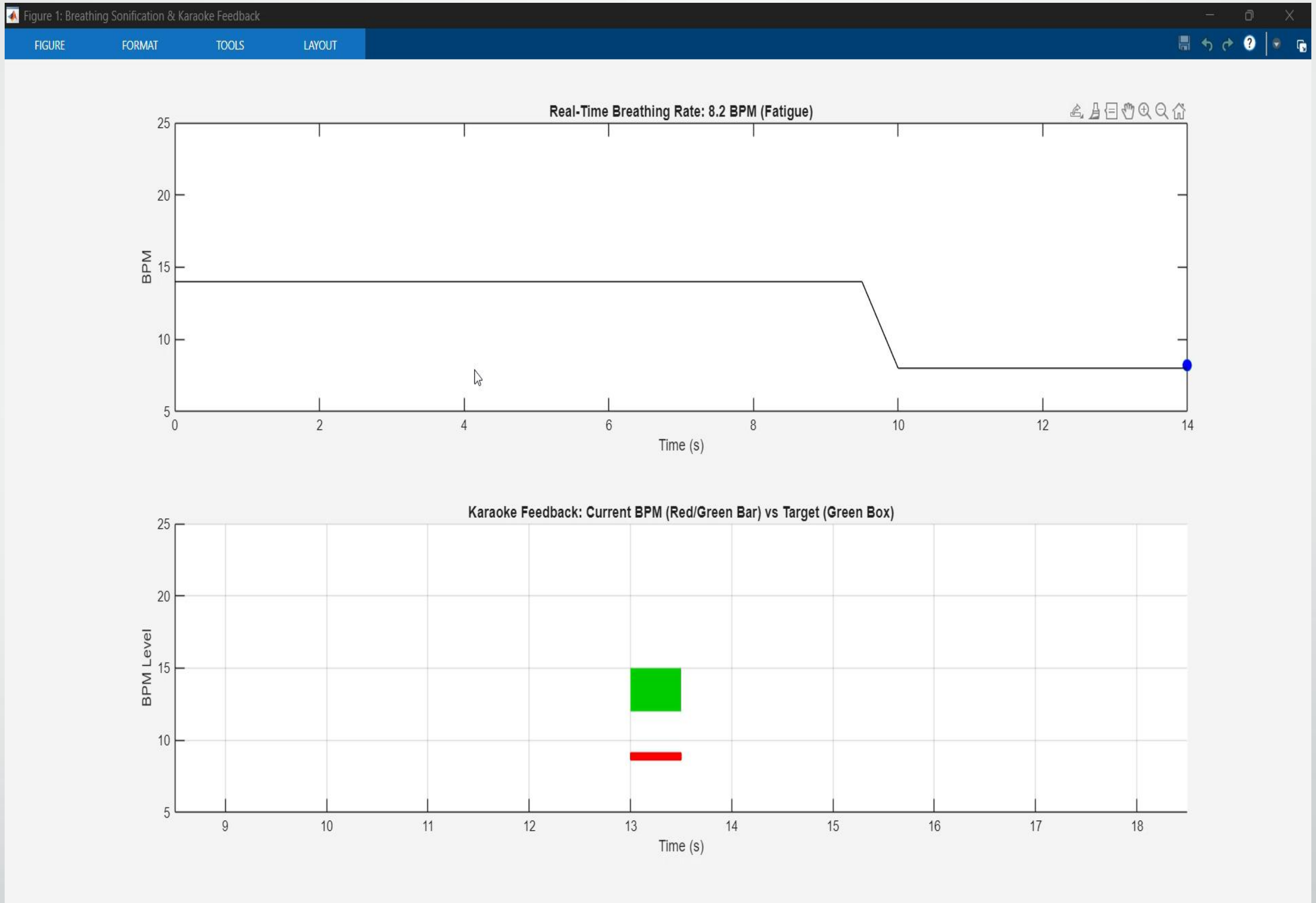


Sine Wave Form



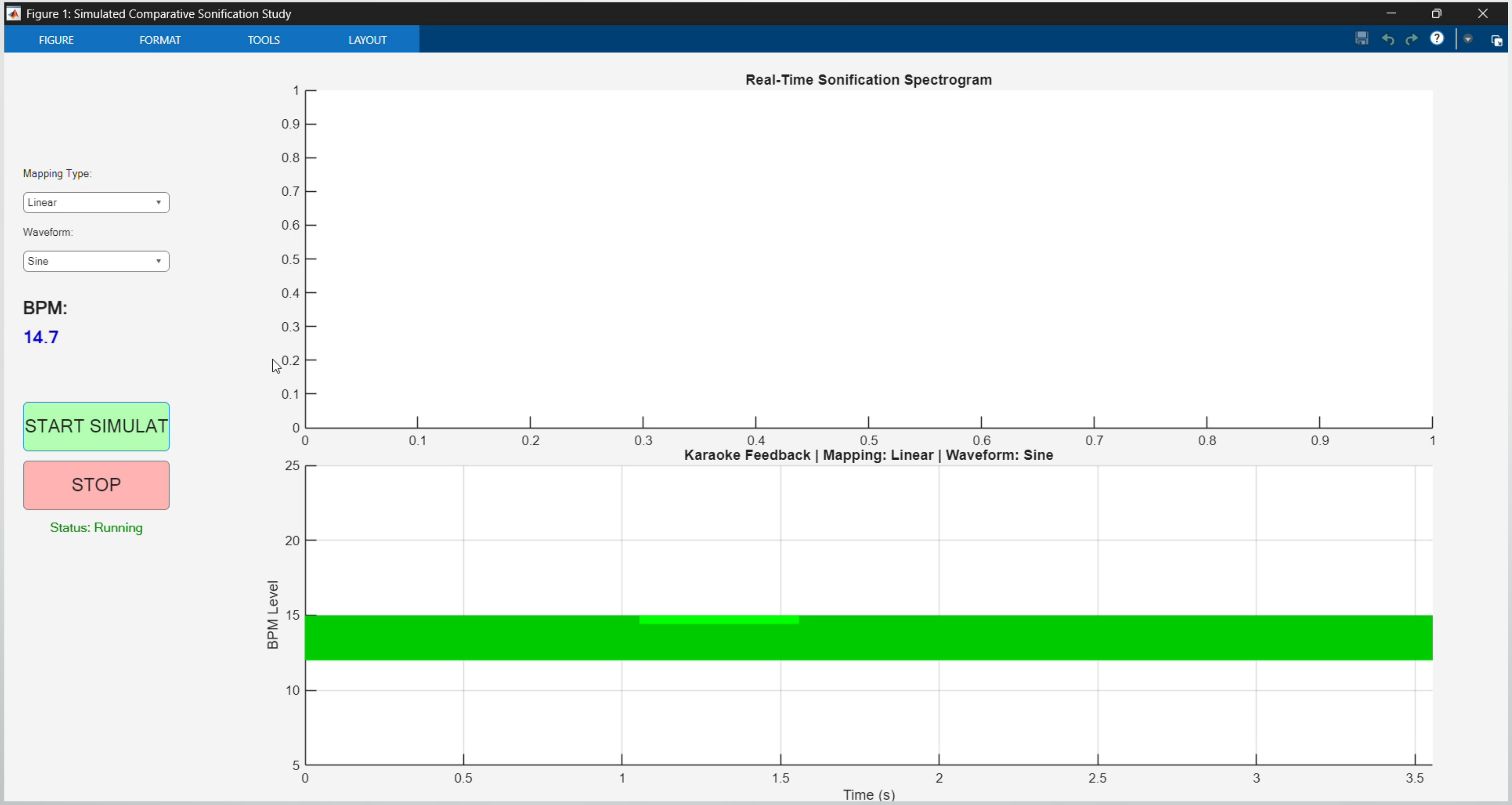
Sine Wave Form

Core Sonification-Karaoke Idea



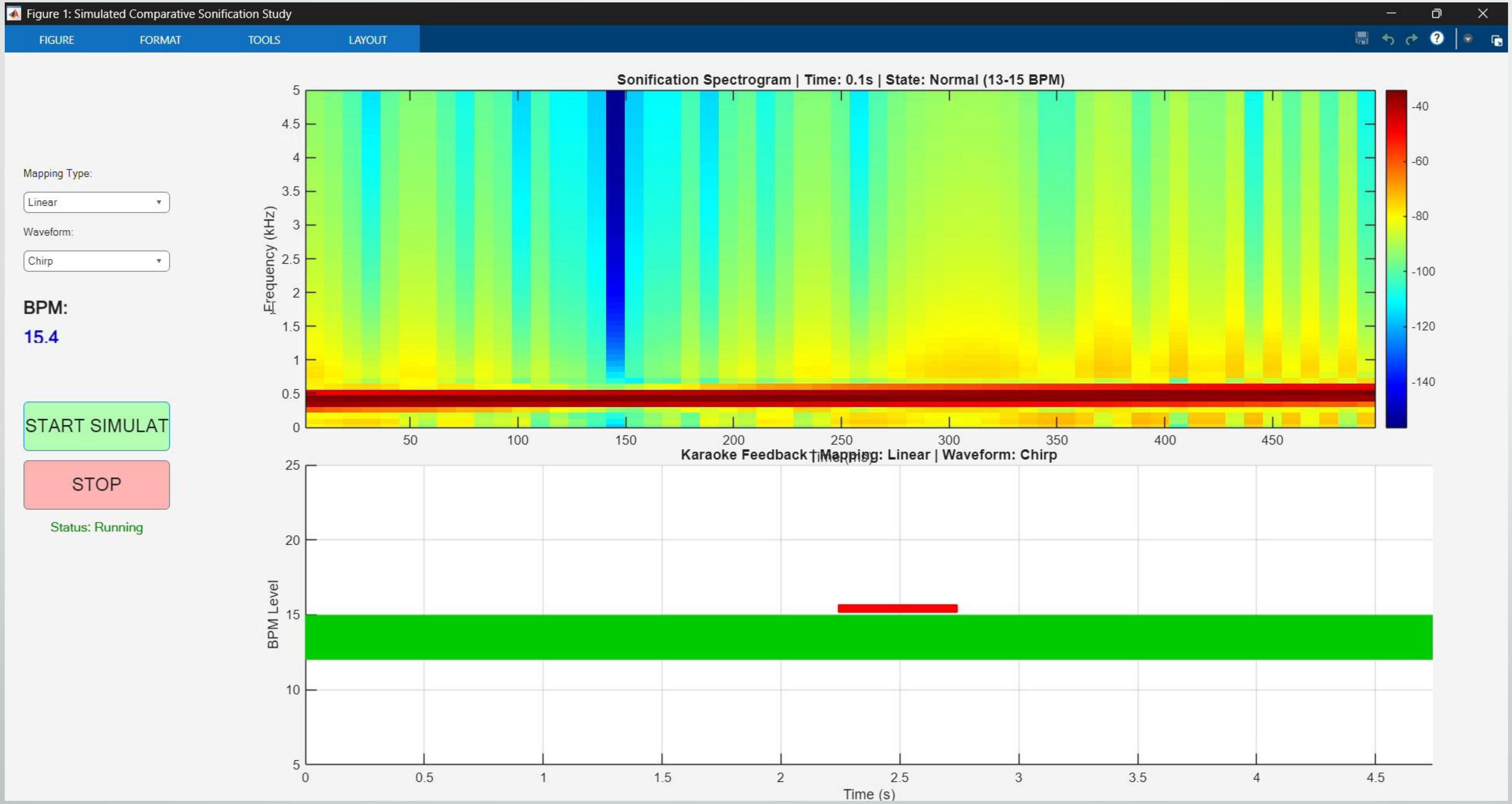
[REAL-TIME BREATHING SONIFICATION CORE SCRIPT (Matlab)]

Real-time Simulated Breathing Sonification Linear-Sine

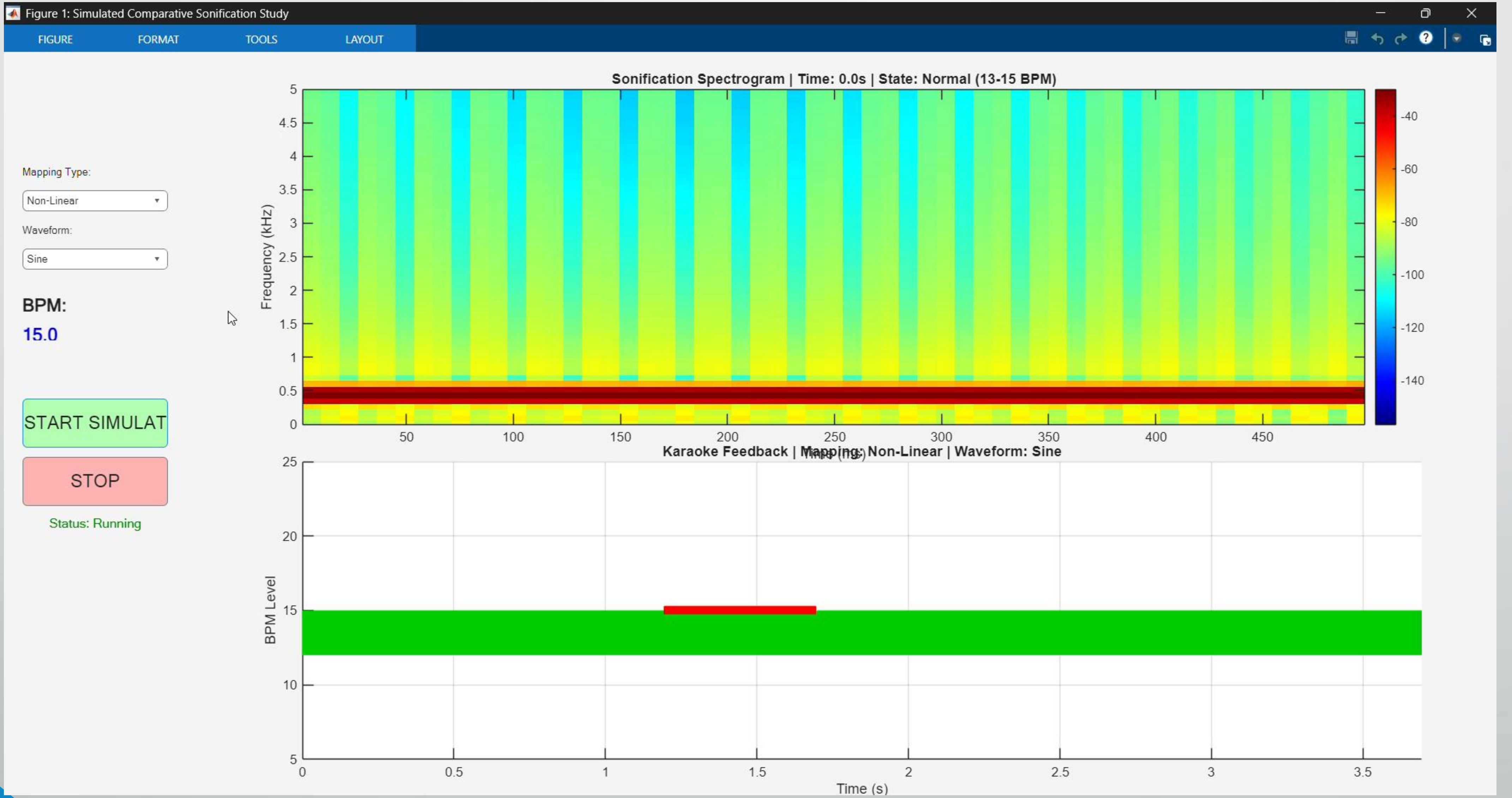


SIMULATED_SONIFICATION_APP.M
Simulated Comparative Sonification Study App for Breathing Rate (BPM)

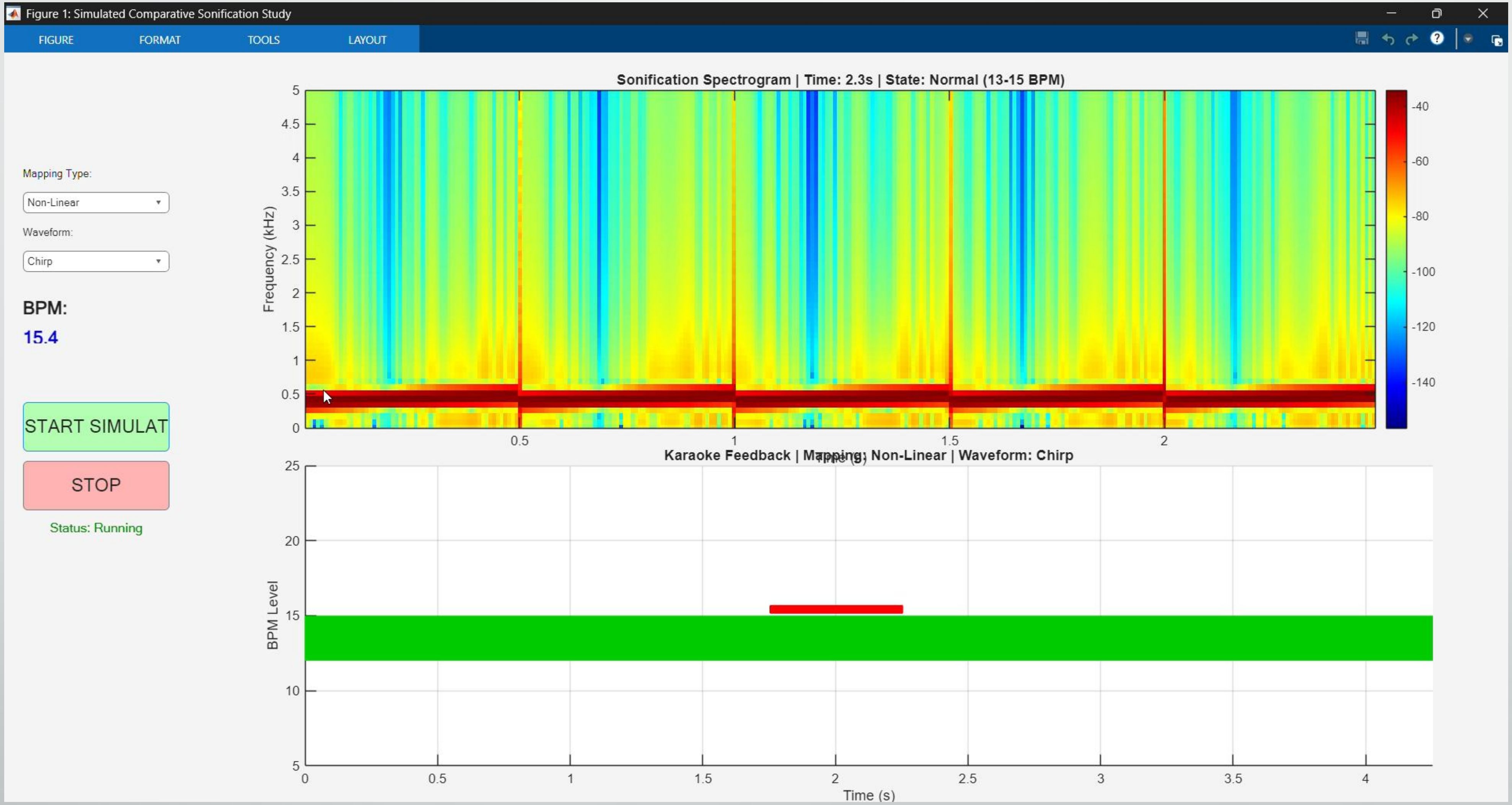
Linear-Chirp



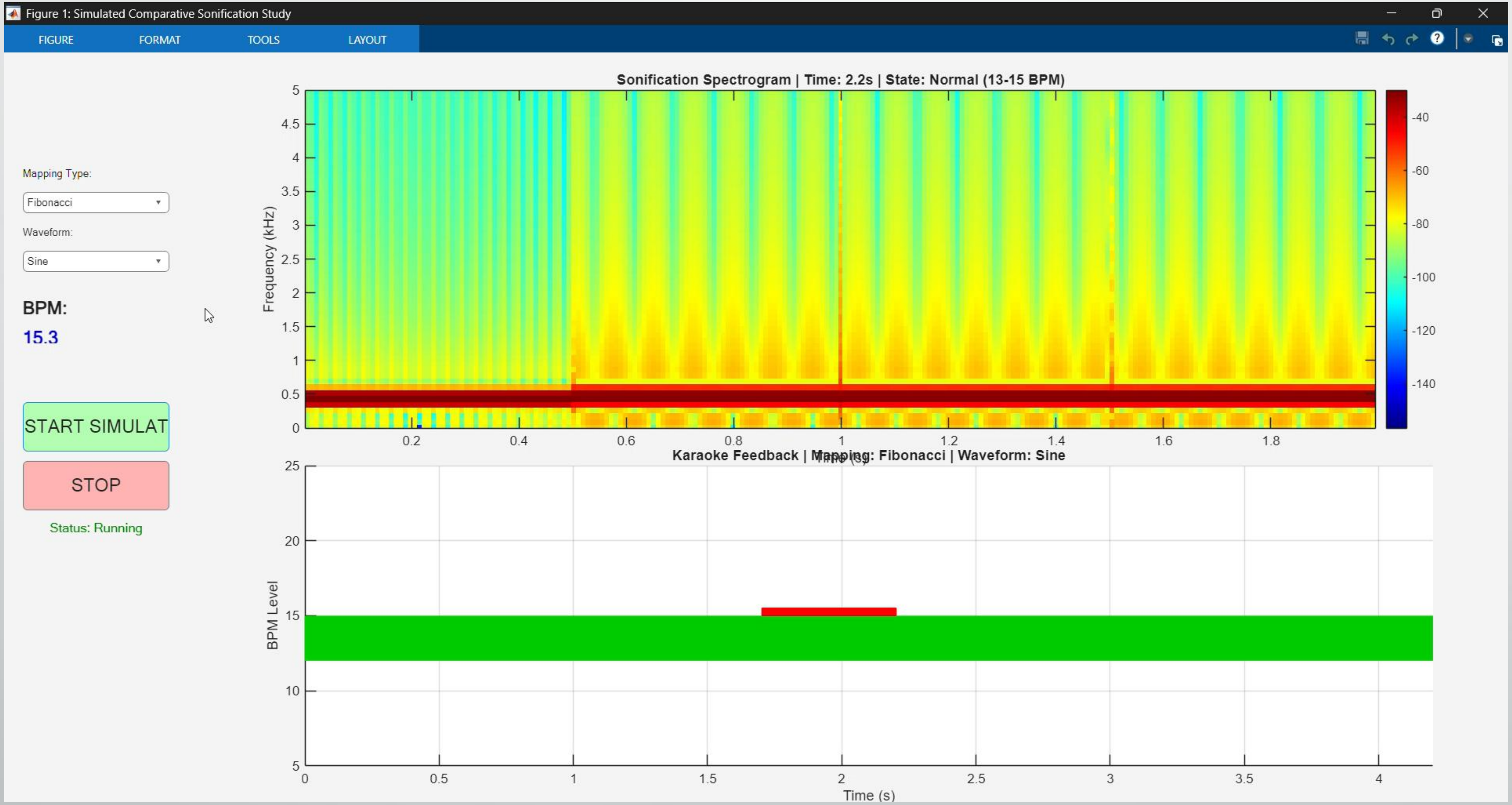
Non-Linear-Sine



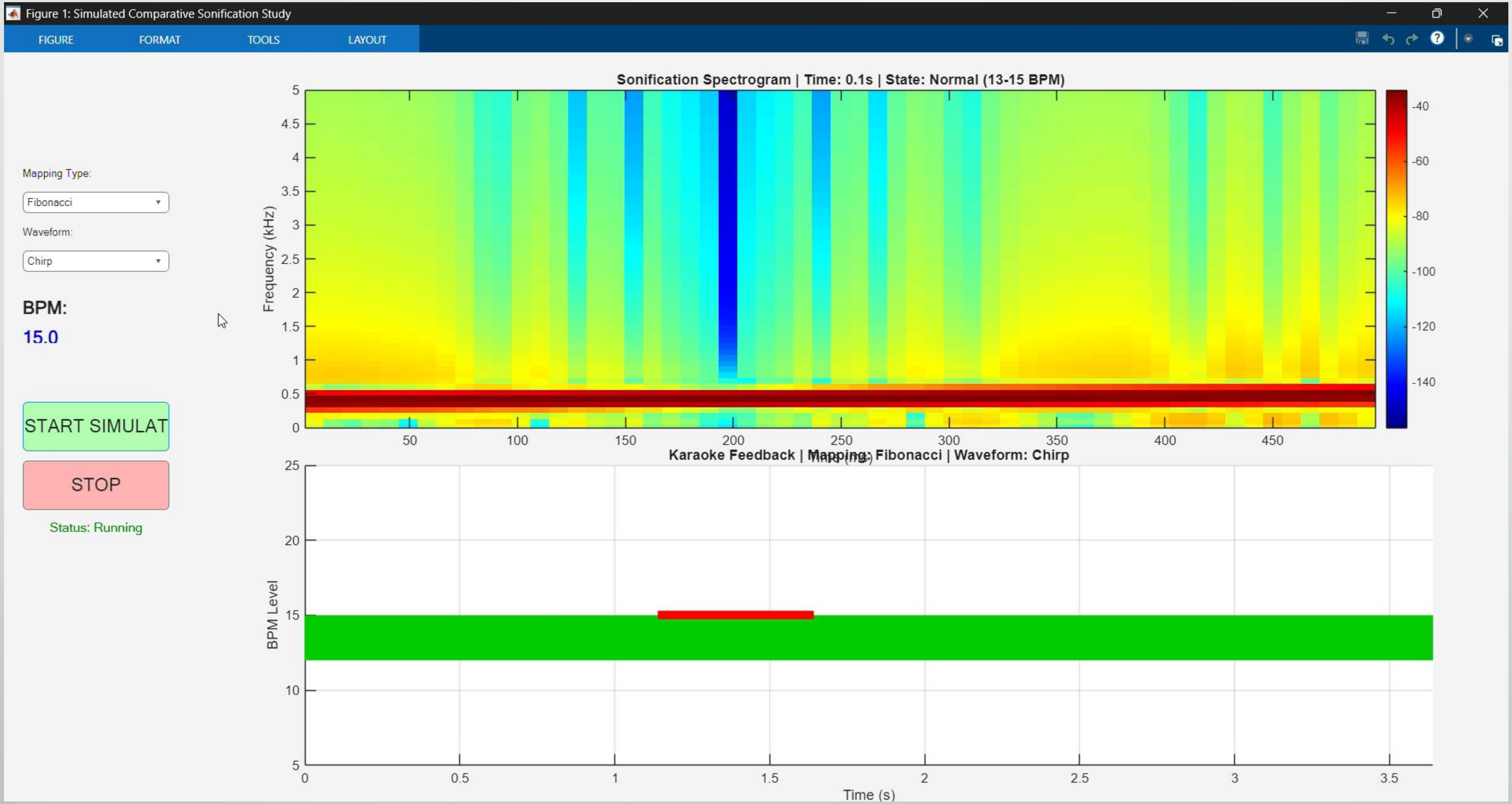
Non-Linear-Chirp



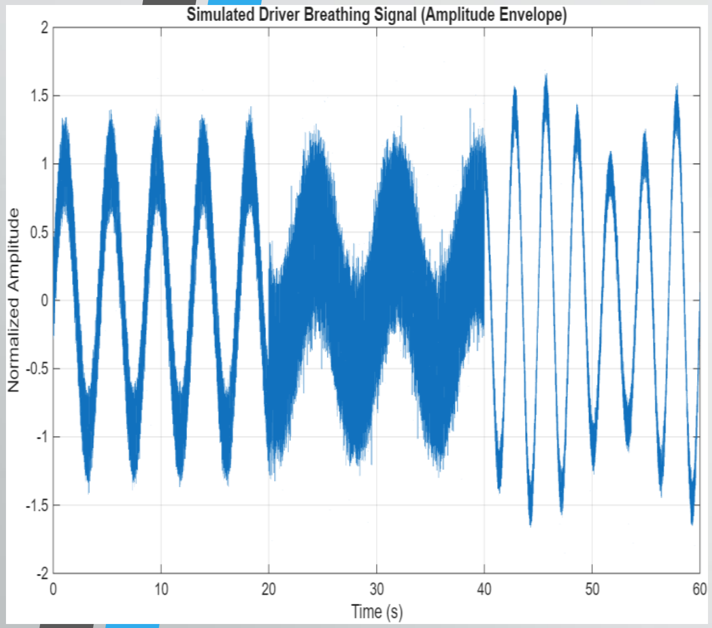
Fibonacci Sine

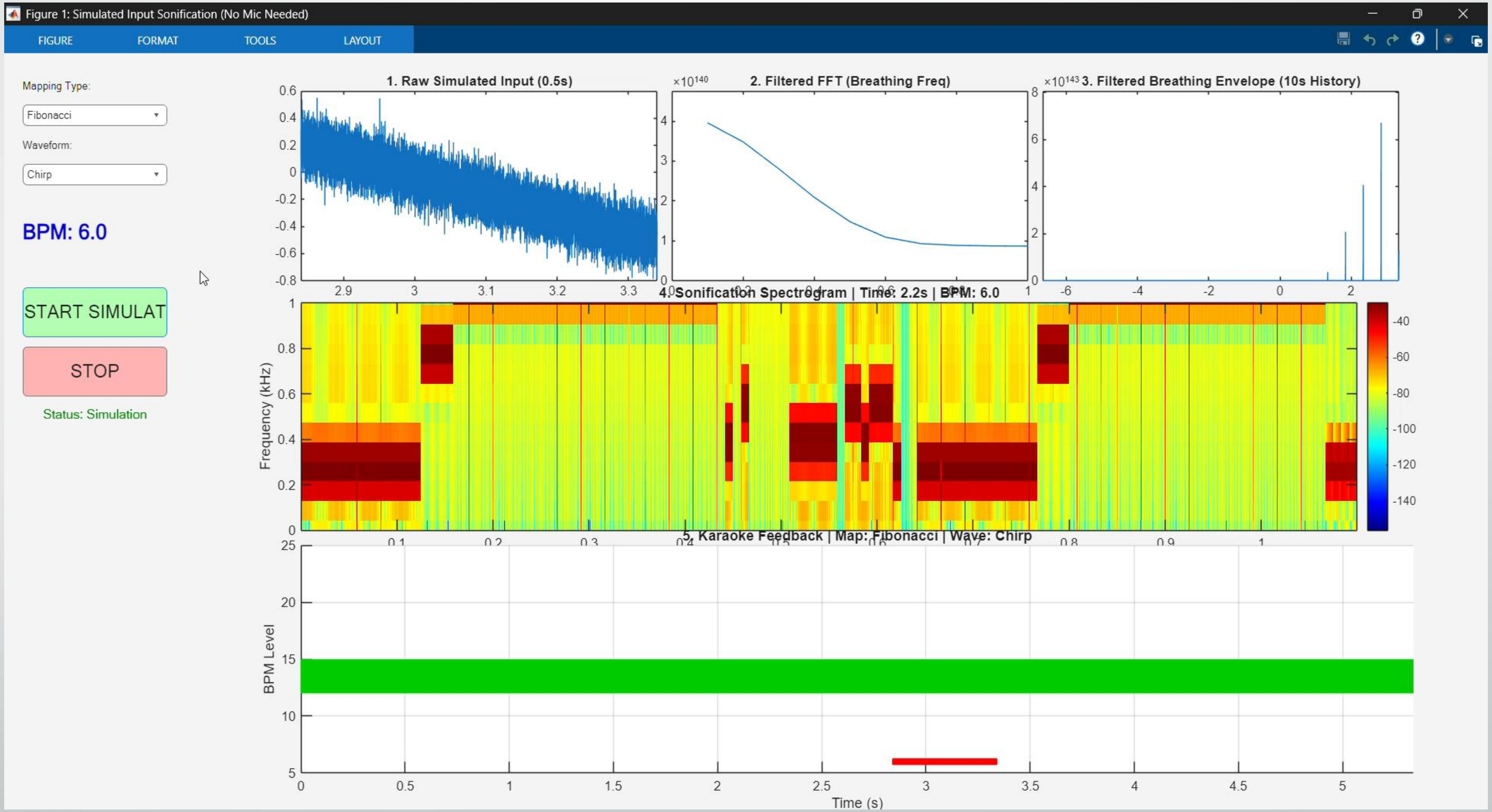


Fibonacci-Chirp

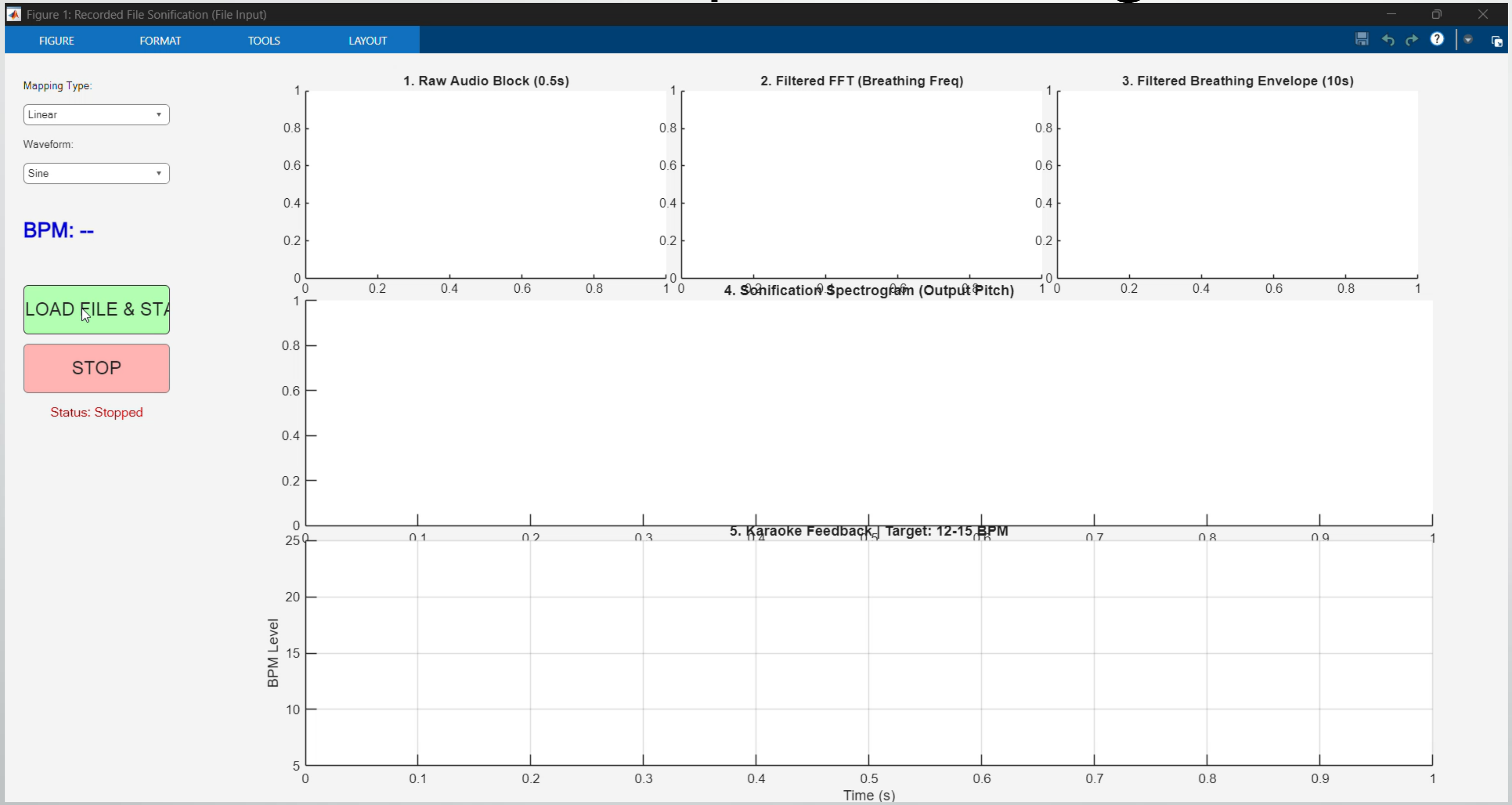


Simulated Audio Input Real time Breathing sonification





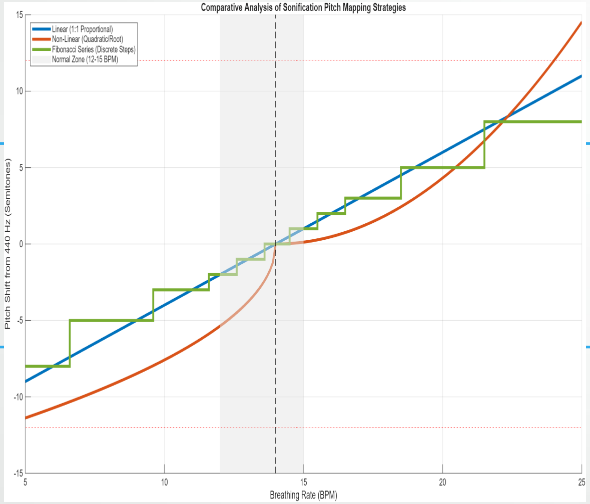
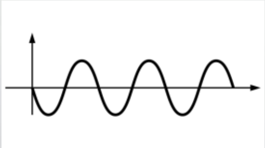
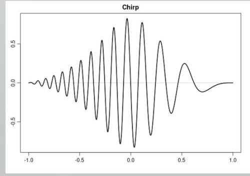
Recorded Audio Input Breathing sonification



Analysis

- The envelope of recorded breathing shows irregularity compared to the smooth reference.
- Spectrogram indicates reduced periodic energy at low frequencies during fatigue simulation.
- FFT plot highlights additional harmonics and noise components.

Comparative Analysis

Design Parameter	Type		Inferred Perceptual Impact	Ideal Application
Pitch Mapping	**Linear**	 	**Highest Tonal Clarity**; provides predictable, immediate magnitude of deviation.	Acute, high-stakes alerts requiring **rapid cognitive response**.
	Non-Linear		**Progressive Warning**; low intrusion near target, but aggressively escalating shift at extremes.	Balancing **low intrusiveness** with a strong, unmistakable critical warning.
	Fibonacci Series		**Harmonic & Less Dissonant**; highest potential for perceived "musical" quality and comfort.	**Self-regulation** and long-term biofeedback to maximize user acceptance.
Waveform	**Sine**		**Pure Tone & Minimalist**; isolates the pitch variable, maximizing the clarity of the warning signal.	Applications where **pitch change is the only required cue**.
	Chirp	 	**Textured Tone & Ambient**; reduces auditory fatigue and promotes long-term listening comfort.	**Continuous background monitoring** over extended periods of driving.

Conclusions

- The study demonstrates that sonification is not a single concept, but a set of design choices. The optimal system for driver fatigue is likely a **hybrid model**.
- A **Chirp Waveform** (for long-term comfort) combined with a **Non-Linear Mapping** (for low intrusiveness + high-urgency warnings) may provide the most effective real-world balance between driver comfort and critical safety alerts.

Limitations of Sonification and Karaoke Feedback

Category	Limitation	Impact/Explanation
Noise Sensitivity	Cabin noise	Need adaptive filters / directional mic
User Adaption	Drivers might habituate to constant sound or find it distracting	Sonification must be subtle
Latency	Filtering + sonification may cause slight delay	Needs efficient real-time implementation
Aesthetic Tuning	Sounds may be unpleasant or confusing if mapping not intuitive.	Subjective design challenge
Evaluation Difficulty	Measuring "understanding" or "comfort" of sound is subjective.	Needs quantitative (signal) and qualitative (user rating) evaluation
Karaoke-style Feedback	Requires visual interface + auditory cue simultaneously.	Can overload driver, useful in training and guided calming techniques

Comparison

Aspect	Camera Based DMS	Audio-Based
Hardware Cost	High (Rs. 20k-25k)	Very low (Rs. 2k-5K)
Processing Cost	Heavy computation	Lightweight
Environmental Robustness	Affected by lighting (eg. night glare, driver position)	Affected by Cabin Noise (Needs noise filtering and microphone placement optimization)
User Privacy	Concern-Continuous face recording	Less Intrusive
Feedback to Driver	Mostly alert based After Fatigue	Continuous self-regulation, early detection of fatigue

Future Work

- In-vehicle testing, ML classification of fatigue states, integration with ADAS.
- Can be extended to breath training apps (for mindfulness, stress relief and sleep. Also beneficial for athletes, swimmers, singers, etc.)
- Karaoke framework can also be adapted to other applications using Sonification as comparative audio feedback model where a *live or simulated signal* is audibly compared to a *reference (healthy or ideal) pattern*.

References

1. Hermann, T., Hunt, A., & Neuhoff, J. G. (Eds.). (2011). The Sonification Handbook. Logos Publishing House.
2. Nicolo, A.; Massaroni, C.; Sacchetti, M.; Schena, E.; and coworkers. "The Importance of Respiratory Rate Monitoring." *Sensors* **2020**, *20*(21), 6396. DOI: 10.3390/s20216396.
3. Peyre, I., Roby-Brami, A., Segalen, M., Giron, A., Caramiaux, B., Marchand-Pauvert, V., Pradat-Diehl, P., & Bevilacqua, F. (2023). *Effect of sonification types in upper-limb movement: A quantitative and qualitative study in hemiparetic and healthy participants*. *Journal of NeuroEngineering and Rehabilitation, 20*, 136. https://doi.org/10.1186/s12984-023-01248-y
4. Van Kerrebroeck, B., & Maes, P.-J. (2021). *A breathing sonification system to reduce stress during the COVID-19 pandemic*. *Frontiers in Psychology, 12*, 623110. https://doi.org/10.3389/fpsyg.2021.623110
5. In-Vehicle Sonification Prototyping Tool for Driver State and Performance Data, Adjunct Proceedings of the 8th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (Automotive UI '16), October 24–26, 2016, Ann Arbor, MI, US
6. Frühholz, S., Trost, W., Péron, J., Grandjean, D., & Zatorre, R. J. (2020). *Neural dynamics of karaoke-like voice imitation in singing performance.* **NeuroImage, 209**, 116517. https://doi.org/10.1016/j.neuroimage.2019.116517
7. Dasa, S. (2024). *Karaoke singing as music therapy: Impact on mental health, anxiety, cognition, and social well-being.* **International Journal of Multidisciplinary Research and Development, 11**(2), 45–51.

Thank you