# Graph Eigenvalue Sound Generator: README

## 1 Introduction

This document serves as a README for a Python script that generates sound and visuals based on graph eigenvalues. It uses various libraries such as NetworkX for graph analysis, sounddevice for sound generation, Matplotlib for plotting, and Streamlit for the layout.

## 2 Graph Eigenvalues

For a graph $G$, eigenvalues ($\lambda$) of its adjacency matrix $A$ are obtained by solving the characteristic equation:

$$\det(A - \lambda I) = 0$$

The eigenvalues can also be computed for the normalized Laplacian and modularity matrices.

### 2.1 Normalized Laplacian Spectrum

The normalized Laplacian spectrum is defined as:

$$L = D^{-1/2} A D^{-1/2}$$

### 2.2 Modularity Matrix

The modularity matrix $B$ is defined as:

$$B = A - \frac{k \times k}{2m}$$

where $A$ is the adjacency matrix, $k$ is the degree vector, and $m$ is the total number of edges.

## 3 Audio Generation

### 3.1 Sine Wave

$$f(t) = \sin(2\pi f t)$$

### 3.2 Square Wave

$$f(t) = \text{sgn}(\sin(2\pi f t))$$

### 3.3 Sawtooth Wave

$$f(t) = \frac{1}{\pi} \arctan(\tan(\pi f t))$$

### 3.4 FM Synthesis

$$f(t) = \sin(2\pi f t + I \sin(2\pi f_m t))$$

where $I$ is the modulation index, $f$ is the carrier frequency, and $f_m$ is the modulating frequency.

### 3.5 Waveshaping Synthesis

$$f(t) = \text{sgn}(\sin(2\pi f t)) \times (1 - e^{-|\sin(2\pi f t)|})$$

## 4 Types of Graphs

In this script, multiple types of graphs are provided as options for generating sound and visuals. Below is a brief description of each graph type:

### 4.1 Complete Graph

A graph where every pair of distinct vertices is connected by a unique edge.

### 4.2 Cycle Graph

A graph that forms a single cycle or a closed chain.

### 4.3 Random Graph

A graph generated using the Erdős–Rényi model, where each edge exists independently with probability $p$.

### 4.4 Star Graph

A graph where all nodes are connected to a central node.

### 4.5 Wheel Graph

Formed by connecting a single vertex to all vertices of a cycle graph.

### 4.6 Lollipop Graph

A graph comprising a complete graph and a path graph connected by a single edge.

### 4.7 Barabási–Albert Graph

A scale-free graph generated using preferential attachment.

### 4.8 Ladder Graph

Consists of two parallel lines with rungs between them, resembling a ladder.

### 4.9 Circular Ladder Graph

A ladder graph where the ends are also connected, forming a cycle.

### 4.10 Path Graph

A linear graph where vertices are connected end to end, but no cycles exist.

### 4.11 Binominal Tree

A balanced tree graph where each node has exactly two children.

### 4.12 Karate Club Graph

A social network graph representing relationships between members of a karate club.

### 4.13 Florentine Family Graph

A graph representing the relationships between prominent families in Renaissance Florence.

### 4.14 Les Miserables Graph

A co-appearance graph of characters in the novel Les Miserables.