# Hackathon 2023

Sound of Silence

October 8, 2023

# Assumptions

We are identifying objects that can produce sounds. By an object, we mean a collection of pixels/cubes in a 3D space. Each of the pixels has a weight $w_j$ assigned to it in the range $[0; 1]$. The weight of an object $O_i$ is defined as:

$$W_i = \sum_{j \in J_i} w_j,$$

Where $J_i$ is the set of indices for the pixels belonging to $O_i$. Additionally, we assign a center of gravity position to each object $O_i$:

$$x_i = \sum_{j \in J_i} x_j w_j, \quad y_i = \sum_{j \in J_i} y_j w_j, \quad z_i = \sum_{j \in J_i} z_j w_j.$$

# The trajectory of a journey in a 3D world.

Let $\gamma(t) = (x(t), y(t), z(t)) = (x, y, z)$ represent the trajectory of the journey in the given 3D space.

We define a plane perpendicular to the velocity vector of a point moving along the curve $\gamma$ as:

$$L : \dot{x}(X - x) + \dot{y}(Y - y) + \dot{z}(Z - z) = 0.$$

While being at the point $\gamma(t)$, we determine the distances of objects $O_i$ from the plane $L$ as:

$$d_i = \frac{L(x_i, y_i, z_i)}{\sqrt{\dot{x}^2 + \dot{y}^2 + \dot{z}^2}}.$$

If $|d_i| < \varepsilon$ for a given parameter $\varepsilon$, we assume that object $O_i$ should emit sound. A subsequent emission of sound by object $O_i$ can occur if the next event $|d_i| < \varepsilon$ is preceded by an event where $|d_i| \geq \varepsilon$.

# The amplitude of sound.

We define the vector connecting a point on the trajectory with each object that is supposed to emit sound as:

$$r_i = (r_{i,x}, r_{i,y}, r_{i,z}) = (x - x_i, y - y_i, z - z_i).$$

This allows us to define the amplitude/volume of sound as the value:

$$A_i = \frac{W_i}{|r_i|^2}.$$

# The pitch or frequency of sound.

The pitch of the sound depends on whether the object we are passing is *above* or *below* the trajectory of movement. To determine the vertical direction, we utilize Frenet formulas, which involve the direction of the binormal vector:

$$b = (b_x, b_y, b_z) = \rho(\dot{y}\ddot{z} - \dot{z}\ddot{y}, \dot{z}\ddot{x} - \dot{x}\ddot{z}, \dot{x}\ddot{y} - \dot{y}\ddot{x}),$$

where $\rho = (\ddot{x}^2 + \ddot{y}^2 + \ddot{z}^2)^{-\frac{1}{2}}$. If $\gamma$ contains straight segments, the vector $b$ is defined in a way that $\dot{b}$ is continuous. The angle $\alpha_i \in [0; 2\pi)$ between the direction of object $O_i$ and the vertical vector $b$ is determined by the relationship:

$$\cos \alpha_i = \frac{b_x r_{i,x} + b_y r_{i,y} + b_z r_{i,z}}{|b| \cdot |r_i|}.$$

# Objects with continuous emission.

Among the objects $O_i$, there are those that will emit sound continuously. In such a situation, only the sound intensity is regulated, which changes with the distance from the object.