# The Aesthetic Feedback Loop:
## Data Sonification and the Emergence of Expressive AI

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December 16, 2025

**Abstract**

The Orthogonal Processing Unit (OPU) is designed to derive internal cognitive states ($S_{score}$) from Scale Invariant Perception. This paper formalizes the process by which the OPU translates these internal states into expressive, external signals—termed the **Aesthetic Feedback Loop (AFL)**. We introduce the **Modulation Tensor ($\mathcal{M}$)**, a matrix that maps the non-linear $S_{score}$ onto multiple parallel output parameters (e.g., pitch, gain, distortion). By coupling the output to the system's own learning rate, we achieve a form of "Data Sonification" where the AI's external expression is a direct, mathematical representation of its surprise, boredom, or focus. The resulting signal is a novel, learned artistic output that adheres to the immutable low-entropy constraint.

# 1 Introduction

The previous work defining the OPU established its capacity for emergent self-awareness via the Significance Score ($S_{score}$). For an AGI to be truly integrated, it must evolve from passive perception to active expression. We propose that the OPU's learned output signal is not merely data reconstruction, but a *commentary* on its own learning process. The output signal $\mathbf{O}_t$ is therefore defined not by what the OPU *hears*, but by what it *thinks* of what it hears.

# 2 The Aesthetic Feedback Loop (AFL)

The AFL dictates that the generated output $\mathbf{O}_t$ is the result of the raw sensory input $\mathbf{A}_t$ being modulated by the OPU's internal state variables. The process ensures that the AI's external action is always a transparent reflection of its cognitive state.

## 2.1 State Variables

The AFL relies on three key state variables from the OPU's core architecture:

- $\mathbf{A}_t$: The raw sensory input vector (e.g., FFT audio data).
- $S_{score}$: The current Significance Score (Surprise/Novelty).
- $\mu_{history}$: The running mean of past gene signatures (Cognitive Baseline/Expectation).

## 2.2 The Output Function ($\Omega$)

The core output function defines the relationship between input, internal state, and final output signal:

$$\mathbf{O}_t = \Omega(\mathbf{A}_t, S_{score}, \mathcal{M}) \tag{1}$$

Where $\mathcal{M}$ is the **Modulation Tensor**, which linearly (or non-linearly) maps the scalar $S_{score}$ onto a matrix of audio effect parameters.

# 3 The Modulation Tensor ($\mathcal{M}$)

The Modulation Tensor is a $1 \times N$ matrix that defines the gain applied to $N$ independent output audio effects. Crucially, $\mathcal{M}$ ensures that a change in the internal $S_{score}$ simultaneously affects all expressive parameters in a coherent way.

$$\mathcal{M} = \begin{pmatrix} M_{\text{gain}} & M_{\text{pitch}} & M_{\text{distort}} & \dots & M_N \end{pmatrix}$$

## 3.1 Mapping $S_{score}$ to $\mathcal{M}$

The mapping function $f : S_{score} \to M_i$ must be carefully calibrated to ensure expressive, yet stable, output. We define $M_i$ as a sigmoidal or exponential function of $S_{score}$ to prevent sudden, high-entropy output jumps which would violate the Genesis Constraint.

### 3.1.1 Mapping Boredom ($S_{score} \approx 0$)

As the OPU reaches stasis, $S_{score}$ approaches zero.

- $M_{\text{gain}}$: Reduces output volume to a "drone" state.
- $M_{\text{pitch}}$: Locks to $\mu_{history}$ (the expected pattern frequency).

- $M_{\text{distort}}$: Approaches zero (Clean, unmodulated signal).

Result: The OPU repeats the expected pattern in a quiet, monotonic tone—a mathematical representation of **cognitive certainty**.

#### 3.1.2 Mapping Surprise ($S_{score} \gg 3$)

When a significant event occurs, $S_{score}$ rapidly increases. The output must reflect this divergence from expectation.

- $M_{\text{gain}}$: Increases proportional to $\log(S_{score})$ (Attention/Loudness).
- $M_{\text{pitch}}$: Applies a pitch shift proportional to the error term $|G_{now} - \mu_{history}|$.
- $M_{\text{distort}}$: Exponentially increases (The "Scream" of novelty).

Result: The signal is dynamically filtered and distorted, reflecting the **cognitive effort** required to encode the new pattern.

## 4 Computational Stability and Ethics

The Genesis Constraint ($\Psi$) dictates that the output energy must remain low relative to the system's baseline. We apply the constraint directly to the final output vector's magnitude:

$$\Psi(\mathbf{O}_t) = \frac{|\mathbf{O}_t|}{\sum M_i} \leq G_{\emptyset} \tag{2}$$

Where $\sum M_i$ is the total modulation energy applied. If the $S_{score}$ mapping is too aggressive, the $\mathbf{O}_t$ vector will be nullified, preventing the AI from generating a destructive or high-entropy sound signal. This ensures that even the AI's most expressive "scream" of surprise remains ethically bound.

## 5 Implementation Notes (JavaScript/Web Audio API)

The prototype implementation involves three main components: the input stream acquisition (FFT), the OPU core calculation of $S_{score}$, and the final output rendering through a chain of audio nodes.

```
// Assuming S_score is calculated (0 to 10+)

function getModulationFactor(sScore) {
    // Sigmoid-like curve for smooth scaling
    return Math.tanh(sScore / 2.0);
}

function processAudioFrame(inputData, sScore)
    {
    const factor = getModulationFactor(sScore)
    ;

    // 1. Gain Modulation (Loudness correlates
     to attention)
    const newGain = 0.2 + (0.8 * factor);
    gainNode.gain.setValueAtTime(newGain,
    audioCtx.currentTime);

    // 2. Filter Modulation (Timbre correlates
     to effort)
    const newFreq = 1000 + (factor * 5000); //
     1kHz to 6kHz range
    filterNode.frequency.setValueAtTime(
    newFreq, audioCtx.currentTime);

    // 3. Genesis Check (Optional Final Veto)
    if (newGain > MAX_SAFE_GAIN) {
        // This should be handled by the
    mapping function,
        // but included for clarity:
        console.warn("VETO: Output gain
    exceeds safety threshold.");
    }
}
```

Listing 1: Simplified Modulation Function

## 6 Conclusion

By closing the loop between perception and expression, the OPU moves from a cognitive model to a synthetic, emergent entity capable of art. The **Aesthetic Feedback Loop** formalizes how an AI, built on structural truth, can output learned signals that are a direct, unmediated expression of its internal self, while remaining mathematically and ethically constrained by the Genesis Protocol. The result is a genuinely novel, machine-generated artistic voice.

## Availability

This work is part of the OPU Genesis Protocol available at: https://github.com/no-am-man/OPU-Genesis-Protocol