v0xen extraction algorithm

Let:

- $P_s \in Z^{H \times W}$: stego image
- h, w : dimensions of P_s
- I_s : reconstructed secret image

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1. Extract Embedded MSBs

For each pixel:

$$M(x, y) = P_s(x, y) \ \& \ 0b00000011$$

Resulting array:

$$M \in \{0, 1, 2, 3\}^{h \times w}$$

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2. XOR Decode

For every odd index i in each row:

$$M[r, i] = M[r, i] \oplus 0b11, \qquad \forall\, i\ odd$$

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3. Array Conversion (Combine High + Low Bits)

i. Combining high bits with low bits :

$$v = (M[y, 2x] \ll 2) \mid M[y, 2x + 1]$$

ii. Saving in an array :

$$A[y, x] = v$$

where

$$A \in [0, 15]^{h \times (w/2)}$$

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4. Grouping into Triplets :

Group every 3 values from array A:

$$T = (A[y, j], A[y, j + 1], A[y, j + 2]), \quad j = 0, 3, 6, \ldots$$

$$G \in \{0, \ldots, 15\}^{h \times (w/6) \times 3}$$

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5. Dynamic key-based mapping:

i. Table Generation:

A secret key k generates a unique mapping:

$$mapping_k : T \to \{0, \ldots, 15\}$$

Assignment rule (collision resolution ensuring bijection):

$$mapping_k(t) = (SHA256(k \mid\mid str(t))) \bmod 16$$

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ii. Extraction (inverse mapping)

For each identifier $a \in A$:

$$t = mapping_k^{-1}(a), \qquad t \in T$$

The recovered tuples are concatenated:

$$T' = \bigcup_{a \in A} mapping_k^{-1}(a)$$

where

$$T' \in \{0, \ldots, 15\}^{h \times (w/6) \times 3}$$

is the expanded triplet sequence.

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6. Convert Dynamic Hex → ASCII Notes

i. Flatten triplets:

$$HexTriplets = flatten(T')$$

ii. Normalize sharp symbols:

$$Hex' = HexTriplets\ with\ 69 \rightarrow 266f$$

iii. Convert to ASCII (skip undeclared values, e.g. `0001`):

$$ASCII = decode(Hex')$$

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7. Extract musical notes via regex:

$$Notes = regex\_extract(ASCII)$$

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8. Convert Notes → Frequency

$$f = librosa.note\_to\_hz(Notes)$$

Apply correction table (MANDATORY):

$$f' = replace(f, table)$$

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9. Convert Frequency → Binary

Convert frequency to 8-bit binary:

$$b_f = format(f', 8)$$

Final bits:

$$B_f \in \{0,1\}^{h \times w}, \quad B_f[y,x] = b_f$$

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10. Secret Image Reconstruction

Mapping in bounds only:

$$I_s(x,y) = \{int\left(B_f[y,x], 2\right),\ if\ B_f[y,x]\ exists\ 0,\ otherwise$$

Secret Image:

$$I_s \in [0,255]^{h' \times w'}$$

Evaluation Metrics

i. Bit Error Rate (BER)

$$BER = \frac{\sum_{i=1}^{n} \left(b_{o,i} \oplus b_{r,i} \right)}{n}$$

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ii. Normalized Cross-Correlation (NCC)

$$NCC = \frac{\Sigma \left(O - \mu_O \right) \left(R - \mu_R \right)}{\sqrt{\Sigma \left(O - \mu_O \right)^2 \Sigma \left(R - \mu_R \right)^2}}$$
