Project Report: Eulerian Video Magnification

April 27, 2025

Abstract

This report details our implementation of Eulerian Video Magnification (EVM), a technique to reveal and amplify subtle temporal variations in videos, imperceptible to the naked eye. Our approach employs spatial decomposition via Laplacian pyramids, followed by temporal bandpass filtering to isolate and enhance specific motion frequencies. This allows for visualization of blood flow, subtle movements, and other applications, offering new insights into video analysis. We discuss the underlying concepts, implementation details, and limitations of the EVM technique.

1 Introduction

This report documents our implementation of Eulerian Video Magnification (EVM), a technique for revealing subtle temporal variations in videos that are difficult or impossible to see with the naked eye. EVM allows us to visualize motions imperceptible to the human eye by applying spatial decomposition, temporal filtering, and amplification to video frames. Our method visualizes blood flow in the face and amplifies small motions (EVM).

2 Project Goals

- Implement the EVM algorithm in Python using libraries such as OpenCV, NumPy, and SciPy.
- Apply EVM to amplify subtle motions in video sequences.
- Demonstrate the applicability of EVM in various scenarios, such as medical diagnostics.

3 Concepts and Implementation

3.1 Spatial Processing (Laplacian Pyramid)

We decompose video frames into multiple spatial frequency components using a Laplacian pyramid. The Laplacian pyramid is constructed by computing the difference between successive levels of a Gaussian pyramid. This ensures that the magnification does not introduce unwanted distortions, especially at high spatial frequencies.

Equation:

$$L_i = G_i - \text{Upsample}(G_{i+1}) \quad (i = 0, 1, 2, ..., n)$$

3.2 Temporal Processing (Bandpass Filtering)

Temporal processing focuses on how pixel values change over time across video frames. Instead of analyzing a single frame, temporal processing considers how intensity or color changes over time. We treat each spatial band as a time series and apply a bandpass filter to extract relevant motion frequencies.

- For Heartbeat & Blood Flow: Frequency range of 0.5-1.5 Hz
- For Breathing Motion: Frequency range of 0.0-1.5 Hz

Bandwidth Equation:

$$\text{Bandwidth} = f_H - f_L \quad (\text{where } f_H = \text{upper and } f_L = \text{lower frequency})$$

3.3 Eulerian Motion Magnification

The bandpass filter is expressed as $B(x,t) = \delta(t)\frac{\partial x}{\partial f(x)}$, where $\delta(t)$ is the small displacement occurring in each frame. We apply the amplification factor α to $B(x,t)$, which varies according to the frequency bands produced during the formation of the Laplacian pyramid of a frame. To determine the safe limit for amplification, we analyze how large a magnified displacement can be before the first-order approximation breaks down.

Equation:

$$\tilde{I}(x,t) = I(x,t) + \alpha B(x,t)$$

Amplification Bound:

$$a \leq \frac{\lambda}{8\delta_{max} - 1}$$

4 Implementation Details

The implementation involves the following steps:

1. **Input Video:** Load a standard video sequence.
2. **Spatial Decomposition:** Apply a Laplacian Pyramid to break the image into multiple scales.
3. **Temporal Filtering:** Treat each spatial band as a time series and apply a bandpass filter to extract relevant motion frequencies.

4. **Motion Amplification:** Amplify the motion frequencies based on their respective frequency bands. High frequencies (L0, L1, L2) use less amplification, and low frequencies (L3 and more) use higher amplification.

5. **Inverse Laplacian Pyramid:** Reconstruct the full-resolution frames with amplified motion using the Inverse Laplacian Pyramid.

6. **Output Video:** Produce the final video with amplified motion.

5 Results

The implemented EVM algorithm successfully achieved the following:

- Visualization of blood flow in the face.
- Amplification and revelation of small motions (EVM).

Figure 1: Input - face.mp4

6 Why Eulerian Approach over Lagrangian?

The Eulerian method analyzes motion by tracking changes in pixel intensities over time at fixed spatial locations. Instead of following objects, it focuses on how intensity values fluctuate due to motion. The Lagrangian method explicitly tracks motion by following object trajectories across frames, estimating displacement using optical flow or feature tracking.

The Eulerian approach has an advantage when detecting changes not visible to the naked eye.

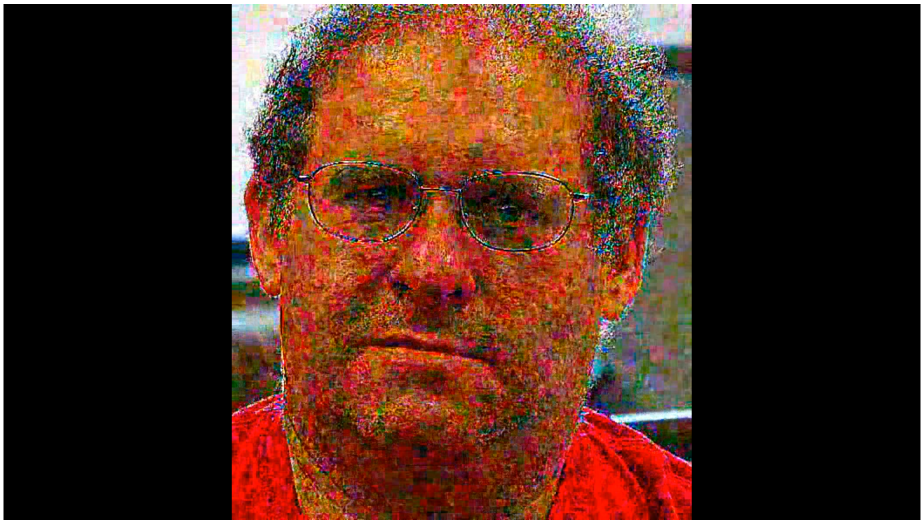

Figure 2: Output after Magnification - face.mp4

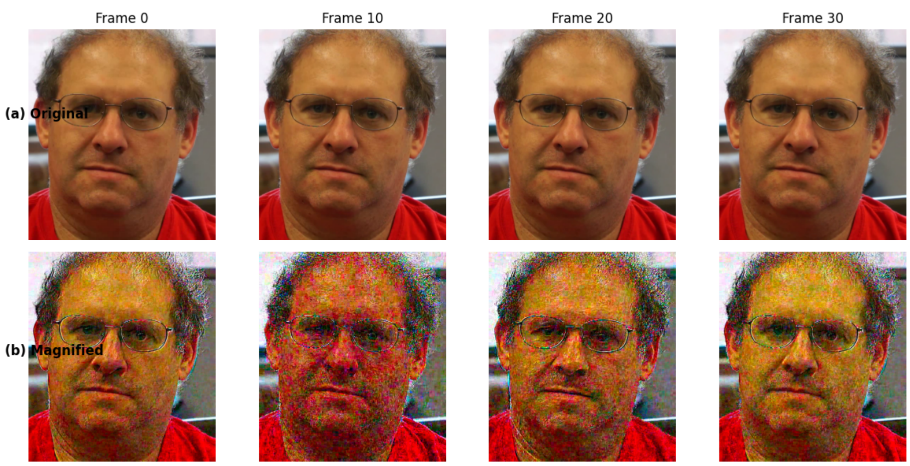

Figure 3: Comparison at each interval - face.mp4

7 Limitations and Errors

- **Phase Distortion Error:** When motion is large, EVM amplifies brightness variations instead of actual displacement.
- **Spatial Leakage:** The multi-scale filtering used in EVM is not perfect at capturing fine motion details. This causes edge distortions and spatial leakage, where movement spreads incorrectly to surrounding regions.

Figure 4: Input - baby2.mp4

Figure 5: Output - baby2.mp4

- **Temporal Aliasing Error:** If the motion frequency exceeds the Nyquist limit of the frame rate, EVM fails to reconstruct motion correctly.
- **Amplification Limitations:** Over-amplification causes hallucinated motion or complete structural breakdown of the video.

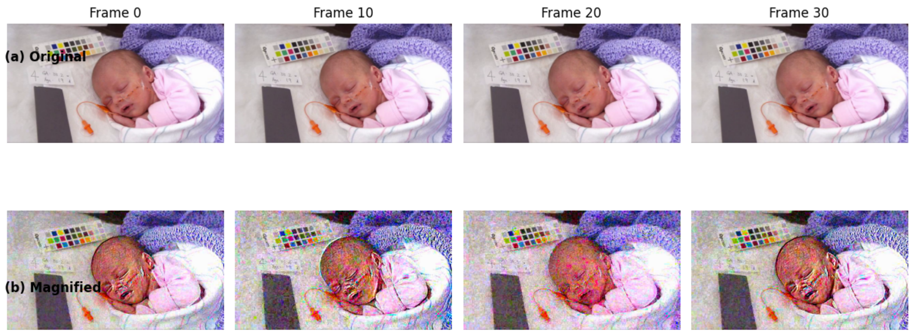

Figure 6: Comparison at each Interval - baby2.mp4

8 Possible Improvements

- Adaptive Filter for Bandpass
- Phase-based approach
- A hybrid approach also including the Lagrangian method

9 Conclusion

The Eulerian Video Magnification (EVM) technique successfully reveals subtle temporal variations in videos. The algorithm offers valuable insights into subtle motions imperceptible to the naked eye.

Bibliography

References

[1] Wu, H.-Y., Rubinstein, M., Shih, E., Guttag, J., Durand, F., & Freeman, W. (2012). Eulerian Video Magnification for Revealing Subtle Changes in the World. *ACM Transactions on Graphics (TOG)*, *31*(4), 1-8.

[2] Rubinstein, M. (2014). Analysis of Temporal Variations in Videos. *MIT Master's Thesis*.

[3] Eulerian Video Magnification. `https://people.csail.mit.edu/mrub/evm/`