Biomimetry Inspired Algorithm for Noise Reduction in Low Light Imagery

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Motivation

- Low light level imagery is crucial to operating safely in a nighttime environment.
- Night Vision Devices (NVD) are widely used by emergency services and in military applications.
- Hardware advancements aim to increase signal reliability in low light conditions but often at the expense of keeping weight at a reasonable level.

Figure 1

- This project aims to show how leveraging advances in processing speed might allow more robust algorithms to be used for enhancing signal reliability in low light conditions.

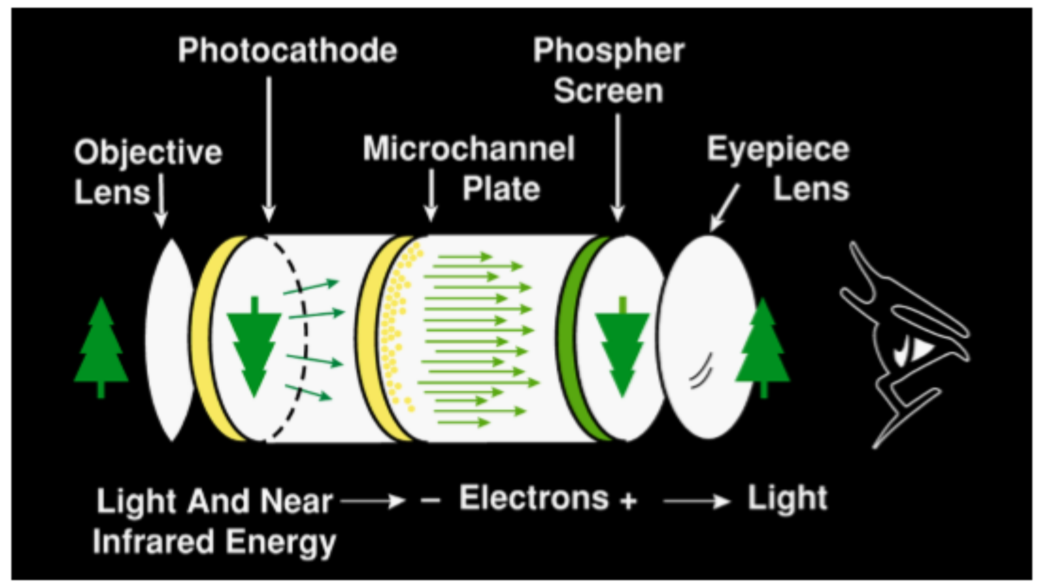


Figure 2 Image Intensifier Tube Internal Components

Related Work

- Insects in particular have been successful at adapting their visual organs to low light levels. Warrant et al. have investigated invertebrates' ability to neurally intensify and sum collected visual signals in both time and space.

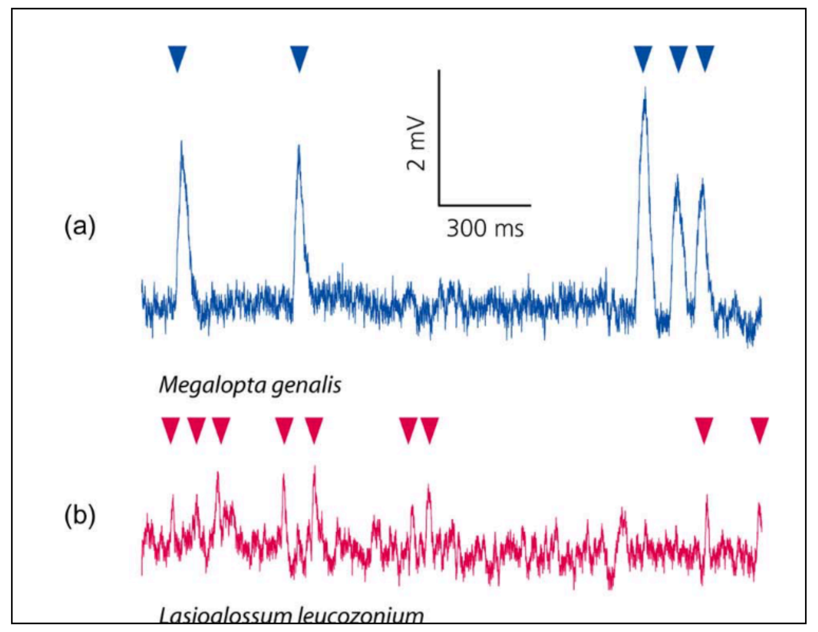


Figure 3

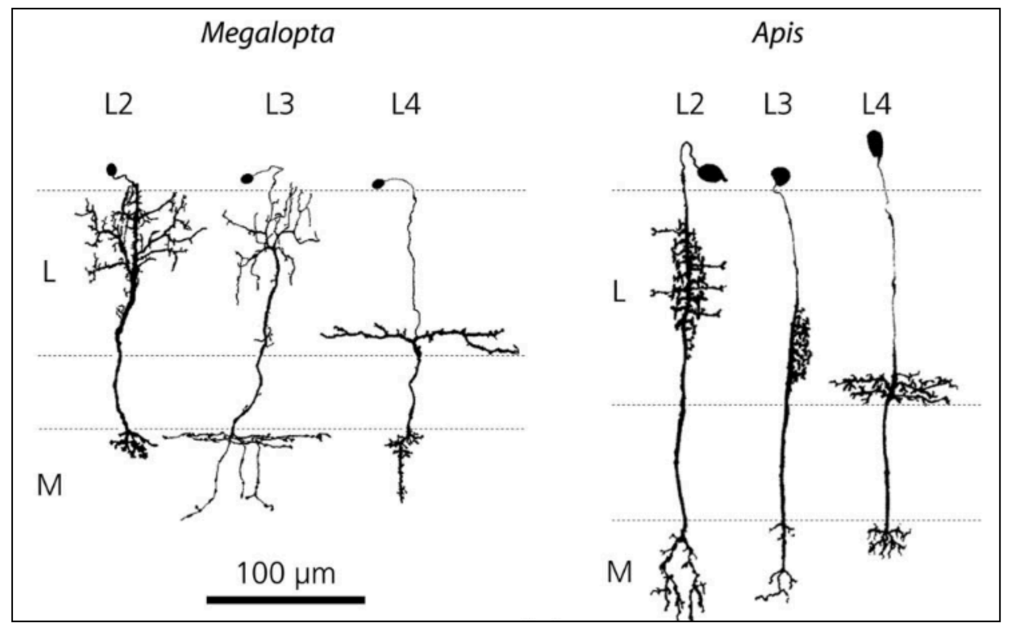


Figure 4

- Much work has concentrated on motion compensated filtering, edge preserving anisotropic diffusion, and block matching techniques.
- The biological adaptation above is the inspiration for a spatio-temporal smoothing technique that borrows elements of those above and adapts them to low light level.

New Technique

- **Step1**: Amplify signal intensity using a contrast-limited adaptive histogram equalization (CLAHE).
  - Ordinary AHE is prone to over amplification.
  - Contrast amplification in the neighborhood of a given pixel is determined by the slope of the transfer function. This slope is proportional to the slope of the cumulative distribution function (CDF), also known as the mapping function.
  - A clip limit is determined that limits the slope of the CDF and, as a result, the transformation function is limited.
  - That part of the histogram that exceeds the clip limit is redistributed among all histogram bins.

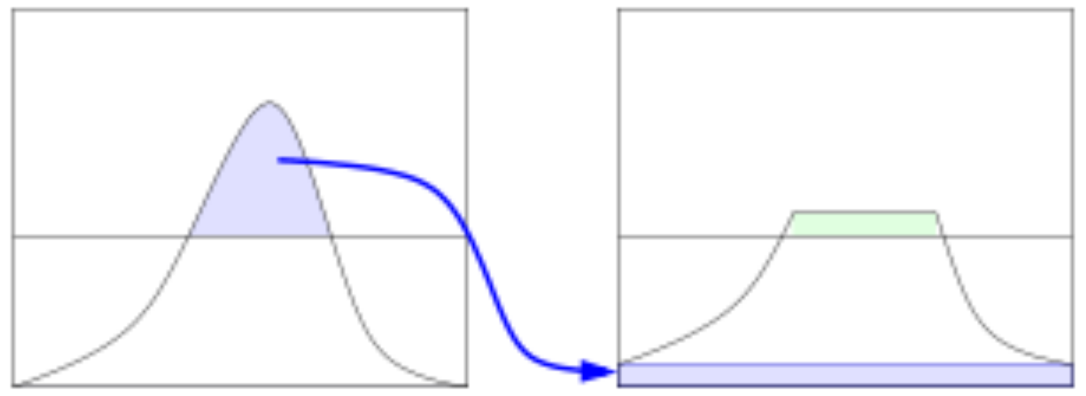


Figure 5

  - Processing time for this amplification technique is improved through interpolation whereby each image is partitioned into tiles containing numerous pixels. The histogram, CDF, and transform function are then calculated for each tile.

- **Step 2**: Once the image undergoes intensity transformation we look to preserve the increased detail (signal) while reducing the resultant noise.
  - Bilateral filtering is a relatively simple and fast method.
  - Block Matching 3D (BM3D) is a powerful filter option with greater edge preserving characteristics.

REFERENCES:

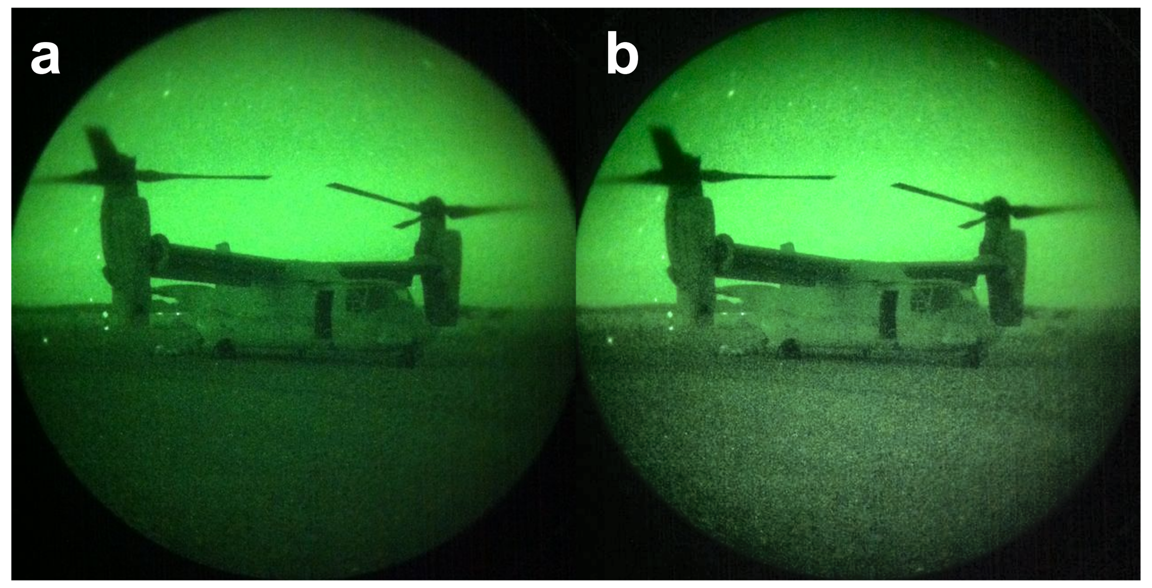
E. J. Warrant, O. Magnus, H. Malm, "The remarkable visual abilities of nocturnal insects: neural principles and bioinspired night-vision algorithms." Proc. of the IEEE, vol. 102, no. 10, pp. 1411-1426, 2014.

S. M. Pizer et al., "Adaptive histogram equalization and its variations," Comput. Vis. Graph. Image Process., vol. 39, pp. 355-368, 1987.

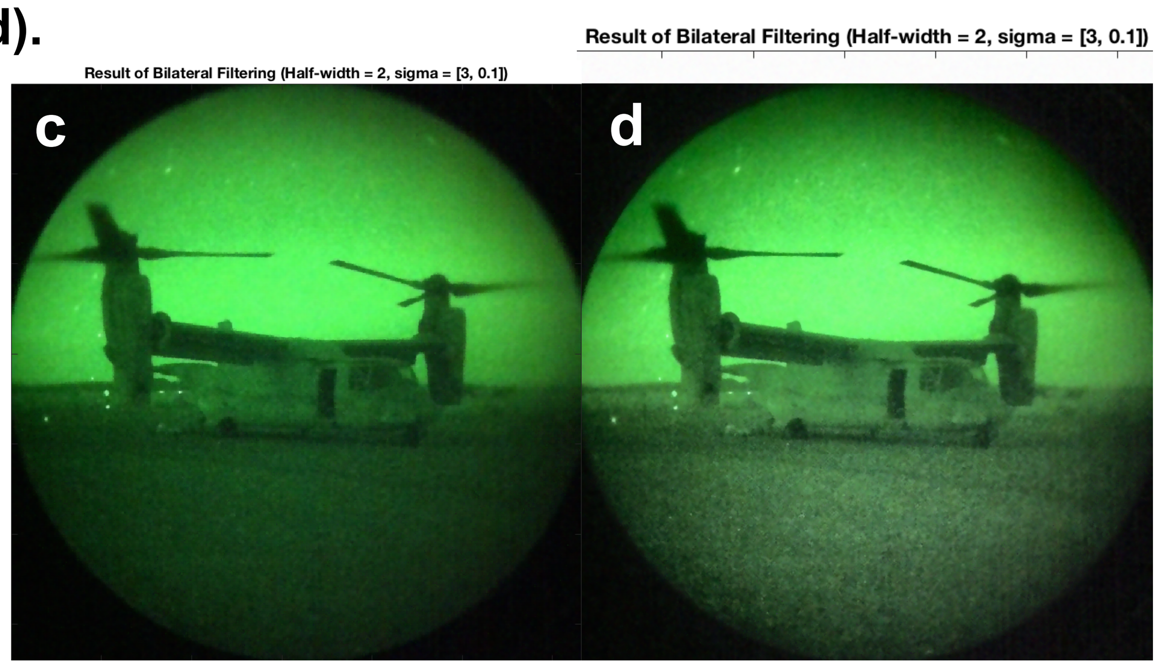
MAWTS-1 Night Vision Device (NVD) Manual, 9th Edition, 19 January 2011.

Experimental Results

- **Intensity transformation applied to low light NVD original image (a) with CLHE, resulting in image (b).**



- **Bilateral filter applied to original image (c) and intensity amplified image (d).**



- **BM3D filter applied to original image (a), with additive noise (e), and to image (b) with (f) and without (g) additive noise.**

CONCLUSION

- While the Bilateral filter offers speed, it does not preserve edge detail as well as the BM3D filter.
- BM3D applied to an intensity amplified image gave by far the best results. Signal increased, allowing more detail in shadows, while noise was kept to reasonable levels.