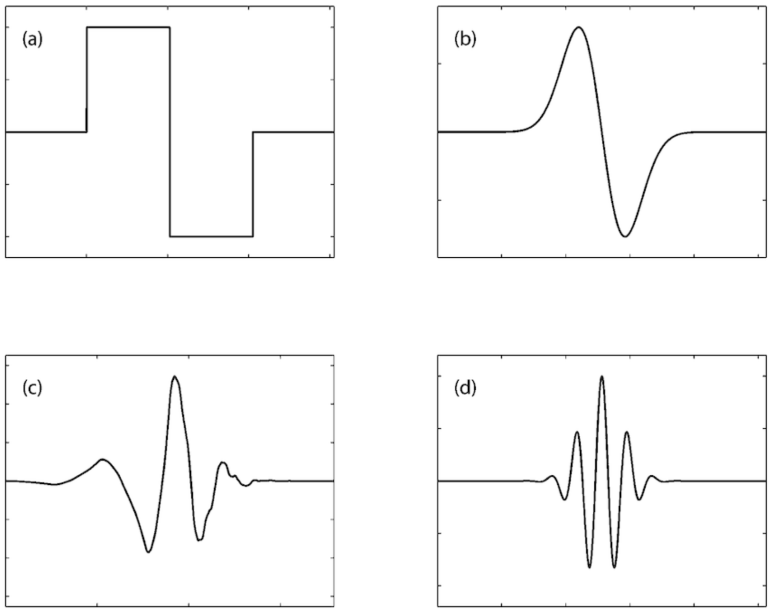
Wavelet Processing

Functions: discrete wavelet transform: matrix math, linear algebra, convolution, decomposition
Inputs: images, artificial matrix data
Metrics: processing time

1. Overview

Wavelets are brief, oscillating signals that begin from and return to a zero value within a finite duration. That characteristic, in conjunction with “scaling” and “shifting,” makes them very useful in signal processing. Scaling a wavelet – stretching it out or compressing it in time – can allow it to represent either the long-term movement of a signal or a shorter-term fluctuation, respectively. Shifting wavelets – aligning their centers to different points with respect to an original signal – can permit them to represent distinct events at varying points in that signal. Thus, it is possible to approximate a signal as a sum of shifted and scaled wavelets, via a “wavelet transform.” This is similar to the intuition behind a Fourier transform, which represents a signal as a sum of infinite-duration sine waves, but a wavelet transform can more effectively deal with signals that have abrupt changes or discontinuities. Wavelet transforms are useful in various applications including image processing, signal denoising, and compression (to name a few). For further information, see https://www.eecis.udel.edu/~amer/CISC651/IEEEwavelet.pdf or https://www.mathworks.com/videos/understanding-wavelets-part-1-what-are-wavelets-121279.html.



Common wavelets: (a) Haar, (b) Gaussian (order 1), (c) Daubechies (order 4), and (d) Morlet. Source: http://dx.doi.org/10.1785/0120060255

MilSpec’s wavelet processing benchmark applies the Haar wavelet (a square-shaped pulse, as above) to denoise sample images or random data (either one- or two-dimensional). Specifically, the test performs a discrete wavelet transform with a configurable number of decompositions, based on open-source implementations for 1D[1] and 2D[2] decomposition (the 2D implementation requires OpenCV, as noted below). The MilSpec benchmark integrates these two implementations with a common testharness, performance measurement tools, and assorted code cleaning/interface modification. Future versions of this benchmark will add additional wavelet choices and/or input data options.

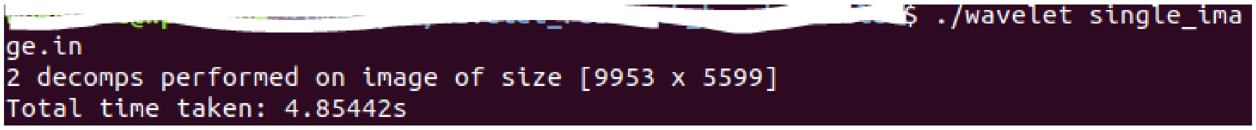
2. System requirements

Platform: Ubuntu 18.04 LTS with g++ 7.4.0. Code may build and run successfully on other versions/platforms, but has not been tested with them.
Storage: ~30MB for code and sample inputs. RAM requirements vary significantly by testcase, from a few KB for small input matrices to ~4GB for very large randomly-generated inputs.
Dependencies: OpenCV 3.2.0 (may work with later versions, but not tested).

3. Build and run

To benchmark:

- Install OpenCV: `sudo apt-get update` and `sudo apt-get install libopencv-dev`
- Verify compatible OpenCV version: `pkg-config --modversion opencv`
- Download and extract the zipfile from www.adacenter.org/milspec
- From the `wavelet/` directory, `make clean && make`
- Choose a testcase: `1d-array.in`, `1d-random.in`, `batch.in` (process multiple input images from a given directory), `random.in`, or `single_image.in`.
- From the `wavelet/` directory, `./wavelet [testcase]`
- Results are displayed in the terminal, as below:



```
[redacted]$ ./wavelet single_ima
ge.in
2 decomps performed on image of size [9953 x 5599]
Total time taken: 4.85442s
```

4. Code structure

Coming soon!

5. MilSpec development notes, errata, changelog

v0.9:

- Changes from baseline wavelet code for MilSpec:
  - Removed unused/unwanted code from baseline implementations (e.g. GUI configuration)
  - Built wrapper for 1D/2D baseline implementations

[1] https://github.com/matteotiziano/simple-wavelet
[2] https://stackoverflow.com/questions/20071854/wavelet-transform-in-opencv/20072775#20072775

- Created makefile
- Added basic configuration options and file-based testcase input
- Created basic testcases
- Added performance metrics

6. Acknowledgements

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The original wavelet processing implementations upon which the MilSpec versions are based are available at https://github.com/matteotiziano/simple-wavelet (1D) and https://stackoverflow.com/questions/20071854/wavelet-transform-in-opencv/20072775#20072775 (2D).