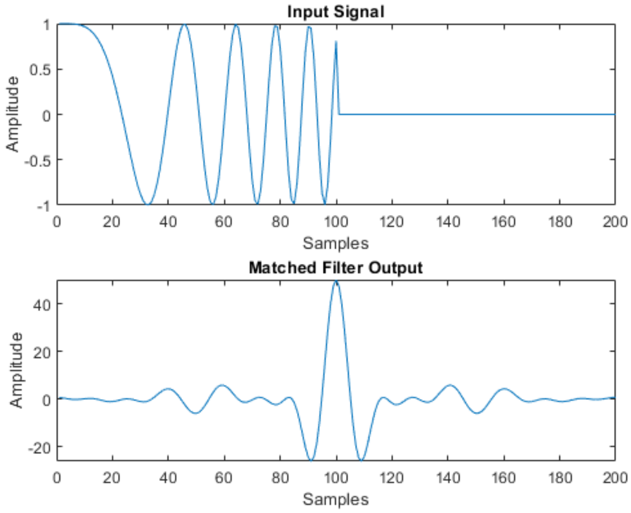
Matched Filtering

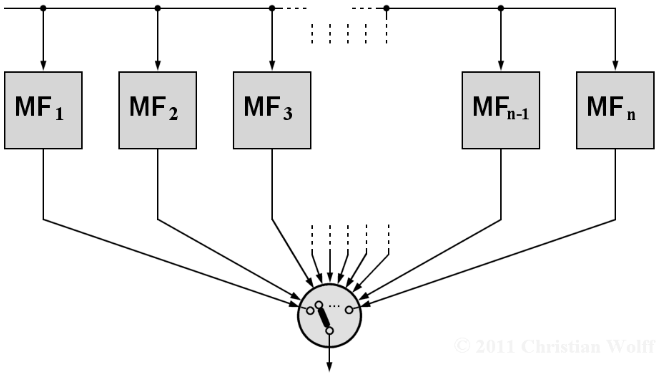
Functions: matrix math, convolution, correlation, 16QAM encode/decode
Inputs: textual data
Metrics: processing time, error rate

1. Overview

Matched filtering is a signal processing technique that aids with signal detection/identification in noisy environments by trying to "match" (correlate) a known signal template against an unknown received signal. It is often used in radar systems with pulse compression (to detect a reflected radar pulse that has a known pattern, in the presence of noise and/or jamming), image processing and communications systems (for denoising), etc. For further reading, see https://crewes.org/ForOurSponsors/ResearchReports/2002/2002-46.pdf or https://www.radartutorial.eu/10.processing/Matched%20Filter.en.html.



Example: using a matched filter to detect a radar "chirp" waveform (source: https://www.mathworks.com/help/phased/ref/phased.matchedfilter-system-object.html)



Example: a radar system may use an array of matched filters to detect different radar return characteristics (source: https://www.radartutorial.eu/10.processing/Matched%20Filter.en.html)

MilSpec's matched filtering benchmark is a custom implementation that inputs a text file, generates a 16QAM signal from the text (with square-root-raised-cosine pulses), adds Gaussian noise,[1] denoises the signal with a matched filter, and then decodes the signal and measures the received error rate. Configuration options include the SNR, sample rate, carrier frequency, etc. A future revision will generalize the application with additional input data and signal generation options, e.g. images and radar pulses.

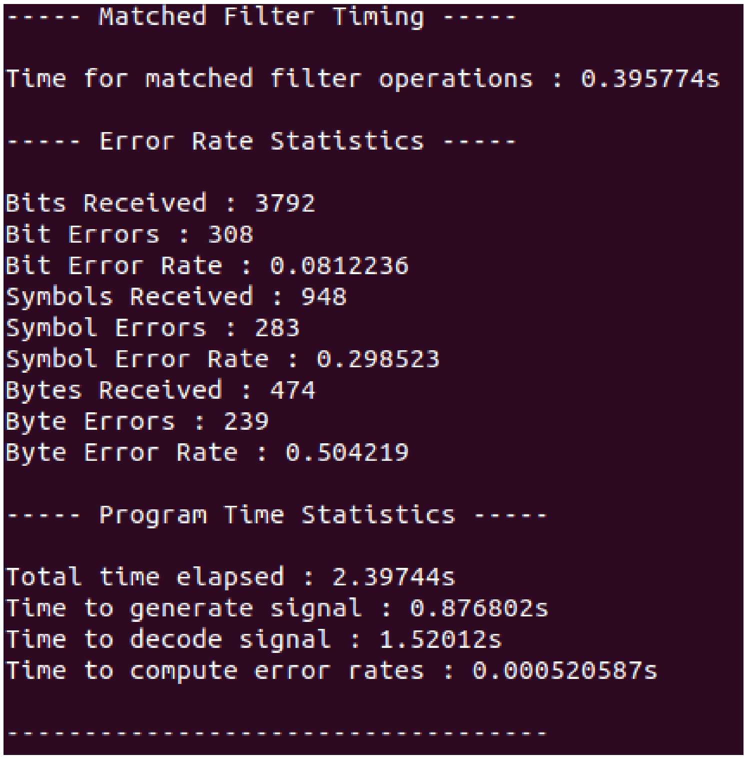
2. System requirements

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: ~100MB for code, sample inputs, and temporary files/output storage.
Dependencies: None.

3. Build and run

To benchmark:

- Download and extract the zipfile from www.adacenter.org/milspec
- From the `MatchedFilter/` directory, `make clean && make`
- From the `MatchedFilter/` directory, `./m`
- Results are displayed in the terminal, as below:



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----- Matched Filter Timing -----

Time for matched filter operations : 0.395774s

----- Error Rate Statistics -----

Bits Received : 3792
Bit Errors : 308
Bit Error Rate : 0.0812236
Symbols Received : 948
Symbol Errors : 283
Symbol Error Rate : 0.298523
Bytes Received : 474
Byte Errors : 239
Byte Error Rate : 0.504219

----- Program Time Statistics -----

Total time elapsed : 2.39744s
Time to generate signal : 0.876802s
Time to decode signal : 1.52012s
Time to compute error rates : 0.000520587s

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[1] https://github.com/divisionby-0/A.W.G.N.

4. Code structure

Coming soon!

5. MilSpec development notes, errata, changelog

v0.9:

- Built baseline matched filtering implementation:
    - 16QAM signal generation with square-root-raised-cosine pulses and Gaussian white noise (configurable SNR)
    - Signal recovery with matched filter
    - Performance instrumentation (execution time and error rate)

6. Acknowledgements

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