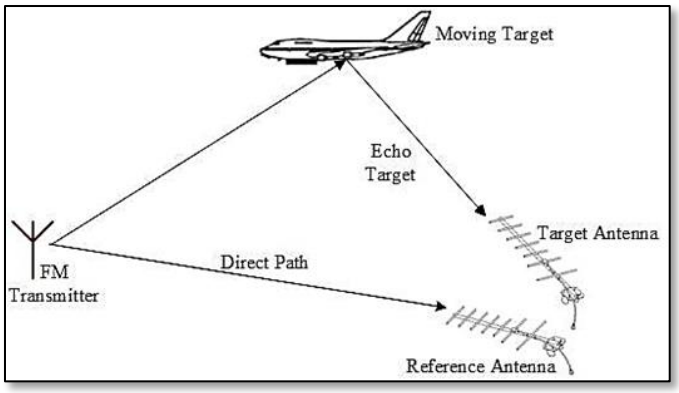
Passive Radar

Functions: FFT, linear algebra, filtering, cross-correlation, beamforming, DoA estimation
Inputs: complex-valued signal samples from radar array and reference antenna
Metrics: per-phase and total processing time

1. Overview

Passive radar is a radar mechanism where the receiver relies on an external signal source, rather than transmitting radar pulses itself. Passive radar processing is broadly similar to that of an active system, e.g. a phased array which electronically steers a radar beam using multiple antennas. However, passive radar requires an additional step to cross-correlate the external signal source (as directly received by a reference antenna) with possible reflections in the radar beam. For more high-level background, see https://apps.dtic.mil/dtic/tr/fulltext/u2/a515506.pdf or https://ieeexplore.ieee.org/document/5547434.



Passive radar detects targets by cross-correlating a directly received reference signal with its reflections in the radar beam
(source: https://qph.fs.quoracdn.net/main-qimg-a48b2c4e92ee168855d48046c244069e)

MilSpec's passive radar benchmark is based on the pyAPRiL project by Tamás Pető,[1] an open-source implementation of a full passive radar pipeline including clutter cancellation, beamforming, cross-correlation, and direction-of-arrival estimation. The MilSpec version rebuilds the baseline Python implementation in C++, incorporates the open-source libeigen[2] and fftw libraries for linear algebra and FFT processing, respectively, and adds performance instrumentation.

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: ~10MB for code and temporary files, plus ~200MB for sample data.
Dependencies: None.

[1] https://github.com/petotamas/APRiL
[2] https://gitlab.com/libeigen/eigen

3. Build and run

To benchmark:

- Download and extract the code zipfile from www.adacenter.org/milspec
- Ensure all input data, properly formatted as per the description in `passiveradar/src/main.cpp` (see below), are placed in the `passiveradar/dataset` directory:
    - Two elements are required: (1) the ground-truth target reference data, in `target_reference_track.txt`, and (2) the received radar returns, in one or more `dataset_[index].txt` files corresponding to sequential time indices.
    - Target reference data format:
      Line 1: `<num_rows> <num_cols>`
      Subsequent lines: `<Time index> <Timestamp> <Latitude> <Longitude> <Altitude> <Speed> <Direction> <Range> <Doppler> <Azimuth>`
    - Radar return data format:
      Line 1: `<Sampling Frequency>`
      Line 2: `<num_rows> <num_cols>`
      Subsequent lines (one per antenna element, where the first line is the reference channel, and the data in each line are the complex-valued samples collected at this file's time index): `real_1 imag_1 real_2 imag_2 ... real_num_cols imag_num_cols`
- From the `passiveradar/` directory, `make clean && make`
- From the `passiveradar/` directory, `./passive`
- Results are displayed in the terminal, as below:

```
====================== RESULTS SUMMARY ======================

Avg time to isolate channels: 0.00772775 seconds
Avg time for beamforming: 0.107594 seconds
Avg time to perform time-domain filter surveillance : 1.33224 seconds
Avg time to detect: 0.153442 seconds
Avg time to find target: 0.000795726 seconds
Avg time to estimate direction of arrival: 4.41843 seconds
Avg total time to process single time index: 8.22667 seconds

Max time to isolate channels: 0.0164568 seconds
Max time for beamforming: 0.113048 seconds
Max time to perform time-domain filter surveillance : 1.37662 seconds
Max time to detect: 0.159107 seconds
Max time to find target: 0.000853522 seconds
Max time to estimate direction of arrival: 4.44788 seconds
Max total time to process single time index: 8.28855 seconds
```

4. Code structure

Coming soon!

5. MilSpec development notes, errata, changelog

v0.9:

- Built baseline passive radar implementation:
    - Ported original pyAPRiL Python implementation to C++
    - Integrated libeigen and fftw for linear algebra and FFT computation
    - General editing/cleanup
    - Added instrumentation for per-phase and overall performance

6. Acknowledgements

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The original passive radar implementation upon which the MilSpec version is based, and the sample data used for the MilSpec benchmark, was developed/collected by Tamás Pető and is available at https://github.com/petotamas/APRiL. Additional details may be found at https://www.tamaspeto.com/Vega/VEGAM20191219K4U0C0S4DVBT. The Eigen library used for linear algebra computations is available at https://gitlab.com/libeigen/eigen.