A real-time Single Pulse detection algorithm for GPUs

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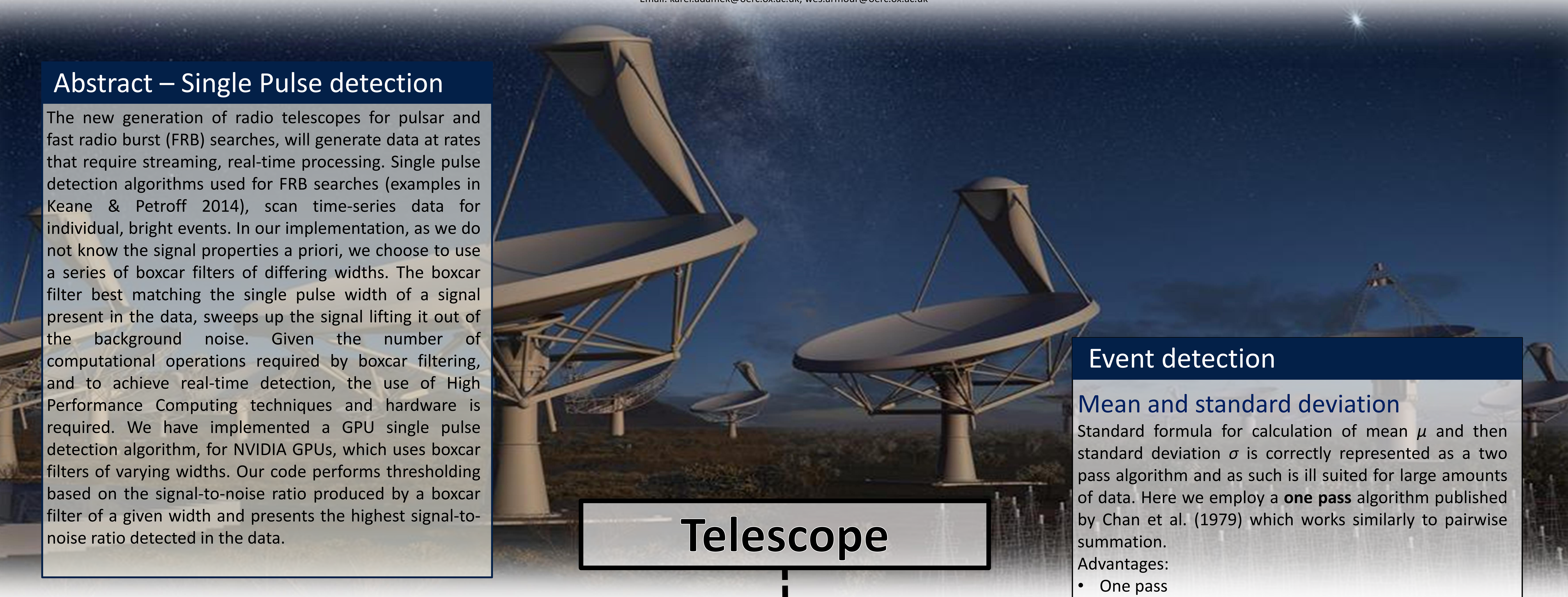
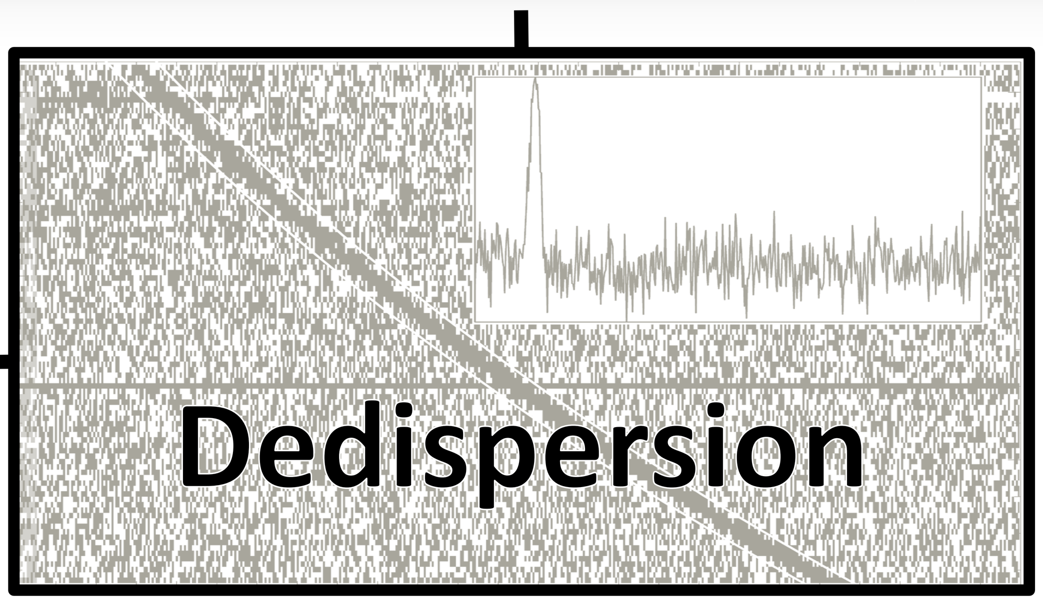


Abstract – Single Pulse detection

The new generation of radio telescopes for pulsar and fast radio burst (FRB) searches, will generate data at rates that require streaming, real-time processing. Single pulse detection algorithms used for FRB searches (examples in Keane & Petroff 2014), scan time-series data for individual, bright events. In our implementation, as we do not know the signal properties a priori, we choose to use a series of boxcar filters of differing widths. The boxcar filter best matching the single pulse width of a signal present in the data, sweeps up the signal lifting it out of the background noise. Given the number of computational operations required by boxcar filtering, and to achieve real-time detection, the use of High Performance Computing techniques and hardware is required. We have implemented a GPU single pulse detection algorithm, for NVIDIA GPUs, which uses boxcar filters of varying widths. Our code performs thresholding based on the signal-to-noise ratio produced by a boxcar filter of a given width and presents the highest signal-to-noise ratio detected in the data.

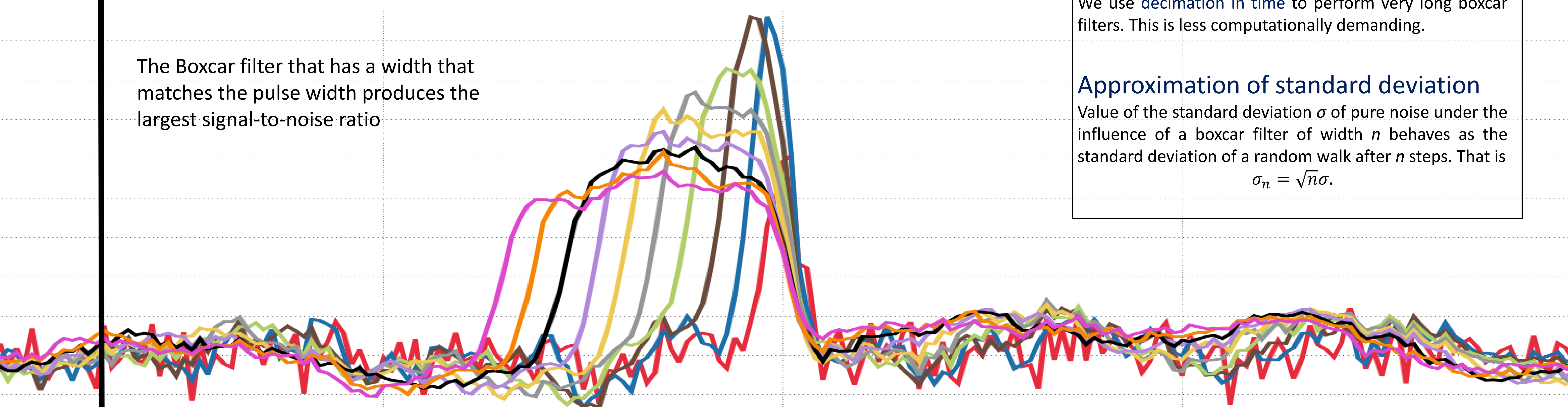
Telescope



Dedispersion

Event detection

- Mean and standard deviation
- Boxcar filters
- Decimation in time



The Boxcar filter that has a width that matches the pulse width produces the largest signal-to-noise ratio

Event detection

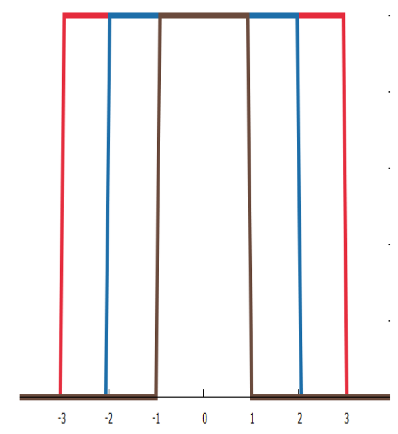
Mean and standard deviation

Standard formula for calculation of mean μ and then standard deviation σ is correctly represented as a two pass algorithm and as such is ill suited for large amounts of data. Here we employ a **one pass** algorithm published by Chan et al. (1979) which works similarly to pairwise summation.

Advantages:

- One pass
- More precise than standard two pass formulae
- Parallel in nature and a good fit for GPUs.

Boxcar filter



Boxcar filter is a simple summation performed in point wise fashion. The boxcar filter is given by the equation

$$y[n] = \sum_{t=0}^{T-1} x[n+t]$$

It is less sensitive then matched filtering, but more general.

We use decimation in time to perform very long boxcar filters. This is less computationally demanding.

Approximation of standard deviation

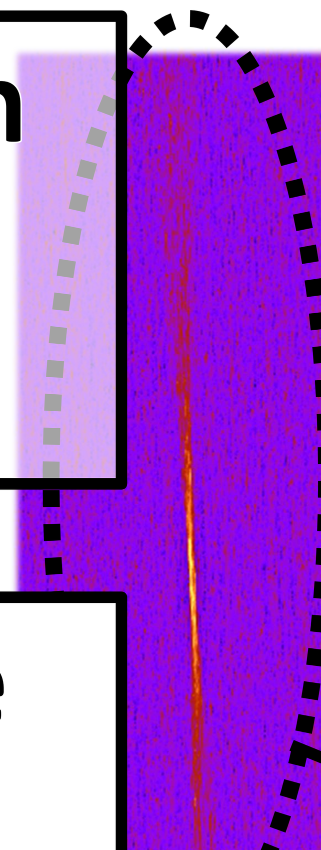
Value of the standard deviation σ of pure noise under the influence of a boxcar filter of width n behaves as the standard deviation of a random walk after n steps. That is

$$\sigma_n = \sqrt{n}\sigma.$$

Candidate selection

- Thresholding
- Clustering
- Candidate list

Storage and offline processing



Candidate selection

Thresholding

- Saves only events above some significance threshold.
- Simpler than clustering and runs faster
- However this produces a lot of candidates

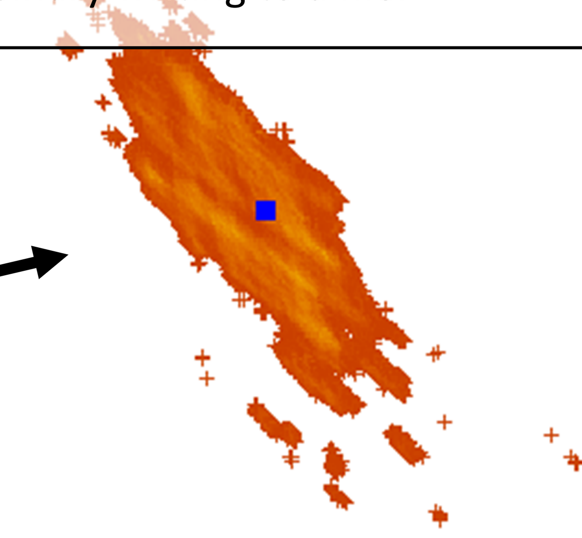
We use atomics with WARP aggregated requests to global memory. This reduces the number of atomic operations.

Clustering

- More complex then Thresholding
- But gives an order of magnitude reduction in number of candidates

We are considering:

- K-means, however this leaves us with the problem of determining how many clusters we should have.
- Percolation



Results

Comparison of our new GPU method with our previous CPU code in Astro-Accelerate using SKA-like data: *CPU: 2.05s ; GPU: 0.12s; Speed-up:* ***17x***

GPU performs 4-times more boxcar filters than the CPU, hence is more sensitive.

The real-time speedup factor of our Astro-Accelerate code has increased to: **4.3x**

This also includes our de-dispersion GPU code [2] and binary writing to a file.

References

[1] Chan T., Golub G., LeVeque R., 1979. Updating Formulae and a Pairwise Algorithm for Computing Sample Variances
[2] Armour W. et al., 2012. A GPU-based Survey for Millisecond Radio Transients Using ARTEMIS, ADASS XXI, Paris, France
[3] Keane E., Petroff E., 2015. Fast radio bursts, search sensitivities and completeness, MNRAS 447, 2852–2856
[4] Lorimer D. R. et al., 2007, A Bright Millisecond Radio Burst of Extragalactic Origin, Science
[5] SKA Website https://www.skatelescope.org