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NSF DWEL Pulse Model from Stationary Scans in Aug. 2014

Generate a DWEL pulse model for a wavelength from a given HDF5 file. The HDF5 files are from several stationary scans collected in Aug. 2014 at UMass Lowell CAR center. ***NOTICE***: the wavelength labels of all NSF DWEL scans used in this document are **swtiched**. All "1064" in the comments and codes is the actual 1548 and vice versa.

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set *wavelength* to the wavelength we are interested. Create data set names and file names. *wavelength*=1548 actually reads 1064 data, vice versa.

```
wavelength = 1064;
wfsetname = ['/', num2str(wavelength), ' Waveform Data'];
```

Establish a baseline for noise removal

We blocked the lasers and collected pure noise returns saved in a HDF5 file. However, there are transient ringing noise in the noise sample returns as well, which makes our extraction of a robust baseline difficult. I tentatively tried median rather than mean to walk around transient noise in the extraction of a baseline.

```
% the input HDF5 file name of noise returns
wirehdf5filename = ['/projectnb/echidna/lidar/Data_DWEL_TestCal/' ...
                    'Calibration_NSFDWEL_20140812/WireSamples/waveform_2014-' ...
                     '08-12-12-12.hdf5'];
% read waveform data
noisewf = single(h5read(wirehdf5filename, wfsetname));
numwf = size(noisewf, 2);
numbin = size(noisewf, 1);
```

Because of transient noises in the waveforms, a mean waveform will be affected and I've seen the effect. Here a median waveform will be tested to see if we can get a better waveform.

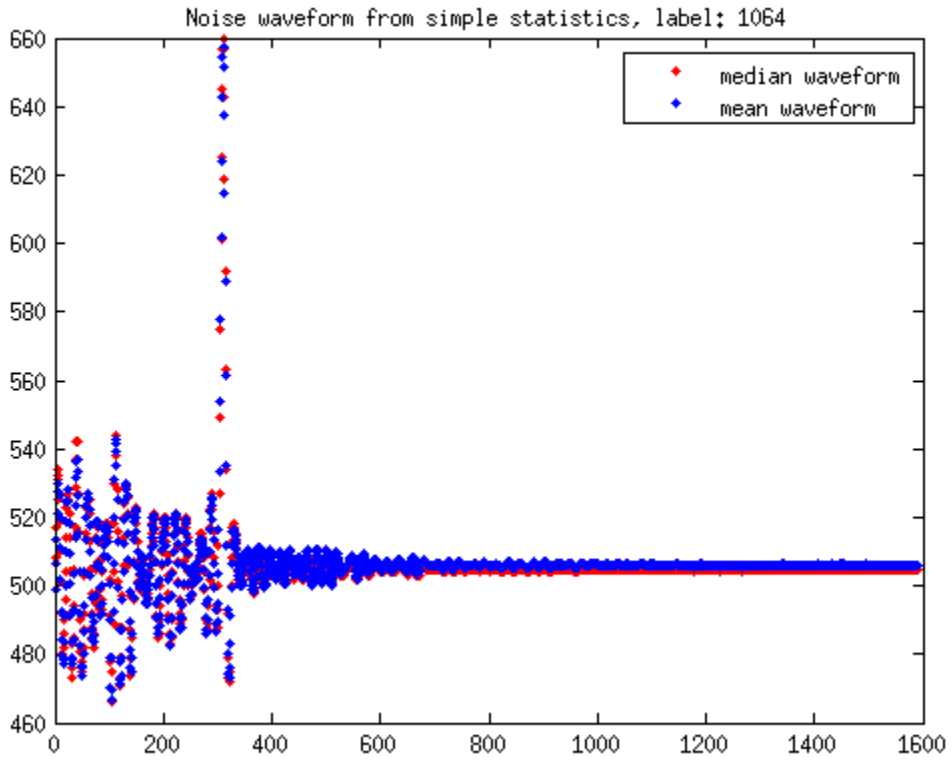
```
mdnoisewf = median(noisewf, 2);
```

Compare the median with the mean waveform

```
meannoisewf = mean(noisewf, 2);
```

Plot the waveforms. Notice that now the first two bins (32 bits) in the waveforms are assigned with pulse sequence number. Skip them if you need the just the waveform data.

```
figure();
plot(mdnoisewf(3:end), '.r');
hold on;
plot(meannoisewf(3:end), '.b');
title(['Noise waveform from simple statistics, label: ', num2str(wavelength)]);
legend('median waveform', 'mean waveform');
```



Extract waveforms from the tube

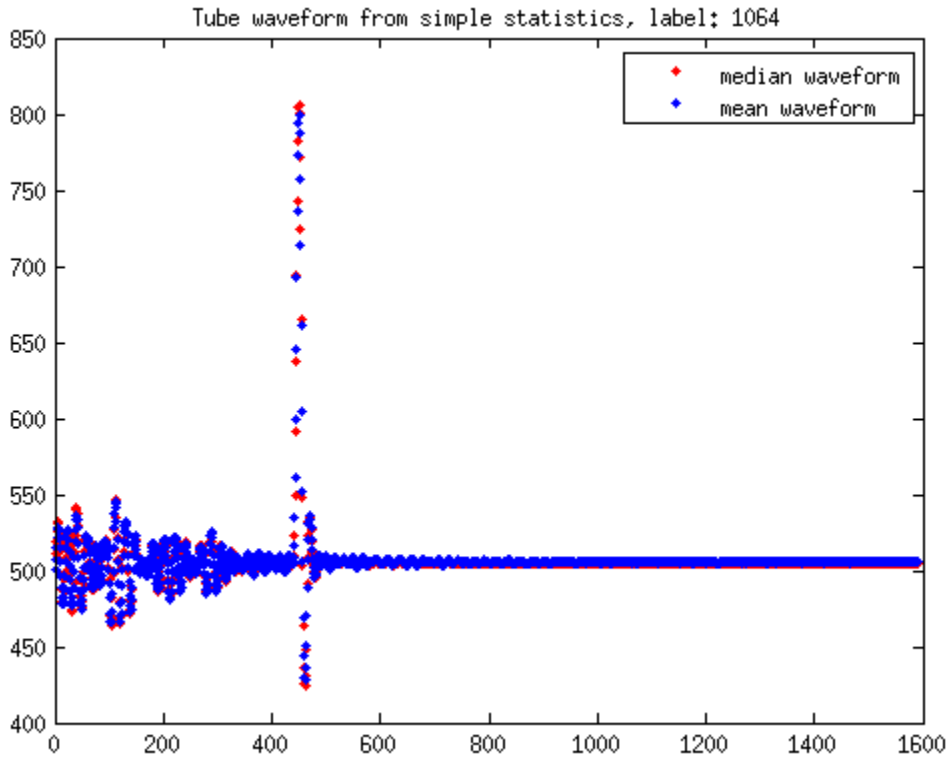
We collected returns from a tube's specular reflection at a few meters away, ~10 m and saved the waveforms in a HDF5 file.

```
% the input HDF5 file name of tube returns
tubehdf5filename = ['/projectnb/echidna/lidar/Data_DWEL_TestCal/' ...
                    'Calibration_NSFDWEL_20140812/TubeSamples/waveform_2014-' ...
                    '08-12-13-58.hdf5'];
% read the 1548 waveform data (actual 1064)
tubewf = single(h5read(tubehdf5filename, wfsetname));
numtubewf = size(noisewf, 2);
numtubebin = size(noisewf, 1);
```

Median waveform here as well. Compare it with mean again.

```
mdtubewf = median(tubewf, 2);
```

```
meantubewf = mean(tubewf, 2);
figure();
plot(mdtubewf(3:end), '.r');
hold on;
plot(meantubewf(3:end), '.b');
title(['Tube waveform from simple statistics, label: ', num2str(wavelength)]);
legend('median waveform', 'mean waveform');
```



Remove baseline and establish pulse model

Subtract the noise waveform from the tube waveform. Slice 160 bins centered at the peak as the pulse model. Then normalize the derived waveform such that the maximum is one.

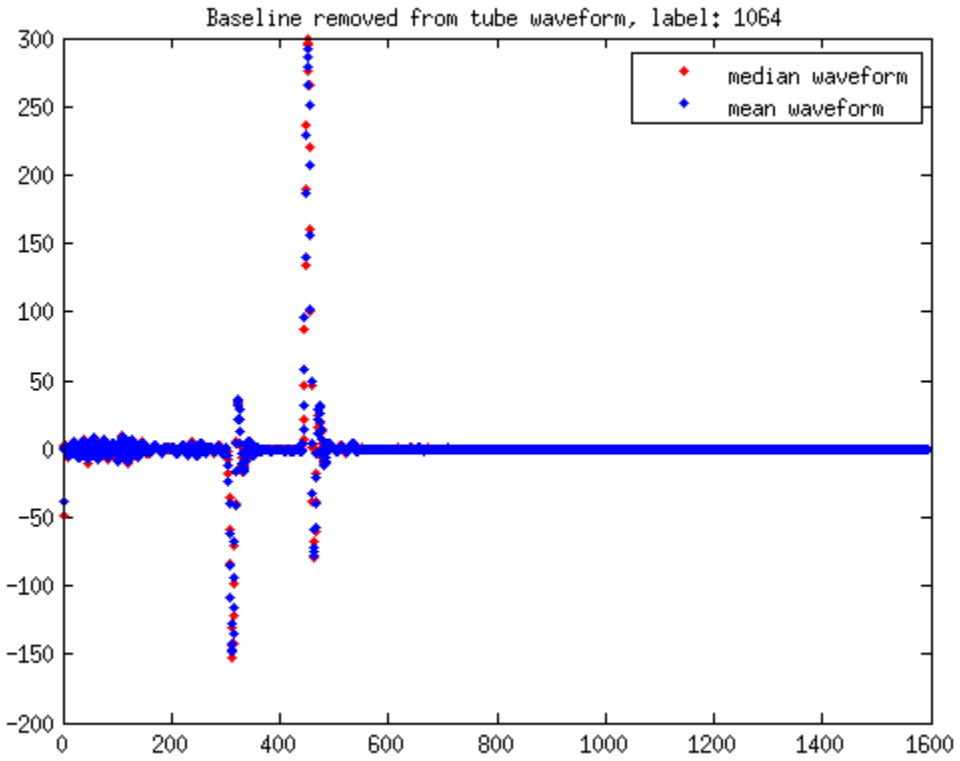
Also compare the pulse model from median and mean.

The median pulse shape shows the same pulse width, trough amplitude and secondary peak amplitude but avoids the bump in front of the mean pulse shape which is from transient noise. Also the head and tail of the pulse shape is cleaner, closer to zero.

```
% remove the baseline
mdpulsemodel = mdtubewf - mdnoisewf;
meanpulsemodel = meantubewf - meannoisewf;
figure();
plot(mdpulsemodel, '.r');
hold on;
plot(meanpulsemodel, '.b');
```

```
title(['Baseline removed from tube waveform, label: ', num2str(wavelength)]);
legend('median waveform', 'mean waveform');

fig2plotly(gcf, 'filename', ['Baseline removed from tube waveform label ', ...
                    num2str(wavelength)], 'open', false);
```



Double check if the background is at zero

We've noticed that the mean background intensity is not at zero level which will give a decreasing trend at the beginning of the pulse model integral. Looking at the beginning and end of the pulse after baseline removal, intensity values are generally zero and small negatives (-1 to -3) and I think this is because median filter somehow gives slightly small values in the tube waveforms than the noise waveforms. It may be because of different sample size of tube waveforms and noise waveforms???

Anyway here we double check the mean background noise level by looking at the average of the first and last 20 bins of a 160-bin section of the whole waveform. Fit a line between the two averages.

```
% slice a section of 161 bins centered at the peak
[pmax, pind] = max(mdpulsemodel);
mdpulsemodel = mdpulsemodel(pind-80:pind+80);
[pmax, pind] = max(meanpulsemodel);
meanpulsemodel = meanpulsemodel(pind-80:pind+80);
% get a mean background and force it to zero.
tmpbgl = mean(mdpulsemodel(1:20))
tmpbgr = mean(mdpulsemodel(end-19:end));
slope = (tmpbgr-tmpbgl)/(length(mdpulsemodel)-10-10);
```

```
tmp = (1:length(mdpulsemodel)); tmp = reshape(tmp, size(mdpulsemodel));
tmpbg = tmpbgl*ones(size(mdpulsemodel)) + (tmp-10)*slope;
mdpulsemodel = mdpulsemodel - tmpbg;

% normalize
[pmax, pind] = max(mdpulsemodel);
mdpulsemodel = mdpulsemodel/pmax;
[pmax, pind] = max(meanpulsemodel);
meanpulsemodel = meanpulsemodel/pmax;
figure();
plot(mdpulsemodel, '.r');
hold on;
plot(meanpulsemodel, '.b');
title(['Normalized pulse model, label: ', num2str(wavelength)]);
legend('median waveform', 'mean waveform');

fig2plotly(gcf, 'filename', ['Normalized pulse model label ', num2str(wavelength)]
           'open', false)
```

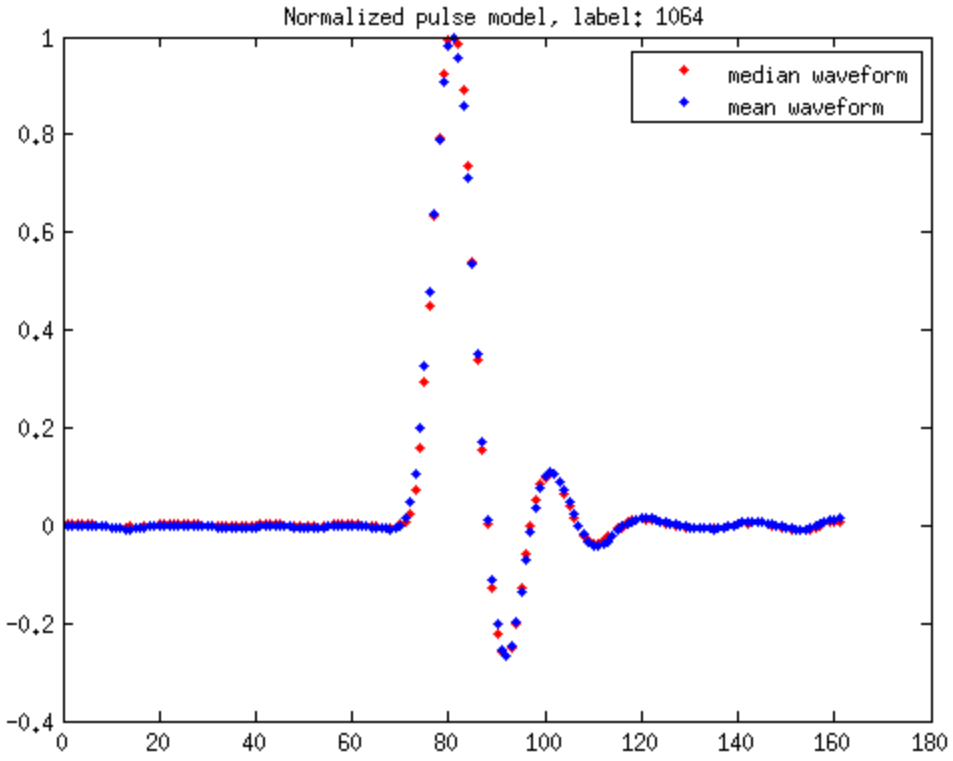
```
tmpbgl =

   -0.9500


ans =

  plotlyfig with properties:

            data: {[1x1 struct]  [1x1 struct]}
          layout: [1x1 struct]
             url: 'https://plot.ly/~zhanli/7'
           error: [1x0 char]
         warning: [1x0 char]
         message: [1x0 char]
        UserData: [1x1 struct]
     PlotOptions: [1x1 struct]
```

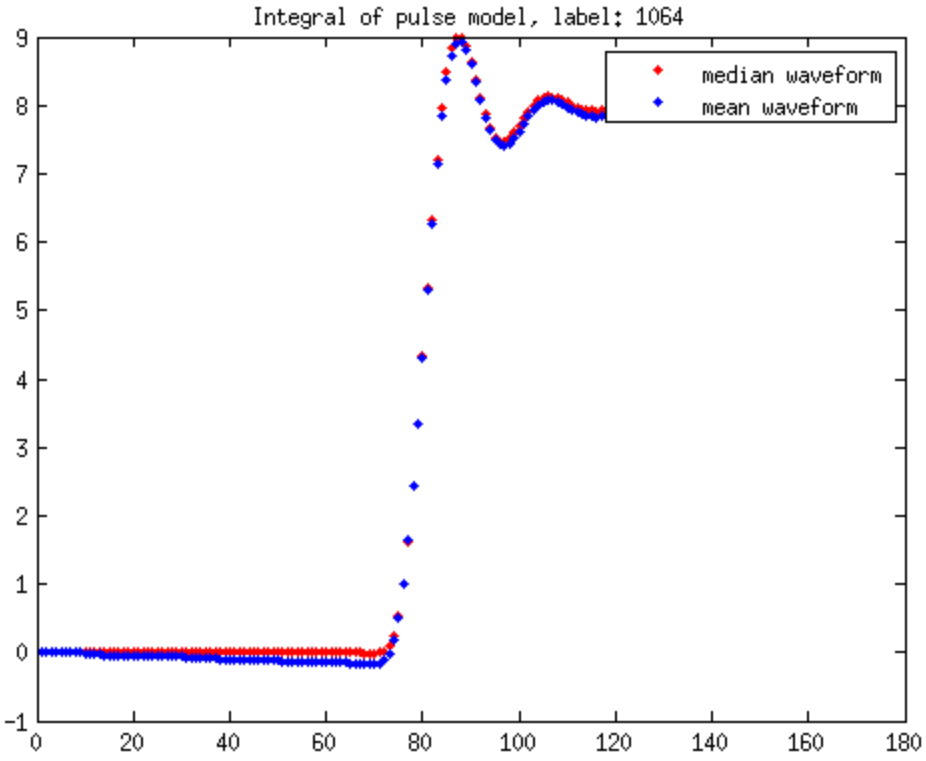


Check the integral of the pulse model

The integral of the median pulse model has lower asymtope value because the head and tail of the median pulse model have bin values closer to zeros.

```
intmdpulse = cumsum(mdpulsemodel);
intmeanpulse = cumsum(meanpulsemodel);
figure();
plot(intmdpulse, '.r');
hold on;
plot(intmeanpulse, '.b');
title(['Integral of pulse model, label: ', num2str(wavelength)]);
legend('median waveform', 'mean waveform');

fig2plotly(gcf, 'filename', ['Integral of pulse model label ', num2str(wavelength)
           'open', false);
```



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