COMPUTING SIGNAL-TO-NOISE RATIO (SNR) USING HISTOGRAM OF ENERGY DISTRIBUTION

Program #4

EE 8993: Speech Processing

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1. PROBLEM DESCRIPTION

In this project we are to implement an algorithm that calculates signal-to-noise ratio (SNR) using the histogram of energy distribution method. Several sets of experiments will be performed and the results of these experiments will be compared to those obtained from the class of 1996.

The speech files used in the experiments consists of one and two-channel data. Both type of data used in the experiments are 16-bit linear data sampled at 8000Hz. The following files are used in the experiments.

Filename	Type
710_b_8k.raw	one-channel
710_s_8k.raw	one-channel
711_g_8k.raw	one-channel
712_f_8k.raw	one-channel
sw2001.raw	two-channel

Table 1: Files that are used in the experiments.

The one-channel data can be obtained from www.isip.msstate.edu/resources/courses/ece_8993_speech/homework/1996/data. The two-channel data is located at isip/d00/switchboard/data/20/2001.

The one-channel data has the following format:

<chan 0 byte 0>< chan 0 byte 1><chan 0 byte 2> etc...

while the two-channel data use an interleave format:

<chan 0 byte 0>< chan 1 byte 0><chan 0 byte 1><chan 1 byte 1> etc...

The first set of experiments includes calculating the SNR of the above raw speech files as a function of the frame and window durations using a signal and noise thresholds of 80% and 20%, respectively. The frame and window durations used are given below:

- frame duration of 5, 10, 20, and 40 msec
- window duration of 10, 20, 30, 60 msec

In the next set of experiments, the SNR is calculated as a function of the signal and noise thresholds using the best set of parameters obtained from the first experiment. The thresholds are given as follows:

- signal threshold 80%, 85%, 90%, 95%
- noise threshold 10%, 15%, 20%, 25%

In the third set of experiments, the SNR is calculated for a chunk of Switchboard data using the best set of parameters obtained from the first and second experiments. The Switchboard file chosen for this experiment is:

2. ALGORITHM

The signal-to-noise ratio also shorted for SNR is a measure of signal quality. It is defined as the ratio of the amplitude of the desired signal to the amplitude of the noise signal.

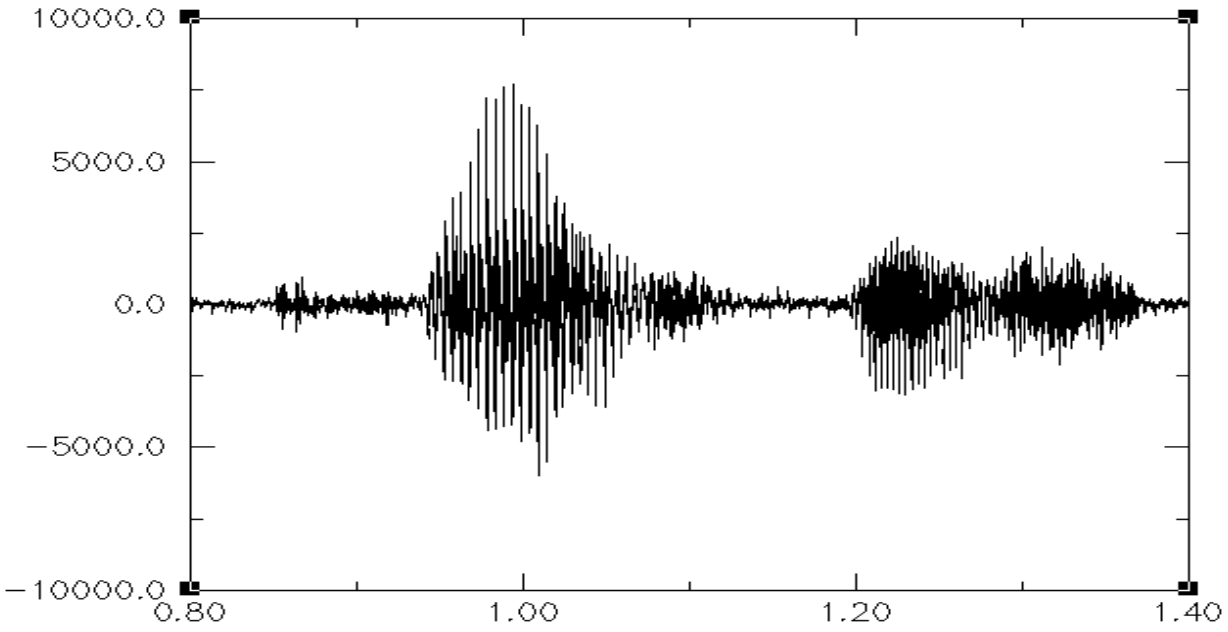

Figure 1: An example of a speech signal.

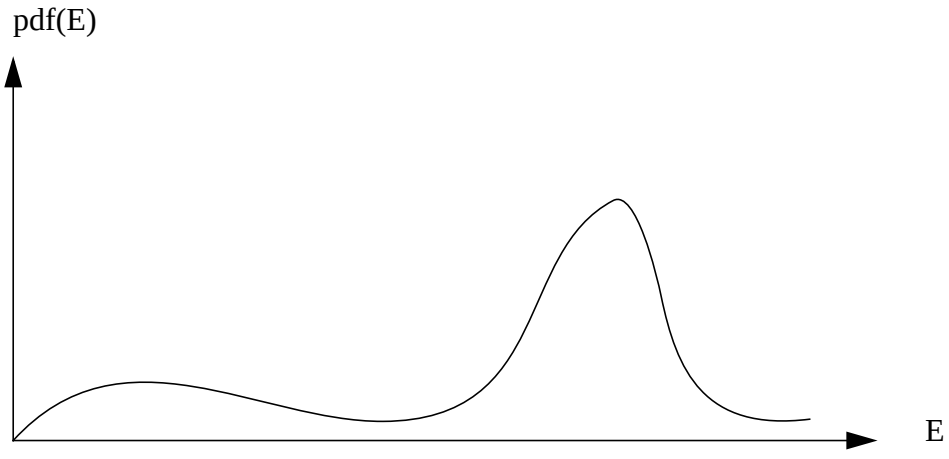

Figure 2: Energy histogram of signal given in Figure 1.

There are many variations of signal-to-noise calculation. In this project, however, we implement the calculation of SNR by using the histogram of energy distribution method. In this method, the energy of the signal is calculated on a frame by frame basis. A histogram of the energy values computed is compiled. So given a signal that looks like the one in Figure 1, the energy histogram might look like one in Figure 2. Since SNR can be defined as:

$$SNR = 10\log\frac{E_s}{E_n} \tag{1}$$

where E_s is the signal energy and E_n is the noise energy. Equation (1) can be alternatively expressed as:

$$SNR = 10\log\frac{(E_s + E_n) - E_n}{E_n} \tag{2}$$

If we can compute the cumulative distribution function (cdf) we can use Equation (2) to get the

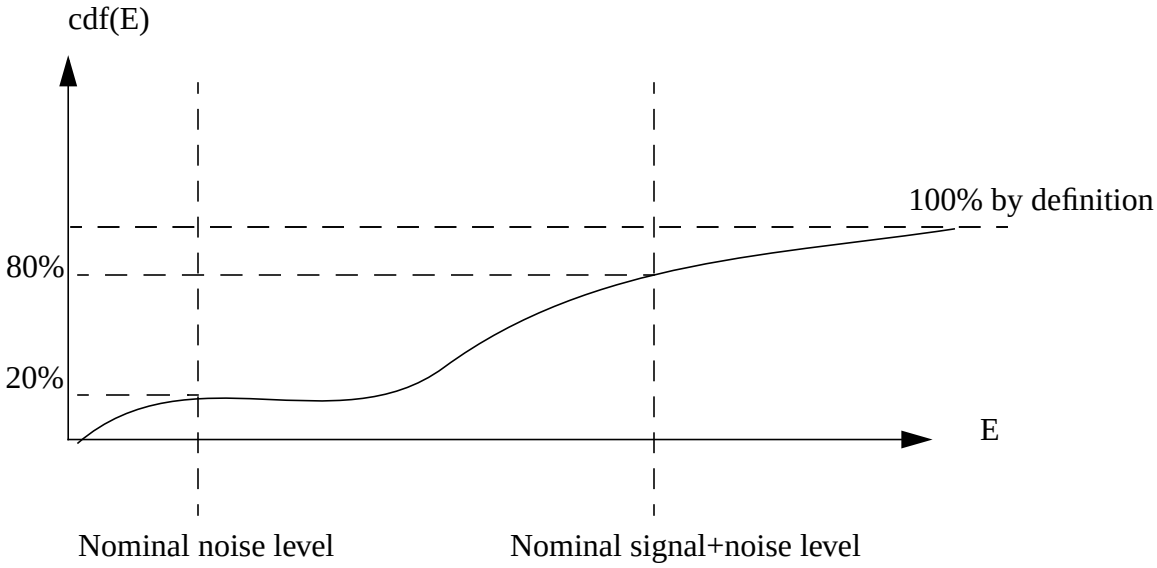

Figure 3: Cdf obtained from pdf given in Figure 2.

SNR. The cdf can be obtained by taking the accumulative of the probability function (pdf). The pdf can be obtained by normalizing the histogram. So back to our example, the cdf of the energy of the signal given in Figure 1 might look like this:

From the cdf, we can "read-off" the signal level E_s and noise level E_n.

The following steps summarize the calculation of the SNR using histogram of energy distribution.

1. Get a frame of data centered on a window. If the window falls out of range, zero pad the window

2.Pre-emphasize the window of data using Equation (3).

$$y(i) = x(i) - 0.95x(i-1) \tag{3}$$

where $y(i)$ is the pre-emphasis value, $x(i)$ is the signal value, $x(i-1)$ is the signal value from the previous window, and 0.95 is the pre-emphasis constant. Pre-emphasis is used to cancel DC bias in the signal.

3.Hamming window the window of data using Equation (4).

$$y(i)) = x(i)\left[0.54 - 0.46\cos\left(\frac{2\pi i}{N-1}\right)\right] \tag{4}$$

where $y(i)$ is the Hamming windowed value, $x(i)$ is the signal value, and N is the total number of samples in the window.

4.Calculate the energy of the window using Equation (5). Save it to calculate the histogram later on.

$$y = \frac{\sum_{i=0}^{N-1} x(i)^2}{N} \tag{5}$$

where y is the energy value of that window, $x(i)$ is the signal value, and N is the total number of samples in the window.

5.Repeat step 1-4 until end of file.

6.Compute the histogram of the energy distribution.

7.Compute the pdf of the histogram.

8.Compute the cdf of the histogram.

9.Compute the SNR using Equation (2).

3. EXPERIMENTAL RESULTS AND DISCUSSION

In this project, three sets of experiments were conducted. The results were compared with those obtained from the class of 1996. In the first set of experiments, we wanted to determine if the frame or window durations have any effect on the SNR. The SNR was calculated for the files given in section 1 with the frame and window duration parameters varied while the other paramters were kept constant. The frame duration was varied from 5 msec to 40 msec, and the

window duration was varied from 10 msec to 60 msec with the noise and signal thresholds remain at 0.20% and 0.80%, respectively. The results are given in Table 2—Table 17. We can see that the frame duration does not have a major effect on the SNR values. Likewise, the window duration has little effect on the SNR values. However, the combination of these two parameters contributes has greater effect on the SNR values. In addition, we can see that the files used for the experiments have varying degree of signal quality with 710_s_8k.raw has the best signal quality of the four files used in testing and 711_f_8k.raw has the worse.

In the second set of experiments, we chose the best parameters obtained from the first experiment, that is, a set of paramters that gives the best SNR for the files tested and determined if noise and signal thresholds have an effect on the SNR. A frame size of 20 msec and a window size of 30 msec give the best results two out of four files tested. These values were used while the noise and signal thresholds were varied from 0.10 to 0.25 and 0.80 to 0.95, respectively. The results are given in Table 18—Table 21. We can see that as the noise and signal thresholds increase the SNR increases. This occurs because the thresholding values that we have chosen have not reached the nominal noise and signal levels. However, this behavior ceases to be true when noise and signal thresholds are above 0.25 and 0.95, respectively. This indicates that there are not much signal energy after 0.90 signal threshold to offset the noise threshold. Figure 8—Figure 11 show scatter plots of SNR as a function of noise and signal thresholds.

In the third set of experiments, we evaluated the SNR on a Switchboard file sw2001.raw using the best paramters from the previous two experiments. sw2001.raw was evaluated using a frame of 20 msec, a window of 30 msec, a noise threshold of 0.20% and a signal threshold of 0.90%. The SNRs for both channels were found to be 36.022926 dB and 30.418713 dB.

file	window (msec)	frame(msec)	SNR
710_b_8k.raw	10	5	16.244802
710_b_8k.raw	10	10	15.866564
710_b_8k.raw	10	20	15.450395
710_b_8k.raw	10	40	15.442480

Table 2: SNR as a function of frame duration with respect to a window of 10 msec for 710_b_8k.raw.

file	window (msec)	frame(msec)	SNR
710_b_8k.raw	20	5	16.414530
710_b_8k.raw	20	10	16.588209
710_b_8k.raw	20	20	16.439322
710_b_8k.raw	20	40	15.943925

Table 3: SNR as a function of frame duration with respect to a window of 20 msec for 710_b_8k.raw.

file	window (msec)	frame(msec)	SNR
710_b_8k.raw	30	5	16.596828
710_b_8k.raw	30	10	16.552950
710_b_8k.raw	30	20	16.691147
710_b_8k.raw	30	40	15.986185

Table 4: SNR as a function of frame duration with respect to a window of 30 msec for 710_b_8k.raw.

file	window (msec)	frame(msec)	SNR
710_b_8k.raw	60	5	16.460327
710_b_8k.raw	60	10	16.393894
710_b_8k.raw	60	20	16.294994
710_b_8k.raw	60	40	16.275549

Table 5: SNR as a function of frame duration with respect to a window of 60 msec for 710_b_8k.raw.

file	window (msec)	frame(msec)	SNR
710_s_8k.raw	10	5	30.861126
710_s_8k.raw	10	10	31.472828
710_s_8k.raw	10	20	31.183504
710_s_8k.raw	10	40	30.692507

Table 6: SNR as a function of frame duration with respect to a window of 10 msec for 710_s_8k.raw.

file	window (msec)	frame(msec)	SNR
710_s_8k.raw	20	5	31.318970
710_s_8k.raw	20	10	31.384382
710_s_8k.raw	20	20	30.903053
710_s_8k.raw	20	40	30.940752

Table 7: SNR as a function of frame duration with respect to a window of 20 msec for 710_s_8k.raw.

file	window (msec)	frame(msec)	SNR
710_s_8k.raw	30	5	31.395359
710_s_8k.raw	30	10	31.369610
710_s_8k.raw	30	20	31.507902
710_s_8k.raw	30	40	31.188627

Table 8: SNR as a function of frame duration with respect to a window of 30 msec for 710_s_8k.raw.

file	window (msec)	frame(msec)	SNR
710_s_8k.raw	60	5	26.745348
710_s_8k.raw	60	10	26.933214
710_s_8k.raw	60	20	27.142965
710_s_8k.raw	60	40	28.054449

Table 9: SNR as a function of frame duration with respect to a window of 60 msec for 710_s_8k.raw.

file	window (msec)	frame(msec)	SNR
711_f_8k.raw	10	5	9.119938
711_f_8k.raw	10	10	9.402864
711_f_8k.raw	10	20	9.066444
711_f_8k.raw	10	40	10.096010

Table 10: SNR as a function of frame duration with respect to a window of 10 msec for 711_f_8k.raw.

file	window (msec)	frame(msec)	SNR
711_f_8k.raw	20	5	9.788088
711_f_8k.raw	20	10	10.13671
711_f_8k.raw	20	20	9.911191
711_f_8k.raw	20	40	9.977847

Table 11: SNR as a function of frame duration with respect to a window of 20 msec for 711_f_8k.raw.

file	window (msec)	frame(msec)	SNR
711_f_8k.raw	30	5	9.949892
711_f_8k.raw	30	10	10.145644
711_f_8k.raw	30	20	9.931570
711_f_8k.raw	30	40	9.815060

Table 12: SNR as a function of frame duration with respect to a window of 40 msec for 711_f_8k.raw.

file	window (msec)	frame(msec)	SNR
711_f_8k.raw	60	5	9.900345
711_f_8k.raw	60	10	9.969599
711_f_8k.raw	60	20	9.951087
711_f_8k.raw	60	40	9.900935

Table 13: SNR as a function of frame duration with respect to a window of 60 msec for 711_f_8k.raw.

file	window (msec)	frame(msec)	SNR
712_g_8k.raw	10	5	10.397092
712_g_8k.raw	10	10	10.233241
712_g_8k.raw	10	20	10.007339
712_g_8k.raw	10	40	10.456532

Table 14: SNR as a function of frame duration with respect to a window of 10 msec for 712_g_8k.raw.

file	window (msec)	frame(msec)	SNR
712_g_8k.raw	20	5	10.545899
712_g_8k.raw	20	10	10.391139
712_g_8k.raw	20	20	10.244164
712_g_8k.raw	20	40	10.392828

Table 15: SNR as a function of frame duration with respect to a window of 20 msec for 712_g_8k.raw.

file	window (msec)	frame(msec)	SNR
712_g_8k.raw	30	5	10.493260
712_g_8k.raw	30	10	10.442673
712_g_8k.raw	30	20	10.301928
712_g_8k.raw	30	40	10.326337

Table 16: SNR as a function of frame duration with respect to a window of 30 msec for 712_g_8k.raw.

file	window (msec)	frame(msec)	SNR
712_g_8k.raw	60	5	10.462374
712_g_8k.raw	60	10	10.472594
712_g_8k.raw	60	20	10.447512
712_g_8k.raw	60	40	10.516697

Figure 4: SNR as a function of window and frame size (for file 710_b_8k.raw).

Table 17: SNR as a function of frame duration with respect to a window of 60 msec for 712_g_8k.raw.

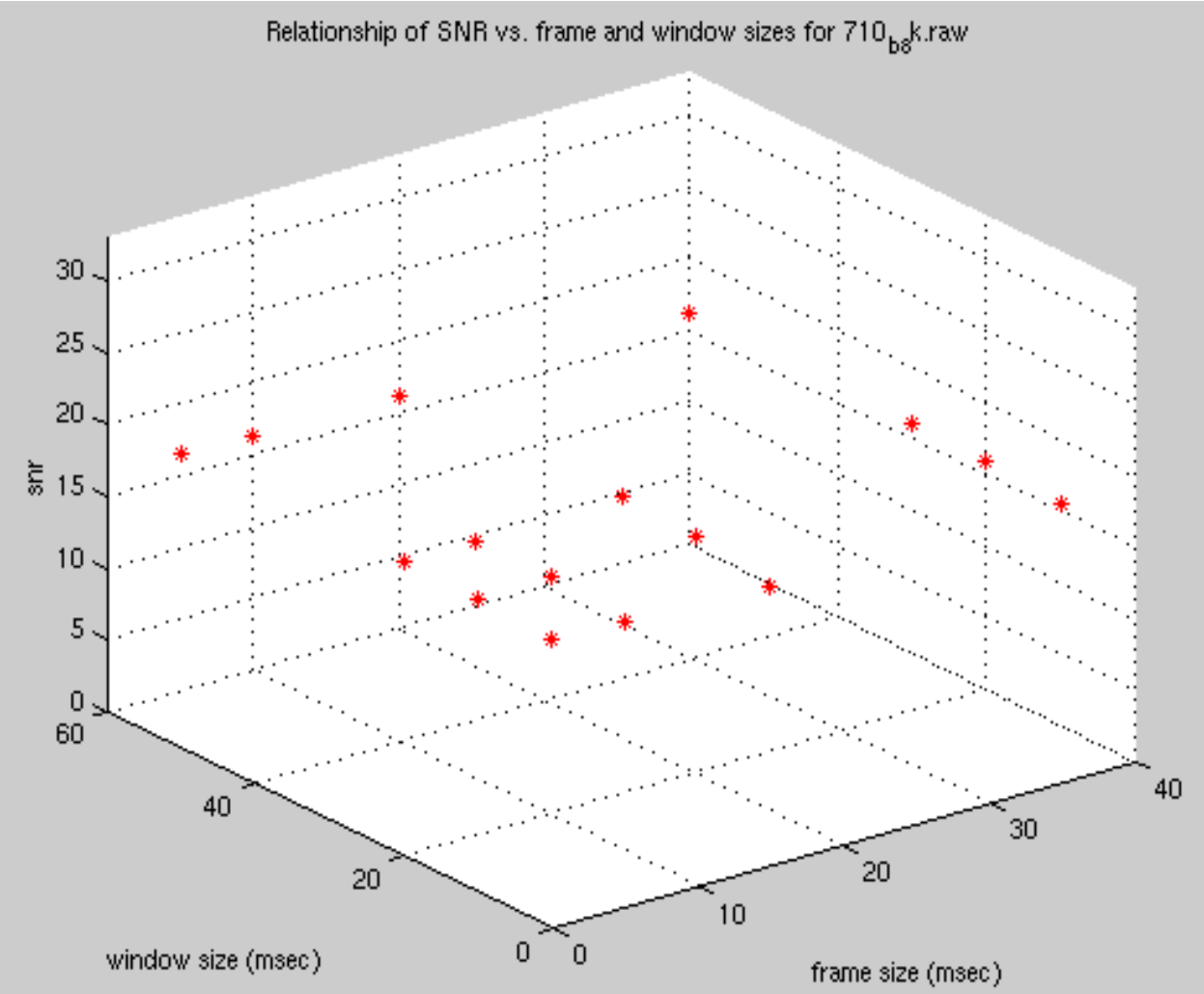

Figure 5: SNR as a function of window and frame size (for file 710_b_8k.raw).

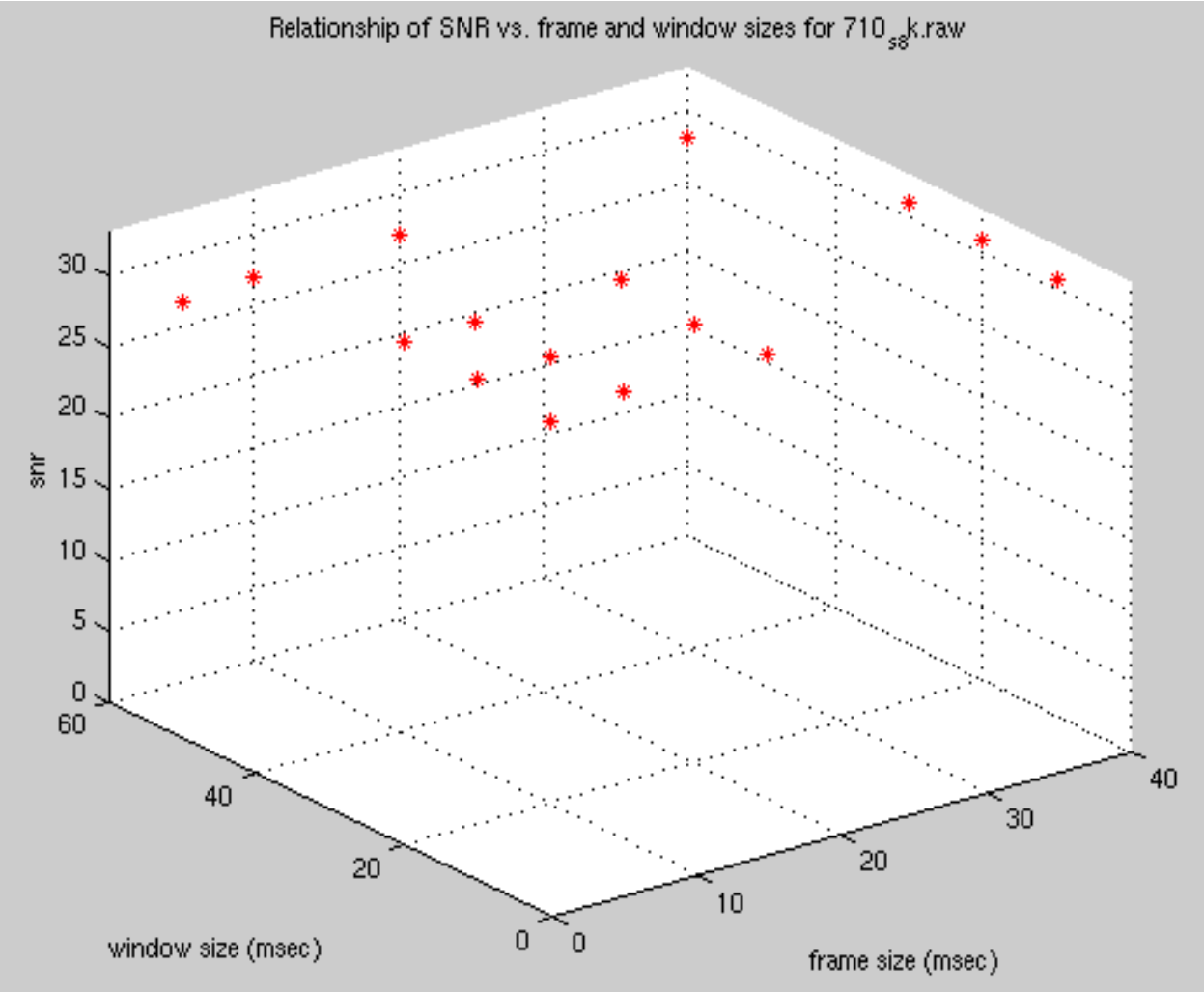

Figure 2: SNR as a function of window and frame size (for file 710_s_8k.raw)

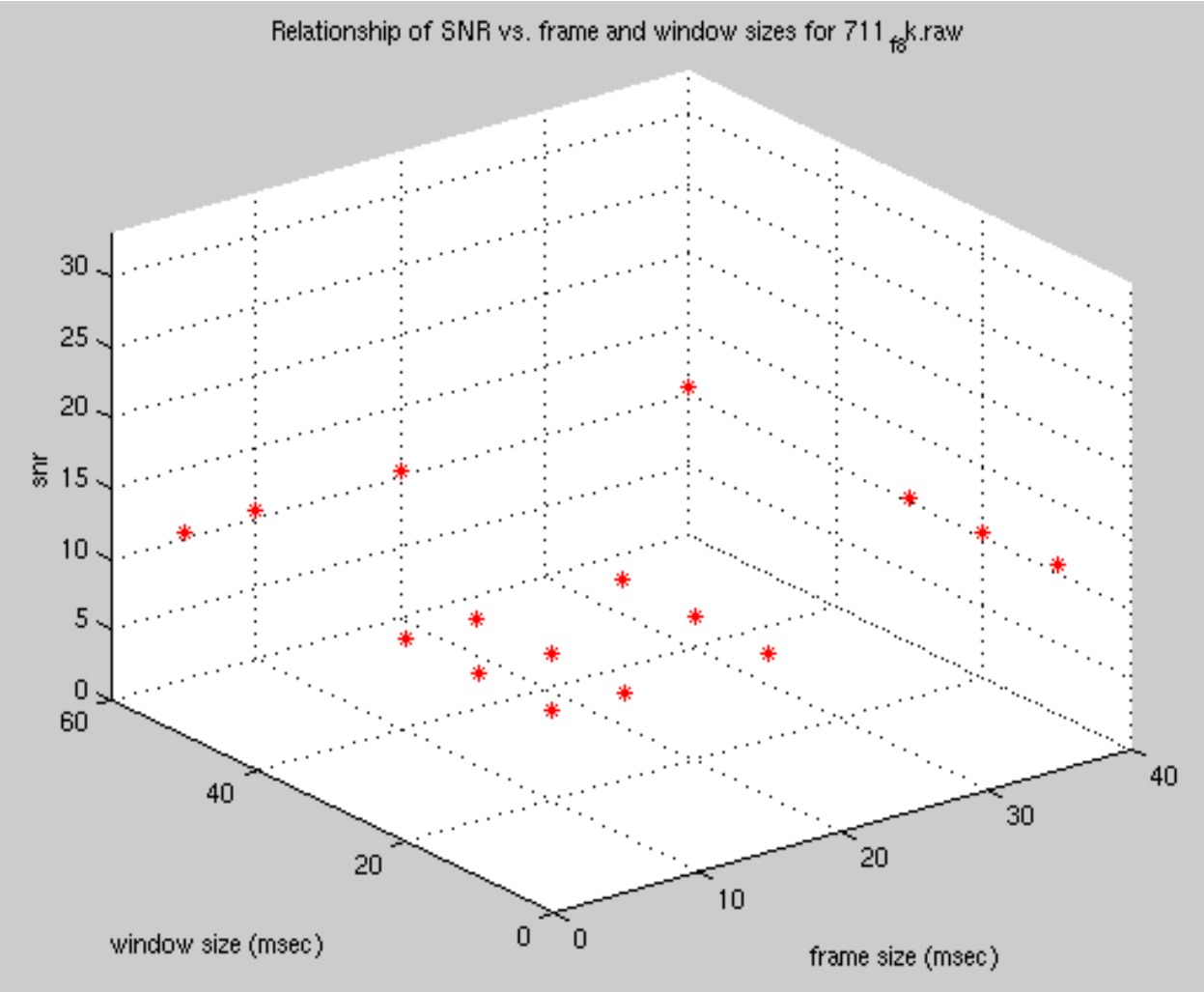

Figure 6: SNR as a function of window and frame size (for file 711_f_8k.raw).

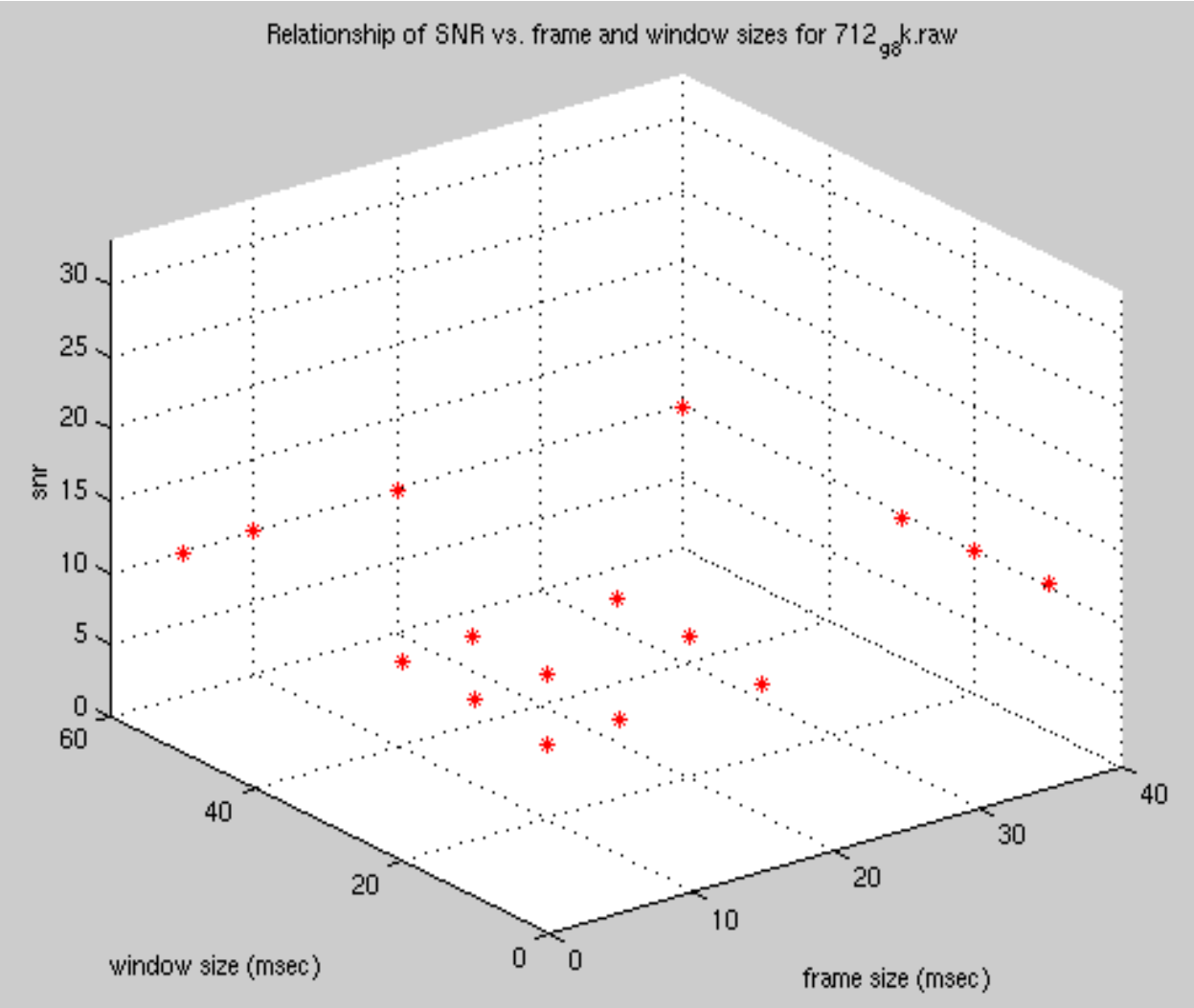

Figure 7: SNR as a function of window and frame size (for file 712_g_8k.raw).

file	noise/signal thresholds	SNR
710_b_8k.raw	0.10/0.80	17.236237
710_b_8k.raw	0.15/0.85	17.959270
710_b_8k.raw	0.20/0.80	16.691147
710_b_8k.raw	0.20/0.90	19.948442
710_b_8k.raw	0.25/0.95	22.077831

Table 18: SNR as a function of noise and signal thresholds for 710_b_8k.raw.

file	noise/signal thresholds	SNR
710_s_8k.raw	0.10/0.80	31.507902
710_s_8k.raw	0.15/0.85	32.866573
710_s_8k.raw	0.20/0.80	31.507902
710_s_8k.raw	0.20/0.90	34.465740
710_s_8k.raw	0.25/0.95	32.752346

Table 19: SNR as a function of noise and signal thresholds for 710_s_8k.raw.

file	noise/signal thresholds	SNR
711_f_8k.raw	0.10/0.80	10.525761
711_f_8k.raw	0.15/0.85	11.181015
711_f_8k.raw	0.20/0.80	9.931570
711_f_8k.raw	0.20/0.90	12.684457
711_f_8k.raw	0.25/0.95	13.755866

Table 20: SNR as a function of noise and signal thresholds for 711_f_8k.raw.

file	noise/signal thresholds	SNR
712_g_8k.raw	0.10/0.80	11.087926
712_g_8k.raw	0.15/0.85	12.195965
712_g_8k.raw	0.20/0.80	10.301928
712_g_8k.raw	0.20/0.90	13.049687
712_g_8k.raw	0.25/0.95	13.929175

Table 21: SNR as a function of noise and signal thresholds for 712_g_8k.raw.

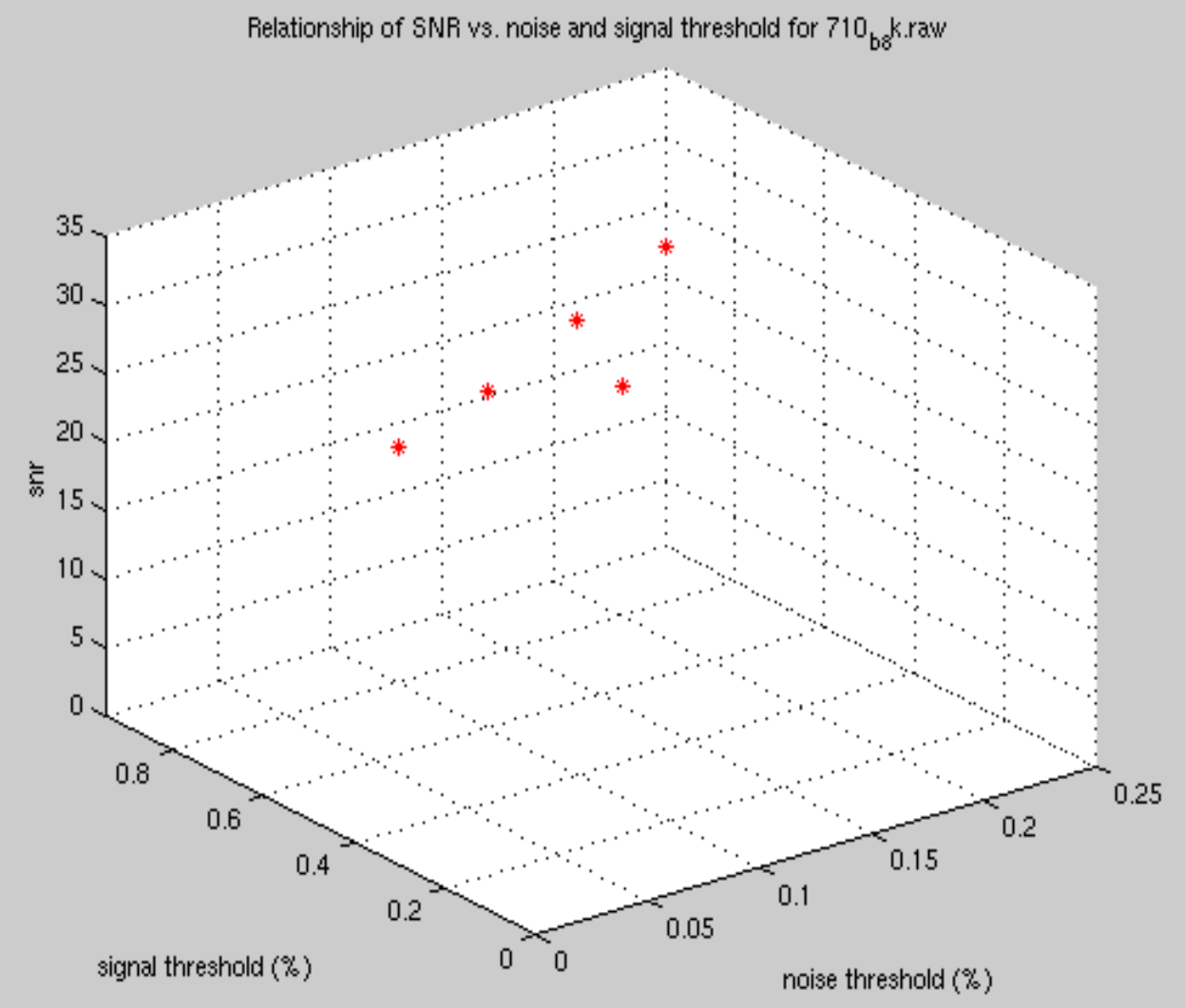

Figure 8: SNR as a function of noise and signal thresholds (20/30 msec frame/window) for file 710_b_8k.raw.

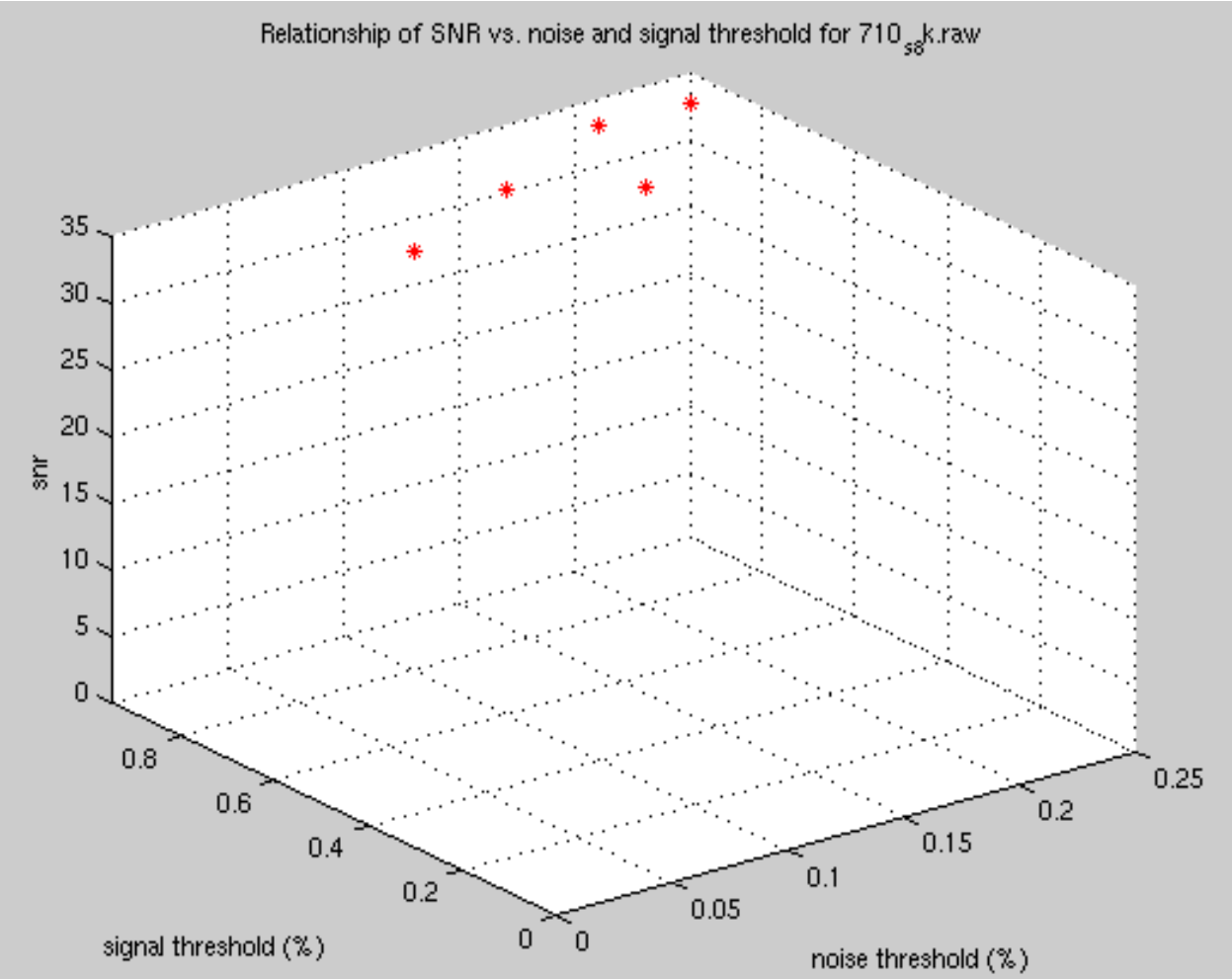

Figure 9: SNR as a function of noise and signal thresholds (20/30 msec frame/window) for file 710_s_8k.raw.

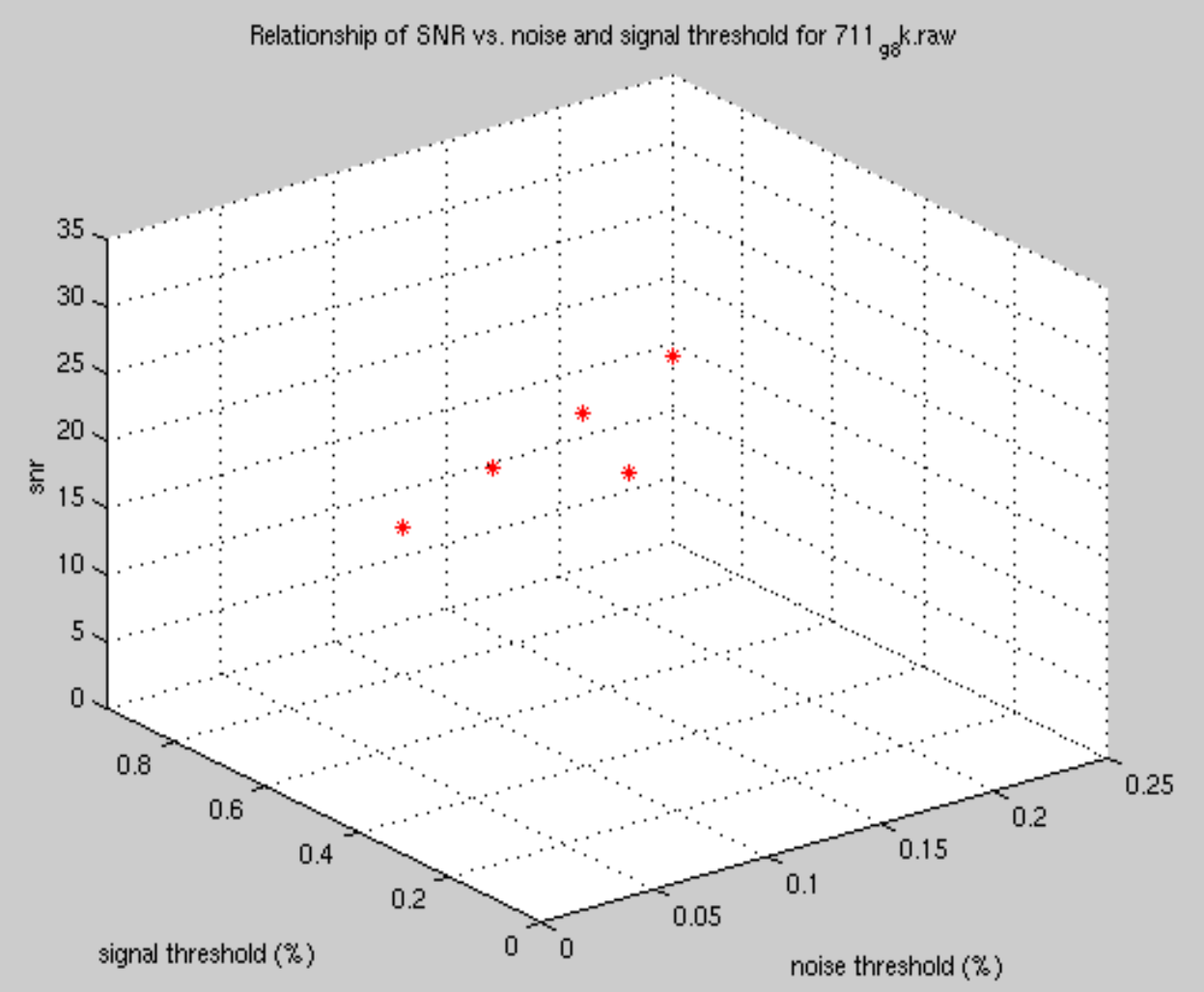

Figure 10: SNR as a function of noise and signal thresholds (20/30 msec frame/window) for file 711_f_8k.raw.

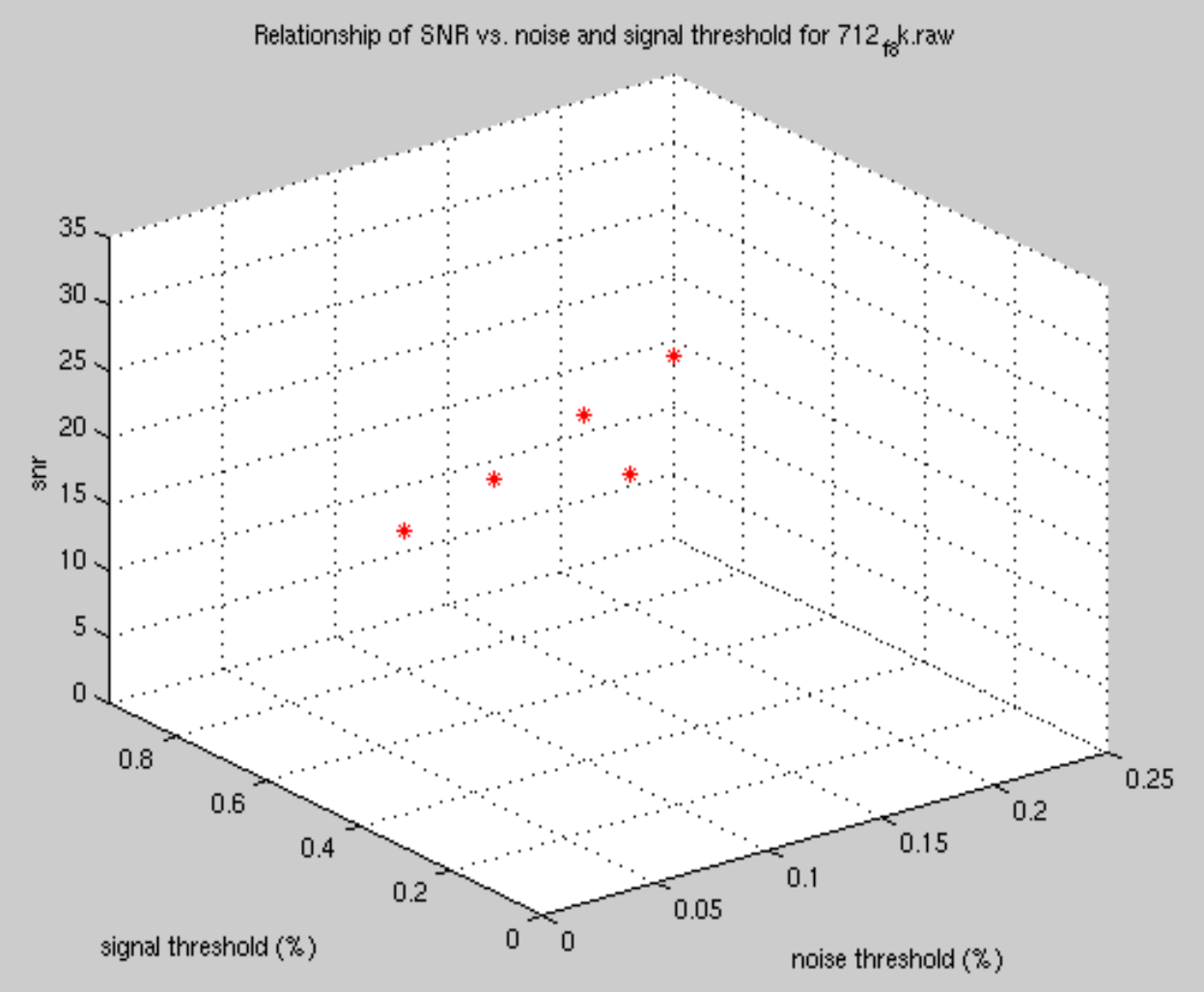

Figure 11: SNR as a function of noise and signal thresholds (20/30 msec frame/window) for file 712_g_8k.raw.