Used Percentage Veto for LIGO/Virgo Binary Inspiral Searches

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Introduction

A challenge for both the Laser Interferometer Gravitational-Wave Observatory (LIGO) and Virgo is to understand the origin of non-astrophysical transients that contribute to the background noise, obscuring real astrophysical signals.

Conventional vetoes (Data Quality flags) only exclude noises whose cause is fairly well known, and therefore many noise transients remain after those vetoes due to their unknown origin. The used percentage veto (UPV) utilizes information from hundreds of channels collecting data from probes around the detector, and it generates vetoes based on statistical properties of those channels to eliminate the noise transients that conventional vetoes could not catch.

Example Glitch in a Auxiliary Channel

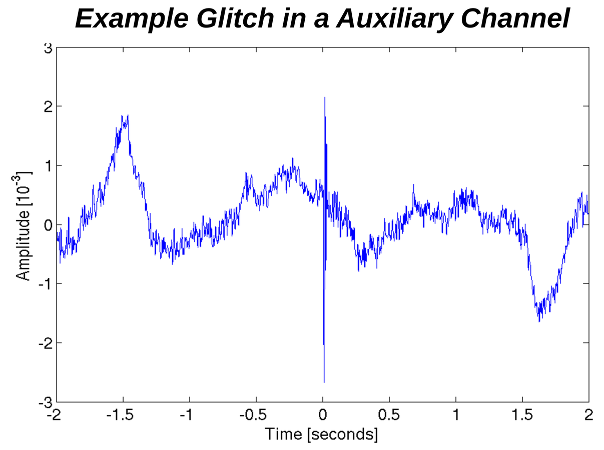

Figure 1: This is a time series of an instrumental channel that keeps the output mode cleaner in resonance. This type of glitch shown here was coupling into our main GW output, but UPV vetoed these glitches successfully.

Methods

UPV is based on finding auxiliary channels that are statistically correlated with the GW channel. It uses KleineWelle (KW) triggers [1], and performs time coincidence between auxiliary channel and the GW channel (+- 1s). It then creates veto segments when the strongly correlated channels have a significance above a certain threshold. UPV uses "used percentage" to measure the correlation (hence its name). Used percentage for an auxiliary channel X at a certain KW significance threshold s is defined as:

$$\text{Used Percentage}(s;X) = 100 \times N_{coinc}(s;X) / N_{total}(s;X)$$

where N_{coinc} is the number of coincident KW triggers in channel X above s, and N_{total} is the number of total KW triggers in the channel X above s.

Use Percentage vs Threshold

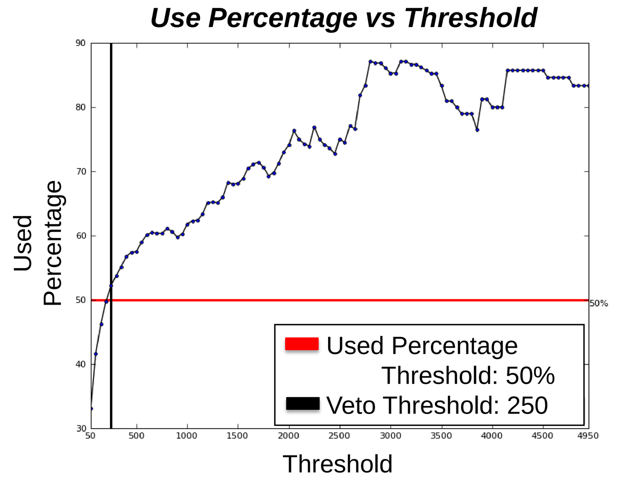

Figure 2: The plot shows used percentage as a function of KW trigger significance for a particular auxiliary channel. UPV picks a significance threshold where the used percentage exceeds 50%, shown as a red line in the plot.

For an ideal veto, used percentage is 100%, but for most of the channels it remains in a few tens of percent for most vetoes in reality. UPV finds channels and thresholds that have a used percentage of at least 50%.

Besides used percentage, we characterize our veto by several other figures of merit. For example, we calculate "efficiency", which tells how many events the veto would eliminate in the gravitational wave channel. We also calculate the dead time of the veto. Since a good veto has high efficiency with low dead time, efficiency/dead time is one of the important measures when we evaluate the effectiveness of the veto.

Efficiency vs Dead Time

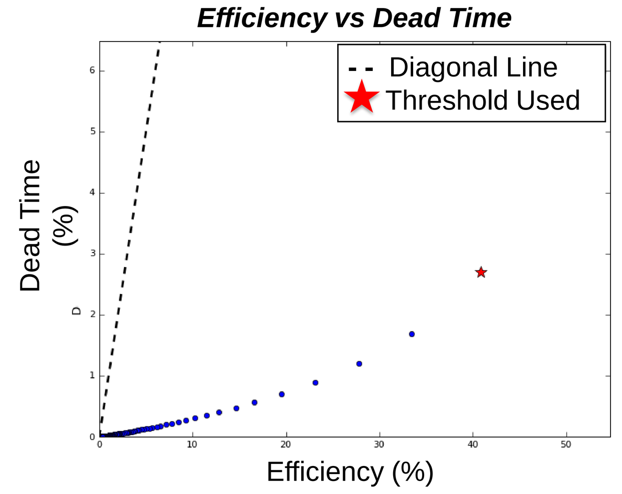

Figure 3: This plot shows efficiency vs dead time. "Good veto" has high efficiency and low dead time, so we would expect the points to be well below the diagonal line (efficiency = dead time). In this case, we can see that the point at our threshold (red star) makes a very effective veto.

Process Diagram of Used Percentage Veto

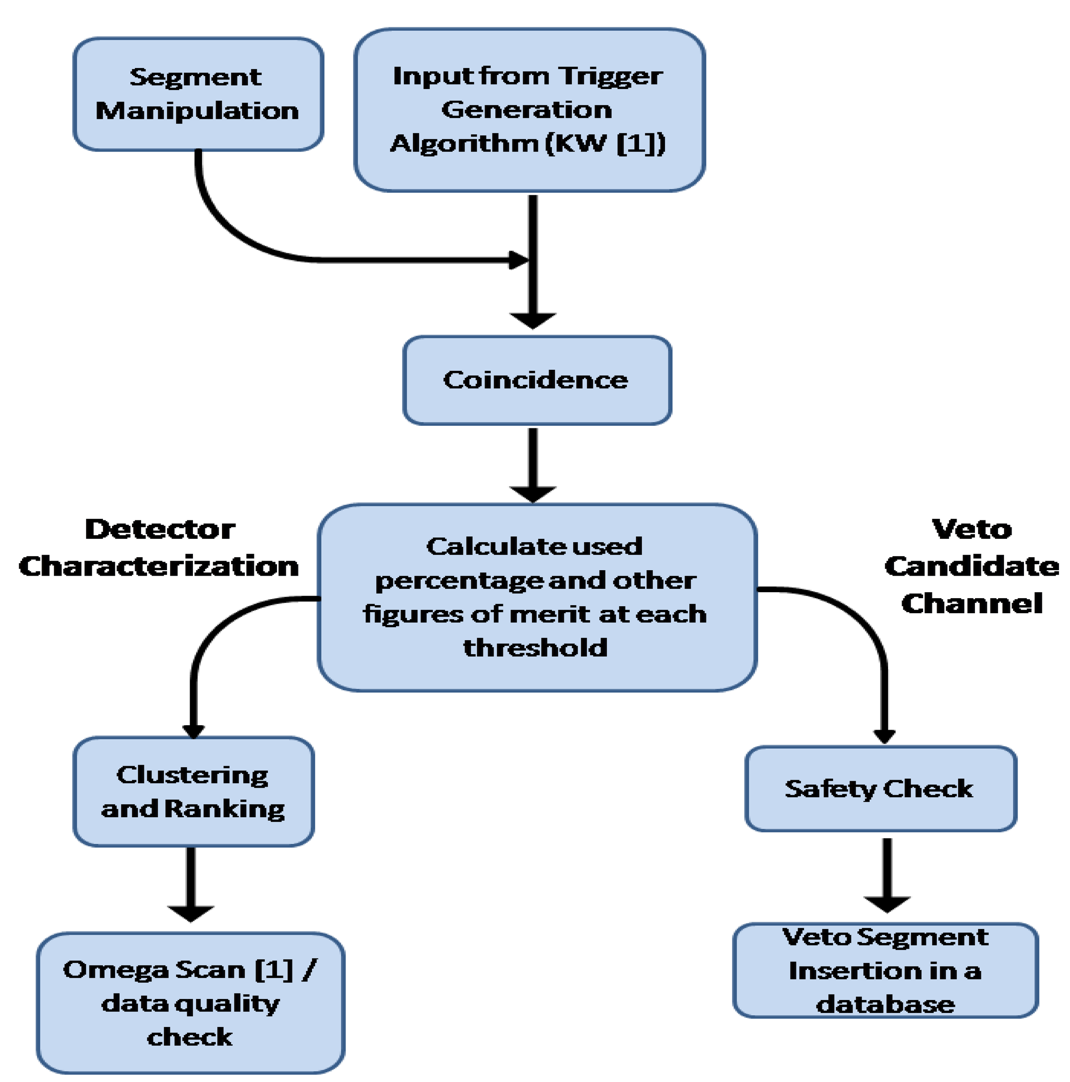

Figure 4: This diagram shows the workflow of UPV for a single auxiliary channel. Figures of merit including used percentage are calculated at each threshold after particularly noisy segments have been excluded. We define vetoes for channels with strong correlation with GW channel. In addition, we use information obtained from this process for detector characterization. This process is done on over 100 auxiliary channels.

Safety Study

Since UPV is based on statistical measurements, it is important that we take sufficient safety cautions so as not to veto a GW signal. One safety study uses simulated GW signals inserted into the data by physically shaking the mirrors (hardware injections).

We define:

$$\text{Safety Probability} = 1 - \text{PoissonCDF}(N_{vetoed} - 1;\ N_{exp})$$

where N_{vetoed} is the number of hardware injections vetoed while N_{exp} is expected to be vetoed assuming uniform distribution. In other words, the safety probability is the Poisson probability that the channel would veto at least N_{vetoed} hardware injections while N_{exp} is expected.

If the safety probability is below a predetermined threshold, the veto segments are not inserted into the database even if the channel is found to be an effective veto.

Application in Detector Characterization

We developed a way to apply this method for detector characterization and to find the physical origins of noise transients. After identifying statistically correlated channels, a follow-up code clusters coincident events between GW channel and auxiliary channels, and thereby classifies noises by correlated channels. For each selected event, the code also gathers and creates information that is helpful for further human investigation (e.g. Omega Scan [1]). The code is running daily to discover new types of glitches.

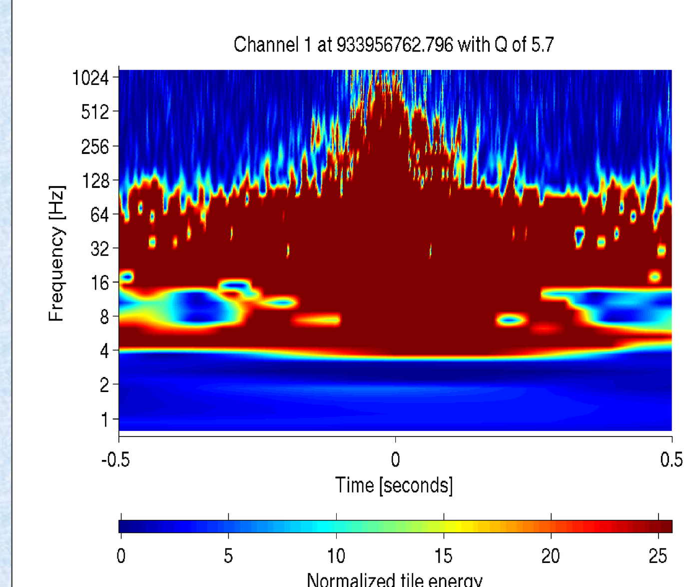

Figure 5: This is a time frequency plot of an auxiliary channel that shows a type of glitch that UPV successfully removed. We are using information obtained through the process to track down the actual cause of glitches.

Conclusions

UPV is contributing to eliminate transients in our data that are hard to be removed by conventional methods. For the ongoing LIGO/Virgo science run, UPV is running week by week automatically, and defining vetoes for binary inspiral searches. As seen in Figure 6, UPV removes high SNR "outlier" glitches.

In addition, UPV is running everyday for detector characterization. It is monitoring day-to-day changes of the detectors with respect to their auxiliary channels, and providing quick feedback for the malfunctioning of some components of the detectors. It also supplies useful information on finding the physical origin of noises, thereby contributing to the improvement of the detectors.

Trigger Number

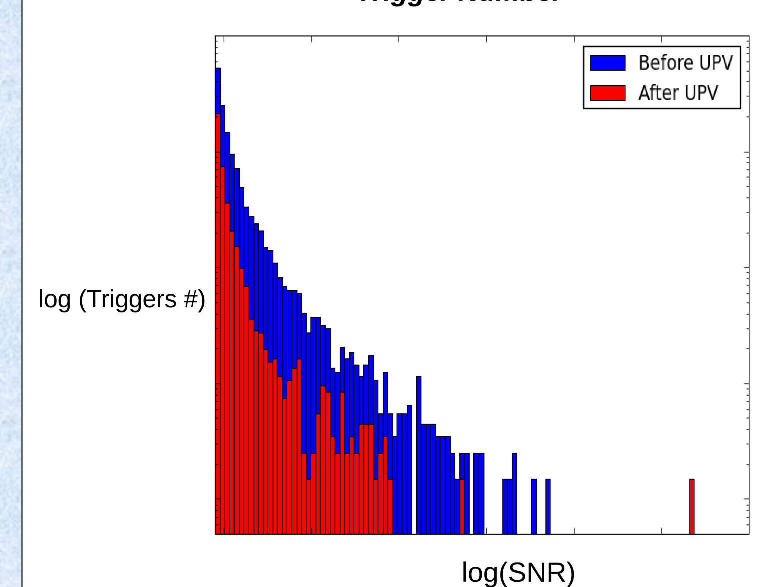

Figure 6: This is a histogram of triggers before and after UPV is applied. We can see that UPV removes many "outliers", helping to obtain stationary data.

Reference

[1] Chatterji, S et al. Multiresolution techniques for the detection of gravitational-wave bursts. Classical and Quantum Gravity 21, S1809, 2004

Acknowledgments

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For further information

Please contact *isogait@carleton.edu*.

Online PDF version of this poster can be found at: *https://virgo.physics.carleton.edu/Tomoki/docs/GWDAW2010_UPV.pdf*

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