METHOD FOR ANALYZING ASTRONOMICAL GAMMA_RAY BURSTS USING SPEECH PROCESSING TECHNIQUES

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ABSTRACT

A method of utilizing speech processing techniques to analyze Gamma-Ray Burst data is presented. Analogies are made that relate the speech processing components to a gamma-ray burst components. The gamma-ray burst components have to be created. These components include a feature vector, a gamma-ray burst model, and a gamma-ray burst language model. Issues addressing the specific nature of gamma-ray burst data are mentioned relative to basic speech processing methodology. Work has been done to create a feature vector but advanced techniques are only mentioned.

1. INTRODUCTION

Analysis in High Energy Astrophysics relies on statistical methods to understand complex astronomical data. One of the hottest topics in High Energy astrophysics that requires further analytical techniques is that of the Gamma-Ray Burst. The source of Gamma-Ray Bursts (GRBs) in High Energy Astrophysics is a mystery. Gamma-Rays from our galaxy and the rest of the universe are measured using space based instruments. The Compton Gamma-Ray Observatory (CGRO) is one of our satellites that measures high energy photons. The Burst and Transient Source Experiment (BATSE) instrument on CGRO measures Gamma-Ray Bursts. A Gamma-Ray Burst (GRB) is a burst of energy recorded by a gamma-ray detector. Gamma Ray Bursts have a duration of a few seconds to hundred of seconds whose energy dwarfs that of the largest know supernova. Their complex nature has kept the source of this intense explosion shrouded in mystery. There does seem to be a few trends that the data does follow that hints that there may be several sources that can result in a GRB. A categorization of these different sources would allow better analysis since it would not be productive to analyze data that was not produced by the same type of phenomenon. Speech Processing techniques could help sort out like type bursts. Typically, a burst is shown as the number of photons that was collected in a 0.064 millisecond time window. A different types of bursts are shown in figure 1. The analysis of the same types of bursts may yield elucidation as to what physics was involved that created it. Description of what created the burst means we will be closer to finding out why the burst happened.

2. SPEECH PROCESSING TECHNIQUES AND GAMMA-RAY BURSTS

The idea that GRB research can benefit from the speech processing techniques lies in there similar nature. They are similar in that both have similar complex temporal input data whose amplitude and duration vary greatly from each speaker or each burst. The major difference, addressed in the conclusion, between speech data and GRB data is that in speech processing you start with a transcription of data to develop your acoustic model

Modern speech processing utilizes statistical pattern recognition. Statistical pattern recognition takes character measurements, denoted features, extracted from the input data and these measurements are used to assign each feature vector one of a number of different classes. These features are assumed to be generated by a state of nature, and therefore the underlying model is of a state of nature or class-conditioned set of probability functions. [1] Speech Processing can be thought of as a series of components as in figure (2). The components include the input signal, the acoustic model, the language model, search, and then the recognized utterance. In the GRB processing a feature vector, a GRB model, and a

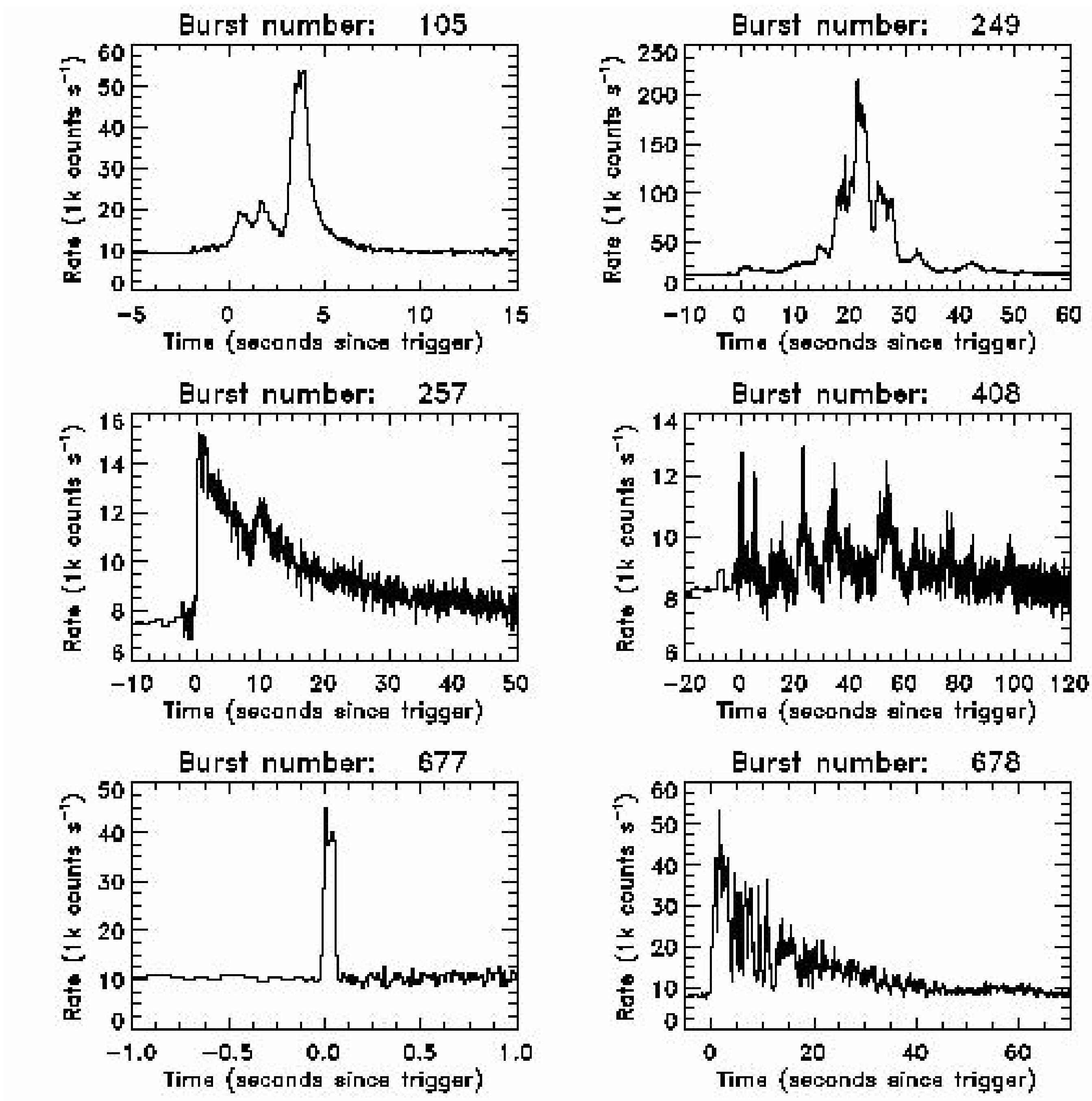

Figure 1. Gamma-Ray bursts tend to follow six basic shapes and there is no transcription for a GRB.

GRB language model will need to be created to have a method analogous to speech processing.

3. GRB MODEL

Speech processing uses the signal from the person and models mechanism that created the signal. This model yields information about the throat that produced the signal. Gamma-ray bursts will go about the process a little bit differently in that the signal will be broken down into basic components and those components will have to be modeled using know astrophysical and physical laws. This break in the analogy represents the break where the problem goes from an engineering problem to one of science. The science needs the model to understand what created the burst. A GRB model must be created to represent the gamma-ray burst signal. Analogous to the acoustic model in speech processing, this GRB model will utilize a feature vector. These features, both temporal and frequency based, describe the shapes in the burst. The shapes must then be reduced into a feature vector so that the pattern can be transcribed. A feature vector for GRB data has been created utilizing the six basic shapes, duration data, fluence data, and Cmin/Cmax data. The latter two are calculated GRB specific data. The features of the six basic shapes include:

- the number of peaks
- the exponential decay following one large peak
- smaller peaks before a main peak
- frequency components (whose exact nature of this is still to be determined)

A GRB model can be created using speech processing techniques once the feature vector is created. K means clustering can be used since the feature points will cluster in a space equal to the number of features. The Euclidean distance can be measured as a means of vector quantizing the feature vector's cluster center. A hidden Markov Model (HMM) approach then

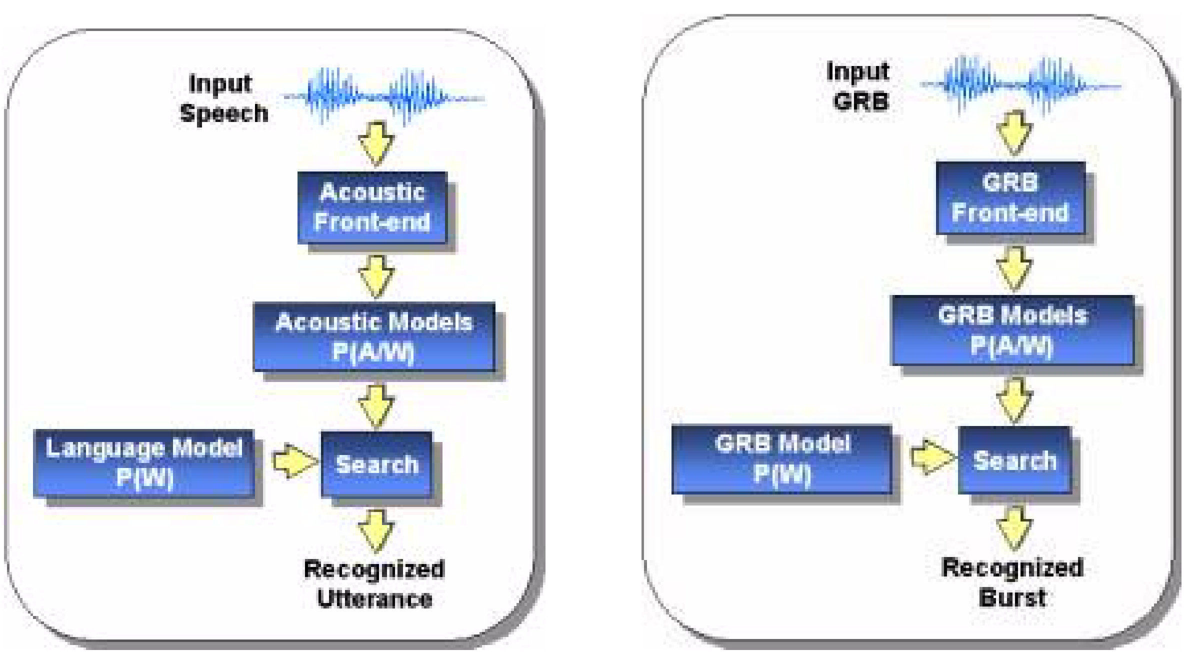

Figure 2. Speech recognition model and a corresponding GRB recognition model. These features will be used to create a GRB model, P(W), which are the six basic shapes.

will be used in the recognition process to allow probabilities that a given feature of a burst will be categorized as one of the defined by the feature vector. The HMM can be trained using either a Baum-Welch or Viterbi algorithms. These methods are explained by Jenlik and Deller. [2,3]

4. GRB LANGUAGE MODEL

A GRB language must be defined. This language model will be the fundamental shapes that comprises a GRB. A language is the underlying information needed to reference the GRB modeled from the input signal. This model is what the recognizer is trying to match. Definition of this model will be done simply by using the fundamental shapes that are in the bursts shown in figure 1. These shapes are the number of peaks, the peak widths, the type of decay after the burst, etc... The language model will also model information in the frequency domain; although, the exact nature of this modeling is to be determined when more frequency information is analyzed and the appropriate literature searched. This language model can assign a specfic character to a specific shape so that each burst that is recognized their will be string of characters that describe each individual GRB. The language model will defines thresholds where features fall within those thresholds then they will be categorized as that type of burst.

5. SEARCH

Search will be a method of classification of the different bursts and tagging characteristics in bursts. New bursts will be sorted into the GRB language model. classification allows for patterns in the data to surface. These patterns will allow better GRB language models to be create. This iteration process should help refine the GRB language model. The tagging of characteristics may also yield identifiable patterns. A metric for evaluating the search results also needs to be determined.

6. CONCLUSION

The absence of a GRB language model limits the usefulness of this direct speech processing engineering approach. This more scientific approach means to use the numerous successes of statistical speech processing as a means of scientific analysis. Similarity can be made in speech processing signals and gamma-ray bursts signals. Hence, utilization of speech processing techniques could yield valuable information about the mechanism behind the GRB. The outlined method sets a direct path for using speech processing methods to further GRB analysis just as speech processing borrowed methods from other areas of research. A new way of looking at the GRB data has been needed and the methods of speech processing may illuminate the hidden structure of the gamma-ray bursts.

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