

# EVENT DETECTION AND CLASSIFICATION

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## ABSTRACT

The IEEE AASP Challenge addresses the problem of acoustic event detection and classification in an office environment. Our system performs segmentation and event classification on a continuous stream of acoustic activity in an office using basic feature extraction techniques and a single layer frame-by-frame classifier. We achieve high classification accuracy in noiseless environments, but performance severely deteriorates in noisy environments.

**Index Terms**— onset, offset, MFCCs, LRT

## 1. INTRODUCTION

The task of event detection and classification is fundamentally important in computational auditory scene analysis (CASA). Detecting events such as words in a sentence of speech, the arrival of a bus or train, or any other common occurrence in an audio stream is the first stage in many speech and audio processing systems. Many such systems then need to classify the detected events in order to take appropriate actions.

In this project submission, the problem of event detection and classification, as applied to an office environment, was approached from a pattern recognition perspective. Our system consists of a segmentation stage, a feature extraction stage, and two classification stages. The first stage detects the onset and offset of events in a live recording, the second extracts features from each event that can be used to classify events, and the final stages classify each detected event on a frame-by-frame basis using a pre-trained likelihood ratio test (LRT) classifier with a MAP decision rule. The performance of the system is evaluated on three datasets: a 5-fold cross-validation using the training dataset itself, the development set with “perfect” segmentation, and the raw development set.

## 2. FEATURE EXTRACTION

In order to classify events, our system extracts an extensive set of features from the provided auditory data. This set includes frequency-based features as well as time-based features, which, together, characterize the data in relative detail. Each of the features

were computed in 50ms windows to balance frequency and time resolution.

### 2.1. Frequency-Based Features

The set of frequency-based features includes the spectral centroid, spectral flux, spectral entropy, short time energy (STE), spectral roll-off, and Mel-frequency cepstral coefficients (MFCCs). Each of these feature highlights different spectral properties of the signal. Short time energy is analogous to the volume of the event and the spectral centroid is essentially the center of mass of the spectrum. They are both expected to be reliable indicators of silence. The spectral flux, also called spectral variation, measures how quickly the power spectrum changes. It can be used to determine the timbre of the audio signal. Different permutations of these features will be tested and the best combination will be used for the system training and classification stages of our system.

### 2.2. Time-Based Features

## 3. TRAINING

The classification stage of our system employs two levels of classification. As input the classifier takes in an event signal and first classifies what type of event it is. Then based upon the type of event the signal is passed through a type-specific classifier which determines the exact event contained in the signal. In the second stage each type has its own classifier.

Each level of classification in the system was trained with features extracted from the provided training data. The first stage classifier was trained using the full set of extracted features for all events. The second stage classifiers were each trained using features extracted only from training signals of the correct type. Additionally, the features used for training were chosen to best describe the type of event being classified.

## 4. SEGMENTATION

Before events within a continuous input signal can be classified, the segments of the input which contain events must be extracted. A speech segmenter[[INSERT DUDE HERE]] accomplishes this by examining the short time energy and spectral centroid features. The segmenter examines peaks of the features and checks them against a threshold to determine the onset and offset of events. The onset and offset times are then used to extract the portions of the input signal which contain an event and pass them on to the classification stage.

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A continuous sound file is input into the segmenter which applies a Chebyshev Type II low pass filter. This step was added to the original segmenter to reduce the amount of background noise and increase onset and offset detection. The segmentation process requires three parameters for feature extraction: window length, step time, and the weight that will be 0 to compare the signal to a threshold. The segmenter was exhaustively tested against the development data to determine the parameters that provided optimal segmentation. Each run of the segmentation test was checked for the number of events it detected. The runs were narrowed down to those that returned the same number of events as the development data indicated. Then the mean square error was calculated using onset and offset times and used to determine the optimal choice of parameters.  $\tau_{(on)i}$  is the estimated onset time and  $\tau_{(off)i}$  is the estimated offset time determined by the segmenter, which is checked against the truth values  $t_{on}$  and  $t_{off}$ .

$$MSE = \min (\tau_{(on)i} - t_{on})^2 + (\tau_{(off)i} - t_{off})^2 \quad (1)$$

The values for the window length, step time, and threshold weight that results in the minimum MSE were 0.05s, 0.04s and 3 respectively. During the exhaustive process, it was also determined that the threshold weight had to be an integer value.

The segmenting function returns a two column vector where the first column indicates each onset, and the second column indicates each event offset. The signal between the onset and offset times is used in the classification stage of the system.

## 5. CLASSIFICATION

After a set of event signals has been segmented, the classifier extracts a full set of features for each event signal. For each event, these features are passed into the first level classifier. Based upon the output of the first stage classifier, each event is labeled with its subgroup.

Each event signal was then passed through the classifier that corresponds to its subgroup label and reclassified based upon the subset of features that best describes its type of event.

Types were chosen such that members of a given type generally have many similar features. The set of features that is used to determine the specific event that occurred in stage two is the set which varies most among the members.

## 6. RESULTS

In order to evaluate the performance of our system we examined the percentage of frames correctly classified with our segmentation and with perfect segmentation. The perfect segmentation and ground truth label for each frame were determined using the annotation to the development data.

The percentage of frames correct given perfect segmentation gives a sense of how well the classification stage of our system performs. Currently, given perfect segmentation, our system correctly classifies 48% of frames.

The percentage of frames correct with segmentation determined by our system when compared to the other metric gives a good sense of how segmentation effects classification. With our segmentation, the system correctly classified 25% of frames.

The confusion matrices of classifier stages of the perfectly segmented events, as well as the events segmented using our algorithm can be seen in Figure 1 and Figure 2 respectively. (We need to make the figure bigger...)

Percent Correct: 63.3103%

|                  |       |             |       |       |        |          |      |          |          |         |       |         |        |        |       |
|------------------|-------|-------------|-------|-------|--------|----------|------|----------|----------|---------|-------|---------|--------|--------|-------|
| Truth \ Response | alert | clearthroat | cough | knock | drawer | keyboard | keys | laughter | pageturn | pendrop | phone | printer | speech | switch |       |
| alert            | 39.1  | 1.6         | 0     | 0     | 0      | 0        | 0    | 0        | 0        | 0       | 59.4  | 0       | 0      | 0      | [64]  |
| clearthroat      | 0     | 100         | 0     | 0     | 0      | 0        | 0    | 0        | 0        | 0       | 0     | 0       | 0      | 0      | [18]  |
| cough            | 0     | 0           | 94.1  | 0     | 0      | 0        | 5.9  | 0        | 0        | 0       | 0     | 0       | 0      | 0      | [68]  |
| knock            | 0     | 0           | 0     | 94.9  | 0      | 0        | 0    | 0        | 0        | 0       | 0     | 0       | 5.1    | 0      | [39]  |
| drawer           | 0     | 0           | 2.3   | 0     | 90.7   | 0        | 0    | 0        | 2.3      | 2.3     | 0     | 0       | 2.3    | 0      | [43]  |
| keyboard         | 0     | 0           | 0     | 0     | 0      | 98.4     | 0    | 0        | 0        | 0       | 0     | 1.6     | 0      | 0      | [64]  |
| keys             | 0     | 0           | 1     | 0     | 0      | 0        | 65.3 | 0        | 32.7     | 1       | 0     | 0       | 0      | 0      | [101] |
| laughter         | 0     | 16.7        | 11.1  | 0     | 0      | 0        | 0    | 72.2     | 0        | 0       | 0     | 0       | 0      | 0      | [18]  |
| pageturn         | 0     | 0           | 0     | 0     | 0      | 0        | 7.7  | 0        | 40       | 49.2    | 0     | 0       | 0      | 3.1    | [65]  |
| pendrop          | 0     | 0           | 35.7  | 0     | 0      | 0        | 0    | 0        | 0        | 64.3    | 0     | 0       | 0      | 0      | [14]  |
| phone            | 0     | 0           | 0     | 0     | 0      | 0        | 0    | 0        | 0        | 0       | 100   | 0       | 0      | 0      | [53]  |
| printer          | 0     | 1.1         | 0     | 0     | 0      | 0        | 0    | 0        | 47.8     | 0       | 51.1  | 0       | 0      | 0      | [90]  |
| speech           | 0     | 1.5         | 0     | 0     | 0      | 0        | 0    | 98.5     | 0        | 0       | 0     | 0       | 0      | 0      | [66]  |
| switch           | 0     | 0           | 0     | 0     | 0      | 0        | 28.6 | 0        | 42.9     | 28.6    | 0     | 0       | 0      | 0      | [14]  |

Figure 1: Example of a figure with experimental results.

Percent Correct: 37.2464%

|                  |         |       |             |       |       |        |          |      |          |          |         |       |        |        |      |
|------------------|---------|-------|-------------|-------|-------|--------|----------|------|----------|----------|---------|-------|--------|--------|------|
| Truth \ Response | unknown | alert | clearthroat | cough | knock | drawer | keyboard | keys | laughter | pageturn | pendrop | phone | speech | switch |      |
| unknown          | 0       | 0     | 5.2         | 0     | 45.8  | 0      | 47.9     | 0    | 0        | 0        | 0       | 0     | 1      | 0      | [96] |
| alert            | 0       | 46.7  | 53.3        | 0     | 0     | 0      | 0        | 0    | 0        | 0        | 0       | 0     | 0      | 0      | [15] |
| clearthroat      | 0       | 0     | 70.4        | 0     | 0     | 11.1   | 0        | 0    | 0        | 0        | 0       | 0     | 18.5   | 0      | [27] |
| cough            | 0       | 0     | 2.2         | 32.3  | 0     | 7.5    | 0        | 58.1 | 0        | 0        | 0       | 0     | 0      | 0      | [93] |
| knock            | 0       | 0     | 0           | 0     | 95.8  | 0      | 4.2      | 0    | 0        | 0        | 0       | 0     | 0      | 0      | [48] |
| drawer           | 0       | 0     | 0           | 0     | 0     | 100    | 0        | 0    | 0        | 0        | 0       | 0     | 0      | 0      | [52] |
| keyboard         | 0       | 0     | 0           | 0     | 0     | 0      | 100      | 0    | 0        | 0        | 0       | 0     | 0      | 0      | [36] |
| keys             | 0       | 0     | 0           | 0     | 0     | 0      | 0        | 0    | 0        | 0        | 68.6    | 5.7   | 0      | 25.7   | [35] |
| laughter         | 0       | 0     | 0           | 0     | 0     | 0      | 0        | 0    | 100      | 0        | 0       | 0     | 0      | 0      | [15] |
| pageturn         | 0       | 0     | 0           | 0     | 0     | 0      | 0        | 12.9 | 0        | 80.6     | 0       | 0     | 6.5    | 0      | [31] |
| pendrop          | 0       | 0     | 0           | 7.4   | 0     | 0      | 0        | 3.7  | 77.8     | 0        | 11.1    | 0     | 0      | 0      | [27] |
| phone            | 0       | 0     | 0           | 0     | 0     | 0      | 0        | 0    | 0        | 0        | 0       | 100   | 0      | 0      | [49] |
| speech           | 0       | 0     | 6.8         | 0     | 0     | 0      | 10.2     | 0    | 93.1     | 0        | 0       | 0     | 0      | 0      | [59] |
| switch           | 0       | 0     | 1.3         | 9.3   | 22.7  | 0      | 16       | 0    | 33.3     | 0        | 0       | 0     | 17.3   | 0      | [75] |

Figure 2: Example of a figure with experimental results.

## 7. CONCLUSION

## 8. REFERENCES

List and number all bibliographical references at the end of the paper. The references should be numbered in order of appearance in the document. When referring to them in the text, type the corresponding reference number in square brackets as shown at the end of this sentence [?], [?]. For  $\text{\LaTeX}$  users, the use of the Bib $\text{\TeX}$  style file IEEEtran.bst is recommended, which is included in the  $\text{\LaTeX}$  paper kit available from the workshop website [?].

## 9. ACKNOWLEDGMENT

The preferred spelling of the word acknowledgment in America is without an "e" after the "g." Try to avoid the stilted expression, "One of us (R. B. G.) thanks ..." Instead, try "R.B.G. thanks ..." Put sponsor acknowledgments in the unnumbered footnote on the first page.