Selective Noise-Cancellation that Deactivates on Detection of Hazardous Sounds in Urban Environments

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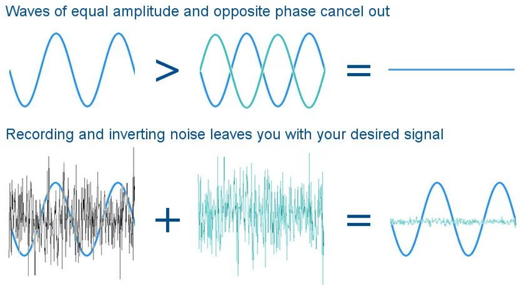
INTRODUCTION

- Many pedestrians using headphones with noise-canceling technology are at risk of injury due to unawareness of their surroundings (Lichenstein et al., 2012).
- This project aims to create selective noise cancellation technology that will recognize and not cancel sounds relevant to public safety (ambulance sirens, speeding cars, etc.).

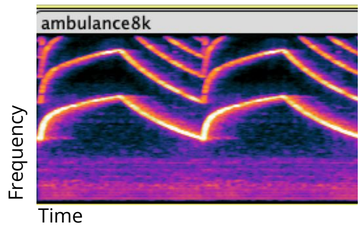
Active Noise Cancellation (ANC)

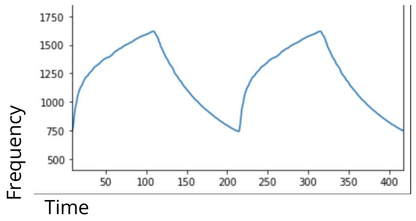


- Active Noise Cancellation (ANC) works by taking the original audio and inverting it, appending the original and inverted audio and creating a flat line.
- This flat line is cancelled sound, that in effect silences all unwanted audio (Elliott et al., 1999).

Ambulance Siren and F0 with YIN

- The ambulance siren has a very distinctive sound and fundamental frequency (F0, lowest frequency/first harmonic) shape.
- As shown in the image on the left, the F0 and its harmonics all have an increasing, decreasing pattern.
- Using librosa.yin, the F0 of the ambulance gets estimated (McFee et al. 2015).
- When plotting the F0 after librosa.yin, you get the fundamental without harmonics (integer multiple of F0) or other audio. (result shown on the right).





Ambulance Detection Algorithm

```
def ambulance_detector(F0):
  F0 = F0[4:-4]
  prev_up = None
  count_up = 0
  count_down = 0
  for f, fnext in zip(F0,F0[1:]):
    sub = fnext - f
    if sub > 0 and prev_up == True:
      count_up += 1
    elif sub < 0 and prev_up == False:
      count_down += 1
    prev_up = True if sub>0 else False
  if count_up > 5 or count_down > 5:
    return True
  else:
    return False
```

- Using the F0 value, we created an ambulance detector function that can monitor whether an ambulance is present.
- This function has a set number of increases and decreases, that an audio file has to meet to be detected as an ambulance.
- If this requirement is met the audio file will return True and be detected as an ambulance.
- If these requirements are not met the function will return as False, and will not detect an ambulance.

Metrics for Siren Detection

$$recall = \frac{true\ positives}{true\ positives\ +\ false\ negatives}$$

- Recall is the proportion of correct hits retrieved by the algorithm out of all possible correct hits.

$$precision = \frac{true\ positives}{true\ positives + false\ positives}$$

- Precision is the proportion of correct hits among all hits retrieved by the algorithm.

Algorithm Evaluation on FSD50K Dataset

- Using the FSD50K dataset I tested 117 short-urban recordings (0.25 hours of audio data) on the ambulance algorithm we developed, to determine when the ambulances were detected, and when they were not (Fonseca et al., 2021).
- This dataset consists of all kinds of urban sounds such as musical instruments, vehicles, human sounds, etc.

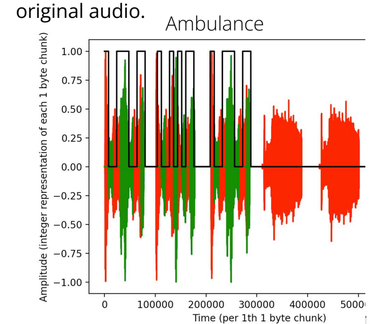
Recall	Precision
88%	39%

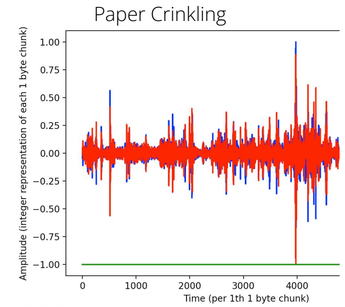
- The recall of the algorithm is high, which shows that there are not many false negatives.
- This precision shows that the algorithm is conservative, and keeps the user safe, however this can be later developed to be more specific.

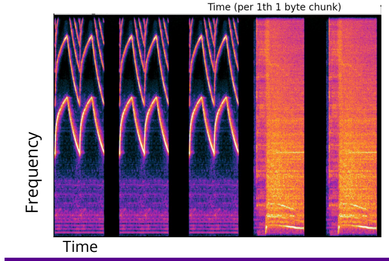
Deployment

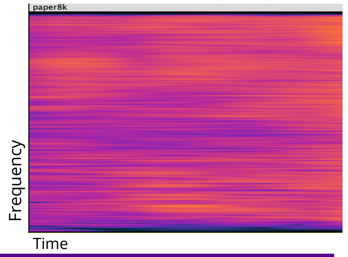
```
F0 = librosa.yin(y, fmin = min_freq, fmax = max_freq, sr=8000)
if len(F0) > 10:
    ambulance_detected = ambulance_detector(F0)
    detections.extend([ambulance_detected] * desired_buffer_size)
    if ambulance_detected == True:
        active = False
        ratio = 2.0
    else:
        active = True
        ratio = 1.0
```

- This algorithm was deployed into Rattlesnake, a noise cancellation application. (Löhnertz et al., 2019)
- When an ambulance is detected, Rattlesnake will not perform noise cancellation.
- When ANC is not active the ratio of inverted to original is 2, going 100% toward original audio.









CONCLUSION

- Once the noise was detected, the algorithm deactivated noise cancellation, when not detected, ANC was active.
- This algorithm can be further developed to detect other hazardous sounds, detect sounds in live mode, and can be implemented into modern audio technology.

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