IMISOUND: An Unsupervised System for Sound Query by Vocal Imitation

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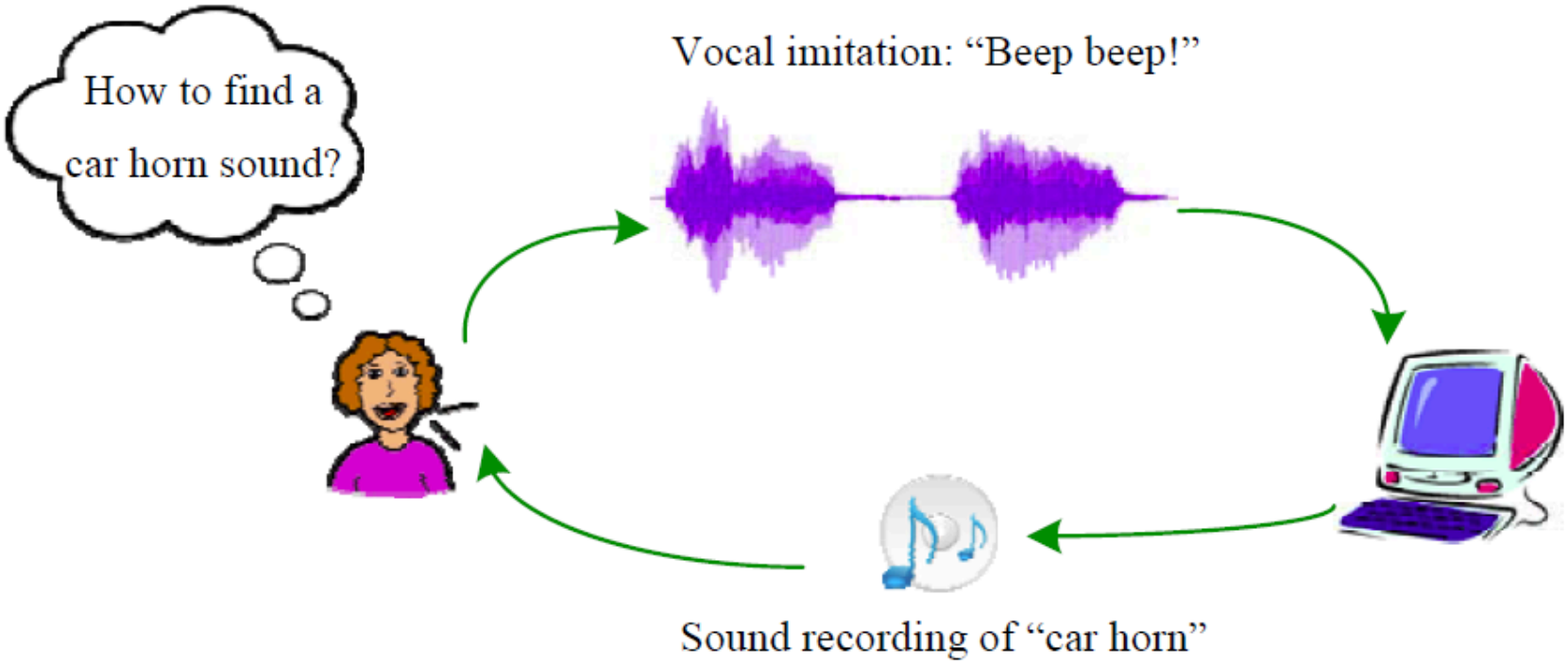
Query by vocal imitation



Query by vocal imitation

For general sounds:

- Dog barking sound (w/ semantic meaning)

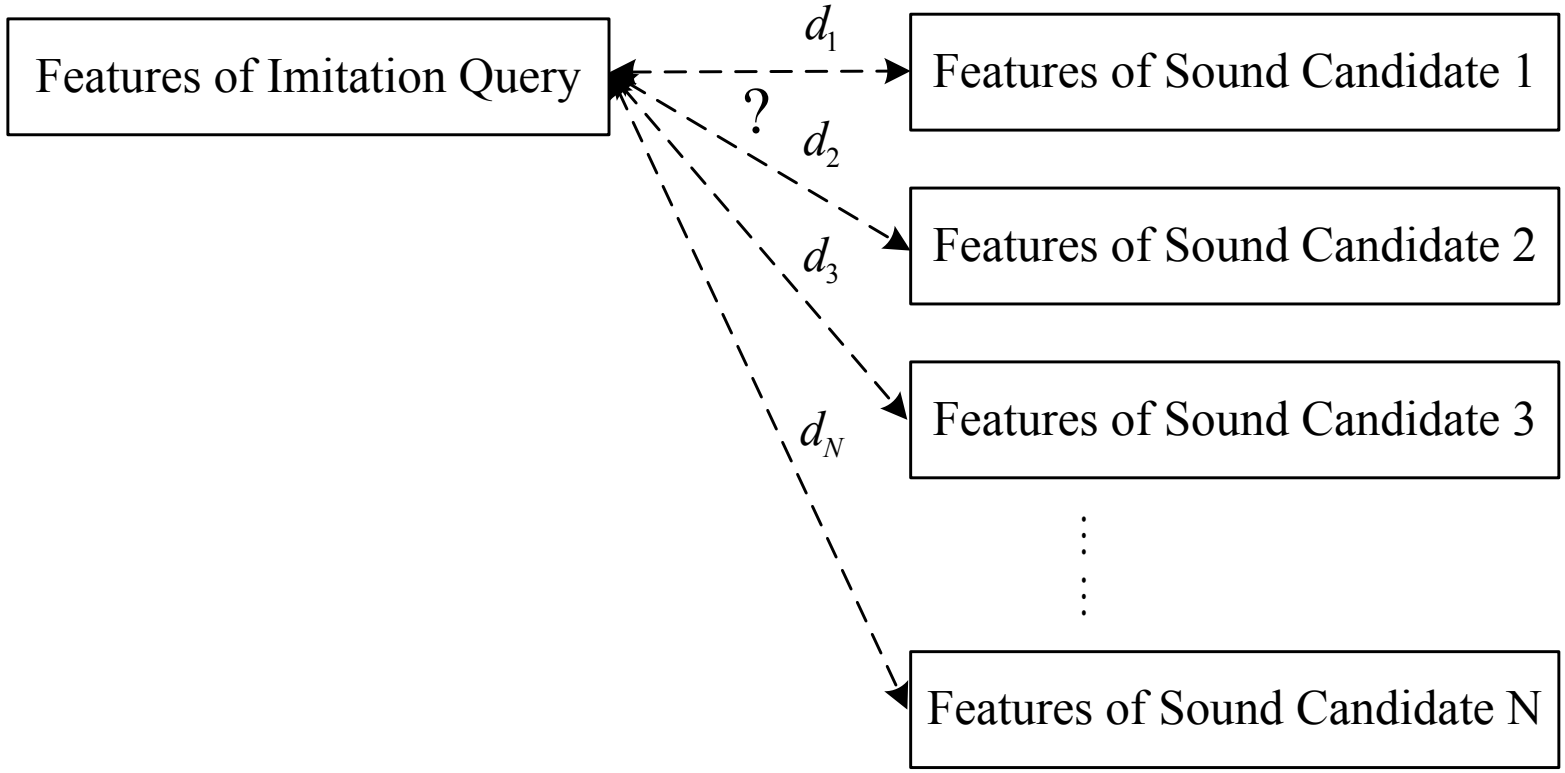
infantile bark or threat bark

Vocal imitation: narrow down the concept

- Synthesized sound (w/o semantic meaning)

Vocal imitation: might be the only way to convey the concept

Towards Sound Retrieval



Challenges

- People tend to imitate different aspects for different recordings

car horn: [ ] cat: [ ] guitar note: [ ]

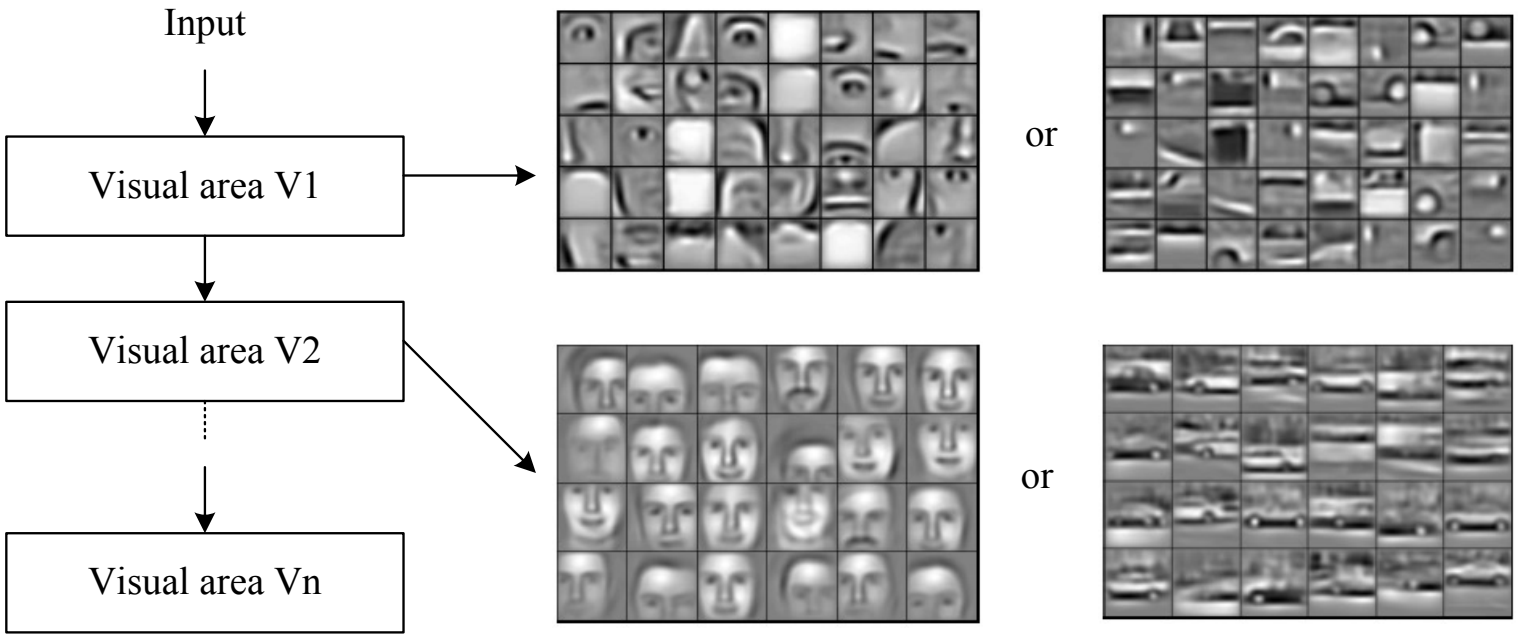
- Even for the same recording, different people may imitate differently

car horn 1: car horn 2: car horn 3:

- Hand crafted features such as pitch, timbre, loudness, etc. would not work well…

- Solution: Deep Neural Networks (DNN)

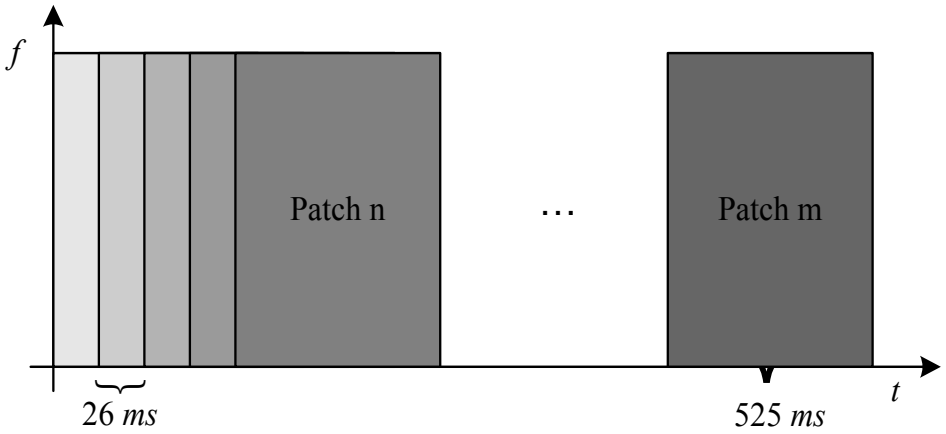
Automatic feature learning



[1] H. Lee, R. Grosse, R. Ranganath, and A. Y. Ng, Unsupervised learning of Hierarchical representations with convolutional deep belief networks, 2011

Pre-processing

Constant Q Transform (CQT) spectrogram



Parameters:

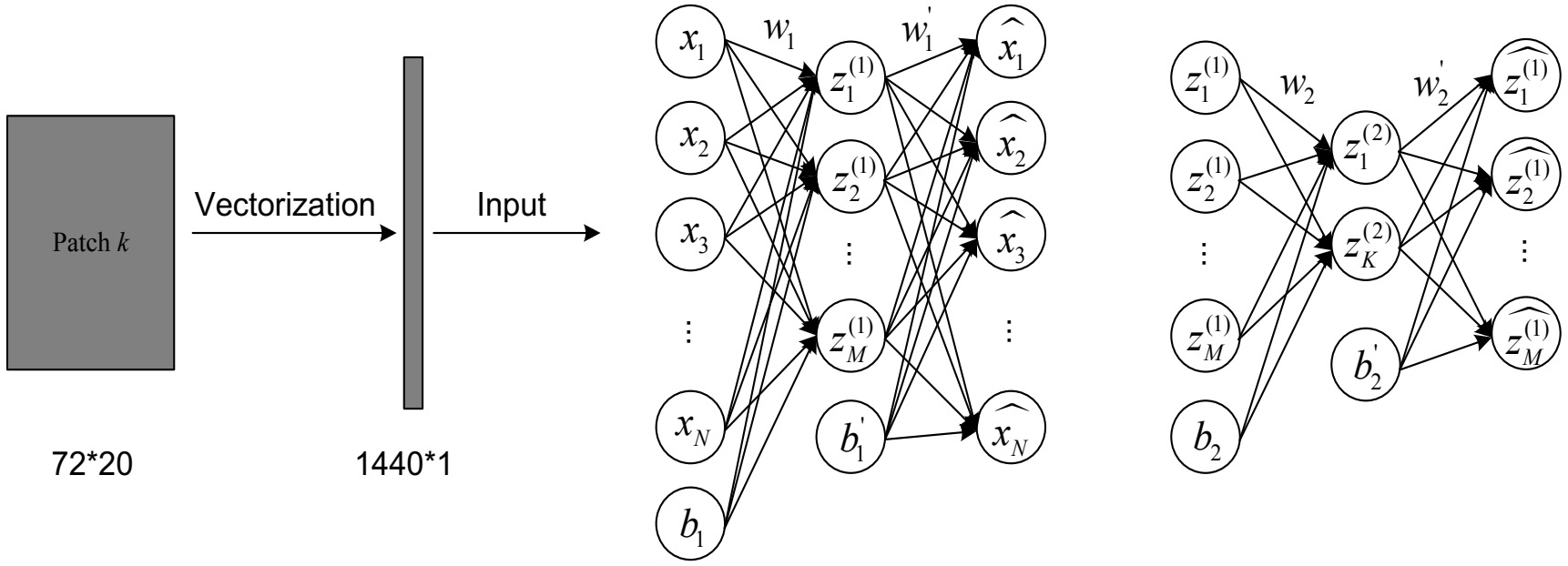
- ✓Patch length: 525 ms (20 frames)
- ✓Freq range: 50-3200 Hz (6 octaves)
- ✓12 bins per octave

Rationale:

- ✓ one syllable in normal English speech: 200 ms
- ✓ 50 Hz to 3200 Hz basically covers telephone frequency range

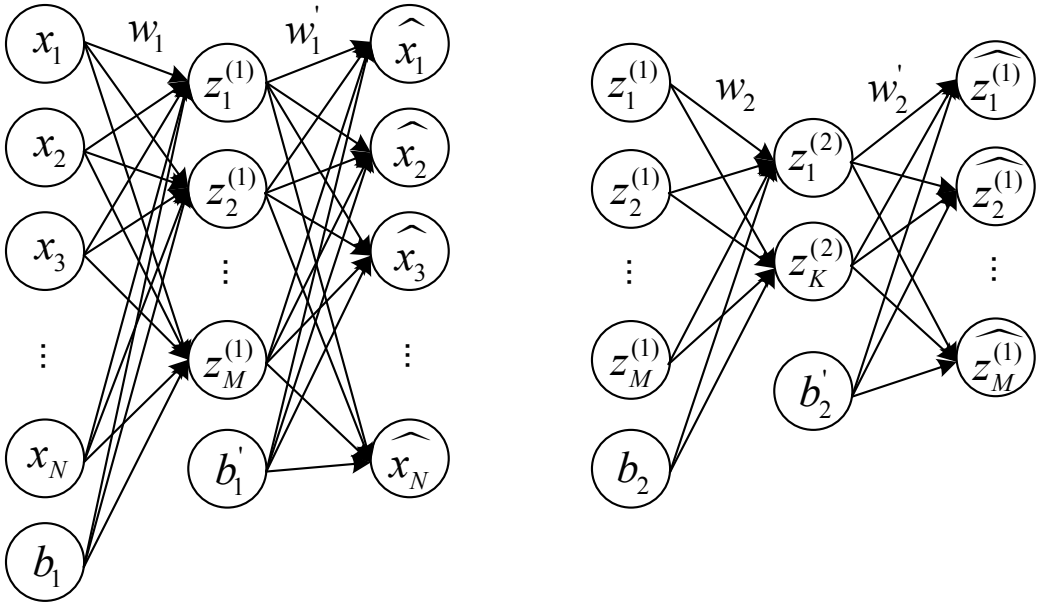
Feature Extraction

- Stacked Auto-encoder (SAE) is chosen as the neural network model



Feature Extraction

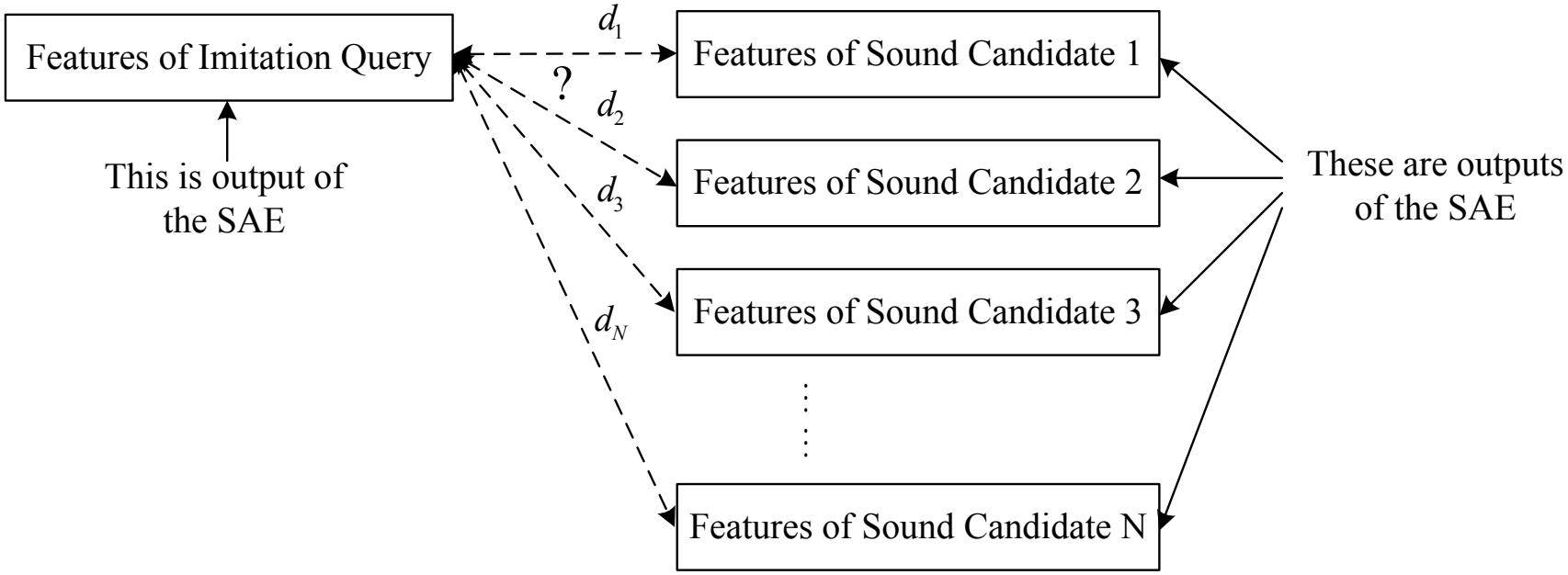
Auto-encoder tries to learn the weights and biases so that the output could approximate the input



1st hidden layer neurons = 500 2nd hidden layer neurons = 100

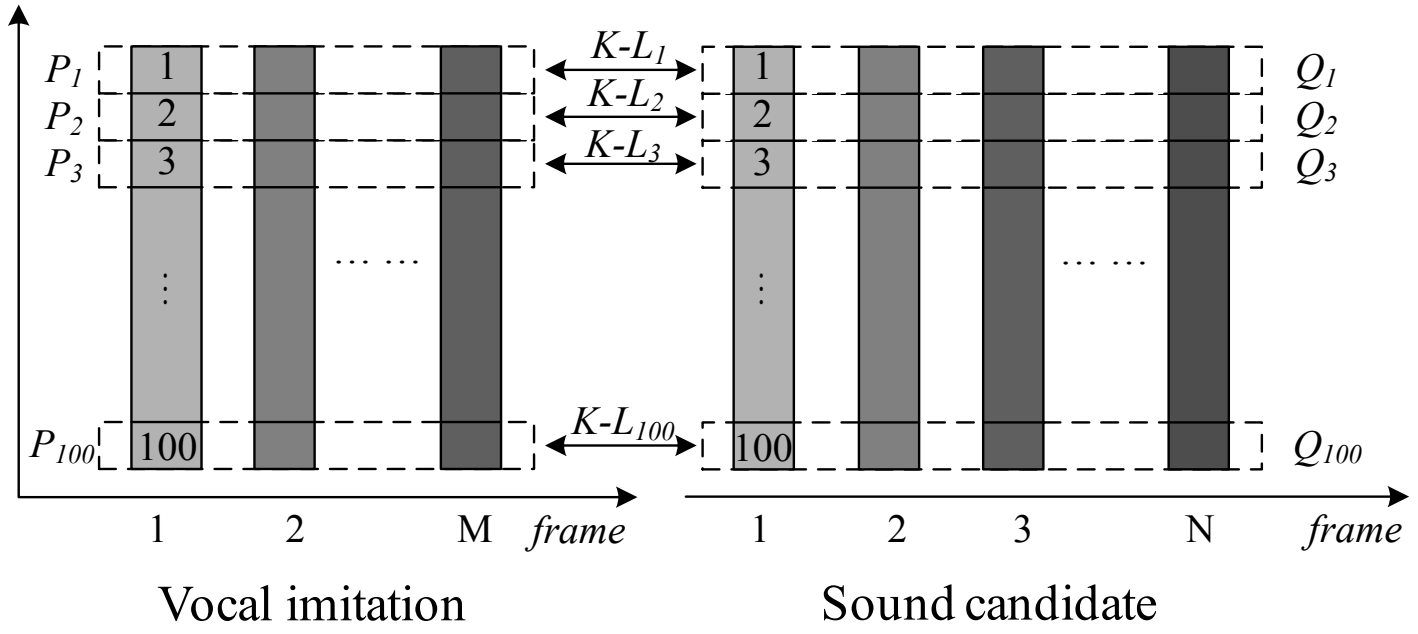
- Weights are trained by half of all the vocal imitations

Distance Calculation

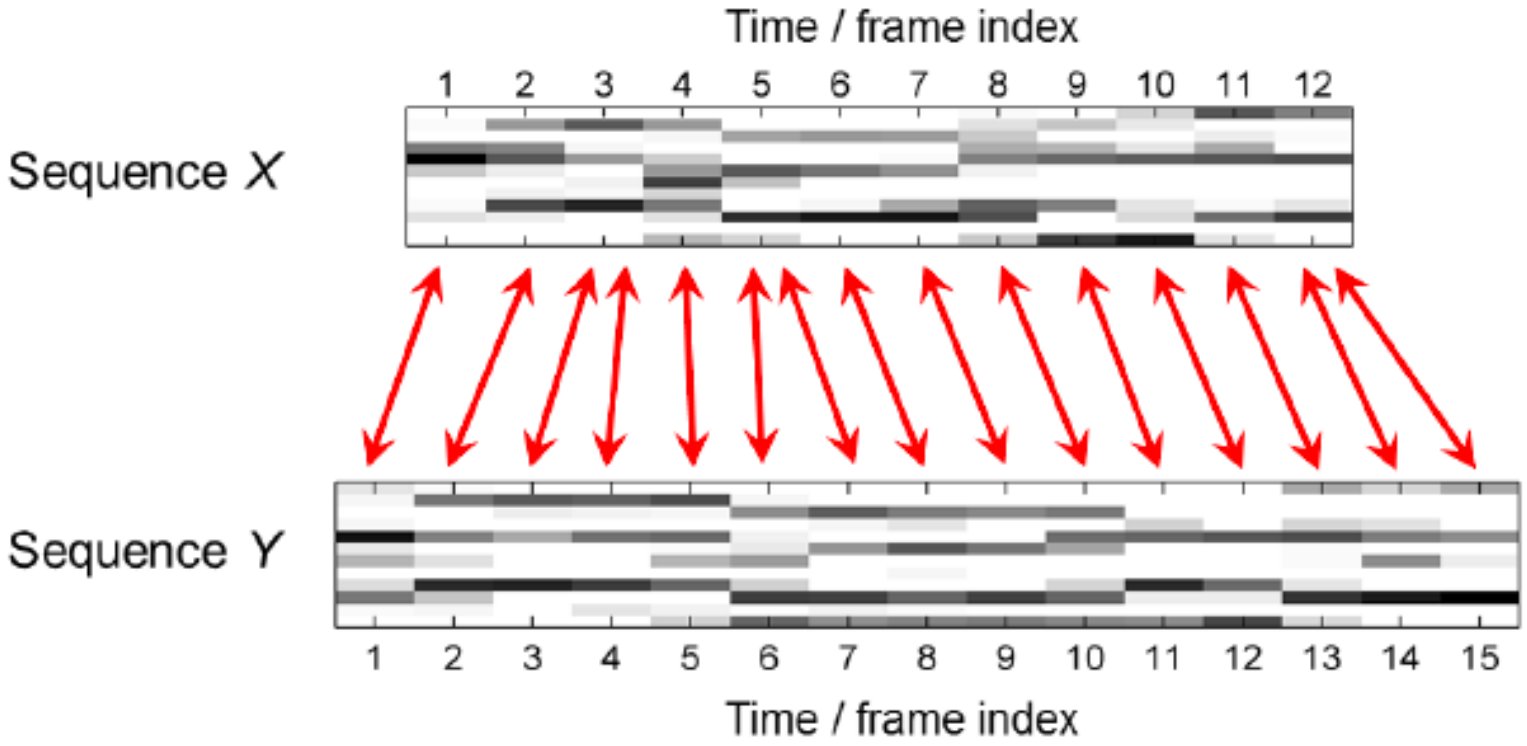


K-L Divergence

$$D_{kl\_sym}(P \| Q) = \frac{1}{2}(D_{kl}(P \| Q) + D_{kl}(Q \| P)) = \frac{1}{2}(\sum_i P(i) \ln \frac{P(i)}{Q(i)} + \sum_i Q(i) \ln \frac{Q(i)}{P(i)})$$

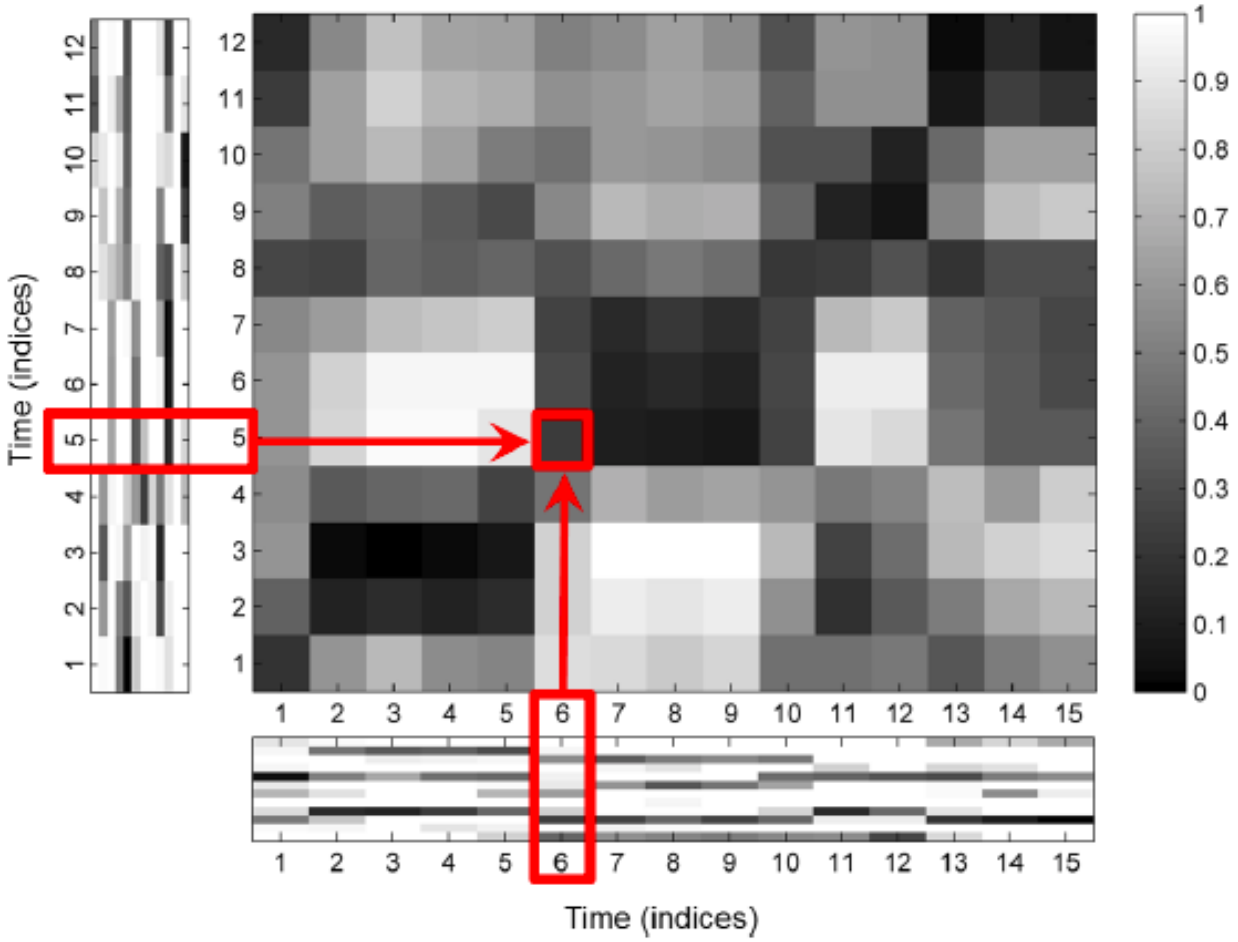


DTW Distance



[1] A. Mueller, First course on music processing, Preliminary version, 2014

DTW Distance

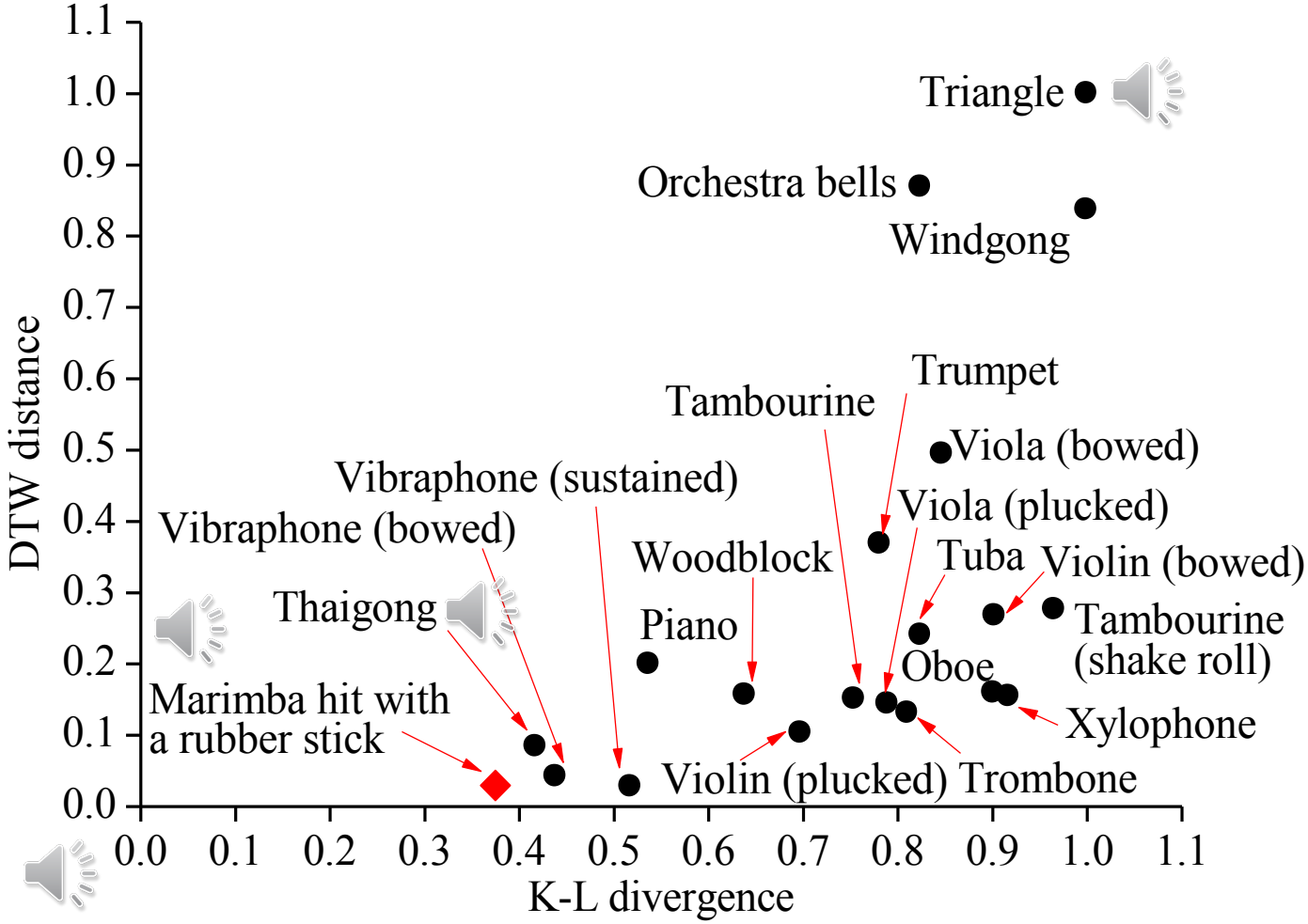


Distance Calculation

- K-L divergence: dissimilarity in probability distribution
- DTW distance: dissimilarity in temporal domain

$$D = \frac{D_{KL}}{\max(D_{KL})} + \frac{D_{DTW}}{\max(D_{DTW})}$$

Sound Retrieval Example



Experimental Setup

1) Use vocal imitations of half of all the sound concepts to train the SAE
    - # hidden layers = 2
    - # neurons in the 1st hidden layer = 500
    - # neurons in the 2nd hidden layer = 100

2) Use the other half for sound retrieval experiment within each category
    - # sound concepts in Acoustic Instruments = 20
    - # sound concepts in Commercial Synthesizers = 20
    - # sound concepts in Everyday = 60
    - # sound concepts in Single Synthesizer = 20

Dataset

Table 1. VocalSketch Data Set v1.0.4 [1]

Category	Sound Concepts (#)	Examples
Acoustic Instruments	Orchestral instruments playing a C note (40)	Orchestra bells Triangle
Everyday	Acoustic events in everyday life (120)	Knocking Sheep
Commercial Synthesizers	Apple's Logic Pro (40)	Metaloid Shimmer
Single Synthesizer	A single 15-parameter subtractive synthesizer playing C note (40)	Subsynth_2217 Subsynth_8828

- Each class has 10 vocal imitations on average

[1] M. Cartwright and B. Pardo, VocalSketch: Vocally imitating audio concepts, in Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems, 2015

Evaluation Measure

- Mean Reciprocal Rank (MRR)

$$MRR = \frac{1}{Q}\sum_{i=1}^{Q}\frac{1}{rank_i}$$

Number of queries in experiment

Rank of the target sound in the returned sound list for the i-th query

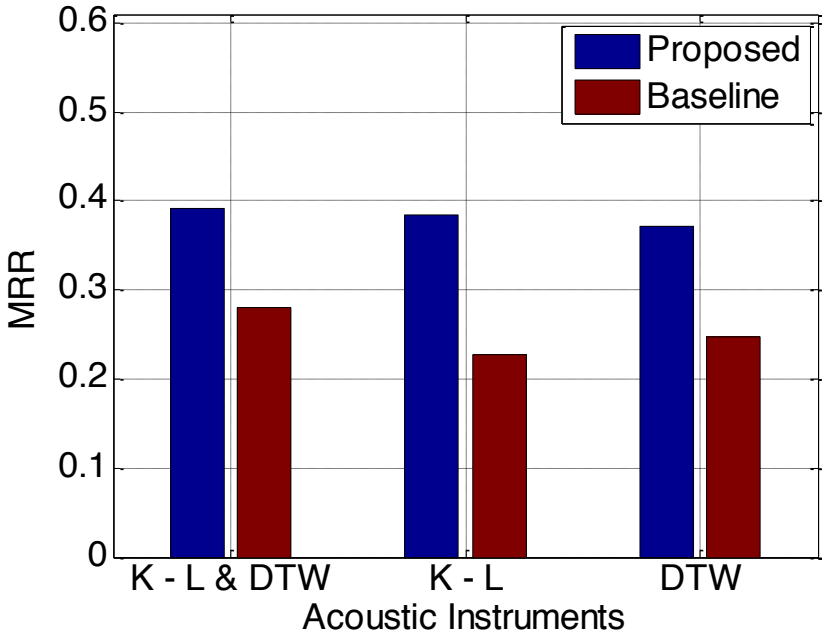
- ✓ 0 <= MRR <= 1
- ✓ The higher the better

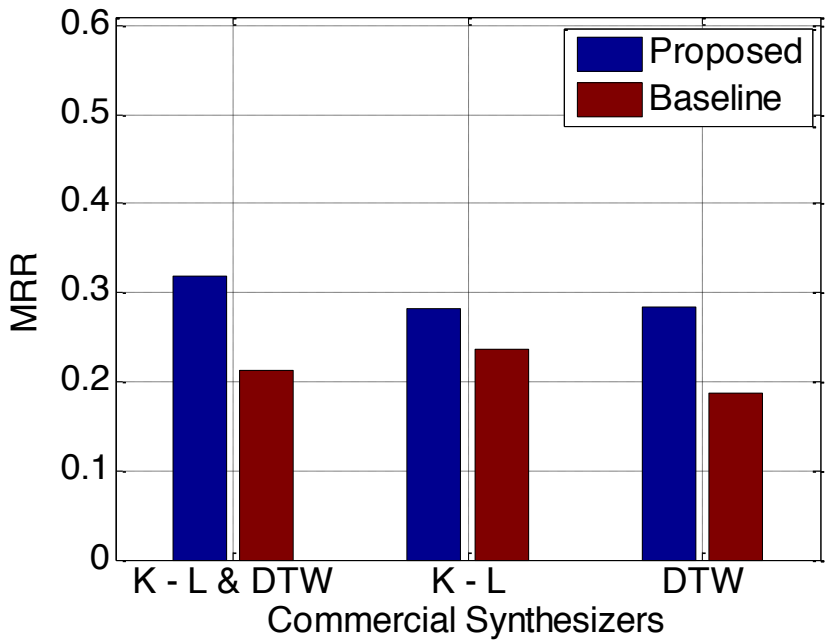
Comparison Method

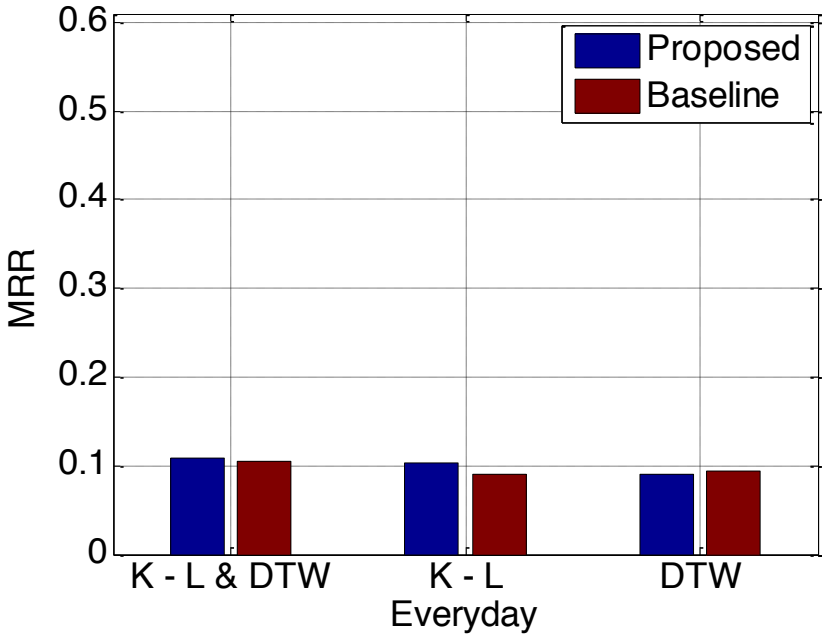
Hand-crafted features:
Mel-frequency cepstral coefficients (MFCC)

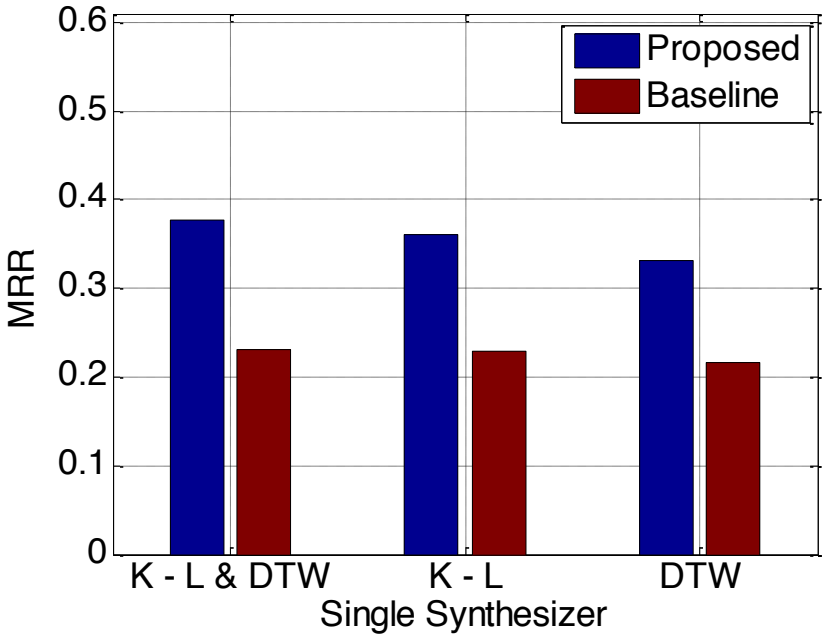
39-dimensional MFCC vectors, including

- 13 MFCC coefficients
- 13 first-order derivatives
- 13 second-order derivatives

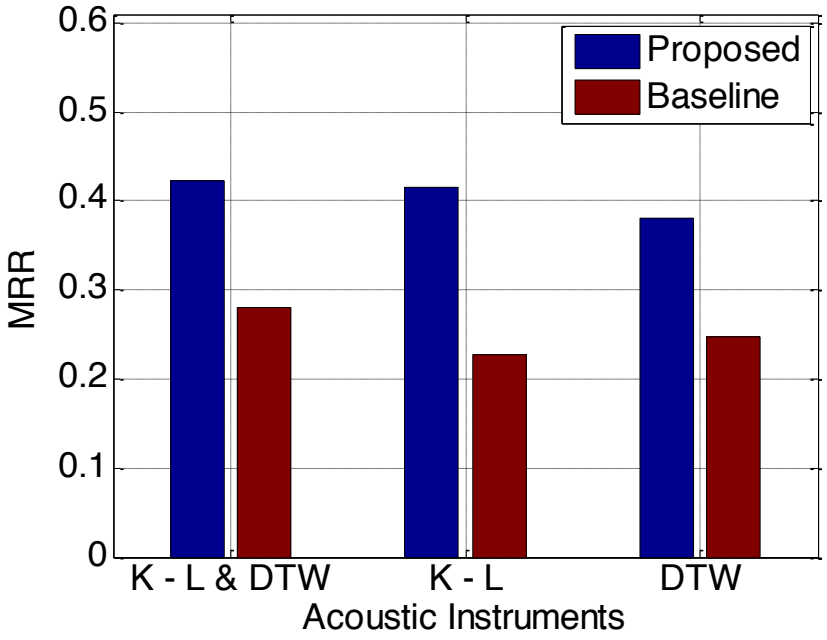


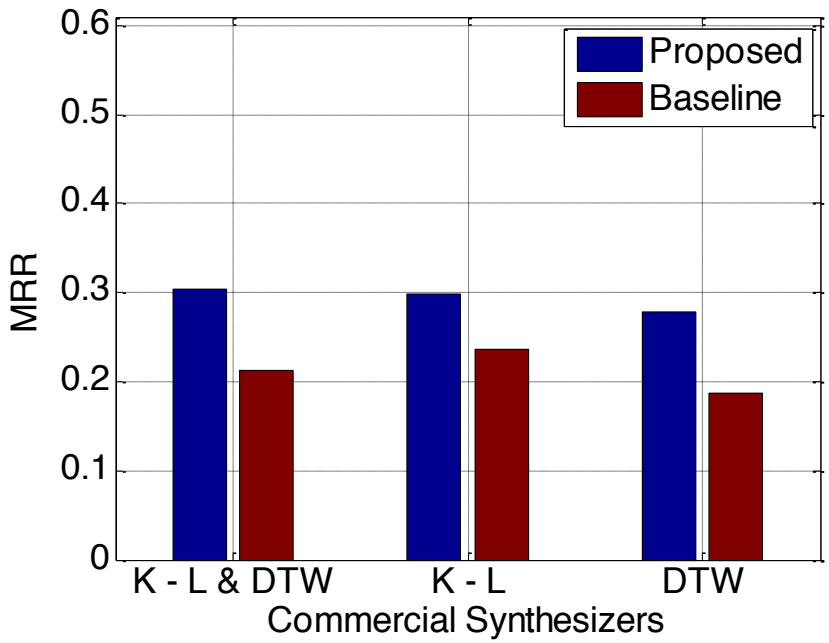


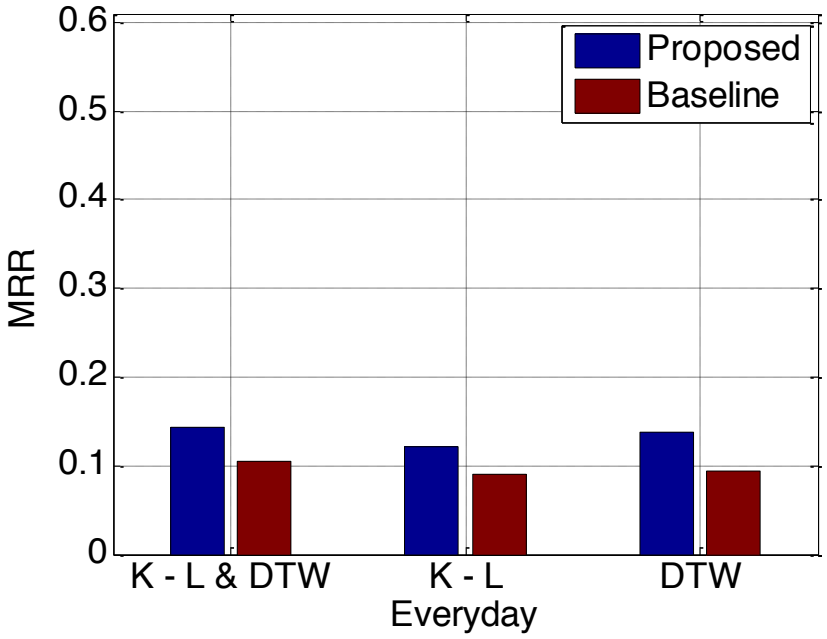


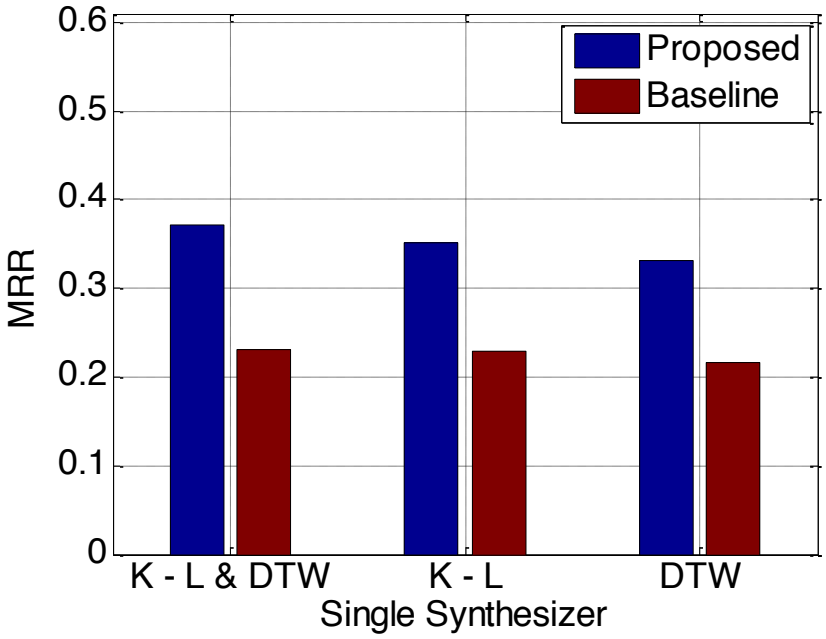


 # neurons in the 1st hidden layer: 500 **# neurons in the 2nd hidden layer: 100**









 # neurons in the 1st hidden layer: 1000 # neurons in the 2nd hidden layer: 600

Conclusions & future work

Conclusions

- Proposed the first unsupervised sound query-by-vocal-imitation system which is evaluated in a large dataset
- Achieved significantly better results by automatic feature learning than hand-crafted features

Future work

- Experiments on CNN and RNN

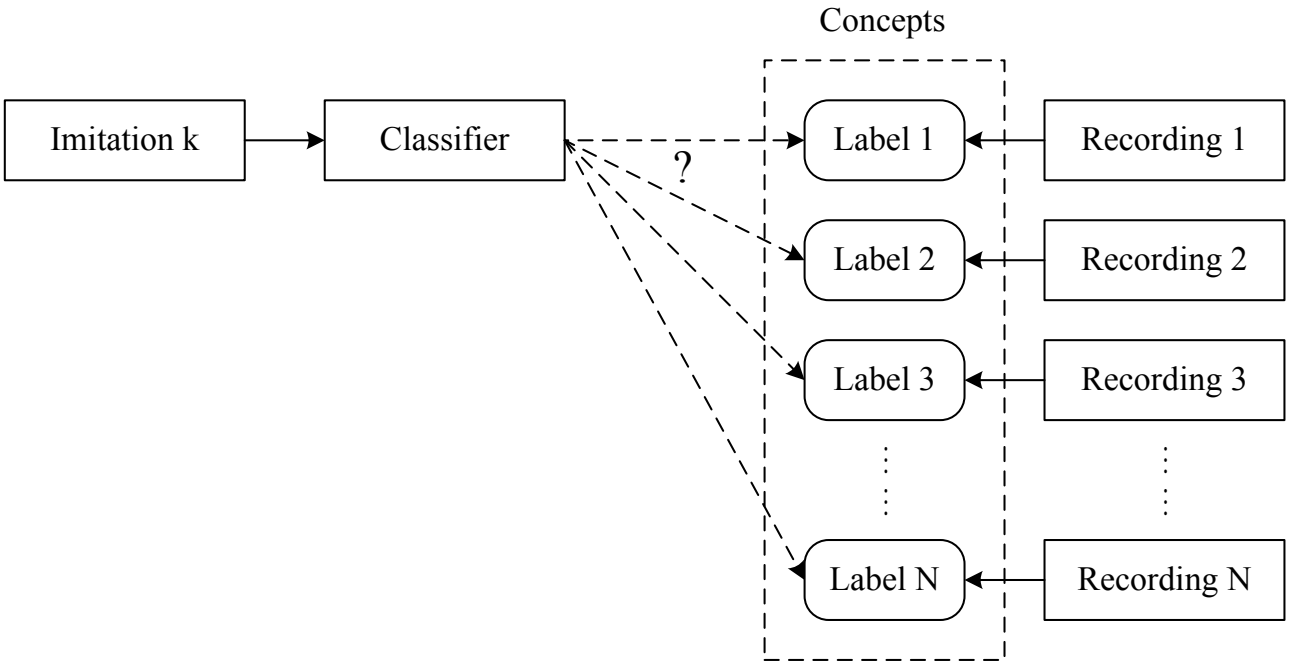
Vision

- Sound query by vocal imitation will be the trend

The End

Thank you for your attention !

Supervised Query-by-Vocal-Imitation System



Assumptions:

- Closed set scenario
- Training data exist for each concept