Voice liveness detection algorithms based on pop noise caused by human breath for automatic speaker verification

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1. Introduction

Automatic speaker verification (ASV)

- An easy-to-use biometric authentication system
- State-of-the-art system: i-vector, PLDA
  - Show potential to support mass-market adoption

Speech Synthesis Techniques (Text-to-speech; TTS)

- Generate natural-sounding artificial speech with targeted speaker's few voices.
- State-of-the-art system: HMM-based, Voice conversion
  - Help individuals with vocal or communicative disabilities

Spoofing attacks against ASV system

- ASV performance is seriously degraded.
- Main types of spoofing attacks:
  Replay, Speech synthesis, Voice conversion
- Some anti-spoofing techniques have been reported.

A fundamental solution against the spoofing attacks is required.

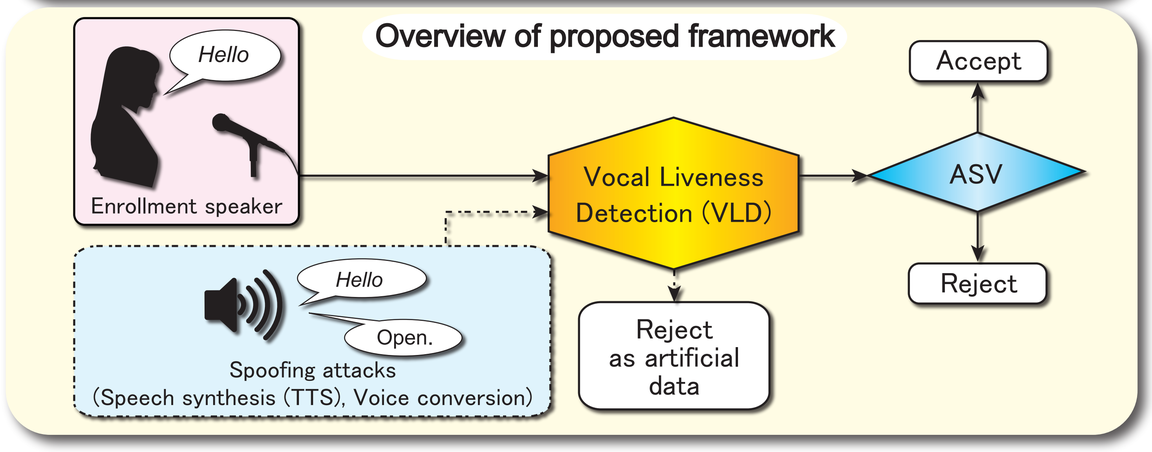
2. Voice Liveness Detection (VLD)

Procedures for spoofing attacks

- Play spoofing speech via loudspeakers

Distinguish input data produced by a live human from input data played via loudspeakers.

Can protect against all types of spoofing attacks



What is the liveness evidence in a speech waveform?

- Voice made by airflow, and it transform to an acoustical signal via a microphone
- **Pop noise phenomena**: a sort of perceived plosive burst
  Only living human caused pop noise.

Pop noise detection leads to reduce the vulnerability of ASV

3. Pop noise detection algorithms

Low-frequency-based single channel detection

- Pop noise appears as high energy regions at very low freqency (Fig.1)
  - Sudden irregular modulations of strong energy
  - Durations typically rangin between 20 - 100 msec
- A min/max energy variation and velocity ensure there will be a relative increment/drop in the pop noise energy.

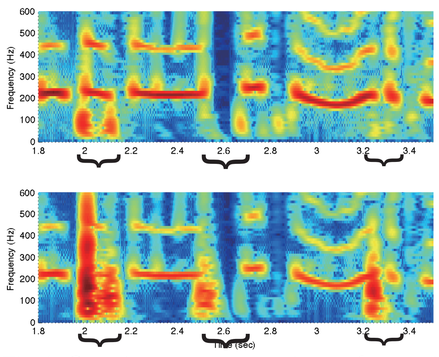


Fig.1, Spectrogram comparison of recording using (top) or not using pop filter (bottom).

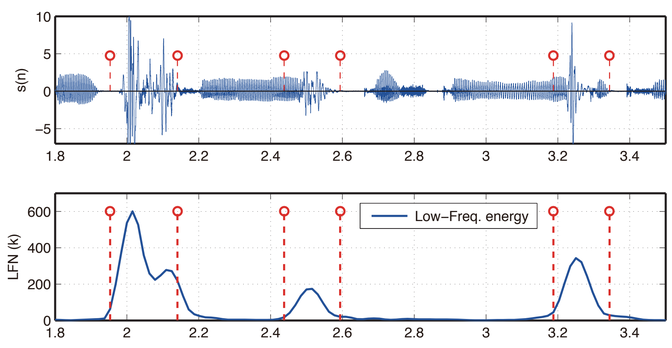


Fig.2, Example of pop noise detection. Time-domain signals(top), average low-band energy(bottom), and the detected pop noise boundaries (red dotted).

Subtraction-based detection with two channels

- Capture the whole freq. components of the pop noise
- Two microphone are used.
  - only one of them has a pop filter (Fig.3)

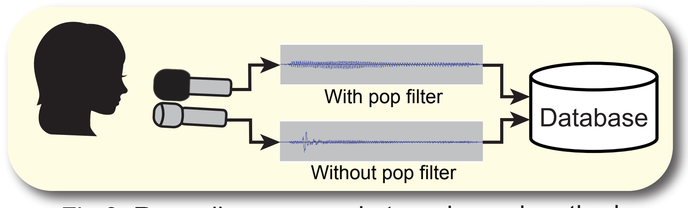


Fig.3, Recording process in two channel method

- Assuming only one signal includes pop noise, it is estimated by subtracting the ordinary speech component as follows:

$$D(b,\omega) = F_p(b,\omega) - C(\omega)F_x(b,\omega)$$

Non-Filtered speech / Filtered speech

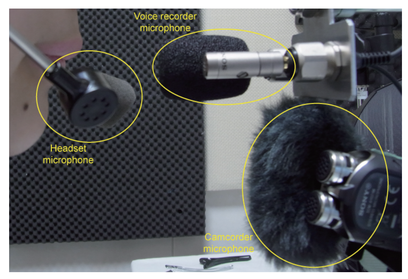
$F(b,\omega)$: STFT
b : Time frame
ω : Angular frequency

- $C(\omega)$ represents a compensation filter between freq. characteristics of the two channels.
- An estimate of $C(\omega)$ to minimize $\sum_{b,\omega}|D(b,\omega)|^2$ can be represented as $C(\omega) = \frac{\sum_b F_p(b,\omega)F_x(b,\omega)^*}{\sum_b |F_x(b,\omega)|^2}$. (* complex conjugate)
- Amplitude of inverse STFT for $D(b,\omega)$ is used for estimating boundaries of the pop noise.

5. Experiments

Experimental conditions

- Database including pop noise is recorded with three kinds of microphones
  - Compatible microphone with camcorder (CAMCORDER)
  - Microphone with a voice recorder (VOICE)
  - Microphone with a headset (HEADSET)
- 17 female Japanese speaker
- 100 sentences for each speaker
- 48kHz sampling
- Training data: 70 sentences per speaker
- Test data: 30 sentences per speaker
- Spoofing data: 31 sentences estimated by HTS adaptation technique



Experimental results

1.Pop noise detection test

- Judge an input signal comes from a live human or a loudspeaker.
- Both method can capture pop noise as liveness evidence
- Pop noise phenomenon depends on the microphone type

		Input	
		Human	Spoof
Judge	Human	Correct	FAR
	Spoof	FRR	Correct

Tab. 1, EER (FAR=FRR) of VLD algorithms with some microphone

Microphone	Single ch.	Two ch.
VOICE	4.73%	29.11%
CAMCORDER	36.06%	45.52%
HEADSET	3.95%	5.88%

2.Combine VLD module and ASV system (VLD+ASV)

- Judge an input signal comes from a live human or a loudspeaker, and judge the input signal is a enrollment speaker or not.

Tab. 2, EER of the ASV system
w/ SA: test data includes spoofing attack data, w/o SA: test data includes no spoofing attack data

Microphone	w/o SA	w/ SA	VLD+ASV	
			Single ch.	Two ch.
VOICE	5.49%	5.53%	5.48%	5.49%
CAMCORDER	4.69%	6.61%	5.23%	5.30%
HEADSET	4.28%	6.61%	4.45%	4.28%

- ASV performance is degraded by SA data
- VLD+ASV performance is almost same as no SA system

Pop noise detection algorithm works well as VLD module

6. Conclusion

- VLD algorithms can reduce the vulnerabilities of ASV against to spoofing attacks.
- Future work: Use larger database, Evaluate other spoofing attacks (e.g., VC, Unit selection), Distinguish pop noise from wind noise.