Acoustic Fingerprints for Access Management in Ad-Hoc Sensor Networks

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07 September 2020

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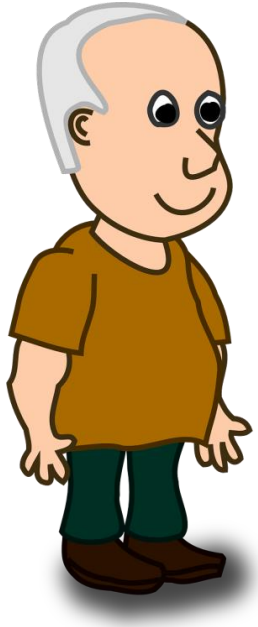
General outline

- Popularity of speech interfaces
- Wireless acoustic sensor networks
- Privacy concerns
- Audio-based device pairing
- Proposed methods
- Results
- Conclusion

Popularity of Speech Interfaces

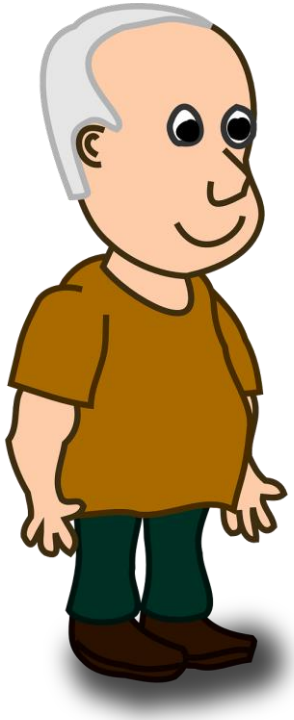


Alexa, order a pizza for dinner

Do you want your usual order from Alfredo´s?

Yes, please

Popularity of Speech Interfaces



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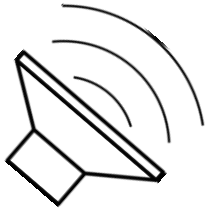


Wireless acoustic sensor networks

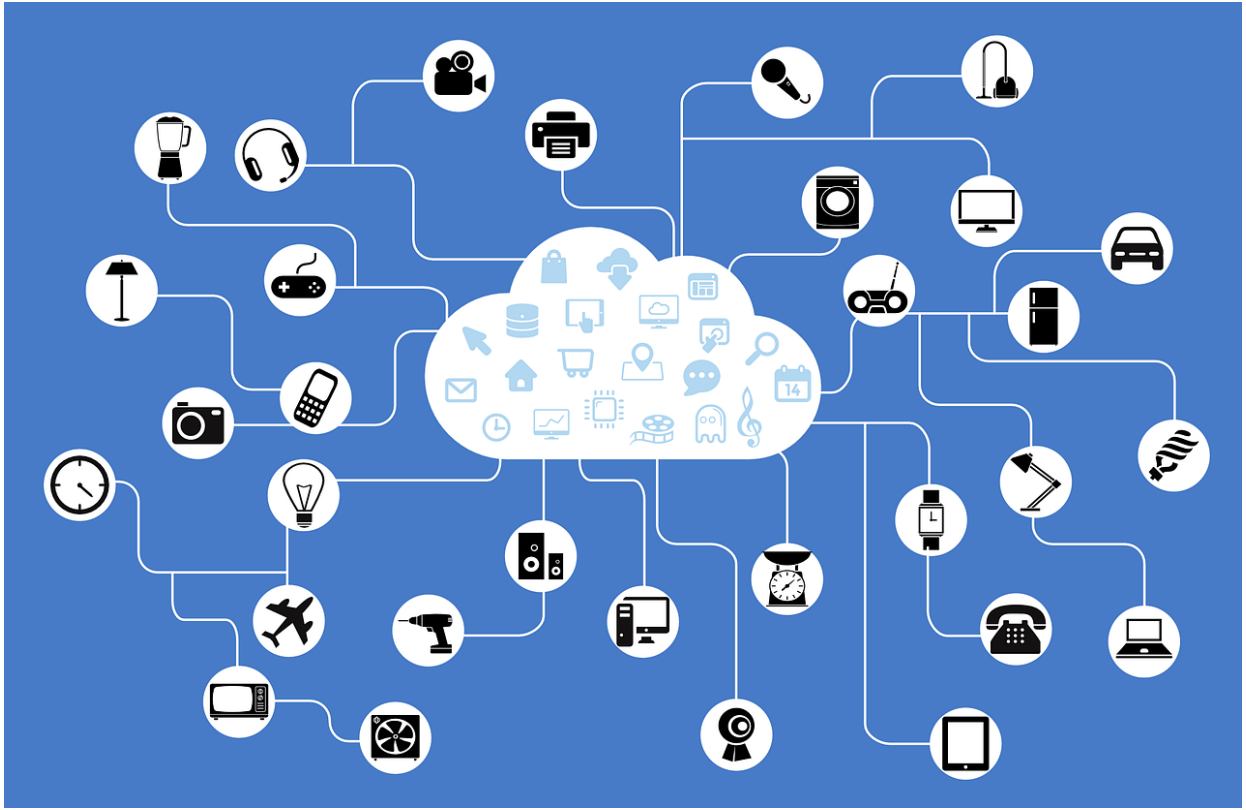
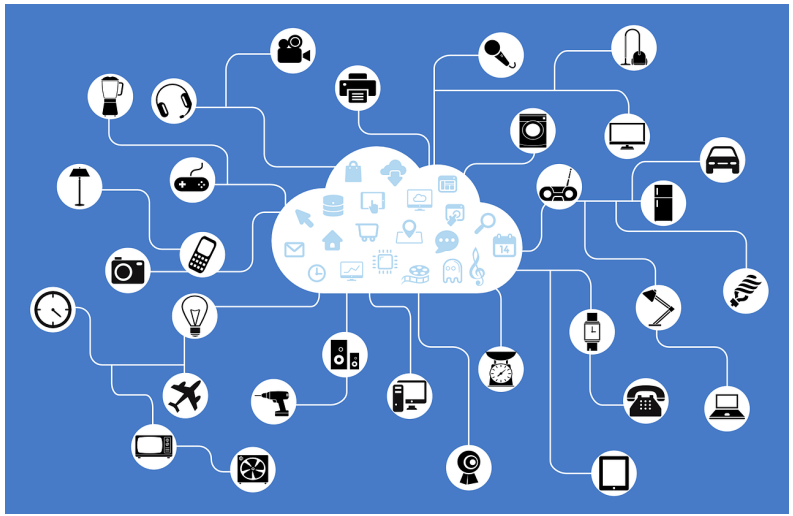


Image extracted from http://pixabay.com

Wireless acoustic sensor networks



- Many electronic devices around us.
- We have methods to synchronize multiple devices in a network.
- They could collaborate together to provide a distributed voice user interface.

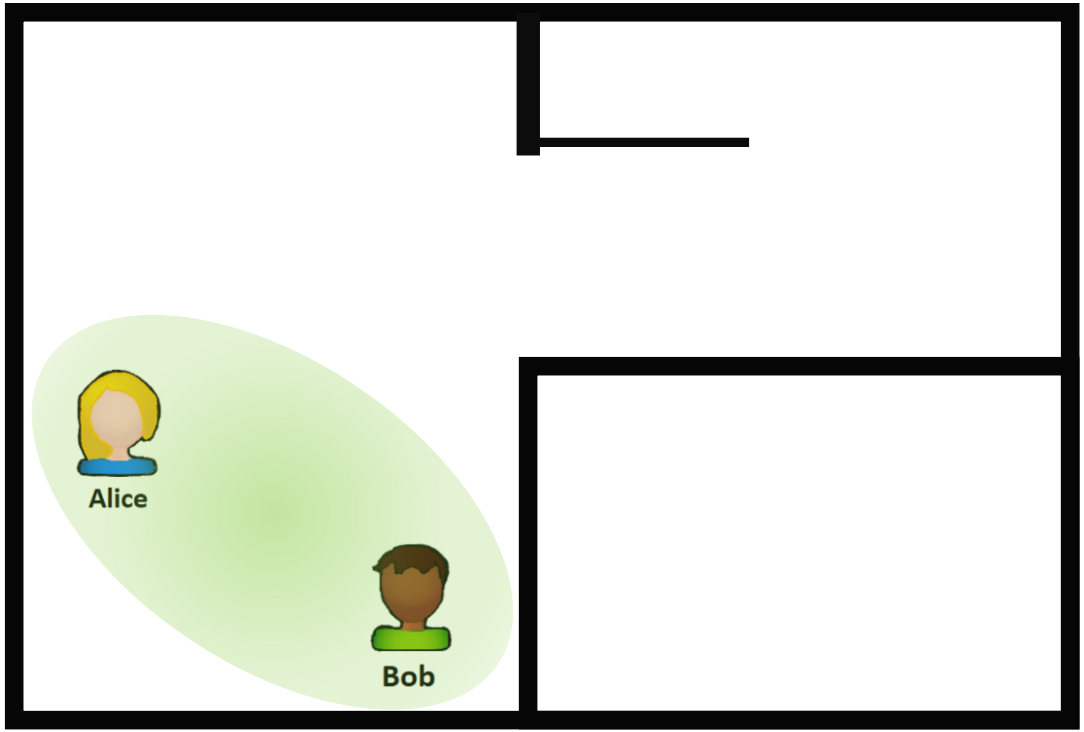
Privacy concerns

- **Multiple devices recording and sharing our voice information**

- **Our voice contains a great amount of personal information.**

- **How can we know which devices in the network can be trusted to process our voice?**

Privacy concerns: Example



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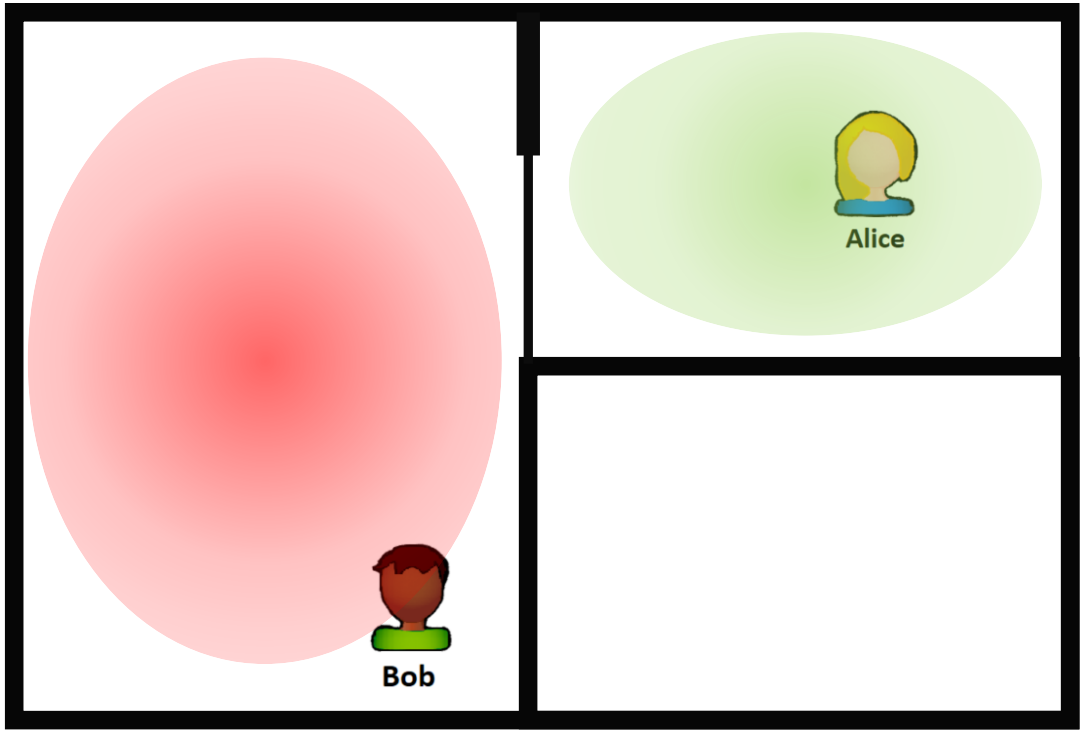
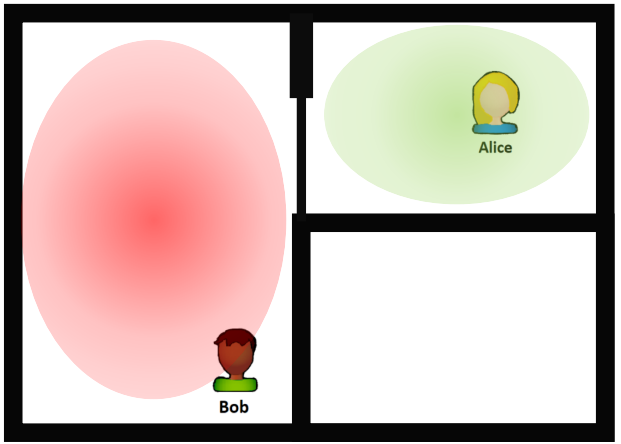


Proximity-based device pairing

- **File sharing applications use Bluetooth signals to detect the proximity of other devices.**
  - Google’s Nearby Share
  - Apple’s AirDrop

Proximity-based device pairing

- File sharing applications use Bluetooth signals to detect the proximity of other devices.
- Physical proximity is not reliable in a conversational setting.



Proximity-based device pairing

- File sharing applications use Bluetooth signals to detect the proximity of other devices.
- Physical proximity is not reliable in a conversational setting.

- Solution: Adapt the authentication to our perception of privacy

How can we protect our privacy?

- **In order to protect the user's privacy, we need to understand how people perceive their privacy.**

How can we protect our privacy?

- People modify the way they talk depending on the privacy of the environment.
- We can use the audio of the environment to recognize devices in proximity.

Acoustic fingerprints

- **An acoustic fingerprint compresses a set of features of the audio signal to allow an easy comparison of audio segments.**

- **A popular application of acoustic fingerprints is music retrieval.**

  - For example: Shazam

Acoustic fingerprints

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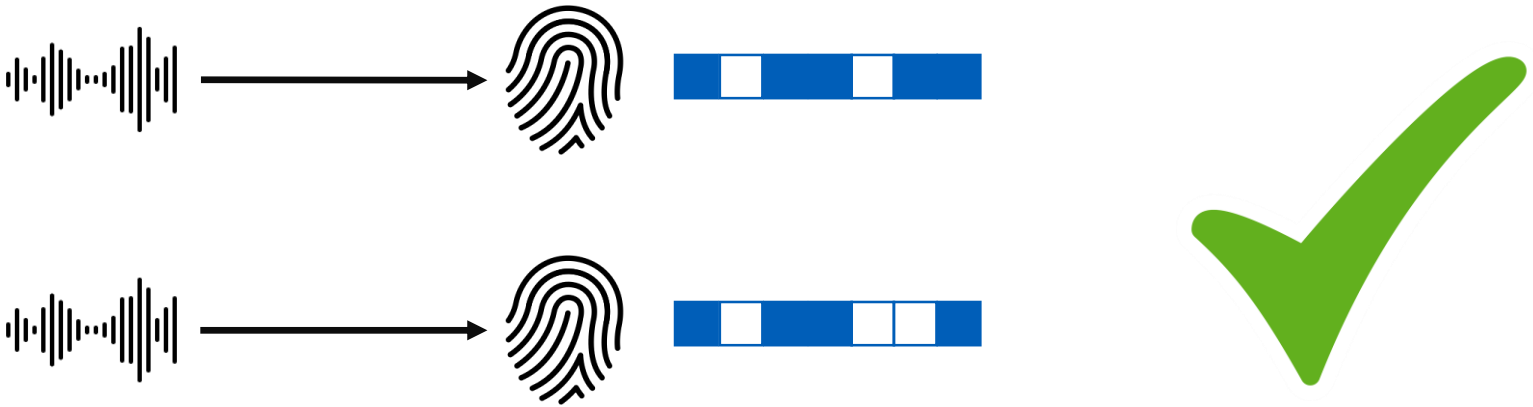

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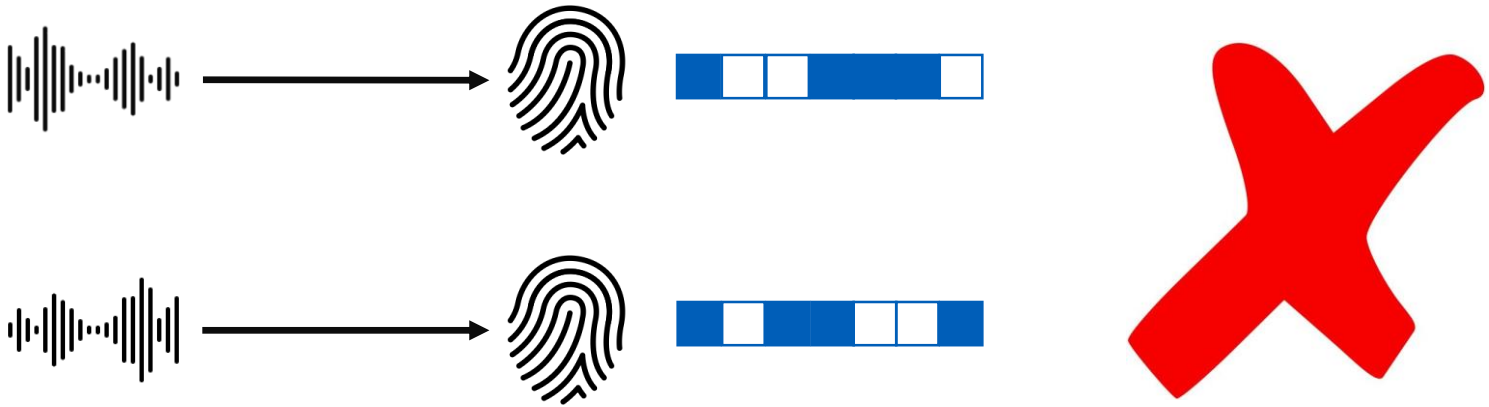
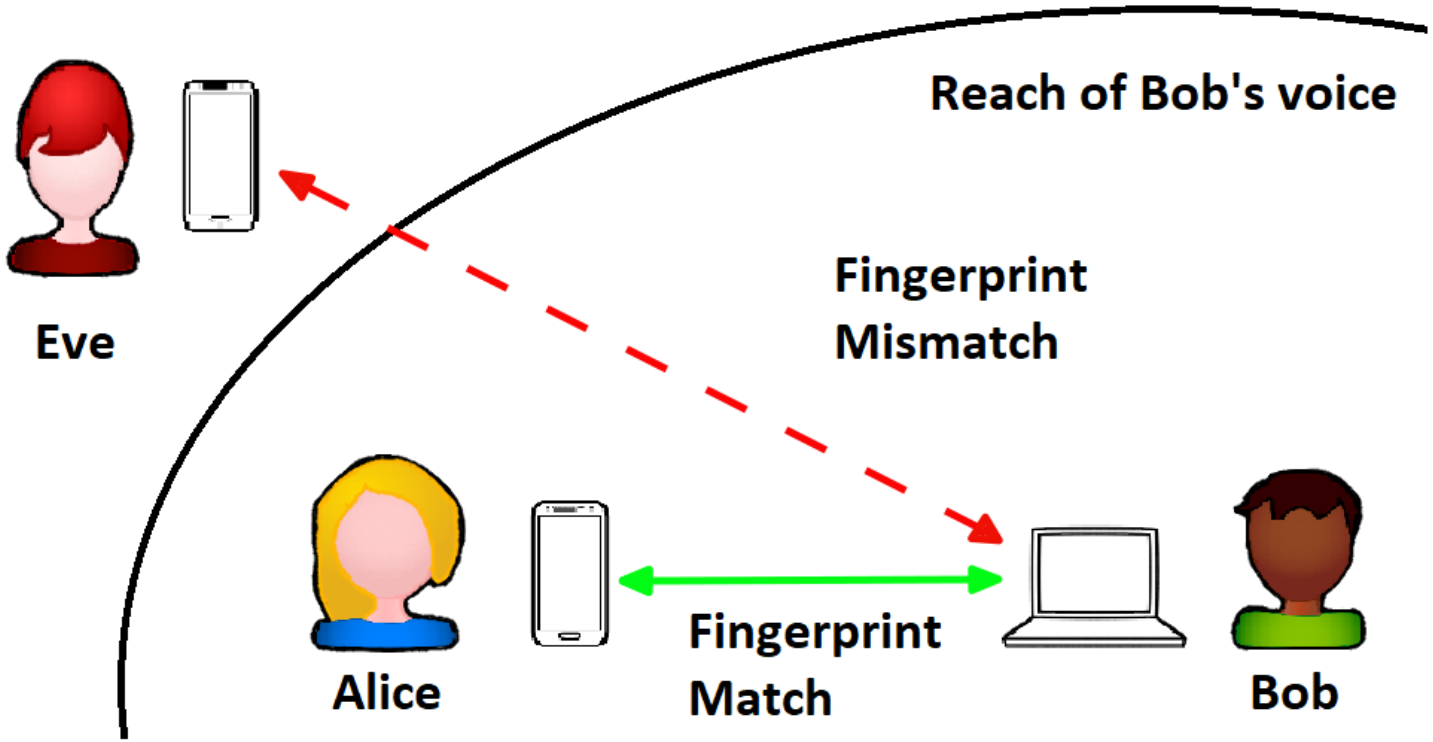


Audio-based device authentication



Audio-based device authentication

- **Previously presented methods:**
  - Mix of audio fingerprints and fuzzy cryptography.
  - Long non-overlapping windows against de-synchronization.
  - The required audio recording is too long for a conversational application.

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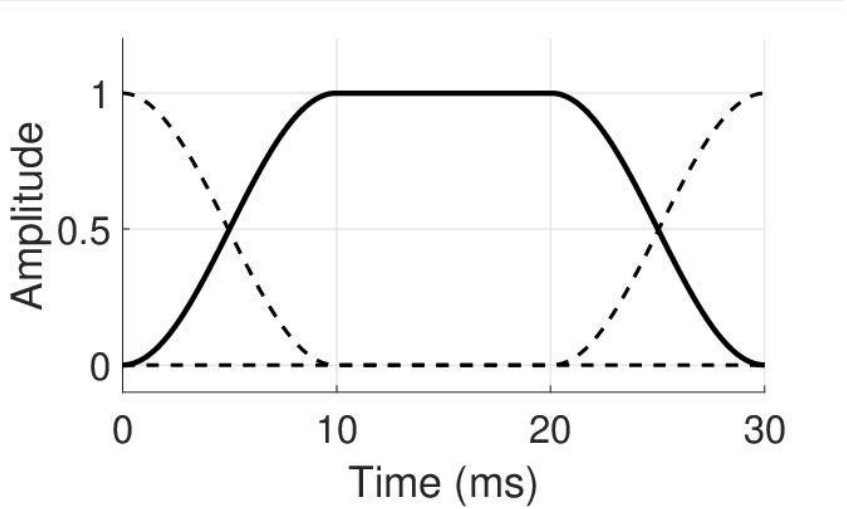
  - The required audio recording is too long for a conversational application.

- **We need to reduce the length of the audio recordings.**

Solution

- **Use similar parameters to typical speech processing applications:**
  - Shorter windows
  - Overlap



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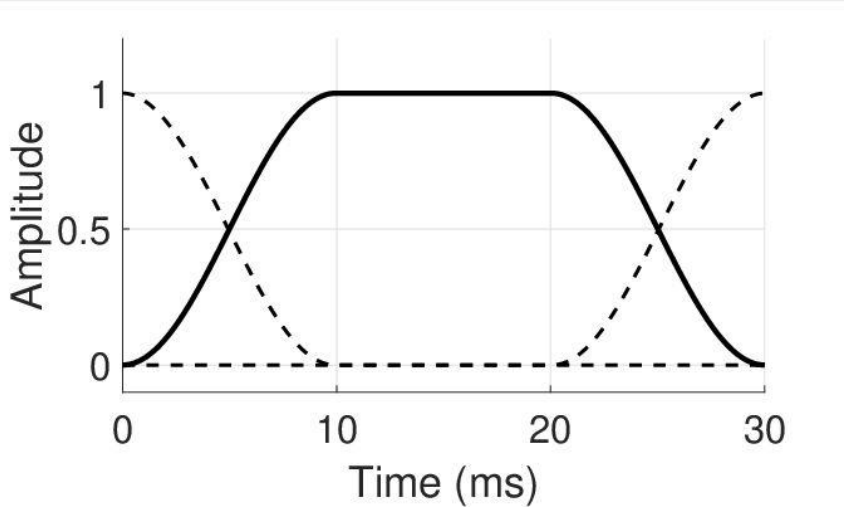
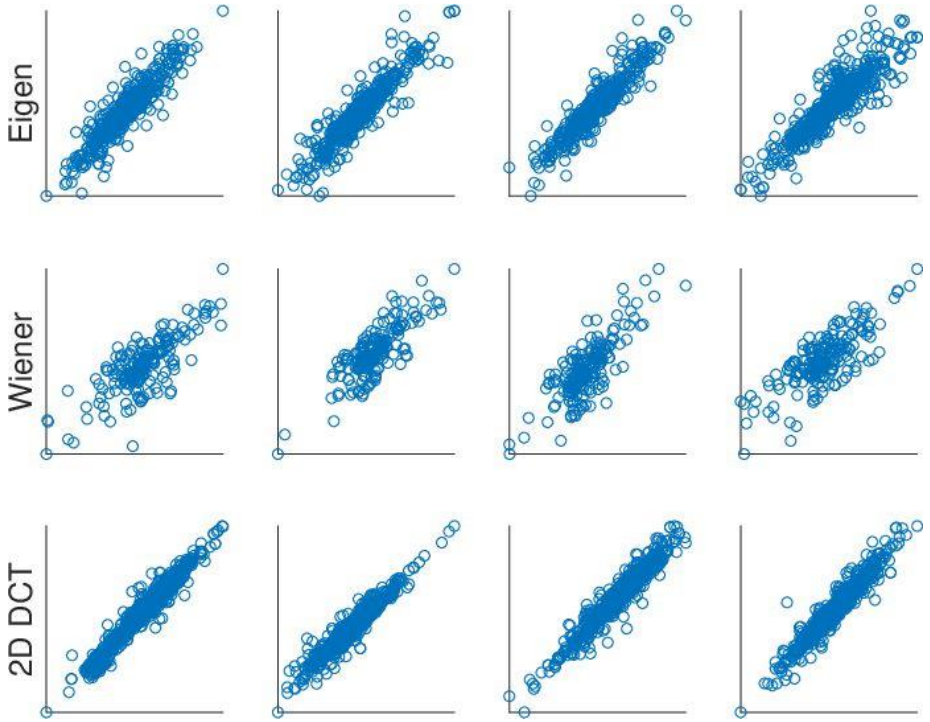


- We propose decorrelation methods to compensate for the degradation in the windowing process.

Decorrelating transformations

- **Eigenvalue decomposition**
- **Wiener filtering**
- **2D - DCT**



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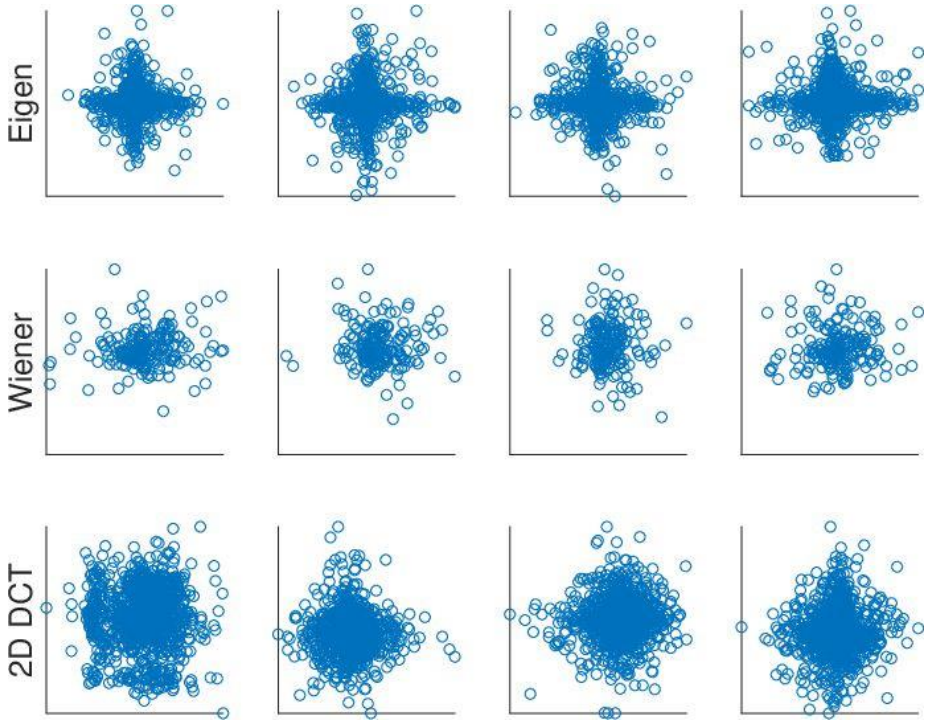
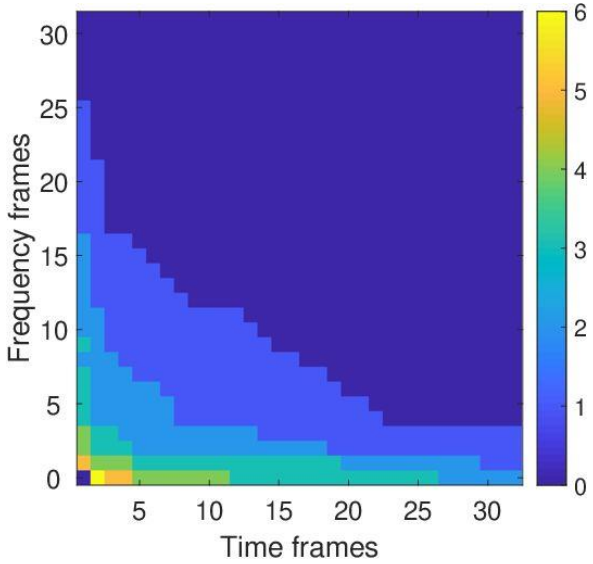
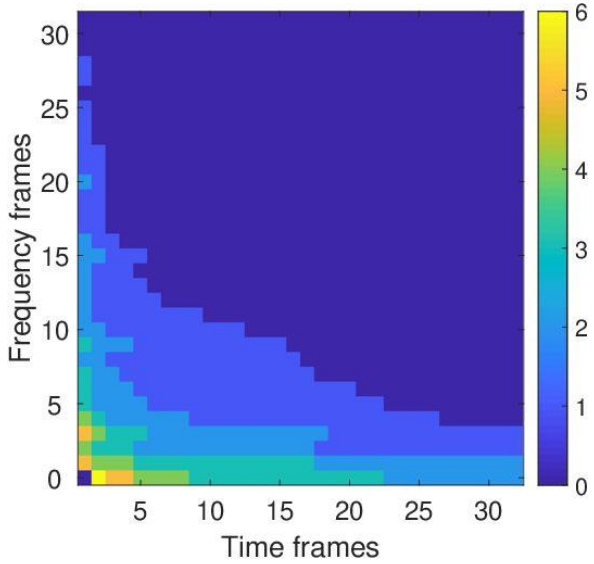


Quantization methods

- **Entropy-based:**



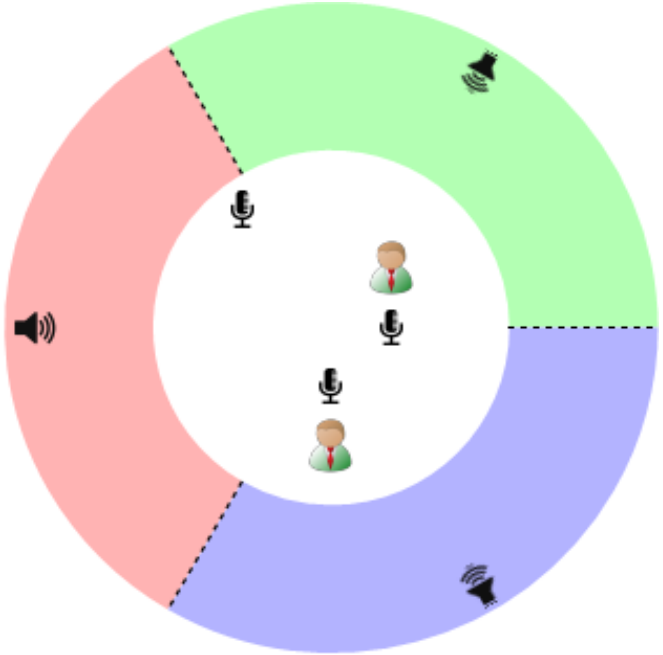
- **Mutual-information-based:**



Experiments

- **Simulated conversation between two speakers.**

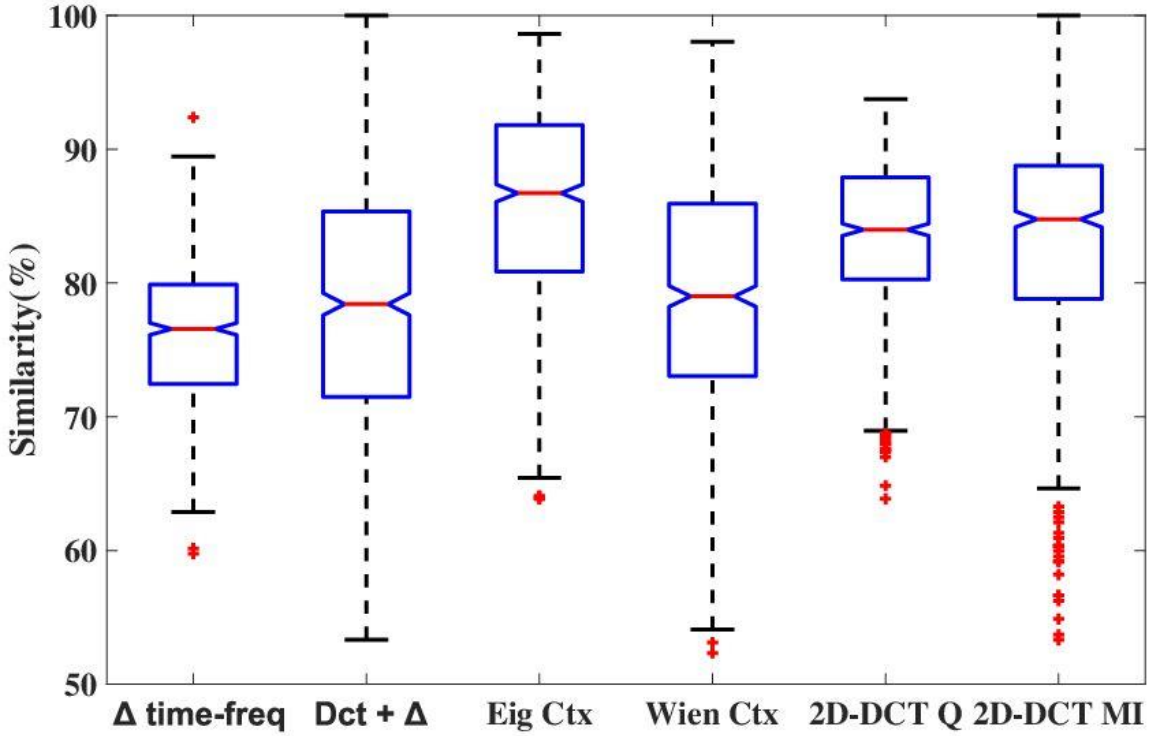
- **Conversation simulated in multiple realistic scenarios.**



Fingerprint parameters

Method	Window length (s)	Window step (s)	Number of windows	Audio length (s)	Number of bits
Reference	0.375	0.375	17	6.375	512
Eigenvalue	0.03	0.02	108	2.17	512
Wiener	0.03	0.02	108	2.17	512
2D DCT	0.03	0.02	128	2.57	512

Results


100
90
80
70
60
50
Similarity(%)
Δ time-freq
Dct + Δ
Eig Ctx
Wien Ctx
2D-DCT Q
2D-DCT MI

Conclusion

- **We propose a combination of short overlapping windows and decorrelation of the energy spectrum of the audio signal for the generation of robust acoustic fingerprints.**
- **The required recording time is considerably reduced while increasing their robustness in conversational applications.**
- **The proposed fingerprints maintain the statistical properties that are necessary in an authentication process.**
- **The fingerprint generation methods do not add a significant computational load, and they can still be performed by low-power devices such as mobile phones.**

Thank you for your attention