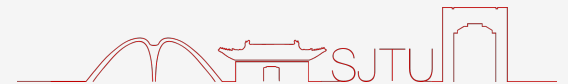# DASIV: Directional Acoustic Sensing based Intelligent Vehicle Interaction System

Dinghua Zhao, Juntao Zhou, Dian Ding, Yu Lu, Yijie Li, Hang Yang, Yi-Chao Chen, Guangtao Xue

Shanghai Jiao Tong University
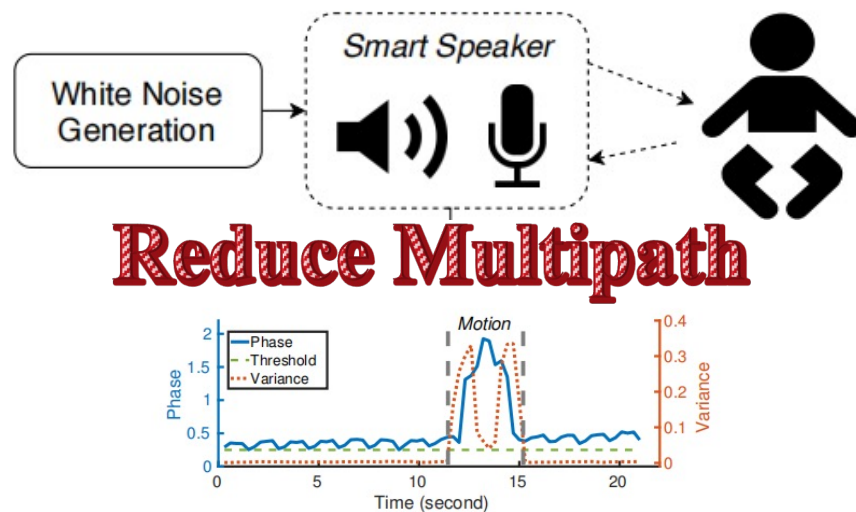
Directional Acoustic Applications

The Increase in Driving Time has Brought More Attention to More Importent Driving Safety and Better Driving Experience.

Existing Solutions – Head Related Transfer Function

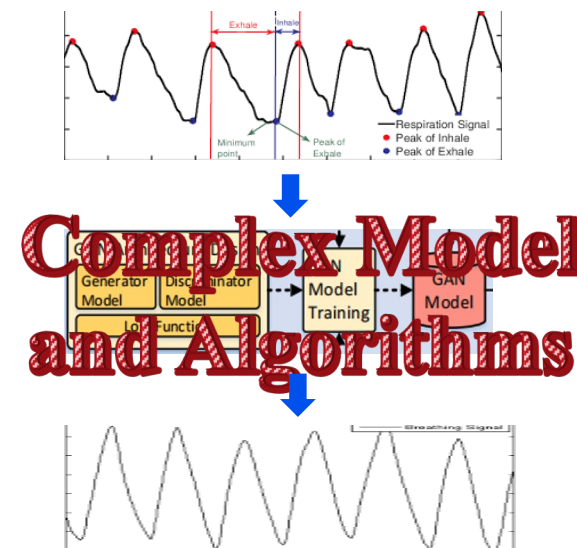**Almost all the work requires reduce multipath and other reflected signals from others activities and objects.**

Complex algorithms are required to separate the breathing waveform of the monitored user.

Reduce Multipath

Complex Model and Algorithms

Using smart speaker and white noise

Using smart phone and GAN model

[1] Wang A, Sunshine J E, Gollakota S. Contactless infant monitoring using white noise[C]//The 25th Annual International Conference on Mobile Computing and Networking. 2019: 1-16.

[2] Xu X, Yu J, Chen Y, et al. BreathListener: Fine-grained breathing monitoring in driving environments utilizing acoustic signals[C]//Proceedings of the 17th annual international conference on mobile systems, applications, and services. 2019: 54-66.

What are we facing?

Small Space

Real-time

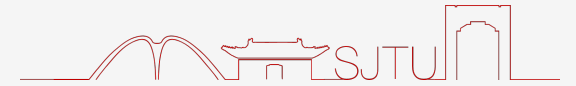**Too Many Multipath**

Complex Model and Algorithms

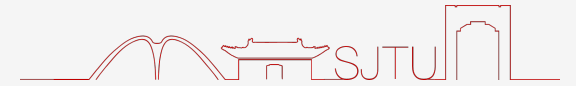Passenger Interference

Driving Action

Convenient

Fine-grained

DASIV: Directional Acoustic Sensing based Intelligent Vehicle Interaction System

Is there a sensing method that can simultaneously meet the requirements of **interference-free**, **high-precision**, and **miniaturized** in-vehicle sensing?
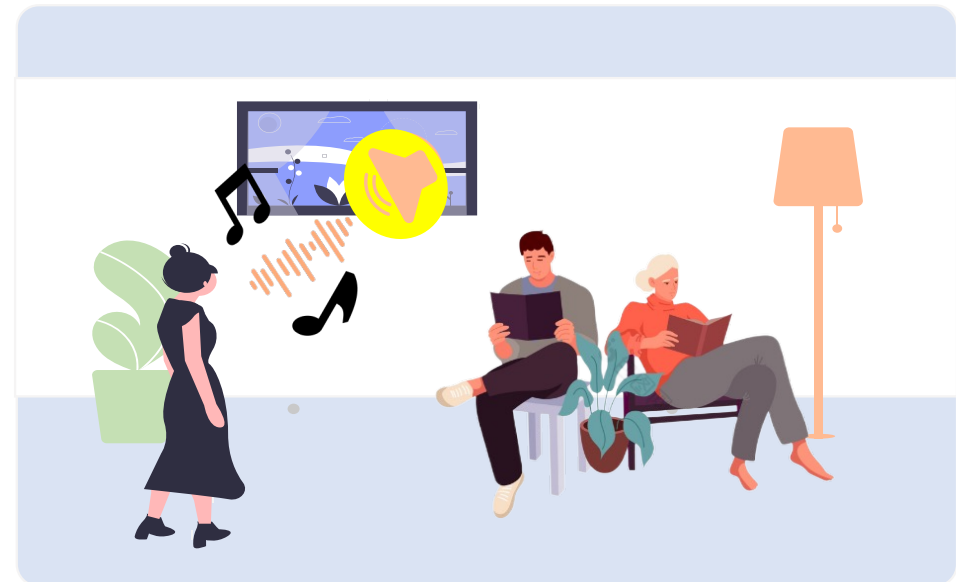
DASIV: Directional Acoustic Sensing based Intelligent Vehicle Interaction System

Directional Acoustic Applications

Is there a sensing method that can simultaneously meet the requirements of **interference-free**, **high-precision**, and **miniaturized** in-vehicle sensing?

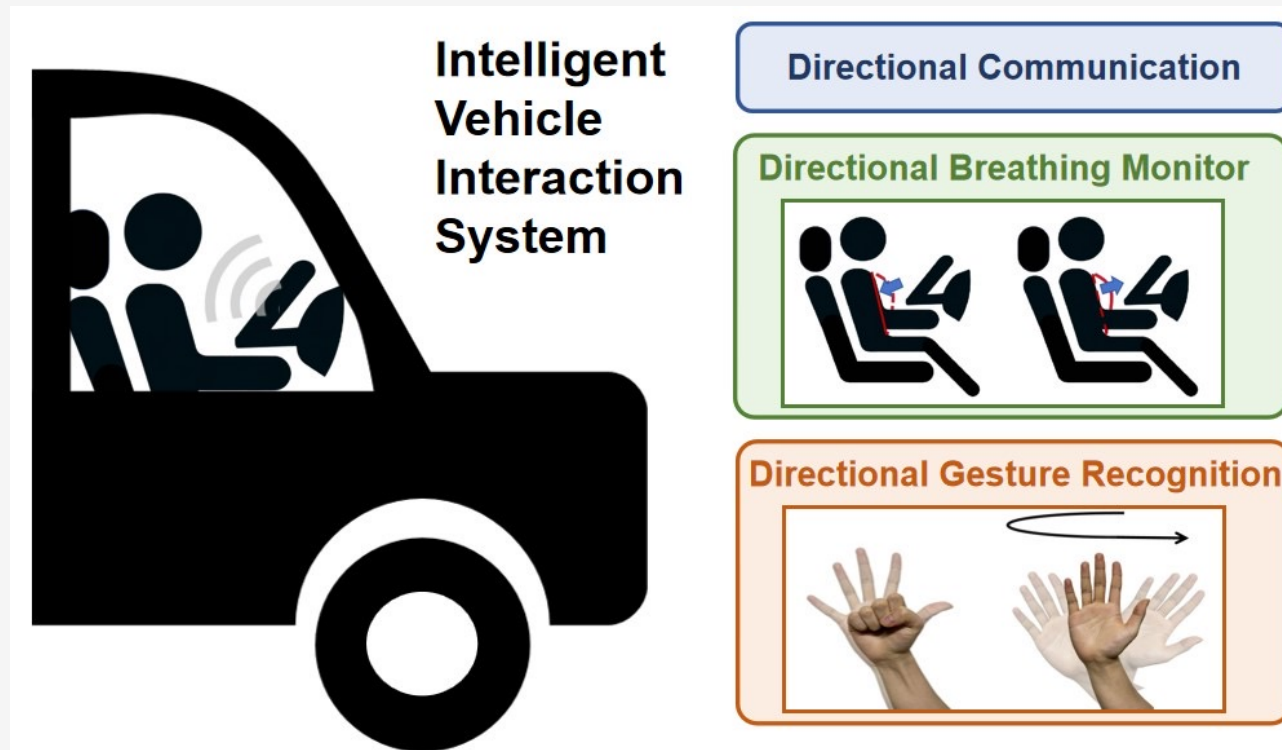Directional Acoustic !

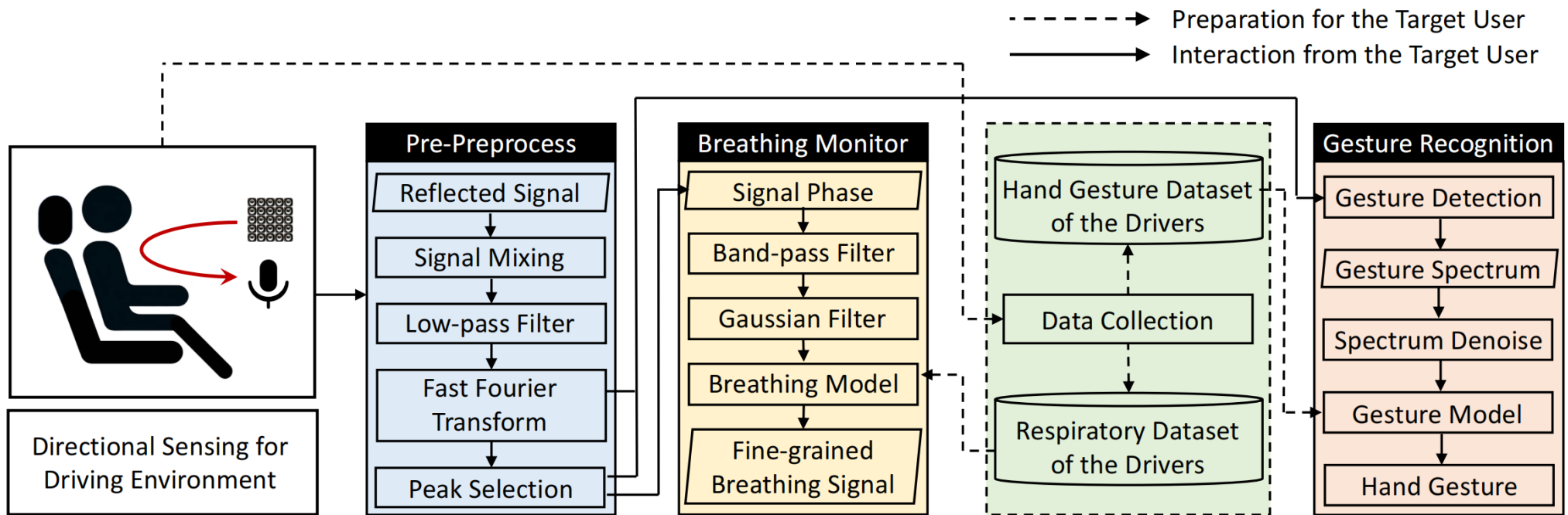# Directional Acoustic Applications
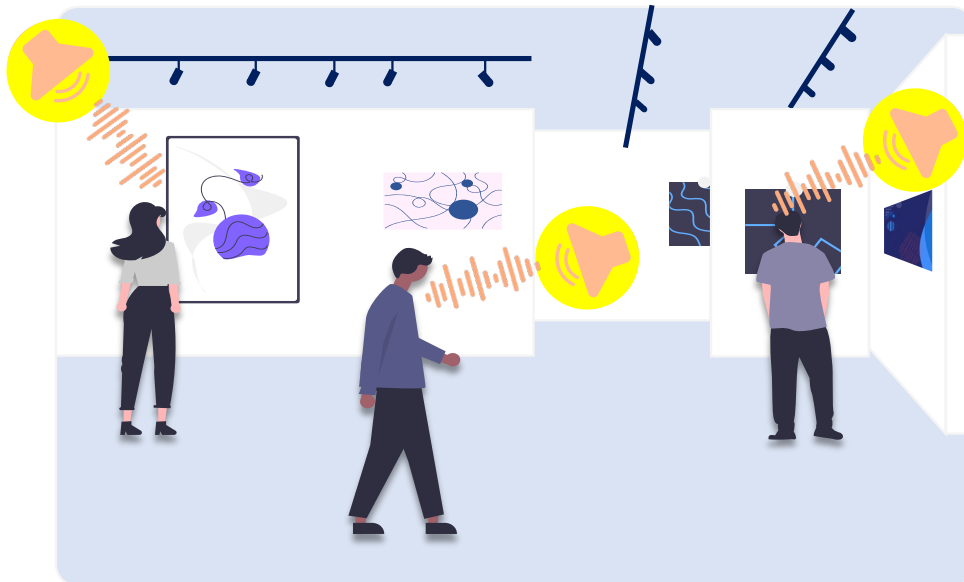
Exhibitions in the Museum

Application in the Home

Directional Communication in Various Real-World Application Scenarios

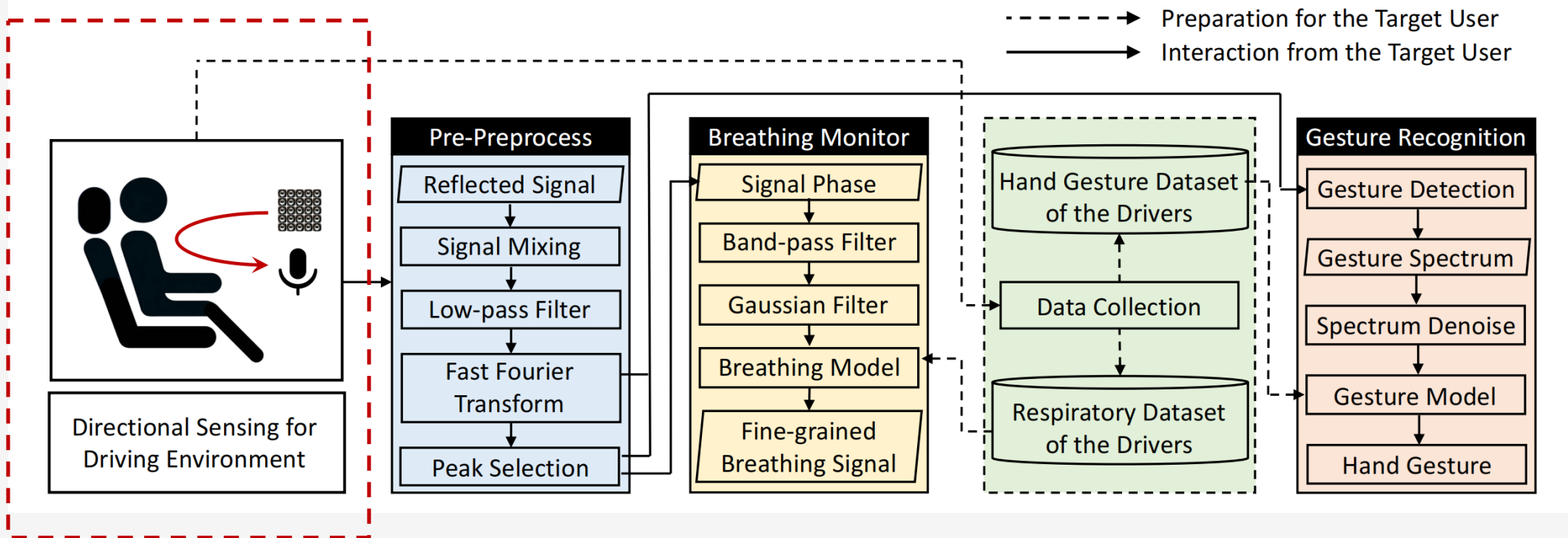DASIV: Directional Acoustic Sensing based Intelligent Vehicle Interaction System

1) **Complexity** of the vehicle environment

2) **Simultaneous** sensing and communication

3) Driving Environment： **The vibration of the vehicle**
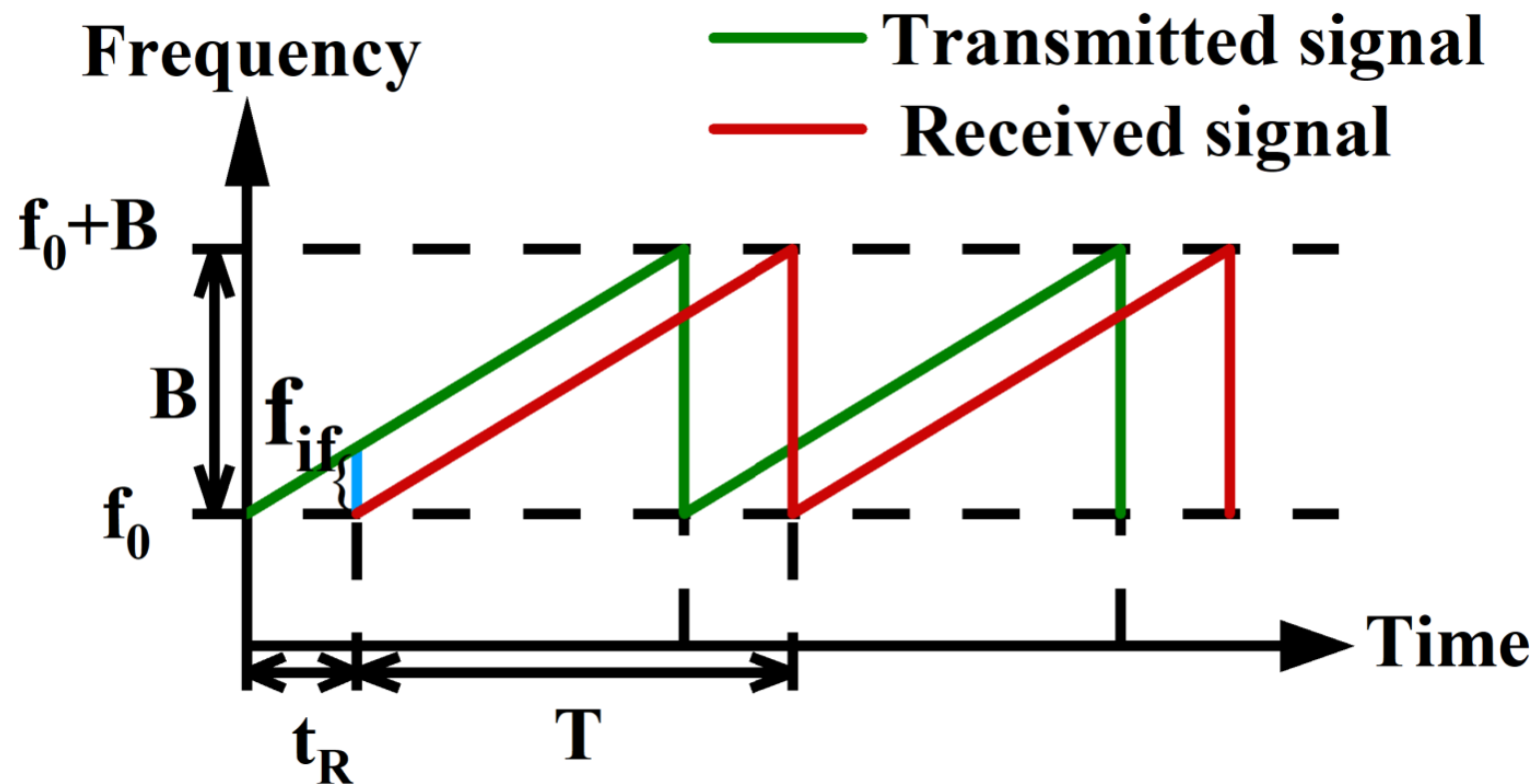
4) Characterization of user hand gestures

System

DASIV: Directional Acoustic Sensing based Intelligent Vehicle Interaction System

System

DASIV: Directional Acoustic Sensing based Intelligent Vehicle Interaction System

Transmitted signal and reflected signal

DASIV: Directional Acoustic Sensing based Intelligent Vehicle Interaction System

FMCW Sensing Distance Change
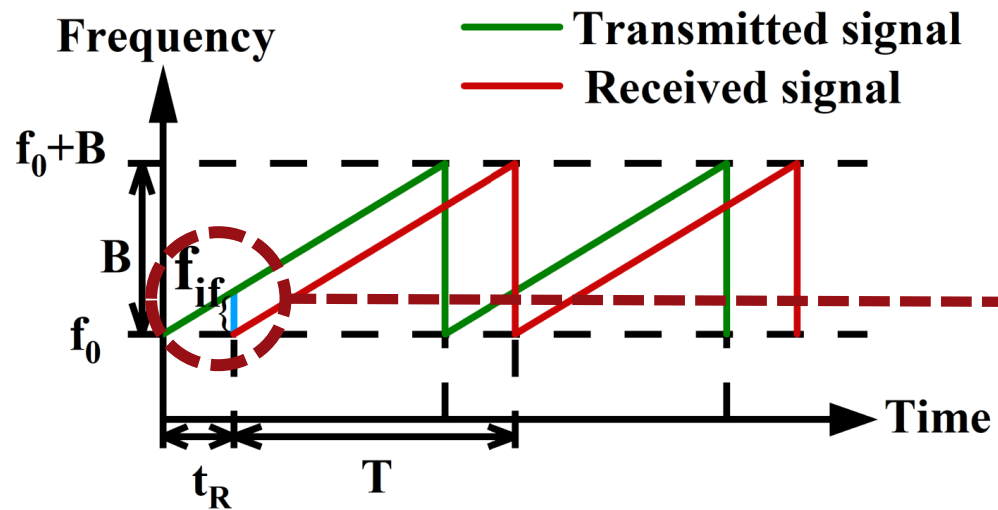
Transmitted signal and reflected signal

DASIV: Directional Acoustic Sensing based Intelligent Vehicle Interaction System

FMCW Sensing Distance Change

Transmitted signal and reflected signal
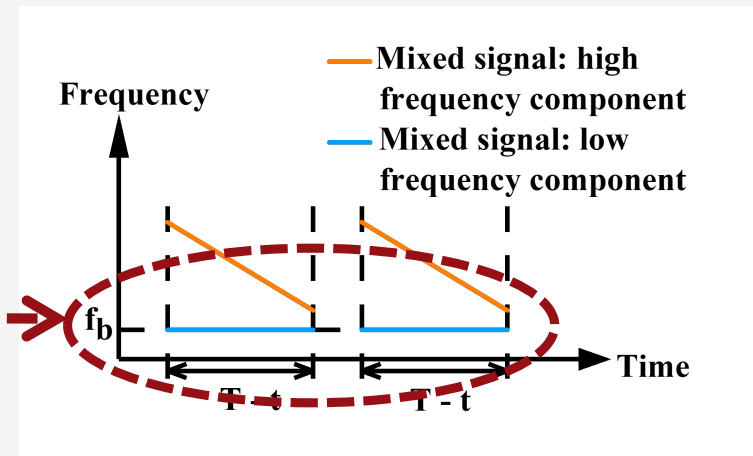
FMCW Sensing Distance Change

Low frequency components of mixed signals

$$x_{tx}(t) = A\cos(\phi(t)) = A\cos(2\pi(f_0 t + \frac{kt^2}{2}))$$

DASIV: Directional Acoustic Sensing based Intelligent Vehicle Interaction System

Low frequency components of mixed signals

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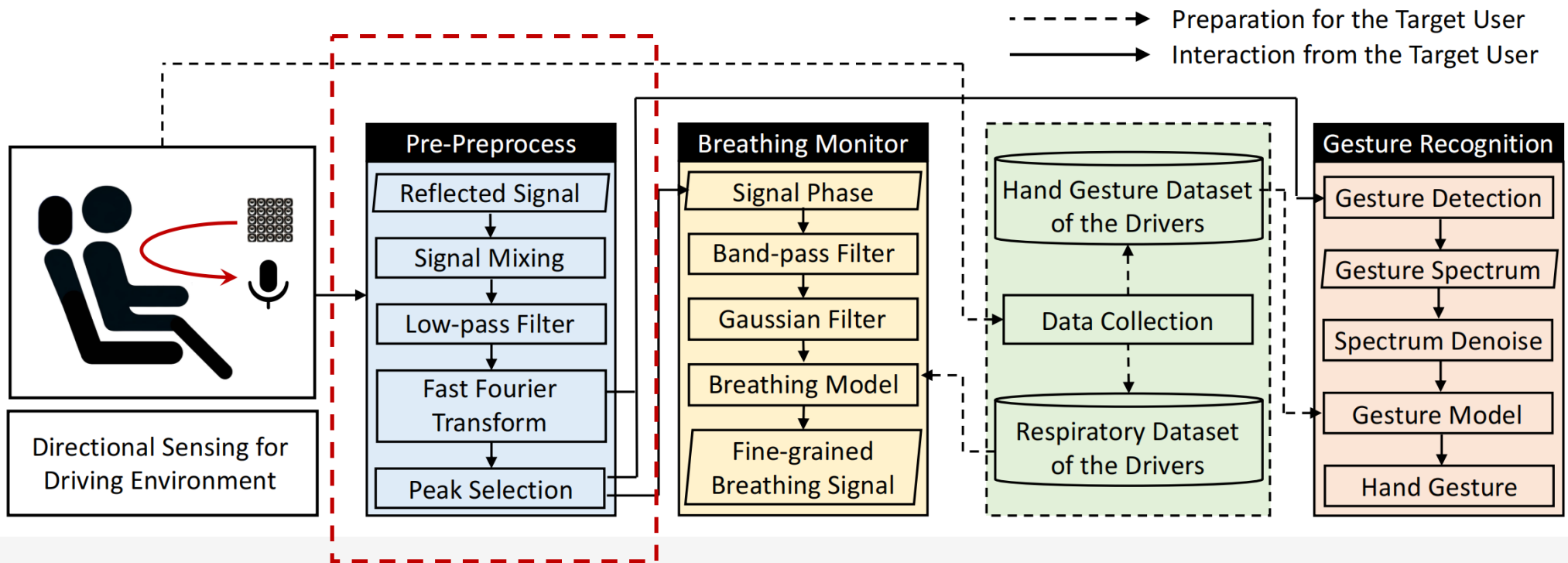$$\phi(t) = 2\pi \int_0^t f(t)dt = 2\pi(f_0 t + \frac{kt^2}{2})$$

DASIV: Directional Acoustic Sensing based Intelligent Vehicle Interaction System

Low frequency components of mixed signals

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$$R = \frac{cf_{if}}{2k}$$

$$\Delta R = \frac{c\Delta f_{if}}{2k} = \frac{c}{2B}$$
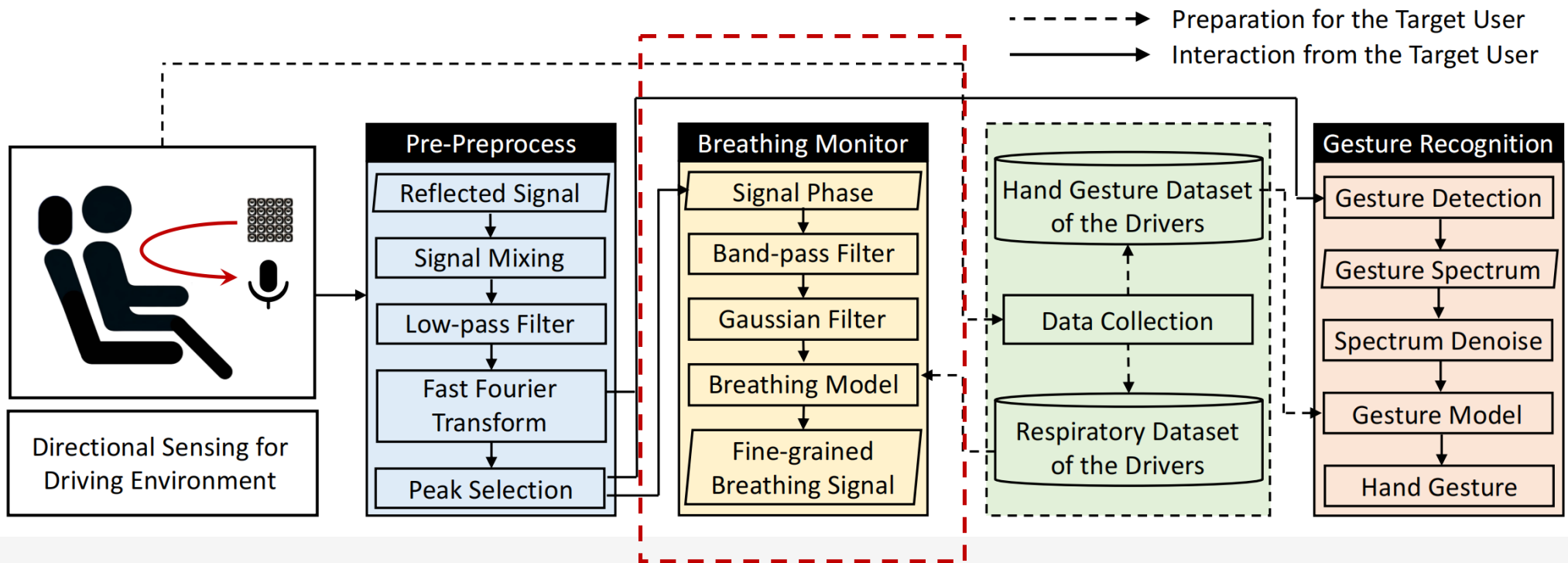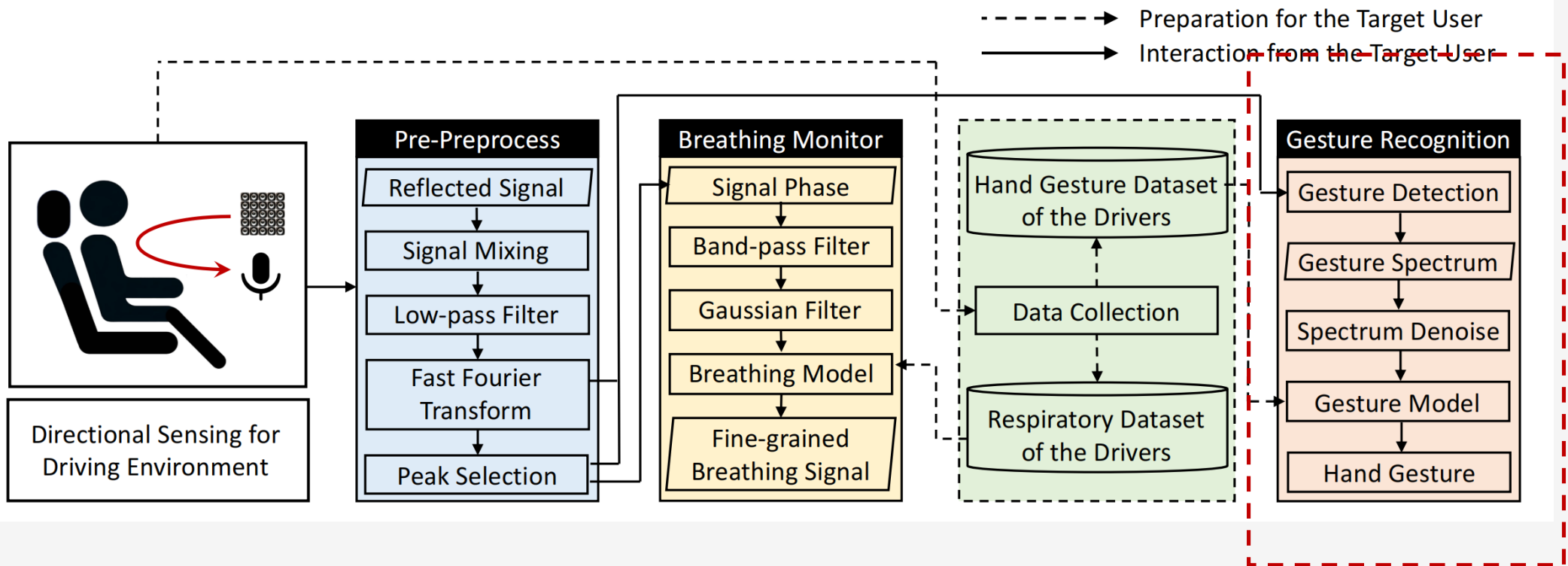
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1) **Complexity** of the vehicle environment

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Using regular speakers

Challenge 1: Complexity of the vehicle environment

Using regular speakers
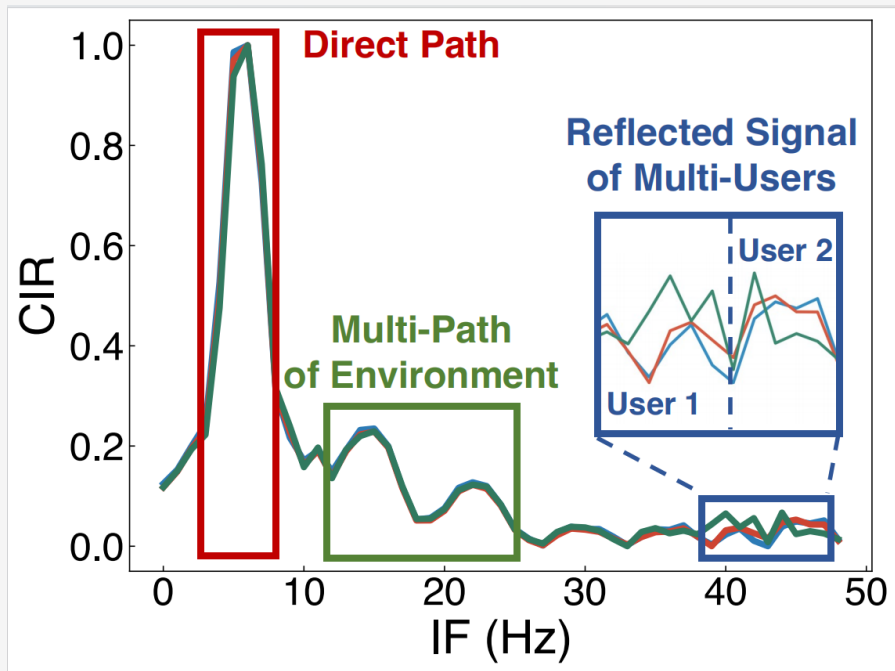
Using directional speakers
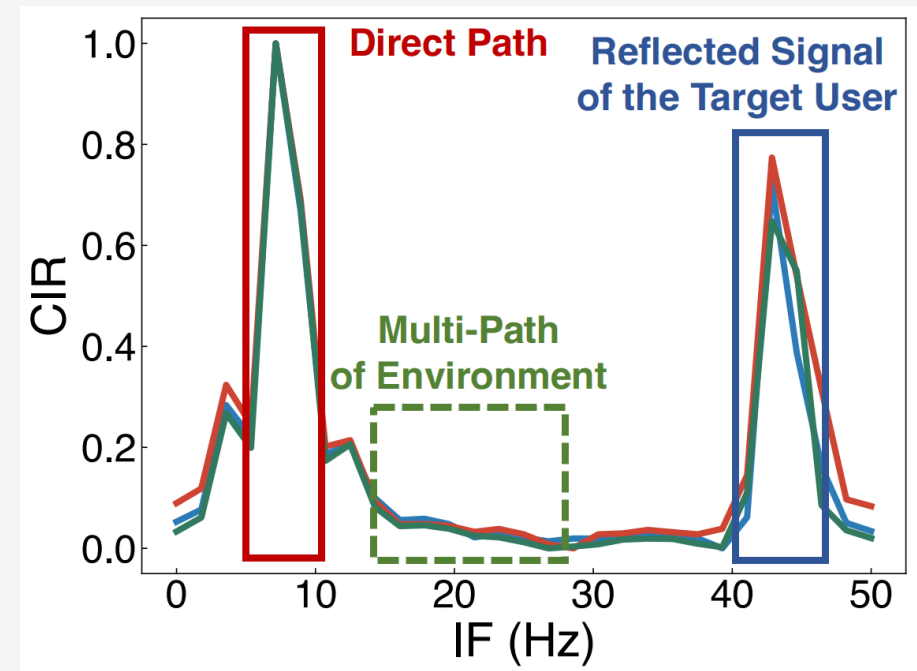
DASIV: Directional Acoustic Sensing based Intelligent Vehicle Interaction System

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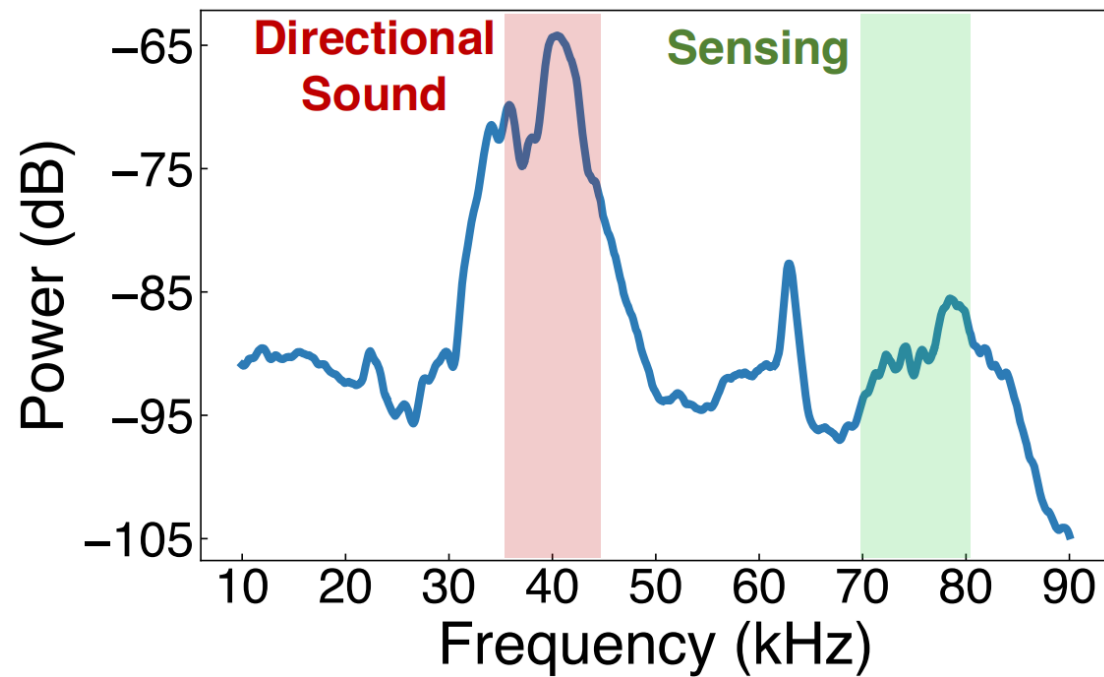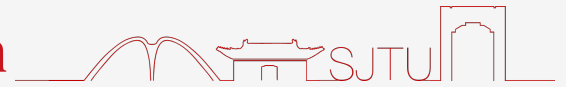
Challenge 3: The vibration of the vehicle
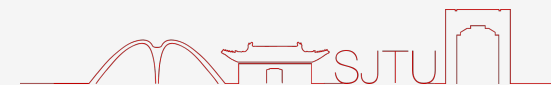
Phase curve and breathing band waveform
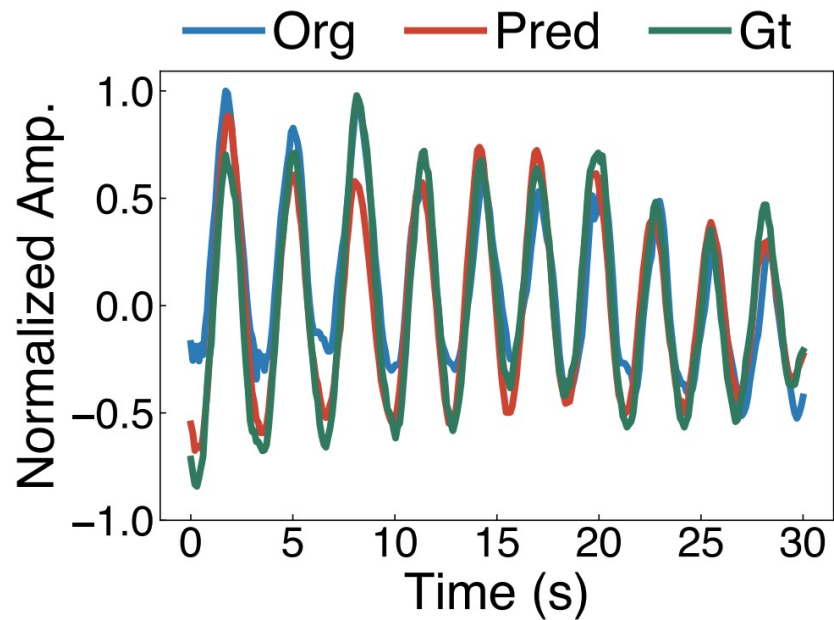
Phase curve and breathing band waveform

DASIV: Directional Acoustic Sensing based Intelligent Vehicle Interaction System

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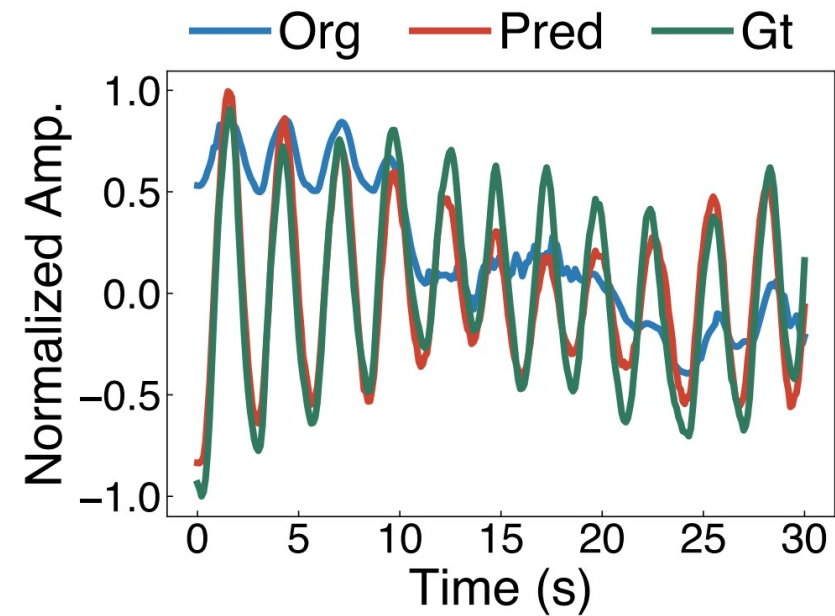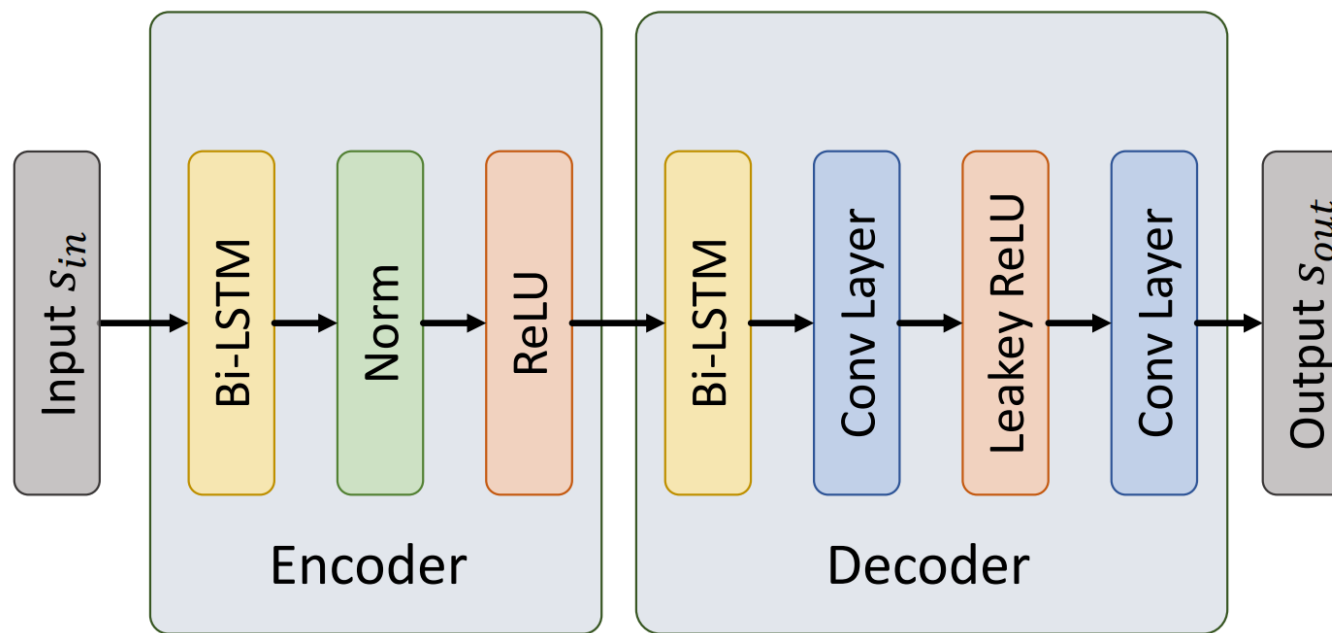
Challenge 3: The vibration of the vehicle

Seq2Seq Model

Bi-LSTM

Input s_{in} → Bi-LSTM → Norm → ReLU → Bi-LSTM → Conv Layer → Leakey ReLU → Conv Layer → Output s_{out}

Encoder

Decoder
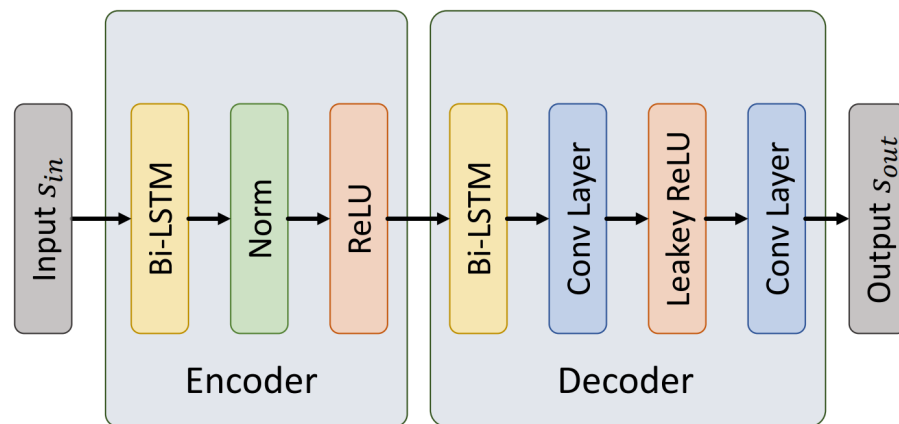
loss function

$$\mathcal{L} = \sum_{i=1}^{L_{out}} (s_{out}[i] - s_{gt}[i])^2$$

DASIV: Directional Acoustic Sensing based Intelligent Vehicle Interaction System
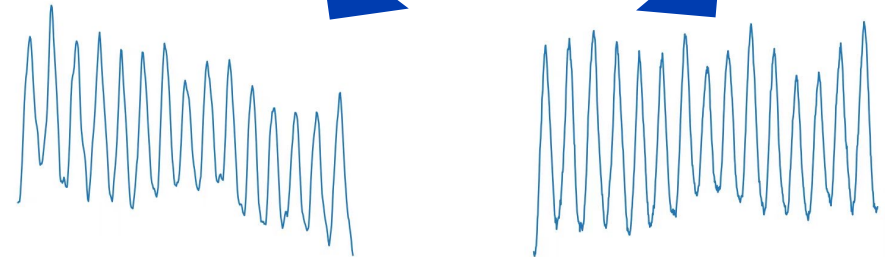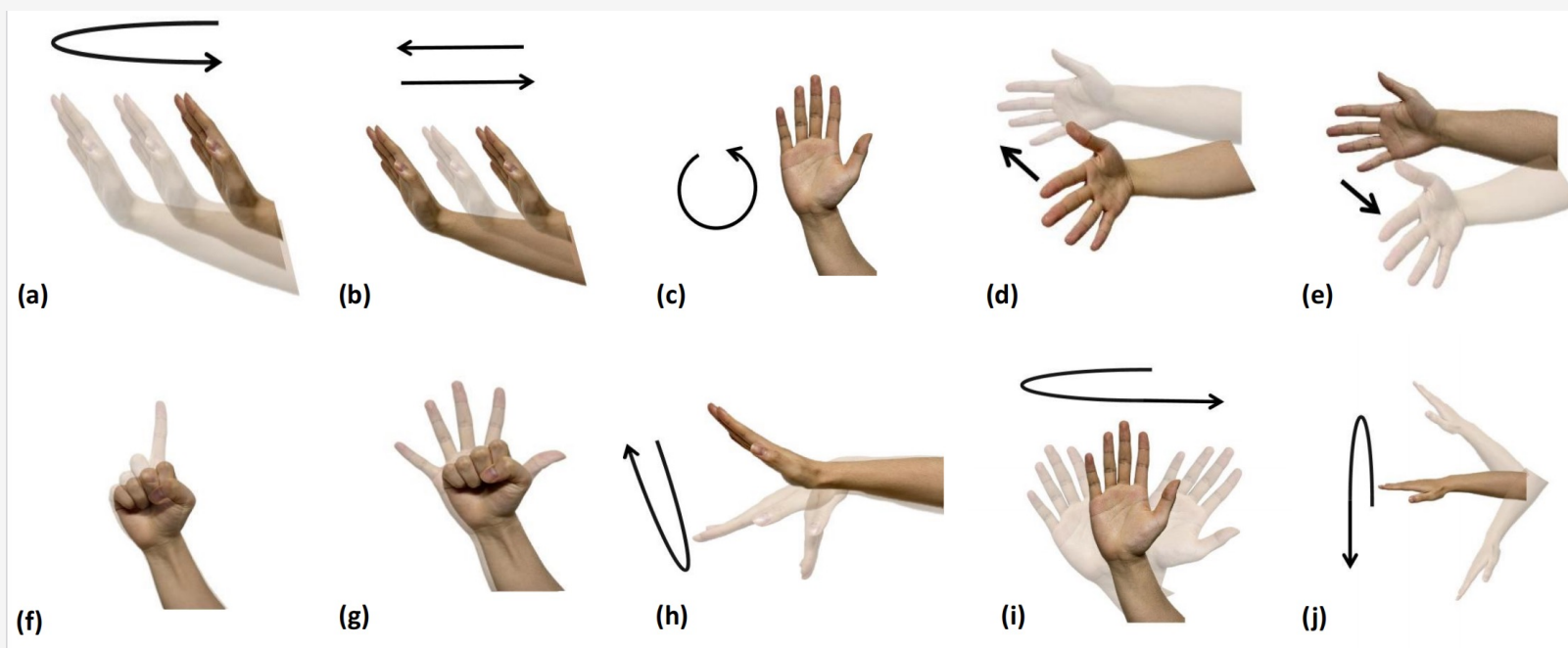
Ten hand gesture

Challenge 4: Characterization of user hand gestures
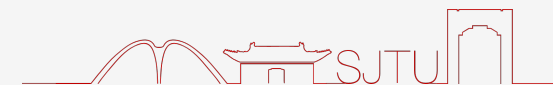
Features
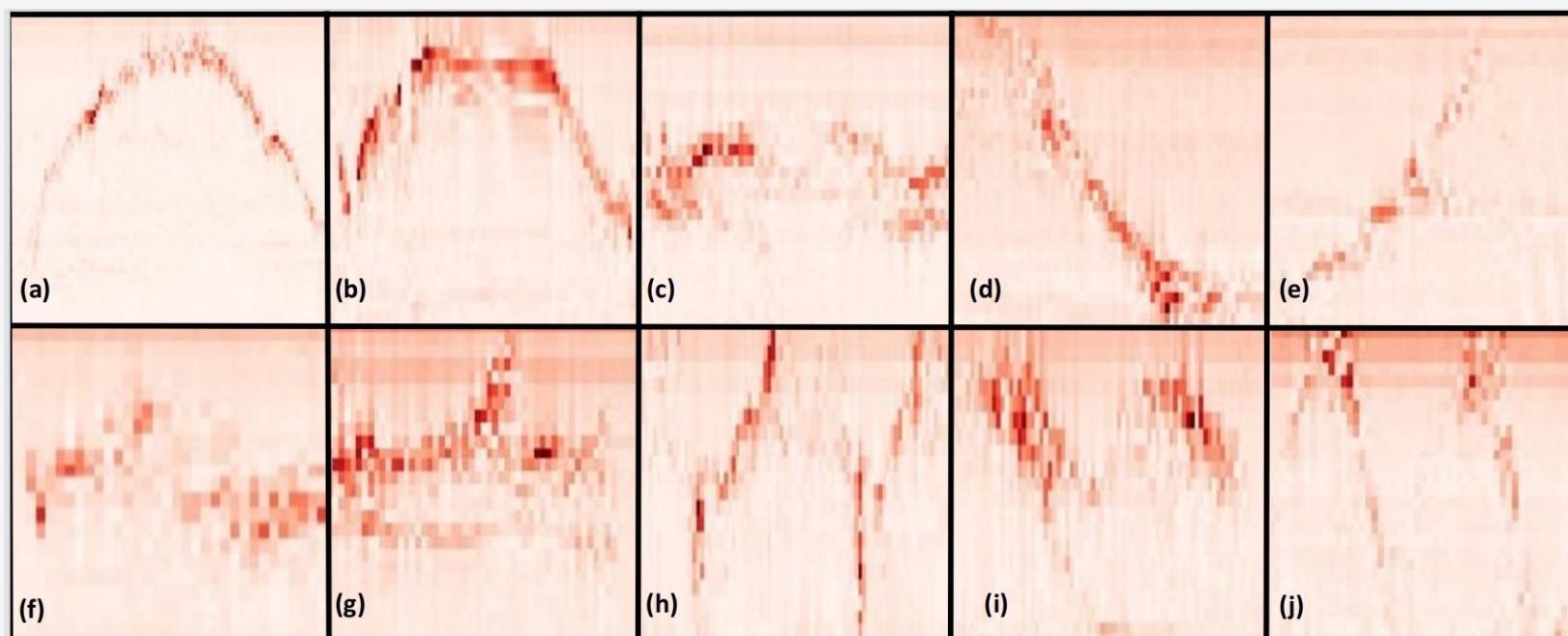
Challenge 4: Characterization of user hand gestures

ResNet with CBAM

DASIV: Directional Acoustic Sensing based Intelligent Vehicle Interaction System

ResNet with CBAM

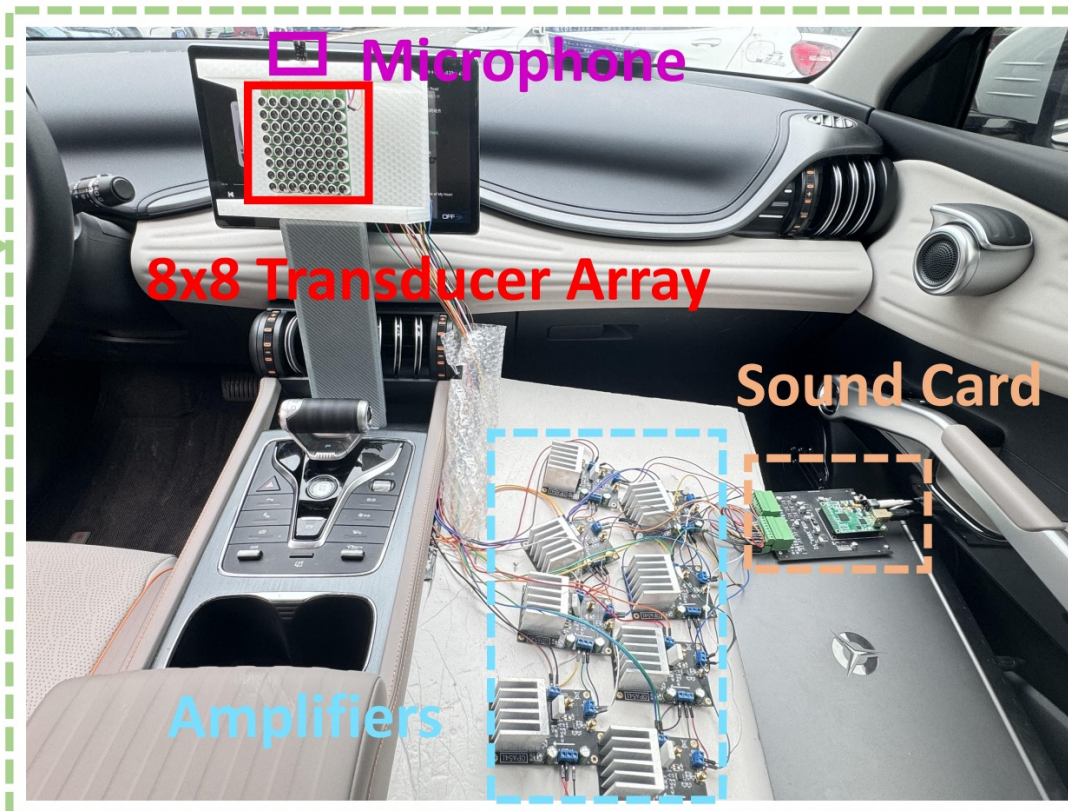**ResNet with CBAM**
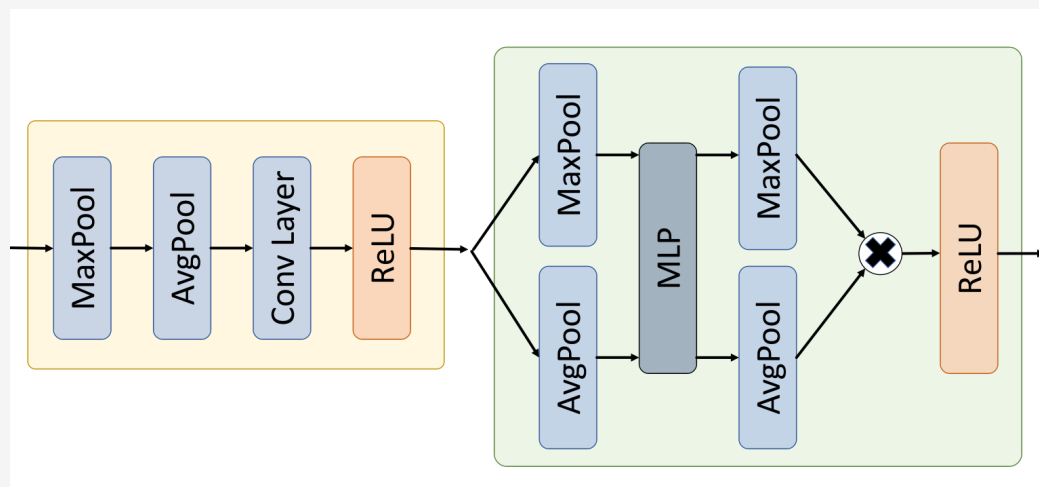
focus
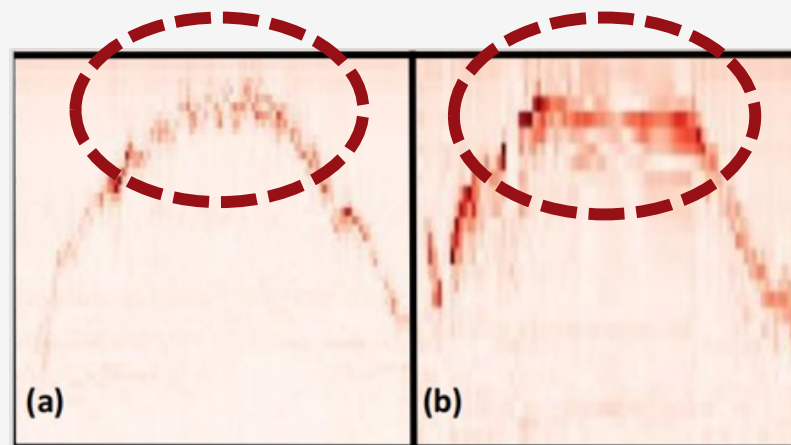
Transmission

Experimental Equipment

Microphone

8x8 Transducer Array

Sound Card

Amplifiers
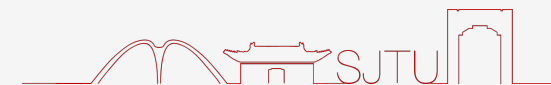
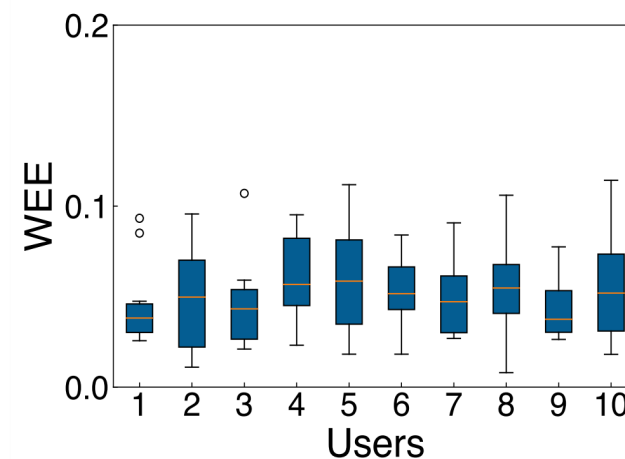# Performance
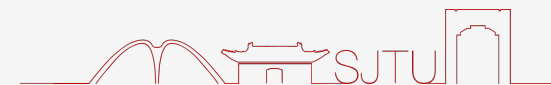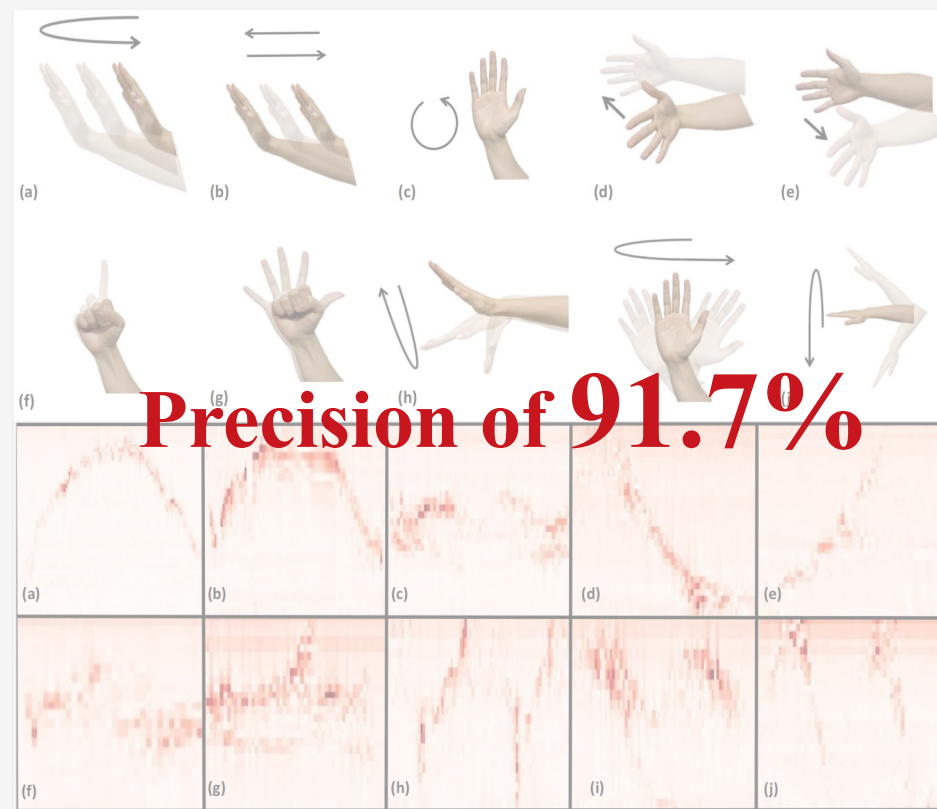

PCC
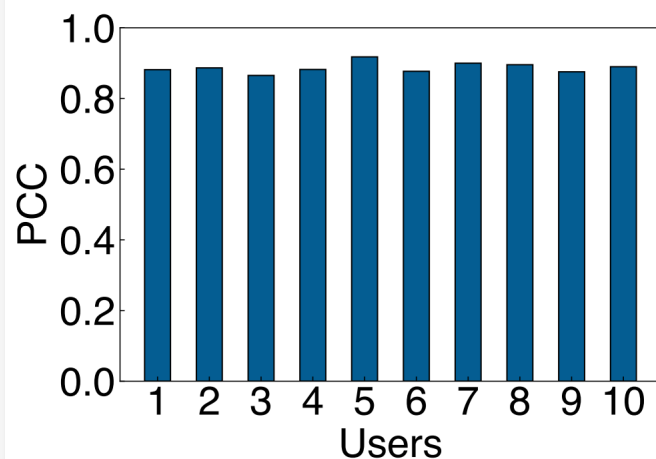
REE
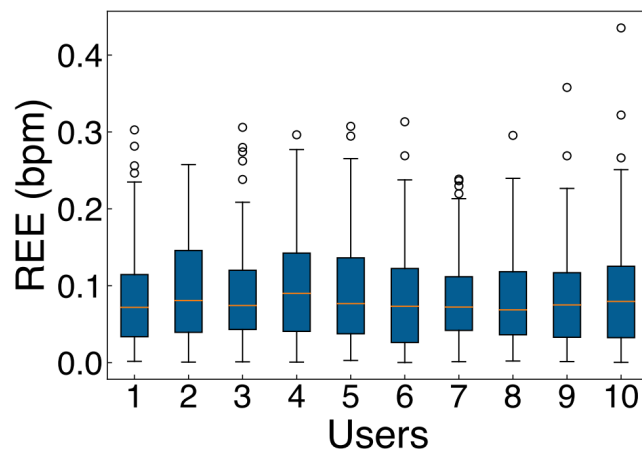
WEE

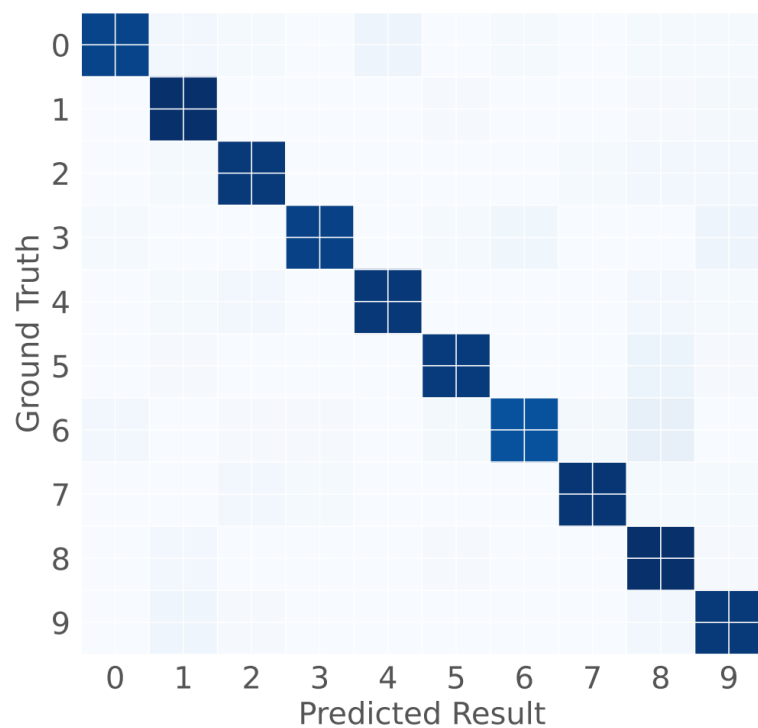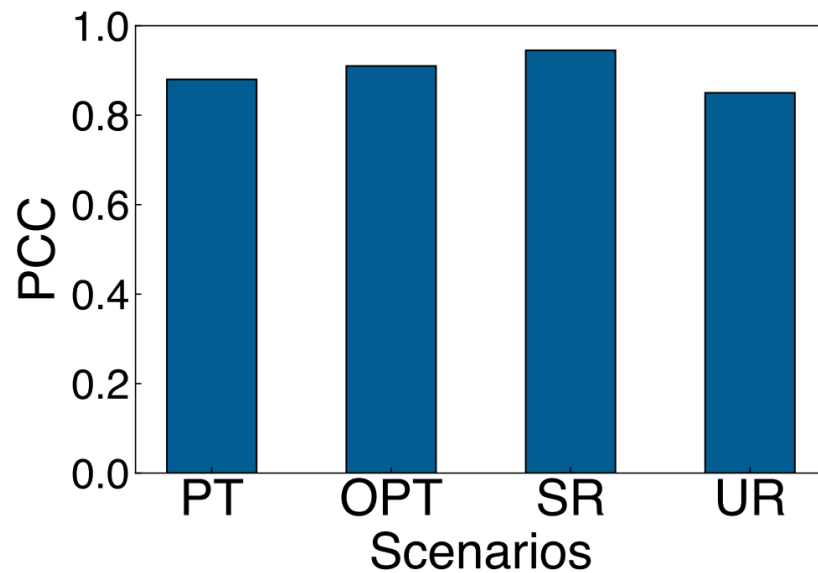**The system can fit the breathing patterns of different users well**
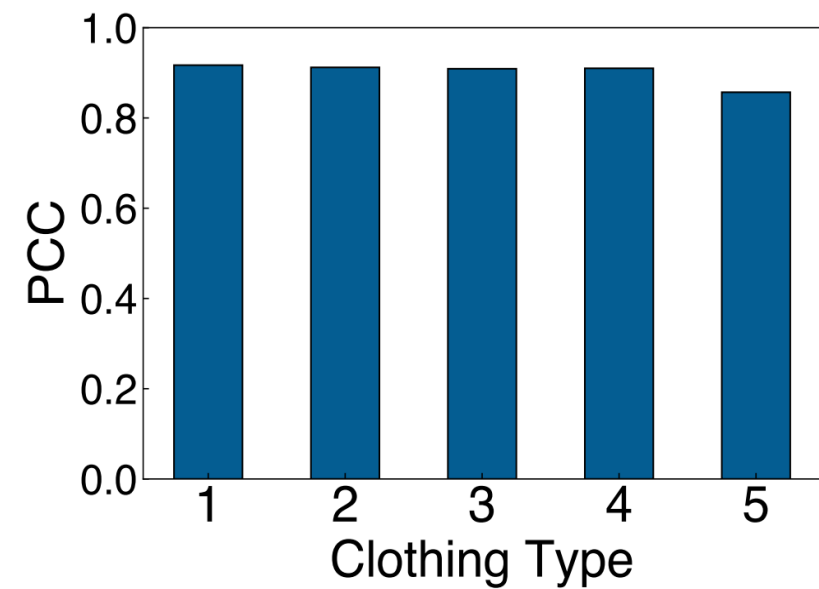
Performance
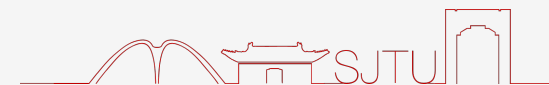
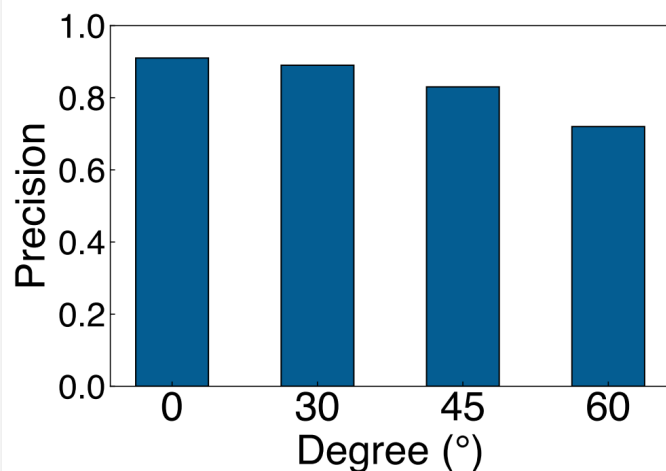**Confusion matrix of hand gesture**

Precision of 91.7%

Performance

The system can achieve good breathing pattern fitting performance under different wearing and driving conditions

DASIV: Directional Acoustic Sensing based Intelligent Vehicle Interaction System
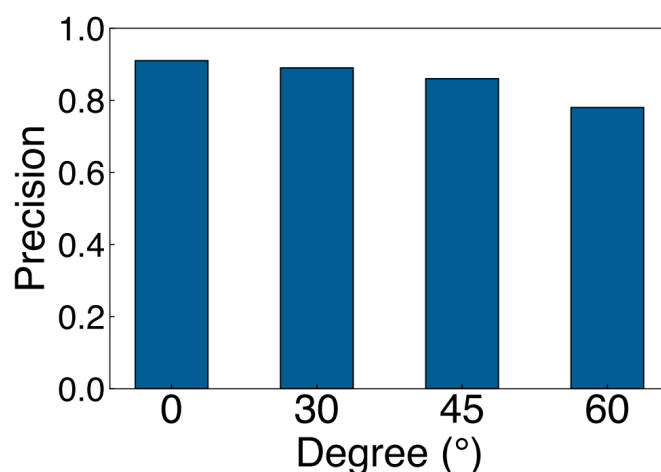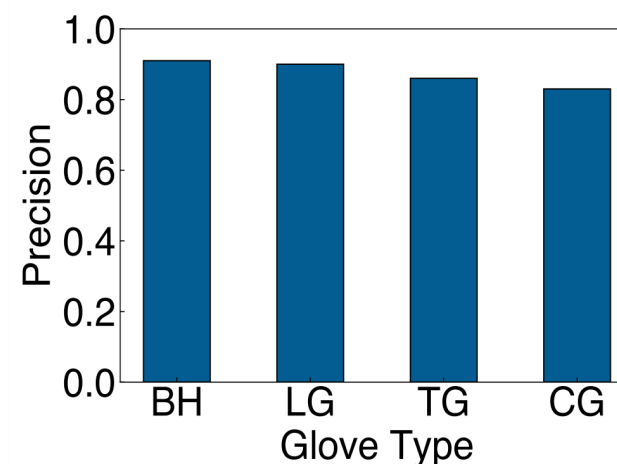
Performance

Bias of Horizonta

Bias of Vertical
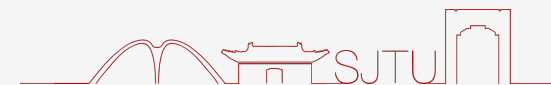
Impact of Glove

The system can achieve good hand gesture recognition performance under gloves and bias

DASIV: Directional Acoustic Sensing based Intelligent Vehicle Interaction System

Conclusion

➢ The first high-precision sensing system based on directional speakers for synchronization with communications in a vehicle environment.

➢ The system can capture weak chest movements based on phase features of FMCW signals and achieve a fine-grained breathing monitor based on Bi-LSTM.

➢ The system defines 10 interaction hand gestures under the driving state and implements ResNet-based high-precision hand gesture.

上海交通大学
SHANGHAI JIAO TONG UNIVERSITY

Thank You