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論文要約

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This dissertation consists of five chapters, outlined in the following sections.

1. Introduction

- In the field called drone audition, drones are equipped with an auditory sensor that allows the drones to understand the surrounding acoustic scene.
- Sound source localization in conventional drone audition have been targeting stationary sound sources, and drones generally fly on a predetermined path. However, drones should be able to track moving sound sources and change their positions actively to improve localization performance.
- In this dissertation, the concept “active drone audition” is introduced as an advanced extension of “drone audition,” and a 3D sound source tracking framework for active drone audition is proposed.

2. Literature Review

- The definition of “active drone audition” and “3D sound source tracking” is declared.
- Existing work related to microphone array processing and sound source localization in drone audition and robot audition has been reviewed.
- This dissertation has identified four issues that still remain in drone audition.
  （1） 3D sound source tracking
  （2） Robustness against drone noise and discretization error
  （3） Assessment of applicability
  （4） Utilization of active motions
- The main contribution of this dissertation is establishing an “active drone audition” framework of 3D sound source tracking that is robust to drone noise and discretization error.

3. Sound Source Tracking Using Spatial Spectrum Integration

- A 3D sound source tracking method named “Particle Filtering with Integrated Multiple signal classification (PAFIM)” is proposed, which utilizes the information of multiple microphone arrays and multiple drones. By utilizing multiple arrays and

drones, issues (1) and (2) can be solved since 3D source location can be constructed from multi-angle observations, and noise robustness will be improved through probabilistic processing of multiple acoustic signals.

- A sound source direction estimation method called the multiple signal classification (MUSIC) method, which is well used in drone audition and robot audition, is explained. In PAFIM, the MUSIC spectrum which is a spatial spectrum calculated through MUSIC method is used during the tracking. By integrating MUSIC spectrum calculated from each microphone array, the locational likelihood distribution of a sound source is obtained, and PAFIM can track moving sound sources by applying particle filtering to the estimated locational likelihood.
- To solve issue (3), an exhaustive numerical simulation is performed to evaluate the tracking performance of PAFIM. In the numerical simulation, the source distance and signal-to-noise ratio (SNR) are changed in steps respectively. Besides, the tracking performance is compared with that of existing work that estimates the source location through triangulation. Simulation results show that PAFIM can track moving sound sources with the least error compared to other tracking methods.
- An outdoor experiment using actual drones was conducted and showed that PAFIM could localize the sound source even in conditions similar to actual use. A simulation that imitates the experiment condition is also conducted and shows similar results to that of the outdoor experiment, which indicates the validity of the simulation mentioned above.

4. Drone Placement Planning for Sound Source Tracking

- Drones should move around the sound sources actively to improve their tracking performance. Hence, this dissertation proposes a drone placement planning method that satisfies the following four policies.
  - A) Drones should track only sound sources that they can hear
  - B) Array-to-source directions should be orthogonal to each other
  - C) Microphone arrays should stay close to the sound source
  - D) Drones should make as small moves as possible
- Policy (A) is set since it is rare that a microphone array can capture the sound of all sources, and the drone should contribute only to the tracking of the source it can hear. Therefore, this dissertation defines the probability of observation to quantify whether the sound source is captured by the microphone array.
- This dissertation has proposed a placement planning method for drones to satisfy

policy (B) – (D). The proposed placement planning has enabled drones to perform multi-angle observation of sound sources and keep a short distance from them, which is expected to improve tracking performance.

- Numerical simulation showed the effectiveness of the proposed method that the drones move actively to assign themselves to the nearest sound source and improve their tracking performance.

5. Conclusion

- This dissertation concludes with a discussion of the contributions of this dissertation to the four issues discussed in chapter 2, as well as future work in active drone audition.