

Research Project / Master Thesis

Imitation Learning for Joint Radar Imaging and Communication

Radar imaging, particularly synthetic aperture radar (SAR) [1], can improve wireless communication performance and security by enabling high-precision environmental awareness (e.g., tracking of ground-moving eavesdroppers in critical scenarios, such as surveillance or post-disaster communication) [2]. Ensuring secure wireless communication requires the knowledge of the eavesdropper's channel state information (CSI), which is difficult to obtain in practice. Most existing works either assume perfect CSI or employ prior position estimates to model the uncertainty in the eavesdropper's location [3].

Recently, in [4], a time-division joint SAR and communication (JSARC) framework was proposed, where an aerial base station alternates between SAR sensing and wireless communication phases. In this framework, SAR sensing is exploited to estimate the eavesdropper CSI, which is then used to intelligently adapt communication strategies in real time in order to enhance the communication secrecy rate. Building on the work in [4], this project aims to further **improve the performance of secure JSARC systems by exploring machine learning-based optimization approaches, with a particular focus on imitation learning** [5]. More specifically, the project investigates a framework in which a learning agent is trained using expert demonstrations generated by a classical optimization solver, see Figure 1. The trained agent subsequently interacts with the environment and learns to generalize to previously unseen dynamic scenarios.

The project objectives can be summarized as follows:

- Study and implement optimization techniques for secure time-division JSARC systems.
- Design and implement an imitation learning framework for the real-time optimization of the considered problem.
- Compare the proposed method with the reinforcement learning solution presented in [4].

To guide the student toward the above objectives, the following **potential** work packages (WPs) are defined. Note that the WPs can be adjusted depending on the student's background, preferences, project type, and available time.

WP1: Literature Review

A targeted literature review is required for the successful completion of the project. This includes, for instance, reviewing the fundamentals of SAR imaging [1], air-to-ground wireless communication [6], reinforcement learning [7], imitation learning [5], mathematical optimization [8], and integrated sensing and communication [2].

WP2: Implementation of an Existing Reinforcement Learning Baseline

This work package focuses on implementing and understanding the existing reinforcement

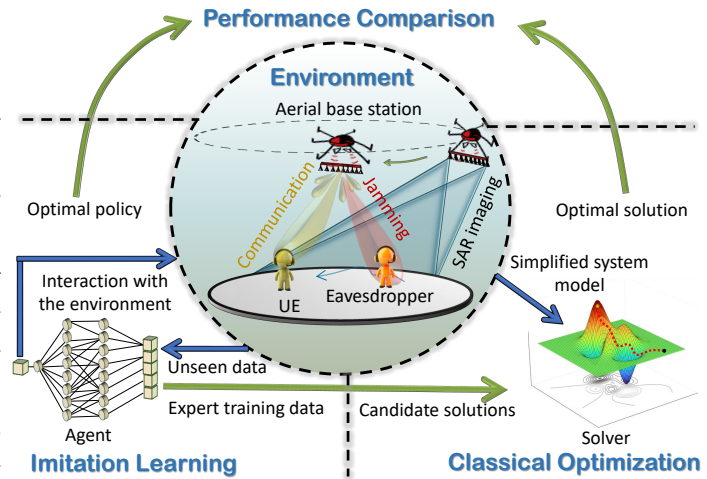


Figure 1: Illustration of the intended imitation learning pipeline for secure JSARC systems. A classical optimization solver is employed to generate an expert policy that is fed to a learning agent. The environment sketch is inspired by [4].

learning solution proposed in [4]. The objective is to use it as a reference for later comparison with the proposed imitation learning approach.

WP3: Development of a Lightweight Classical Solver

An offline lightweight optimization solver will be developed for the considered secure time-division JSARC problem under simplified assumptions (e.g., assuming prior knowledge of the eavesdropper’s CSI (i.e., trajectory) and forcing equal-aperture SAR sensing to reduce the problem complexity). The generated solutions are needed as an input for WP4.

WP4: Development of an Imitation Learning Framework

This work package focuses on designing and implementing an imitation learning pipeline for the considered optimization problem, see Figure 1. Using the classical solver as an expert policy, a learning agent will be trained to imitate the generated expert decisions and generalize to unseen dynamic scenarios.

WP5: Performance Evaluation and Analysis

The developed approaches will be evaluated and compared in terms of communication performance and generalization capability to the reinforcement learning-based baseline in [4].

PREREQUISITES

Scientific skills	Interest in communication and sensing. Basic knowledge of convex optimization and reinforcement learning .
Programming skills	Experience in Python programming.
Language skills	English fluency

SUPERVISOR	Dr.-Ing. Amine Lahmeri {amine.lahmeri}@fau.de
------------	--

Start date: TBD
End date: TBD

References

- [1] A. Moreira *et al.*, “A tutorial on synthetic aperture radar,” *IEEE Geosci. Remote Sens. Mag.*, vol. 1, no. 1, pp. 6–43, 2013.
- [2] A. Liu *et al.*, “A survey on fundamental limits of integrated sensing and communication,” *IEEE Commun. Surv. Tutor.*, vol. 24, no. 2, pp. 994–1034, 2022.
- [3] G. Zhang, Q. Wu, M. Cui, and R. Zhang, “Securing UAV communications via joint trajectory and power control,” *IEEE Trans. Wireless Commun.*, vol. 18, no. 2, pp. 1376–1389, 2019.
- [4] M.-A. Lahmeri, A. Khalili, Y. Liu, A. Schmeink, and R. Schober, “Deep reinforcement learning for cognitive time-division joint SAR and secure communications,” 2026, submitted to IEEE Glob. Commun. Conf.
- [5] A. Hussein, M. M. Gaber, E. Elyan, and C. Jayne, “Imitation learning: A survey of learning methods,” *ACM Comput. Surv.*, vol. 50, no. 2, pp. 1–35, 2017.
- [6] W. Khawaja *et al.*, “A survey of air-to-ground propagation channel modeling for unmanned aerial vehicles,” *IEEE Commun. Surv. Tutor.*, vol. 21, no. 3, pp. 2361–2391, 2019.
- [7] R. S. Sutton and A. G. Barto, *Reinforcement Learning: An Introduction*, 2nd ed. Cambridge, MA, USA: MIT Press, 2018.
- [8] S. Boyd and L. Vandenberghe, *Convex optimization*. Cambridge University Press, 2004.