Figure 1 : AI generated image by Dall-E 3

Generative AI: Introduction and applications to radar imagery

2024 IEEE Radar Conference Tutorial Proposal

Luc Vignaud & Nicolas Trouvé

RÉPUBLIQUE FRANÇAISE
Liberté Égalité Fraternité

ONERA
THE FRENCH AEROSPACE LAB

This tutorial presents an in-depth exploration of cutting-edge developments in generative artificial intelligence, emphasizing its transformative potential for Synthetic Aperture Radar (SAR) imagery and, to a more limited extent, broader radar applications. Beginning with an essential review of generative AI's core principles, including adversarial techniques and transformer-based models, the session will offer a comprehensive survey of its applicability. It will delve into the fusion of language and vision, unveiling a novel paradigm of capabilities. The discussion will include concrete examples and insights into the latest advancements. Further, we will cover aspects of database management, enhancement, annotation, and curation. The tutorial will conclude with a discussion on practical considerations, encompassing ethical, legal, and hardware challenges.

Duration: 3 hours

Prerequisites: Participants should have a basic knowledge of machine learning concepts and deep learning-based methodologies, coupled with familiarity with the principles of radar imaging and its unique attributes.

- **Detailed Tutorial Plan:**
- **Generative Model Architectures: Overview and Fundamentals**
    - Introduction to generative models: Architecture, inference mechanisms, Autoencoders/VAEs, latent space exploration, adversarial techniques, U-Net, and ResNet architectures.
    - Discussion on training methodologies, loss functions, and inference processes.
- **Radar-Specific Considerations and Modelling Challenges**
    - Examination of radar imaging nuances: Signal dynamics, complex data processing, statistical models, and speckle effects.
- **Applications in Image Processing**
    - Techniques for image compression and encoding.
    - Advances in object detection and image segmentation.
- **Multimodal and Natural Language Processing Applications**

- Overview of text encoding methods.
- Text-to-image generation through diffusion models.
- Content analysis via image-to-text conversion.
- Image-to-image transformation (style transfer, ControlNet).

- **Model Training and Refinement**
  - Exploration of training frameworks.
  - Strategies for model fine-tuning and the application of LoRA methods.
- **Data Management Strategies**
  - Managing extensive datasets with generative AI: Image analysis, automated annotation, addressing data quantity and quality, synthetic data generation, and augmentation techniques.
- **Addressing Practical Deployment Concerns**
  - Deployment strategies, hardware limitations, and model simplification through distillation.
  - Discussing ethics, predictability and explainability in the context of generative AI applications.

Dr. Luc Vignaud is a former student of Ecole Normale Supérieure de Lyon. He received his Master/DEA in Signal Processing at Supelec (Ecole Supérieure d'Electricité) in 1993 and his PhD on "Radar Imaging of non-stationary Scenes" in 1996 at UPMC (now Paris Sorbonne University). Since, he is a research engineer in The Radar Department of ONERA, The French Aerospace Lab. He is an external Professor at Supelec Paris-Saclay University and UPMC Paris La Sorbonne University where he lectures "Radar Signal Processing" within the "Masters in Embedded Sensors Systems". He has presented several tutorials at international radar conferences and Nato Lecture Series. Since 2001, he has been chairing 5 Nato Task Groups and co-organized 2 Nato Specialist Meetings on SAR/ISAR Target Recognition. He has been recipient of the 2017 Science and Technology individual Scientific Award. His research interests are mainly in the field of radar signal and SAR/ISAR images processing, radar simulations, and machine/deep learning.

Dr. Nicolas Trouvé completed his studies at the Institut d'Optique Graduate School and earned his PhD from Ecole Polytechnique in 2011. Following his academic pursuits, he joined ONERA, The French Aerospace Lab, contributing as a research engineer in the Radar Department. In 2018, he took on the role of leading the Simulation, Environment, and Modeling team, also coordinating the EMPRISE® project in partnership with the French Ministry of Defense (DGA). His work focuses on exploring the synthesis, simulation, and modeling of radar signals and images, utilizing both traditional physical approaches and modern machine learning techniques.