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FA/MA: Range-Doppler map upsampling for single channel chirp sequence radar using Deep Learning.

Description: Chirp sequence radars are Frequency Modulated Continuous Wave radar systems with steep frequency ramps. This allows for large bandwidths and consequently high range resolution. Furthermore, range and Doppler estimation can be decoupled and a 2D range-Doppler map can be computed with 2D FFT processing of a 2D baseband data cube in time domain.
As any other sensor, chirp sequence radars have limited resolution. In case of single channel (no angular information), unipolar (no polarimetric information) chirp sequence radars, range resolution is mainly limited by signal bandwidth and Doppler resolution is limited by carrier frequency and coherent processing interval (CPI). Carrier frequency is usually fixed for a given system, bandwidth may be restricted by regulations, system cost etc., and CPI can be limited by object motion or radar ego-motion.
Deep learning methods have shown impressive capabilities to upscale signals to higher resolutions. Especially in the computer vision domain, multiple commercial super resolution products for images and video games have emerged, e.g. the super resolution systems (Dynamic Super Resolution - DSR and Deep Learning Super Sampling – DLSS) by Nvidia.
This thesis shall study Deep Learning based upsampling methods for a chirp sequence radar from Infineon at the ISS. Thereby, range-Doppler maps shall be processed by a neural network architecture capable of super resolution (e.g. a Conditional Generative Adversarial Network (CGAN)). Real dataset collection can be performed at low cost and time consumption with a dataset collection scheme recently proposed at the ISS.

Work package:

- Literature study of FMCW radar.
- Literature study of Deep Learning based super resolution/upsampling algorithms, e.g. for computer vision, radar imaging (SAR/ISAR) and range-Doppler maps.
- Collection of a large dataset of (low-resolution, high-resolution) data cube pairs with our radar that shall be further used for supervised-learning based range-Doppler map upsampling. Machine learning best practices (e.g. independence of training and test data) shall be considered for dataset collection.
- Setup of a training and evaluation pipeline with a simple dummy network.
- Study and optimization of the range-Doppler map upsampling algorithm. CGAN may be used as a framework through its strong signal-to-signal translation capabilities and training speed. Different network architectures, e.g. CNNs, U-Nets, Transformers etc., and various loss functions, input pre/post-processings etc. shall be investigated.

Prerequisites:

- Interest in the topic and ability to work indepedently
- Programming experience, ideally Python (keras, tensorflow, pytorch, jax, numpy ... or similar)
- Deep Learning lecture and ideally also DL lab participation
- Ideally radar knowledge, e.g. automotive radar systems for autonomous driving lecture