# EXPLOITING ARTIFICIAL INTELLIGENCE FOR PERFORMANCE-OPTIMIZED RAW DATA QUANTIZATION IN INSAR SYSTEMS

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Synthetic aperture radar (SAR) represents nowadays a well-recognized technique for a broad variety of remote sensing applications, being able to acquire high-resolution images of the Earth's surface, independently of daylight and weather conditions. Next-generation SAR systems will bring significant improvements in performance through the exploitation of digital beam forming (DBF) techniques in combination with multiple acquisition channels, bi- and multi-static sensor configurations, together with the use of large bandwidths. This will allow, among others, to overcome the limitations imposed by conventional SAR imaging for the acquisition of wide swaths and, at the same time, of finer resolutions. These paradigms are currently being widely applied in innovative studies, technology developments and mission concepts by several space institutions and industries. The significant improvements that can be achieved in terms of acquisition capabilities are associated with the generation of huge volumes of data, which, in turn, set harder requirements for the onboard memory and downlink capacity of the system. Indeed, present global SAR mapping missions, such as Sentinel-1 or TanDEM-X, or future missions, such as NISAR and especially ROSE-L and Sentinel-1 Next Generation, will acquire data over selected areas with a temporal sampling down to one week, resulting in large data volumes which need to be handled by the SAR sensor.

In this scenario, the efficient digitization of the SAR raw data represents an aspect of crucial importance as, on the one hand, it directly defines the amount of on-board data volume but also, on the other hand, it affects the quality of the generated SAR products. These two aspects must be traded off due to the limited acquisition and downlink capacity and onboard resources of the system. One of the most widely used compression schemes for SAR raw data digitization is the Block-Adaptive Quantization (BAQ) [1]. In the last years, building on the principle of BAQ, novel algorithms have been proposed, allowing for a finer performance and resource optimization. These methods are based on acquisition-dependent compression schemes, as in the case of the FDBAQ [2], or combined with the implementation of non-integer data rates [3]. In the context of the Performance-Optimized BAQ (PO-BAQ), the basic concept of the original BAQ is further extended in [4], which represents a first attempt for an optimization of the resource allocation depending on the performance requirement defined for SAR and InSAR product. Such an optimization can be achieved by exploiting the a-priori knowledge of the SAR backscatter statistics of the acquired scene, an information which must therefore be made available to the sensor, in form of look-up-tables (LUTs) or backscatter maps, hence leading to an increased required computational effort and resources. Overall, the above-mentioned SAR compression approaches are not fully adaptive with respect to the acquired raw data, since the quantization settings are derived from prior considerations and do not account for the actual radar backscatter statistics at the time of the SAR survey. Indeed, the quantization performance depends on the local characteristics of the illuminated scene on ground, which are, in turn, linked to the local topography, targets characteristics and illumination geometry, resulting in different backscatter absolute levels and degrees of heterogeneity.

In order to overcome these limitations, Artificial Intelligence (AI) represents a promising approach in the remote sensing community, since it enables scalable exploration of big data and bringing new insights on information retrieval solutions [5]. In this work, we investigate the use of AI, and in particular of deep learning (DL), for on-board SAR raw data compression, with the aim of deriving an optimized and adaptive data rate allocation, depending on a pre-defined performance requirement. The latter can be defined on typical SAR and InSAR quality metrics which are affected by raw data quantization, such as the Signal-to-Quantization Noise Ratio (SQNR), the interferometric coherence loss or the SAR/InSAR phase error.

We propose to approach the described problem as a deep supervised semantic segmentation task, where the number of bits to be allocated for quantization is derived on board and is identified as the target output class. To generate the reference bitrate maps required during the training of the proposed DL architecture, we exploit experimental TanDEM-X data acquired in BAQ-bypass conditions (i.e. the data are quantized with an 8-bit ADC), which are then re-compressed on ground using different BAQ rates (i.e., 2, 3, 4, 5 and 6 bits/sample). In this way, we assess the impact of SAR quantization on the desired performance parameter, and starting from this a reference bit rate map (BRM) is derived by considering the minimum local bitrate which satisfies the given requirement. A large variety of different landcover classes as well as acquisition geometries need to be considered for the generation of the complete training data set, in order to be representative and so to properly generalize the proposed DL model.

After the generation of the two-dimensional bit rate map during the DL architecture inference stage, a state-of-the-art quantizer, such as the BAQ, is locally applied to the input raw data samples, leading to the generation of a quantized raw data matrix with local variable bitrate.

A clear advantage of this approach relies in the fact that the quantization bitrate maps are dynamically generated from the raw data matrix that is given as input feature map to the DL architecture. This means, e.g., that when considering the same area of acquisition, different bitrate maps can be generated depending on the local characteristics of the backscatter at the time of the SAR survey.

Aim of this research work will be to provide a complete analysis including the detailed description of the uncompressed SAR raw data, the adopted DL architecture(s) used for efficient data compression, as well as the overall performance assessment with respect a state-of-the-art quantizer.

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