Semantic Information Discovery and Complex-Valued Deep Architectures for SAR Data Processing

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Abstract. *In the first year of my PhD project, as the fifteenth Early Stage Researcher (ESR) of the MENELAOS-NT project, I have focused on two objectives of my thesis. In the first objective, I have exploited semantic data mining techniques for latent information discovery from various Earth Observation images. In the second goal and as the continuity of the first aspect, I have studied complex-valued deep architectures for Synthetic Aperture Radar (SAR) data processing in order to utilize both the amplitude and phase information in SAR images.*

Keywords. Earth observation, data mining, semantic information, synthetic aperture radar (SAR), complex-valued neural network, classification

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1 Introduction

My work in the last year was focused on two main topics (1) the semantic data mining for information discovery from Earth Observation (EO) images, and (2) complex-valued deep architectures for SAR data processing. In this regard, I have published three conference paper IGARSS 2021 [1], EUSAR 2022 [2] and IGARSS 2022 [3], and one peer-reviewed journal paper IEEE J-STARS [4].

The title of my research project is "Deep learning for SAR data in presence of adversarial samples" and the main objective is to develop deep learning solutions for spontaneous adversarial samples in SAR data classification. In order to achieve this goal, I started my research with generative models and datamining for latent semantic information discovery from EO images. Later, I started the development of complex-valued deep architectures for complex-valued SAR data processing and generating a complex-valued SAR annotated dataset. In the next step, I will focus on the elaboration of uncertainty-aware deep architectures and complex-valued generative models for SAR data classification.

2 Research Focus

My main focus on this research was on two main topics, (1) generative models and semantic data mining techniques for latent information discovery from EO images in various contexts, and (2) development of complex-valued deep architectures for SAR data processing in order to comprehensively harness the amplitude and the phase information of the complex-valued SAR images. A brief introduction on each of these topics is provided in this section.

2.1 Semantic Analysis

Regarding the semantic information discovery, the main objective and focus of my study was on the lack of semantic data mining researches for remote sensing applications in different contexts. I implemented data mining latent semantic information discovery methods, based on the Latent Dirichlet Allocation (LDA) and Bag of Visual Words (BOVW) models for various EO images and acquired satisfactory results for different application scenarios. The experimental results demonstrated the applicability of the semantic data mining techniques for information discovery in different remote sensing applications. In this respect, I presented the results of the semantic data mining in the IGARSS 2021 conference [1] and published the extended version of the research in the IGARSS 2021 special issue of the IEEE J-STARS journal [4]. Figure 1 represents an example application of the semantic data mining for EO images. In this example, three scenes of the Sentinel-1 SAR image are classified into 7 different semantic classes, using conventional classification approaches (e.g., Gabor features and Support Vector Machine (SVM) classifier). However, several misclassifications are evident in the classification results (Figure 1, left images). A semantic data mining method, based on the LAD and BOVW models is applied on the classified maps to remove the misclassified

patches and the patches with ambiguous semantic labels (Figure 1, right images). The removed patches are represented with black colour. The semantic data mining reduced the since of the dataset by about 10%, however the annotation quality is improved drastically and the number of the misclassified patches are reduced noticeably. More examples and further explanations are provided in the [1] and [4] articles.

2.2 Complex-valued Deep Architectures

Regarding the complex-valued SAR data processing, the main goal of the study is to exploit both the amplitude and phase information of SAR data in deep learning methods. Despite the remarkable developments and the state-of-the-art results of the real-valued deep networks for various SAR processing applications, these networks neglect the phase component of the complex-valued SAR data, which contains considerable valuable information, especially for constructed and urban areas classification. A few studies have proposed the conversion methods for real-valued mathematical operators into the complex domain, which are necessary for the development of complex-valued deep networks.

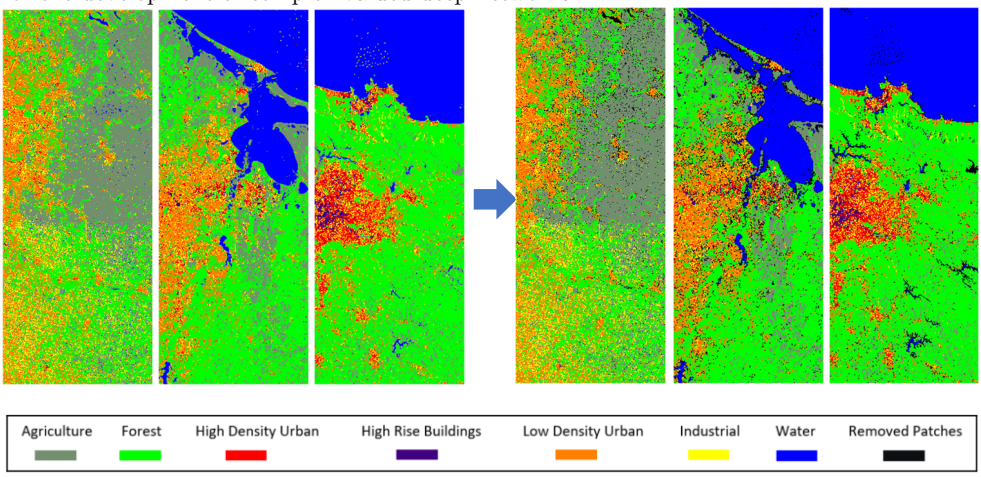

Figure 1. An example application of the semantic data mining for EO images.

As a part of my project, I developed a library of the necessary functions for complex-valued neural networks, based on the real-valued operators of the PyTorch library in the Python environment. I defined a Complex-Valued Convolutional AutoEncoder (CV-CAE), using the developed library, and obtained satisfactory reconstruction of the complex-valued SAR images from the azimuth subaperture decompositions for Sentinel-1 StripMap Single Look Complex (SM SLC) data. The evaluation measures illustrated that the developed CV-CAE preserves the coherency and the phase information of the complex-valued SAR images. Moreover, to examine the coherency preservation of the CV-CAE, the subaperture images from the reconstructed SAR images are calculated and compared with the subaperture images from the original SAR data. The very high correlation between the subaperture images demonstrated the coherency preservation of the CV-CAE. In this regard, I have published

two conference papers (EUSAR 2022 [2] and IGARSS 2022 [3]). My ongoing work in this field is aimed at the utilization of the complex-valued latent representation of the SAR images in the CV-CAE in order to develop a complex-valued classification of SAR data for urban areas. A complex-valued Convolutional Neural Network (CV-CNN) will be developed to classify the SAR patches, utilizing the latent representation of the CV-CAE network.

3 Conclusion

In conclusion, I have studied semantic data mining methods, including BOVW and LDA models, for latent information discovery for remote sensing applications in different contexts and demonstrated the necessity of semantic data mining for state-of-the-art EO systems. Moreover, I studied the complex-valued deep architectures for SAR data processing. Complex-valued networks will enable us to take advantage of the amplitude and phase components of the SAR data and extract more useful information from a limited number of annotated SAR images for urban areas classification.

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