Proposal for a Bachelor / Master Thesis

Type of thesis / Line of study:	Masters Thesis / Computer Science
Title of the thesis:	Learning-Based Hyperspectral Image Compression Using A Spatio-Spectral Approach
Candidate:	Sprengel, Niklas
Matriculation number:	380009
Advisors(s):	Fuchs, Martin
Supervisors(s):	Prof. Demir, Begüm
Planned period:	03/23 - 09/23

1. Introduction / Scientific Background / Related Work

Learning-based image compression in the RGB-domain is a well-known researched topic. Most approaches use Hyperprior models to accomplish this [1][2]. These Hyperprior models generally consist of an encoder network that extracts latent features of the input images, an entropy coder that compresses and decompresses the latent space losslessly (excluding quantization losses) and a decoder network to reconstruct the original image with as little distortion as possible. However, the compression of hyperspectral images is much more complex due to the high number of spectral bands. Therefore the models used for RGB compression are not directly applicable to hyperspectral image compression. The current state of the art model uses an autoencoder consisting of a one-dimensional convolutional neural network (CNN) applied pixel-wise to the spectral dimension [3]. There are also models using 2D-convolutions [4] applied to the spatial dimension while ignoring the spectral dimension and another paper using a Hyperprior model [5], however these approaches are used on images with low channel numbers ranging from 3 to 100. The approaches are therefore also not directly applicable to the dataset that will be used in the thesis, which is the large-scale HySpecNet11k dataset that has 202 channels per image patch.

2. Problem Statement / Goals of the Thesis

The main problem that this thesis aims to solve is that the commonly used compression techniques for images with low spectral resolution cannot be applied to hyperspectral images with a high number of bands.This is because scaling up a model designed for low spectral resolution to a higher resolution also results in a model with more parameters, which are then often not trainable on the currently available hardware. One example of this is that many of these approaches transform the image with the dimensions (C, H, W) into the dimension (F, H/2, W/2) in the first layer where F is the number of filters in the convolutional layers and C, W and H are channels, height and width respectively. A RGB compression scheme might use F=192 which is a large increase in total information compared to the input image. An appropriate increase of F to match images with 202 channels is not possible because the number of parameters grows immensely. The goal of the thesis is to combine a one-dimensional autoencoder network to reduce the number of channels in the image by performing spectral compression. The latent representation in the bottleneck of this network can then be interpreted as an image with a smaller amount of channels and compressed using a model working on the spatial dimensions of the latent representation. Since the field of hyperspectral image compression is currently in the early stages of research, multiple architectures will be compared for the inner encoder model. The latent space of the outer one-dimensional encoder will also be analyzed as it is the input for the inner encoder. Preliminary research shows that spatial dependencies do remain in the latent representation.

3. Thesis Approach / Plan of Implementation

A one-dimensional spectral network for the outer encoder-decoder pair will be optimized. Furthermore a two-dimensional spatial compression network for the inner autoencoder will be developed. The outer and inner autoencoder will then be combined to form an end-to-end spatio-spectral compression model. The main focus will lie on improving the compression performance by using different architectures for the inner and the outer autoencoder as well as implementing techniques to improve the simultaneous training of the two encoder-decoder pairs. This is not trivial since both the performance of the inner autoencoder depends on the outer encoder and decoder and the performance of the outer decoder depends on the outputs from the inner model.

4. Time frame

03/23 - 09/23

5. Bibliography

[1] Ballé, J., Minnen, D., Singh, S., Hwang, S. J., & Johnston, N. (2018). Variational image compression with a scale hyperprior (arXiv:1802.01436). arXiv. https://doi.org/10.48550/arXiv.1802.01436
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[3] Kuester, J., Gross, W., Middelmann, W. F. I., Image Exploitation, G., Fraunhofer IOSB, E., & Image Exploitation, G. (2021). 1d-Convolutional Autoencoder Based Hyperspectral Data Compression. 15–21. https://doi.org/10.5194/isprs-archives-XLIII-B1-2021-15-2021
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