A
Summer Internship Report
On
"Radiometric Correction using AI techniques"

(IT346 – Summer Internship - I)

Prepared by
Harshvardhan Goplani (21IT041)

Under the Supervision of
Assistant Professor
Dhaval Patel

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SMT. KUNDANBEN DINSHA PATEL DEPARTMENT OF INFORMATION TECHNOLOGY
Chandubhai S. Patel Institute of Technology (CSPIT)
Faculty of Technology & Engineering (FTE), CHARUSAT
At: Changa, Dist: Anand, Pin: 388421.
July,2024

DECLARATION BY THE CANDIDATE

We hereby declare that the project report entitled "**Software Developer in Java/Springboot**" submitted to Chandubhai S. Patel Institute of Technology, Changa in partial fulfillment for the requirement for the award of the degree of **B.Tech** in Smt. Kundanben Dinsha Patel Department of Information Technology, CSPIT/FTE, is a record of bonafide IT346 - Summer Internship - I carried out by us under the guidance of **Prof. Dhaval Patel**. We further declare that the work carried out and documented in this project report has not been submitted anywhere else either in part or in full and it is the original work, for the award of any other degree or diploma in this institute or any other institute or university.

Harshvardhan Goplani (21IT041)

Prof. Dhaval Patel
Smt. Kundanben Dinsha Patel Department of Information
Technology, CSPIT, CHARUSAT-Changa.

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CERTIFICATE

This is to certify that the report entitled “**Radiometric Correction using AI Techniques**” is a bonafied work carried out by **Harshvardhan Goplani (21IT041)** under the guidance and supervision of **Assistant Professor Dhaval Patel** & **Sri. Sumit Saxena** for the subject **Summer Internship – I (IT346)** of 7th Semester of Bachelor of Technology in **Department of Information** at Chandubhai S. Patel Institute of Technology (CSPIT), Faculty of Technology & Engineering (FTE) – CHARUSAT, Gujarat.

To the best of my knowledge and belief, this work embodies the work of candidate himself, has duly been completed, and fulfills the requirement of the ordinance relating to the B.Tech. Degree of the University and is up to the standard in respect of content, presentation, and language for being referred by the examiner(s).

Under the supervision of,

Dhaval Patel
Assistant Professor
Smt. Kundanben Dinsha Patel Department of Information Technology
CSPIT, FTE, CHARUSAT, Changa, Gujarat

Dr. Parth Shah
Head of Department(IT)
CHARUSAT, Changa, Gujarat

Sumit Saxena
Scientist, SD
SAC, ISRO, Ahmedabad

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Thanks,
Harshvardhan Goplani (21IT041)
Chandubhai.S.Patel Institute of Technology

ABSTRACT

I carried out my internship at SAC, ISRO, Ahmedabad. SAC, ISRO is a major centre of Indian Space Research Organization (ISRO), which carries out design of space-borne instruments for ISRO space missions. This internship is an opportunity to know and develop deep learning model for radiometric correction of satellite image sent by various images. The purpose of this internship is to develop a deep learning model which applies radiometric correction to the satellite images to remove noise in form of lines.

During my internship period I have worked on Dual Deformable Transformer (DDT) model to apply radiometric correction to the images given by satellite. I was assigned to first start with reading the required research papers on radiometric correction and to understand the working and architecture of DDT model. This helped in understanding the model thoroughly, so that I could develop the model and optimize it to generate better results. The parameters used to judge the precision of the model were PSNR (peak signal to noise ratio) and SSIM (structural similarity index measure).

In conclusion, this was an opportunity to develop and enhance skills and competencies in my career field which I achieved.

DESCRIPTION OF COMPANY

The Space Applications Centre (SAC) of the Indian Space Research Organization (ISRO) is in Ahmedabad, Gujarat, India. SAC is a premier research and development center dedicated to the design and development of payloads for communication, remote sensing, and meteorological satellites. It plays a crucial role in harnessing space technology for societal benefits, including satellite-based communication, weather forecasting, and disaster management. SAC focuses on the development of advanced payloads and technology for satellite communication, remote sensing, meteorology, and space science missions. The center designs and develops payloads for satellite communication, which are used for television broadcasting, telephony, and internet services across India.

SAC develops remote sensing instruments and applications for earth observation, which are used for agriculture, forestry, water resources, urban planning, and environmental monitoring. The center also works on meteorological instruments that help in weather forecasting and climate studies, contributing to disaster management and mitigation efforts. SAC contributes to various space science missions by developing scientific instruments and payloads that help in understanding space and planetary phenomena.

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CHAPTER 1 INTRODUCTION

1.1 INTERNSHIP OBJECTIVES

- Internships are utilized in several different career fields, including architecture, engineering, healthcare, economics, advertising and many more.
- Internships are generally thought of to be reserved for college students looking to gain experience in a particular field. However, a wide array of people can benefit from Training Internships in order to receive real world experience and develop their skills.
- An objective for this internship is to gain knowledge through real life experience in various areas of user experience while keeping theeducational background in view.
- To understand the overall use of backend development frameworks such as Springboot and how to use it in developing a full-fledged application.
- To work and deliver creatives as per the briefs and deadlines.
- Utilizing internships is a great way to build your resume and develop skills that can be emphasized in your resume for future jobs. When you are applying for a Training Internship, make sure to highlight any special skills or talents that can make you stand apart from the rest of the applicants so that you have an improved chance of landing the position.

1.2 What is Radiometric Correction

1.2.1 What is Radiometric Correction?

Radiometric correction is a crucial preprocessing step in remote sensing and satellite imagery analysis. It involves the adjustment of pixel values in an image to correct for sensor, atmospheric, and illumination effects, ensuring that the recorded digital numbers accurately represent the true reflectance or radiance of the Earth's surface features.

1.2.2 Need for Radiometric correction?

Radiometric correction is essential in remote sensing and satellite imagery analysis for several reasons. It ensures the accuracy, consistency, and comparability of the data, which are crucial for reliable analysis and interpretation. Raw satellite data often contain distortions due to sensor noise, atmospheric effects, and varying illumination conditions. Radiometric correction adjusts the pixel values to accurately represent the true reflectance or radiance of the Earth's surface features.

1.3 Responsibilities as Research Intern

- Thinking creatively to develop model and to optimize it efficiently
- Testing the model for different satellite images
- Creating satellite images from given binary files
- Creating testing and evaluation code to check the accuracy of the model

CHAPTER 2: PROJECTS

2.1 Introduction to Radiometric Correction

2.1.1 Radiometric Correction

Radiometric correction is a crucial preprocessing step in remote sensing and satellite imagery analysis. It involves the adjustment of pixel values in an image to correct for sensor, atmospheric, and illumination effects, ensuring that the recorded digital numbers accurately represent the true reflectance or radiance of the Earth's surface features.

2.1.2 Need for Radiometric Correction

Radiometric correction is essential in remote sensing and satellite imagery analysis for several reasons. It ensures the accuracy, consistency, and comparability of the data, which are crucial for reliable analysis and interpretation. Raw satellite data often contain distortions due to sensor noise, atmospheric effects, and varying illumination conditions. Radiometric correction adjusts the pixel values to accurately represent the true reflectance or radiance of the Earth's surface features.

2.1.3 Types of Radiometric Correction

There are four main types of radiometric correction: radiometric calibration, atmospheric correction, topographic correction, and sensor normalization. Radiometric calibration converts the digital numbers (DN) of the image pixels to physical units, such as radiance or reflectance. Atmospheric correction removes or reduces the effects of atmospheric scattering, absorption, and haze on the image. Topographic correction adjusts the image for the variations in illumination and reflectance caused by the terrain relief. Sensor normalization harmonizes the images from different sensors or dates by eliminating the differences in radiometric characteristics.

2.1.4 Applying Radiometric Correction

The methods and tools for applying radiometric correction vary depending on the type of correction, the sensor, and the image characteristics. For instance, radiometric calibration can be done using calibration coefficients or equations, and many software packages like ENVI or ERDAS IMAGINE have built-in functions for this purpose. Atmospheric correction models and algorithms, such as the Dark Object Subtraction (DOS), Fast Line-of-sight Atmospheric Analysis of Spectral Hypercubes (FLAASH), or Second Simulation of a Satellite Signal in the Solar Spectrum (6S) are also available. Similarly, software like ENVI or ATCOR offer topographic correction models and algorithms like Cosine Correction, Minnaert Correction, or C Correction. Lastly, sensor normalization techniques like histogram matching, regression-based adjustment, or empirical line method can be employed with software such as ENVI or ERDAS IMAGINE offering built-in functions for this purpose.

2.2 Learning Dual-branch Deformable Transformer

Dual-branch Deformable Transformer (DDT) network for image denoising. DDT applies parallelly local and global branches with the deformable attention strategy. Specifically, we first divide the input feature into patches using different rules in both branches, then perform deformable attention inside patches in the local branch and among the same relative locations of each patch in the global branch. In the deformable attention, we reduce the number of key-value pairs, preserving more informative ones adaptively and saving calculational costs furtherly. In this way, global receptive fields and local aggregations are both involved in our Transformer model with linear complexity by the dual-branch structure, and the deformable attention mechanism also reduces redundant calculations.

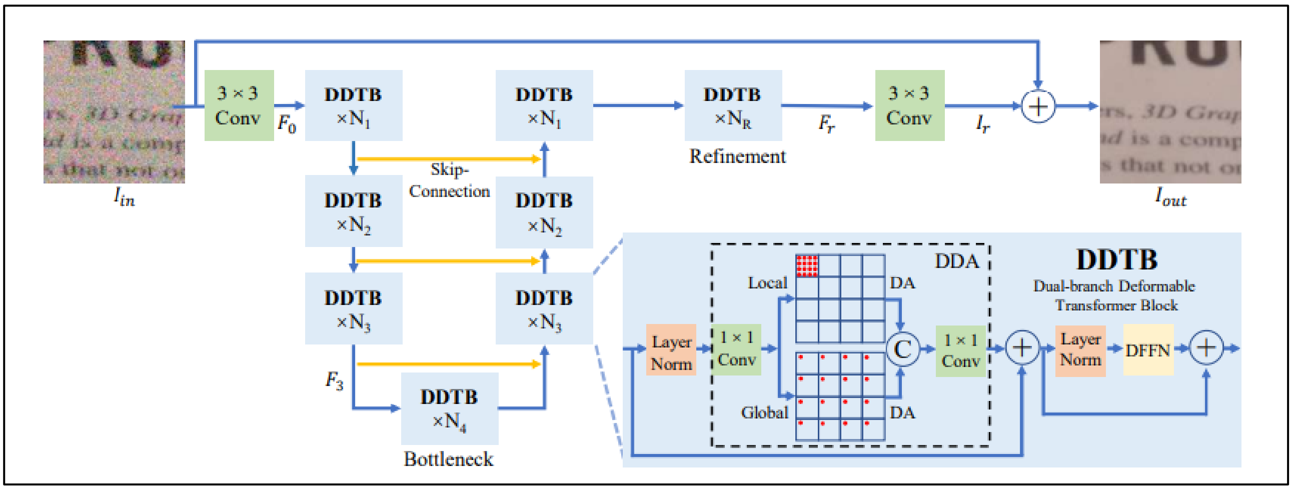

Fig 1.1 DDT Architecture

2.3 Understanding DDT Architecture

Given a noisy image Iin ∈ R H×W×3 , the input is first projected into the feature F0 ∈ R H×W×C by a 3×3 convolution layer. Then the feature F0 goes through a 4-stage Unet-like encoder-decoder architecture. Each stage includes multiple DDTBs and a sample layer (i.e. down sample or up sample). The output feature F3 ∈ R H 8 × W 8 ×8C goes through the Bottleneck and is fed into the decoder. The decoder has a symmetrical structure, where an up sample layer is used at the beginning of each stage. The skip-connection is used to boost performance, and we use the concatenation operation and a 1×1 convolution layer for feature fusion.

2.4 Overall Pipeline approach

Given a noisy image Iin ∈ R H×W×3 , the input is first projected into the feature F0 ∈ R H×W×C by a 3×3 convolution layer. Then the feature F0 goes through a 4-stage Unet-like encoder-decoder architecture. Each stage includes multiple DDTBs and a sample layer (i.e. down sample or up sample). The output feature F3 ∈ R H 8 × W 8 ×8C goes through the Bottleneck and is fed into the decoder. The decoder has a symmetrical structure, where an up sample layer is used at the beginning of each stage. The skip-connection is used to boost performance, and we use the concatenation operation and a 1×1 convolution layer for feature fusion.

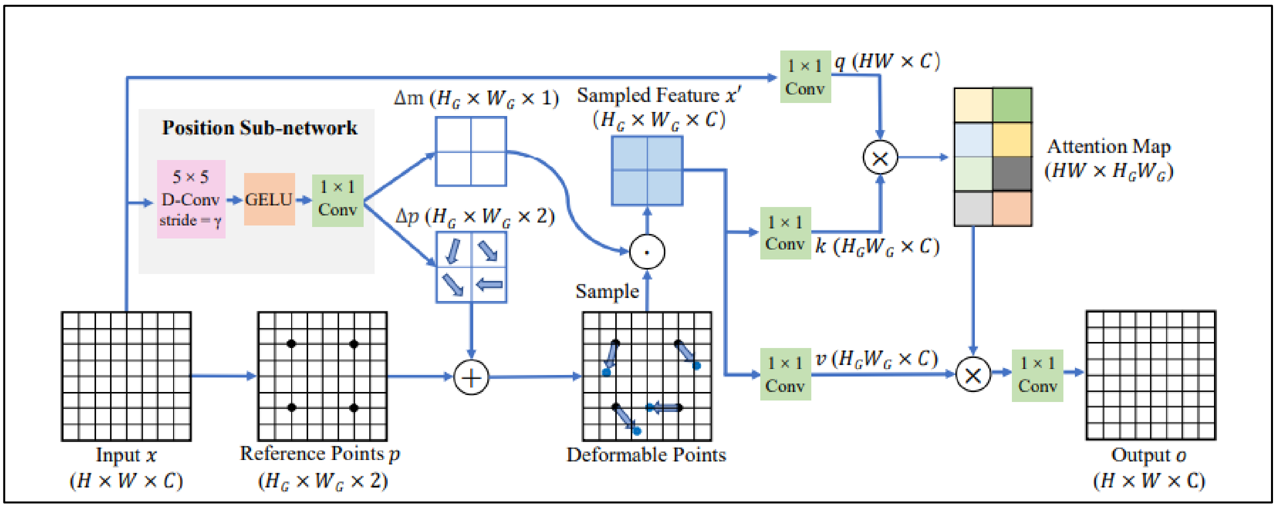

Fig 1.2 Structure of Deformable attention

2.5 Analysis of Computational Cost

Our method consists of DDTBs with different scales. The computational costs of DDTB come mainly from Dual-branch Deformable Attention (DDA), which consists of two convolutional layers and a dual-branch structure.

2.5.1 Convolutional layers

There are two 1×1 convolutional layers in DDA for channel expanding and feature fusion, respectively. We denote each of them as:

$$\Omega(\text{Conv}) = 2HWC^2$$

Method	F(G)	P(M)	SIDD [5]		DND [25]	
			PSNR	SSIM	PSNR	SSIM
Restormer [12]	155	26.1	**40.02**	**0.960**	40.03	**0.956**
MAXIM [18]	339	22.2	39.96	**0.960**	39.84	0.954
Uformer-B [10]	86	50.9	39.89	**0.960**	**40.04**	0.956
SRMNet [32]	285	37.6	39.72	0.959	39.44	0.951
MIRNet [33]	785	31.8	39.72	0.959	39.88	**0.956**
MPRNet [4]	573	15.7	39.71	0.958	39.80	0.954
CycleISP* [34]	184	2.8	39.52	0.957	39.56	**0.956**
DANet [35]	30	63.0	39.30	0.916	39.59	0.955
VDN [36]	44	7.8	39.28	0.909	39.38	0.952
IPT* [19]	380	115.3	39.10	0.954	39.62	0.952
RIDNet* [37]	98	1.5	38.71	0.914	39.26	0.953
DDT (ours)	86	18.4	39.83	**0.960**	39.78	0.954

* denotes methods using additional training data.

Fig 1.3 Results on Real world denoising data on SIDD and DND datasets

2.5.2 Dual Branch Structure

The deformable attention (DA) is applied in the local and global branches. We take the local branch as an example to illustrate the computational costs. We first divide the input into patches with size p × p × C, so we get HW/p2 patches. We feed them into DA for local feature extraction. The hyper-parameter in DA for controling the number of keys and values is γ. We take each branch's costs as:

$$\Omega(\text{Branch}) = \frac{2\gamma^2+2}{\gamma^2}HWC^2 + \frac{2p^2+29}{\gamma^2}HWC + \frac{2}{\gamma^2}HW$$

2.6 DDT Implementation

DDT adopts a 4-stage encoder-decoder architecture. Following we set the number of DDTBs from the 1st stage to Bottleneck as (4, 6, 6, 8) with the number of attention heads (1, 2, 4, 8) and 4 extra blocks for the Refinement stage. The channel number in the 1st stage is set as 32, which will increase gradually in deeper stages. We use AdamW [41] optimizer($\beta1$ = 0.9, $\beta2$ = 0.99, weight decay 1e −4) and L1 loss with 300K iterations for optimization. The learning rate is initialized as 3e −4 and reduce to 1e −6 with the cosine annealing scheduler. Progressive learning strategy from 128×128 to 256×256 is also used, and we utilize rotation and flips for data augmentations. All training processes are conducted on 4 NVIDIA TITAN Xp GPUs.

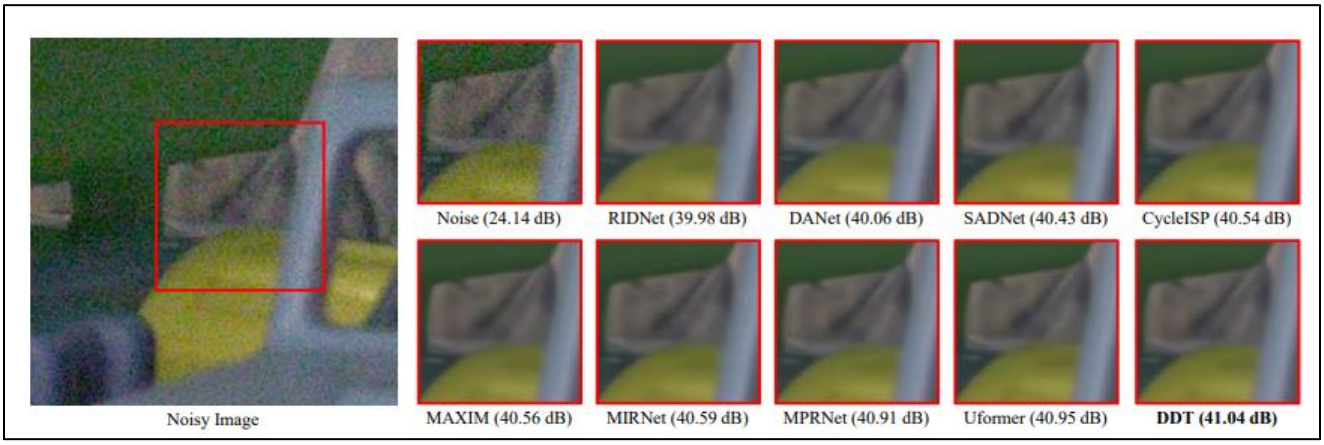

Fig 1.4 Results on different datasets

2.7 Ablation Studies

In this section, we conduct ablation studies to evaluate the performance of the dual-branch structure and deformable attention on the SIDD dataset.

2.7.1 Dual Branch

To evaluate the effectiveness of dual-branch structure, we conduct experiments with a single branch (i.e. only using local or global branch). For a fair comparison, we double the number of channels when using a single branch to keep the same parameters as the dual-branches. We observed similar results when using a single branch. However, by combining them into the parallelly dual-branch structure, the PSNR improved by 0.06dB and 0.05dB, respectively.

2.7.2 Deformable Attention

Deformable attention reduces redundant computations and focuses on more important regions. We compared with multilayer perceptron (MLP) and standard multi-head self-attention (MHSA) which have quadratic complexity to show our deformable attention's effectiveness and high efficiency. We adjust the number of layers in MLP and the number of channels in MHSA to maintain a similar number of parameters (∼18.4M). It shows the detailed results that our deformable attention achieves the best performance with only 71.1% and 54.8% computational costs of MLP and MHSA.

CHAPTER 3: CONCLUSION

In nutshell, this internship was an excellent, rewarding, and useful experience. I gained new knowledge, skills and met new people. I got to explore to what was happening in the real world, how my design and thought process can be used to make things happen and how design nuances can change the game. I got insight into professional practice. I was a fresher to the startup culture, where everyone is a hustler trying to meet the targets and brainstorming to make things happen. Working at a startup is an incredible experience that I had. Two main things that I learned were the importance of time-management and self- motivation. At last, this internship has given me new insights and motivation to pursue a career in Deep learning.

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