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A Deep Generative model for dehazing Multispectral Remote Sensing Satellite Images

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Abstract / Objective of the Project

Thus Multispectral remote sensing images are helpful, but Haze or pollution can impede them, which makes them unsightly and makes valuable information useless.This proposed work is implemented using the Modern Deep Learning techniques to dehaze the multispectral satellite images. We have used a Deep Generative model to remove haze from images. By using generative models, images can be denoised without information loss, supporting the project's objective.A public-domain satellite image dataset is used for training our model. It has the capability to learn underlying data distribution. Existing systems can be made more efficient by integrating this approach.

Objective of the Project

- To create a dataset which is near to real world data instead of using synthetically created data.
- Reconstruction of Haze images using image-to-image translation methods based on GANs utilizing the above synthesised dataset

Existing Approaches (Literature Survey)

I

- Binghui Huang, Zhi Li, Chao Yang, Fuchun Sun, and Yixu Song, Proposed a model that performed Dehazing multi-sensor Optical Satellite Imagery using a Conditional Generative Adversarial Network(**cGAN**) in [1].
- The objective was to dehaze optical satellite images which had corresponding SAR masks, using a cGan.
- This work has implemented a cGAN in which the discriminator was built using 70x70 PatchGAN and a generator using the encoder-decoder network with dilated blocks and skip connections. SAR information was passed to generator.

Existing Approaches (Literature Survey) I(cont..)

- A new synthetic dataset was proposed compromising 1200 images of data. Due to lack of real-time data. The synthetic dataset was made using Photoshop software and different levels of haze namely thin, medium, and thick have been added.
- The results are evaluated by Peak-signal to noise ratio (**PSNR**) and Structural Similarity index measure(**SSIM**). Also, **MASK-RCNN** was used for comparing the segmentation accuracy with the ground truths. Finally, the comparison was made between existing baseline models.

Existing Approaches (Literature Survey) II

- Xin He, Wanfeng Ji and Jinpeng Xie et al proposed a work that illustrated Contrastive Learning based cycleGAN to dehaze optical satellite images using unpaired datasets input and target data.[2]
- In this study, asymmetric contrastive cycle GAN (ACC-GAN) was used to dehaze optical satellite images along with a transfer network to form an asymmetric structure.
- The proposed model improvised cycleGAN methodology by making use of Contrastive learning. The contrastive constraint was introduced in the latent space which ensures quality of reconstructed image.

Existing Approaches (Literature Survey) II(Cont..)

- The proposed model was trained and tested on both study-related datasets(SateHaze1k, RESIZE) and as well as on out-of-subject datasets for general verification. Quantitative metrics like Peak Signal to Noise Ratio (PSNR) and Structural SIMilarity index (SSIM) were used.

- The authors planned to explore the contribution of contrastive learning for other vision tasks like denoising and deblurring

Existing Approaches (Literature Survey) III

- Anna Hu, Z. Xie, Y Xu, and, L Wu framed an unsupervised haze removal method for Optical Remote Sensing Images by improvising existing GAN architecture [3].
- The objective of this paper was to remove haze from Optical Satellite Imagery using an unsupervised methodology. The state of art cycleGan was improvised and used to achieve the motive.
- The proposed method used two generative models made based on CNN using DenseNet Block and two discriminative models made based on CNN. An additional Edge-Shaping loss function was introduced.

Existing Approaches (Literature Survey) III(Cont..)

- In this work, a dataset was created and the data was processed by adding synthetic noise to the clear images. The results were compared with the existing baseline models after achieving the objective.

- The authors had planned to decrease the time complexity of the approach by recognizing the training process.

Existing Approaches (Literature Survey)
IV

- Xiang Chen and Yufeng Huang proposed Dehazing Single Remote Sensing(RS) imagery using Memory-Oriented(MO) GAN.[4]

- The objective of this work was to use MO unpaired Learning to dehaze Optical Remote Sensing Imagery using GAN.

- The proposed model has a generator that is made up of a memory module(LSTM) and a U-Net autoencoder and a discriminator that is based on CNN.

Existing Approaches (Literature Survey) IV(Cont..)

- The dataset was assembled into a group of haze and clear images from the Landsat 8 OLI. The experimental results outperformed on dataset compared to the other baseline models.
- The work concluded that the proposed model worked better on real-world non-uniform haze conditions compared to other existing models.

Existing Approaches (Literature Survey)

V

- Xiao Sun and Jindong Xu suggested a method to dehaze Remote Sensing(RS) using Cascade GANs.[5]

- The objective of this paper was to create synthetic data similar to real-world data by using a GAN, learning to dehaze the former using another GAN, and finally cascading both.

Existing Approaches (Literature Survey) V(Cont..)

- Two GANs are cascaded together, the first GAN is built upon convolutional layers and was used for learning to haze, and the second one has a self-attention module built on top for learning to dehaze.
- Benchmark datasets RICE-I and RICE-II were used to perform the learning process. Compared to the other baseline models, experimental results were better.
- The study concluded cascading network has performed well due to the well synthesized dataset and unsupervised learning.

Existing Approaches (Literature Survey)
VI

- Yitong Zheng, Jia Su, Jia Su, Mingliang Tao, and Ling Wang proposed an enhanced attention guide (AG) GAN using unpaired remote sensing data for dehazing.[6]

- The objective of this work was to dehaze remote sensing images using the AG GAN network with unpaired remote sensing data.

Existing Approaches (Literature Survey) VI(Cont..)

- The state of art cycleGAN was used to achieve this task with the attention guide mechanism. An additional loss function apart from total variation loss was adopted.
- Due to the lack of availability of less-paired data, new synthetic data was created for the work which contains 7000 images.
- The study has concluded that the output image quality was improved which not only outperformed existing models but also was applicable to most real-time remote sensing tasks.

Existing Approaches (Literature Survey)
VII

- Xianhong Zhang proposed a GAN based on texture attention for dehazing Remote Sensing(RS) images.[7]
- The objective of this paper was to optimize the existing architecture by adding the attention framework to dehaze RS images.
- A texture attention generator was used built using Cellular Neural Networks(CNN). Global and local discriminators were used to improve the quality of the generated results.

Existing Approaches (Literature Survey) VII(Cont..)

- A synthetic dataset was created using Photoshop software of randomly chosen 800 RS images. In order to test the model 200 real-world haze images were used.
- The work has concluded that satisfying results were obtained on the dataset and has outperformed the existing state-of-art models.

Existing Approaches (Literature Survey)
VIII

- Faramarz N. D., Mohammad R. M., and Mohsen S. proposed a framework for cloud removal in Remote Sensing (RS) images using GAN and SAR-to-Optical translation.[8]

- The objective of this paper was to remove clouds from RS images firstly by converting the SAR image to Oprtical Image and then using a cGAN to reconstruct the corresponding cloud image.

Existing Approaches (Literature Survey) VIII(Cont..)

- The work used two GANS, one for SAR-To-Optical and the other for cloud removal. Both the GANs follow encoder-decoder architecture with Dialated, Residual, and Inception modules.

- The data was collected from the SEN1-2 dataset and a synthetic paired dataset is made by extracting clouds from the clouds-38 dataset and adding it to clear images using alpha bending.
- The model has outperformed existing architectures and produced quality reconstructed images.

Existing Approaches (Literature Survey)

IX

- Liquan Zhao, Yupeng Zhang, and Ying Cui have proposed a model for Remote Sensing (RS) image dehazing.[9]

- The work's objective was to design a GAN based on Attention Encoder-Decoder (AED) for RS image dehazing.

- A GAN was developed in which the generator was based on AED with skip connections and a distillation module. The discriminator was built based on the Markovian discriminator network

Existing Approaches (Literature Survey) IX(Cont..)

- The proposed model was tested on an open-source RICE dataset.
- The authors have concluded that despite the image restoration process was successful, the model suffered from consuming more training time due to its complex architecture.

Existing Approaches (Literature Survey)

X

- Pengyu Wang, Hongqing Zhu, Han Zhang, and Nan Wang have proposed a Single Image Dehazing a methodology using twofold GAN.[10]

- The objective of this paper was to generate real-world hazy images instead of using synthetic data for training for Single image dehazing based on GAN so that the proposed work better adapts to untrained real-world data.

Existing Approaches (Literature Survey) X(Cont..)

- The proposed work has two sub-models. The Generators of both networks are based on Encoder-Decoder models while the discriminator was based on the VGG-16 model.
- Five synthetic datasets have been used to train and test the performance of the proposed networks.
- The authors have successfully implemented and addressed the issue but images that have low lighting conditions have performed poorer on this model.

Existing Approaches (Literature Survey)

XI

- Y. Dong, Y. Liu, H. Zhang, S. Chen, and Y. Qiao proposed a fusion-based discriminator GAN for single Image dehazing in [11].

- The objective of this work was to dehaze the images using GAN-based architecture by using a fusion discriminator which takes into account the frequency information of the image.

Existing Approaches (Literature Survey) XI(Cont..)

- The proposed model generator was based on the Encoder-Decoder structure and frequency information was supplied to the discriminator.

- The model was trained and tested on several real-world including their synthetic dataset.

- The work concluded that the model was successful in dehazing the given images with less color distortion.

Existing Approaches (Literature Survey)
XII

- Y.Wang et al proposed an image dehazing methodology using modified cycle GAN via Spectral Normalized (SN) Soft Likelihood Estimation.[12]
- The objective of this work was to propose an unsupervised methodology for dehazing images to produce optimal results.
- The generator was based on Encoder-Decoder with residual blocks and a discriminator based on SN convolutional network.

Existing Approaches (Literature Survey) XII(Cont..)

- The model was trained on the real-world unpaired dataset and was tested on video-based data.

- The work concluded that the proposed model was able to dehaze the images to a more realistic output.

Existing Approaches (Literature Survey)
XIII

- D. Engin, A. Genc and H. K. Ekenel, proposed an improvised version of cycle GAN for single Image dehazing.[13]
- The objective of this work was to update the existing cycle GAN architecture to dehaze images without actually estimating the atmospheric scattering model parameters.
- Cycle GAN architecture was used and a new loss function was added named perpetual loss function alongside existing cycle consistency loss.

Existing Approaches (Literature Survey) XIII(Cont..)

- The model was trained and tested on the real-world haze image dataset and the results were analyzed the same.
- The work concluded that the model has generated high visual quality images due to the addition of perpetual loss.

Existing Approaches (Literature Survey)

- Y. Qu, Y. Chen, J. Huang, and Y. Xie proposed an enhanced pix2pix model for dehazing images.[14]

- The objective of this work was to solve the dehazing problem like an image-to-image Translation problem

- The generator was based on the pix2pixHD model with enhancing blocks and a multiscale discriminator was used.

Existing Approaches (Literature Survey) XIV(Cont..)

- The proposed model was tested on RESIDE dataset and using was tested using different variants of the above proposed model.

- Experimental results were satisfactory on both synthetic and real real-world datasets and images generated had kept the color and structure.

Existing Approaches (Literature Survey)

- B.S.N.V. Chaitanya and Snehasis Mukherjee proposed Single Image(SI) Dehazing by improvising existing cycleGAN architecture[15].
- The objective of this work was to dehaze images without estimating the atmospheric scattering model parameters using unpaired training data.
- The generator network was an encoder-decoder based architecture with AOD-net and the discriminator was based on Convolutional network. A weighted SSIM loss function was added to the existing cycle GAN's loss function.

Existing Approaches (Literature Survey) XV(Cont..)

- The datasets used for training and testing were both synthetic and real-world datasets in an unpaired fashion.
- The work concluded that the proposed model which included a haze-specific transformer was beneficial in the process of dehazing the images.

Existing Approaches (literature survey)

S.No	Title	Model	Dataset	Drawbacks
[1]	Single Satellite optical Imagery Dehazing using SAR image Prior Based on Conditional Generative Networks.	Model : cGan Generator(G) : Encoder-Decoder network Discriminator(D): 70x70 patchGAN	Custom dataset is built using photoshop software on sentinel-1&2 images.	Model is trained on synthetic data of relatively less size.
[2]	Unsupervised Haze Removal for Aerial Imagery Based on Asymmetric Contrastive CycleGAN	Model : cycleGan G: Encoder-Decoder D: Convolutional Neural Net	SateHaze1k, RESIDE datasets, OverWater dataset, Real-Haze Dataset.	
[3]	Unsupervised Haze Removal for High-Resolution Optical Remote-Sensing Images based on Improved GAN	Model : (ES-CCGAN) Edge-sharpening cycle consistency GAN G : based on CNN. D : based on CNN.	Custom dataset is created by adding perlin, interpolated, smoothed noise.	Model is complex and takes a lot of computation time.

Existing Approaches (literature survey)

S.No	Title	Model	Dataset	Drawbacks
[4]	Memory-Oriented Unpaired Learning for Single Remote Sensing Image Dehazing	Model: G : MultiStage attention-recurrent+U-NET D : CNN based	Custom dataset of haze and clear images from the Landsat 8 data.	
[5]	Remote Sensing Images Dehazing Algorithm based on Cascade Generative Adversarial Networks	Model : 2 GANs G : CNN based D: CNN bases	RICE-I and RICE-II datasets.	
[6]	Unpaired Remote Sensing Image Dehazing Using Enhanced Attention-Guide GAN	Model : cycleGAN G : Attention based network D : same as G	Custom data set of 7000 ship images synthesized using python	

Existing Approaches (literature survey)

S.No	Title	Model	Dataset	Drawbacks
[7]	Research on Remote Sensing Image De-haze Based on GAN	Model:Texture attention GAN G : Cellular NN D : Convolutional NN	Synthetic dataset of 700 images using photoshop	
[8]	Cloud Removal in Remote Sensing Images Using GAN and SAR-to-Optical Image Translation	Model: G: Encoder-decoder D : Encoder-Decoder		
[9]	An Attention Encoder-Decoder Network Based on GAN for Remote Sensing Image Dehazing			

Existing Approaches (literature survey)

S.No	Title	Model	Dataset	Drawbacks
[10]	An Attention Encoder-Decoder Network Based on Generative Adversarial Network for Remote Sensing Image Dehazing			
[11]	FD-GAN: Generative Adversarial Networks with Fusion-discriminator for Single Image Dehazing			

Existing Approaches (literature survey)

S.No	Title	Model	Dataset	Drawbacks
[12]	Cycle-SNSPGAN: Towards Real-World Image Dehazing via Cycle Spectral Normalized Soft Likelihood Estimation Patch GAN			
[13]	Cycle-Dehaze: Enhanced CycleGAN for Single Image Dehazing			
[14]	Enhanced Pix2Pix dehazing network			

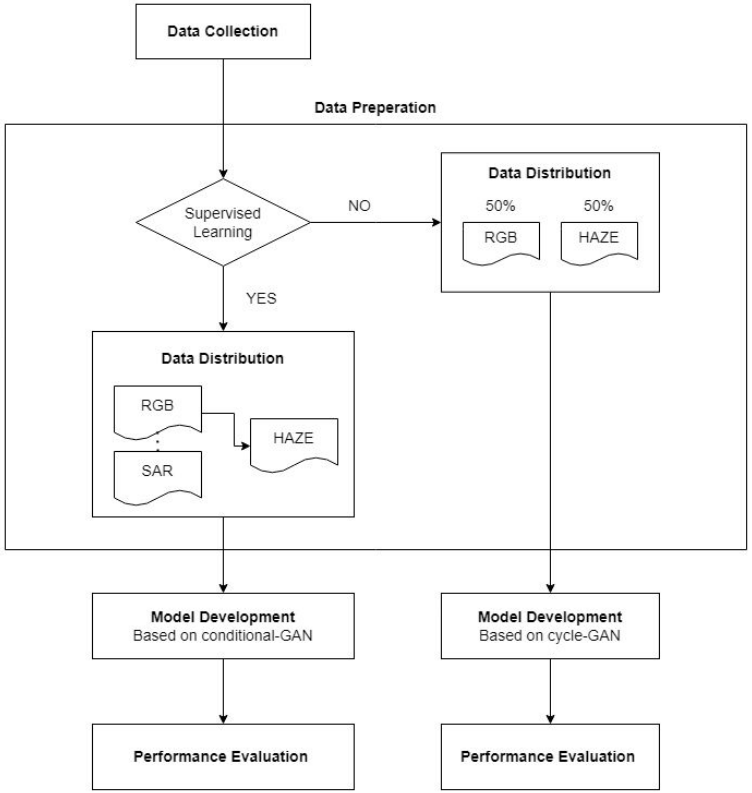
Existing Approaches (literature survey)

S.No	Title	Model	Dataset	Drawbacks
[12]	Cycle-SNSPGAN: Towards Real-World Image Dehazing via Cycle Spectral Normalized Soft Likelihood Estimation Patch GAN			
[13]	Cycle-Dehaze: Enhanced CycleGAN for Single Image Dehazing			
[14]	Enhanced Pix2Pix dehazing network			

Existing Approaches (literature survey)

S.No	Title	Model	Dataset	Drawbacks
[15]	Single image dehazing using improved cycleGAN			

Proposed Method: Architecture Diagram



Proposed Method: Modules

- **Data Collection :**
  Data from Sentinel-1&2 is taken for the study.
- **Data Preparation:**
  Depending on the mode of learning the data is prepared
- **Model Development:**
  Model is developed using either supervised or unsupervised learning methodology using GAN
- **Performance Evaluation:**
  The proposed model is tested against the statistical measures as well as qualitative comparison with other existing approaches.

Conclusion

- In this work we have built the custom dataset which narrows the gap between real-time data and the synthetic data using GAN unlike traditional approaches.
- A new generative model has been developed both using supervised and unsupervised learning methods for comparative study.
- The proposed method has performed better than other models which have used synthetic dataset via traditional methods.

References

1. B. Huang, Z. Li, C. Yang, F. Sun and Y. Song, "Single Satellite Optical Imagery Dehazing using SAR Image Prior Based on conditional Generative Adversarial Networks," *2020 IEEE Winter Conference on Applications of Computer Vision (WACV)*, Snowmass, CO, USA, 2020, pp. 1795-1802, doi: 10.1109/WACV45572.2020.9093471.
2. X. He, W. Ji and J. Xie, "Unsupervised Haze Removal for Aerial Imagery Based on Asymmetric Contrastive CycleGAN," in IEEE Access, vol. 10, pp. 67316-67328, 2022, doi: 10.1109/ACCESS.2022.3186004.

References

3. A. Hu, Z. Xie, Y. Xu, M. Xie, L. Wu, and Q. Qiu, “Unsupervised Haze Removal for High-Resolution Optical Remote-Sensing Images Based on Improved Generative Adversarial Networks,” *Remote Sensing*, vol. 12, no. 24, p. 4162, Dec. 2020, doi: 10.3390/rs12244162.

4. X. Chen and Y. Huang, "Memory-Oriented Unpaired Learning for Single Remote Sensing Image Dehazing," in IEEE Geoscience and Remote Sensing Letters, vol. 19, pp. 1-5, 2022, Art no. 3511705, doi: 10.1109/LGRS.2022.3167476

References

5.X. Sun and J. Xu, "Remote Sensing Images Dehazing Algorithm based on Cascade Generative Adversarial Networks," 2020 13th International Congress on Image and Signal Processing, BioMedical Engineering and Informatics (CISP-BMEI), Chengdu, China, 2020, pp. 316-321, doi: 10.1109/CISP-BMEI51763.2020.9263540.

6. Y. Zheng, J. Su, S. Zhang, M. Tao and L. Wang, "Dehaze-AGGAN: Unpaired Remote Sensing Image Dehazing Using Enhanced Attention-Guide Generative Adversarial Networks," in IEEE Transactions on Geoscience and Remote Sensing, vol. 60, pp. 1-13, 2022, Art no. 5630413, doi: 10.1109/TGRS.2022.3204890.

References

7. Zhang, X. Research on Remote Sensing Image De‑haze Based on GAN. *J Sign Process Syst* 94, 305–313 (2022), doi: 10.1007/s11265-021-01638-2

8. F. N. Darbaghshahi, M. R. Mohammadi and M. Soryani, "Cloud Removal in Remote Sensing Images Using Generative Adversarial Networks and SAR-to-Optical Image Translation," in IEEE Transactions on Geoscience and Remote Sensing, vol. 60, pp. 1-9, 2022, Art no. 4105309, doi: 10.1109/TGRS.2021.3131035.

References

9. L. Zhao, Y. Zhang and Y. Cui, "An Attention Encoder-Decoder Network Based on Generative Adversarial Network for Remote Sensing Image Dehazing," in IEEE Sensors Journal, vol. 22, no. 11, pp. 10890-10900, 1 June 1, 2022, doi: 10.1109/JSEN.2022.3172132.

10 . P. Wang, H. Zhu, H. Huang, H. Zhang and N. Wang, "TMS-GAN: A Twofold Multi-Scale Generative Adversarial Network for Single Image Dehazing," in IEEE Transactions on Circuits and Systems for Video Technology, vol. 32, no. 5, pp. 2760-2772, May 2022, doi: 10.1109/TCSVT.2021.3097713.

References

11 . Y. Dong, Y. Liu, H. Zhang, S. Chen, and Y. Qiao, “FD-GAN: Generative Adversarial Networks with Fusion-Discriminator for Single Image Dehazing”, *AAAI*, vol. 34, no. 07, pp. 10729-10736, Apr. 2020.

12 . Y. Wang et al., "Cycle-SNSPGAN: Towards Real-World Image Dehazing via Cycle Spectral Normalized Soft Likelihood Estimation Patch GAN," in IEEE Transactions on Intelligent Transportation Systems, vol. 23, no. 11, pp. 20368-20382, Nov. 2022, doi: 10.1109/TITS.2022.3170328.

References

13 . D. Engin, A. Genc and H. K. Ekenel, "Cycle-Dehaze: Enhanced CycleGAN for Single Image Dehazing," 2018 IEEE/CVF Conference on Computer Vision and Pattern Recognition Workshops (CVPRW), Salt Lake City, UT, USA, 2018, pp. 938-9388, doi: 10.1109/CVPRW.2018.00127.

14 . Y. Qu, Y. Chen, J. Huang, and Y. Xie, "Enhanced Pix2pix Dehazing Network," 2019 IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR), Long Beach, CA, USA, 2019, pp. 8152-8160, doi: 10.1109/CVPR.2019.00835.

References

15. B. S. N. V. Chaitanya and S. Mukherjee, “Single image dehazing using improved cycleGan,” *Journal of Visual Communication and Image Representation*, vol. 74, p. 103014, 2021, doi: 10.1016/j.jvcir.2020.103014.