DisMon-GAN: 24X7 All-Weather Optical Domain Surveillance using Progressively Growing Adversarial Networks with Patch Discriminator

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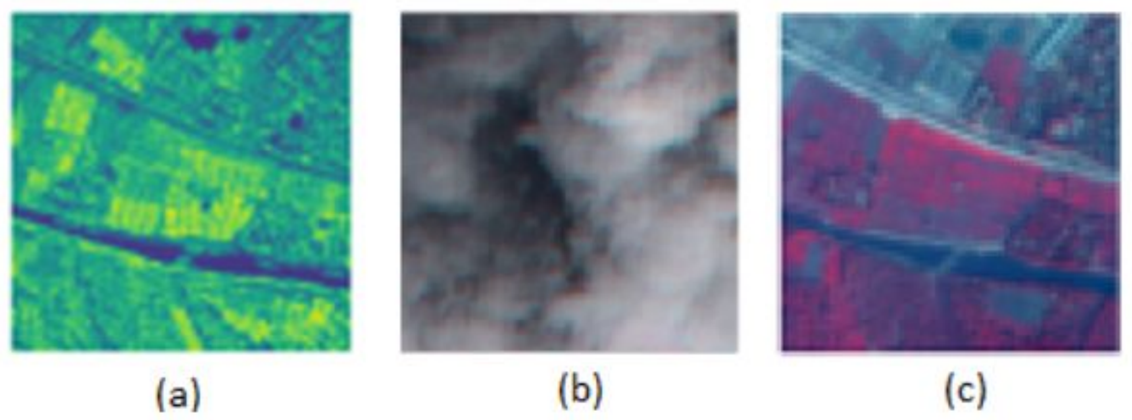

Fig. The synthesized optical image by DisMon-GAN using Risat-2, SAR sensor image as evidence. (a) The originally imaged Risat-2 data passed as input. (b) Original Cartosat-2S image with cloud over the same region that was imaged in temporal proximity. (c) The generated optical image with only the SAR image as evidence. The network generates an optical image with semantic features and radiometry.

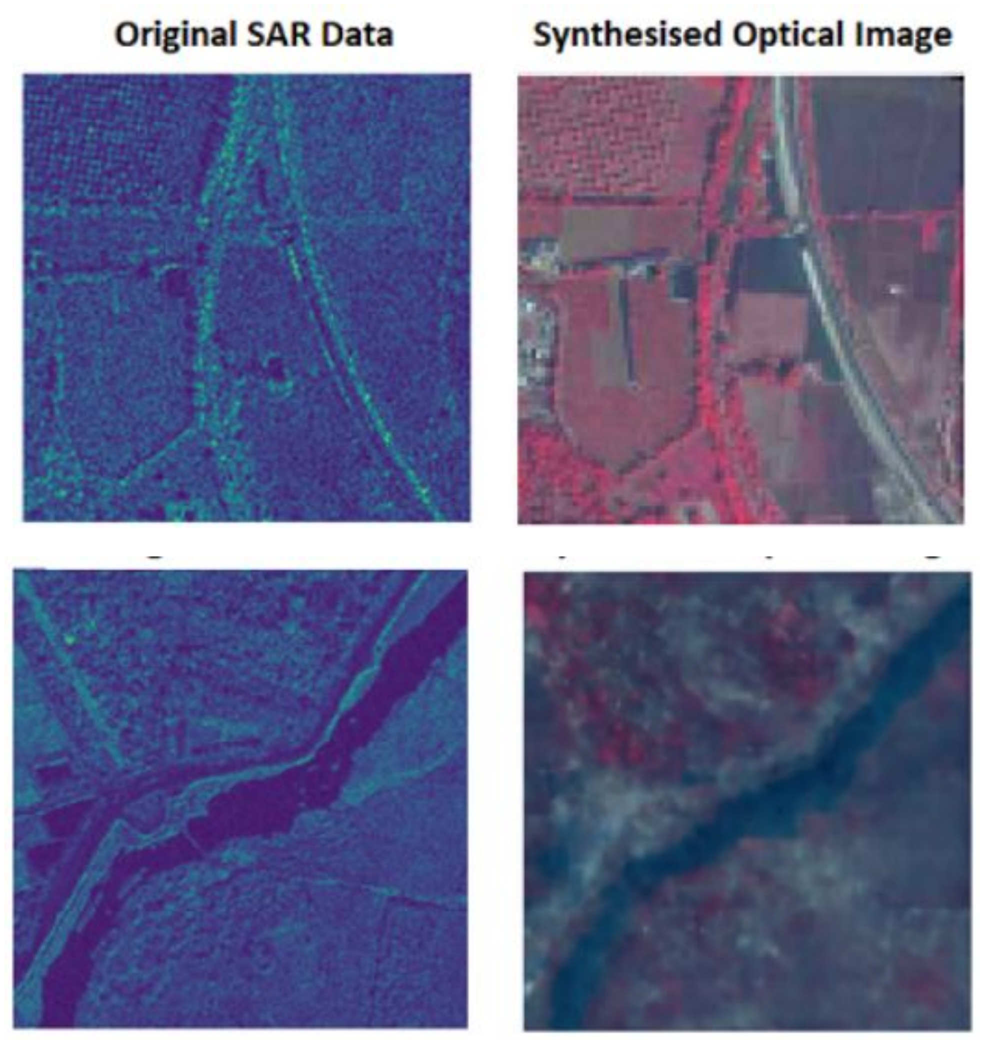

Fig. On the left, are the monochromatic images of SAR. The top sample is a successful generation of optical image using DisMon-GAN. However, the bottom sample is an example of failure. Especially at the scenes with smoother reflections and higher speckle.

Context

- Cyclones and floods are significant disasters seen by south-east Asian countries. With cloud occlusions on the affected regions, monitoring the disaster becomes tedious.
- Synthetic Aperture Radars (SAR) can penetrate through the clouds (due to their microwave frequencies) and image the area underneath.
- Being active sensors, they also can image around the clock. These properties enable the domain experts to use SAR images for disaster monitoring
- However, even professionals find it challenging to interpret the data since the human eye is unfamiliar with the impact of distance-dependent imaging, signal intensities observed in the radar spectrum, and image features associated to speckle or post-processing procedures.

Methodology

- We propose to use the spatial features extracted from the SAR images and generate optical images conditioned over these spatial features.
- A user can view the same information in SAR image, but in optical domain.
- We propose a **DisMon-GAN**, a Generative Adversarial Network (GAN) to synthesize realistic and semantic optical images by conditioning them over the microwave satellite image.
- A novel custom loss function has been designed to address the radiometry of remote sensing images. Transfer learning with progressive growth of networks has proven to be most efficient.

Major Contributions

- We propose a progressively growing architecture for our generator and discriminator network that helps in faster convergence, stable training and mode variation.
- We also propose the novel usage of deep radiometry loss from inspired from RTC-GAN, where radiometry features are extracted from a pre-trained RTC-GAN feature extraction network.
- We have generated state-of-the-art optical images with 15 dB improvement in PSNR and 0.25 improvement in SSIM index compared to the previous state-of-the-art method.
- This method can be directly adopted to various other image translation applications in remote-sensing, without any modification required.

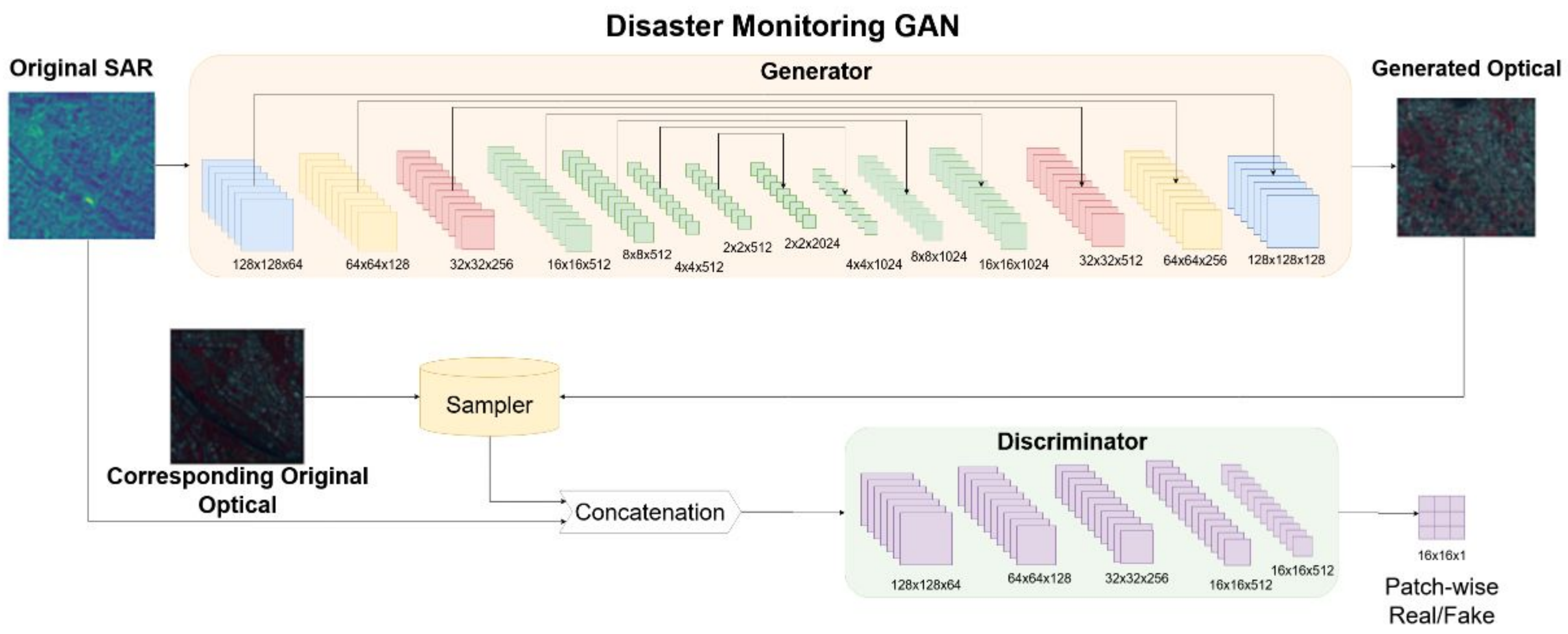

Fig. The proposed network architecture of a Disaster Monitoring GAN network. The model consists of a generator (to synthesis optical images from SAR images) and a patch discriminator (to classify each patch of the provided image as real or fake)

EXPERIMENT

Table 1. Ablation Study of loss functions used to train DisMonGAN. The metrics considered are PSNR, SSIM (0-1) and Mean Opinion Score (1-10). * represents final model loss.

Loss	PSNR (dB)	SSIM	M.O.S
L1+Entropy	20.17	0.57	3.4
L2+Entropy	18.03	0.42	2.7
L1+Entropy+Radiometry*	**37.25**	**0.85**	**8.3**
S-Cycle-GAN [1]	11.2	0.37	-
FG-GAN [3]	21.51	0.61	-

Table 2. Comparison of radiometry characteristics of SNR at low and high pixel value uniform patches between the original Cartosat2S and generated images.

Source	SNR-High (dB)	SNR-Low (dB)
Cartosat2S	59.23	49.56
Generated	55.69	42.24

Table 3. Comparison of DisMonGAN performance on various other microwave sensors without exclusive training.

Source	PSNR (dB)	SSIM
NovaSAR	27.38	0.56
Risat-1	30.46	0.65
Risat-2	37.25	0.85

[1] Wang, L., Xu, X., Yu, Y., Yang, R., Gui, R., Xu, Z.,Pu, F. (2019). SAR-to-optical image translation using supervised cycle-consistent adversarial networks. IEEE Access, 7, 129136-129149.

[3] Zhang, J., Zhou, J., Lu, X. (2020). Feature-guided SAR-to-optical image translation. IEEE Access, 8, 70925-70937

Conclusion

Disaster Monitoring is a critical application of remote sensing and challenging task given the weather conditions and time constraints. This work addresses the ease in usage of data and the generation of optical images from spatial information-rich SAR data. The proposal of **DisMon-GAN**, a novel, end-to-end trainable, progressively growing GAN architecture enabled spatially accurate and radiometrically realistic generation of high dimensional optical images. This model can be used efficiently for analysis during a disaster due to its less computational time and can deploy scene based help systems for disaster victims.