

**4<sup>th</sup> INTERNATIONAL CONFERENCE ON INNOVATIVE COMPUTING  
& COMMUNICATION (ICICC-2021)**

**20-21 February 2021.**

**Cloud Image Prior: Single Image Cloud Removal**

**Anirudh Maiya, Shylaja S. S**

**Department of Computer Science and Engineering, PES University, Bangalore, India**

## 1. INDEX:

- ABSTRACT
- INTRODUCTION
- LITERATURE REVIEW
- PROPOSED METHODOLOGY
- RESULTS AND DISCUSSION
- CONCLUSION
- FUTURE WORK
- REFERENCES

## 2. ABSTRACT:

- Cloud removal from satellite images is addressed as an inverse problem
- Cloudy regions are treated as missing/corrupted pixels and inpainted in an unsupervised setting
- Eliminate the task of gathering huge datasets to learn the mapping between cloudy and cloudy-free images
- Structure of a convolutional neural network is a good prior and is sufficient to solve an inpainting problem using Deep Image Prior algorithm [1]
- Effectiveness of the technique is demonstrated on Sentinel-2 satellite imagery



### 3. INTRODUCTION:

What is an Inverse problem?

$$y = A \cdot X$$



$X$



$y$

#### **Uses:**

- Denoising
- Inpainting
- Super resolution
- Deblurring

Often,  $y = A \cdot X + n$   
where  $n$  is noise.

Hence solutions to inverse problems are ill-posed and non-unique

***Problem : Given  $y$ ,  $A$  find  $X$***

### 3. INTRODUCTION

- Convolutional Neural Networks (Conv. Nets) have been used in remote sensing domain:
  - Semantic Segmentation of Crops [2]
  - Detecting Urban footprints [3]
- Often, clouds obstruct/envelope satellite images, hence cloud removal as a pre-processing step is imperative for other remote sensing tasks.



## 4. LITERATURE REVIEW :

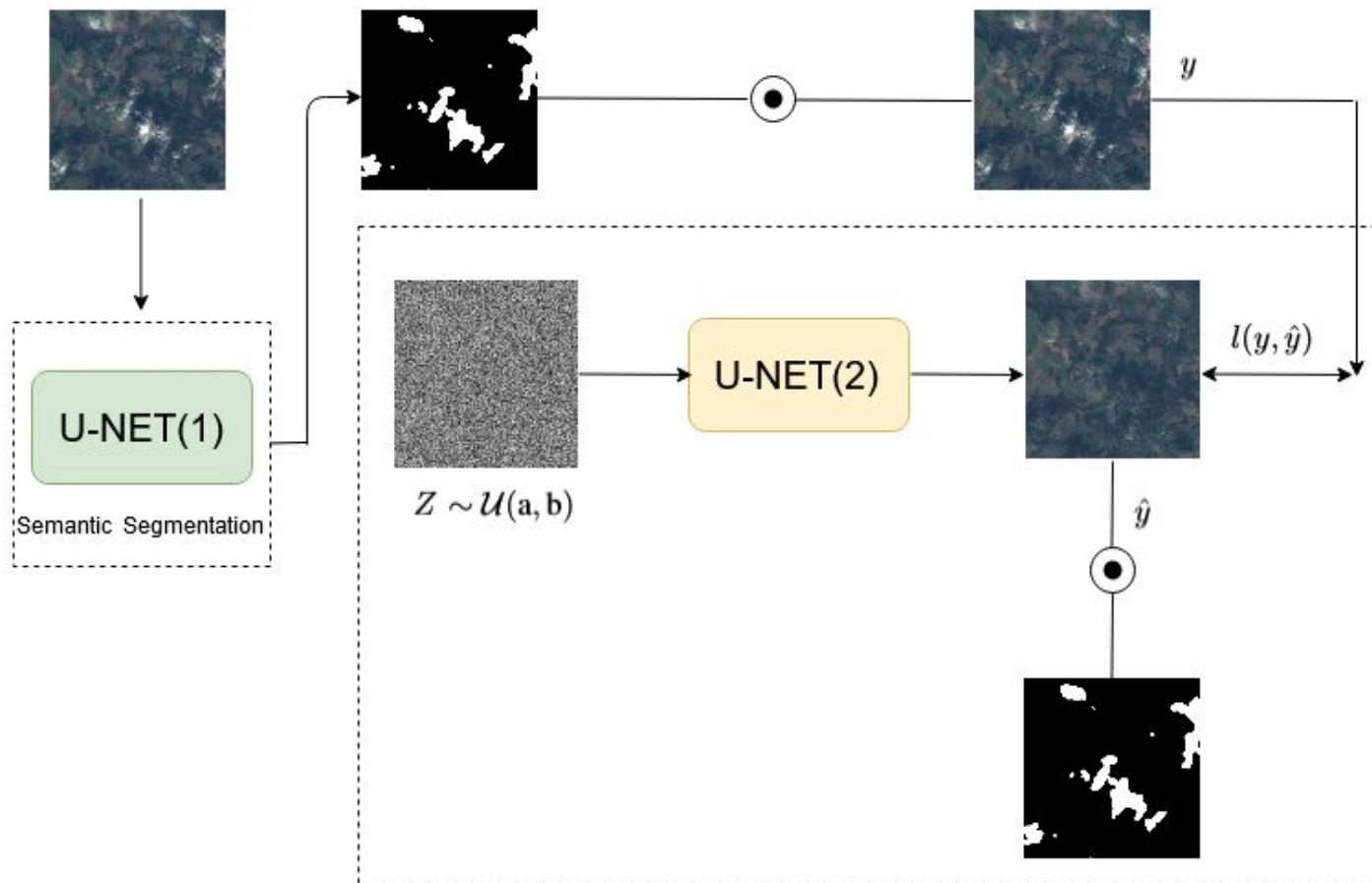
### ***Cloud-Gan: Cloud Removal for Sentinel-2 Imagery Using a Cyclic Consistent Generative Adversarial Networks***

- Uses Generative Adversarial Networks to learn the mapping between cloudy and cloud free images
- Has an additional cycle consistency loss to constrain the generator
- Requires gathering of data to learn the mapping

### **Thick Clouds Removal From Multitemporal ZY-3 Satellite Images Using Deep Learning**

- Uses multisource data (content, spectral and texture) to build a unified framework
- Hence uses three different Conv. Nets.
- Requires gathering of data to learn the mapping

## 5. PROPOSED METHODOLOGY :



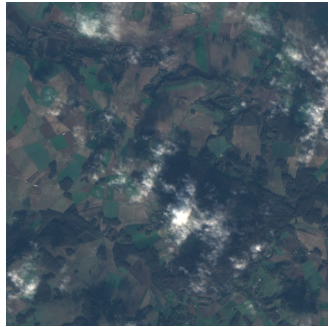
Cloud Removal is done in two stages:

1. Cloud Segmentation (detection)
2. Cloud Removal

Hence, we have two different Conv. Nets (U-Nets).

## 5. PROPOSED METHODOLOGY :

How to model cloud removal as an inverse problem?



$y$



$A$

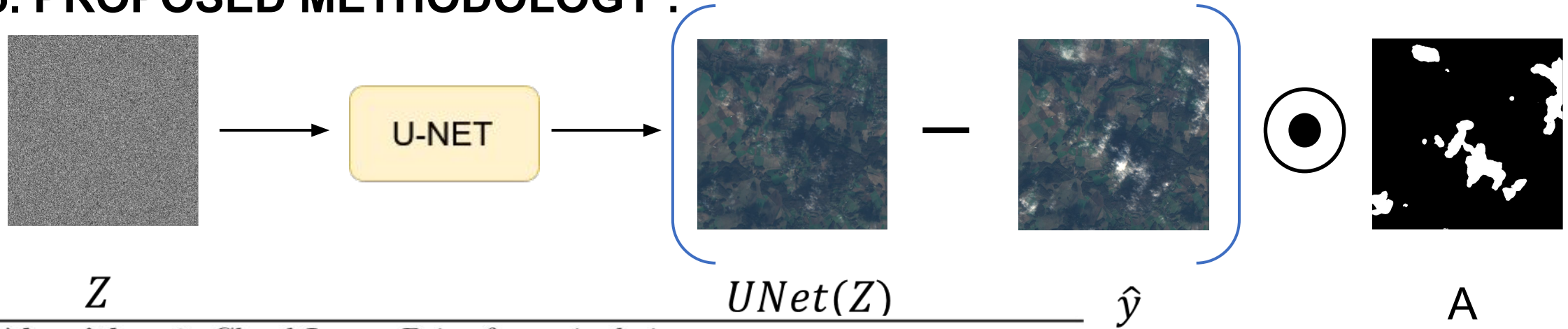


$X$

Given  $y$  and  $A$ , find cloud-free image  $X$



## 5. PROPOSED METHODOLOGY :




---

### Algorithm 2: Cloud Image Prior for a single image

---

**Require:**  $\hat{y}$  - Corrupted Image (Cloudy Image)

**Require:**  $m$  - Mask (from Cloud Segmentation)

**Require:**  $\alpha$  - Step Size

- 1: Initialize  $z$  with meshgrid where  $z \in R^{H \times W \times 2}$
- 2: Obtain segmentation mask  $m$  from trained Cloud Segmentation model
- 3: Solve the optimization problem by finding the parameters of the network.  
 $\theta_t = \theta_{t-1} - \alpha \cdot \nabla_{\theta} J(\theta_{t-1})$  where  $J$  is the cost function defined as
- 4: Find the solution to the desired inpainting problem after the model has converged.

$$y^* = f_{\theta^*}(z)$$

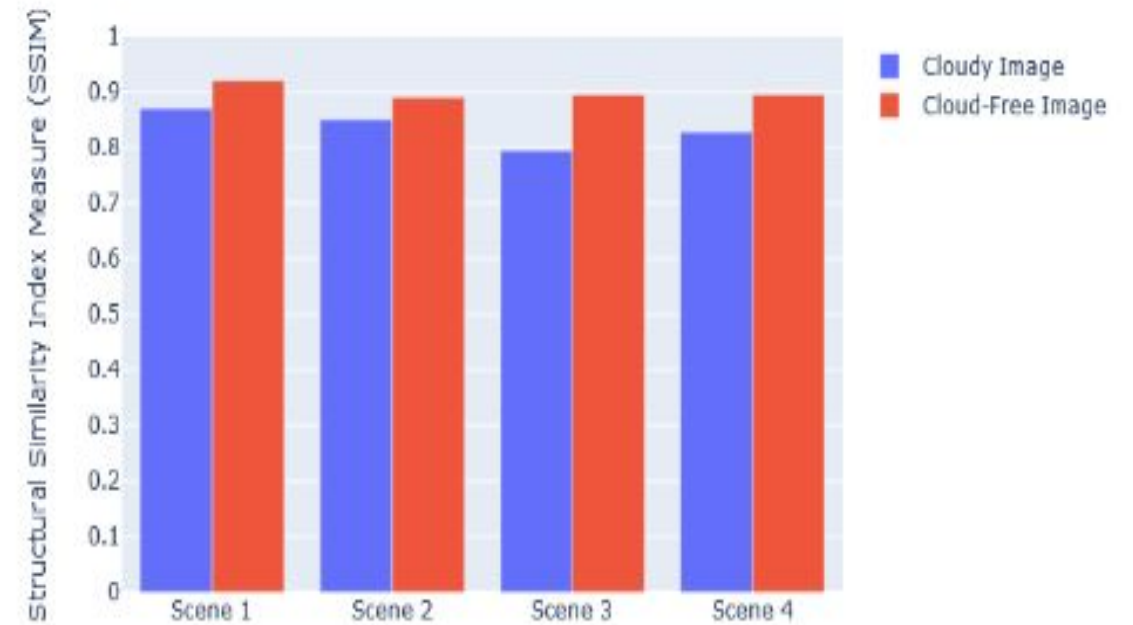
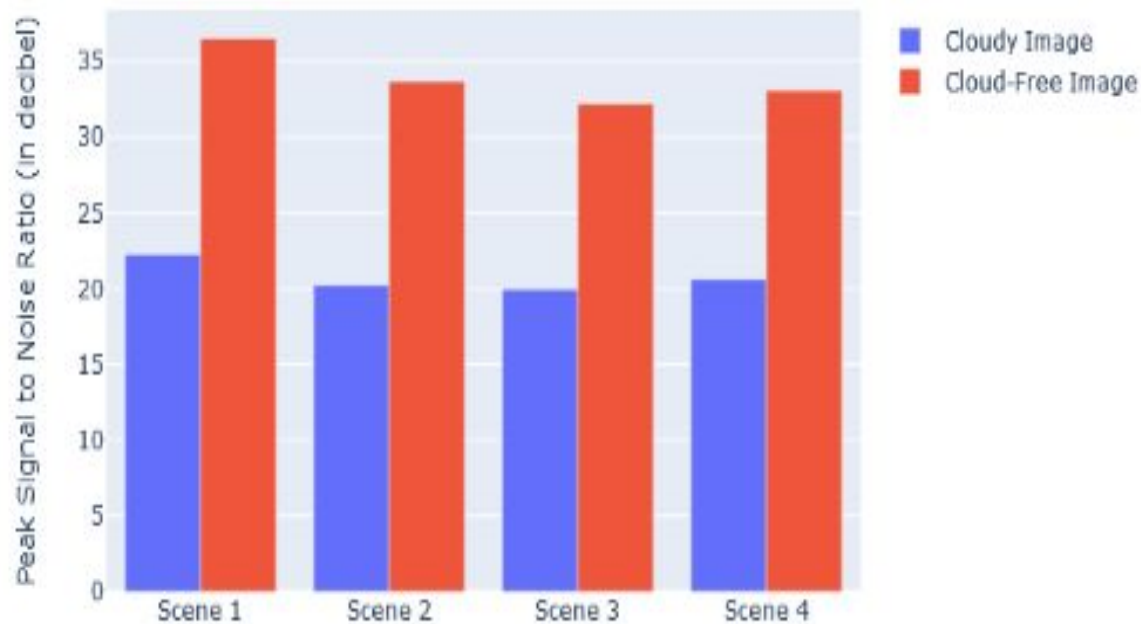

---

## 7. RESULTS & DISCUSSION:



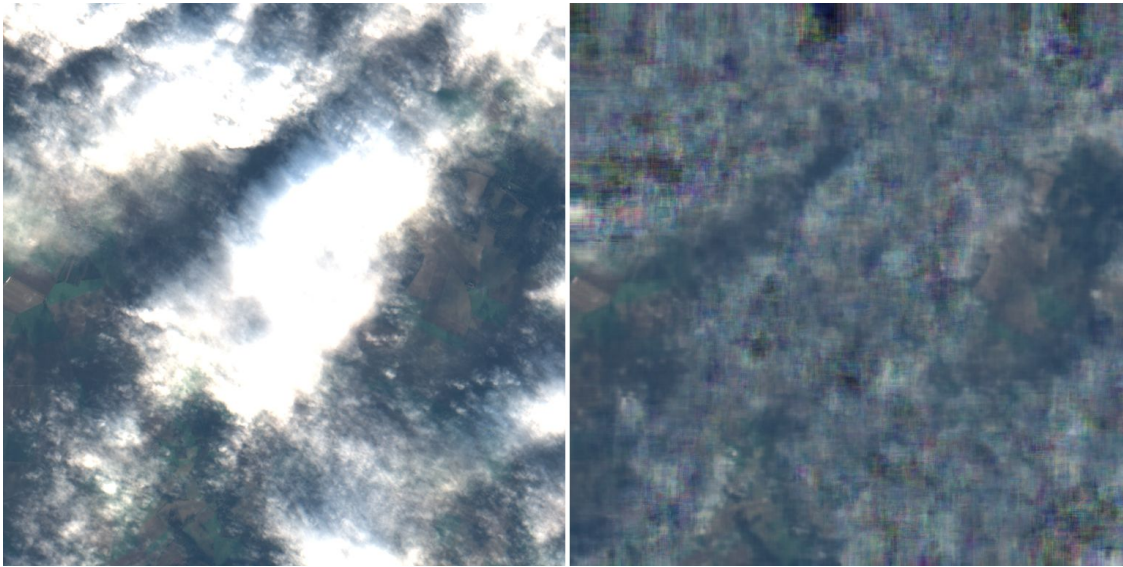


## 7. RESULTS & DISCUSSION:



Quantitative results such as PSNR and SSIM on four different scenes

## 7. RESULTS & DISCUSSION:



- Grainy output is produced when the image is significantly enveloped with clouds

## 9. CONCLUSION:

- Cloud removal is done with a single image
- Structure of the network contains significant amount of information and is sufficient to learn the prior
- Good baseline for superior/exotic supervised techniques to compete with

## 10. FUTURE WORK

- Removal of cloud shadows
- More granularity w.r.t thin and thick clouds
- Utilize other bands from Sentinel-2



## 10. REFERENCES :

1. D. Ulyanov, A Vedaldi and V.S. Lempitsky, Deep Image Prior, International Journal of Computer Vision, vol. 128, pp. 1867–1888, 2020
2. P. Singh and N. Komodakis, Cloud-Gan: Cloud Removal for Sentinel-2 Imagery Using a Cyclic Consistent Generative Adversarial Networks, in IEEE International Geoscience and Remote Sensing Symposium, pp. 1772-1775, 2018
3. Y. Chen, L. Tang, X. Yang, R. Fan, M. Bilal and Q. Li, Thick Clouds Removal From Multi-temporal ZY-3 Satellite Images Using Deep Learning, in IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, vol. 13, pp. 143-153, 2019

Q & A