Pre-processing for UAV Based Wildfire Detection

A Loss U-net enhanced GAN for Image Restoration

Linhan Qiao[1] Youmin Zhang[1]* Yaohong Qu[2]

[1]Department of Mechanical, Industrial and Aerospace Engineering, Concordia University, Montreal, Canada

[2]School of Automation, Northwestern Polytechnical University, Xi'an, China

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Outline

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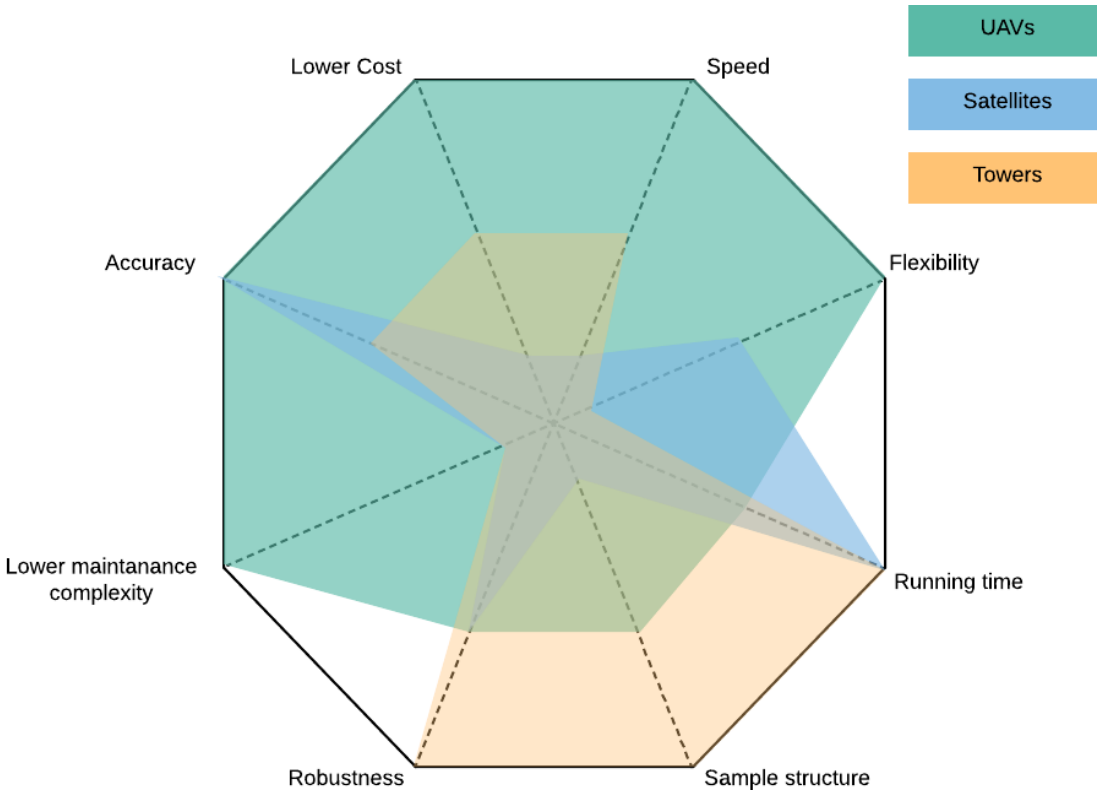

Qualitative compare the performance of UAV, satellite and surveillance tower in forest protection

Unmanned aerial vehicles (UAVs) wildfire application advantages:

- Lower maintenance complexity
- Lower cost
- Higher speed
- Higher flexibility

The recorded images are always distorted or of finite resolution (Kulkarni, 1990).

$$y = Hf + n \tag{1}$$

where the original image f is of support $N \times N$ (f: vector $N^2 \times 1 \Rightarrow H$ could be a $N^2 \times N^2$ matrix $\Rightarrow$ Gaussian denoising: $H = I$).
Find an $\hat{f}$ which could minimize the norm:

$$||y - H\hat{f}|| \tag{2}$$

$$(H^T H)\hat{f} = H^T y \tag{3}$$

Generalized inverse filter (Dabov, 2007)

Methods in recent year:
Feature learning methods ⇒ Deep neural networks (DNNs).

Problems: Too big model; Works only for one aspect (blurring, noise).

- To sharp the images and de-noise the frame.
  * Generative adversarial network (GAN) (Goodfellow, 2014).
- To capture the main features of the sequences, frames.
  * Perceptual loss network (Justin, 2016).

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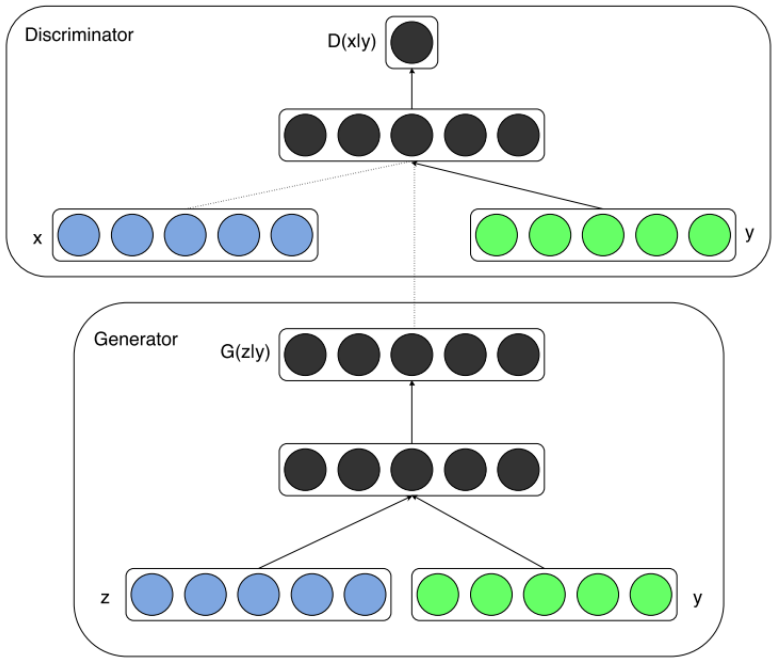
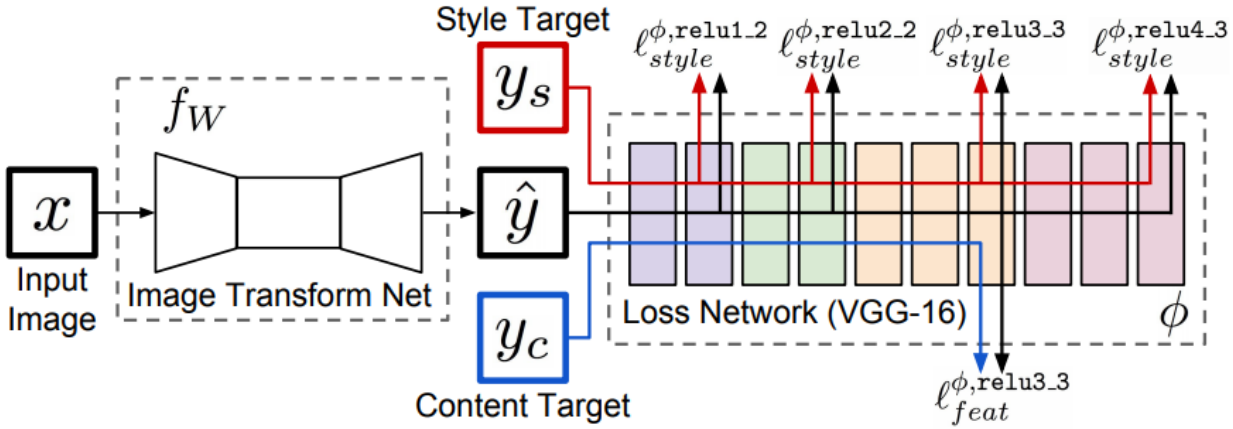


Conditional adversarial network

(Goodfellow, 2014)

Conditional adversarial network is more likely fitting the situation where there is a special training demand, like the black white images to colored images.

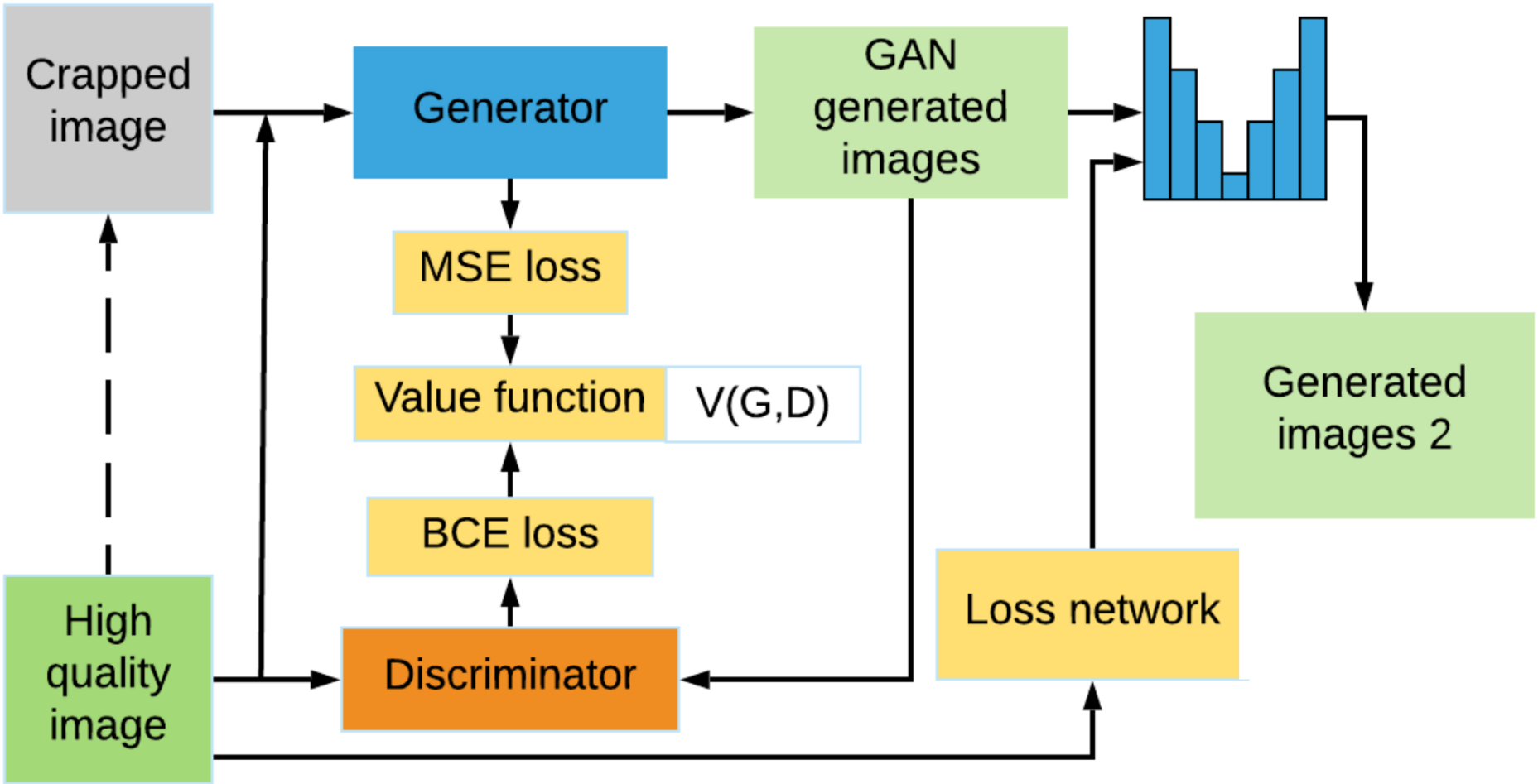
Loss U-net enhanced GAN model



Perceptual loss transfer model(Justin, 2016)

- Image transform net: encoder-decoder
- Loss network: reconstruction feature loss

Loss U-net enhanced GAN model



Loss U-net enhanced GAN brief block chart

- VGG-16 is still chosen to be a loss network to simplify the problem, other models also will work.

Value function $V(G, D)$: balance the loss of generator (G) and the discriminator (D)(Goodfellow, 2014).

$$\min_G \max_D V(G, D) = \mathbf{E}_{x\ p_{data}x}[\log D(x)] + \mathbf{E}_{z\ p_z z}[\log(1 - D(G(z)))] \tag{4}$$

Mean squared error loss for generator:

$$\mathrm{MSE}(y, \hat{y}) = \frac{\sum_{i=0}^{N} (y_i - \hat{y}_i)^2}{N} \tag{5}$$

Binary cross entropy (BCE) loss for discriminator:

$$\mathrm{BCE}(y, p) = \begin{cases} -\log(p) & \text{if } y = 1 \\ -\log(1-p) & \text{otherwise} \end{cases} \tag{6}$$

where $y \in \pm 1$ specifies ground truth class, $p \in [0, 1]$ is the probability of the estimation of the discriminator model from the label $y = 1$.

- The loss network Φ defines loss functions $l_1 \cdots l_k$.
- Every loss computes a scalar value $l_i(\hat{y}, y_i)$.
- The U-net does the work $\hat{y} = f_W(\hat{y}_{middle})$.

To minimize a weighted combination loss through stochastic gradient descent:

$$W^* = \arg\min_W E_{\hat{y}_{middle}, y_i}[\sum_{i=1} \lambda_i l_i(f_W(\hat{y}_{middle}, y_i))] \tag{7}$$

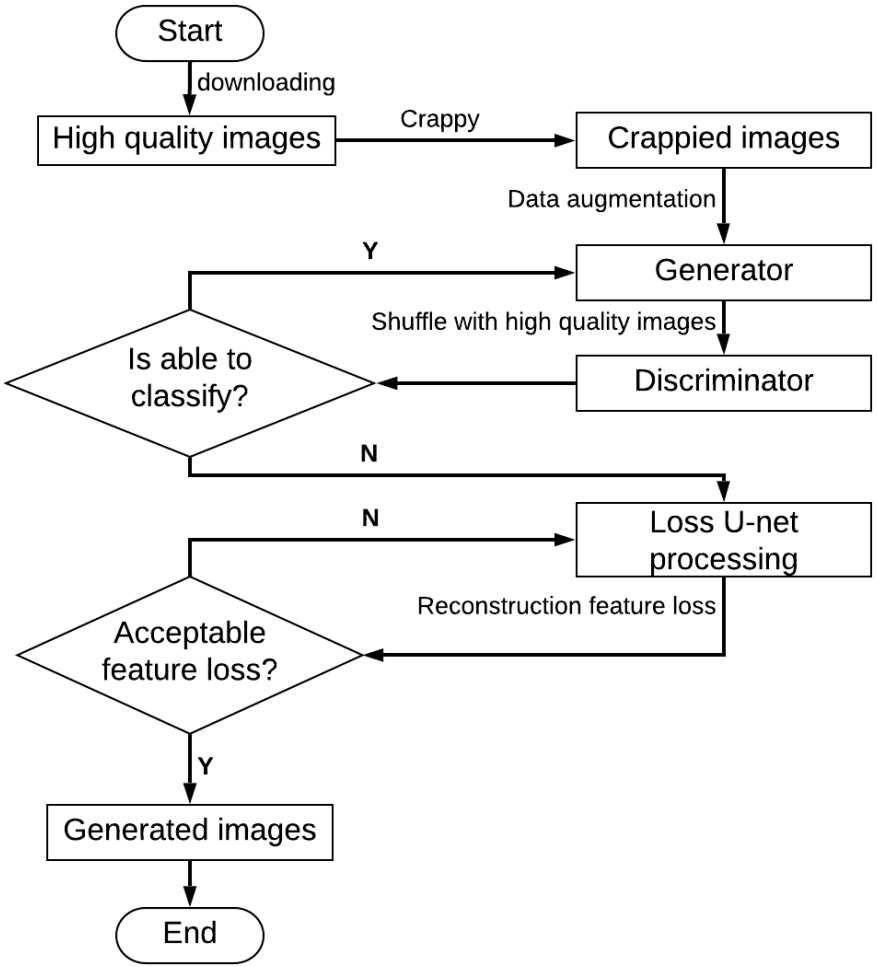
- The U-net encourages images but not only for the pixels.
- Assume j is a convolutional layer, $\Phi_j(\hat{y}_{middle})$: $C_j \times H_j \times W_j$.

Squared, normalized Euclidean distance between feature representation:

$$l^{\Phi,j}_{feat}(\hat{y}, y) = \frac{1}{C_j H_j W_j} \|\Phi_j(\hat{y}) - \Phi_j(y)\|_2^2 \tag{8}$$

Outline

Training and testing



Loss U-net enhanced GAN for image restoration programming work flow chart

Using fastai API on GCP

- Google cloud platform supports computation online.
- Fastai API: a higher level API based on pytorch.(Howard, 2020)

Training and testing

```
class crappifier(object):
    def __init__(self, path_lr, path_hr):
        self.path_lr = path_lr
        self.path_hr = path_hr

    def __call__(self, fn, i):
        dest = self.path_lr/fn.relative_to(self.path_hr)
        dest.parent.mkdir(parents=True, exist_ok=True)
        img = PIL.Image.open(fn)
        targ_sz = resize_to(img, 96, use_min=True)
        img = img.resize(targ_sz, resample=PIL.Image.BILINEAR).convert('RGB')
        w,h = img.size
        q = random.randint(10,90)
        ImageDraw.Draw(img).text((random.randint(0,w//2),random.randint(0,h//2)), str(q), fill=(255,255,255))
        img.save(dest, quality=q)
```

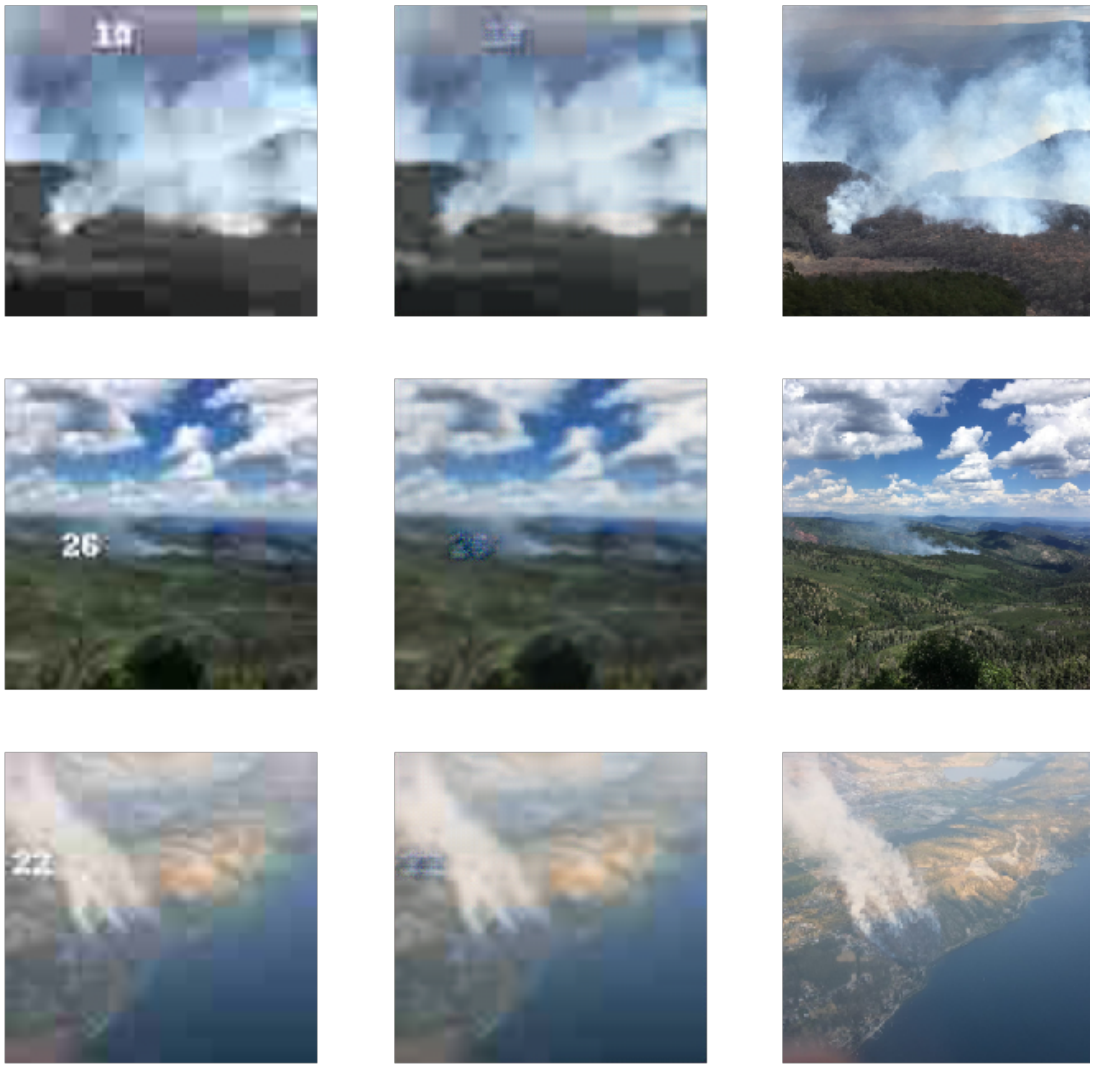
```
def get_data(bs,size):
    data = (src.label_from_func(lambda x: path_hr/x.name)
            .transform(get_transforms(max_zoom=1.05, flip_vert=True, max_lighting=0.1, max_warp=0.), size=size, tfm_y=True)
rm to data augmentation
            .databunch(bs=bs).normalize(imagenet_stats, do_y=True)) # imegenet_stats to pre_train

    data.c = 3
    return data
```

Crappy and transform augmentation result

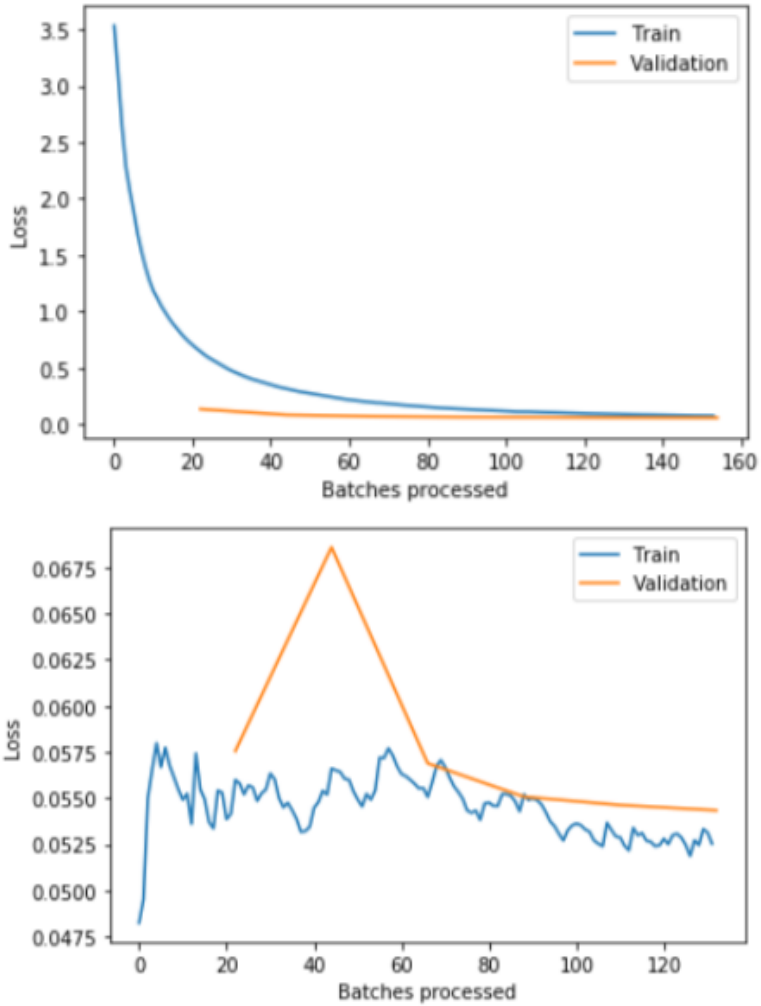
- Random location number water mark.
- Smaller number, lower quality.

- Imagenet pre-train (not good enough)
- Data augmentation: src.transform



One epoch U-net generator performance

- Only freezed encoder part.
- Left: crapped images.
- Middle: generated images.
- Right: target images.

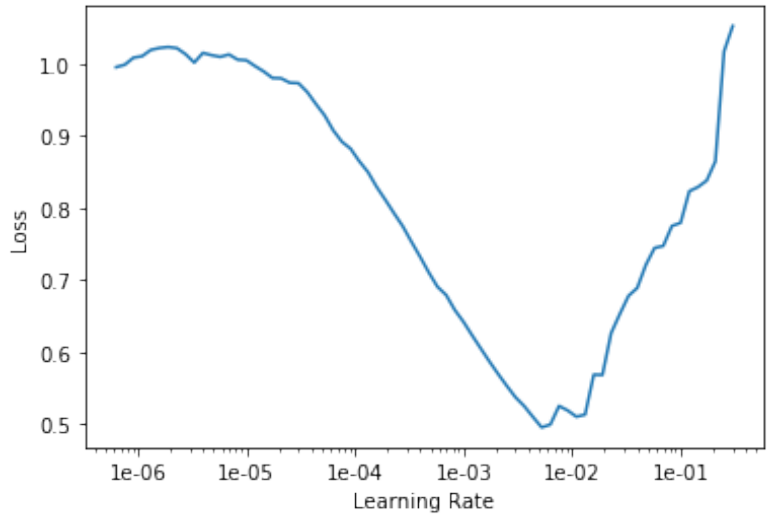


U-net generator loss performance

- Encoder: training set loss performs good, validation set loss is low at beginning.
- Encoder-Decoder: jumping out of a local optimum. Simulated fire annealing.

Training and testing

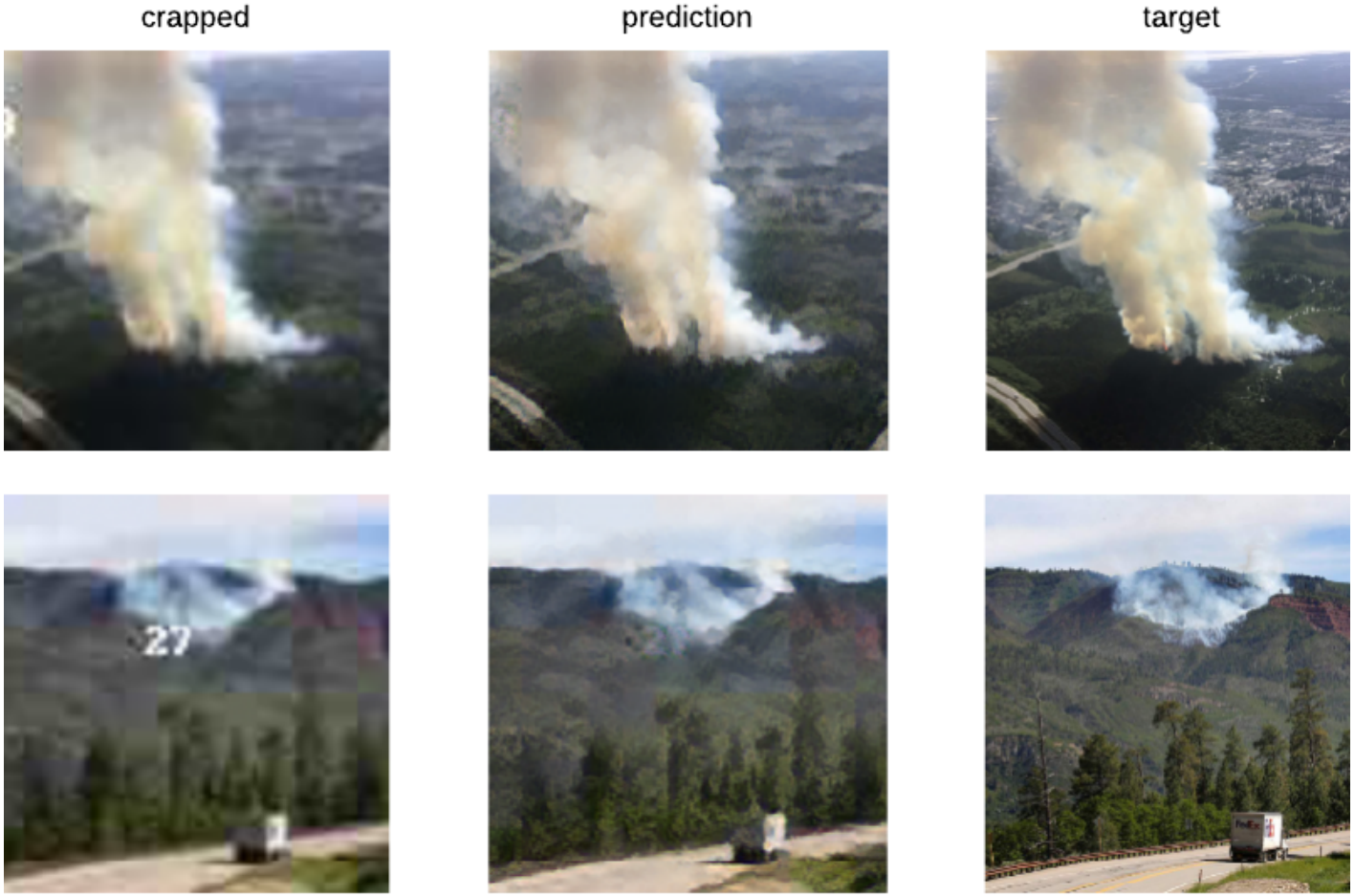
A data batch to train the discriminator



Finding a learning rate for discriminator

- Locating the lowest point and go back 10 times.
- Max slope point.

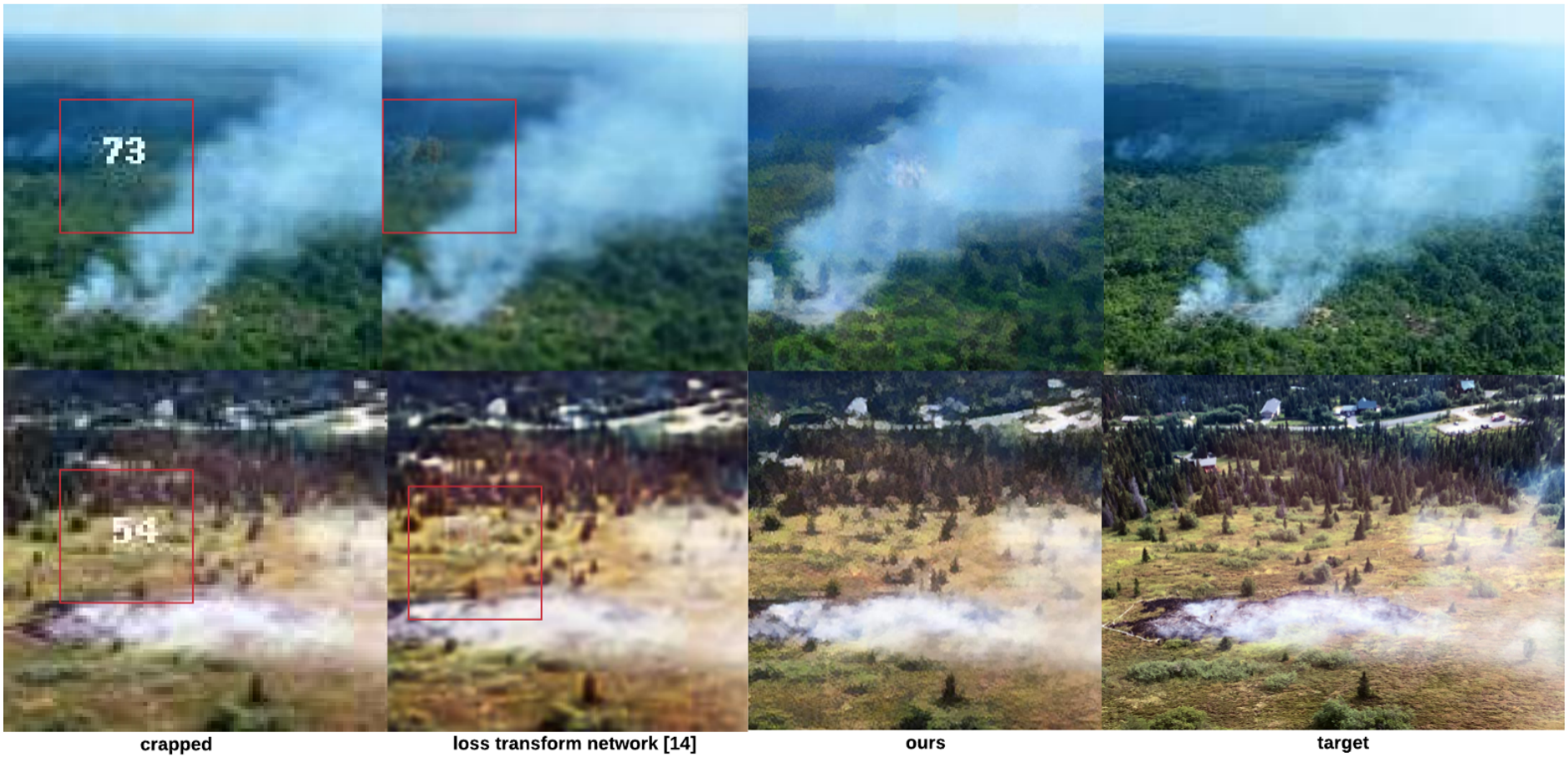
Training and testing



GAN generated output.

- The de-noising and robustness performed okay, but the objects are not sharped enough.

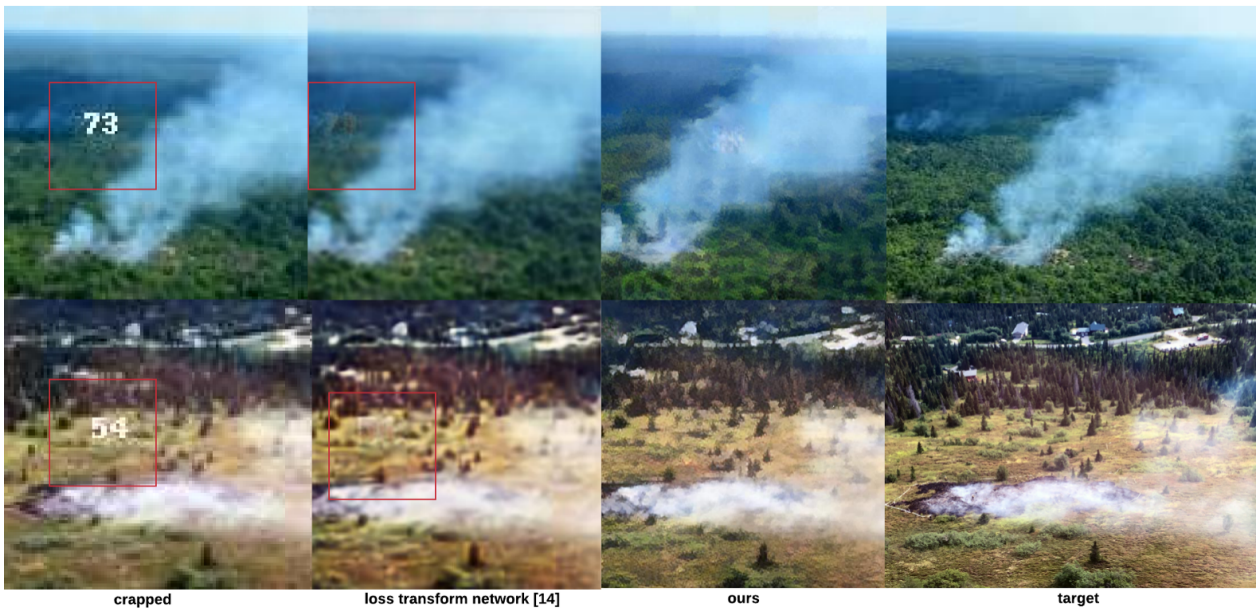
Training and testing



Loss U-net GAN generated results compare with perceptual loss network results

Outline

- This scheme nearly removed the entire number mark(Acceptable robustness and de-noising ability).
- Compression results showed a better performance for big scaled scenery images.
- Still lack enough data, a new kind of data set needs to be fund.
- Hard to identify the edge of non-rigid body items like smoke.



For more information

Dr. Youmin Zhang

Fellow CSME, Senior Member AIAA, Senior Member IEEE, Member ASME, Member CASI, Member AUVSI/USC

Phone: (514) 848-2424
x5225
Email:
ymzhang@encs.concordia.ca

Diagnosis, Flight Control & Simulation (DFCS) Lab.
Networked Autonomous Vehicles (NAV) Lab.
Department of Mechanical, Industrial, and Aerospace Engineering (MIAE)
& Concordia Institute of Aerospace Design and Innovation (CIADI)
Concordia University
1455 de Maisonneuve Blvd. W.
Montreal, Quebec H3G 1M8, Canada

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- **The 2020 International Conference on Unmanned Aircraft Systems (ICUAS'20), June 9-12 (postponed to Sept. 1-4), Athens, Greece (http://www.uasconferences.com) (NEW: Submission deadline is Mar. 1, 2020)**
- **News on Radio-Canada International: Looking for a lift in the fight against forest fires (2019-10-28)**
- **News on CTV News Channel** (during 37:15-40:00 min)**: Concordia's research work for forest fires monitoring (2019-10-26)**
- **News on La Presse: Des drones pour lutter contre les incendies de forêt (2019-10-23)**
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Thank You!

* If you have any questions or you think our work is interesting, please feel free to contact us: 742954173@qq.com
* The cod and data set is available at: https://github.com/qiaolinhan/ws-preprocess