RescueNet: Joint Building Segmentation and Damage Assessment from Satellite Imagery

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Motivation

- Aiding Humanitarian Aid and Disaster Response (HADR) operations
- Existing baseline approaches use 2 stage detect and compare/classify approach
  - Not end-to-end trainable
  - Achieve poor results

Prior Work

- Joseph Xu et al. *Building Damage Detection in Satellite Imagery Using Convolutional Neural Networks*. AI + HADR Workshop 2019
  - First Stage: Faster RCNN for building detection
  - Second Stage: Multi-Input Image Classifier (Pre/Post-Disaster Image)
- Ritwik Gupta et al. *Creating xBD: A Dataset for Assessing Building Damage from Satellite Imagery.* WACV 2020.
- Ritwik Gupta et al. *xBD: A Dataset for Assessing Building Damage from Satellite Imagery. Arxiv*
  - First Stage: U-Net based building localization
  - Second Stage: Custom ResNet-50 Image Classifier.

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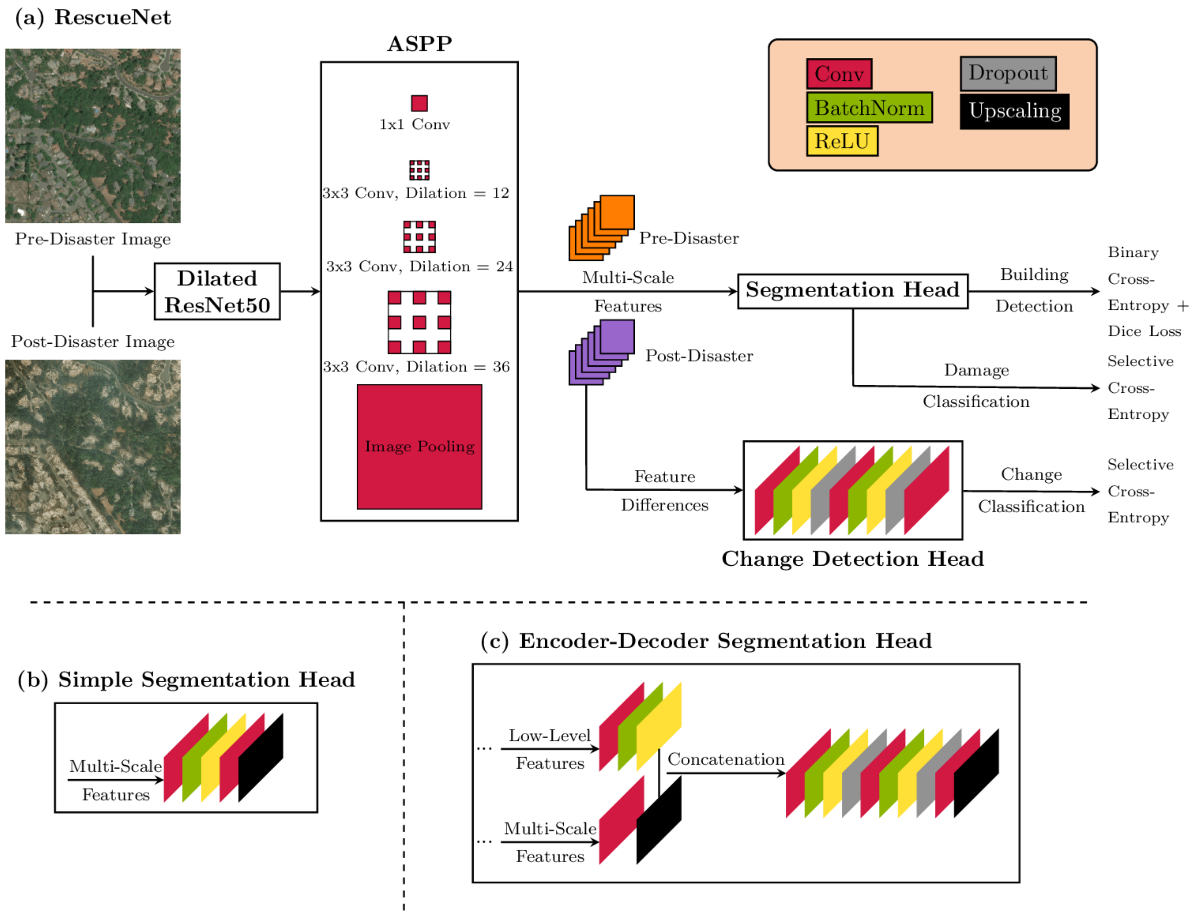
Our Method

- Unified end-to-end model
  - Building Segmentation
  - Change Detection
- Novel Localization Aware loss function

RescueNet



(a) RescueNet
Pre-Disaster Image
Post-Disaster Image
Dilated ResNet50
ASPP
1x1 Conv
3x3 Conv, Dilation = 12
3x3 Conv, Dilation = 24
3x3 Conv, Dilation = 36
Image Pooling
Conv
BatchNorm
ReLU
Dropout
Upscaling
Pre-Disaster
Multi-Scale Features
Post-Disaster
Segmentation Head
Building Detection
Binary Cross-Entropy + Dice Loss
Damage Classification
Selective Cross-Entropy
Feature Differences
Change Detection Head
Change Classification
Selective Cross-Entropy
(b) Simple Segmentation Head
Multi-Scale Features
(c) Encoder-Decoder Segmentation Head
Low-Level Features
Multi-Scale Features
Concatenation

Localization Aware Loss

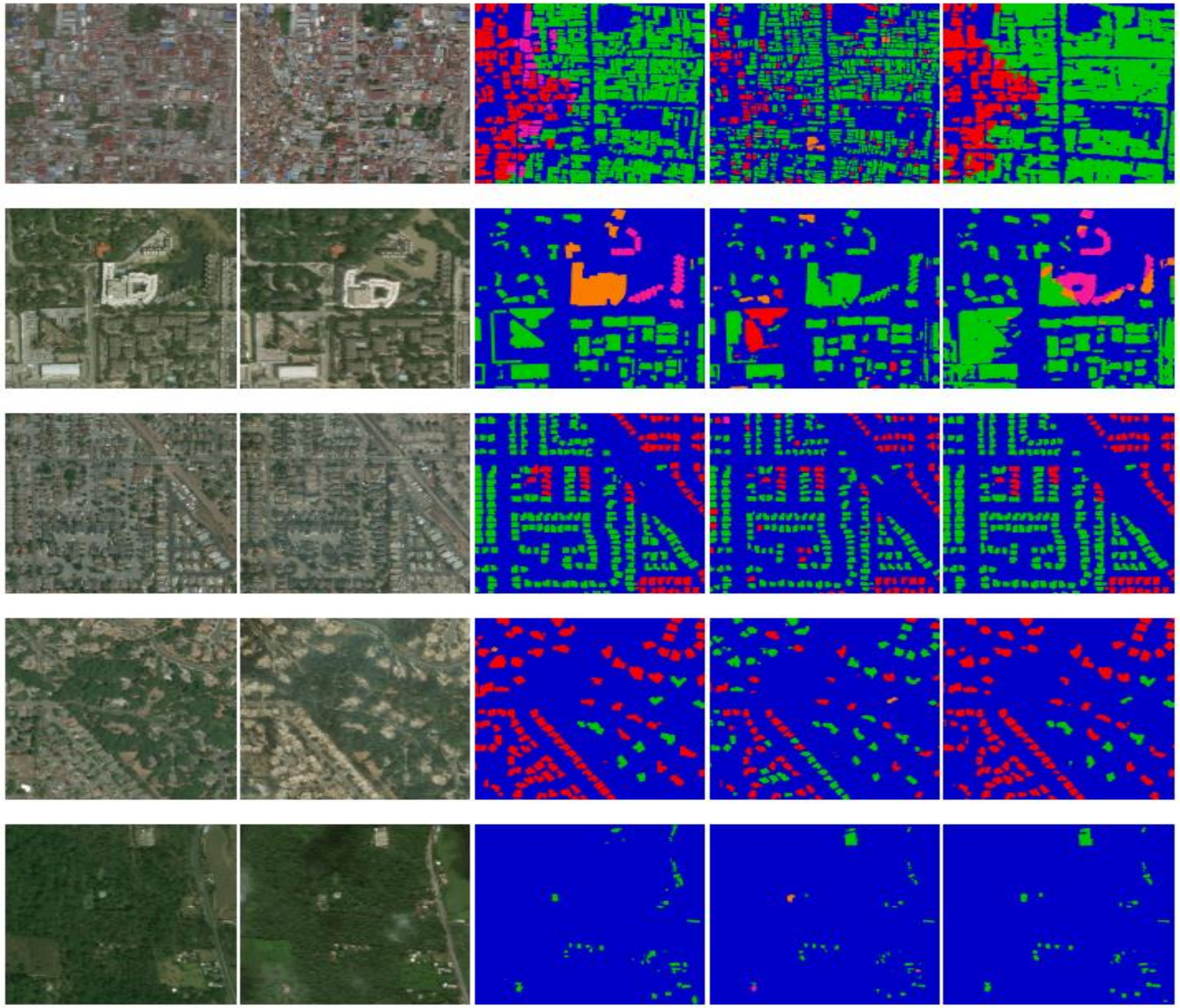
- Only applies classification loss gradients to foreground locations
- Localization loss applies to all locations

$$L(y_i, \hat{y_i}) = \begin{cases} -log(\hat{y_{il}}) + \sum_{k \in C} -log(\hat{y_{ik}}) & \text{if } y_{il} = 1 \\ -log(1 - \hat{y_{il}}) & \text{if } y_{il} = 0 \end{cases}$$

Experiments

- xBD dataset
- Pre- and Post- Disaster Images
- ~9,000 image pairs
- Multiple disaster types: Earthquake, Hurricane, Volcanoes etc
- Multiple Locations across the world

Qualitative Results



(a) Pre-Disaster (b) Post-Disaster (c) Ground Truth (d) Baseline Prediction (e) Prediction (Ours)

Quantitative results

- xView Metric
- Combines Building Localization and Damage Classification F1-Scores

$$Score = 0.3 * F1_{loc} + 0.7 * \frac{n}{\frac{1}{F1_{cls1}} + \cdots + \frac{1}{F1_{clsn}}}$$

Model	Localization Score	Damage Score	Overall Score
Ours	0.84	0.74	**0.77**
Baseline [1]	0.79	0.03	0.26

Class wise F1 Scores

Damage class	Baseline (Our Split)	RescueNet (Ours)
undamaged	0.7211	0.8832
minor	0.0235	0.5628
major	0.0105	0.7711
destroyed	0.4262	0.8079
Harmonic Mean	0.0282	0.7348

Generalization Results

- Disasters are split in 2 groups: Tier 1 & Tier 3 (Following *Gupta et al.*)

GENERALIZATION ACROSS REGIONS AND DISASTER TYPES

		Score		
Train Set	**Test Set**	**Localization**	**Damage**	**Overall**
Tier1 Train	Tier1 Valid.	0.79	0.60	0.66
Tier1 Train	Tier3	0.77	0.37	0.50

Ablation Study

Loss Function	Score
Cross-Entropy Loss	0.69
Localization Aware Loss	0.75
Localization Aware Loss + Dice Loss	**0.77**
Segmentation Head Architecture	
Simple (Convolution+Upscaling)	0.74
Encoder-Decoder	**0.77**
Change Detection Head	
Without change detection head	0.76
With change detection head	**0.77**

Thank you !