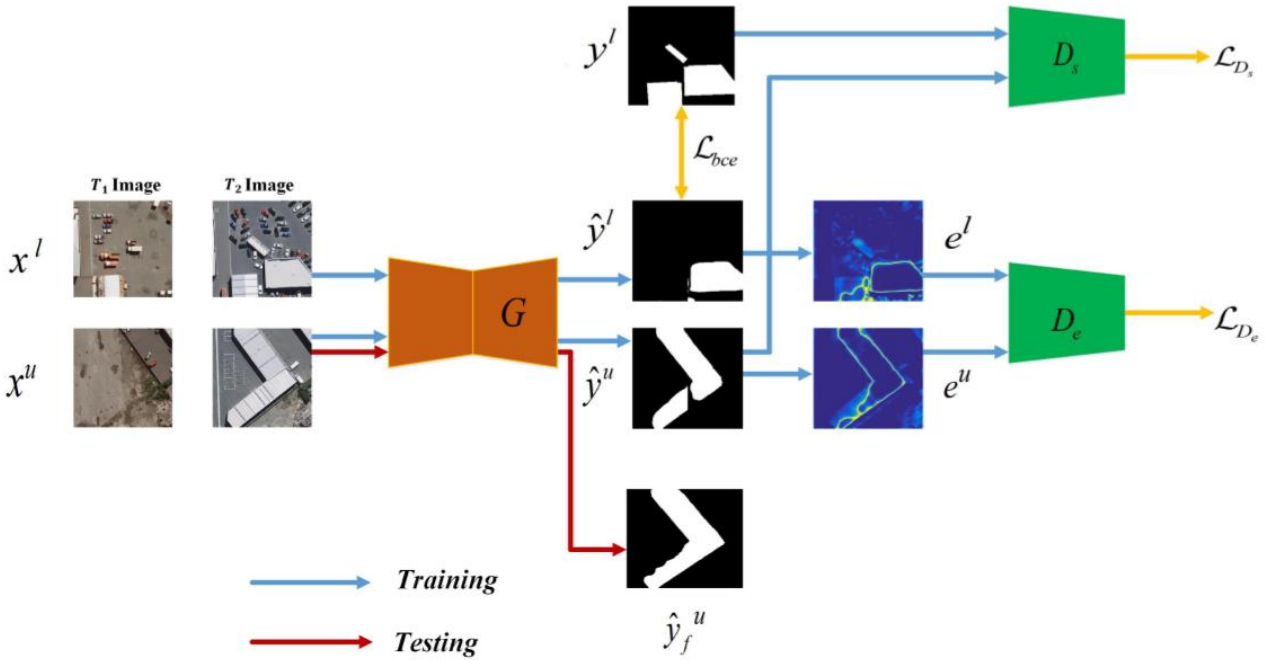
SemiCDNet: A Semisupervised Convolutional Neural Network for Change Detection in High Resolution Remote-Sensing Images

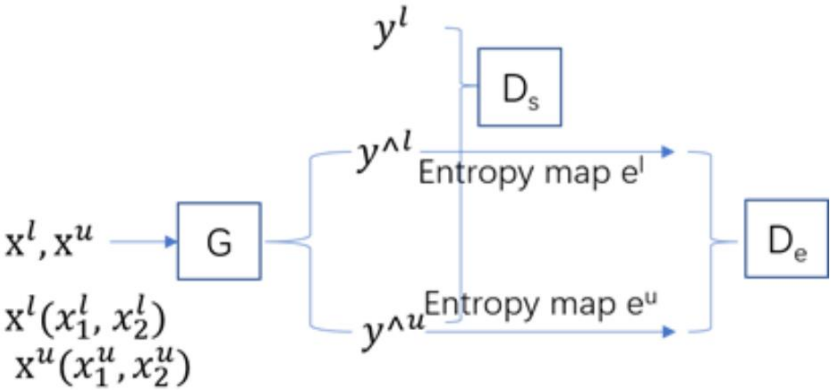
Daifeng Peng , Lorenzo Bruzzone , Fellow, IEEE, Yongjun Zhang , Member, IEEE, Haiyan Guan , Senior Member, IEEE, Haiyong Ding, and Xu Huang

Outline

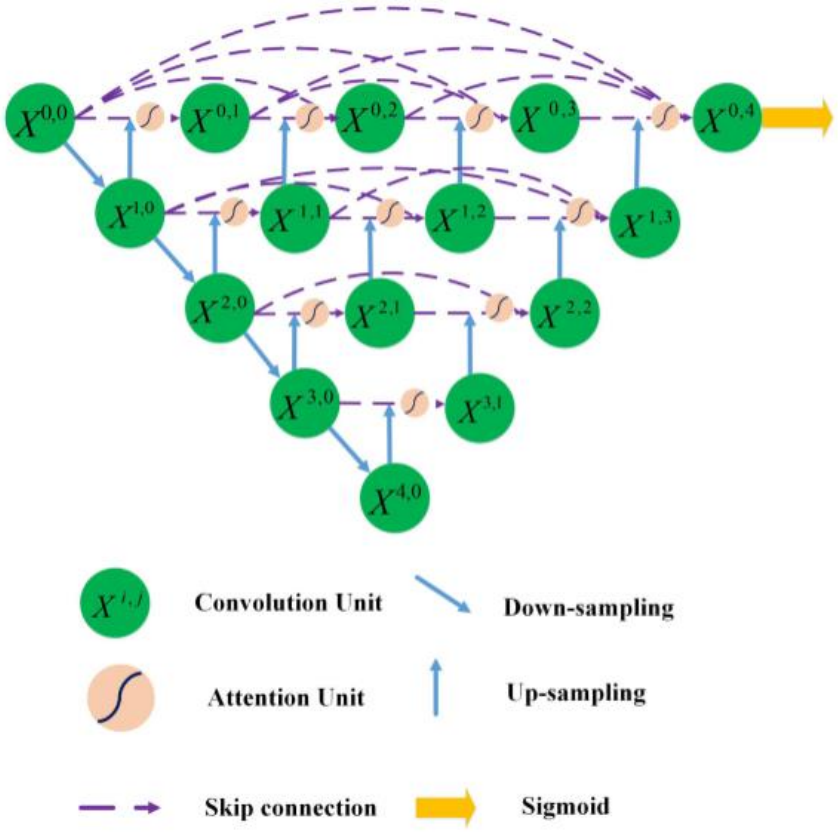
- Contribution
  - A novel end-to-end SemiCDNet is proposed for the semisupervised CD task. To improve segmentation performance, a light-weighted attention module is embedded into the UNet++ network.
  - A challenging data set is constructed by employing VHR satellite images, which will be released publicly for the benefit of promoting RS CD research using DL techniques.
- Experiments
- Ablation Study

SemiCDNet Architecture

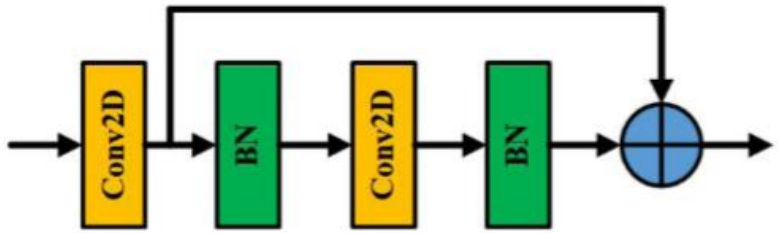




Segmentation Network



avoid the gradient vanishing problem during the networktraining

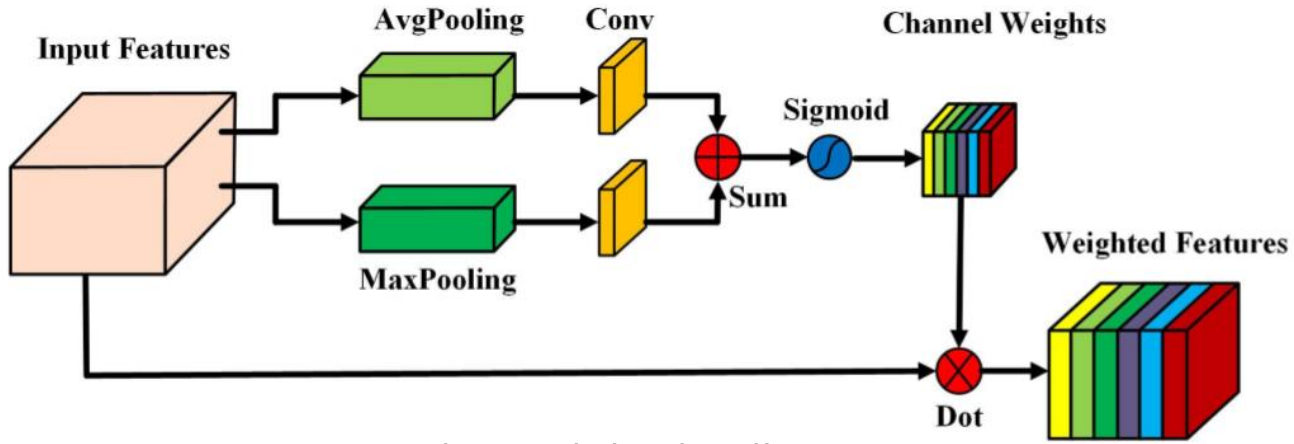


convolution unit in detail

1) semantic gap exists for high-level and low-level features, which leads to some discrepancy and confusion for the network after fusing them directly and
2) redundant information will be generated as not all the combined features are useful for the network.

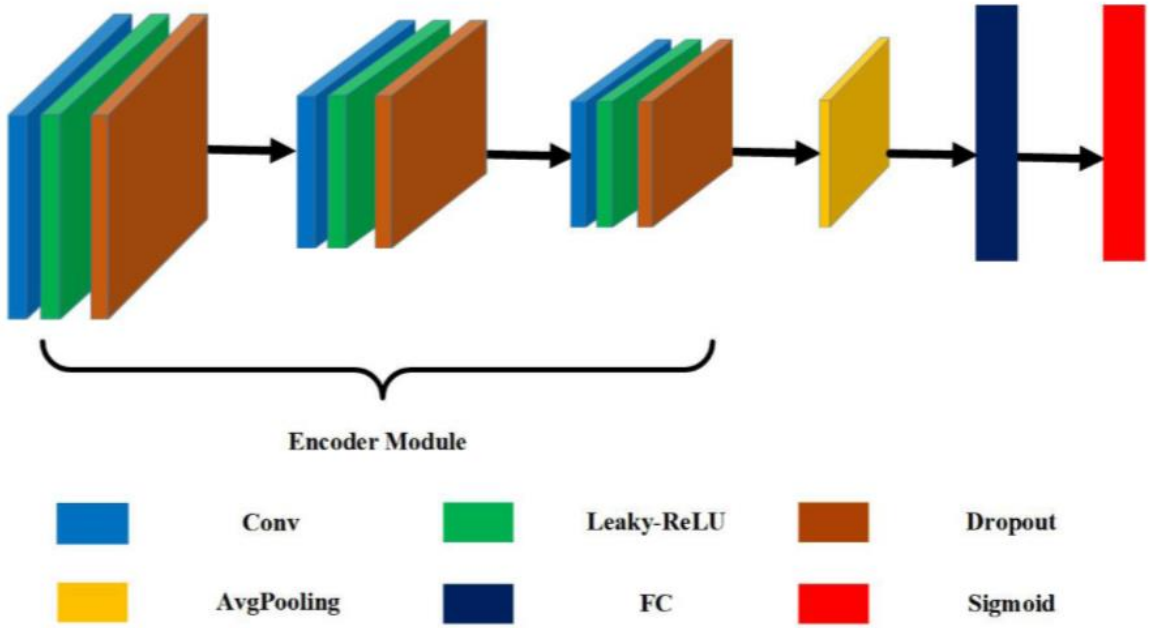
↓

an attention mechanism is adopted



attention unit in detail

Discriminator Network



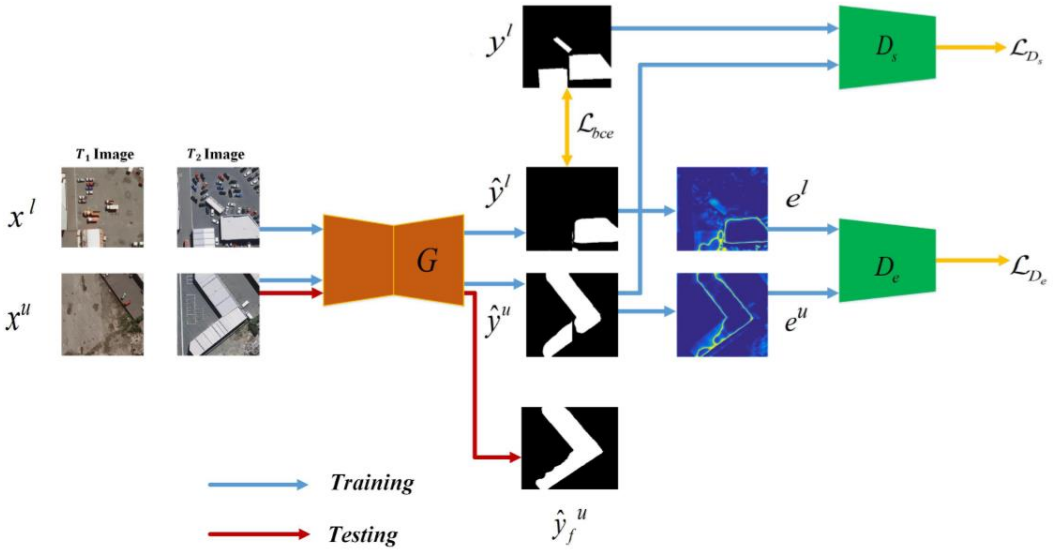
Loss Function

$$\mathcal{L}_G = \mathcal{L}_{\text{bce}} + \lambda_s \mathcal{L}_{\text{adv}}^{D_s} + \lambda_e \mathcal{L}_{\text{adv}}^{D_e}$$

weighted binary cross-entropy loss

segmentation adversarial loss

Entropy Adversarial Loss



$$\mathcal{D}_{\mathcal{L}} = \{(x_i^l, y_i^l)\}_{i=1}^{M}$$

$$\mathcal{D}_{\mathcal{U}} = \{(x_i^u)\}_{i=1}^{N}$$

$$\min_{\theta_F}\left\{\frac{1}{M}\sum_{i=1}^{M}\mathcal{L}_{\text{seg}}(x_i^l, y_i^l) + \frac{1}{N}\sum_{i=1}^{N}\mathcal{L}_{\text{semi}}(x_i^u)\right\}$$

Loss Function

$$\mathcal{L}_G = \mathcal{L}_{\text{bce}} + \lambda_s \mathcal{L}_{\text{adv}}^{D_s} + \lambda_e \mathcal{L}_{\text{adv}}^{D_e}$$

weighted binary cross-entropy loss

segmentation adversarial loss

Entropy Adversarial Loss

$$\mathcal{L}_{\text{bce}} = -\frac{1}{M}\left[\beta \sum_{j \in y_+^l} \log(P(y_j = 1)) + (1-\beta) \sum_{j \in y_-^l} \log(P(y_j = 0))\right]$$

$$\beta = |y_-^l|/(|y_+^l| + |y_-^l|)$$

$$1 - \beta = |y_+^l|/(|y_+^l| + |y_-^l|),$$

Loss Function

$$\mathcal{L}_G = \mathcal{L}_{\text{bce}} + \lambda_s \mathcal{L}_{\text{adv}}^{D_s} + \lambda_e \mathcal{L}_{\text{adv}}^{D_e}$$

weighted binary cross-entropy loss

segmentation adversarial loss

Entropy Adversarial Loss

$$\mathcal{L}_{D_s} = \frac{1}{M} \sum_{x^l, y^l \in \mathcal{D}_\mathcal{L}} \mathcal{L}_D(y^l \oplus x^l, 1) + \frac{1}{N} \sum_{x^u \in \mathcal{D}_\mathcal{U}} \mathcal{L}_D(G(x^u) \oplus x^u, 0)$$

$$\mathcal{L}_\mathcal{D}(y^p, y^t) = -y^t \log(y^p) - (1 - y^t) \log(1 - y^p)$$

$$\mathcal{L}_{\text{adv}}^{D_s} = \frac{1}{N} \sum_{x^u \in \mathcal{D}_\mathcal{U}} \mathcal{L}_D(G(x^u) \oplus x^u, 1).$$

Loss Function

$$\mathcal{L}_G = \mathcal{L}_{\text{bce}} + \lambda_s \mathcal{L}_{\text{adv}}^{D_s} + \lambda_e \mathcal{L}_{\text{adv}}^{D_e}$$

weighted binary cross-entropy loss

segmentation adversarial loss

Entropy Adversarial Loss

$$\mathcal{L}_{D_e} = \frac{1}{M} \sum_{x^l, y^l \in \mathcal{D}_\mathcal{L}} \mathcal{L}_D(E(x^l) \oplus x^l, 1) + \frac{1}{N} \sum_{x^u \in \mathcal{D}_\mathcal{U}} \mathcal{L}_D(E(x^u) \oplus x^u, 0).$$

$$\mathcal{L}_{\text{adv}}^{D_e} = \frac{1}{N} \sum_{x^u \in \mathcal{D}_\mathcal{U}} \mathcal{L}_D(E(x^u) \oplus x^u, 1).$$

Experiment

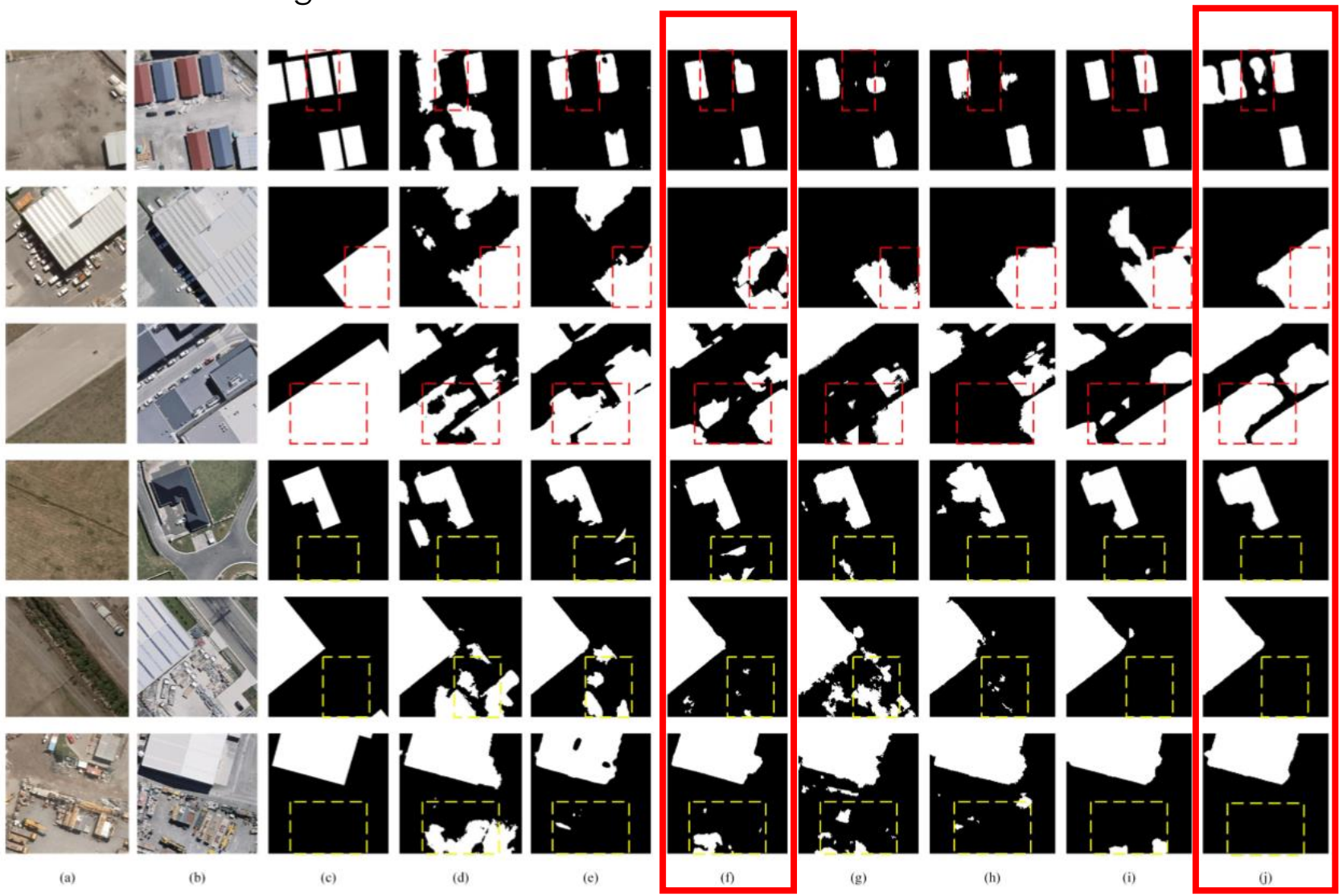
WHU Building Data Set

Experiment

Google data set

Experiment

WHU Building Data Set



(a) Image T1. (b) Image T2. (c) Reference change map. (d) FC-EF-Res. (e) FCN-PP. (f) UNet++_att. (g) AdvNet. (h) CycleGAN. (i) s4GAN. (j) Proposed SemiCDNet.

Experiment

Google data set

(a) Image T1. (b) Image T2. (c) Reference change map. (d) FC-EF-Res. (e) FCN-PP. (f) UNet++_att. (g) AdvNet. (h) CycleGAN. (i) s4GAN. (j) Proposed SemiCDNet.

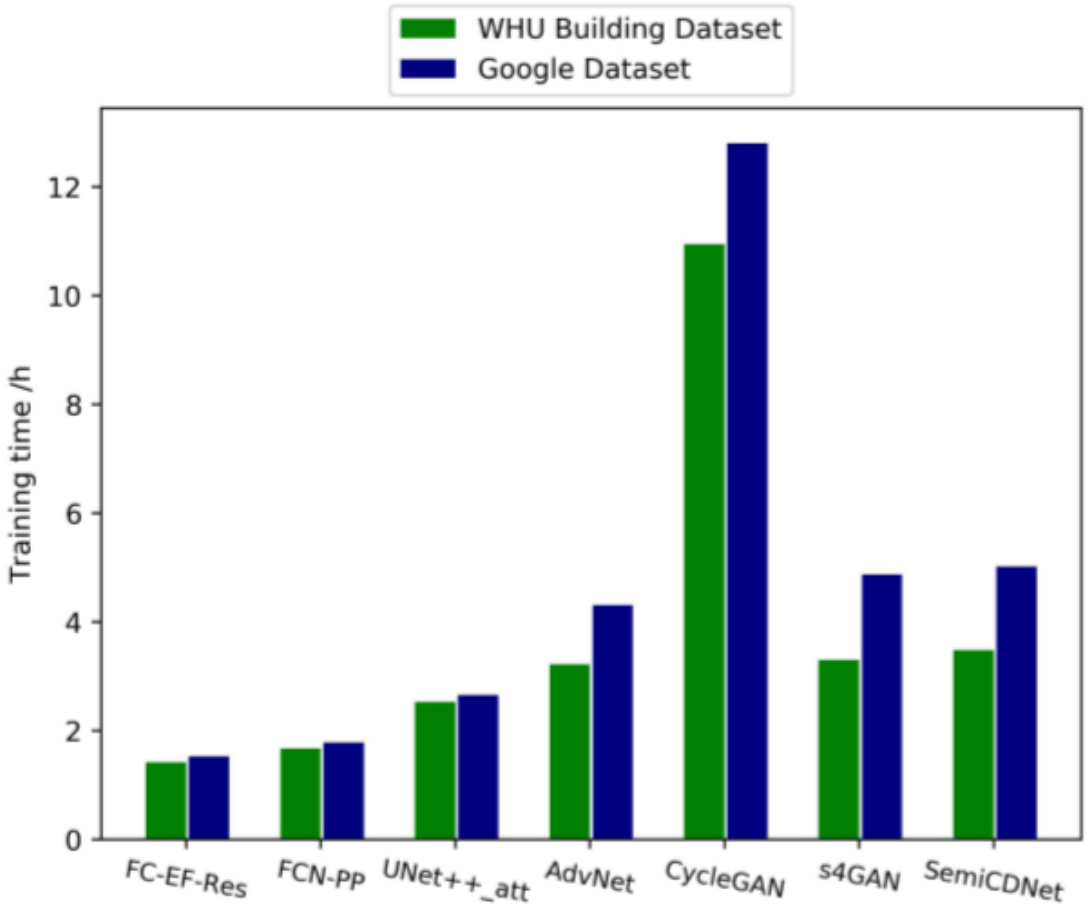
Experiment

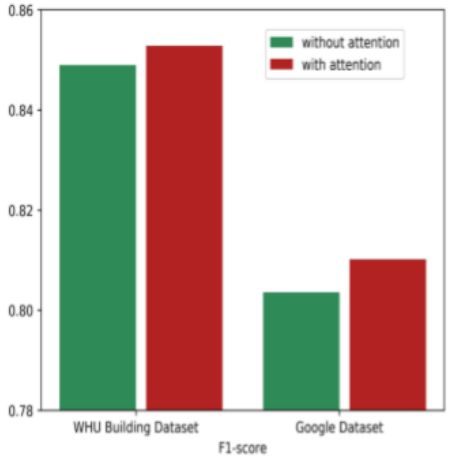
Method	Labeled Ratio											
	5%			10%			20%			50%		
	F1	OA	Kappa	F1	OA	Kappa	F1	OA	Kappa	F1	OA	Kappa
FC-EF-Res	0.7715	0.9116	0.7177	0.8145	0.9328	0.7737	0.8451	0.9467	0.8129	0.8561	0.9513	0.8268
FCN-PP	0.7694	0.9212	0.7219	0.8110	0.9351	0.7719	0.8475	0.9512	0.8186	0.8539	0.9504	0.8240
UNet++_att	0.7749	0.9297	0.7308	0.8265	0.9448	0.7938	0.8499	0.9502	0.8200	0.8673	0.9577	0.8458
AdvNet	0.7599	0.9238	0.7149	0.8159	0.9404	0.7839	0.8400	0.9483	0.8093	0.8760	0.9584	0.8510
CycleGAN	0.7255	0.9191	0.6794	0.7807	0.9315	0.7405	0.8017	0.9338	0.7620	0.8330	0.9450	0.8000
s4GAN	0.8174	0.9425	0.7836	0.8493	0.9501	0.8194	0.8557	0.9523	0.8272	0.8772	0.9593	0.8528
SemiCDNet	**0.8290**	**0.9434**	**0.7962**	**0.8528**	**0.9517**	**0.8240**	**0.8657**	**0.9559**	**0.8403**	**0.8774**	**0.9595**	**0.8538**

Method	Labeled Ratio											
	10%			20%			40%			60%		
	F1	OA	Kappa	F1	OA	Kappa	F1	OA	Kappa	F1	OA	Kappa
FC-EF-Res	0.7381	0.8460	0.6261	0.7810	0.8710	0.6822	0.7870	0.8613	0.6781	0.8098	0.8747	0.7078
FCN-PP	0.7295	0.8385	0.6144	0.7977	0.8743	0.7001	0.8014	0.8745	0.7029	0.8163	0.8860	0.7253
UNet++_att	0.7441	0.8550	0.6415	0.7978	0.8796	0.7045	0.8167	0.8868	0.7258	0.8281	0.8898	0.7384
AdvNet	0.7173	0.8273	0.5939	0.7882	0.8657	0.6834	0.8034	0.8742	0.7022	0.8267	0.8795	0.7258
CycleGAN	0.7145	0.8483	0.6131	0.7641	0.8545	0.6562	0.7780	0.8625	0.6740	0.7923	0.8656	0.6877
s4GAN	0.7397	0.8369	0.6214	0.8070	0.8829	0.7152	0.8224	0.8895	0.7320	0.8351	0.8935	0.7466
SemiCDNet	**0.7627**	**0.8621**	**0.6610**	**0.8102**	**0.8864**	**0.7207**	**0.8243**	**0.8905**	**0.7346**	**0.8389**	**0.8964**	**0.7525**

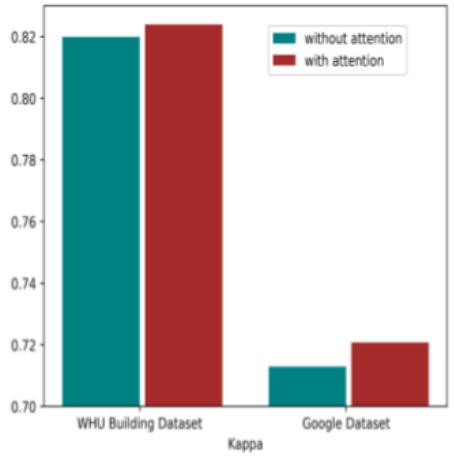
F1-score (F1)　　overall accuracy (OA)　　Kappa coefficient (Kappa)

Ablation Study





(a)



(b)

Method	WHU Building Dataset	Google Dataset
w/o D_s D_e	0.8265	0.7978
w/o D_s	0.8490	0.8061
w/o D_e	0.8456	0.8003
Proposed	**0.8528**	**0.8102**