GLOBECOM 2021

A Comparative Study of Deep-Learning-Based Semi-Supervised Device-Free Indoor Localization

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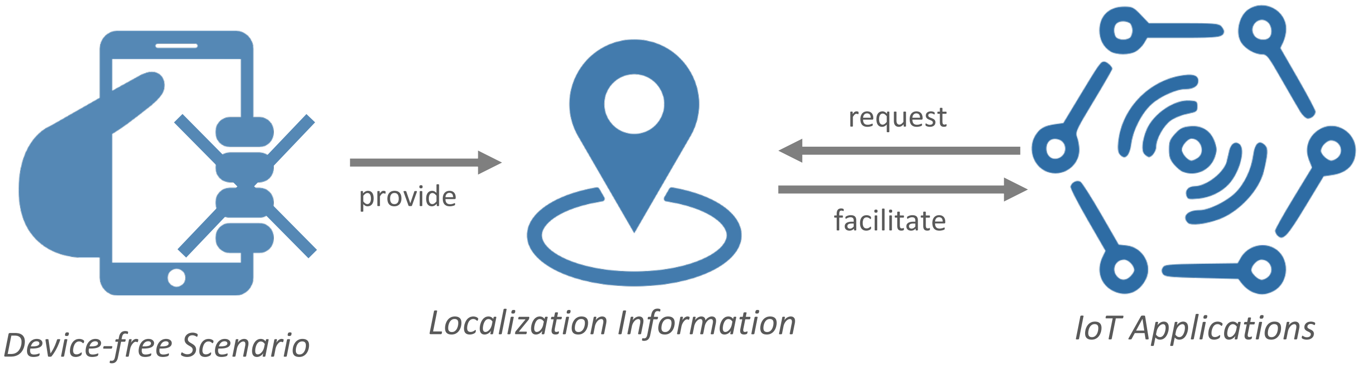
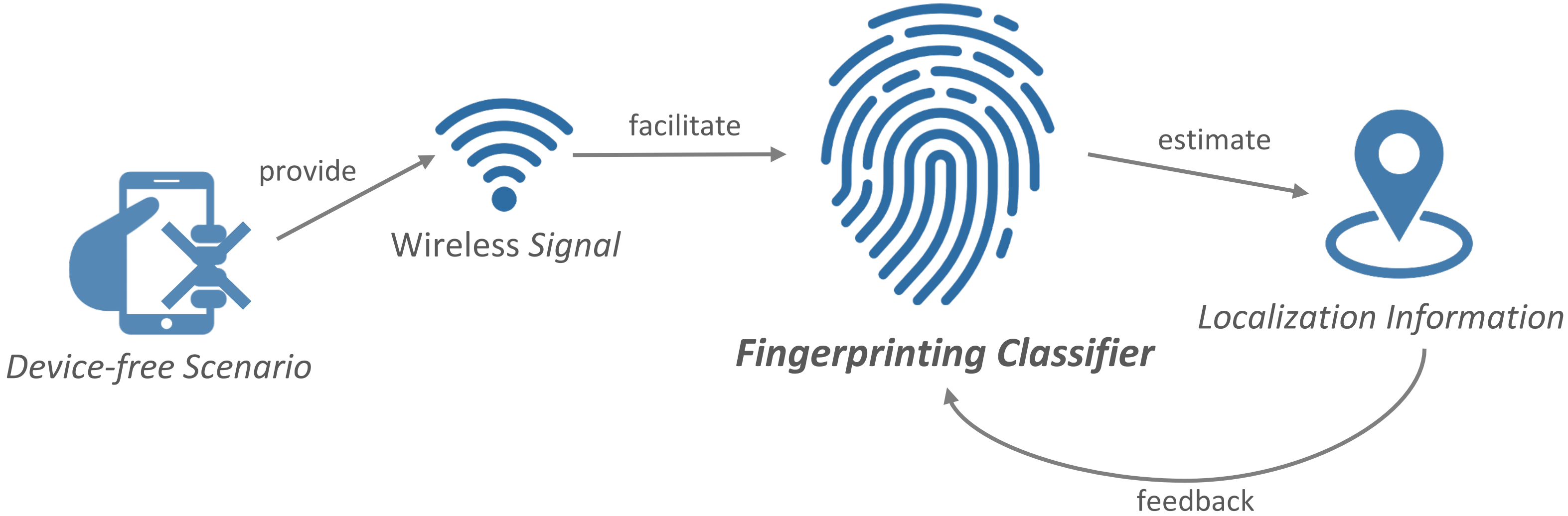
What is *device-free* indoor localization?



How to solve device-free indoor localization?



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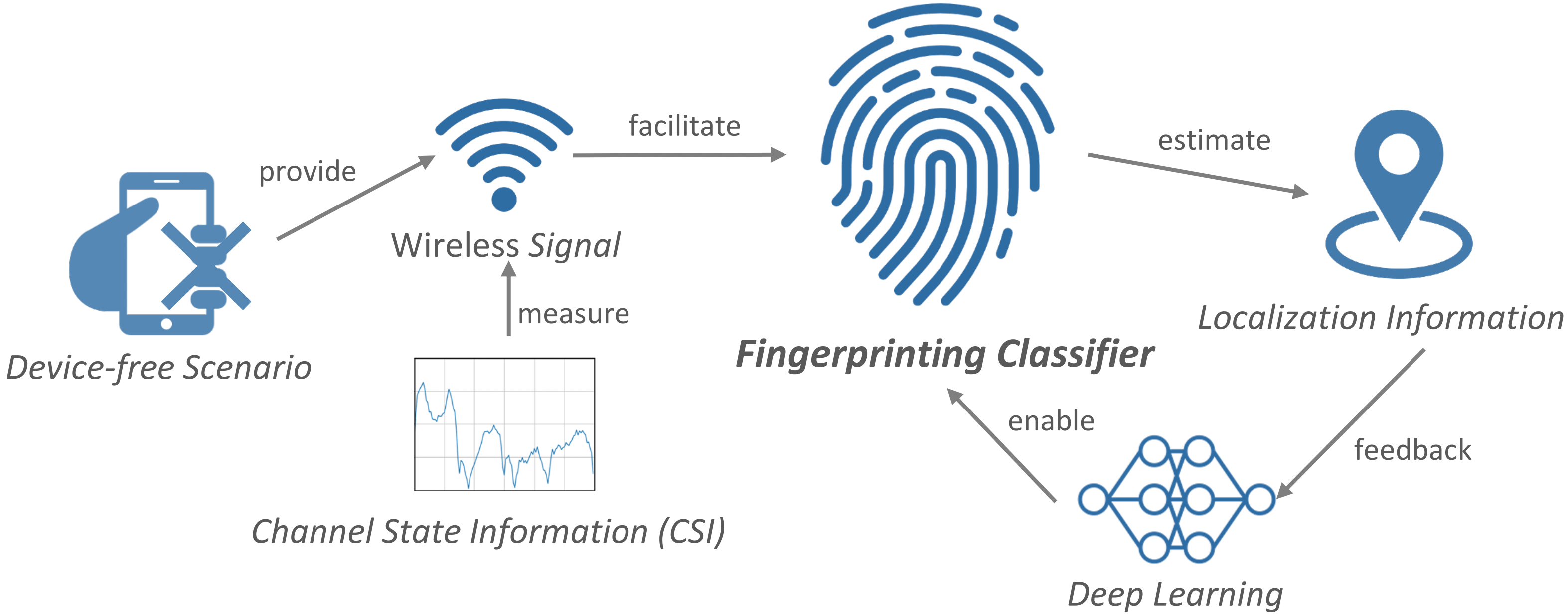
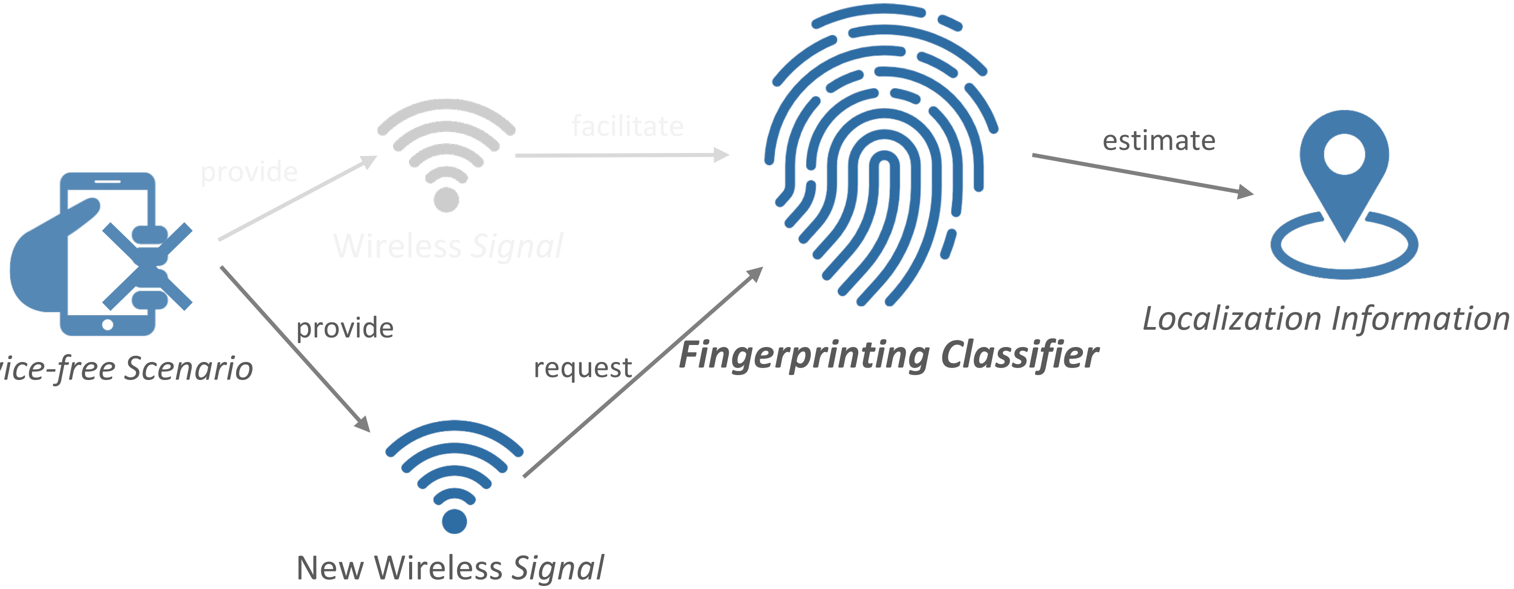
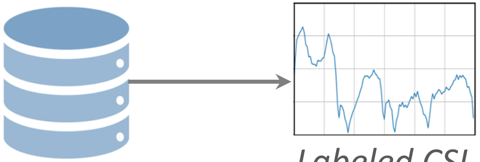


How to solve device-free indoor localization?



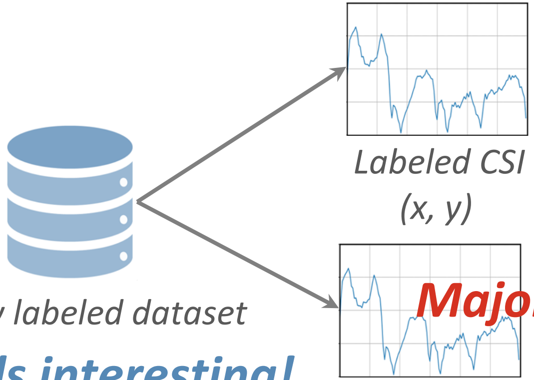
What is *semi-supervised*?



Completely labeled dataset

Labeled CSI
(x, y)

Good result but…
cost too much!



Partially labeled dataset

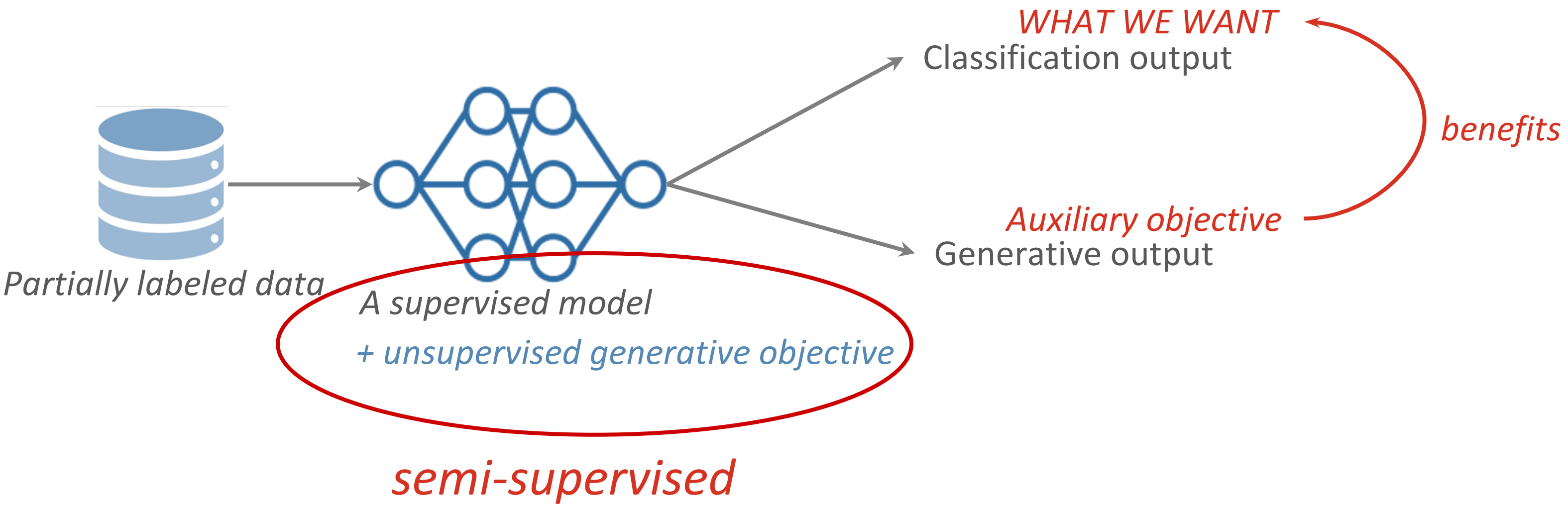
Labeled CSI
(x, y)

Majority

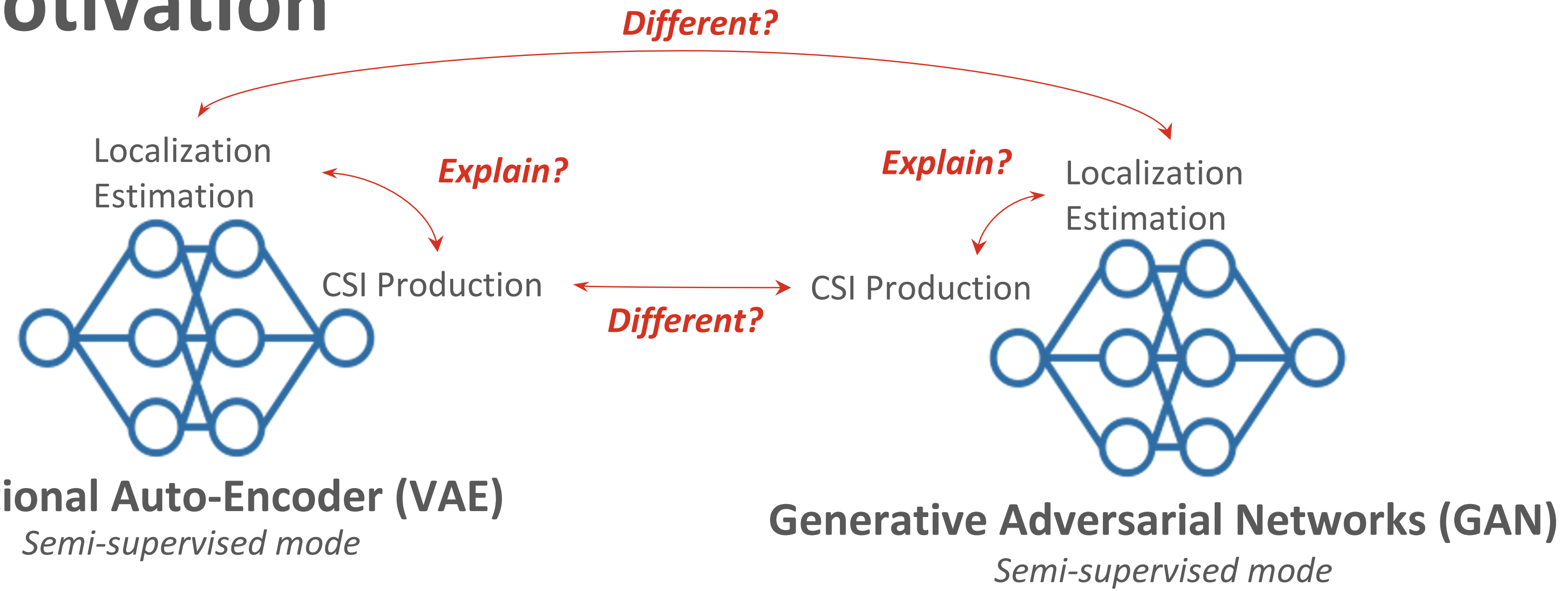
unlabeled CSI
(x,)

Sounds interesting!
Give it a try!

How to *semi-supervised*?

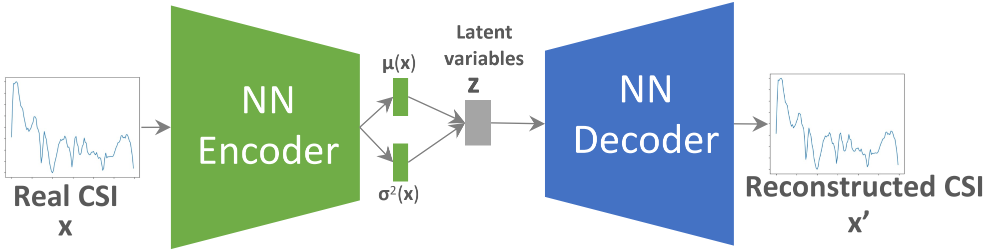


Our motivation



Semi-Supervised Variational Auto-Encoder (VAE)

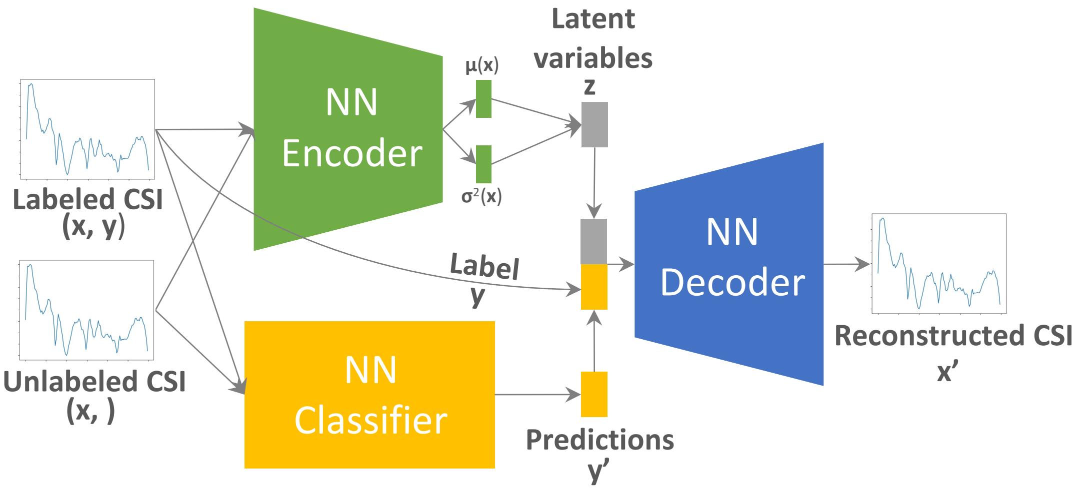
This is an ordinary VAE*.



This is an ordinary classifier.

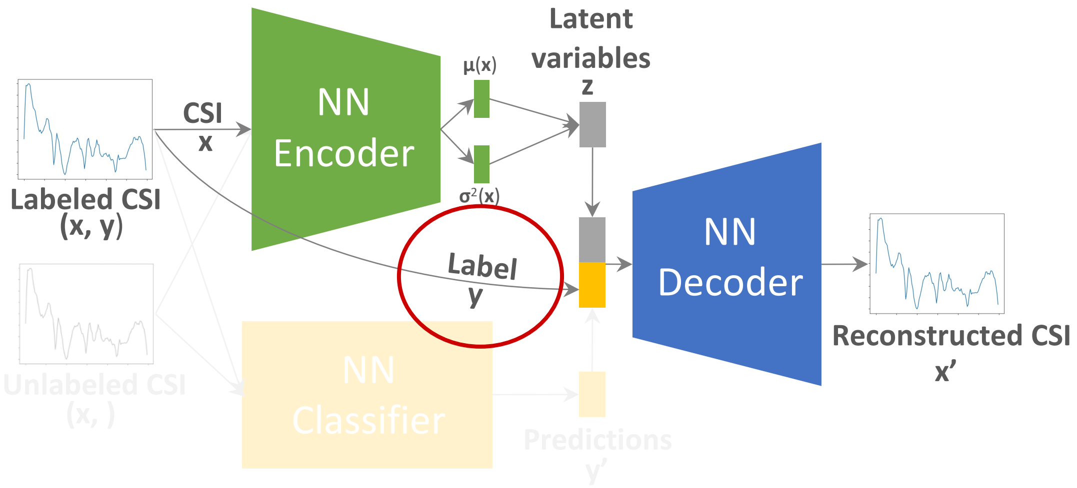
*D. P. Kingma and M. Welling, "Auto-encoding variational bayes," in Proc. 2nd International Conference on Learning Representations, ICLR, 2014.

This is the *semi-supervised* VAE*.

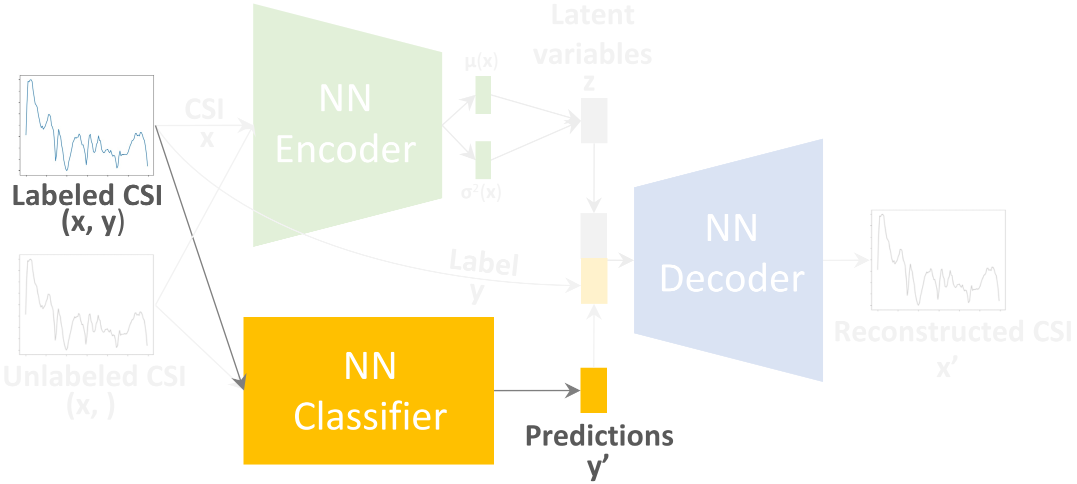


*D. P. Kingma, S. Mohamed, D. J. Rezende, and M. Welling, "Semisupervised learning with deep generative models," in Proc. Neural Information Processing Systems Conference, NeurIPS, 2014.

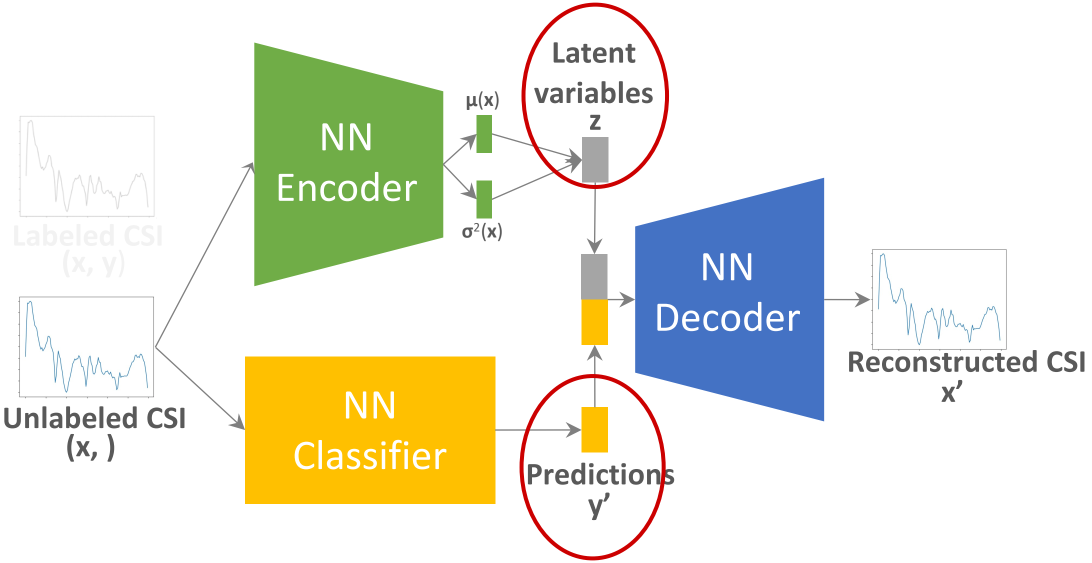
Train the *semi-supervised* VAE with *labeled* CSI.



Train the *semi-supervised* VAE with *labeled* CSI.

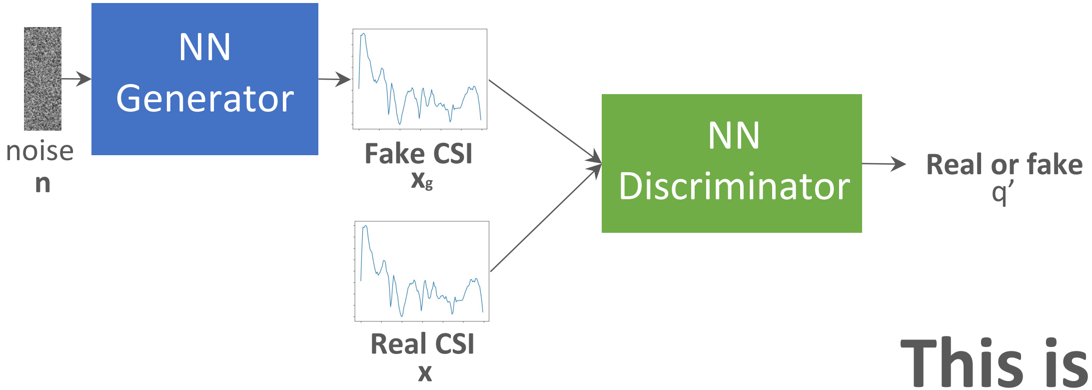


Train the *semi-supervised* VAE with *unlabeled* CSI.



Semi-Supervised Generative Adversarial Network (GAN)

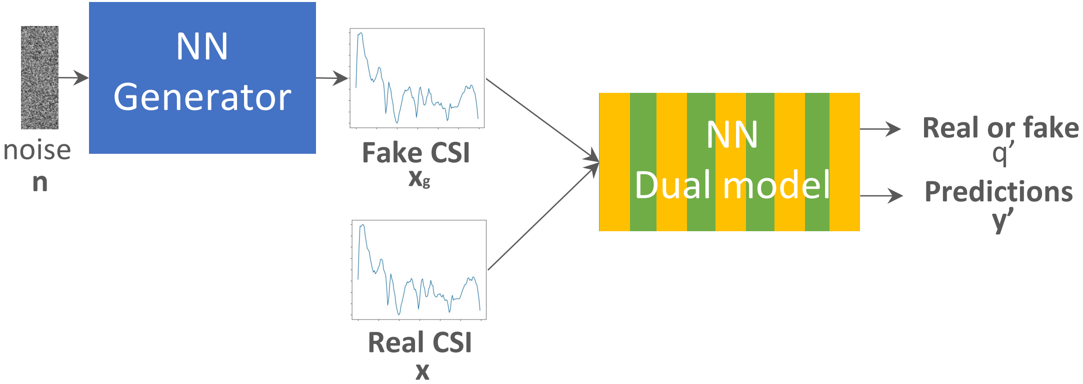
This is an ordinary GAN*.



This is an ordinary classifier.

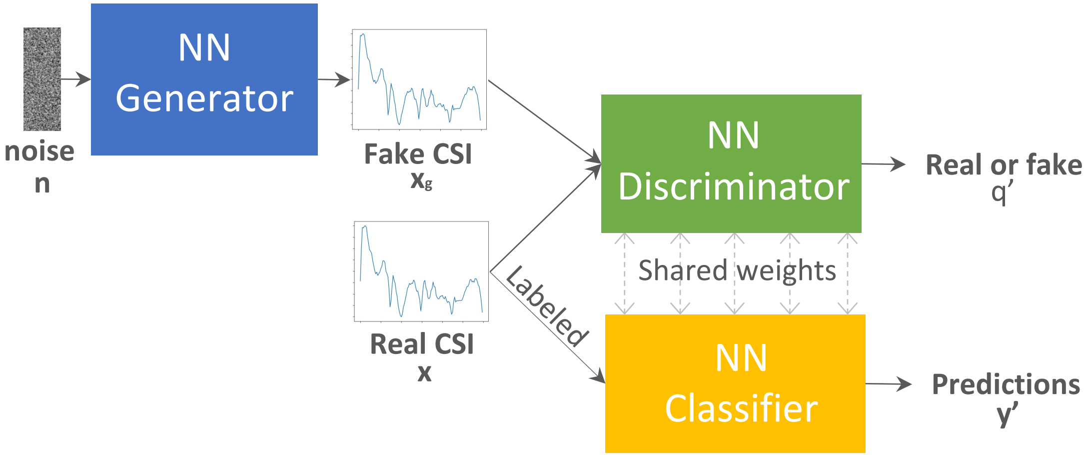
*I. Goodfellow, J. Pouget-Abadie, M. Mirza, B. Xu, D. Warde-Farley, S. Ozair, A. Courville, and Y. Bengio, “Generative adversarial nets,” in Proc. Advances in Neural Information Processing Systems 27, NeurIPS, 2014.

This is the *semi-supervised* GAN*.



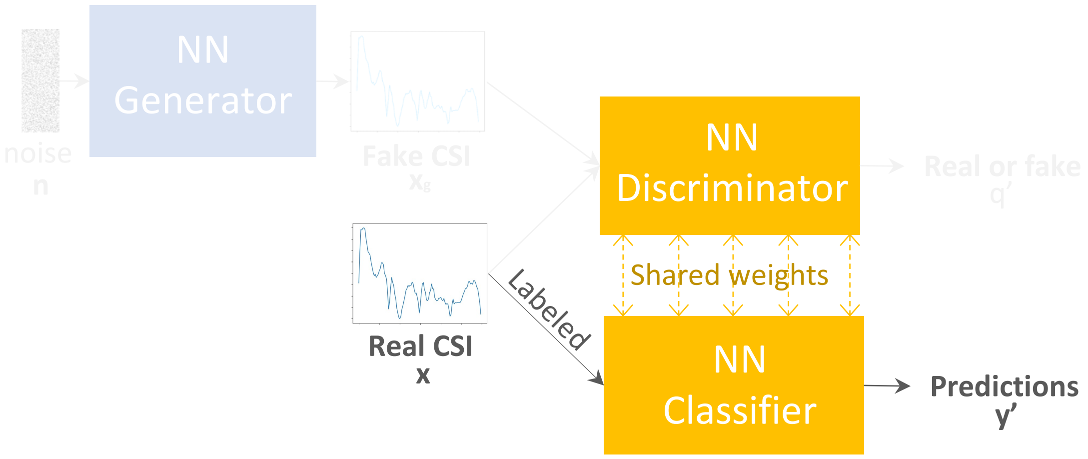
*A. Odena, "Semi-supervised learning with generative adversarial networks," in Proc. Workshop on Data-Efficient Machine Learning, ICML, 2016

Consider the two model with *shared weights*.

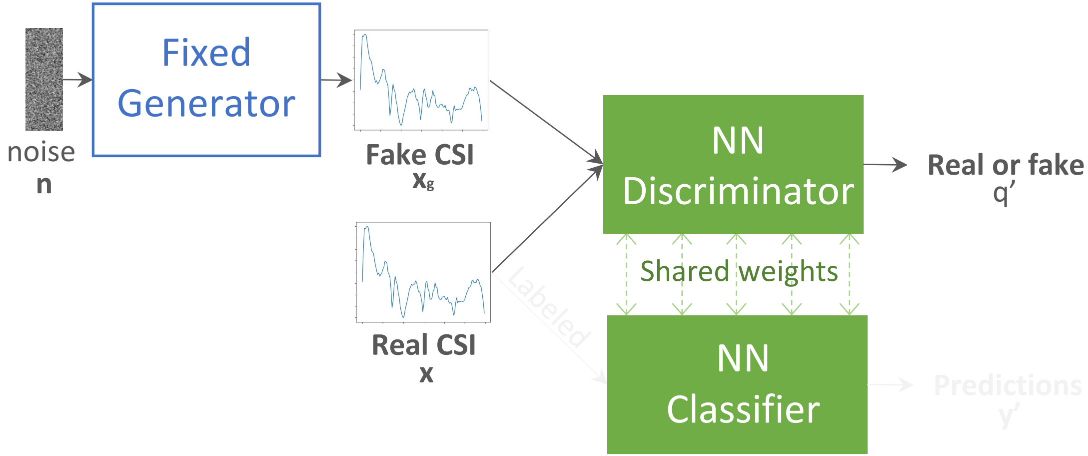


T. Salimans et al, “Improved techniques for training GANs, in Proc. Neural Information Processing Systems Conference, NeurIPS, 2016

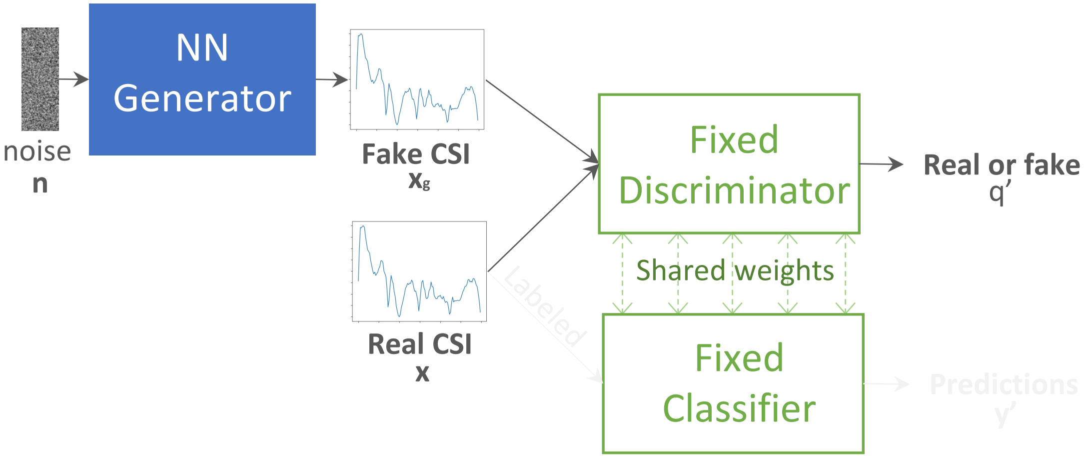
Train the *semi-supervised* GAN with *labeled* CSI.



Train the *semi-supervised GAN* with *unlabeled* CSI.



Train the *semi-supervised GAN* with *unlabeled* CSI.



Scenario 1

Conference Room

Number of locations (M)

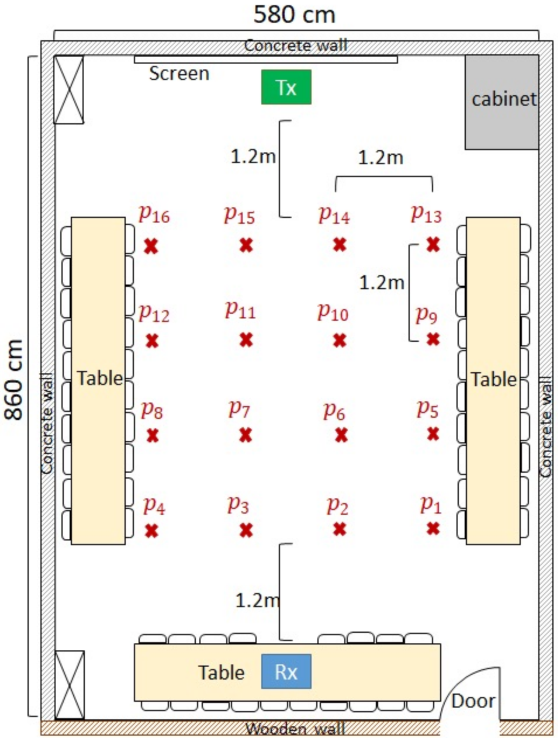
16

Training CSI

400 per location

Testing CSI

200 per location



All the indoor environment are at Research Center for Information Technology Innovation, Academia Sinica, Taiwan.

Scenario 2

Lounge

Number of locations (M)

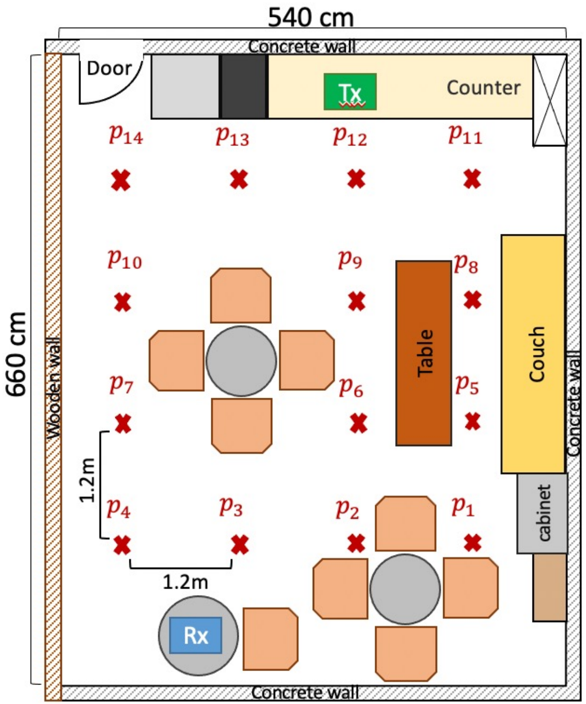
14

Training CSI

768 per location

Testing CSI

164 per location



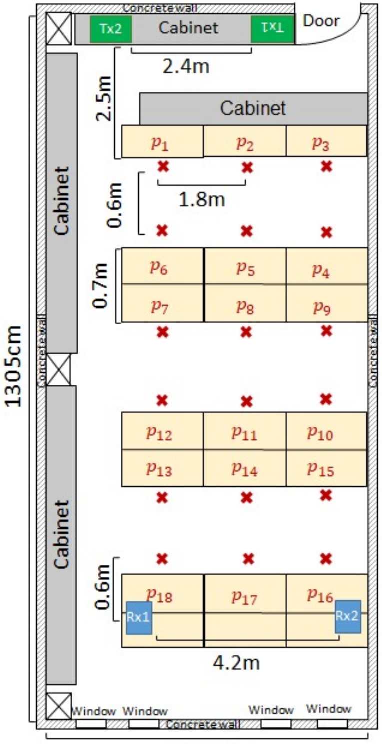
All the indoor environment are at Research Center for Information Technology Innovation, Academia Sinica, Taiwan.

Scenario 3
Office

Number of locations (M)
18

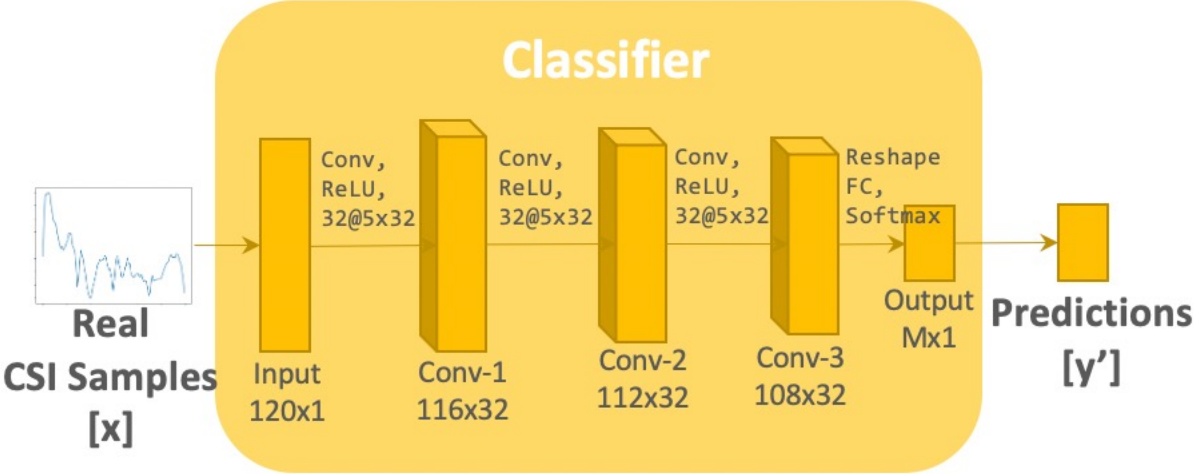
Training CSI
400 per location

Testing CSI
100 per location

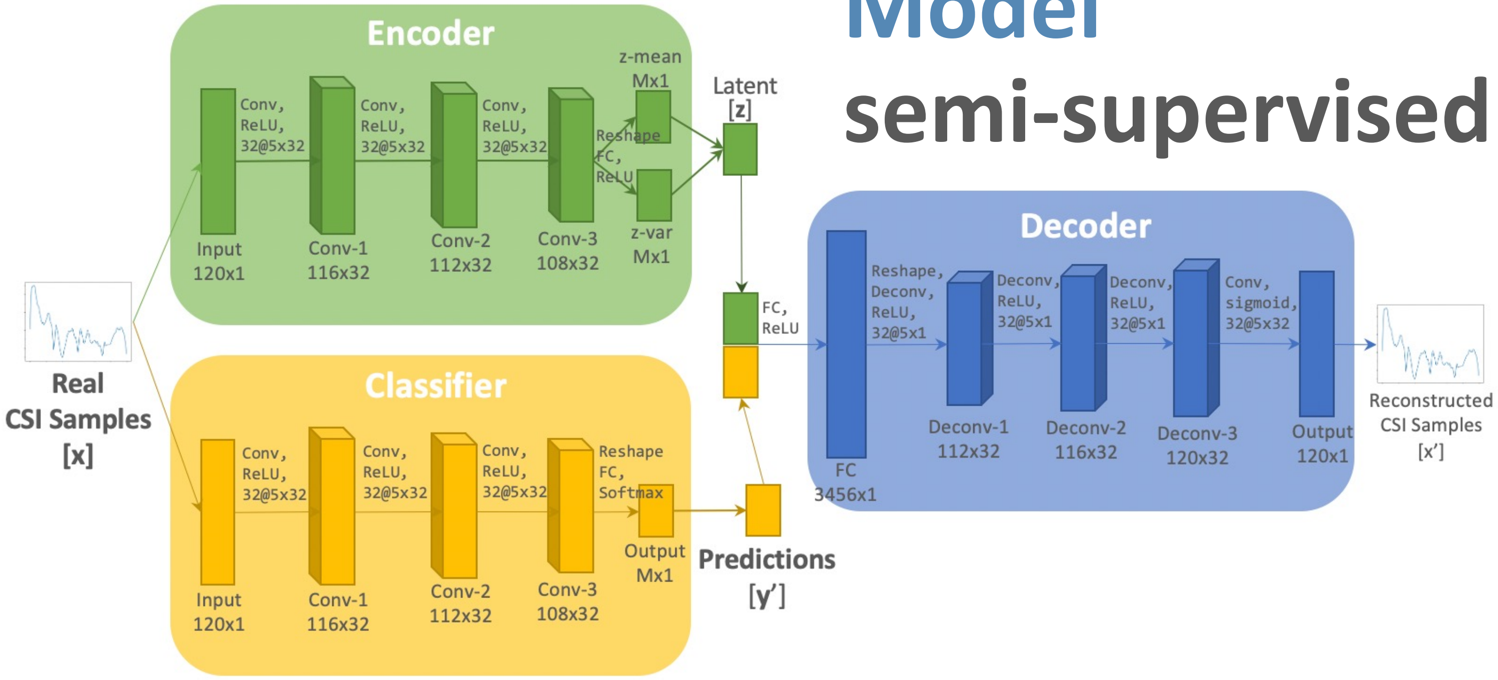


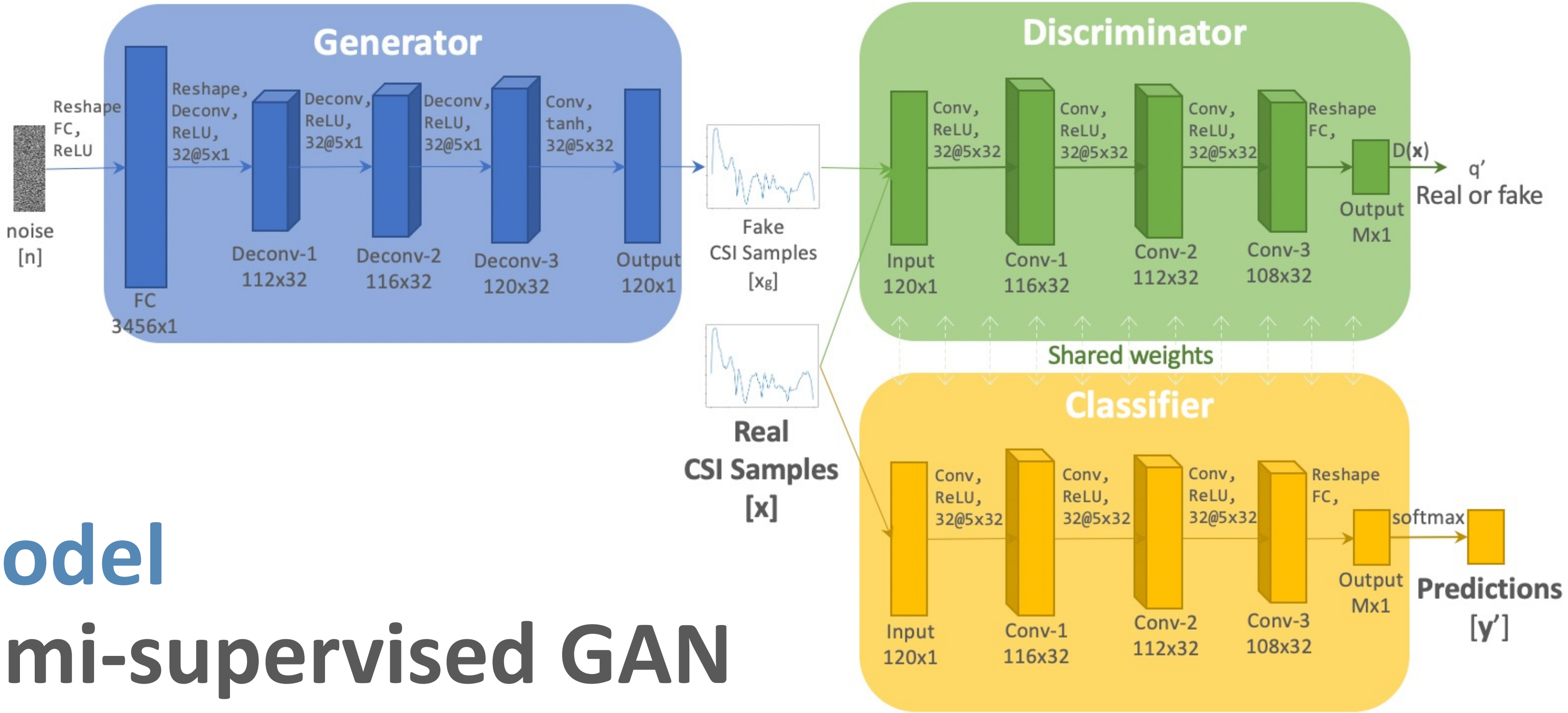
All the indoor environment are at Research Center for Information Technology Innovation, Academia Sinica, Taiwan.

Model
fully-supervised CNN



Model
semi-supervised VAE





Model
semi-supervised GAN

Comparison: Localization Performance

More labels

Scenario 1 Conference Room				Scenario 2 Lounge				Scenario 3 Office			
L	CNN	VAE	GAN	L	CNN	VAE	GAN	L	CNN	VAE	GAN
16	50.9%	61.7%	65.8%	14	39.9%	22.2%	35.6%	36	49.0%	64.4%	66.7%
32	63.2%	58.5%	67.0%	28	52.8%	31.4%	40.7%	72	66.9%	70.4%	70.4%
160	75.1%	73.5%	78.5%	140	70.5%	52.2%	55.4%	144	81.2%	78.9%	85.1%
3200	81.9%	72.7%	77.5%	5376	73.0%	50.5%	58.2%	3600	90.0%	81.1%	87.1%
6400	82.1%	73.0%	77.1%	10752	74.0%	62.7%	62.0%	7200	92.1%	87.1%	83.7%

*The performance is represented by the overall classification accuracy.

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32	63.2%	58.5%	67.0%	28	52.8%	31.4%	40.7%	72	66.9%	70.4%	70.4%
160	75.1%	73.5%	78.5%	140	70.5%	52.2%	55.4%	144	81.2%	78.9%	85.1%
3200	81.9%	72.7%	77.5%	5376	73.0%	50.5%	58.2%	3600	90.0%	81.1%	87.1%
6400	**82.1%**	**73.0%**	**77.1%**	**10752**	**74.0%**	**62.7%**	**62.0%**	**7200**	**92.1%**	**87.1%**	**83.7%**

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+ 4.1%

+ 13.4%

+ 3.3%

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6400	82.1%	73.0%	77.1%	10752	74.0%	62.7%	62.0%	7200	92.1%	87.1%	83.7%

− 11.0%

− 9.1%

+ 14.9%

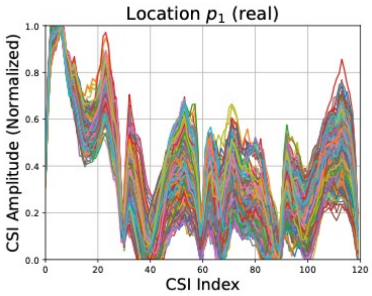
− 4.3%

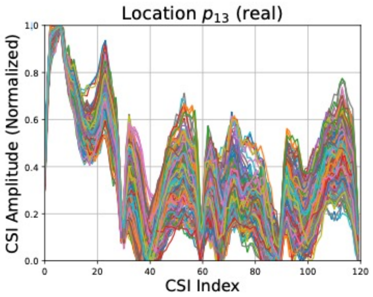
+ 17.7%

*The performance is represented by the overall classification accuracy.

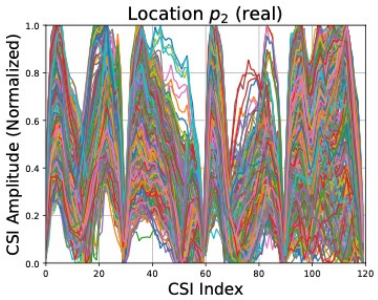
Comparison: The Real CSI

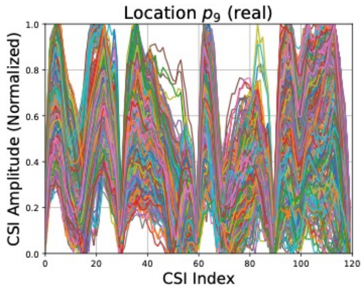
Scenario 1 Conference Room





Scenario 2 Lounge



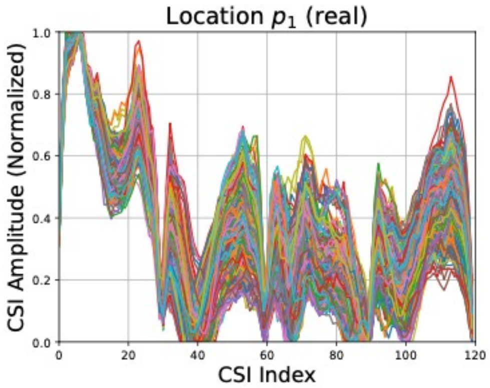


More noisy!

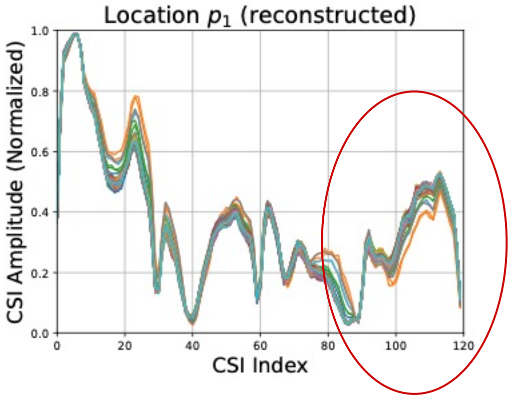
Introduction Methods Experiment **Discussion** Conclusion

Comparison: Generative Performance

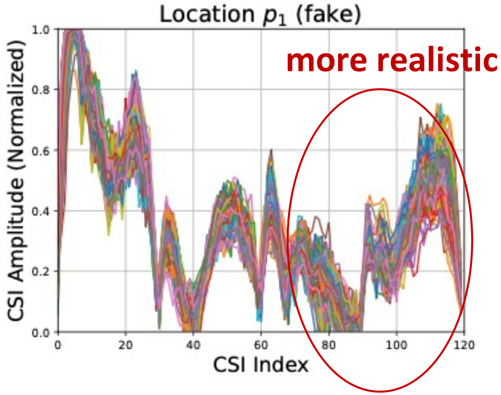
Scenario 1 Conference Room



Real CSI



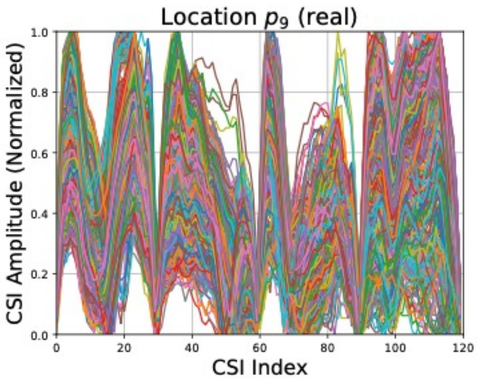
VAE



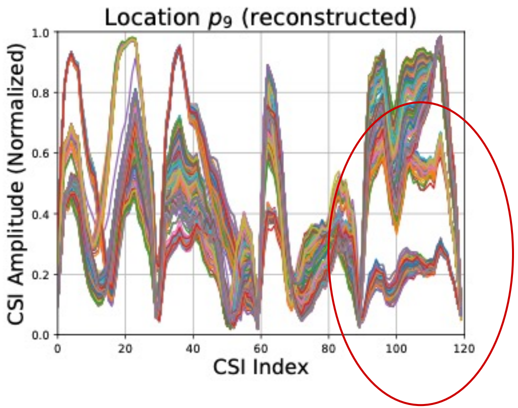
GAN

Comparison: Generative Performance

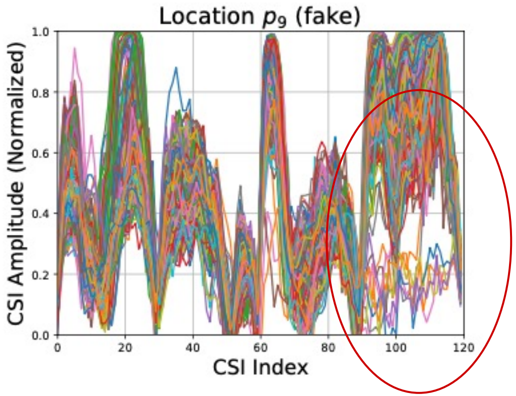
Scenario 2 Lounge



Real CSI



VAE



GAN

1. Semi-supervised VAE and GAN generally exhibit advantages over supervised CNN in the few labeled data regime, where GAN outperforms VAE.

2. Noisy CSI data could affect semi-supervised learning more negatively than supervised learning.

3. The comparative performance of semi-supervised VAE and GAN may be attributed to their different generative mechanisms and different generative results.

Thank you for your attention!

Q&A

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