Supervised learning to approximate model observer in task-based measure of image quality (IQ).

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TASK-BASED IQ APPROACH

Imaging system1, Observer1,…

Imaging system2, Observer2,…

Observer
Human Observer (HumO) or Numerical Observer (NO)

Task
Detection of tumor, localization of lesion,…

FOM
FOM_{IS1} VS FOM_{IS2}
FOM_{HO} VS FOM_{NO}

Comparison of FOMs

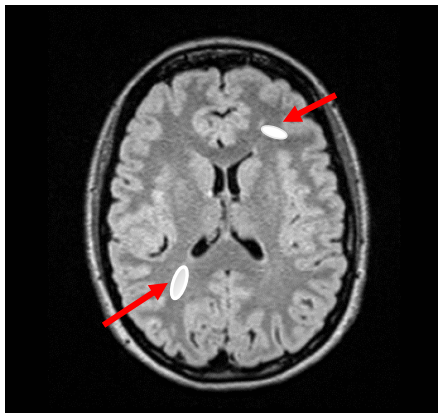
Better FOM
=
Best Imaging System

Tasks

Covid
(covid-CT database)

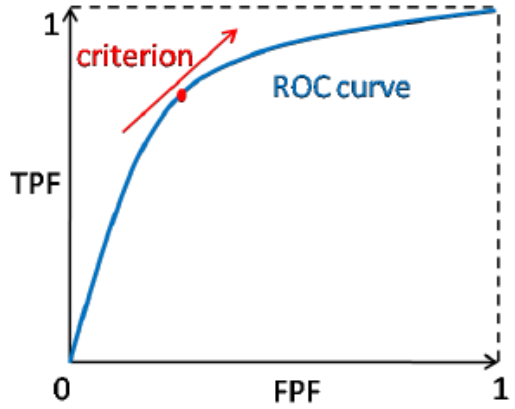
Non covid
(covid-CT database)

Detection



Multiple sclerosis **detection/localisation**

FOM



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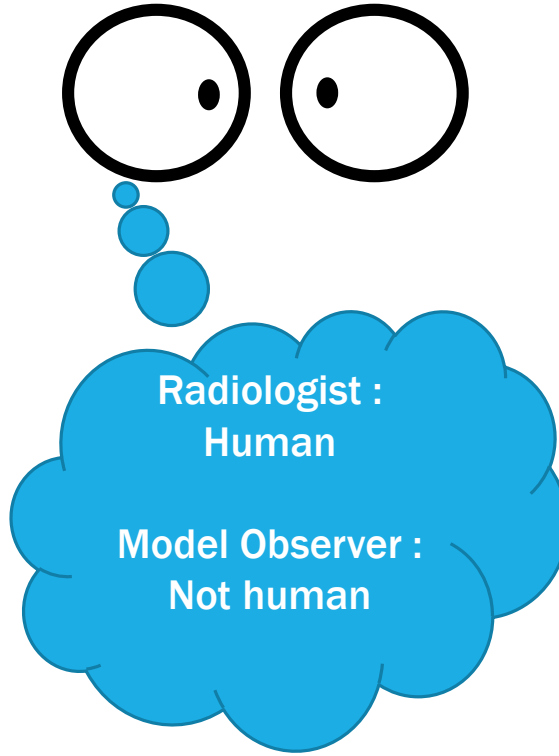
THE OBSERVER

$$H_0 : \mathbf{g} = \mathcal{H}\mathbf{f}_b + \mathbf{n} \equiv \mathbf{b} + \mathbf{n},$$
$$H_1 : \mathbf{g} = \mathcal{H}(\mathbf{f}_b + \mathbf{f}_s) + \mathbf{n} \equiv \mathbf{b} + \mathbf{s} + \mathbf{n},$$

$\mathcal{H}_0$: signal-absent

$\mathcal{H}_1$: signal-present

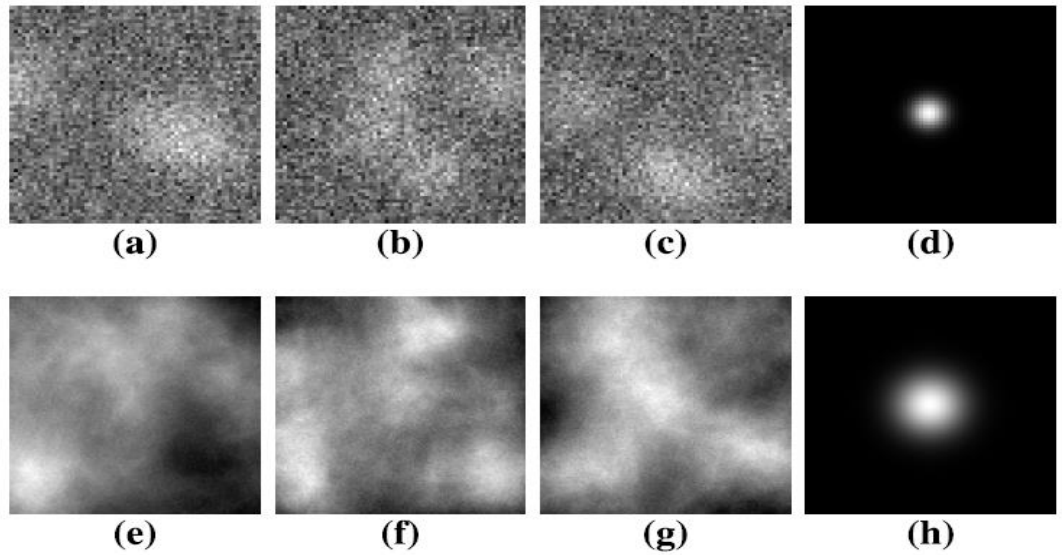


Model Observer(MO):

- The ideal observer IO :
  - IO test statistic : lot of stats
- Hotelling observer (HO) :
  - HO test statistic : stats again

THE DATA (SIMULATED)

	Detection task
signal-known-exactly (SKE)	Non-random process
signal-known statistically (SKS)	Random process
Background-known-exactly (BKE)	Non-random process
Background-known statistically (BKS)	Random process



(a)-(c) Signal-present measurements SKE/BKS detection task with the lumpy background model.
(e)-(g) Signal present measurements SKE/BKS detection task with the CLB model.

« The grond truth »

SKE-BKE	**IO & HO Analytically**
SKE_BKS (lumpy background)	**IO MCMC & HO Cov-matrix decomp**
SKS-BKS (lumpy background)	**IO MCMC & HO Cov-matrix decomp**
SKE-BKS (Clustered lumpy background)	**No IO & HO Cov-matrix decomp**

MCMC: Markov-chain Monte Carlo

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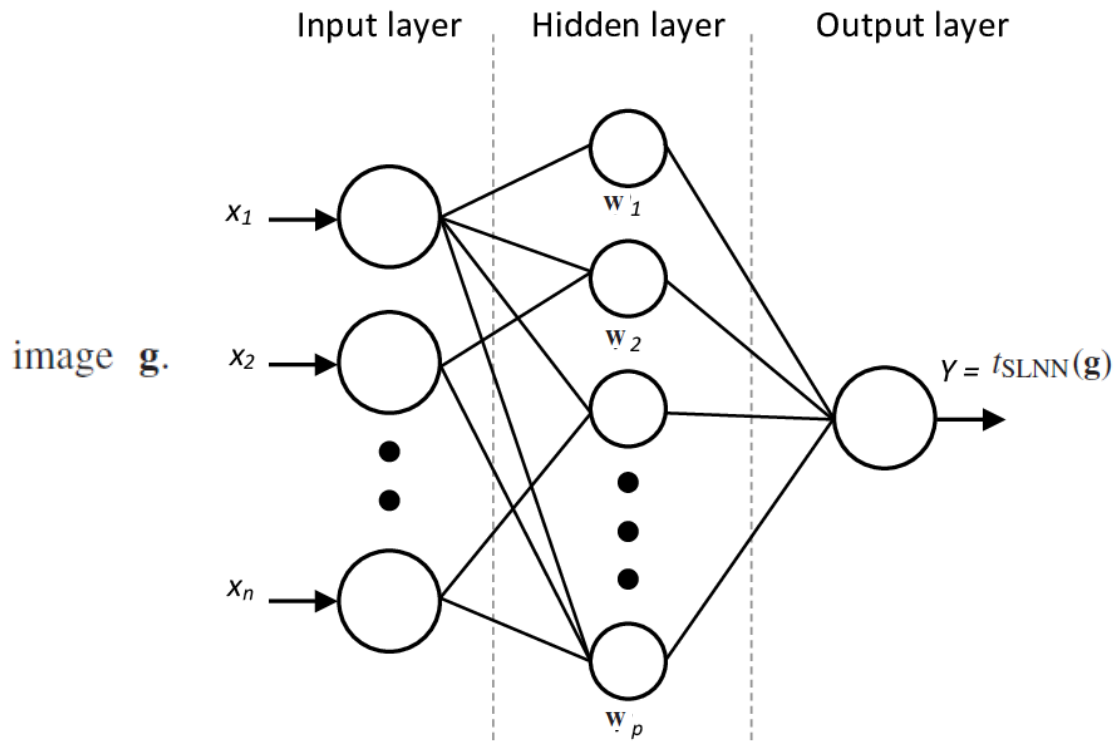
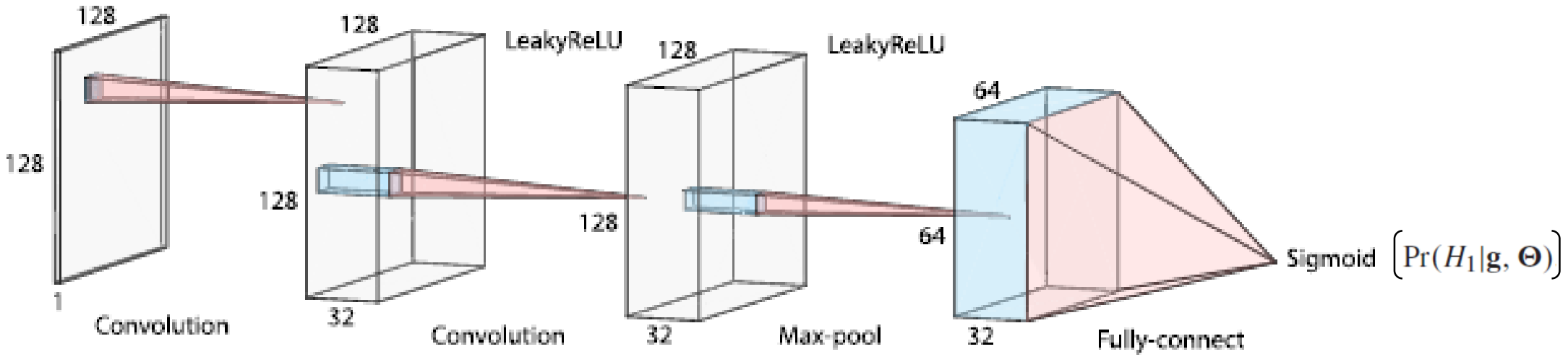


SLNN FOR APPROXIMATING THE HO TEST STATISTIC



CNN ARCHITECTURE EMPLOYED FOR APPROXIMATING THE IO TEST STATISTIC*

$\boldsymbol{\Theta}$: Neurons weights

*Trained on NVIDIA TITAN X GPU.

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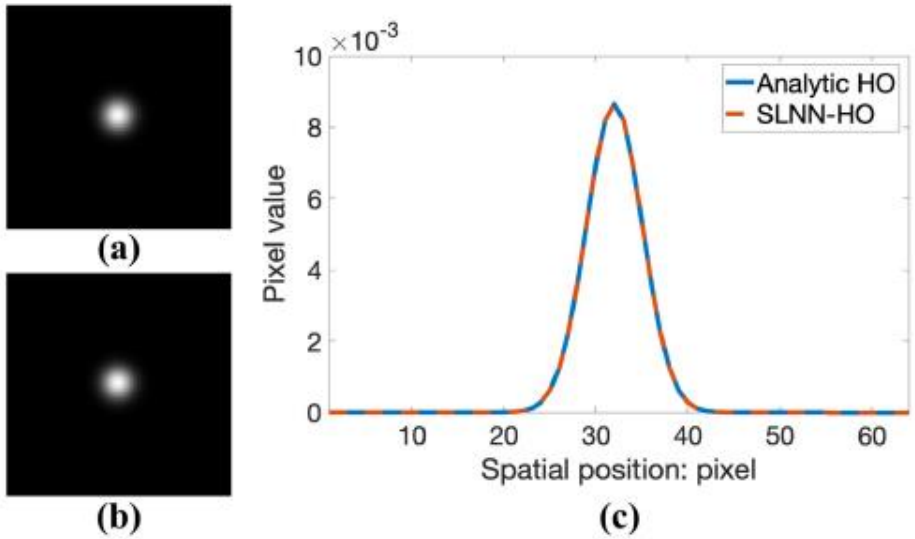
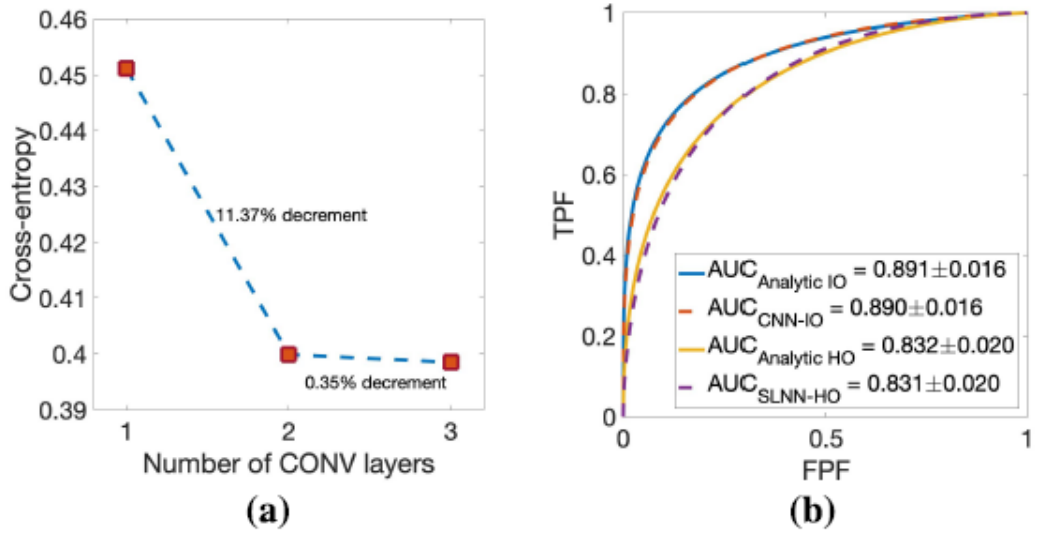
SKE/BKE Signal Detection Task

	Training dataset (mini-batches)	Validation /Testing dataset	Conv Layers	AUC	The efficiency	MSE (CNN-IO MCMC-IO)
HO approximation	1000	200	1 (SLNN)	0.83	-	-
IO approximation	100,000	200	3 (CNN)	0.89	99.14% (respect to IO)	0.3%



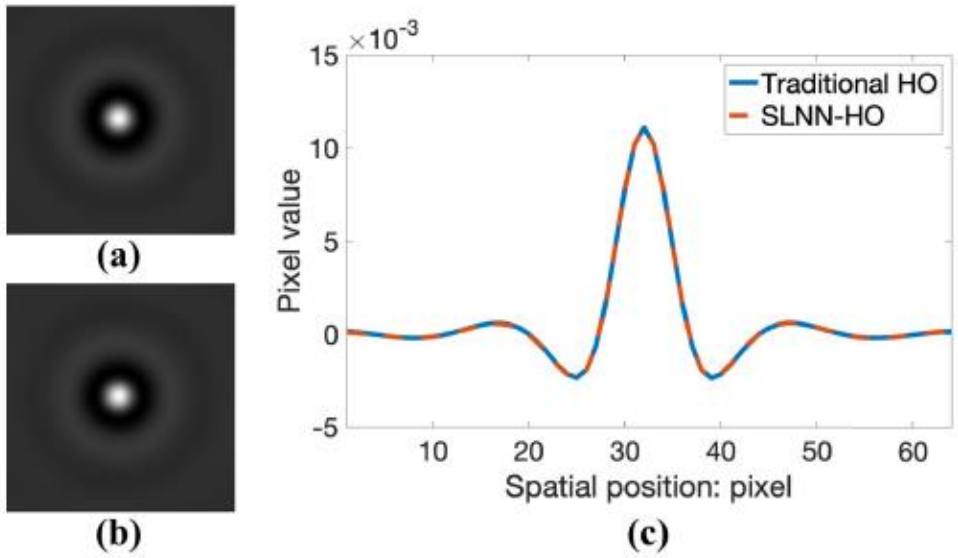
Comparison of the Hotelling template in the SKE/BKE case. (c) Center line profiles in (a) and (b).



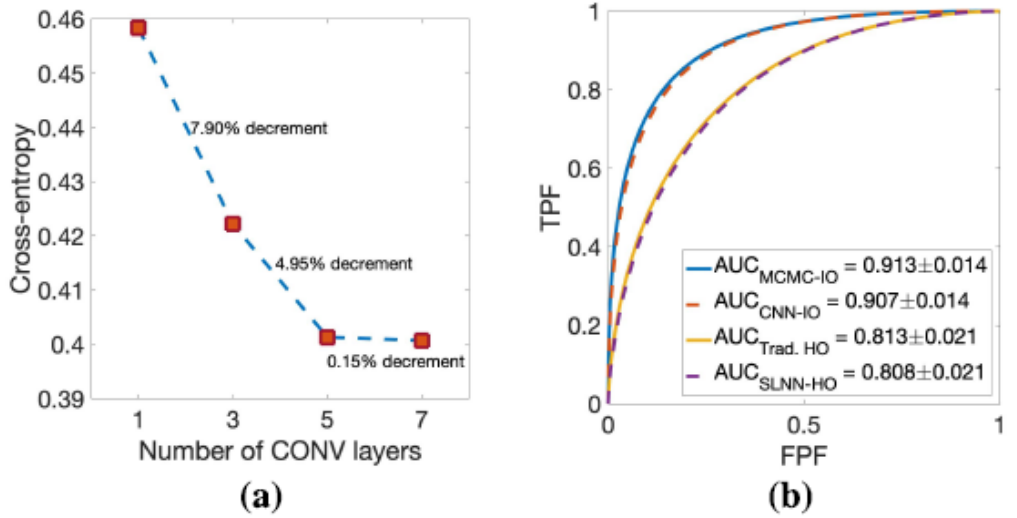
(a) Validation cross-entropy values of CNNs having one to three CONV layers.
(b) Testing ROC curves for the IO and HO approximations.

SKE/BKS Signal Detection Task With Lumpy Background

	Training dataset (mini-batches)	Validation /Testing dataset	Conv Layers	AUC	The efficiency	MSE (CNN-IO MCMC-IO)
HO approximation	1000 (2 epochs)	200	1 (SLNN)	0.808	–	–
IO approximation	100,000 (200 epochs)	200	7 (CNN)	0.907	94.64% (respect to MCMC-IO)	0.84%



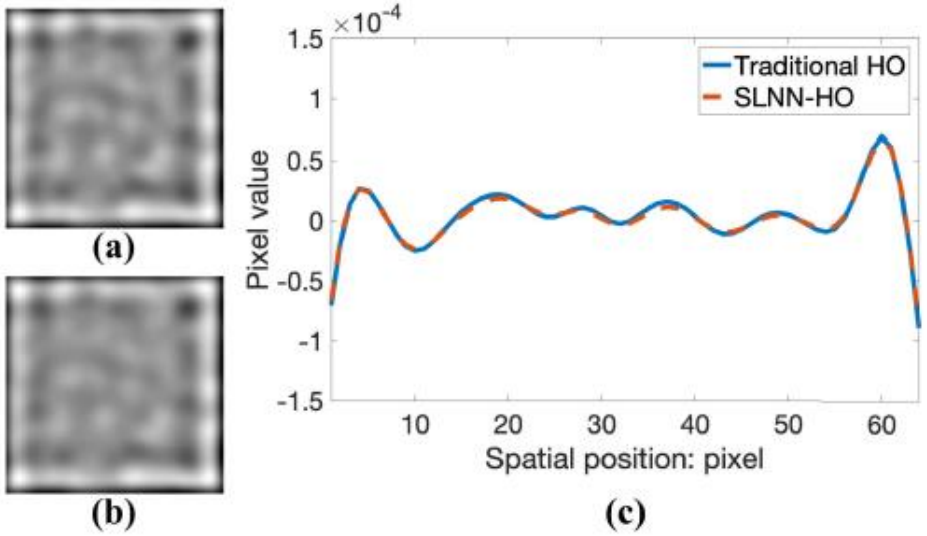
Comparison of the Hotelling template in the SKE/BKS case. (c) Center line profiles in (a) and (b).



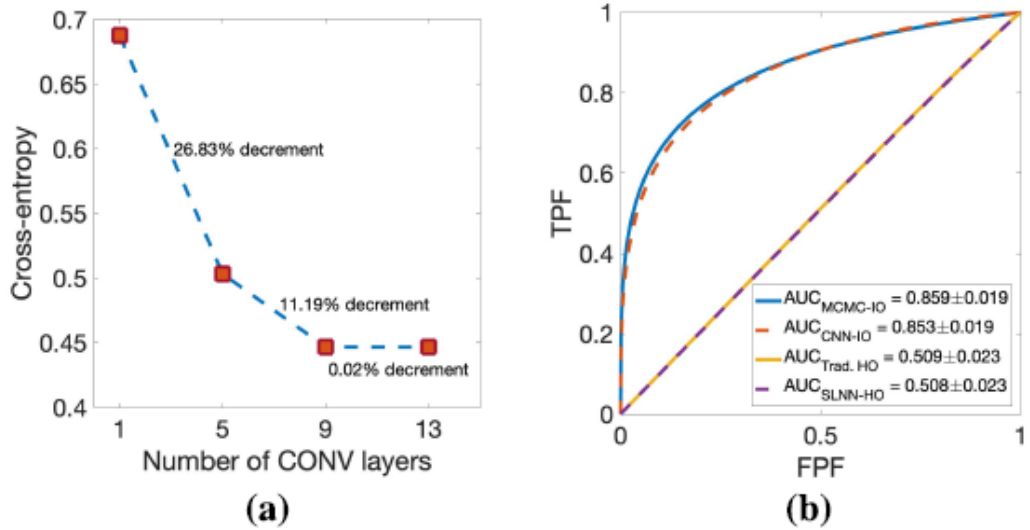
(a) Validation cross-entropy values of CNNs having one to seven CONV layers. (b) Testing ROC curves for the IO and HO approximations.

SKS/BKS Signal Detection Task With Lumpy Background

	Training dataset (mini-batches)	Validation /Testing dataset	Conv Layers	AUC	The efficiency	MSE (CNN-IO MCMC-IO)
HO approximation	1000 (2 epochs)	200	1 (SLNN)	0.508	–	–
IO approximation	300,000 (600 epochs)	200	13	0.853	95.14% (respect to MCMC-IO)	1.46%

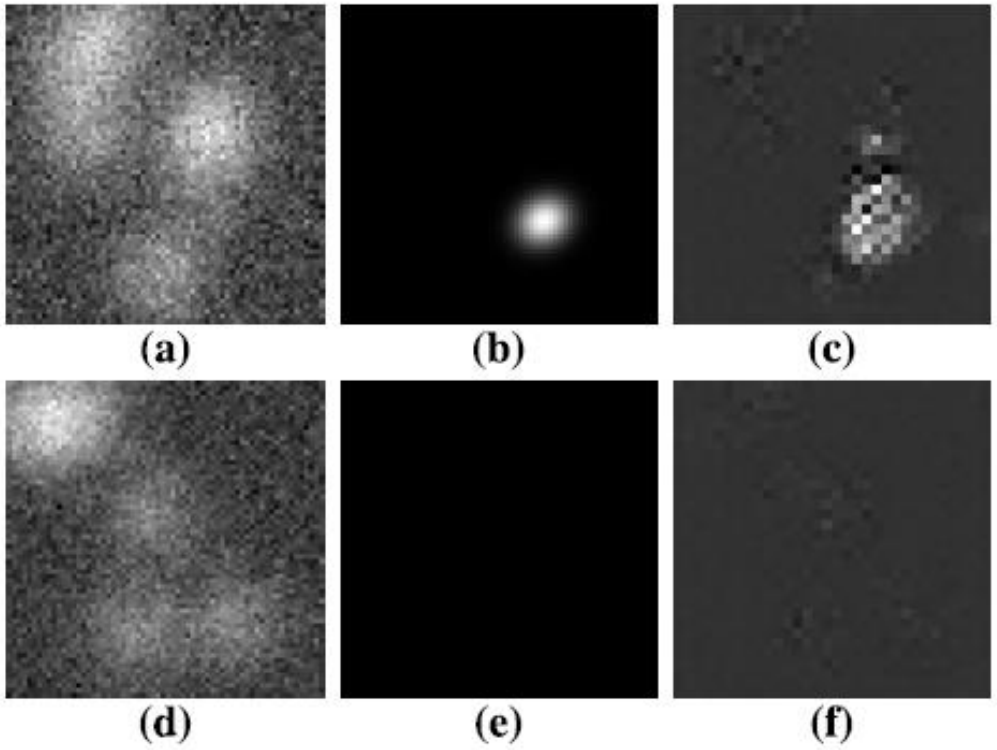


Comparison of the Hotelling template in the SKS/BKS case. (c) Center line profiles in (a) and (b).



(a) Validation cross-entropy values produced by CNNs having 1 to 13 CONV layers. (b) Testing ROC curves for the IO and HO approximations.

WHAT CNN VISUALISES?



(a) Signal-present measurements. (b) signal contained in (a). (c) The signal feature map corresponding to (a).(d) Signal-absent measurements. (e) signal absent in (d). (f) The signal feature map corresponding to (d). In the signal feature maps, the regions around the signals were activated by the CNN.

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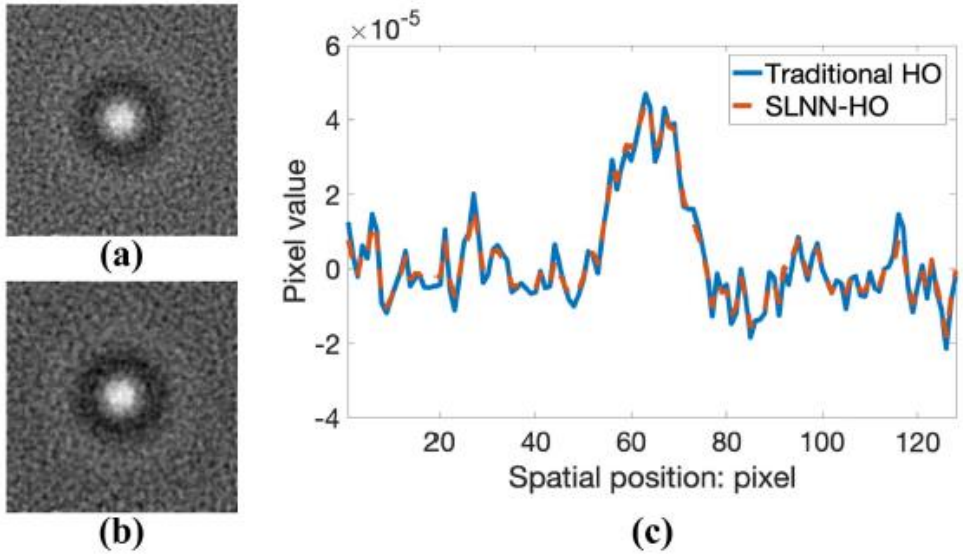
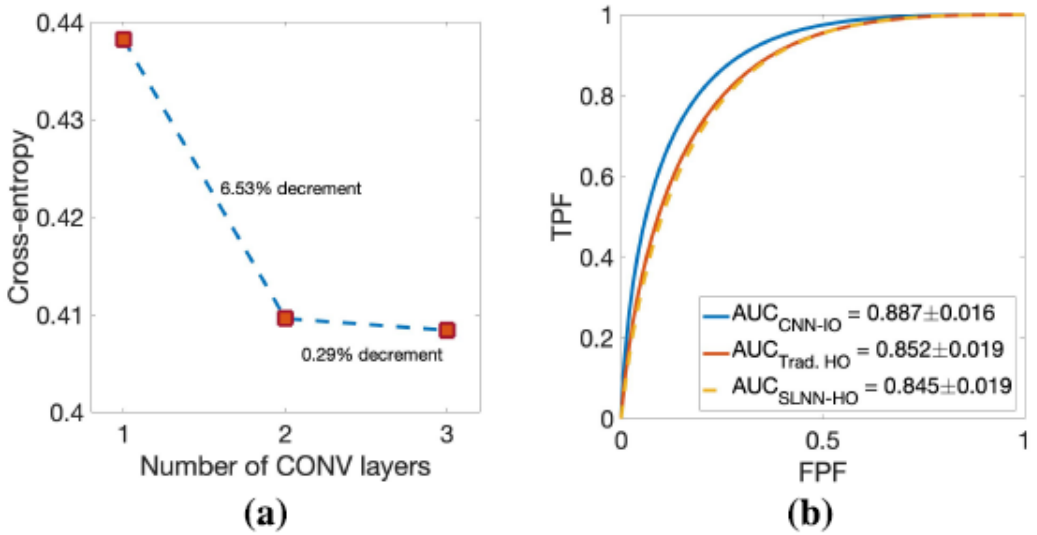
SKS/BKS Signal Detection Task With Clustered Lumpy Background Lumpy Background

	Training dataset (mini-batches)	Validation /Testing dataset	Conv Layers	AUC	The efficiency	MSE
HO approximation	40000 (20 epochs)	200	1 (SLNN)	0.845	–	–
IO approximation	100,000 (50 epochs)	200	3 (CNN)	0.887	Not feasible	Not feasible



Comparison of the Hotelling template. (c) Center line profiles in (a) and (b).



(a) Validation cross-entropy values of CNNs having one to three CONV layers. (b) Testing ROC curves for the IO and HO approximations.

CONCLUSION

They explored a family of CNNs that possess different numbers of CONV layers.
By adding more CONV layers, the representation capacity of the network is increased and the test statistic can be more accurately approximated.

The study does not provide methods for determining other architecture parameters such as the number of FC layers and the size of convolutional filters.

NEEDS

Approximating IOs & HOs by use of experimental images

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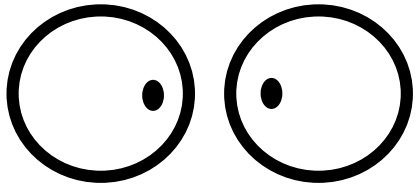
THATS IT!

THANK YOU



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