DropConnect Is Effective in Modeling Uncertainty of Bayesian Deep Networks

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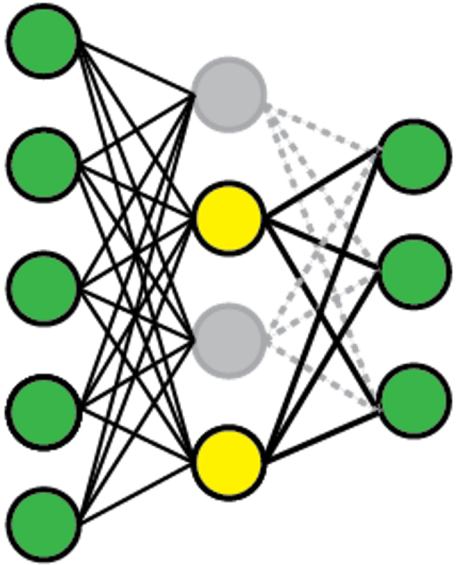
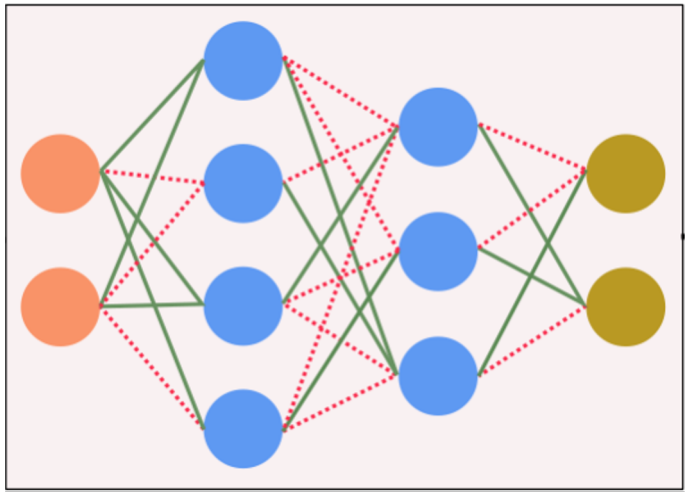
Dropout vs. DropConnect





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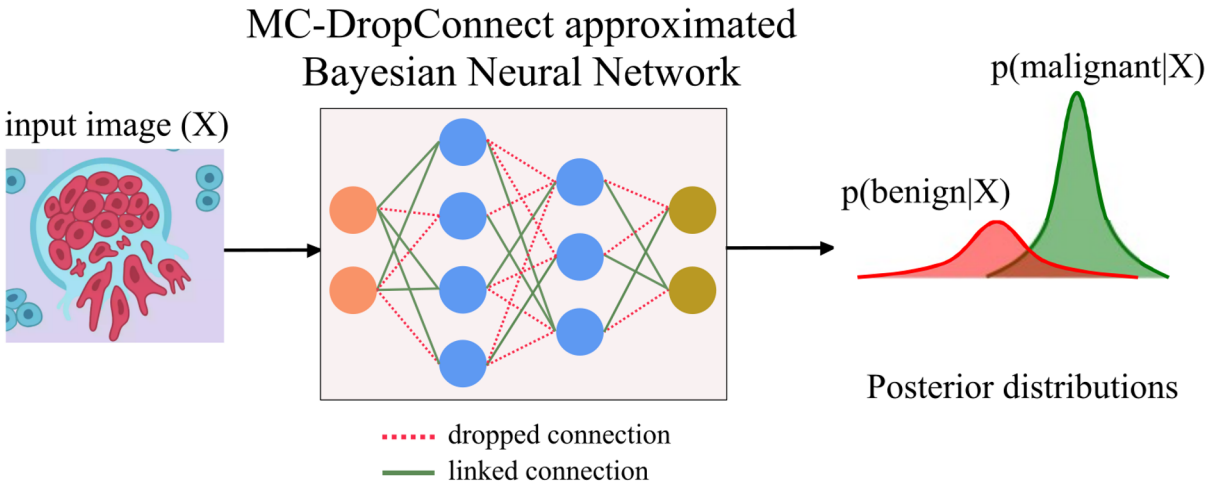
DropConnect as Bayesian Approximations

- Generalized version of MC-Dropout
- Apply the Bernoulli variational distribution directly to the model weights



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MC-Dropout vs. MC-Dropconnect

- Compare in terms of:
  - Prediction accuracy (Ground truth label available; simple!)
  - Uncertainty estimation quality! (No ground truth for uncertainty values; How?!)
- Introduce measures to quantify the uncertainty estimation performance

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Uncertainty Evaluation Metrics

- When making prediction, there are 4 possible scenarios:
  1. Incorrect & uncertain (TP)
  2. Correct & certain (TN)
  3. Incorrect & certain (FN)
  4. Correct & uncertain (FP)

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Uncertainty Evaluation Metrics

1. **Negative Predictive Value (NPV):**

   If a model is certain about its prediction, the prediction should be correct

$$\text{NPV} = P(\text{correct} \,|\, \text{certain}) = \frac{P(\text{correct}, \text{certain})}{P(\text{certain})} = \frac{\text{TN}}{\text{TN+FN}}$$

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Uncertainty Evaluation Metrics

2. **True Positive Rate (TPR):**

If a model is making an incorrect prediction, the uncertainty should be high.

$$\text{TPR} = P(\text{uncertain} \,|\, \text{incorrect}) = \frac{P(\text{uncertain}, \text{incorrect})}{P(\text{incorrect})} = \frac{\text{TP}}{\text{TP+FN}}$$

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Uncertainty Evaluation Metrics

3. **Uncertainty Accuracy (UA):**

$$\mathrm{UA} = \frac{\mathrm{TP}+\mathrm{TN}}{\mathrm{TP}+\mathrm{TN}+\mathrm{FP}+\mathrm{FN}}$$

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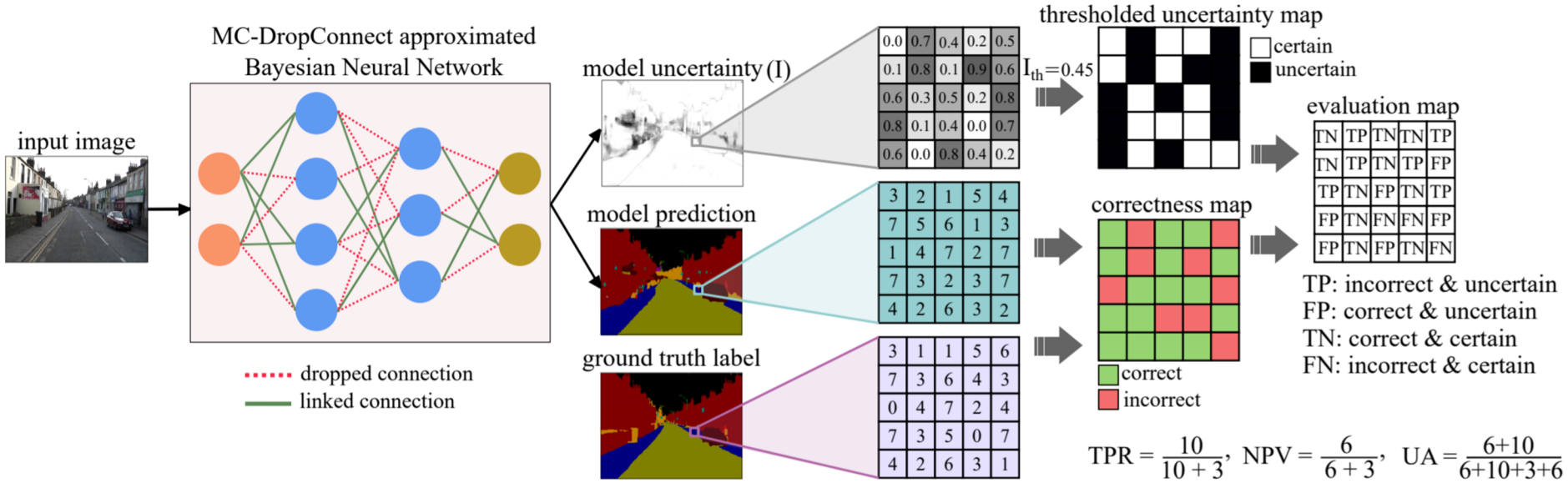
Example: in semantic segmentation setting



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Classification

TABLE I

TEST PREDICTION ERROR (%) AND UNCERTAINTY ESTIMATION PERFORMANCE OF THE LENET AND FCNET NETWORKS AND THEIR BAYESIAN ESTIMATES ON THE MNIST AND CIFAR-10 DATASETS.

		Prediction Error (%)		Uncertainty metrics AUC (%)		
		Standard	MC-sampling	TPR	NPV	UA
MNIST (LeNet-5)	None	0.99	-	-	-	-
	MC-Dropout	0.75	0.77	31.24	98.77	97.48
	MC-DropConnect	**0.70**	**0.57**	**41.67**	**99.57**	**98.87**
CIFAR-10 (FCNet)	None	12.00	-	-	-	-
	MC-Dropout	**10.92**	10.57	38.24	92.12	82.89
	MC-DropConnect	11.34	**10.15**	**40.29**	**94.31**	**87.27**

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Classification

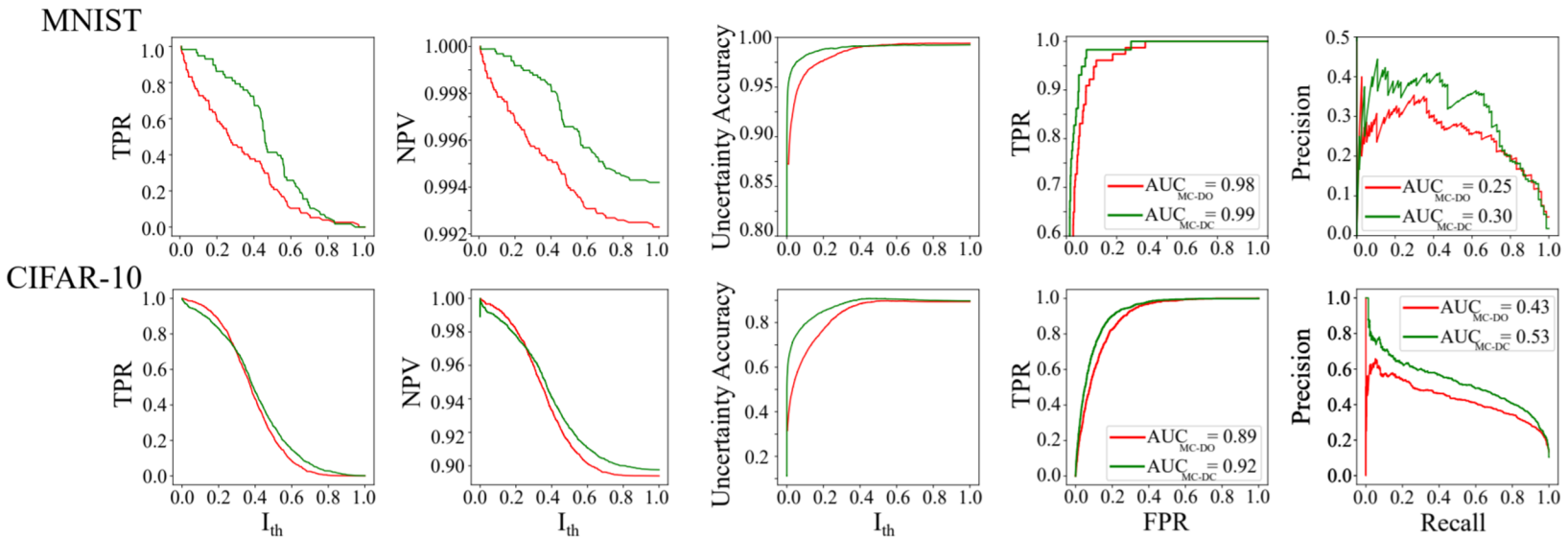

Fig. 2. **Illustrating the quantitative uncertainty estimation performance for the classification task using the proposed evaluation metrics.** Note that when varying the uncertainty threshold, our proposed MC-DropConnect approximated BNN (shown in green) generally performs better than MC-Dropout (shown in red) for both MNIST (Top) and CIFAR-10 (Bottom) datasets.

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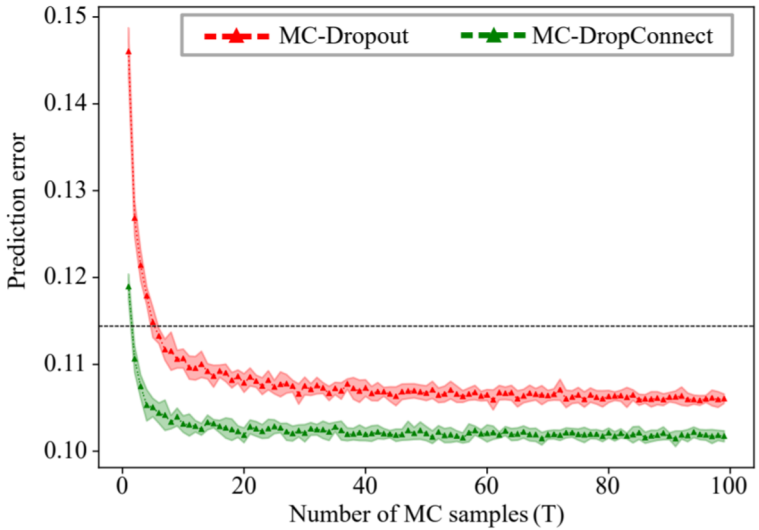

Fig. 6. **Test error of the FCNet on CIFAR-10 for different numbers of forward-passes in MC-Dropout and MC-DropConnect, averaged with 10 repetitions.** The shaded area around each curve shows one standard deviation. The black dotted line shows the test error for the same neural network with no sampling.

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Segmentation

TABLE II

QUANTITATIVE PREDICTION AND UNCERTAINTY ESTIMATION PERFORMANCE OF THE VARIOUS FRAMEWORKS ON THE CAMVID, CITYSCAPES, AND CT-ORGAN DATASETS. OUR QUANTITATIVE ANALYSES SUPPORT THE SUPERIOR PERFORMANCE OF THE MC-DROPCONNECT IN TERMS OF BOTH SEGMENTATION ACCURACY AND UNCERTAINTY ESTIMATION QUALITY.

Data (Model)	Uncertainty Estimation Method	Prediction Performance (%)			Uncertainty metrics AUC (%)		
		Pixel accuracy	Mean accuracy	Mean IOU	TPR	NPV	UA
CamVid (SegNet)	None	79.46	65.03	46.31	-	-	-
	MC-Dropout	80.99	65.46	47.31	17.23	82.48	80.18
	MC-DropConnect	**82.92**	**67.47**	**49.53**	**21.63**	**86.54**	**82.78**
CityScapes (ENet)	None	87.50	55.30	44.08	-	-	-
	MC-Dropout	87.38	56.35	44.11	6.12	88.67	84.89
	MC-DropConnect	**88.87**	**63.83**	**50.25**	**9.61**	**90.33**	**85.57**
CT-Organ (VNet)	None	95.19	96.44	65.49	-	-	-
	MC-Dropout	94.11	**97.73**	67.07	**10.81**	86.41	91.51
	MC-DropConnect	**97.90**	97.71	**72.77**	6.69	**87.03**	**92.59**

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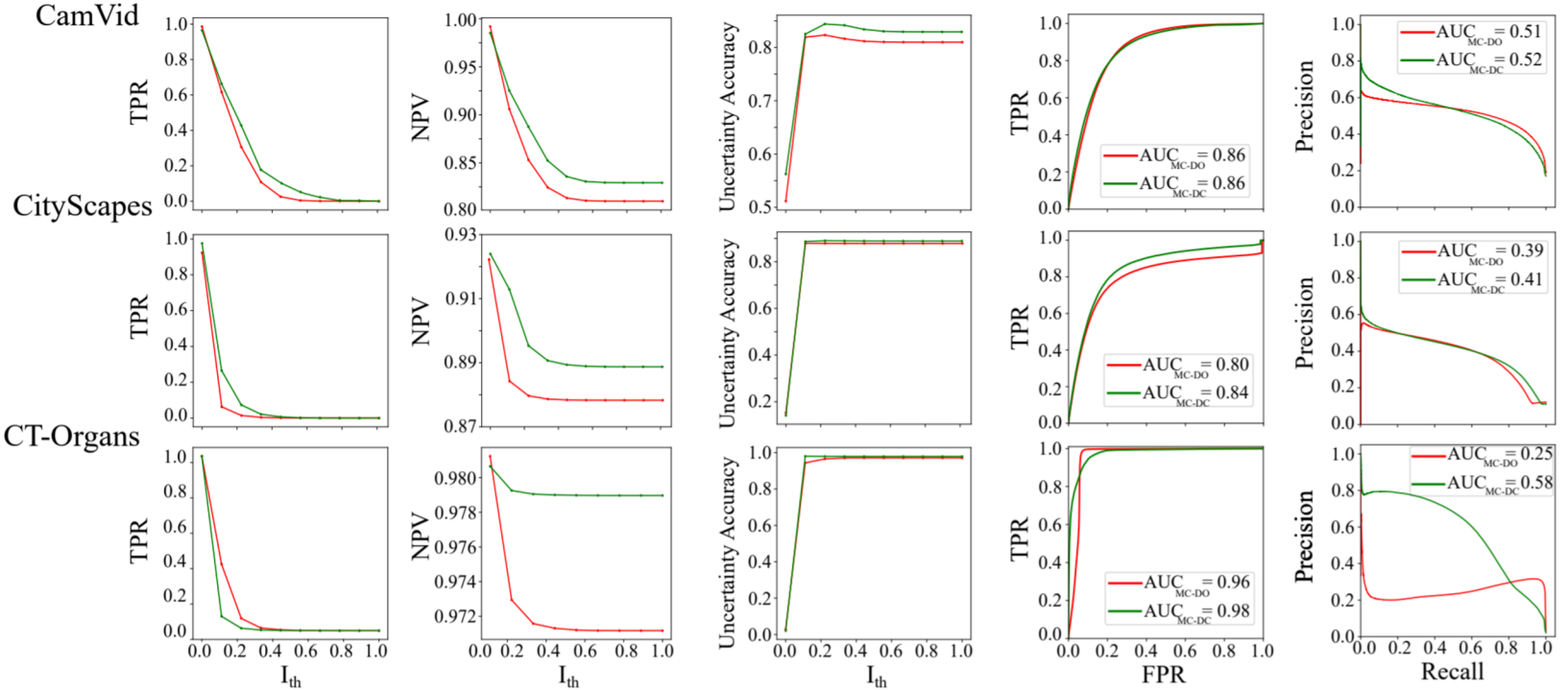
Segmentation



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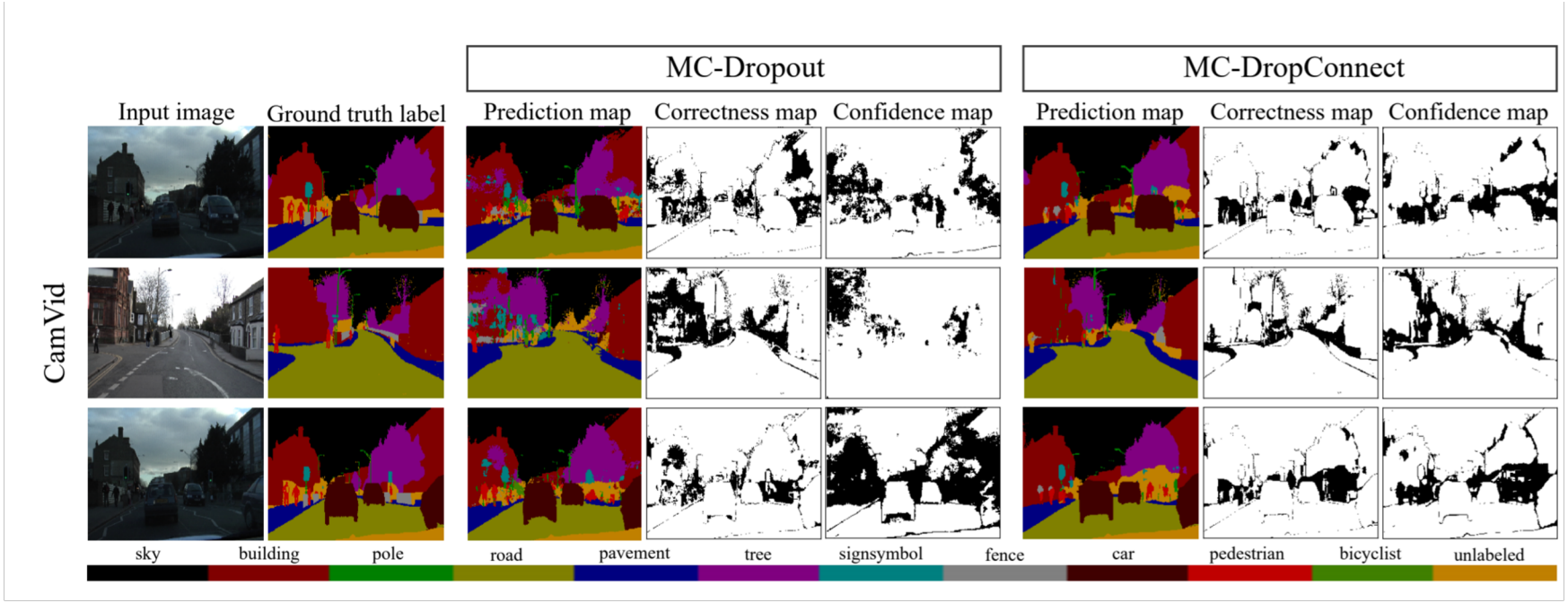

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