Bayesian SegNet:

Model Uncertainty in Deep Convolutional Encoder-Decoder Architectures for Scene Understanding

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http://mi.eng.cam.ac.uk/projects/segnet/

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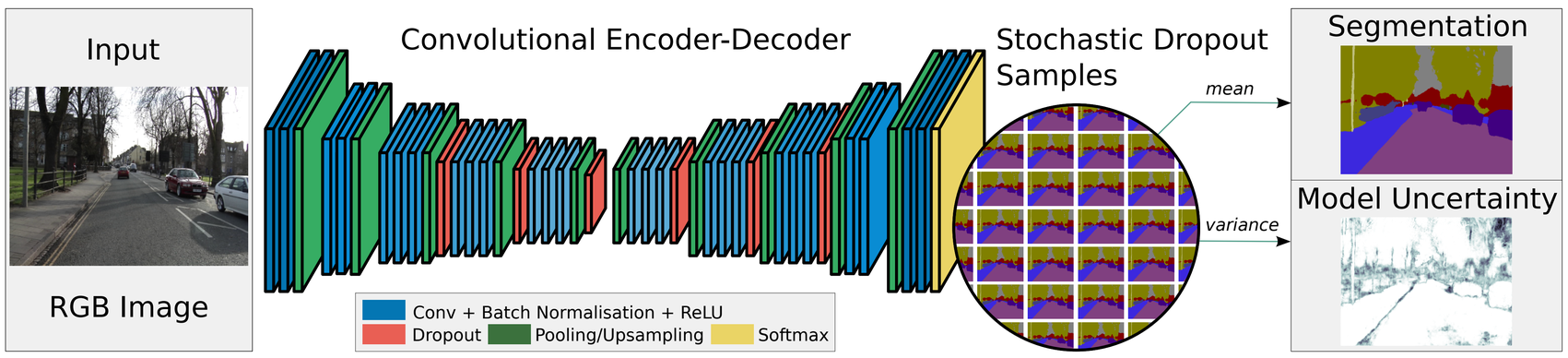
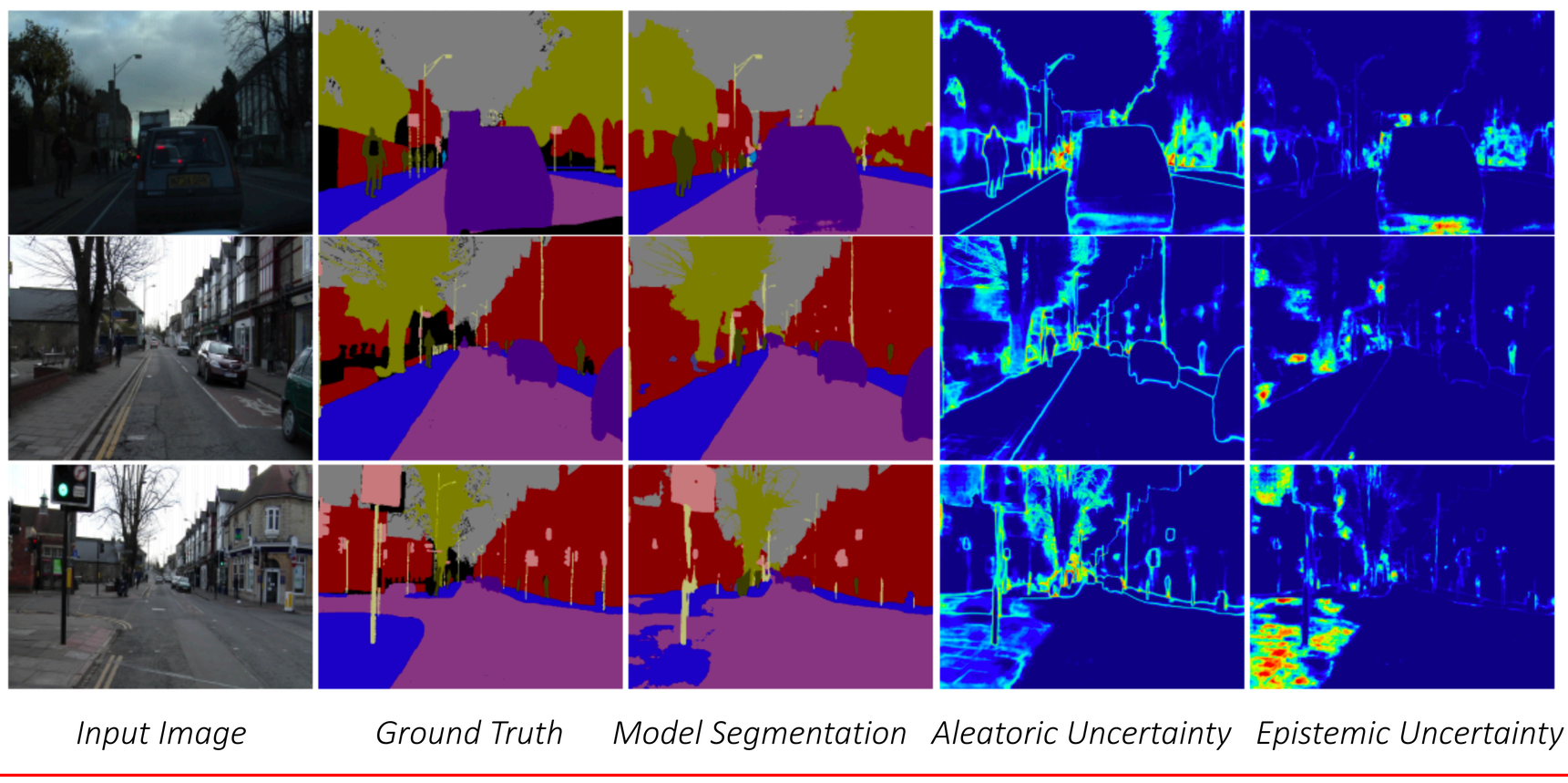
We use **Monte Carlo dropout sampling** at test time to generate a posterior distribution of pixel class labels.



Bayesian SegNet architecture

Model	Standard	Bayesian
DilationNet	71.3%	**73.1%**
FCN	62.2%	**65.4%**
SegNet	59.1%	**60.5%**

PASCAL VOC 2012
Test Server Performance



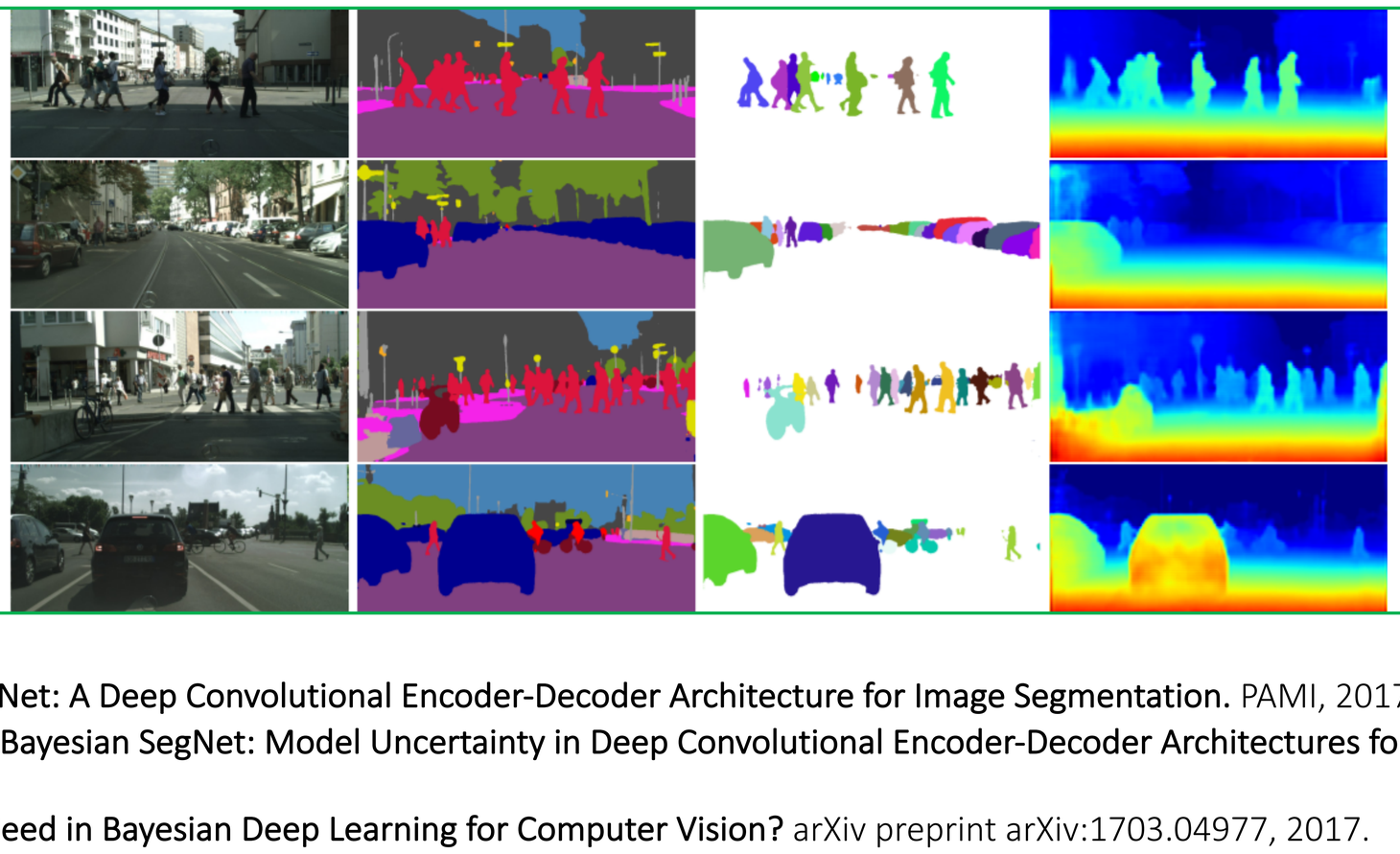
Input Image *Ground Truth* *Model Segmentation* *Aleatoric Uncertainty* *Epistemic Uncertainty*

Insights

- We can obtain **per-class model uncertainty estimates** for scene understanding models
- Bayesian inference more important in **late encoder** and **early decoder** layers
- **Improves segmentation performance by 2-3%** across popular models
- MC dropout **outperforms weight averaging** after 6 samples and converges after 40 samples
- Especially **effective for small datasets** (e.g. CamVid)
- Model uncertainty increases for **rare and difficult classes**
- Model uncertainty is useful for safe autonomous **decision making**, **active learning** and **label propagation**

Further Applications

- Distinguish **Aleatoric** (sensor) uncertainty and **Epistemic** (model) uncertainty [3]
- Use uncertainty to improve **multi-task learning** [4]
- Semantic **segmentation**, **instance** segmentation and **depth** regression from a single input image [4]



References

1. Vijay Badrinarayanan, Alex Kendall, Roberto Cipolla. **SegNet: A Deep Convolutional Encoder-Decoder Architecture for Image Segmentation.** PAMI, 2017.
2. Alex Kendall, Vijay Badrinarayanan and Roberto Cipolla**. Bayesian SegNet: Model Uncertainty in Deep Convolutional Encoder-Decoder Architectures for Scene Understanding.** BMVC, 2017.
3. Alex Kendall and Yarin Gal. **What Uncertainties Do We Need in Bayesian Deep Learning for Computer Vision?** arXiv preprint arXiv:1703.04977, 2017.
4. Alex Kendall, Yarin Gal and Roberto Cipolla. **Multi-Task Learning Using Uncertainty to Weigh Losses for Scene Geometry and Semantics**. arXiv preprint arXiv:1705.07115, 2017.