Bayesian Neural Networks

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April 23, 2024

Neural Networks (NN)
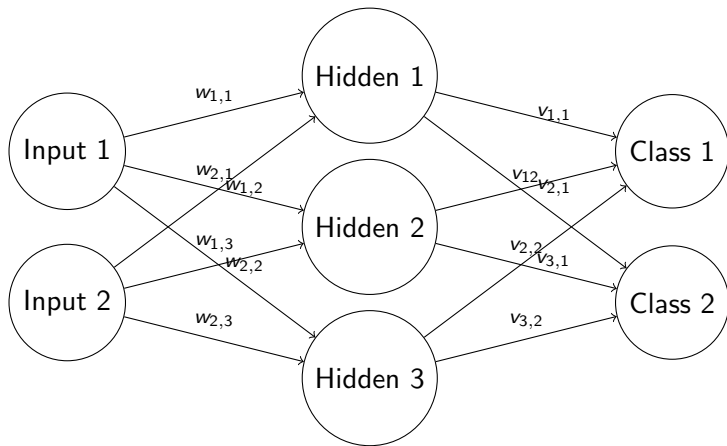

Figure: Example neural network

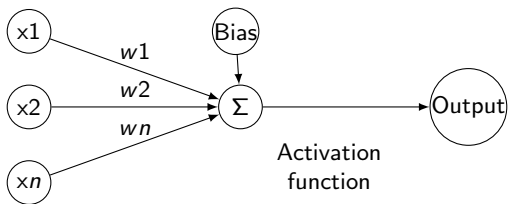# A Neural Network Neuron

Figure: Example neural network neuron

Issues with Neural Networks

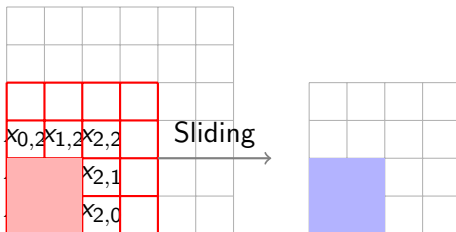Figure: XKCD: "*Machine Learning*"
[**xkcd-ml**]

- Stir data and pray
- Interpretability problems
- Lots of data required
- Risk of overfitting
- Unpredictable failures to generalize
- No uncertainty quantification
- Computationally expensive

Convolutional Neural Networks (CNN)

Sliding

$x_{0,2}$ $x_{1,2}$ $x_{2,2}$

$x_{2,1}$

$x_{2,0}$

Convolutional Kernel   Input Matrix

Output Feature Map

Convolutional Neural Networks (CNN)
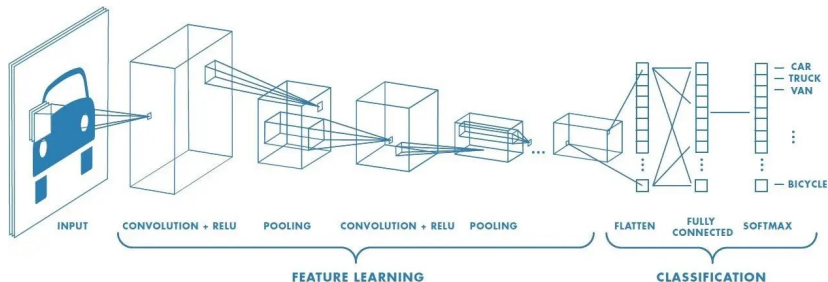
Figure: CNN pipeline [**eli5CNN**]

Why we use CNNs

Figure: XKCD: "*Self Driving*"
[**xkcd-self-driving**]

- Fewer parameters
- Encode spatial patterns
- More efficient for image tasks

Neural Networks
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Simulation
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Closing
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Bayesian Neural Network
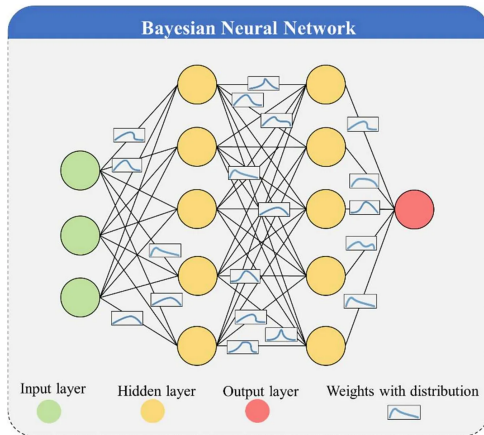
Figure: Example BNN [**FleszarBNN**]

BNN Neuron
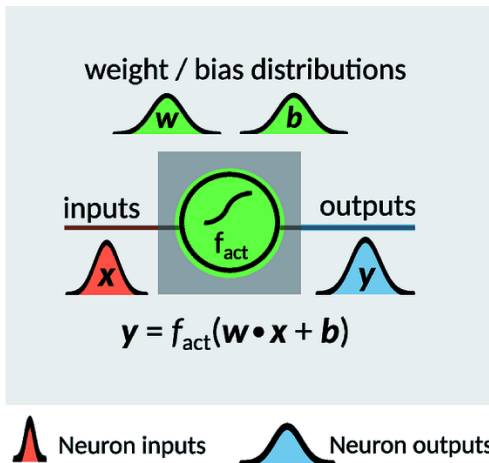
Figure: Example BNN Neuron [**hase2019machine**]
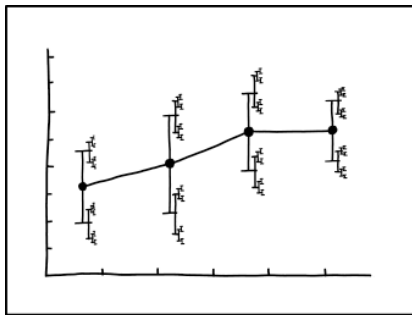
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Why we use BNN

Figure: XKCD: "*Error Bars*"
[**xkcd-self-driving**]

- Well-calibrated uncertainty
- Handles sparse data while minimizing overfitting
- More predictable failures
- Formalizes prior knowledge and assumptions
- Inherent sequentiality

Applications

Figure: XKCD: "*Simple Answers*"
[**xkcd-simple-answers**]

- Uncertainty quantification
  - Engineering, Medicine, Finance, ...
- Sparse data
  - Anywhere data is expensive
  - Medical diagnosis
  - Molecular biology
- Warnings before failing to generalize
  - Autonomous driving
  - Engineering
- Sequentiality

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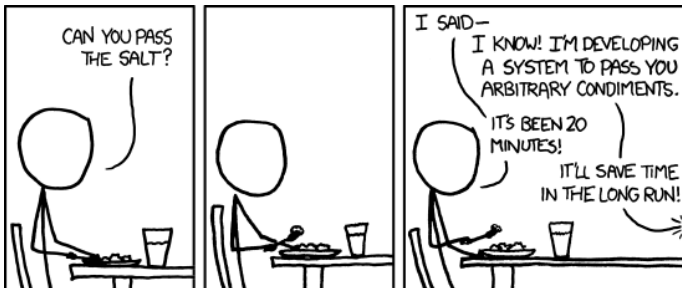
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Difference between BNNs and BCNNs

Figure: XKCD: "*The General Problem*" [**xkcd-general-problem**]

The relationship between BNNs and BCNNs is the same as NNs and CNNs.
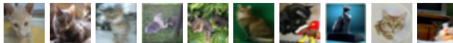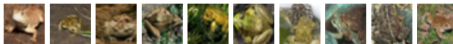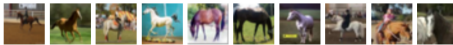
CIFAR-10

Figure: Example CIFAR-10 images [**cifar10**]

Hyperparameters

Hyperparameter	CNN	BCNN
Epochs	100	100
Learning Rate	0.001	0.003
Regularization Rate	0.001	0.001
Optimizer	Adamw	Adamw

Results

Metric	CNN	BCNN
Train Accuracy	84.96%	81.27%
Validation Accuracy	61.76%	59.21%
Time to Train	16 min 11 sec	22 min 11 sec

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Accuracy over time (CNN)

Validation vs Train accuracy (CNN)

Accuracy over time (BNN)

Validation vs Train accuracy (BNN)

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Confusion Matrix (CNN)

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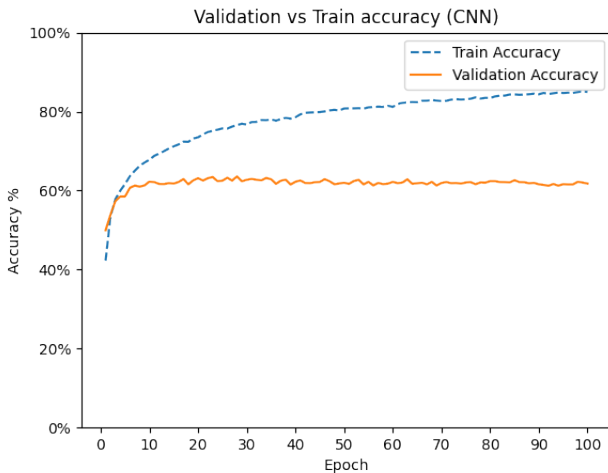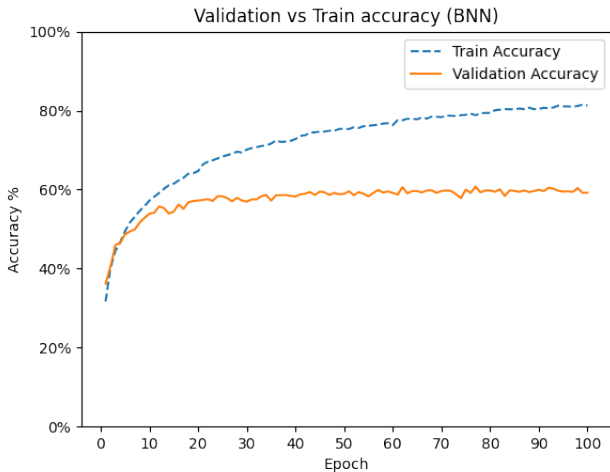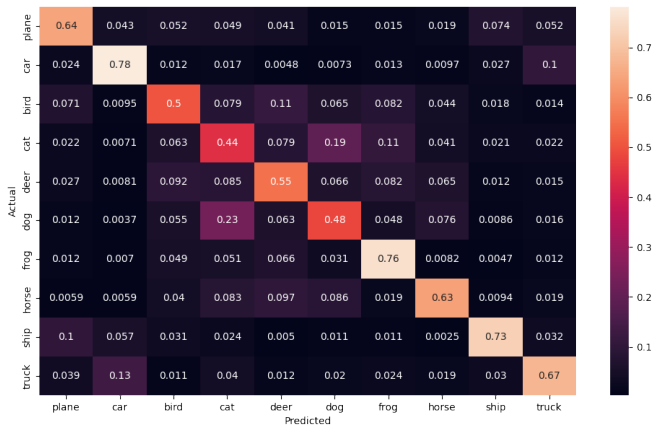
Confusion Matrix (BCNN)
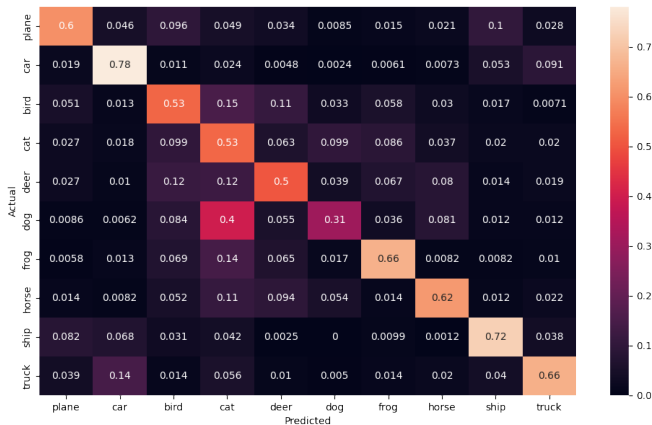
Live Demo
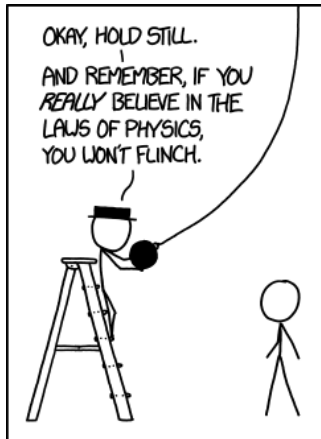
Figure: XKCD: "*Laws of Physics*" [**xkcd-laws-of-physics**]

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Questions

Figure: XKCD: "*Simple Answers*" [**xkcd-simple-answers**]

References I