Convolutional Variational Autoencoders for Dark Matter Anomaly Detection

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Overview

Neural Networks

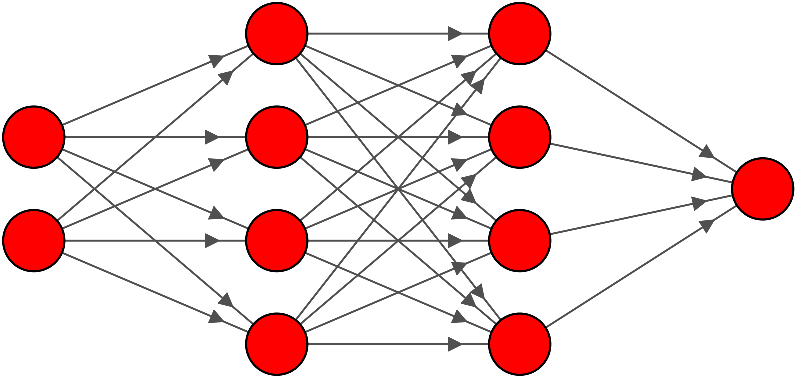


Figure: An example of an artificial neural network.

Neural Networks

$$a_j^i = \sigma\left(\sum_k (w_{jk}^i a_k^{i-1}) + b_j^i\right) \tag{1}$$

where,

- a_j^i is the output (also known as activation value) of the j^{th} node in the i^{th} layer,
- σ is the chosen activation function for that layer,
- w_{jk}^i is the weight connecting the k^{th} node in the $(i-1)^{\text{th}}$ layer to the j^{th} node in the i^{th} layer,
- a_k^{i-1} is the output of the k^{th} node in the $(i-1)^{\text{th}}$ layer,
- b_j^i is the bias value of the j^{th} node in the i^{th} layer.

Autoencoders

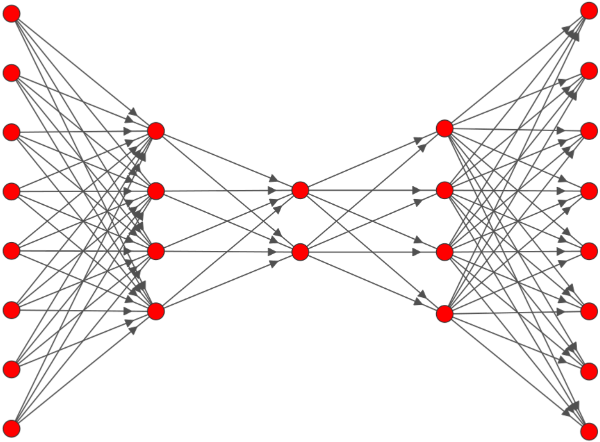
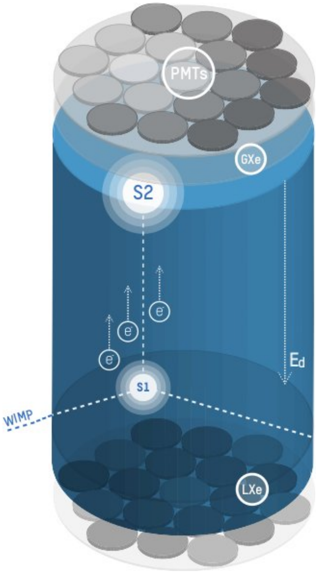


Figure: An example of a simple autoencoder.

XENON1T Detector



Reference

Convolutional Neural Networks for Direct Detection of Dark Matter

Charanjit K. Khosa,[1,*] Lucy Mars,[1,†] Joel Richards,[1,‡] and Veronica Sanz[1,2,3,§]

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XENON1T Detector Response Images

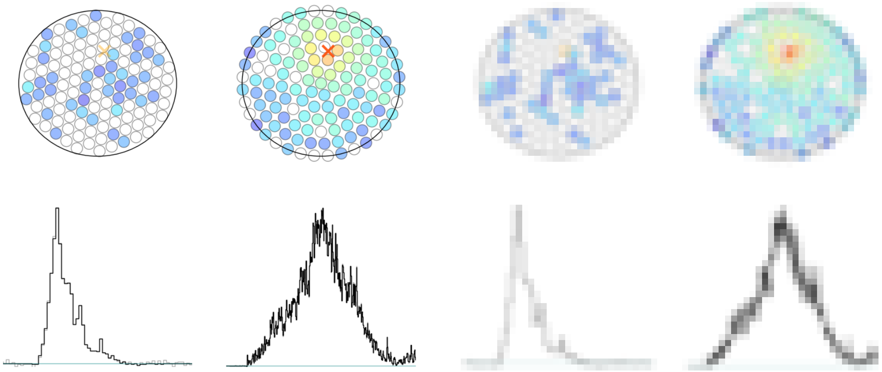

Figure: Top: An example of an 800×800 electron recoil event image before (left) and after (right) reducing the resolution to 75 × 75.

Network Architecture

- $75 \times 75 \times 3$ input layer
-
    - 128 filters,
    - 3×3 kernel size,
    - stride length of 3,
    - LeakyRelu activation with $\alpha = 0.05$
- Latent space has 512 nodes (256 means and 256 standard deviations)
- Reflection of above architecture for decoder

Training and Testing

Train the network for 200 epochs on 8000 electron recoil event images in mini-batches of 100 and test on 2000.

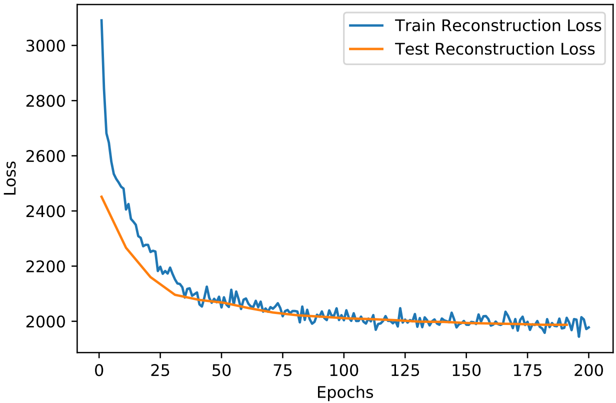

Figure: The reconstruction loss per epoch for the training and testing sets for the CVAE.

Signal and Background Reconstruction

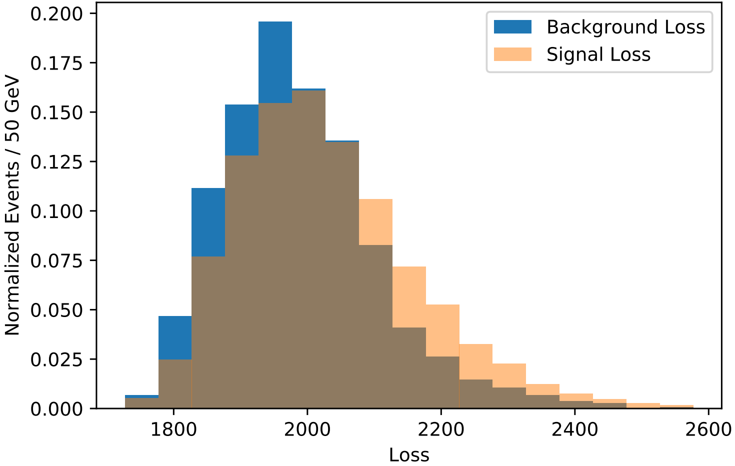

Figure: Normalised reconstruction loss distributions for the electron recoil (background) sample and a 500 GeV WIMP particle (signal).

Pseudo-data and Background Reconstruction

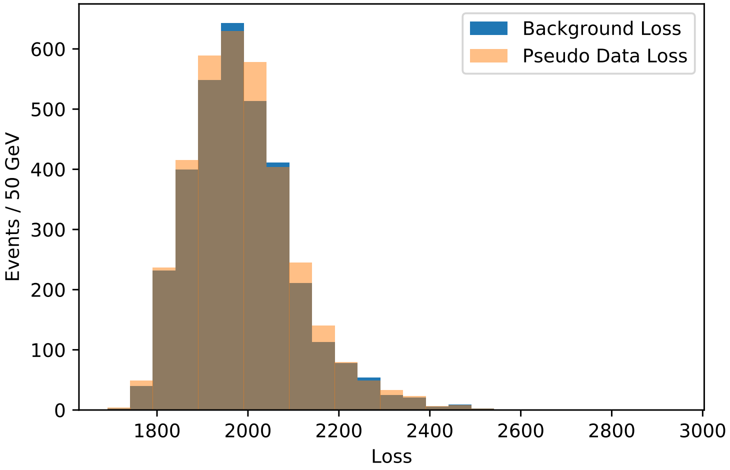

Figure: The reconstruction loss distributions for the electron recoil (background) sample and the pseudo-data sample normalised to realistic expected event count

Summary and Conclusion

We covered:

- Neural Networks
- Convolutional Variational Autoencoders
- XENON1T Detector
- CVAE Reconstruction for Signal, Background and Pseudo-data

Thank You