Neutrino Physics with Deep Learning on NOvA
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Our Convolutional Visual Network (CVN) neutrino event classifier[1] trains on the top and side views of the event independently for all but the last layer of the network.

Improvements to CVN classic event classifier used in 2018 analysis
Training labels from final data, not GENIE
Independent training for anti-neutrino events
Architecture and training sample optimization

The newest deep learning development on NOvA is simultaneous reconstruction and identification using instance aware semantic segmentation.

One network: particle ID, clustering, & reconstruction


Bounding Boxes: The network defines regions of interest and from them builds bounding boxes aiming to contain all of one particle in one box.
Labels: A softmax function is used to classify the contents of each box.
Clustering: Pixel by pixel clusters are defined to closely contain single particles.

Clustering is challenging for long tracks. Complementing the inputs with adjacency information is a promising approach at improving clustering efficiency.

Data-driven cross-checks use minimum bias cosmic ray data or well identified data in the near detector to check for indications of bias in the models.
In a Muon Removed Electron (MRE) event, a muon track from a selected muon neutrino interaction is replaced by a simulated electron of the same energy.
CVN ID is in good agreement between data MRE events and MC.

NOvA’s single particle classifier[3] works on reconstructed clusters. The network is trained on the two views of the cluster and the two views of the whole event.

Single particle ID benefits from contextual information

Applications of Deep Learning on NOvA:
Event ID [CVN]:
Muon neutrino disappearance, electron neutrino appearance, and NC, CC-NC, CC interactions
Particle classifier:
Single particle ID for energy reconstruction of electron neutrino events, neutral pion mass peak
Applications in progress:
Fiend-die selection with single particle ID for cross sections analysis, single particle ID for energy reconstruction of mu, energy, and charge reconstruction.

Example application: Reconstructing neutral pion events through photon identification using our single particle classifier.
On NOvA, photons from the decay of neutral pions are used as a calibration cross check. They are a useful gauge for understanding detector response to electromagnetic energy.

The two photons travel some distance before pair producing and initiating electromagnetic showers.
The two photons can be reconstructed and identified using the single particle classifier from the previous section.

Can you beat our neural networks?