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Neural Networks at the Tevatron

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presented by B. Denby

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Abstract

This paper summarizes neural network applications at the Fermilab Tevatron, including the first online hardware application in high energy physics (muon tracking); the CDF and D0 neural network triggers; offline quark/gluon discrimination at CDF; and a new tool for top to multijets recognition at CDF.

1. Online Muon Tracking with a VLSI Neural Net

A VLSI neural network chip has been used in a test beam experiment and with cosmic rays to calculate online, without deadtime, the slope and intercept of muon tracks traversing a prototype D0 drift chamber [1]. The neural network tracking has an intercept resolution of about 1 millimeter, about fifty times better than the resolution of the existing D0 muon trigger which uses only hodoscopic information. This resolution is only about a factor of two worse than the best obtainable offline, but is available in a few microseconds. The network uses signals from the time to voltage converters attached to each sense wire of the chamber to calculate the track parameters. A four layer version of this setup has recently been tested as well, with improved resolution [2].

2. The CDF and D0 Neural Net Triggers

The CDF experiment at the Fermilab Tevatron has three neural network triggers [3] utilising the Intel ETANN chip [4]: a central photon isolation trigger; a central semileptonic b trigger; and a plug electron isolation trigger. Analog signals from a 5 by 5 trigger tower region of the calorimeter appear on the backplane of a special fastbus crate loaded with fastbus boards containing the ETANN's. The CDF 1992 run is currently in progress and the hardware is being debugged. First results should be appearing soon.

An previous publication [5] described a hardware network to calculate the position along the wire direction of a track hit in muon drift chambers. In further work [6], the outputs of three such networks from three layers of chambers are combined into another hardware network in order to calculate the intercept of tracks in the direction along the wire. This could be used in conjunction with the track finding perpendicular to the wire described in section 1 as part of an upgrade to the D0 muon trigger.

3. Offline Quark Gluon Discrimination at CDF

A feedforward network was trained to tag the parton ancestry of jets produced in proton antiproton collisions at the Tevatron [7]. Eight input variables were used: 1)number of charged tracks; 2) fraction of Et contained in cone of radius 0.2; 3) fraction of Et contained in annulus between radii of 0.2 and 0.4; 4) fraction of Et contained in annulus between radii of 0.4 and 0.7; 5) Et weighted first phi moment; 6) Et weighted first eta moment; 7) Pt/Et of the leading particle; 8) distance in eta-phi space between jet axis and leading particle. The net was trained using jets generated with the Pythia and Herwig Monte Carlo programs. The trained net was then applied to real CDF data. The mean network ouptut was found to increase with

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jet Et (figure 1), while the Monte Carlo quarks and gluons, had a network output distribution that was flat in Et. This result suggests that the real data becomes richer in quarks as Et increases, as expected from QCD. The exercise was repeated using feature map techniques with some improvement in performance.

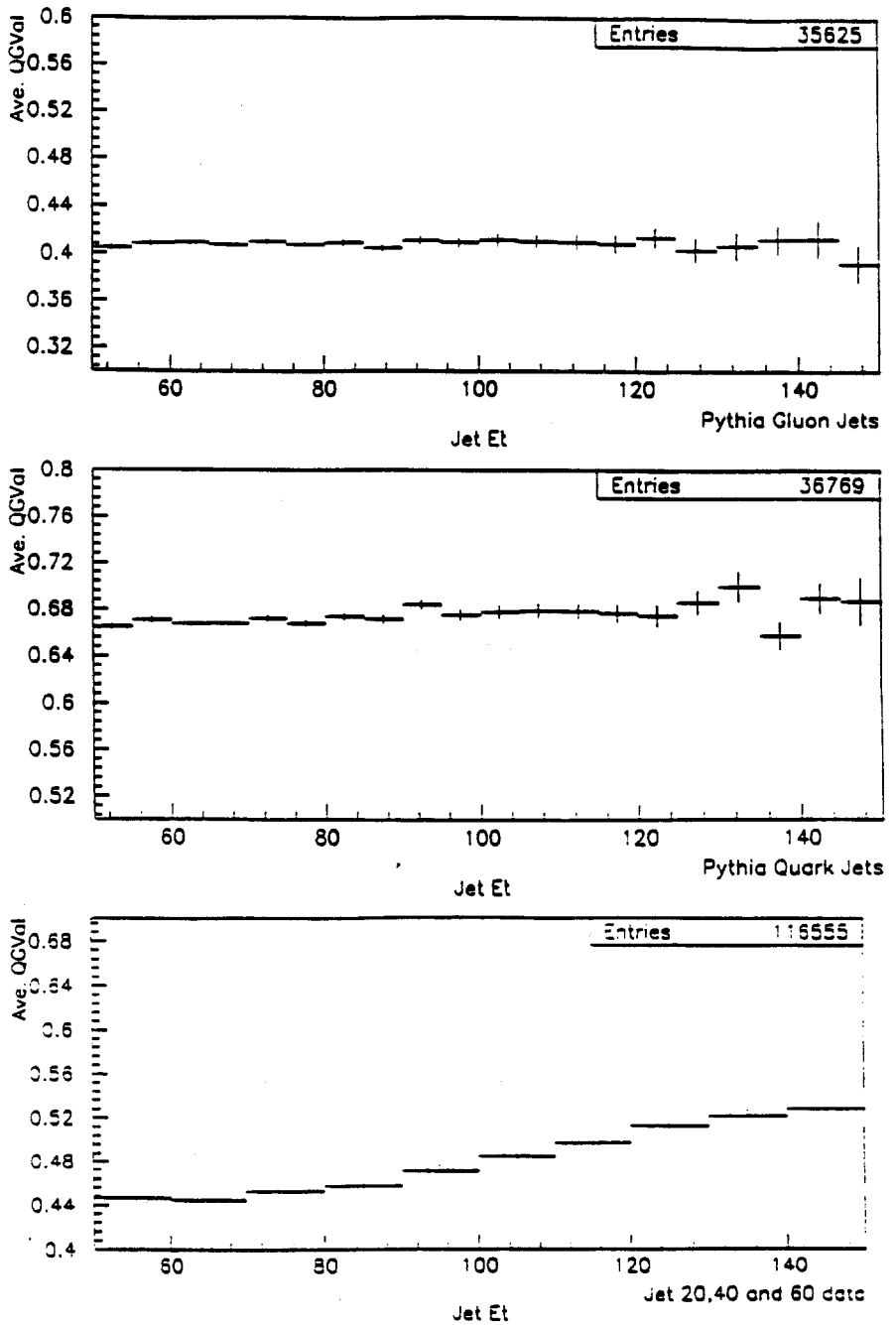


Figure 1. Response of feedforward neural network to Monte Carlo gluons and quarks and to real CDF jets.

3. A New Tool for Top to Multijets Recognition at CDF

A multilayer perceptron (MLP) with a single layer of hidden units and one output unit was used to discriminate between Monte Carlo ttbar events generated with Isajet and Herwig (passed through the CDF detector simulation program QFL) and real QCD background events from the 1989 run of the CDF experiment. Both signal and background events were required to have at

least six jets of Et greater than 10 GeV and a total summed Et of all jets of at least 240 GeV. The signal data was a roughly uniform mix of top masses of 100, 120, 130, and 150 GeV. The network had 18 inputs consisting of the Et, eta, and phi of the six leading jets. Approximately 1250 real background events were available after the above cuts and requiring all jets within letal<2.4. Of these, 400 were reserved for testing the net, and the remaining 850 were used for training. Because of the paucity of training data, the number of events was double to 1700 by including a copy of each event with eta changed to -eta (this flipping in eta was *not* done for the Monte Carlo events). The training set consisted of these 1700 events and 1700 Monte Carlo signal events, while the test set contained the remaining 400 background events and 400 signal events.

Figure 2

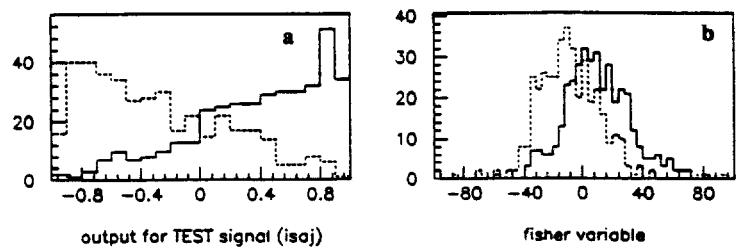
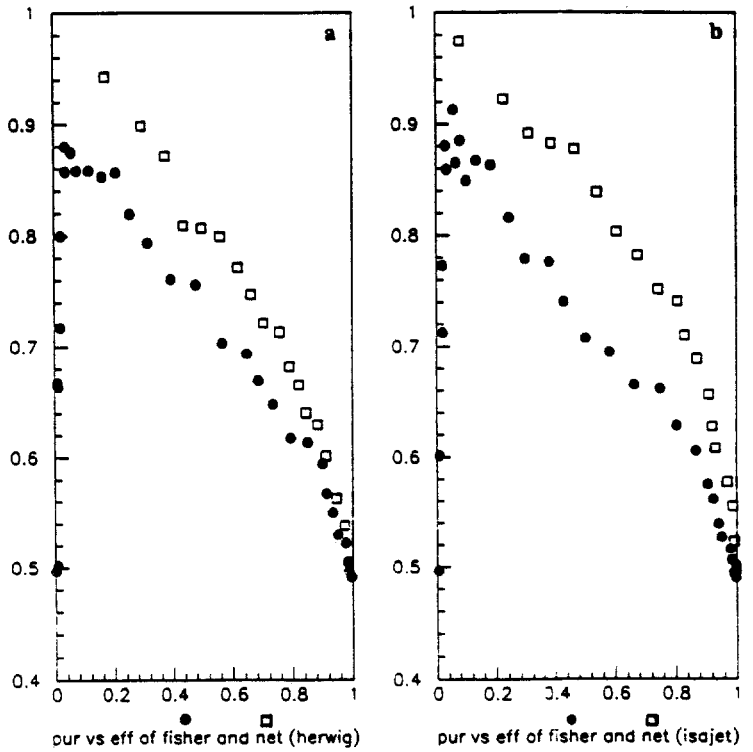


Figure 3



The network was trained using standard gradient backpropagation. Networks with 2, 5, and 10 hidden units were tried. The 5 unit net had better performance than the 2 unit net, but the 10 unit net was no better than the 5 unit net. Results here refer to the 5 unit net. Figure 2a shows the network output distribution for the test set after training on Isajet signal data for 4096 epochs. The Fisher linear discriminant variable was also calculated for the same data set (after training it on the training set) and is shown in figure 2b. The Fisher and net distributions for Herwig are similar but show somewhat worse separation. The overal performance of these

classifiers can be rated in a plot of purity versus efficiency as shown in figure 3 both for Herwig (a) and for Isajet (b). The plot is constructed by moving a cut in output variable across the distributions in figure 1 and recording the fraction of events above this cut which are signal (purity) versus the fraction of total signal events above the cut (efficiency). Note that the purity and efficiency are defined for *equal* populations of signal and background. The performance of the Fisher discriminant is worse in both cases, as expected. Work is continuing to develop the network as a tool to improve the signal to background ratio for the ttbar to multijets channel.

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