Proposed IRAC Rad-Hit Detection Algorithm
Russ Laher (laher@ipac.caltech.edu)
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Hidden-Layer Artificial Neural Network (HL-ANN)

- Equivalent mathematical representation:

\[
O = f \left( \theta_o + \sum_{j=1}^{N} w_{Oj} f \left( \theta_j + \sum_{i=1}^{M} w_{ji} S_i \right) \right)
\]

\[
f(x) = \left(1 + e^{-x}\right)^{-1}, \quad O = \text{output}, \quad S_i = \text{inputs}
\]
• Inputs: 5×5-pixel sub-region of image data after the following pre-processing:
  1. Bandwidth correction, DN wrap-around, etc.
  2. Flat-fielding
  3. Median-background subtraction
  4. Conversion to DN/second.

• Output: Posterior probability of rad-hit presence at center pixel of 5×5-pixel sub-region

• HL-ANN Features:
  - Nonlinear processing (not constrained by limitations of linear processing)
  - Architecture is suitable for general mapping (inputs must be bounded), and has been proven capable of learning a variety of complex patterns
  - Relatively few underlying assumptions required (does not require Gaussian-distributed noise or constant targets for optimality)

• Advantages:
  - Superior performance: Tests on 12-µm simulated WIRE data yield PFA=6×10^{-6} at PD=0.8
    (Cf. PFA=2×10^{-3} at same PD using adaptive linear-matched spike filter followed by Bayesian classifier)
  - Straightforward sliding-window, fixed-filter application
  - Not compute-intensive (relatively fast)
  - Output is probability of rad-hit presence
• Disadvantages
  - Fixed filter
    - Does not adapt to current image
    - Performance relies on generality of training set, fidelity of simulated images in training set, rad-hit model, and quality of the training
  - Long training times to calculate ANN weight-set (1-2 weeks)
  - Training method requires initial target “enrichment”

• Requires different ANN weight-set for each IRAC band

• Training image-data set
  - Relatively-crowded field (such as M38 star cluster), for less aggressiveness on point sources
  - ~50 images (different noise exemplars and rad-hit positions)
  - 1% of pixels affected by rad hits

• ANN Training and Performance Testing:
  - Standard backpropagation for iteratively computing hidden-layer ANN weight sets
  - Weights are updated after each complete pass through the training set, with gain and momentum parameters controlling the process
  - Minimizes mean-squared error (MSE) between filter output and ANN goal (1=rad hit present, 0=otherwise)
  - During training MSEs and PD/PFA performance are measured for the training set
  - PD/PFA performance on other test image-data sets is also measured
• Other possible architectural enhancements
  - Symmetrization of weights
  - Apply cross-entropy minimization for possibly faster training convergence

• Training and testing results using simpler ANN architecture (functional link net):
  - Performance: PFA=9×10^{-5} at PD=0.8
  - Trains much faster than HL-ANN (days instead of weeks)

• Next up: plan to train and test HL-ANN on simulated IRAC images