AN OVERVIEW OF THE NEURON RING MODEL

Rod Taber
Center for Applied Optics
University of Alabama in Huntsville
Huntsville, AL 35899

ABSTRACT

The Neuron Ring model employs an avalanche structure with two important distinctions at the neuron level. Each neuron has two memory latches; one traps maximum neuronal activation during pattern presentation, and the other records the time of latch content change. The latches filter short term memory. In the process, they preserve length 1 snapshots of activation history. The model finds utility in pattern classification. Its synaptic weights are first conditioned with sample spectra. The model then receives a test or unknown signal. The objective is to identify the sample closest to the test signal. Class decision follows complete presentation of the test data. The decision maker relies exclusively on the latch contents.

This paper presents an overview of the Neuron Ring at the seminar level. The appendix contains the information in slide format.

REFERENCES


APPENDIX

The next fifteen pages are slides describing the Neuron Ring model.
NEURON RING
SPATIOTEMPORAL PATTERN RECOGNIZER

- EVOLVED FROM GROSSBERG AVALANCHE
- DEVELOPED BY TABER, DEICH 1987
- USES NEW NEURON CALLED DPNL
  - Dot Product Neuron with Latches
- DEFINITION: SPATIOTEMPORAL PATTERN
  - A PATTERN EQUIVALENT TO A SECTION OF A SONG
NEURON RING
GROSS ARCHITECTURE

DPNL 1  DPNL 2  ...  DPNL N

SINGLE RING FOR A SINGLE SIGNAL
DOT PRODUCT NEURON WITH LATCHES

INTERNALS

CONTROL

M = MAX LATCH

T = TIME LATCH

DE = DIFFERENTIAL EQUATION FOR DX/DT

X_1 X_2 X_N
NEURON RING
DIFFERENTIAL EQUATION IN DIFFERENCE FORM

\[
X_i^{\text{NEW}} = X_i^{\text{OLD}} + A(-aX_i^{\text{OLD}} + b[l_i^{1\text{ OLD}} + l_i^{2\text{ OLD}}])
\]

= DOT PRODUCT OF WEIGHTS AND ACTIVATION

\[
[e]^+ = 0 \text{ IF } e \leq \Phi \quad \text{ELSE } [e]^+ = e
\]

\[
A(e) = e \text{ IF } e > \Omega \quad \text{ELSE } A(e) = ce
\]

\[A = \text{ATTACK FUNCTION} \quad c \Phi \Omega = \text{CONSTANTS} \]
\[b = \text{AMPLIFICATION FACTOR} \]
NEURON RING TRAINING

• TRAINING IS FAST
  - IN DIAGRAM WEIGHTS ARE INTERNAL TO DPNL
  - WEIGHT VECTOR = TEMPLATE
  - ACTIVATE CONTROL LINES
  - COPY TEMPLATE TO THE WEIGHT REGISTERS
  - DEACTIVATE CONTROL LINES
  - RING IS READY FOR EXCITATION

• WORKS BEST IF TEMPLATE = CENTROID OF PATTERN CLASS
  - CENTROID CAN BE FOUND VIA AVQ
NEURON RING
FUZZY POST-PROCESSING

- ANALYSIS IS BASED ON [M] AND [T] LATCHES
  THESE DRIVE CHIP OUTPUT LINES
- DOT PRODUCT IS MEASURE OF SIGNAL-TEMPLATE MATCH
- IF EACH SIGNAL-TEMPLATE PAIR MATCH THEN DONE
- USUALLY, PERFECT MATCH IS NOT POSSIBLE
- NEXT BEST THING IS TO ESTIMATE DEGREE OF MATCH
  - THIS IS DONE VIA FUZZY THEORY
NEURON RING
FUZZY THEORY

● EACH DPNL CONTAINS WEIGHT VECTOR = SIGNAL SECTION
  – DPNL 1 CONTAINS FIRST X MILLISECONDS OF SIGNAL
  – DPNL 2 CONTAINS SECOND X MILLISECONDS
  – DPNL N CONTAINS LAST X MILLISECOND SLICE

● EACH DPNL IS A MINIATURE FEATURE DETECTOR
● EACH DPNL RECEIVES, DURING COURSE OF ACTIVATION, ALL OF THE TEST SIGNAL
● THEREFORE
  – N DPNLs IN A RING GENERATE N ACTIVATIONS EACH

● AT END OF ACTIVATION
● THIS IS KEY:
● EACH M LATCH CONTAINS A MEASURE OF BEST MATCH
NEURON RING
POSSIBILITY DISTRIBUTION AND SIGMA-COUNT

- IMAGINE ALL DPNLs FULLY EXCITED AFTER TEST PRESENTATION

  - PERFECT = (1,1,1,...1)

  - BUT WE HAVE:

    - OBSERVED = (M_1 M_2 M_3... M_N)

    - WHERE M REAL NUMBER IN (0,1)

- COMPUTE POSSIBILITY (OBSERVED IS PERFECT)

  - POSS(O IS P) = OBSERVED \cap PERFECT = PAIRWISE MIN

  - THEREFORE POSS(O IS P) = OBSERVED M VECTOR

  NEXT STEP: COMPUTE ZADEH'S \Sigma-COUNT = DEGREE OF MATCH
NEURON RING
SIGMA-COUNT = DEGREE OF SIGNAL-TEMPLATE MATCH

- $\Sigma$-COUNT = FUZZY SET CARDINALITY = ARITHMETIC ADDITION

- EXAMPLE:
  - $F = \{.1, .2, .6\}$
  - $\Sigma(F) = .1 + .2 + .6 = .9$
  - $\%$MATCH $= 100(\Sigma$COUNT$/$PERFECT)$

- EXAMPLE:
  - $\%$MATCH $= 100(0.9/3) = 30\%$

- WE WOULD SAY THIS RING MATCHES THE TRAINING TEMPLATE TO DEGREE .3
NEURON RING
EXTENSION TO MULTIPLE SIGNALS

• GENERATE 1 RING PER SIGNAL
  - EXCITE EACH RING WITH SAME TEST SIGNAL
  - FORM TABLE, ONE ROW PER SIGNAL

\[
\begin{array}{c|c|c|c|c|c|c}
\text{RING 1} & \text{RING 2} & \cdots & \text{RING N} \\
\hline
\end{array}
\]
NEURON RING
MULTIPLE SIGNALS

- FORM VECTOR Q = \{Σ Σ ... Σ\}
- FORM R = Q\textbackslash MAX(Q)
- BAYES DECISION RULE:
  - TEST SIGNAL = SIGNAL i IF Σᵢ = MAX(R)
- FIND MAX VALUE IN VECTOR R, INDEX IS THE SIGNAL
  (MAX OF R WILL BE 1!)
- ORDERED VECTOR R IS NOT PROBABILITY!

- EACH ELEMENT IN R IS SUPPORT FOR THE HYPOTHESIS: THE SIGNAL IS i

- PROBABILITY WOULD REQUIRE WE HAVE OTHER INFORMATION

- WE DON'T - JUST ACOUSTIC SIGNATURES
NEURON RING

FURTHER REFINEMENTS

- SAMPLING PHASE TOLERANCE FOR SINGLE RING
- T LATCH WITHIN DPNL CONTAINS TIME THE MAX LATCH CHANGED
  - FORM VECTOR \( U = \{T_1, T_2, T_3, \ldots, T_n\} \)
    - \( U \) SHOULD BE IN ASCENDING ORDER
- EXAMPLE \( U = \{1 \text{ PM}, 2 \text{ PM}, 3 \text{ PM} \ldots\} \)
- IF NOT, TEST SAMPLE SECTIONS RECEIVED OUT OF ORDER
- SORT \( U \) TO DISCOVER ORDER
- SUPPOSE \( U = \{2 \text{ PM}, 1 \text{ PM}, 3 \text{ PM}\} \) THEN INSTEAD OF ABC, WE RECEIVED BAC
NEURON RING
A EUCLIDEAN 2-D METRIC BASED ON M AND T

- WE HAVE THE Σ METRIC ALREADY
- DEVELOP DISTANCE METRIC BY
  - COUNTING # SWAPS NEEDED TO BRING U BACK TO ORDER

\[ D_i = \left[ (1 - X_i)^2 + Y_i \right]^{1/2} \]

X = NORMALIZED Σ COUNT FOR RING i

Y = NORMALIZED NUMBER OF SWAPS (i.e. #/(N-1) FOR N RINGS)
NEURON RING
2-D DISTANCE METRIC

- If all neurons fired maximally and in order, our metric point would be (1,0)
  - 1 = Maximum normalized Σ
  - 0 = No swaps required
- Result of test run (x,y)
- 0 ≤ x ≤ 1, 0 ≤ y ≤ 1
- Distance away from perfect ...

Signals may fall into natural clusters
Equidistant signals are in the same equivalence class
NEURON RING
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INTERNALS

$X_1$ $X_2$ $X_N$

$w_1$ $w_2$ $w_N$

$M$ $T$

CONTROL

$M = \text{MAX LATCH}$

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$DE = \text{DIFFERENTIAL EQUATION FOR DX/DT}$
NEURON RING
DIFFERENTIAL EQUATION IN DIFFERENCE FORM

\[ \text{NEW} \quad X_i = X_i + A(-aX_i + b[l_i + l^{12}]) \]

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\begin{align*}
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NEURON RING
FUZZY POST-PROCESSING

- Analysis is based on [M] and [T] latches these drive chip output lines

- Dot product is measure of signal-template match

- If each signal-template pair match then done

- Usually, perfect match is not possible

- Next best thing is to estimate degree of match

  - This is done via fuzzy theory
NEURON RING
FUZZY THEORY

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<table>
<thead>
<tr>
<th>Σ</th>
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<tbody>
<tr>
<td>RING 1</td>
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<td>RING 2</td>
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<tr>
<td>...</td>
</tr>
<tr>
<td>RING N</td>
</tr>
</tbody>
</table>
NEURON RING
MULTIPLE SIGNALS

- Form vector \( Q = \{ \Sigma \Sigma \ldots \Sigma \} \)
- Form \( R = Q' \max(Q) \)
- Bayes decision rule: signal if \( \Sigma = \max(r) \)
- Find max value in vector \( R \), index is the signal.

(Max of \( R \) will be 1)
NEURON RING
NOTES

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• EACH ELEMENT IN R IS SUPPORT FOR THE HYPOTHESIS: THE SIGNAL IS i

• PROBABILITY WOULD REQUIRE WE HAVE OTHER INFORMATION

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NEURON RING
2-D DISTANCE METRIC

- IF ALL NEURONS FIRED MAXIMALLY AND IN ORDER OUR METRIC POINT WOULD BE (1,0)
  - 1 = MAXIMUM NORMALIZED Σ
  - 0 = NO SWAPS REQUIRED
- RESULT OF TEST RUN (X,Y)
  - 0 ≤ X ≤ 1, 0 ≤ Y ≤ 1
  - DISTANCE AWAY FROM PERFECT ...

SIGNALS MAY FALL INTO NATURAL CLUSTERS
EQUIDISTANT SIGNALS ARE IN THE SAME EQUIVALENCE CLASS