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# Adaptive Resonance Theory

ART Networks

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# ART Networks

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- Work by clustering + nuances
- Several varieties:
  - ART1: Discrete patterns
  - ART2: Continuous patterns ...
  - Fuzzy ARTMAP
- Attempt to address the “stability/plasticity dilemma”:
  - stability: recognized patterns should be insensitive to noise
  - plasticity: system should be capable of learning new patterns

# ART Networks

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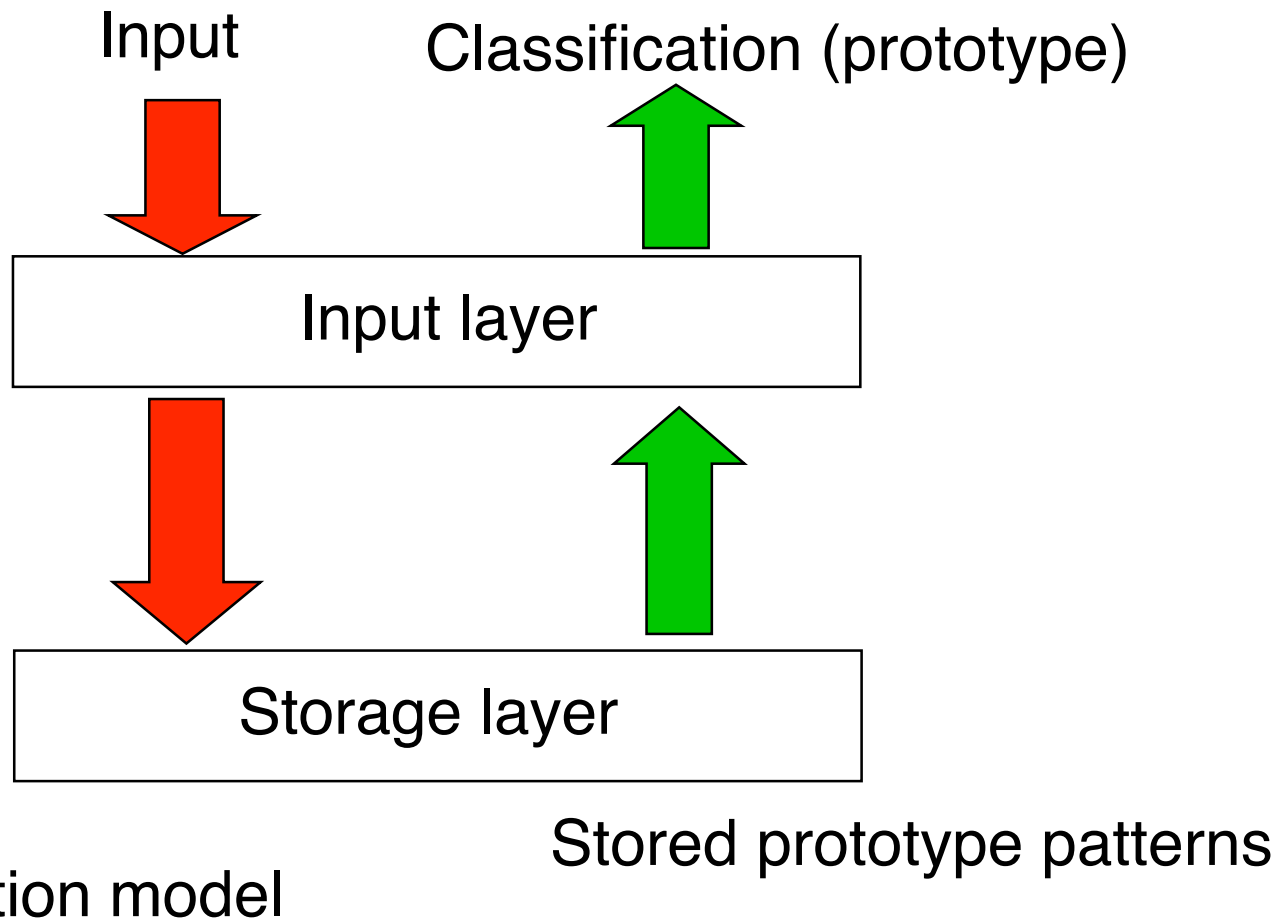
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- Combine supervised and unsupervised (competitive, clustering)
- Dynamically create new categories
- Biologically motivated by an ODE model
- Models short- and long-term memory

# ART Layers

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# ART1

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- Two kinds of explanations:
  - algorithmic
  - neural
- We concentrate on the first.
- The second is more complicated, since it involves ways to achieve the control aspects of the algorithmic approach.

# Basic ART Operation

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- Input pattern presented to input layer
- Storage layer indicates tentative hypothetical classification
- Input layer decides if hypothetical is **close enough**; if so, done.
- If not, storage layer indicates alternate hypothesis.
- The above two steps are repeated until the hypothetical classification is accepted.

# ART Operation

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- All hypotheses could be rejected; in this case, a **new** class is created in the storage layer.
- “resonance” = mutual reinforcement between input and storage layers
- “adaptive” = weights are adjusted when resonance occurs

# ART1 (Discrete Patterns)

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- training pattern  $x \in \{0, 1\}^n$
- prototype patterns  $w_j \in \{0, 1\}^n$
- Storage unit computes  
 $y_j = w_j x / \|w_j\|^2$  for each prototype
- The winner is the prototype with the largest  $y_j$
- For acceptance,  $y_j > \|x\|^2 / n$ , where  $n$  is the number of dimensions.
- This means that sufficiently-many bits must **match**.

# ART1

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- Assuming that the acceptance test is passed, it is also required that

$$w_j x / \|x\|^2 > \rho$$

where  $\rho$  is an adjustable parameter called **vigilance**.

This means that the input and the pattern share a sufficient fraction of 1's.

# ART1

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- If the acceptance test is passed, but the vigilance test is not:
  - the prototype in question is temporarily omitted from consideration;
  - a new competition takes place
- until a prototype is found for which both tests are passed.
- If no prototype is found, a new class  $k$  is created with

$$w_k = x$$

# ART1

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- The **higher** the **vigilance**, the more likely a new pattern is to be introduced.
- Lower vigilance will allow one input to pass as another pattern.

# ART1 Issues

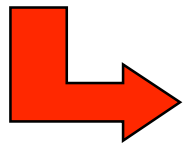
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- Subset-Superset dilemma:
  - If one pattern is **contained in** another, then a given input may have the same inner product with two different prototypes.
  - Can be resolved by allowing weights other than  $\{0, 1\}$  and **normalizing** the prototypes.
  - Neural normalization can be achieved by an on-center, off-surround competition.

# ART1 Demo

Increasing **vigilance** causes the network to be more selective, to introduce a new prototype when the fit is not good.



The screenshot shows a software window titled "nnd16a1" with a menu bar (File, Edit, Tools, Window, Help) and a main area divided into "Neural Network DESIGN" and "ART1 Algorithm".

**Pattern Grids:** Four 5x5 grids labeled "Pattern 1" through "Pattern 4". Pattern 1 has a 3x3 green block in the top-left. Pattern 2 has a 2x3 green block in the bottom-middle. Pattern 3 has a 3x3 green block in the top-middle. Pattern 4 has a 2x2 green block in the top-left. Each grid has a "Present" button below it.

**Prototype Grids:** Four 5x5 grids labeled "Prototype 1" through "Prototype 4". Prototype 1 has a 2x3 red block in the bottom-middle. Prototype 2 has a 2x2 red block in the top-middle. Prototype 3 has a 2x3 red block in the top-middle. Prototype 4 is a solid 5x5 red grid.

**Vigilance (rho):** A slider bar at the bottom is set to 0.6, with a range from 0.0 to 1.0.

**Instructions:** A text box on the right says: "Click on the green grids to define patterns. Click on the buttons to present them. The ART1 network's prototype patterns are shown below. Use the slider bar to set the ART1 vigilance." Below this are "Clear", "Contents", and "Close" buttons.

**Logo:** A small logo in the top right corner shows a stylized head with "010" inside.

Try different patterns

# ART: Neural Version

