Learning

"We are what we repeatedly do. Excellence, then, is not an act but a habit."
Aristotle (384-322 B.C.)

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Adaptron Inc.

Learning is a process that results in the acquisition and improvement of perception, action and thinking habits.

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- Learning
  - Intrinsic motivation
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This presentation introduces the topics of recognition habits, action habits and thinking habits.
And binons are the design and implementation of habits. They can be learnt and can be performed.
It explains how the hierarchical neural network of binons grows and learns.
Learning is based on intrinsic motivation. It is used to control the growth of the perception-action tree as new things are learnt.

Requirements

- Habits
  - Represent knowledge
    - What is known
  - Represent skills
    - What can be done
  - Are learnt
    - Continuously
  - Composed of simpler habits
  - Designed as binons

From a psychology perspective habits capture what we know and what we can do. Habits are what we learn.

There are spatial and temporal recognition habits and spatial and temporal action habits.

We reuse and combine well known habits to recognize more complicated things and perform more complicated tasks.

If Habits are what is required then binons are the design solutions. Binons represent habits.

Habit Types

- Recognition habits
  - Parallel habits (P-Habits)
    - Spatial pattern recognition
  - Sequential habits (S-Habits)
    - Temporal pattern recognition
- Action habits (A-Habits)
  - Spatial – configurations of action devices
  - Temporal – tasks
- Thinking habits (T-Habits)

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We have recognition habits that are used to identify things in space and time.

Action habits involve parallel configurations of multiple action devices (muscles).

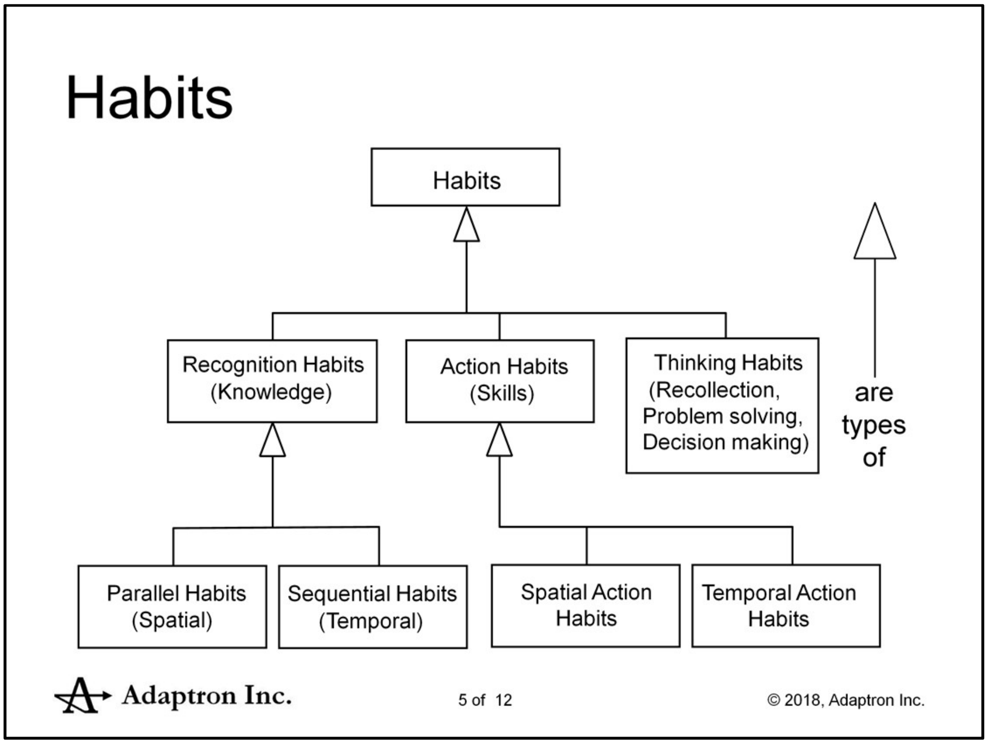
We have action habits that are used to perform behaviour over time.

And this is explained in the Action Learning presentation.

We also learn how to think. The results are thinking habits.

These are techniques we use to recall memories, solve problems and make decisions.

This is explained in more detail in the Thinking presentation.

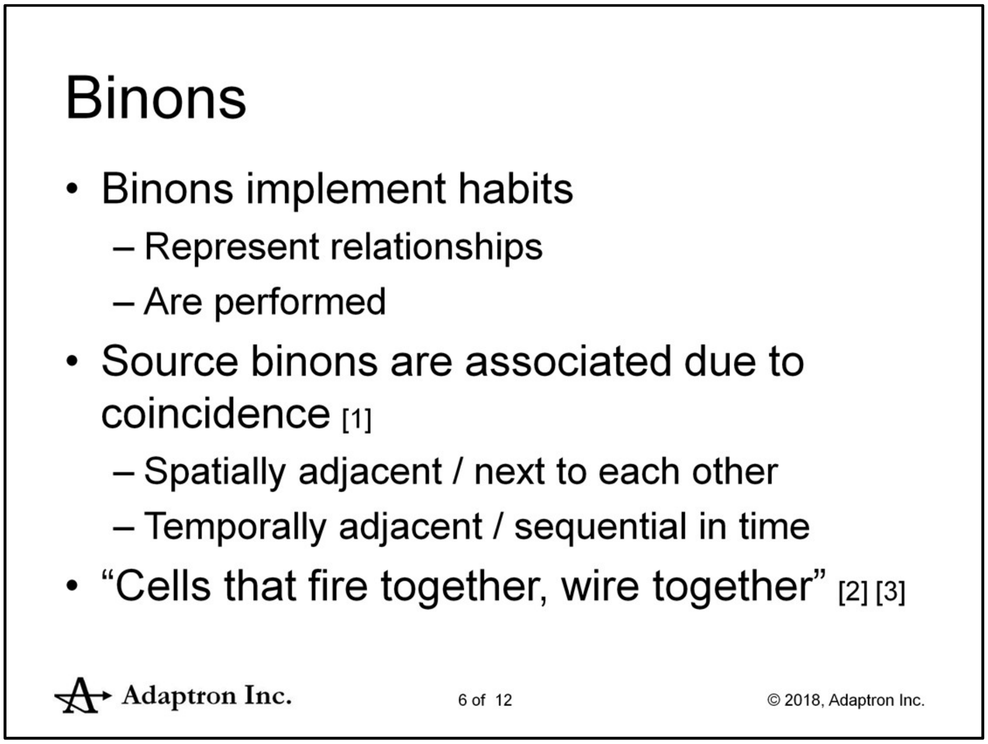


This is a UML Class diagram - generalization hierarchy.

It categorizes habits using the generalization relationship.

Habits are more general.

Action Habits are more specialized. They are a kind of or a type of Habit



Habits are the requirements and binons implement them.

Binons not only contain information they are also represent things that can be done.

With a one or two dimensional array of sensors the values detected have a built in spatial dependency.

They are next to each other. The same applies to temporal order.

This is built into the binon structure as the left to right order of trigger and goal source binons.

Reverse the two source binons and you have a different pattern.

Learning

- Based on intrinsic motivation [4]
  - Novelty and familiarity
- Binon tree grows / evolves as new patterns discovered
- Able to represent all possible combinations
  - Depends on whether they occur

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Learning can be guided by intrinsic and extrinsic motivations.

Only intrinsic motivation has been modeled in Adaptron at this point in time.

Novelty and familiarity play a central role in learning.

A nice property of information processing is that novelty and familiarity detection is built-in.

If something matches what is in memory it is familiar. If it is not in memory then it must be novel.

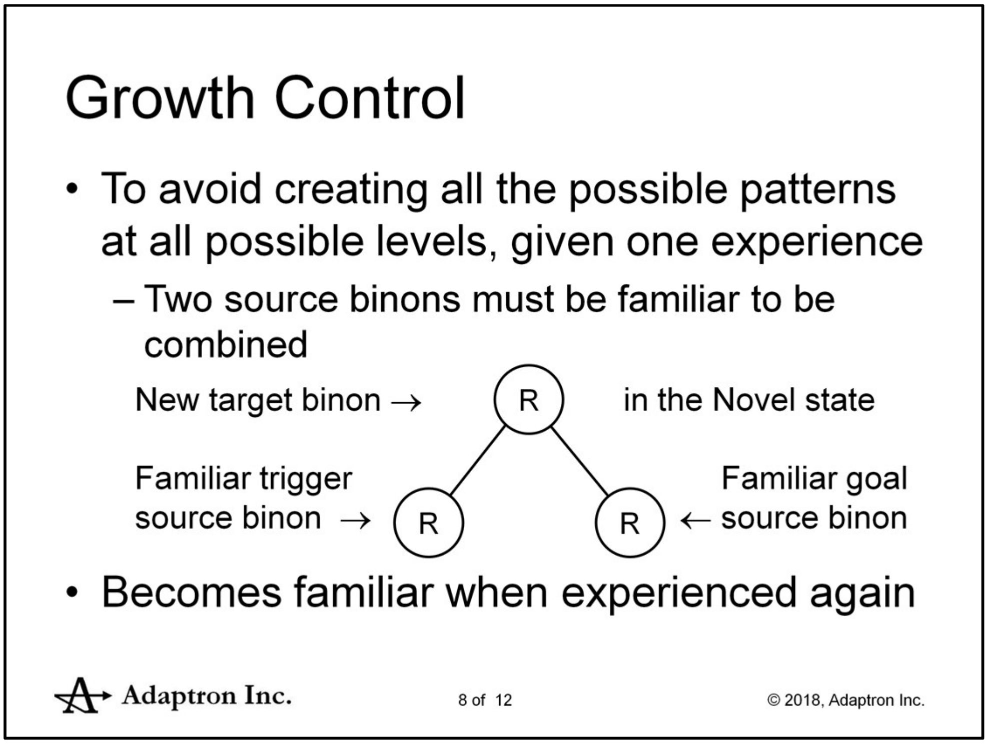
The pursuit of novelty results in curiosity and exploratory behaviour.

Every thing that is learnt is represented in memory as binons.

Thus the binon tree is continuously growing / evolving as new things are learnt.

There is no limitation on the breadth or depth of the hierarchy.

All possible combinations must be representable but whether they are represented or not will depend on how often they occur.



The growth of the tree must be slowed down so that not every possible representation is produced for every experience.

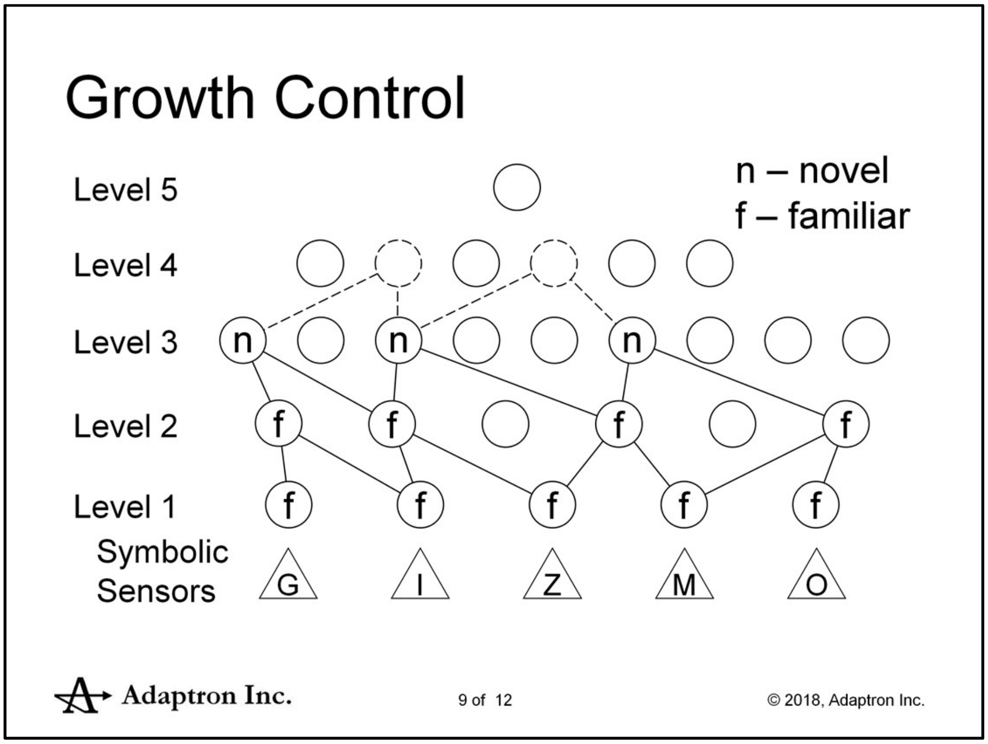
So the rule is to only create a new binon if its two source binons are familiar.

And they become familiar if experienced a second time.

The same rule applies for spatial and temporal binons.

Low-level patterns occur more frequently. Fewer high-level patterns exist. Noise tends to be filtered out at lower levels.

This is effectively a simple probabilistic / stochastic approach which says those things that occur more frequently will be learnt.



As you learn there is a boundary of novel binons at the top of the known tree which slowly becomes familiar as experiences repeat.

Quote from Barto, Andrew G., Intrinsic Motivation and Reinforcement Learning, a paper in the book [4] Intrinsically Motivated Learning in Natural and Artificial Systems.

Berlyne, Daniel. E. - " He … hypothesized that moderate levels of novelty (or more generally, arousal potential) have the highest hedonic value because the rewarding effect of novelty is overtaken by an aversive effect as novelty increases (as expressed by the "Wundt Curve," p. 89, of Berlyne 1971). This is consistent with many other views holding that situations intermediate between complete familiarity (boredom) and complete unfamiliarity (confusion) have the most hedonic value: the maximal effect of novelty being elicited by "a stimulus that is rather like something well known but just distinct enough to be 'interesting' " (Berlyne 1960). Many of these hypotheses fall under the heading of optimal level theories. "

Berlyne, D.E.: Aesthetics and Psychobiology. Appleton-Century-Crofts, New York (1971)

Berlyne, D.E.: Conflict, Arousal., Curiosity. McGraw-Hill, New York (1960)

The Learning Process

1. Recognize all known patterns
   1.1 For each level of complexity
   - Count repeating parts
   - Find known patterns
2. Create new patterns
   - From unused known patterns
   - Using the growth control rules

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Recognition of existing / known patterns takes place first and faster than creation of new patterns.

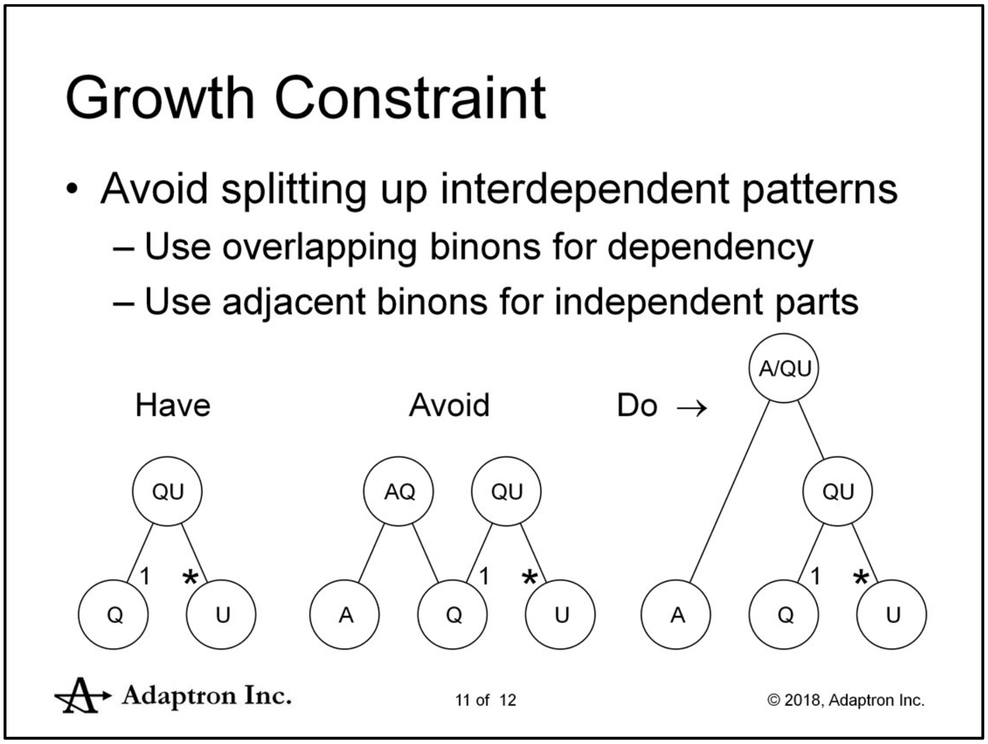
The recognition of known patterns “uses up” lower level patterns, such that they cannot be used to create new patterns.

In step 1. any novel patterns from previous experiences will become familiar.

By counting the repeating parts you determine the quantities for the quantity ratios.

An area of current research is exactly where in step 1 and 2 known separated same or similar parts are recognized and new ones created.

This is necessary to reproduce the Gestalt grouping principles which treat the gap between same or similar objects as the background.



I’m also currently working on this particular growth constraint.

The idea is that if the parts of an object are interdependent and have only ever been experienced in that combination then do not

combine any subparts of the whole that would split up the object’s pattern. The interdependency is determined based on the multiplicity being one.

Only when parts become independent because they are combined with two or more other parts can they be combined in an adjacent structure.

Novel parts are assumed to be independent until they are combined the first time. Then they are dependent.

References

[1] Y. Gatsoulis, E. Kerr, J.V. Condell, N.H. Siddique, and T.M. McGinnity, 'Novelty detection for cumulative learning', in Proc. of Towards Autonomous Robotic Systems 2010 (TAROS'10), pp. 62–67, Plymouth, UK, (2010).

[2] Frégnac, Y. (1995). Hebbian synaptic plasticity: comparative and developmental aspects. In M. A. Arbib (Ed.), The Handbook of Brain Theory and Neural Networks. Cambridge, Massachusetts: MIT Press.

[3] Hebb, D.O. (1949). The Organization of Behavior. New York, John Wiley & Sons.

[4] Baldassarre, Gianluca and Mirolli, Marco Editors. (1998). Intrinsically Motivated Learning in Natural and Artificial Systems, Springer, Publishers

Some relevant references.