Hierarchies [1]

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Hierarchies are structures that represent the relationships between things as a tree.
The hierarchies described in this presentation are compositional hierarchies in which more complex things are made of simpler parts.

This presentation describes how the network of binons is structured for the purposes of representing things.
And it introduces two other networks, configuration tree for tracking where something happened and the activation tree to represent the whole experience.

Contents

- Three hierarchies
  - Recognition – Action [2]
  - Configuration
  - Activation
- Binary tree structure
- Overlapping and Adjacent structures
- Reuse
- Independent properties, sensors & senses

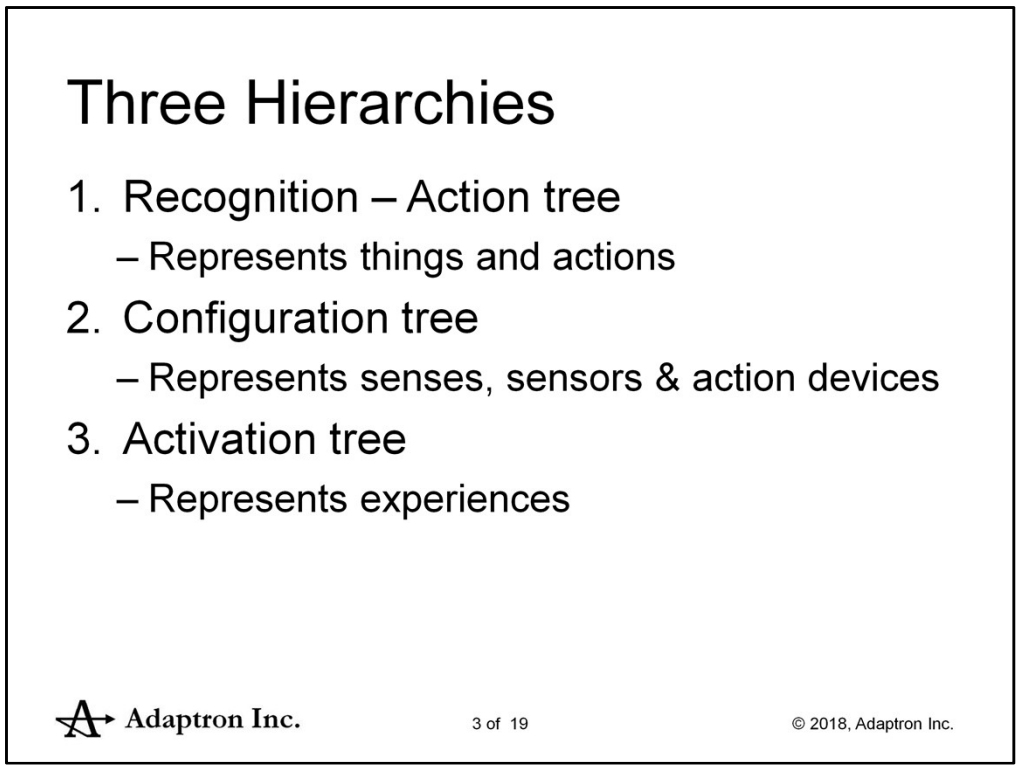
There are three trees; the recognition-action, configuration and activation trees.

Only the recognition-action trees contains binons but all three trees use a binary structure.

The Binons form a compositional tree. Simpler binons are reused to form more complicated ones.

Both magnitude and symbolic values can be perceived.

The Activation tree is used to capture the experience information. It is the short term memory.
This presentation focuses on structural principles such as how to represent overlapping versus adjacent things
and how to represent things that are independent.
How binons learn and how the network grows is explained in the next presentation on Learning.

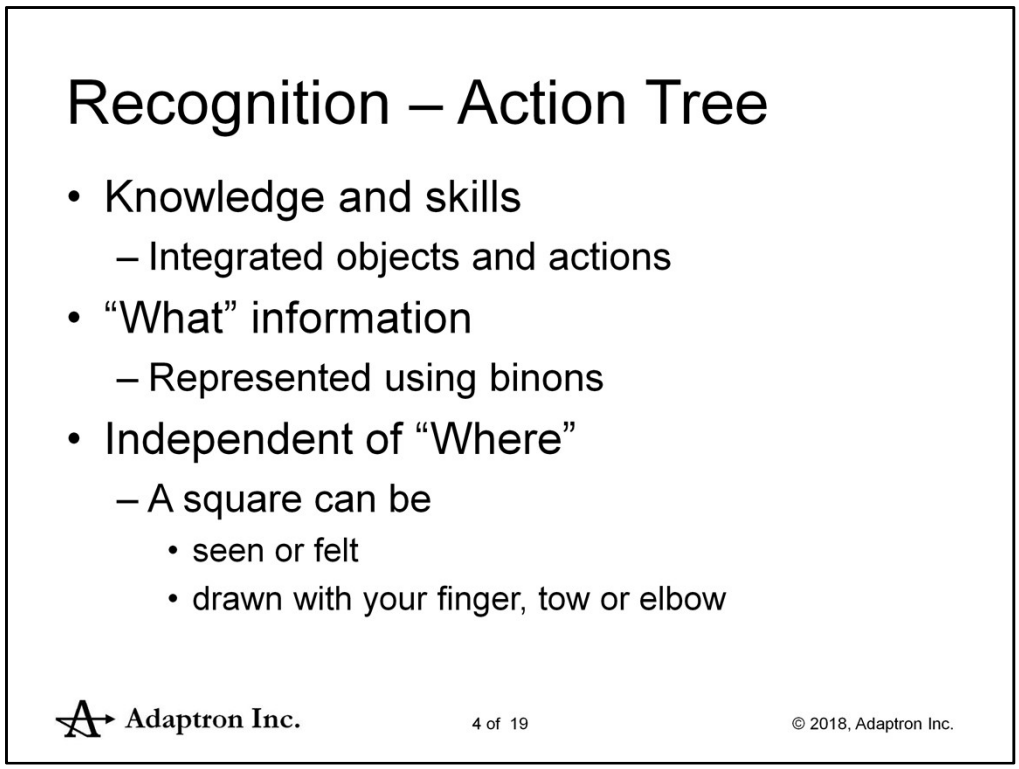


1/ The **Recognition – Action** tree represents things that are recognized and actions learnt in an integrated hierarchy.

2/ The **Configuration** tree is used to represent **Where** to pay attention and which action devices to use.

3/ The **Activation** tree tracks the experience measurements of What was perceived or done and Where.

All three are binary trees however binons are only used in the Recognition-Action tree.



The **Recognition - Action** tree represents things that are recognized and actions learnt in an integrated hierarchy.

They are independent of the configuration tree (Where - sense, sensors and action devices).

You can recognize a square on any sense that has a two dimensional perception.

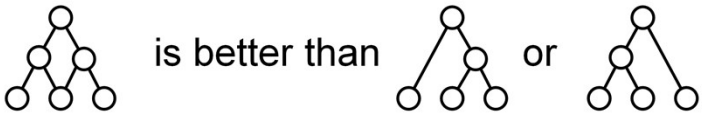
A square can be seen, it can be drawn on your back, and you can even recognize it if you close your eyes and someone moves your hand in a square.

You can draw a square with your toes, with your fingers and your elbow.

A Dolphin can both see and use sound to recognize an object.

Binary Tree Structure

- Many possible configurations



- Restricts links to just the level above
- Able to represent all possible combinations
- Everything has a single representation
- Simpler
- Symmetric

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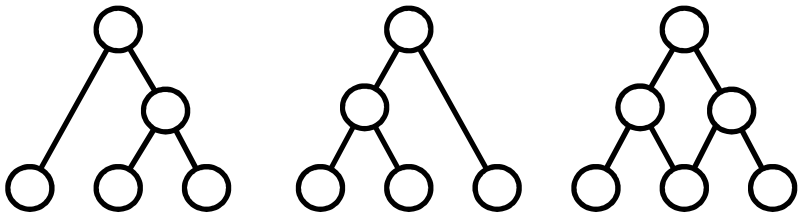
These are some of the key characteristics of the binary tree structure.

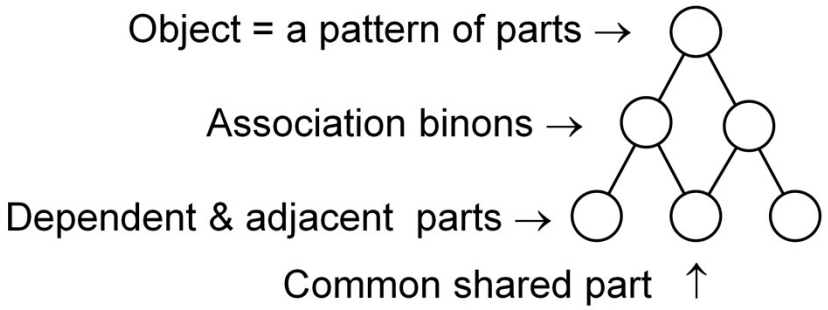
All possible combinations must be representable at all levels of complexity and only represented one way.

The symmetric structure does this and its simple.



Overlapping Structure

- A pattern of dependent and adjacent parts
- Common shared parts



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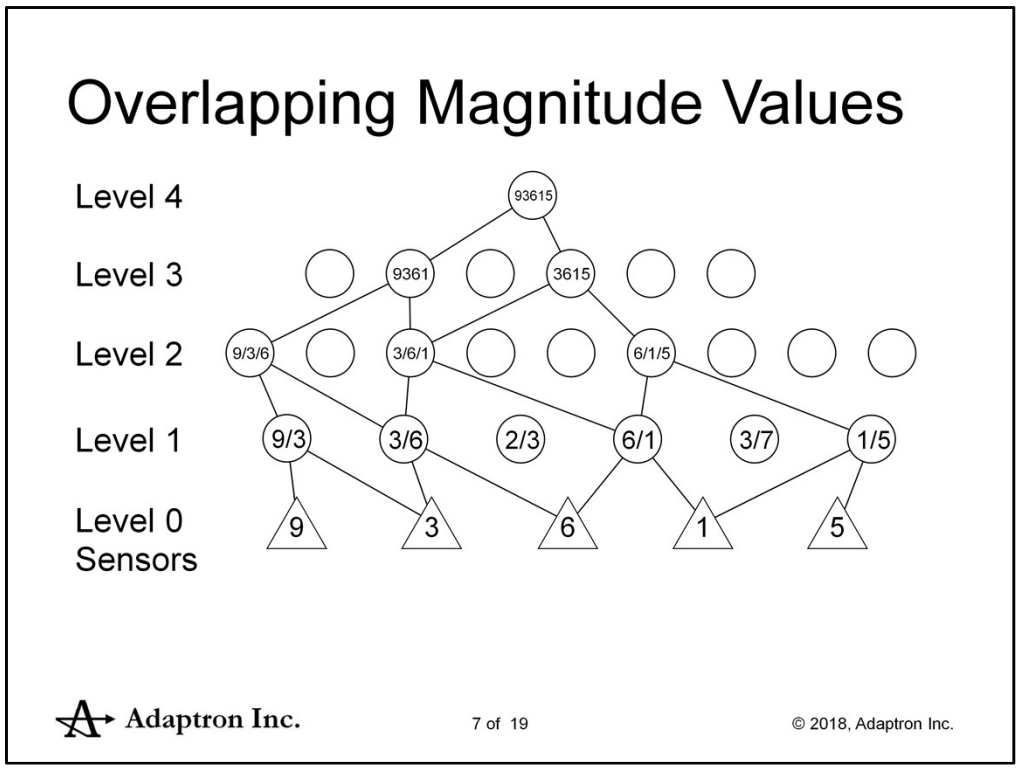
I use the overlapping structure to represent patterns.

An Object is a pattern of parts. The parts are adjacent (next to each other).

This results in “left-of” and “right-of” dependency relationships.

This is represented by the association binons.



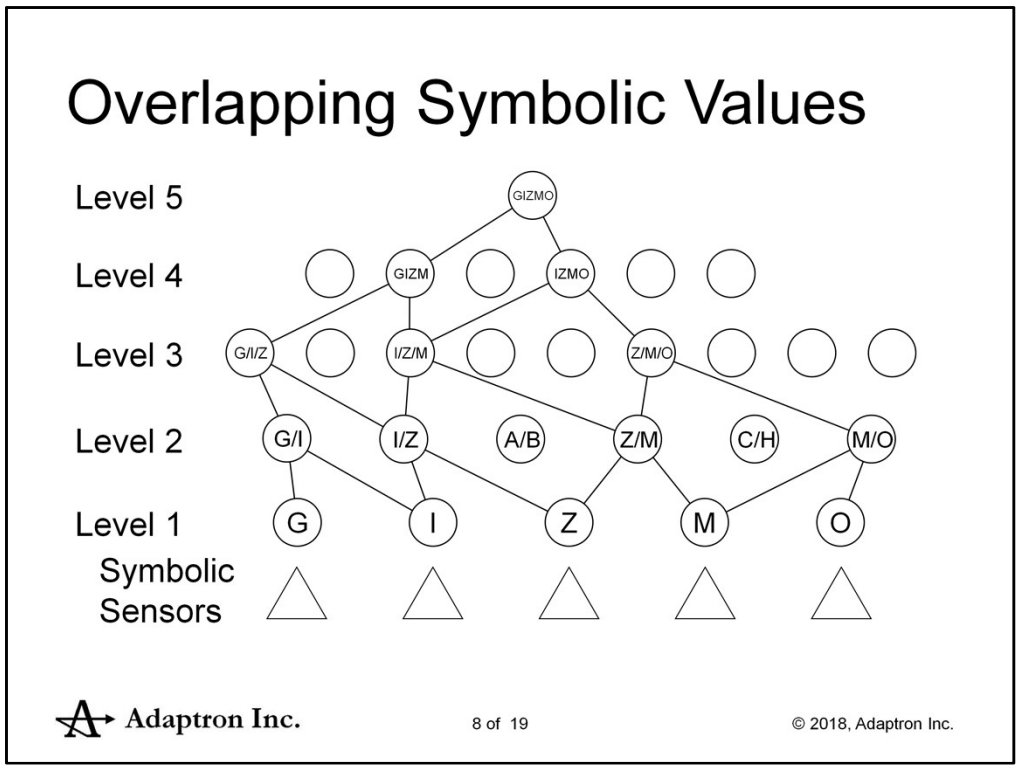
With magnitude values the level 1 ratios are the first identifiable things. They are edges.

Higher level binons would actually contain zero ratio values but they represent the combinations of the level 1 ratios.

This example shows the relative intensity binons based on the intensity magnitudes measured by the sensors.

The same overlapping binary structure is used at all levels.

[Level 1 binons contain values representing the ratios, higher levels of overlapping binons actually contain zero values representing a 1/1 ratio. The multi-valued ratios on the diagram are for displaying what the binons represent based on their combination of source binons.]



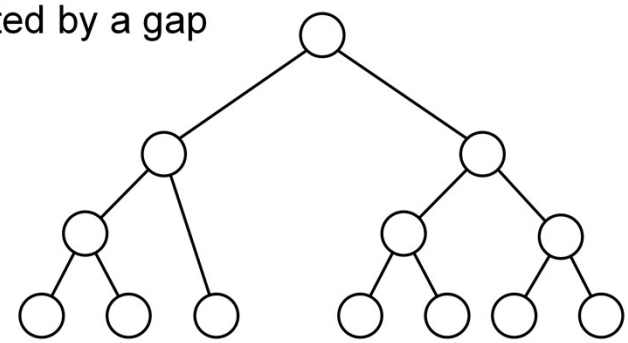
With symbolic input the level 1 binons represent the symbols.

Again the ratio values in level 2 and higher binons would all be zero but they would represent the combinations of the level 1 symbols.

[Level 1 binons contain values representing the symbols, higher levels of overlapping binons actually contain zero values representing a 1/1 ratio. The multi-valued ratios on the diagram are for displaying what the binons represent based on their combination of source binons.]

Adjacent Structure

- Adjacent parts
  - Next to each other
  - Or separated by a gap



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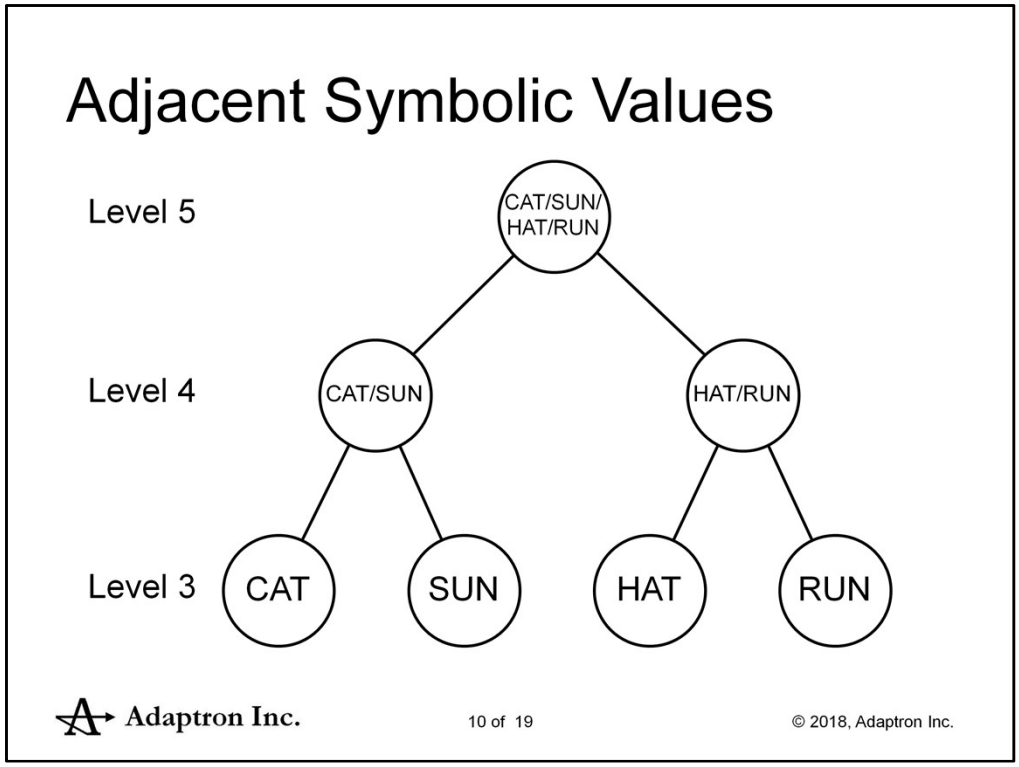
My current thinking is that overlapping structures are used to represent patterns in which all the parts are interdependent.

That is, the parts maintain the same relationship to each other.

And the adjacent structure is used when the parts are found to be independent.

That is when the parts are found to be adjacent to more than one other part.

In adjacent structures links are not restricted to just one level above.



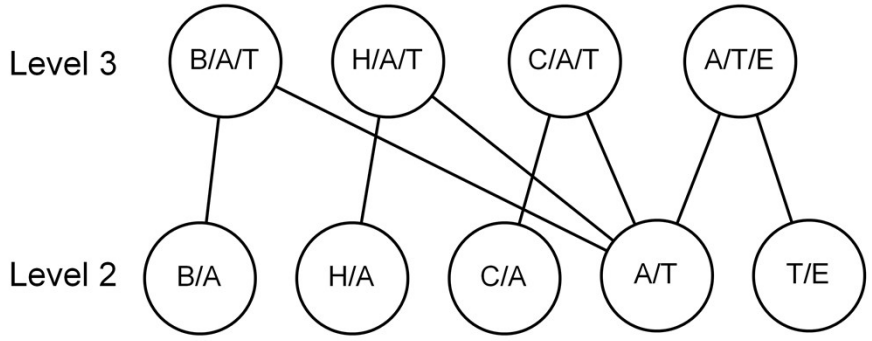
This is an example of an adjacent symbolic binary structure in which the words are the parts and

they have been combined adjacently.

[These binons would actually contain zero values representing a 1/1 ratio. The binon values on the diagram are for displaying what the binons represent based on their combination of source binons.]

Reuse

- Lower level source binons are reused
- Higher level target binons are more specific



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AT is reused. It is the goal source binon for 3 goal target binons at level 3 and the trigger source binon for one trigger target binon at level 3.

Binons can be independent because of different properties perceived by the same sense.

The sensors that perceive these properties in that sense are independent.

An example is colour and brightness sensors (cones and rods).

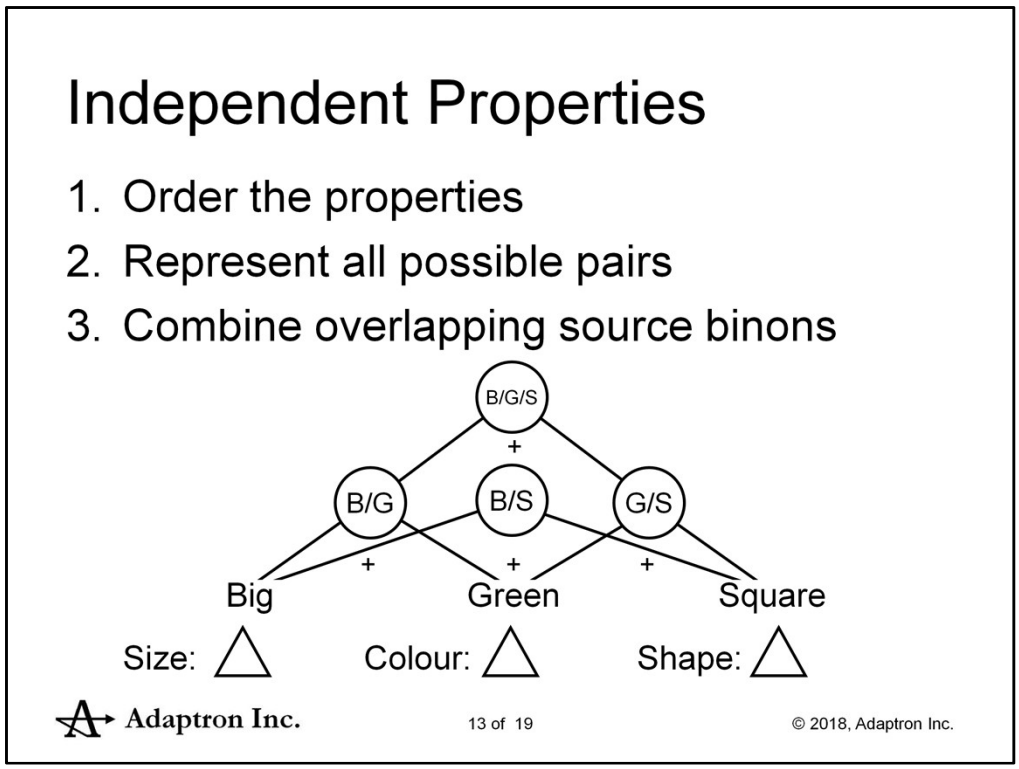
Sensors can be of the same type but have no spatial relationship to each other and therefore independent.

An example is touch on the tongue and touch on the foot.

Senses are all independent from each other. Each measures a different type of energy.

Temporal independence is not possible because one thing is always experienced before or after another.

If they are experienced at the same time then you have spatial recognition.



To obtain all the possible combinations:

1/ Order the properties. Size first, Colour second and Shape third.

2/ Create all possible pairs of the level 1 binons maintaining this left to right order as in the first row or symbolic binons (Big, Green and Square).

3/ For each higher level of complexity combine the lower level ratios that have an overlapping subpart.

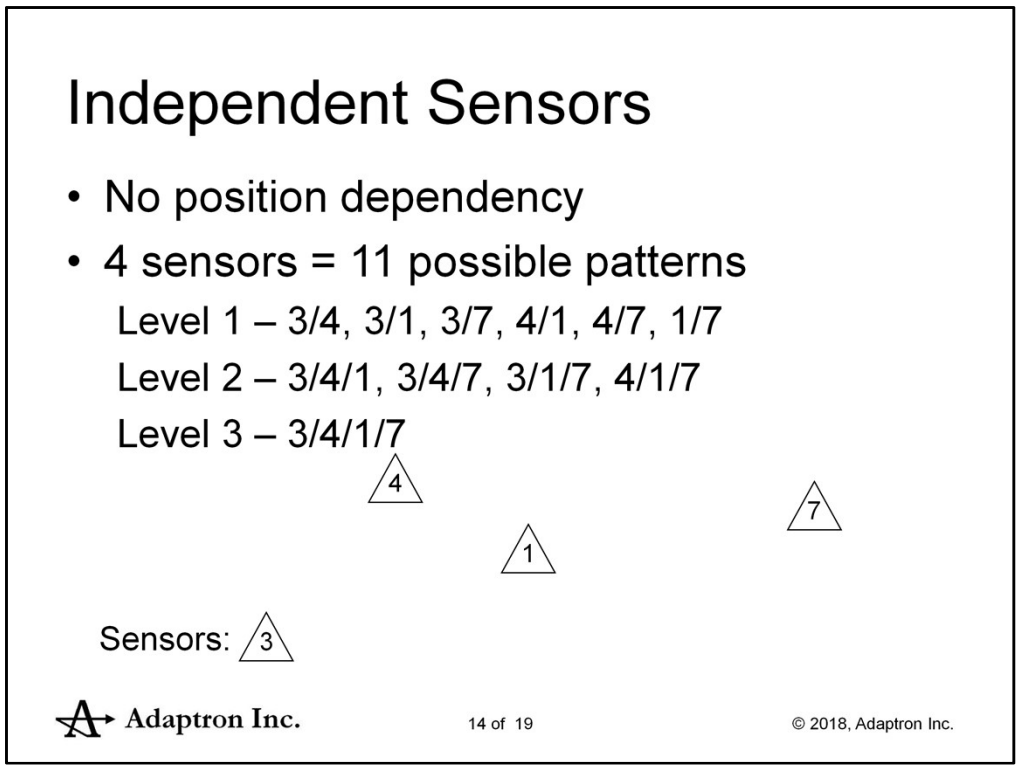
For example B/G overlaps with G/S and that produces B/G/S.

If properties are independent then the number of possible combinations is (2^N)-1 –N where N is the number of properties

(which is the same as the number of sensors). N=3 gives 4 combinations.

Because the properties are independent the Green Square thing is the same as the Square Green thing.

The combination B/G/S is the same as B/S/G, G/B/S, G/S/B, S/G/B, and S/B/G.



If the sensors are independent then they are not ordered and the pattern 3/4 is the same as 4/3.

The combination 3/4/1 is the same as 3/1/4, 4/1/3, 4/3/1, 1/3/4, and 1/4/3.

To obtain all the possible combinations use the same process as on the previous slide:

1/ Order the sensors.

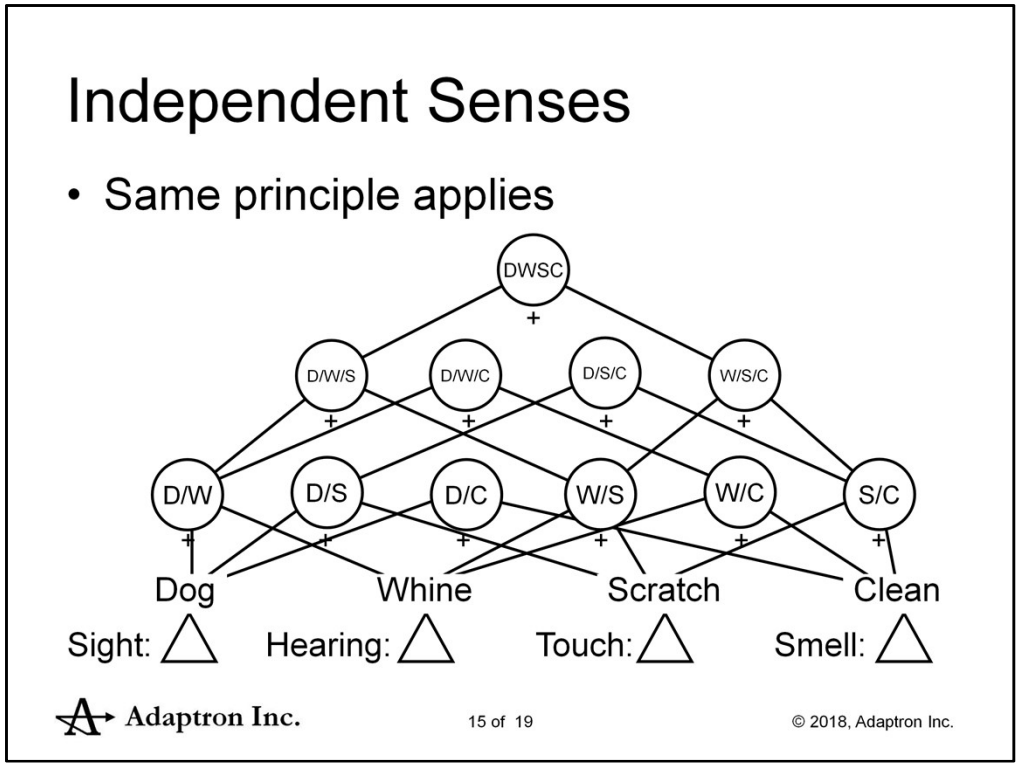
2/ Create all possible level 1 pairs / ratios as in the first row, always maintaining the left to right order.

3/ For each higher level of complexity combine the lower level ratios that have an overlapping subpart.

For example 3/4/1 overlaps with 4/1/7 and that produces 3/4/1/7.

If sensors are independent then the number of possible patterns is (2^N)-1 –N where N is the number of sensors.

N=4 gives 11 combinations



A Multimodal experience. The configuration tree for this perception would be the same structure.

Senses are independent – therefore they are not ordered and thus the Clean Scratching Whining Dog thing

is the same as the Whining Scratching Clean Dog thing.

To obtain all the possible combinations use the same process as on the previous slide:

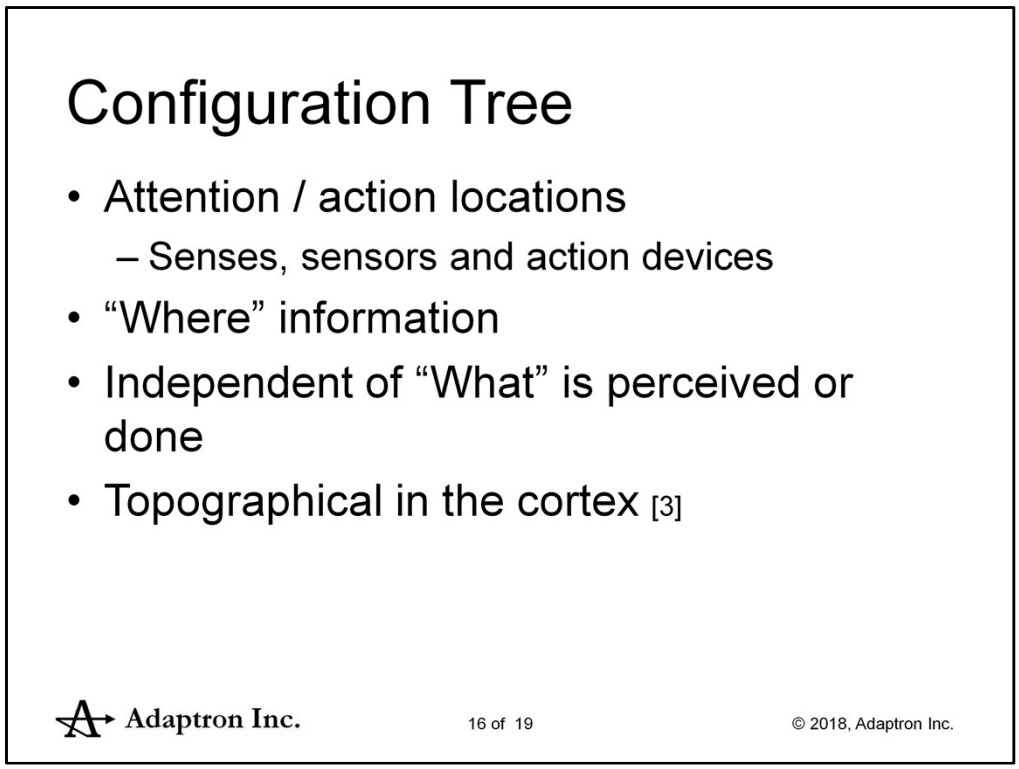
1/ Assigns an order to the senses.

2/ Create all possible pairs of the level 1 binons maintaining the left to right order as in the first row of symbolic binons (Dog, Whine, Scratch, Clean).

3/ For each higher level of complexity combine the lower level ratios that have an overlapping subpart.

Senses are independent and the number of possible combinations is (2^N)-1 –N where N is the number of senses.

The number of senses happens to be the same as the number of level 1 binons because senses always produce symbolic values.



The **Configuration** tree is used to represent **Where** to pay attention and which action devices to use.

In the brain it is represented by the locations on the cortex (topographical).

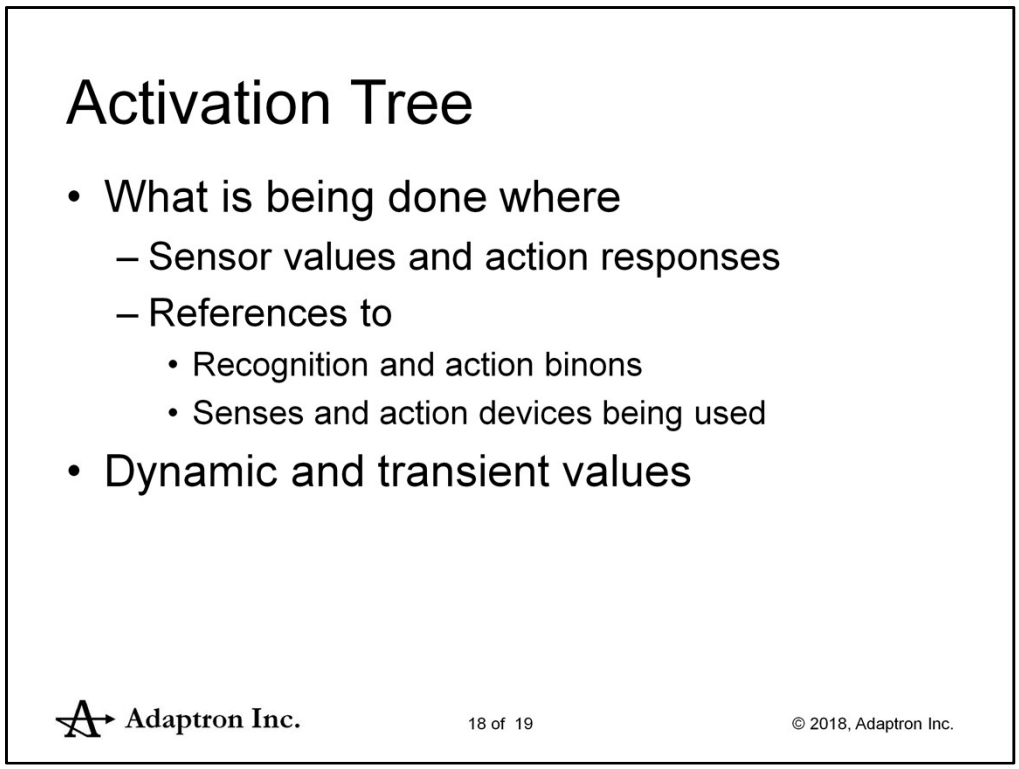
For example, the layout in the cortex for the sense of touch is practically the same as the layout for motor control.

This hierarchy is described in more detail in the Experiences presentation.

Configuration Tree

- Where perceived
  - Combination of senses, sensor types and sensors
    - Sight, cones and rods, fovea
    - Hearing, hair cells, 300 to 700 Hz
- Where done
  - Combination of action device types and action devices
    - Wheels, front right wheel
    - Arms, right arm

The configuration tree represents where something is perceived or where something is done.



The **Activation** tree tracks the measurements from the senses and responses for the action devices.

It contains the absolute values derived from the experiences.

This information is kept only as long as it is required to contribute to learning habits.

It keeps track of what is being perceived and what is being done and the senses and action devices being used.

This hierarchy is described in more detail in the Experiences and Temporal recognition presentations.

References

[1] Fidler, S., Boben, M. & Leonardis, A. (2009) Learning Hierarchical Compositional Representations of Object Structure. In S. Dickinson, A. Leonardis, B. Schiele & M. Tarr (Eds.), Object Categorization: Computer and Human Vision Perspectives. New York: Cambridge University Press.

[2] Bienenstock, E. & Geman S. (1995). Compositionality in Neural Systems. In M. A. Arbib (Ed.), The Handbook of Brain Theory and Neural Networks. Cambridge, Massachusetts: MIT Press.

[3] Lee I. Newman, Thad A. Polk (2007). The Emergence of Semantic Topography in a Neurally-Inspired Computational Model, 8th International Conference on Cognitive Modeling, 2007. Edited by Richard L. Lewis, Thad A. Polk, and John E. Laird

Another interesting reference is:

Taylor P., J. N. Hobbs, J. Burroni & H. T. Siegelmann (2015). The global landscape of cognition: hierarchical aggregation as an organizational principle of human cortical networks and functions. *Sci. Rep.* 5, 18112; doi: 10.1038/srep18112 (2015).