Adaptron Architecture

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This presentation explains the high level design of the software for the Adaptron cognitive architecture.

Adaptron's software architecture consists of two subsystems – one subsystem for representing and controlling behaviour and the other for representing and controlling mental processes. Each subsystem is efficiently structured using deep compositional hierarchies of binary neurons (binons).

Adaptron is also a physical symbol system. Allen Newell wrote that:

"A physical symbol system has the necessary and sufficient means for general intelligent action."

However, Adaptron is not a traditional AI system that just manipulates symbols based on logic.

It uses patterns of discrete interacting functional components called binons, to represent the knowledge and abilities gained from experience and to control its behavioural and mental processes.

Contents

- Purposeful
- Grounded
- General-purpose
- Dual subsystems
- Adaptable
- Action control
- Mental processes

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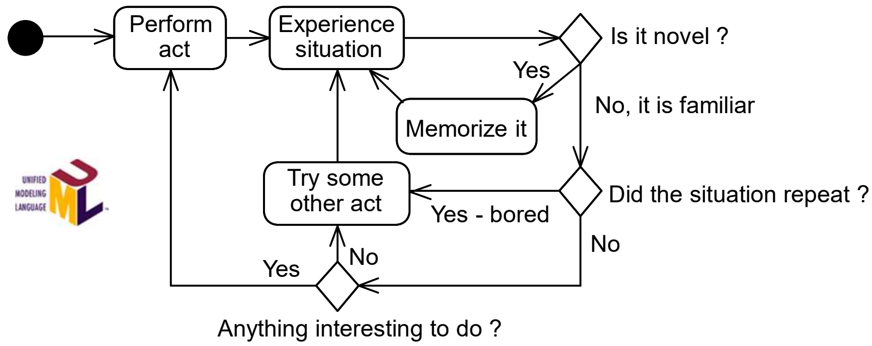
In this presentation I explain these main architectural features of Adaptron.

They correspond to requirements as described in the requirements presentation.

Purposeful

- Intrinsic motivation only
  - Exploration to find interesting situations
  - Practice to increase reliability of actions



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Only intrinsic types of motivation are currently built into Adaptron’s design.

It performs trial and error learning to explore and experience new situations.

It practices actions by repeating them until reliable outcomes can be predicted.

The Unified Modeling Language (UML) activity diagram illustrates a simplified version of Adaptron’s exploration process.

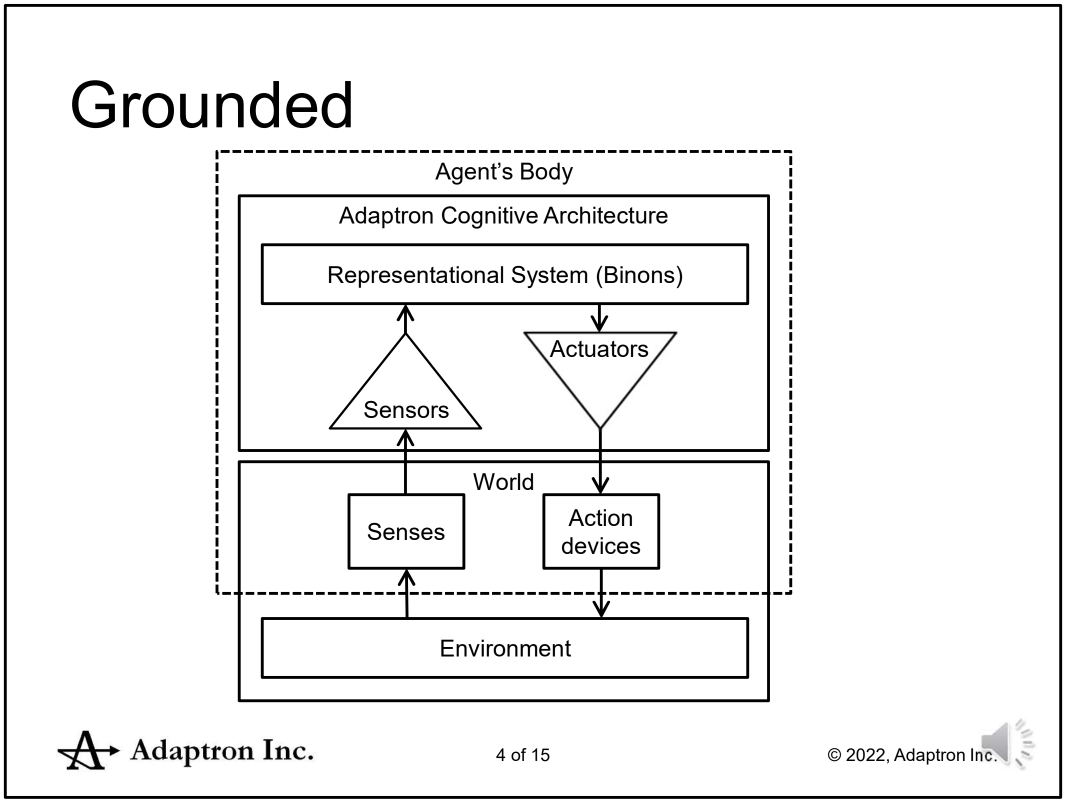
After performing an act there is a resulting situation. If it is novel, it is memorized and Adaptron perceives the next situation.

If this continues it is being entertained with novel stimuli.

If a situation is familiar and it was a repeat of the previous one then Adaptron is bored and it tries some other random act.

This is action babbling. But if the situation did not repeat and it knows of something interesting to do it performs that act.

If it does not know of something interesting it tries some other random act and perceives the resulting situation.



Adaptron is connected to its environment via a configuration of senses and action devices.

Any number and combination of senses and action device types can be used.

These interface devices are in the world outside Adaptron as part of the agent's body.

They can wear, fail and behave independently from what Adaptron does.

An important layer inside Adaptron is that of its sensors and actuators.

They allow it to communicate with the world via the senses and action devices.

Grounded

- Sensor and actuator property values
  - Source of all knowledge and abilities
  - Concepts grounded on them [1]
- Values may be non-symbolic/numeric or symbolic
  - Numeric values used to derive symbolic ones
- A sense of time
- An event driven architecture
  - Input-process-output cycle [2]

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All of Adaptron's knowledge and abilities are grounded on sensor and actuator property values.

And concepts used in reasoning are grounded on this knowledge.

Sensor and actuator property values can be non-symbolic numeric such as loudness or symbolic such as characters.

Numeric sensor values are used in the derivation of ratios that become symbolic representations of relationships.

Adaptron also has a sense of time

Adaptron is an event driven architecture based on an input-process-output (IPO) model.

General–Purpose

- Binary neurons (binons) are general-purpose representational components
- Represent all types of objects and events
  - Percepts, acts and concepts
  - Properties independent of sense [3]
  - Relational properties [4]
- Functional components for control

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Adaptron is a general-purpose architecture, not only because of the variety of interface devices it can use but also because it is built from binons which are general-purpose representational components.

They can represent all types of objects and events. This includes percepts from perception, acts for performing actions, concepts in reasoning, property values independent of sensor types and relations between these things.

Binons are also functional components that can be learnt and used to control actions.

General–Purpose

- Compositional hierarchical structure [5]
  - Reuse of percepts and acts
- Sensory memory
- Long-term memories [6]
  - Behavioural perception-action hierarchies
  - Mental conceptualization-control hierarchies

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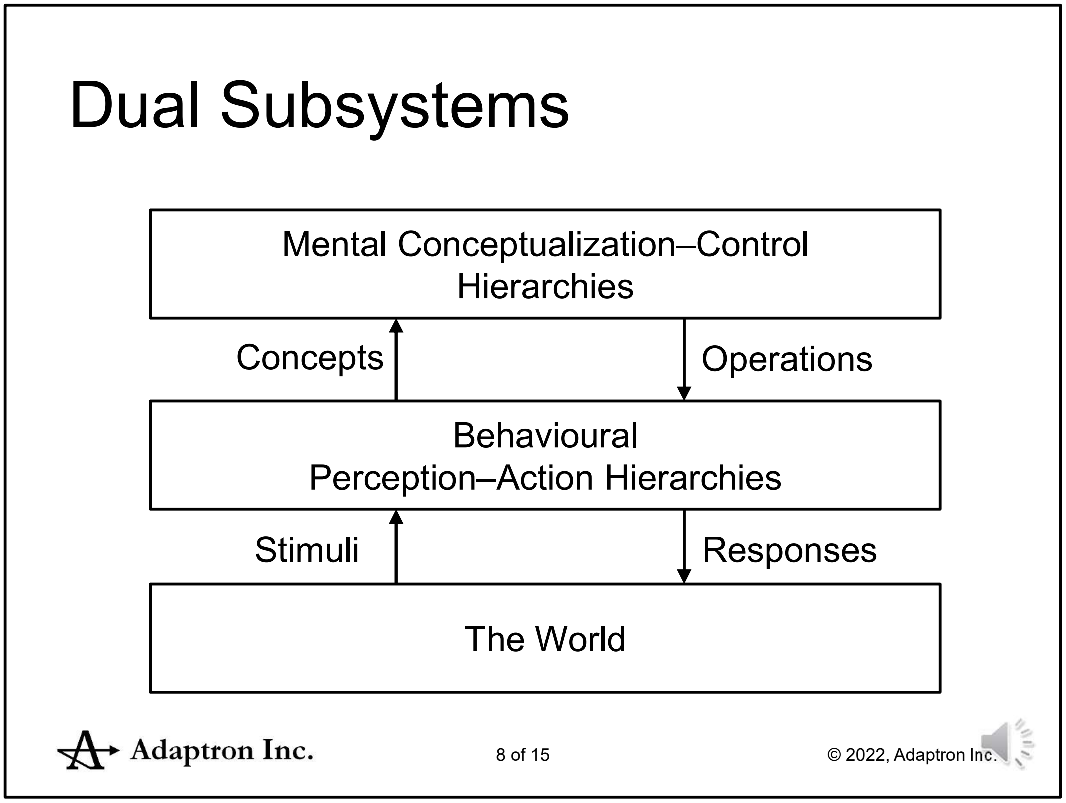
The architectural structure of Adaptron is also general-purpose. Binons representing percepts and acts are combined into compositional hierarchies.

The simpler percepts and acts derived from the interface devices are reused and composed into more complex ones.

A sensory memory maintains a transient record of the properties of the most recent stimuli.

Adaptron’s long-term memories are composed of binons that are contained in two subsystems.

They are the behavioural perception-action hierarchies and the mental conceptualization-control hierarchies.



This dual subsystem architecture allows for the performance and control of behaviour in parallel with mental concentration.

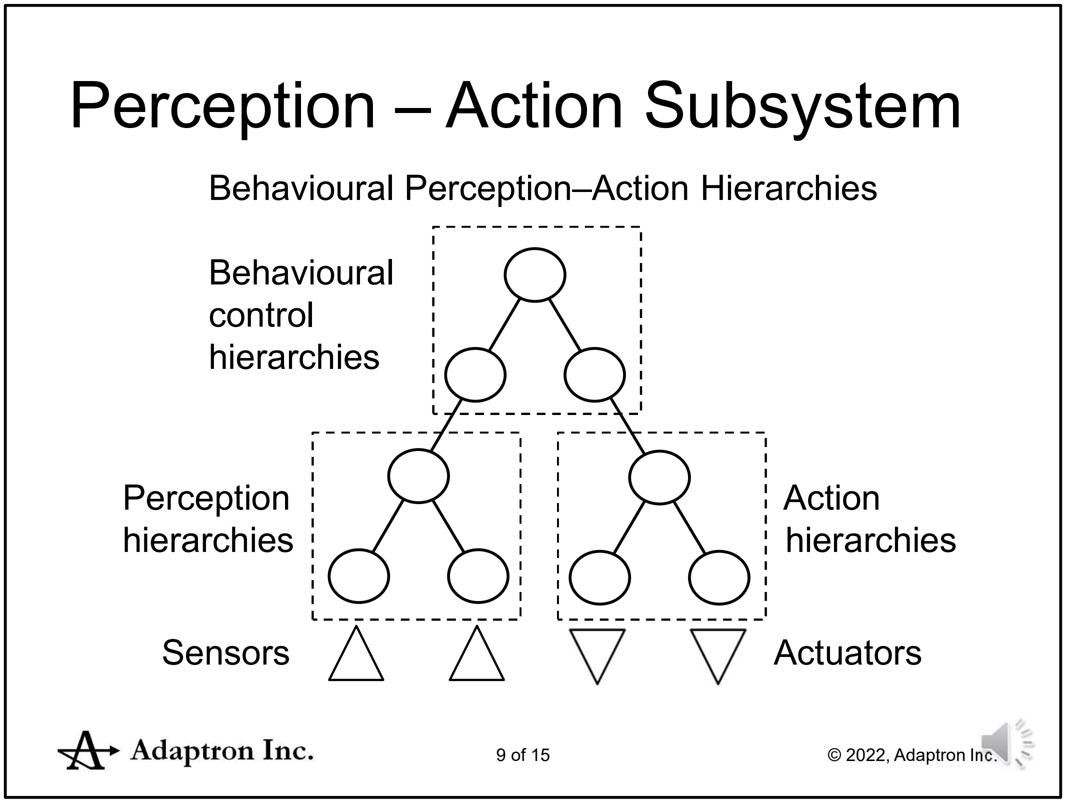
The behavioural subsystem interacts with the world via sensors and actuators.

And then percepts in the behavioural subsystem are recalled as concepts for reasoning by the mental subsystem.

Conscious mental operations are performed on the behavioural hierarchies of binons to either recall percepts, pay attention to the senses or initiate and perform actions.

There are no interface devices like sensors or actuators between the mental and behavioural subsystems.

All mental operations directly access percepts in the behavioural subsystem.



The internal structure of the behavioural perception-action subsystem is made up of the perception hierarchies that are used in perception, action hierarchies of action habits and hierarchies of behavioural control binons that relate percepts with acts and vice versa.

Adaptable

- Stages of learning
  - Involuntary
    - Reflexes
    - Babbling
  - Deliberate
    - Reuse
    - Practice [7]
  - Automatic [8]
    - Habits
- Dual process theory [9]

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To be adaptable Adaptron must be capable of learning everything that is more complex than sensory properties, primitive acts and reflexes.

In Adaptron, learning of new binons goes through a number of stages. In the involuntary stage new percepts are learnt because the built-in orienting response attracts attention to unexpected changing stimuli. If there are any action reflexes built into the body new action outcomes are learnt.

However, when Adaptron is bored, action babbling produces random acts and this becomes a source of new actions and resulting percepts.

Once percepts and actions have been memorized they can be deliberately reused until they are familiar. They also get reused in transfer learning.

It is the reuse of known actions in new situations. For example, you have learnt to use a potato peeler on potatoes and carrots and then you try to peel an apple with it and you find out you can.

But actions don't always produce the same results. The results may depend on the situation in which the action was performed or they are affected by the unpredictability of the world. Therefore, actions need to be practiced until the resulting situations can be reliably predicted with a high degree of certainty.

Once they are reliable actions can be started consciously as a result of an intention to perform them and then they execute automatically. Just like tying a shoe lase or eating with a knife and fork. These are habits.

Binons transition through these stages. They are novel when first experienced. They are familiar when they are experienced again. They are deliberate when recognized or performed and become automatic habits once they are predictable and reliable.

This is consistent with the dual process theory of cognition, which distinguishes between explicit/reasoning/deliberate (system 2) and implicit/automatic (system 1) processes.

Action Control

- Ready or active action habits
- Consciously activated
- Start when triggered by a situation
- Execute subconsciously
- Order of execution driven by the situation [10]
- Repeat if situation repeats
- Many executing simultaneously
- Deactivated when actuators repurposed
- Complex actions composed of simpler ones [11]

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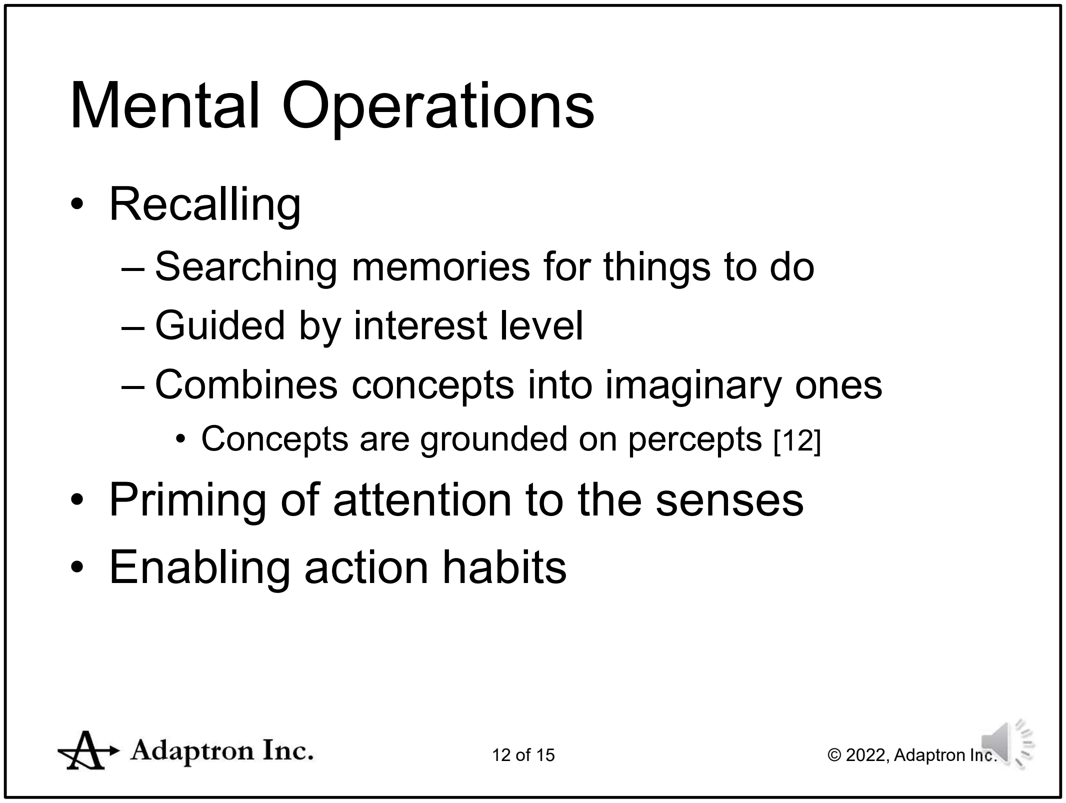
Action control in Adaptron depends on the state of action habits. Once they are known and reliable they are ready for use but they must be consciously activated before they will operate. Once active, they are triggered by the recognition of their triggering situation. They are then executed subconsciously. If they are complex action habits containing a sequence of acts then the order in which the acts are executed is driven by the sequence of situations that result from previous acts. While they are active, if a situation repeats then the act is repeated. Many acts can be active and executing at the same time provided they are not using the same action devices. As soon as a new action habit is activated that uses the same action device as a previously activated one the previous one is deactivated. Complex action habits are structured as compositional hierarchies of simpler ones.

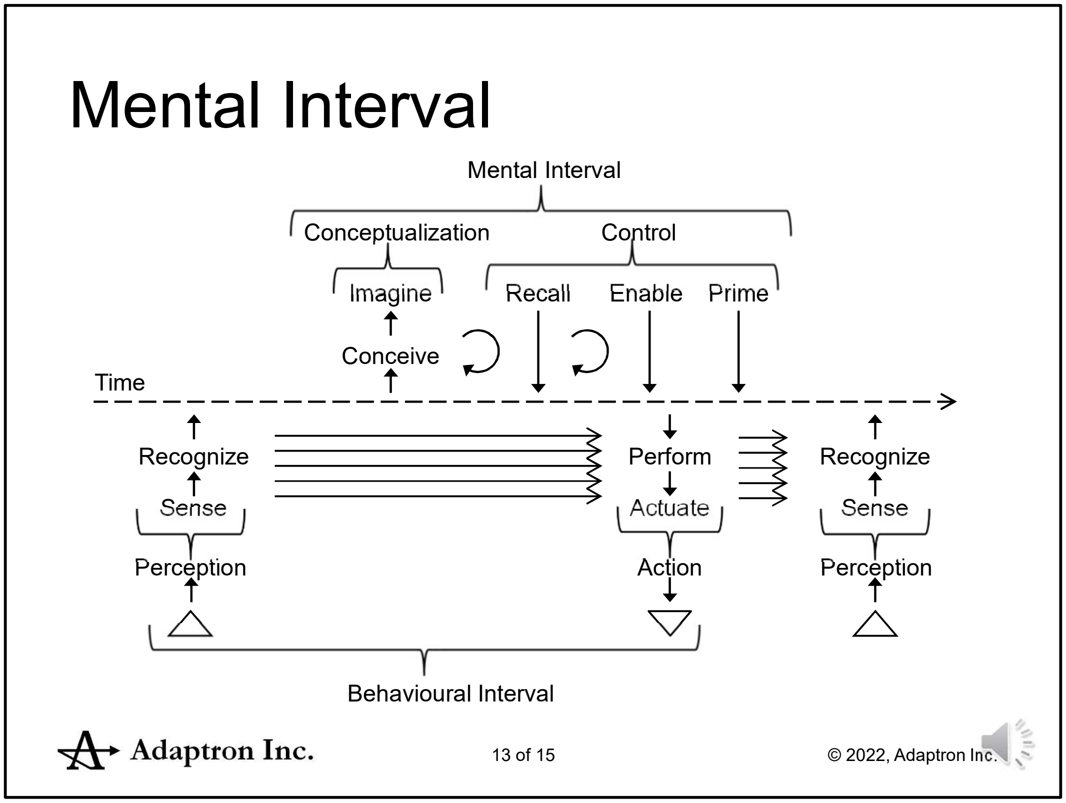


In Adaptron the mental operations are recalling percepts and concepts, priming attention to senses and enabling action habits.

Recalling searches the hierarchies of perceptual memories for resulting situations that are interesting. When interesting percepts are found then either attention is paid to the senses, using priming, to re-experience them or if required an action habit is enables so it becomes active and it gets triggered by the current situation.

When a percept is recalled it is a concept. A series of recalled percepts can be combined to form an imaginary concept.

Such concepts remains grounded on the percepts from which they are composed.



In Adaptron a behavioural interval consists of a perception event and one or more action events. These repeat in a cycle.

Perception includes sensing and then recognizing percepts, while action consists of performing and then actuating acts on action devices.

A mental interval begins after attention is paid to a percept. This results in the conceiving of percepts as concepts and the possible formation of imaginary concepts. Perceptual memories are then recalled in sequence, guided by their interest level until one is found that is the result of an action worth performing.

If it is a reliable action habit it is enabled and mental control may go back to recalling percepts. However, if it is an action that needs to be reused or practiced then it is enabled and the percept of its outcome is primed as expected. This ends the mental interval which has performed some reasoning steps, started some action habits and is paying attention to what should happen next.

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Here are two pages of references as identified in the slides.

Seven on this slide and five more on the last one.

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