

COMP250: Artificial Intelligence

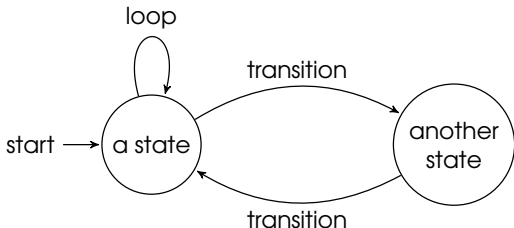
3: Behaviour trees

Finite state machines

Finite state machines

- ▶ A **finite state machine (FSM)** consists of:
 - ▶ A set of **states**; and
 - ▶ **Transitions** between states
- ▶ At any given time, the FSM is in a **single state**
- ▶ **Inputs** or **events** can cause the FSM to transition to a different state

State transition diagrams

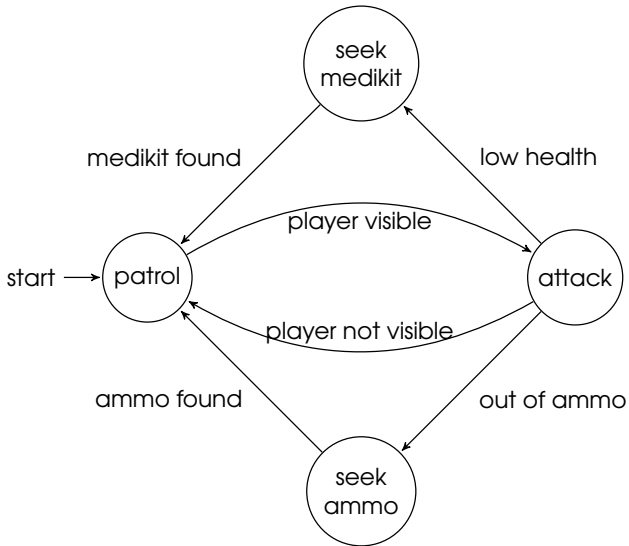


- ▶ FSMs are often drawn as **state transition diagrams**
- ▶ Reminiscent of **flowcharts** and certain types of **UML diagram**

FSMs for AI behaviour

The next slide shows a simple FSM for the following AI behaviour, for an enemy NPC in a shooter game:

- ▶ By default, patrol (e.g. along a preset route)
- ▶ If the player is spotted, attack them
- ▶ If the player is no longer visible, resume patrolling
- ▶ If you are low on health, run away and find a medikit.
Then resume patrolling
- ▶ If you are low on ammo, run away and find ammo.
Then resume patrolling



Other uses of FSMs

As well as AI behaviours, FSMs may also be used for:

- ▶ UI menu systems
- ▶ Dialogue trees
- ▶ Token parsing
- ▶ ...

Beyond FSMs

Some topics for you to research, for when plain old FSMs aren't enough...

- ▶ Hierarchical FSMs
- ▶ Nested FSMs
- ▶ Stack-based FSMs
- ▶ Hierarchical task networks
- ▶ ...

Plus the topic we will be looking at today: **behaviour trees**

Behaviour Trees

Behaviour trees (BTs)

- ▶ A **hierarchical** model of decision making
- ▶ Allow **complex behaviours** to be built up from **simple components**
- ▶ Allow for **more complex** behaviours than FSMs
- ▶ First used in Halo 2 (2005), now used extensively
- ▶ Also used in robotics and other non-game AI applications

Using BTs

- ▶ Fairly easy to implement; plenty of resources online
- ▶ Some engines (e.g. Unreal) have BTs built in
- ▶ We will be using the free **Behaviour Machine** library for Unity

BT basics

- ▶ A BT is a **tree** of **nodes**
- ▶ On each game update (i.e. each frame), the root node is **ticked**
 - ▶ When a node is ticked, it might cause some or all of its **children** to tick as well
 - ▶ So ticks propagate down the tree from the root
- ▶ A ticked node returns one of three **statuses**:
 - ▶ Success
 - ▶ Running
 - ▶ Failure
- ▶ “Running” status allows nodes to represent operations that **last multiple frames**

Node types

- ▶ There are **three main types** of BT node
- ▶ **Leaf** nodes
 - ▶ No children
 - ▶ Represent actions (i.e. the AI agent actually doing something)
- ▶ **Decorator** nodes
 - ▶ One child
 - ▶ Modify the execution of the child
- ▶ **Composite** nodes
 - ▶ Control which of the children are executed on each tick

Leaf nodes

- ▶ Represent **atomic actions**
 - ▶ I.e. actions which can't sensibly be broken down into smaller actions
- ▶ E.g. walk to, crouch, attack, open door
- ▶ Status:
 - ▶ Success means "the action is done"
 - ▶ Failure means "the action cannot be done"
 - ▶ Running means "the action is still in progress"
- ▶ Leaf nodes can also be used to represent **conditions**
 - ▶ E.g. "is my health below 10%?"
 - ▶ Returns success for true, failure for false
- ▶ Leaf nodes often have **parameters** to allow for reuse in different situations

Leaf node example

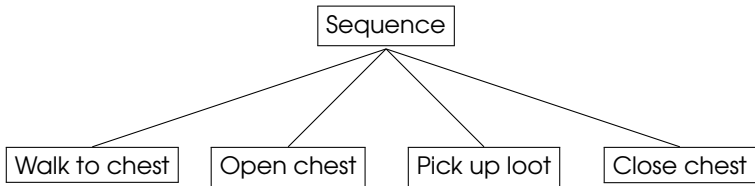
```
using UnityEngine;
using System.Collections;
using BehaviourMachine;

public class GoTo : ActionNode
{
    public GameObjectVar objectToMove;
    public Vector3Var target;
    public FloatVar speed;

    public override Status Update()
    {
        float distance = (objectToMove.Value.transform.position - target.Value). ←
            magnitude;
        float step = speed.Value * Time.deltaTime;
        if (distance < step)
        {
            objectToMove.Value.transform.position = target.Value;
            return Status.Success;
        }
        else
        {
            objectToMove.Value.transform.position = Vector3.MoveTowards( ←
                objectToMove.Value.transform.position, target.Value, step);
            return Status.Running;
        }
    }
}
```

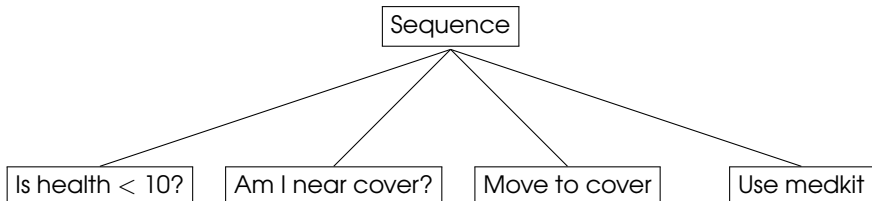
Composite nodes: sequence

- ▶ Run each child, in order
- ▶ If **any** child returns failure, stop and return failure
- ▶ If **all** children return success, stop and return success



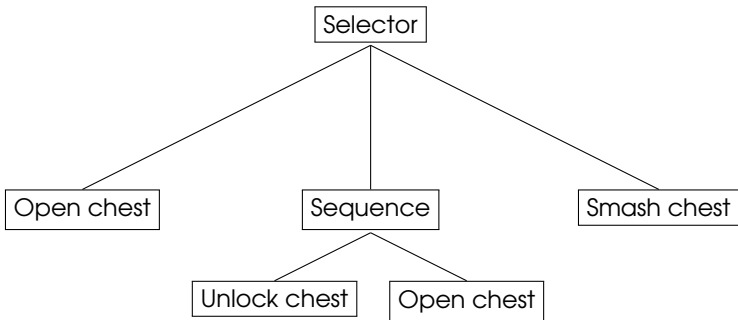
Sequence nodes and conditions

- A sequence node can be used like an `if (cond1 && cond2)` statement



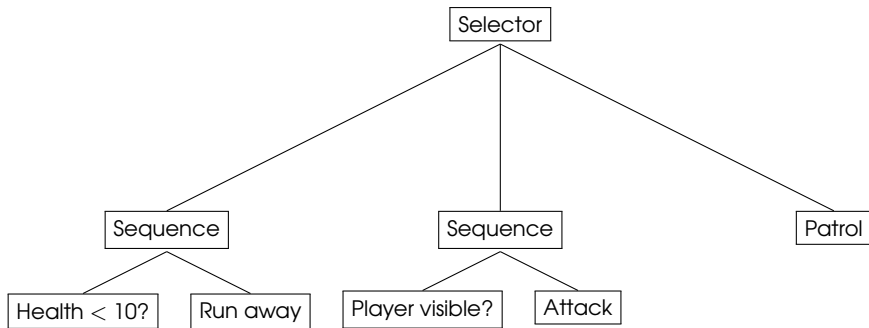
Composite nodes: selector

- ▶ Run each child, in order
- ▶ If a child returns failure, move onto the next one
- ▶ If **any** child returns success, stop and return success



Selectors and priority

- Order of selector children represents the **priority** of different alternatives



Sequence vs selector

- ▶ Sequence: perform a list of actions; if one of them fails then abandon the task
- ▶ Selector: try a list of alternatives; stop once you find one that works
- ▶ Sequence works like **and**, selector works like **or**

Other composite nodes

- ▶ Execute children in **random** order
- ▶ Execute children in **parallel**
- ▶ Most BT frameworks allow programmers to create custom composite nodes

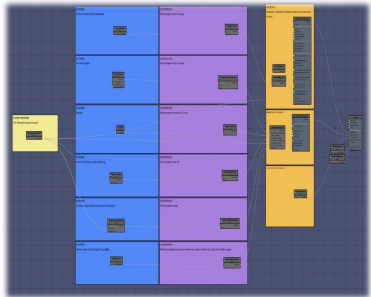
Decorator nodes

- ▶ **Inverter:** if child returns success then return failure, and vice versa
- ▶ **Repeater:** run the child a number of times, or forever
- ▶ Most BT frameworks allow programmers to create custom decorator nodes

Blackboard

- ▶ It is often useful to **share** data between nodes
- ▶ A **blackboard** (sometimes called a **data context**) allows this
- ▶ Blackboard defines **variables**, which can be **read** and **written** by nodes
- ▶ Blackboard can be **local** to the AI agent, **shared** between several agents, or **global** to all agents
- ▶ (Shared blackboards mean that your AI has “telepathy” — this may or may not be desirable!)

BTs in The Division



[http://www.gdcvault.com/play/1023382/
AI-Behavior-Editing-and-Debugging](http://www.gdcvault.com/play/1023382/AI-Behavior-Editing-and-Debugging)

Portfolio task proposals