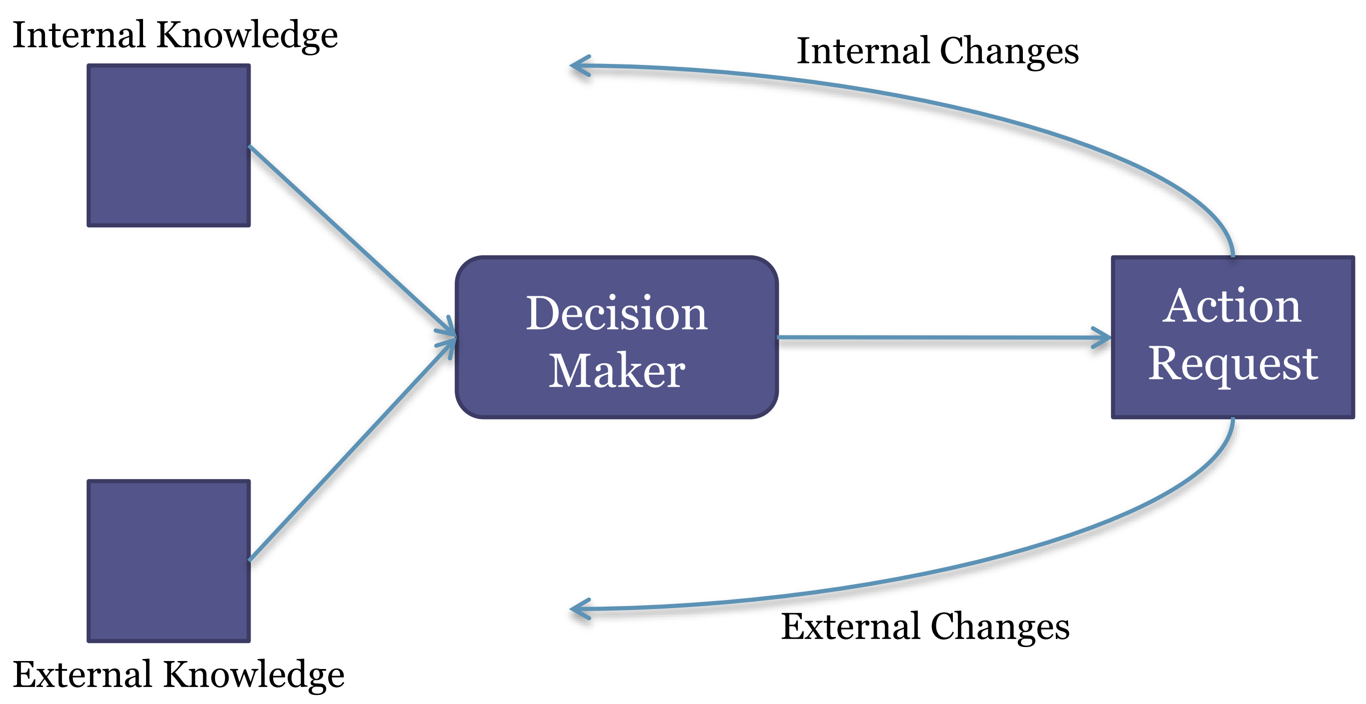
CS230
Game Implementation Techniques

Lecture 14

Outline

- Decision Making
  - Decision Trees
  - State Machines
    - FSM (Finite State Machines)
    - Hierarchical State Machines
- FSM Scripting Language
- AI Behavior in Platformer

Decision Making (1/2)

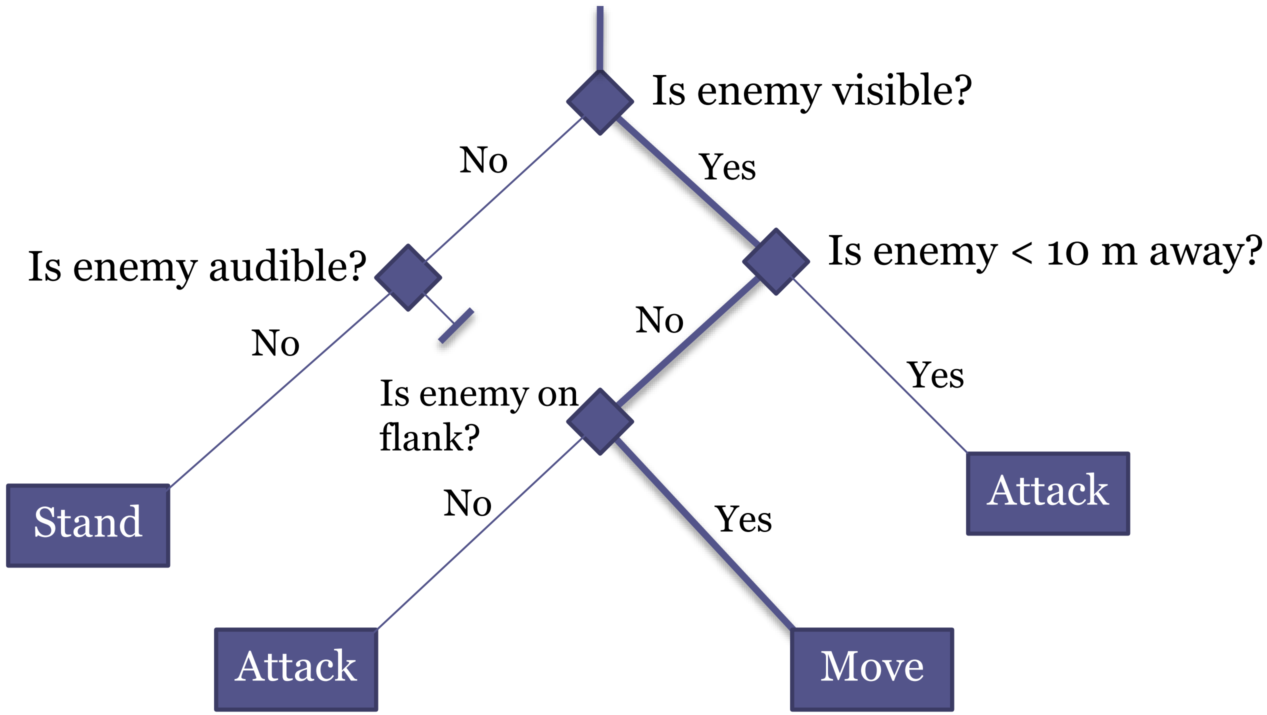


Decision Making (2/2)

- The input is the knowledge that a character possesses. The knowledge could be broken down into two sections:
  - External knowledge
  - Internal Knowledge

- The output would be the action

Decision Trees (1/2)



Decision Trees (2/2)

- A decision tree is just a series of questions that help a unit decide what to do given its current situation
  - Often a series of yes/no questions
  - This leads to a *binary tree*

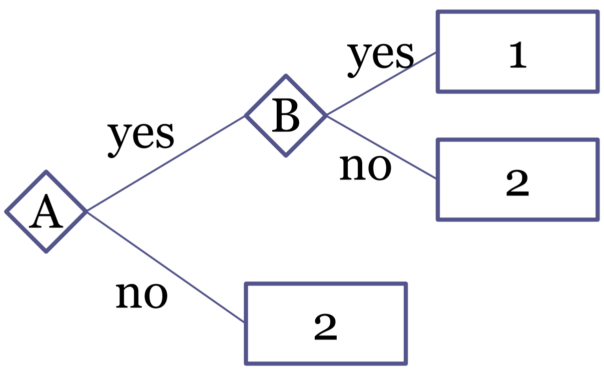
- Each terminal (or *leaf) node represents a state,* e.g., *attack, hide, patrol, etc.*

Decision Trees Node

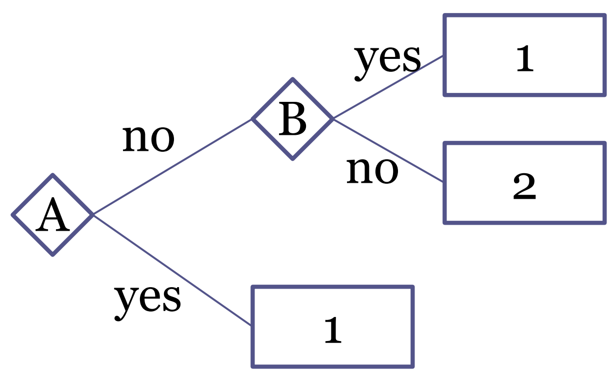
```
struct NodeTree
{
	//void * data; //or int //or object *...
	NodeTree * left;
	NodeTree * right;

	virtual NodeTree * Execute() = 0;
	void MakeDecision();
};
```

Combinations of Decisions

If A AND B then action 1, otherwise action 2

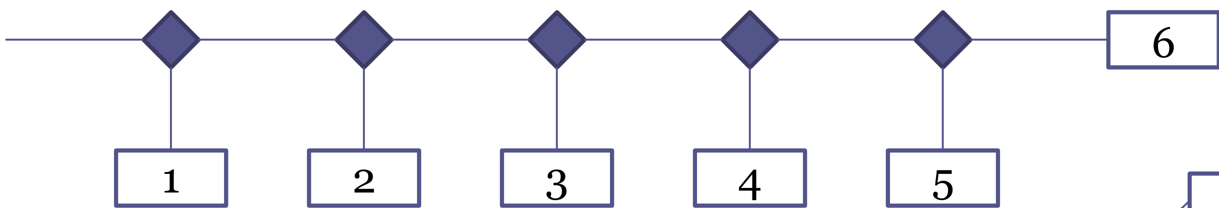


If A OR B then action 1, otherwise action 2

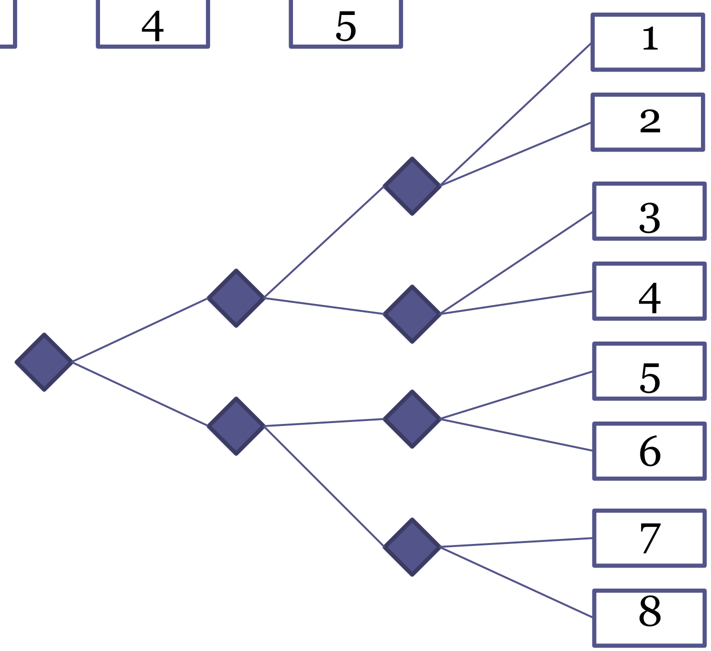


Balancing Trees

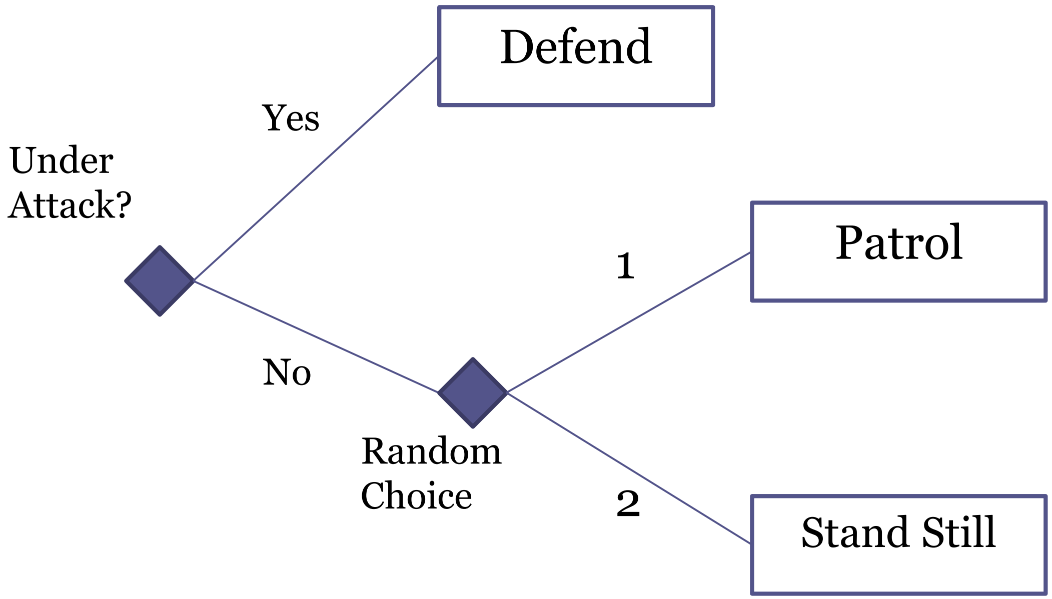
Unbalanced tree



Balanced tree



Random Decision Trees (1/2)



Random Decision Trees (2/2)

```
struct RandomDecision (Decision)
   lastFrame = -1
   lastDecision = false

def  test()
   # check if our stored decision is too old
   if frame() > lastFrame + 1
      # make a new decision and store it
      lastDecision = randomBoolean()

   # either way we need to update the frame value
   lastFrame = frame()

   # we return the stored value
   return lastDecision
```

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Finite State Machines

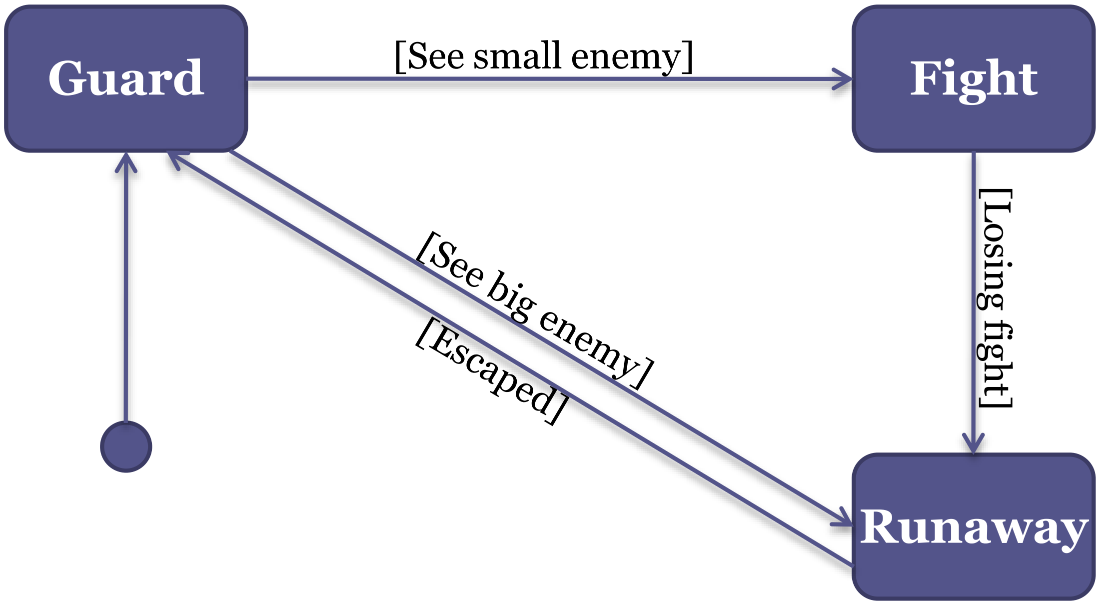

*Diagram based on UML state chart diagram format

A Generic Implementation (1/3)

- The state machine manager keeps track of the set of possible states and records the current state it is in.
- The transition simply reports to the state machine manager whether it is triggered or not.

A Generic Implementation (2/3)

- At each iteration, the state machine manager's update function is called and checks if any transition from the current state occurred.

- Transitions can have priorities and the higher in priority is called.

A Generic Implementation (3/3)

- It is important not to assign a high priority for an edge, where its condition is the condition's subset of an edge with a lower priority.

- Ex:
  Transition 1: if (left)
  Transition 2: if (left and up)

Pseudo-Code

```
class State:
        m_transitions //Holds the list of transitions

        getAction ()
        getEntryAction ()
        getExitAction ()
        getTransitions ()
```

```
class Transition:
        isTriggered ()
        getTargetState ()
        getAction ()
```

```
class FSM:
        m_states  //Holds the list of states
        m_initialState
        m_currentState

        Update()  //Checks and applies transitions
```

Hard-Coded FSM

Example:

```
class FSM:
        enum State: PATROL, DEFEND, SLEEP
        myState   //Holds the current state

        Update()
                if  myState == PATROL:
                        # example transitions
                        if  canSeePlayer(): myState = DEFEND
                        if  tired(): myState = SLEEP
                elif   myState == DEFEND:
                        if  not  canSeePlayer(): myState = PATROL

                elif   myState == SLEEP:
                        if  not  tired (): myState = PATROL
```

Pros and Cons

- Easy to write but difficult to maintain
- Fast to implement for all but huge state machines
- The need to write the AI behavior for each character
- Hierarchical state machines are difficult to coordinate using hard-coded FSM

FSM with Macros (1/3)

Example:

```
bool  FSM::States ( StateMachineEvent  event,  int  state)
{
   BeginStateMachine
                  State ( STATE_0 )
                                 OnUpdate
                                                Wander ();
                                                if ( SeeEnemy () ) SetState (STATE_1 );
                                                if ( Dead () ) SetState (STATE_2 );
                  State (STATE_1 )
                                 OnUpdate
                                                Attack ();
                                                SetState (STATE_0 );
                                                if ( Dead () ) SetState (STATE_2 );
                  State (STATE_2 )
                                 OnUpdate
                                                RotSlowly ();
  EndStateMachine
}
```

FSM with Macros (2/3)

Example:

```
bool   FSM::States ( StateMachineEvent  event,  int  state)
{
   if( state < 0 ) {
       if( 0 ) {
           return ( true );
       }
   } else if( state == STATE_0) {
               if( 0 ) {
                               } OnUpdate
                                       Wander ();
                                       if ( SeeEnemy () ) SetState (STATE_1 );
                                       if ( Dead () ) SetState (STATE_2 ); }
               State (STATE_1 )
                               OnUpdate
                                       Attack ();
                                       SetState (STATE_0 );
                                       if ( Dead () ) SetState (STATE_2 );
               State (STATE_2 )
                               OnUpdate
                                       RotSlowly ();
  EndStateMachine
}
```

FSM with Macros (3/3)

- Pros:
  - Structure
    - All state machines have a consistent format
  - Readability
  - Debugging
- Cons
  - Hard to maintain (when adding macros) so it is important to determine requirements at the beginning

Macros are like Legos

```
bool Agent::States( StateMachineEvent event,
                    MSG_Object * msg, int state )
{   if( state < 0 ) {
        if(0) {
            return( true );
        }
    } else if( STATE_Name == state ) {
        if(0) {
            return( true );
        } else if( EVENT_Enter == event ) {
            //C++ code 1
            return( true );
        } else if( EVENT_Message==event && MSG_Name==msg->GetMsgName() ) {
            //C++ code 2
            return( true );
        }
    } else {
        assert( 0 && "Invalid State" );
        return( false );
    }
    return( false );
}
```

```
BeginStateMachine
    DeclareState(STATE_Name)
        OnEnter
            //C++ code 1
        OnMsg(MSG_Name)
            //C++ code 2
EndStateMachine
```

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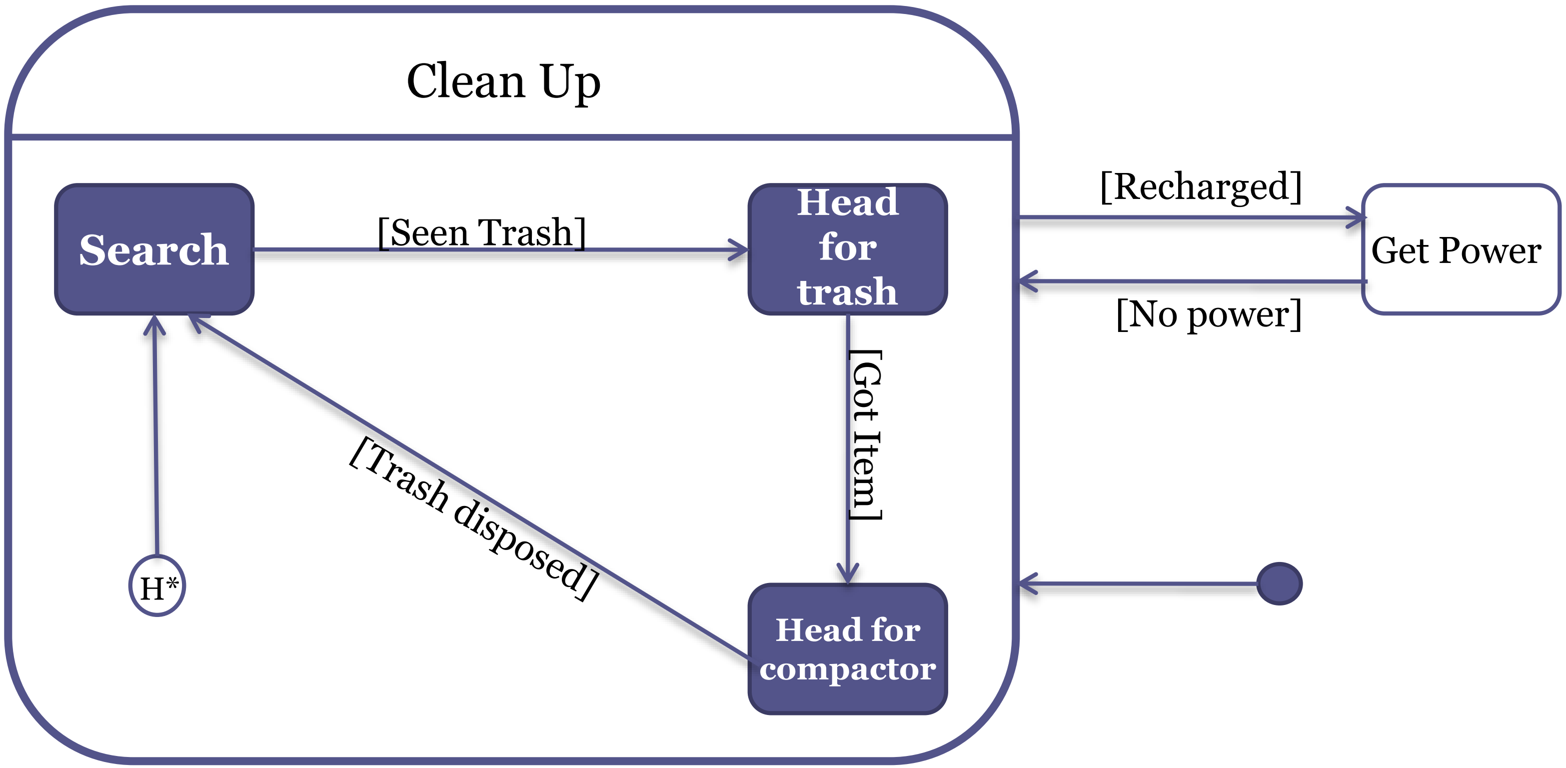
Hierarchical State Machines



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FSM Scripting Language (1/2)

- Used by designers
- No compilation needed when changes are done

FSM Scripting Language (2/2)

Example:

```
Behavior Patrol
begin

variable
        integer  targetActor

transition
        # listen for enemies
        if  ( targetActor )
             switch ( “Attack” , targetActor )

sequence
       # Patrol
        do forever
        begin
            goto  GetLocation ( “WaypointA” )  walk
            idle 2
            # do more stuff
        end
end
```

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Platformer AI

State: GOING LEFT

Inner State : On Enter

Set X velocity to MOVE_LEFT
Inner State = On Update

Inner State : On Update

If collision on left side OR left bottom cell not collidable:
    Set Velocity X to 0
    Initialize idle counter
    Inner State = On Exit

Inner State : On Exit

Idle counter -= Frame Time
If(Idle counter <= 0)
    State = Going Right
    Inner State = On Enter

State: GOING RIGHT

Inner State : On Enter

Set X velocity to MOVE_RIGHT
Inner State = On Update

Inner State : On Update

If collision on right side OR right bottom cell not collidable :
    Set Velocity X to 0
    Initialize idle counter
    Inner State = On Exit

Inner State : On Exit

Idle counter -= Frame Time
If(Idle counter <= 0)
    State = Going Left
    Inner State = On Enter

References

- Artificial Intelligence for Games by Ian Millington
- AI Game Programming Wisdom 2 by Steve Rabin