



Goal-Oriented Action Planning: Ten Years Old and No Fear!

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SUMMIT

GAME DEVELOPERS CONFERENCE®

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Goal-Oriented Action Planning (GOAP) at Monolith Productions

- Developed for F.E.A.R. in 2004
 - Jeff Orkin developed
- Used in many Monolith titles :
 - F.E.A.R., F.E.A.R. 2
 - Condemned, Condemned 2
 - Middle-earth : Shadow of Mordor





Goal-Oriented Action Planner

- Goals

Goals	Desired World State
Kill Enemy	Attacking Target X
Use Work Node	Using Node Y
Idle	Idling



Goal-Oriented Action Planner

- Goals
 - Fixed priority

Goals	Desired World State
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Goal-Oriented Action Planner

- Goals
 - Fixed priority
 - IsValid()

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Goal-Oriented Action Planner

- Goals
 - Fixed priority
 - IsValid()
 - Desired world state

Goals	Desired World State
Kill Enemy	Attacking Target X
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Goal-Oriented ***Action*** Planner

- Actions

Actions	Satisfies World State	Requires World State
Melee Attack	Attacking Target X	At Target X Equipped Melee
Ranged Attack	Attacking Target X	Near Target X Equipped Ranged
Goto Target	At Target X Near Target X	
Switch Weapon	Equipped Z	
Play Node Animation	Using Node Y	At Node Y
Goto Node	At Node Y	
Idle	Idling	



Goal-Oriented ***Action*** Planner

- Actions
 - IsValid() for Desired World State

Actions	Satisfies World State	Requires World State
Melee Attack	Attacking Target X	At Target X Equipped Melee
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Goal-Oriented **Action** Planner

- Actions
 - IsValid() for Desired World State
 - May require more World State

Actions	Satisfies World State	Requires World State
Melee Attack	Attacking Target X	At Target X Equipped Melee
Ranged Attack	Attacking Target X	Near Target X Equipped Ranged
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Goal-Oriented Action Planner

- World State



Goal-Oriented Action Planner

- World State
 - Collection of variables
 - Used to communicate desire :
 - Use node X
 - Be attacking character Y



Goal-Oriented Action Planner

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 - Use node X
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 - Desired world-state for each potential plan



Goal-Oriented Action Planner

- World State
 - Collection of variables
 - Used to communicate desire :
 - Use node X
 - Be attacking character Y
 - Desired world-state for each potential plan
 - AI has a current world-state



Goal-Oriented Action Planner

- World State
 - Collection of variables
 - Used to communicate desire :
 - Use node X
 - Be attacking character Y
 - Desired world-state for each potential plan
 - AI has a current world-state
 - Often, only care about a few at a time



Goal-Oriented Action ***Planner***

- Building a plan



Goal-Oriented Action ***Planner***

- Building a plan
 - Find a valid goal



Goal-Oriented Action ***Planner***

- Building a plan
 - Find a valid goal
 - Find an action that satisfies the goal



Goal-Oriented Action ***Planner***

- Building a plan
 - Find a valid goal
 - Find an action that satisfies the goal
 - Find an action that satisfies the previous action



Goal-Oriented Action ***Planner***

- Building a plan
 - Find a valid goal
 - Find an action that satisfies the goal
 - Find an action that satisfies the previous action
 - Repeat until current world-state is matched.



Goal-Oriented Action ***Planner***

- Building a plan
 - Find a valid goal
 - Find an action that satisfies the goal
 - Find an action that satisfies the previous action
 - Repeat until current world-state is matched.
 - On failure, continue down list of goals.



Goal-Oriented Action ***Planner***

- Building a plan (continued)
 - Use A^* to path-find from goal's desired world-state to current world-state.
 - Path distance is a set cost per action.
 - Heuristic is the number of world-states that still need to be satisfied.



Goals	Requires World State
Kill Enemy	Attacking Target X
Use Work Node	Using Node Y
Idle	Idling

Current World State

Equipped Melee

Actions	Satisfies World State	Requires World State
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Goals	Requires World State
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Idle	Idling

Current World State

Equipped Melee

**Kill
Enemy**

Attacking Target X

Actions	Satisfies World State	Requires World State
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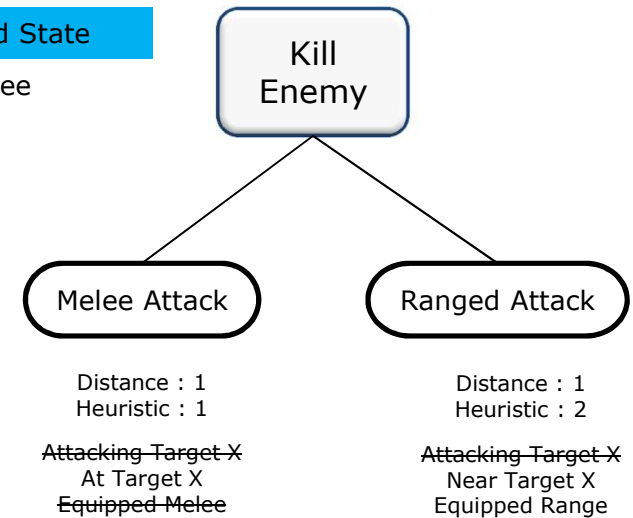


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Current World State

Equipped Melee



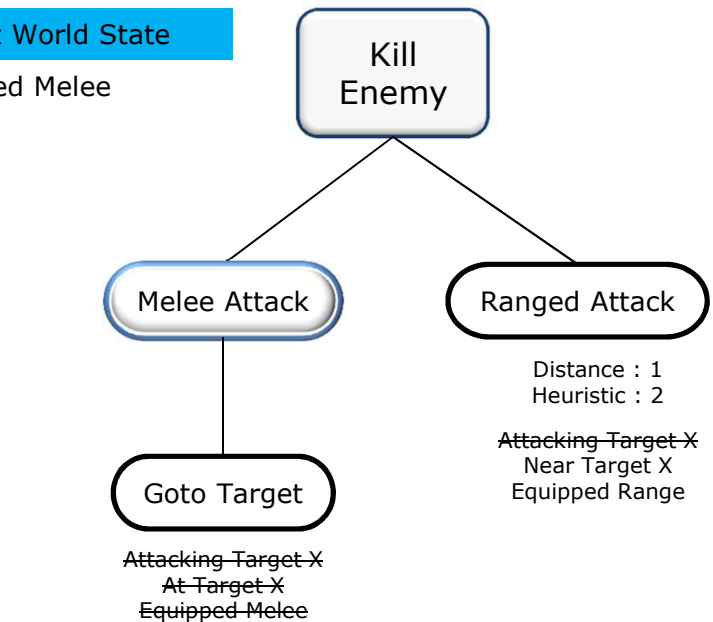


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Idle	Idling	

Current World State

Equipped Melee



Matches Current World State!



Goals	Requires World State
Kill Enemy	Attacking Target X
Use Work Node	Using Node Y
Idle	Idling

Current World State

Equipped Melee

Plan

- Goto Target
- Melee Attack

Enemy dies.

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GOAP Overview

- For a clearer explanation see :
 “Applying Goal-Oriented Action Planning to
 Games” by Jeff Orkin
 AI Game Programming Wisdom 2, 2004

GOAP in Middle-Earth:Shadow of Mordor

MIDDLE-EARTH
SHADOW OF MORDOR



GOAP in Middle-Earth:Shadow of Mordor

- Up to 50 AI's using planner per frame

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SHADOW OF MORDOR



GOAP in Middle-Earth:Shadow of Mordor

- Up to 50 AI's using planner per frame
- Using the great, great grandchild of Jeff's original implementation

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Performance

- Minimize number of world-state variables

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Performance

- Minimize number of world-state variables
 - Planning costs scale with variable count

Performance

- Minimize number of world-state variables
 - Planning costs scale with variable count
 - Most of the boolean states were folded into one enumeration

Performance

- Keep plan length short

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Performance

- Keep plan length short
 - Move logic out of the planner into other systems!

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Performance

- Keep plan length short
 - Move logic out of the planner into other systems!
 - The planner does not need to do everything.

Performance

- Keep plan length short
 - Move logic out of the planner into other systems!
 - The planner does not need to do everything.
 - Let other specialized systems take some of the burden.

Low level systems



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Low level systems

- Movement



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Low level systems



- Movement
- Head tracking

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Low level systems

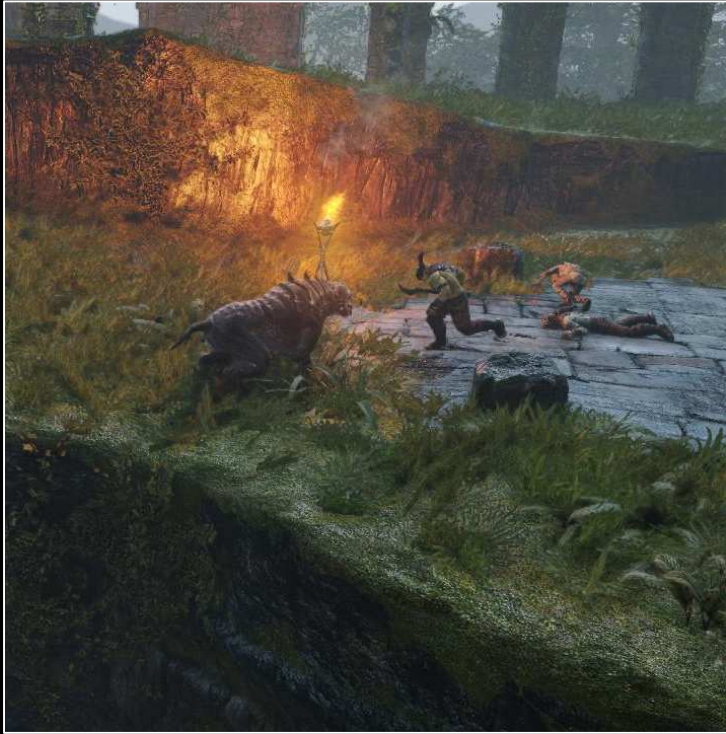


- Movement
- Head tracking
- Animation selection
 - Weapon sheathing

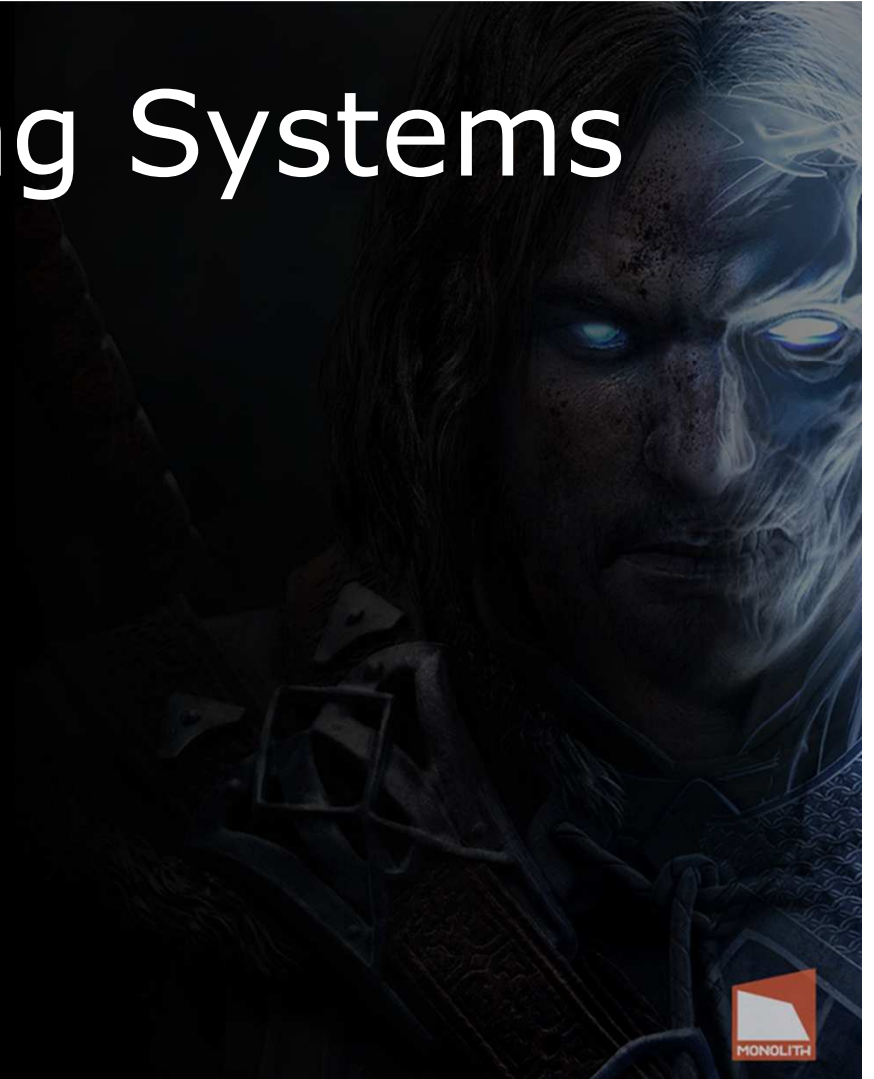
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Planner Driving Systems



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Planner Driving Systems

- Sensors

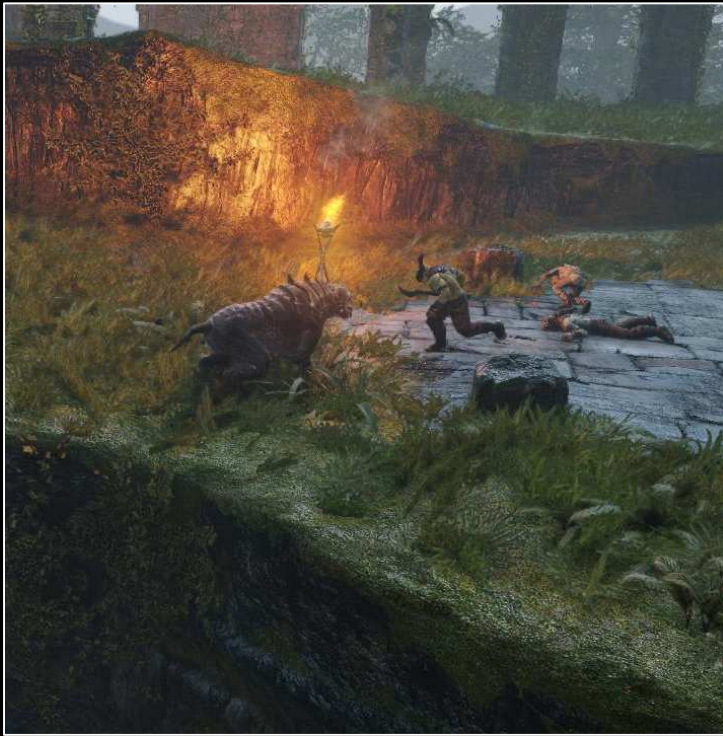


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Planner Driving Systems

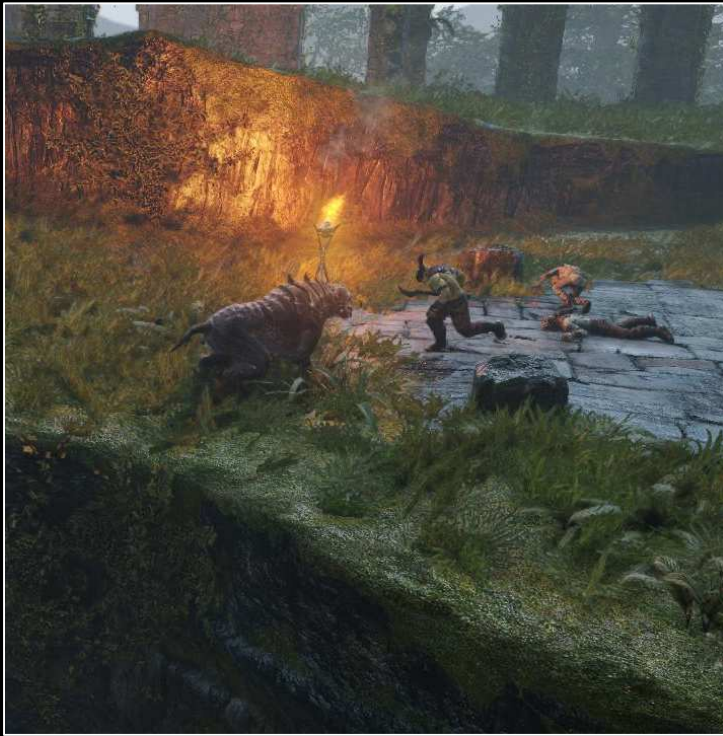
- Sensors
- Target Selection



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Planner Driving Systems

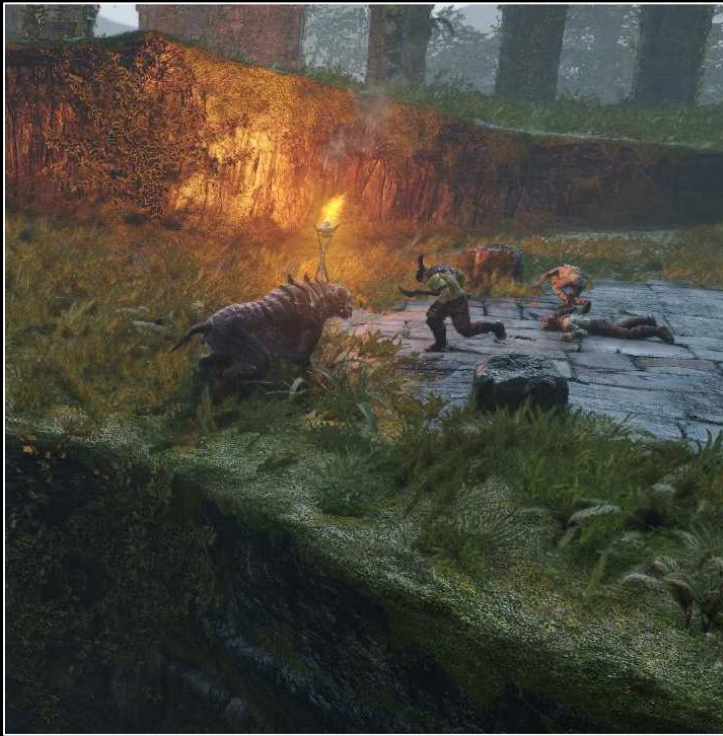


- Sensors
- Target Selection
- Awareness

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Planner Driving Systems



- Sensors
- Target Selection
- Awareness
 - Alert, Suspicious, Ambient

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High Level Systems

- Investigations



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SHADOW OF MORDOR



High Level Systems



- Investigations
 - AI registers interest
 - Role is assigned to AI
 - Lead Investigator
 - Watch investigator's back
 - Dismiss immediately
 - Planner executes the assigned role

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Conclusion

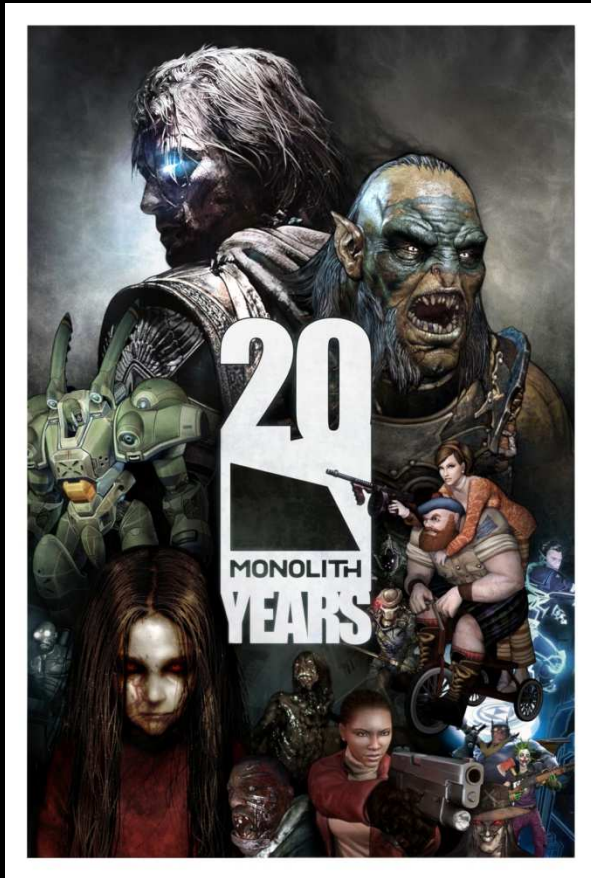
- Move stand-alone logic out of the planner!

Conclusion

- Move stand-alone logic out of the planner!
 - Reduces CPU load of your AI

Conclusion

- Move stand-alone logic out of the planner!
 - Reduces CPU load of your AI
 - Improving behaviors becomes easier



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