

Game Playing AI for Simulated DnD Encounters

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Abstract

DnD simulator with game-playing agents for automatic play testing.

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Figure 1: An example of what an DnD encounter might look like. This uses a grid based system with physical miniatures to represent creatures

1 Simulation

This is a prototype version of a DnD encounter simulator (see 1). It currently allows creatures to complete one movement and one action (in that order) per turn. The movement available is determined by a speed, which determine how many spaces a creature can move in a turn. The way I implemented it, a space is worth 10 ft, but it would be easy to make this larger or smaller. The only action available current is attack, where the attacking creature rolls (with a bonus) to beat their opponents AC. The game runs until all of one party is dead (at 0 hp) or a turn limit is reached. The turn limit was determined by the thrown food theory, which is the estimated amount of time it would take for a party to be feed up with an encounter and decide to throw food at the GM.

1.1 Grid

A grid (or map) is defined by a width and a height. Pieces can be added to the grid, as long as they have a position attribute. The grid class allows you to do things such as find the distance between two points, get the pieces that are in a range of position, or get the enemy closest to a creature.

1.2 Creature

There are 4 main attributes of a creature:

- HP: The max amount of health that the creature can have and what health it has when it takes a long rest. This can be a discrete value or a dice string that is rolled.
- AC: This is the armor class of the creature, which signifies how difficult it is to damage the creature.
- Speed: This is how many tiles a creature can move in a turn. This is loosely related to 10ft in 5e.
- Actions: This is a list of actions available to a creature. They can choose from these actions and the NullAction (does nothing) when deciding on a action per turn.

Every implementation of a creature must also have a turn method that decides what movement and action a creature makes given a game state. I talk below about what agents are implemented in this demo.

1.3 Action

A action is something a creature can do on it's turn. It must have a avail actions method that gives every combination of action and movement possible given a creature. Actions are given as new instances of a action object.

1.3.1 Attack

An attack has 3 main properties.

- **Modifier:** How much is added to a 1d20 hit roll. This value must beat the target's AC to inflict damage
- **Damage Dice:** This is a string in the form of "2d8 + 6" that tells how much and what value of dice should be rolled to deal damage. This will be rolled each time damage is done.
- **Distance:** This is how far from the creature the attack can reach. There is also an optional parameter for min distance which tells the smallest distance a creature can be from creature for attack to work.

Side-effects (such as a target being knocked prone) is not implemented in this simulation. Additionally

2 Monster Manual

A very small subset is implemented in this simulation. The monsters were chosen based on what would be most easily represented in this simulation, along with having a range of challenge ratings and abilities.

The Monster Manual file includes the following monsters along with a function to create a new creature given a monster template (dictionary) and a creature class.

2.1 Attacks (From least to most Powerful)

- Spear: range 0-6, damage: "1d6", hit: +2
- Bite: range 0-1, damage: "1d4 + 2", hit + 4
- scimitar: range 0-1, damage: 1d6 + 1
- shortsword: range: 1, damage: 1d6 + 2, hit +4
- shortbow: range: 8-32, damage: 1d6+2, hit +4
- ram: hit + 5, damage: 1d6 +3, range 0-1
- javelin: hit: +5, damage: 1d6 + 3, distance: 3-12
- crossbow: hit: +3, 1d8 + 1, range: 0-1
- longbow: hit: +3, damage: 1d8 +1, range: 15-60
- claws: hit: +4, damage: 2d4 + 2, range: 0-1
- midbite: hit + 2, damage: 2d6 + 2, range: 0-1
- great ax: hit + 5, damage: 1d12 + 3, range: 0-1
- bigbite: hit +5, damage: 2d6 + 3, range: 0-1

2.2 Creatures

Below I describe what creatures are implemented from the monster manual, listed in order of challenge rating. Note not all features of all creatures are fully actualized in this prototype.

2.2.1 1/8 Challenge Rating

- **Bandit:** close and wide range weapons. HP of 11, and a AC of 12. Average speed. https://5thsrld.org/gamemaster_rules/monsters/bandit/ (see 2).
- **Merfolk:** moderate range weapon. HP of 11 and a AC of 11. Slow speed. https://5thsrld.org/gamemaster_rules/monsters/merfolk/ (see 7)

2.2.2 1/4 Challenge Rating

- Elk: close range attack. AC of 10 and a HP of 15. High speed. https://5thsrdr.org/gamemaster_rules/monsters/elk/ (see 4).
- Skeleton: short and very long range attack. AC of 13 and HP of 13. Average speed. https://5thsrdr.org/gamemaster_rules/monsters/skeleton/ (see 9).

2.2.3 1/2 Challenge Rating

- Orc: close and wide range weapons. AC of 13 and HP of 15. Average speed. https://5thsrdr.org/gamemaster_rules/monsters/orc/ (see 6).
- Gnoll: close mid and wide range attacks, AC of 15, HP of 22. Average speed. https://5thsrdr.org/gamemaster_rules/monsters/gnoll/ (see 8).

2.2.4 1 Challenge Rating

- Dire Wolf: close range attack. AC of 14, HP of 37. High speed. https://5thsrdr.org/gamemaster_rules/monsters/dire_wolf/ (see 3).
- Ghoul: Close attacks. HP of 22 and AC of 12. Average speed. https://5thsrdr.org/gamemaster_rules/monsters/ghoul/ (see 5).

3 Agents

There are five agents implemented in this example. Two, random and aggressive, are used as baselines to test the general game playing AI. JinJerry and Shyne are general game playing AI that are the main focus of this project. There is also an implementation of a human agent, that isn't much explored here.

3.1 Human

The human implementation of creature allows a human player to choose actions for a creature. The user will be presented the current game state, along with all available movement and action combinations to choose from. However the current implementation of this makes it almost unusable. That being said is it a useful agent for testing purposes.

3.2 Random

As the name implies, the random agent randomly selects a movement and action from the available turn choices.

3.3 Aggressive

The aggressive agent is a rule based agent that is a useful base line for testing other agents. It keeps a rank of it's available actions from most to least powerful (determined by expected damage). Non-attack actions (for example NullAction) are set to 0. The aggressive agent will chose the action with the highest damage that it can complete on it's turn. It will decide on movement based on which movement within range of this action is closest to the closest enemy on the map. Like the name implies, this is an estimate of an aggressive player, most likely a tank of some sort.

3.4 JinJerry

JinJerry is an algorithm made for the 2014 general video game playing competition [1], where it won second place. JinJerry is a very lightweight version of a Monte Carlo search algorithm. It simulates games to a particular depth for each available action and evaluates them. The JinJerry algorithm works as follows.

- 1: **for** Every action a in available action **do**
- 2: Create a copy of the game
- 3: Implement action on copy
- 4: Starting value = evaluate new game state
- 5: Forward model to depth D
- 6: New value = evaluate game state again
- 7: Set value of action a to max(starting value, new value)
- 8: **Return** action a with highest value

The static evaluator I created to implement JinJerry works off the assumption that a party wants to maximize their own health and minimize their opposing parties health. Therefore the static evaluation is set at the HP ratio (current hp total divided by max hp total) for the creatures team minus the opposing teams HP ratio.

As shown the result section below, this algorithm works against random agents, but is not successful against the aggressive agent. Additionally the large amount of available actions per turn (on the order of 40-50), means that this algorithm is significantly slower than aggressive.

3.5 Shyne

I created the Shyne agent to counteract the downfalls of JinJerry, while still being faster than a Monte Carlo game search algorithm. I predicted the single forward modeling, along with the amount of randomness in DnD, was part of the lack of success of JinJerry. However, the large amount of actions available, meant that all actions couldn't be completely explored realistically. Therefore I created the Shyne agent to explore actions initially at shallow depths to eliminate enviable actions early. It works as follows:

- 1: Set value of every action to 0
- 2: **for** Every depth d in depths **do**
- 3: **for** Every action a in available action **do**
- 4: Create a copy of the game
- 5: Implement action on copy
- 6: Forward model to depth D
- 7: New value = evaluate game state again
- 8: Set value of action a to average(current value, new value)
- 9: Sort all actions
- 10: Eliminate the bottom half of all actions
- 11: **Return** action a with highest value

The Shyne agent used the game static evaluation as JinJerry.

This algorithm takes in a list of depths that can effect it's behavior. The list explored in this project was [0, 10, 20, 30, 40], so that more time is spent on actions with high predicted values. However, other depth models could be explored. For example something like [10, 10, 10, 10] would produce a result more similar to Monte Carlo Game Search (except for the elimination of poor performing actions).

Initial tests showed that this algorithm was not significantly slower than JinJerry and it has been able to outperform both JinJerry and the Aggressive agent.

4 Tournament

The tournament was designed to test the performance of different decision algorithms against each other. It plays a specified number of games, each time randomizing the parties. The parties are created by first randomly selecting a party size, p (by default is between 2 and 5 players). Then it randomly selects p creatures from the Monster Manual described above. For every game identical creatures sets are used

for both parties, so that differences are due to agent ability and not power difference. Once creatures are decided, creatures are created using the given creature class for each team. Creatures are placed in starting positions so that teams are on opposite sides of the grid. After a game is played, the winner is recorded and the parties are randomized again.

5 Results

It should be noted that it took up to several minutes to play a single game in this prototype, so trial sizes are fairly small. However, in the instances where more games were played I found similar results as with the smaller trial sizes demonstrating the validity of even these small trials. The goal of this project was to create an agent that is able to beat both a random and a rule based agent, without any explicit knowledge of the game (except for success metrics such as HP ratios).

5.1 JinJerry

5.1.1 Against Random

JinJerry successfully outperforms Random agents. Out of 10 trials (and a depth of 40), it won 5 and 5 times out. While this shows the superiority of JinJerry, the amount of times it timed out (exceeded the turn limit) is concerning regarding its success.

5.1.2 Against Aggressive

Even with a depth set to 40, JinJerry is unable to outperform Aggressive. During a trial of ten games, JinJerry won three times, Aggressive also one three times, and 4 times the turn limit was exceeded. At any lower depth level JinJerry consistently loses to Aggressive. Setting a depth beyond 40 is unrealistic, as even with a party size of 4 this would simulate 10 turns (half of maximum turns). It is also important to note that JinJerry runs on several scales of magnitude slower than aggressive. The lack of success from JinJerry shows that the additional computation costs are not worth it for this algorithm.

5.2 Shyne

5.2.1 Against JinJerry

The Shyne agent is able to consistently outperform the JinJerry agent. With depths set to [0, 10, 20, 30, 40] and a JinJerry depth of 20, Shyne won 5 games out of 9, where JinJerry won only 1 (3 games timed out). Additionally, Shyne took a similar scale of time to JinJerry.

5.2.2 Against Aggressive

Shyne performs very well against the aggressive agent. Over 9 trials it won 6 times, Aggressive won once and the game tied twice. To validate the success of Shyne, I ran a trial of 50 games over night. In this trial Shyne won 70% of its games, where Aggressive only won once, and the games tied for 28% of the time.

Appendices

A Game Logs

A.1 JinJerry Against Random

Game 0 of 10
Party Size 2

BANDIT

Medium humanoid (any race), any non-lawful alignment

Armor Class 12 (leather armor)

Hit Points 11 (2d8 + 2)

Speed 30 ft.

STR	DEX	CON	INT	WIS	CHA
11 (+0)	12 (+1)	12 (+1)	10 (+0)	10 (+0)	10 (+0)

Senses passive Perception 10

Languages any one language (usually Common)

Challenge 1/8 (25 XP)

ACTIONS

Scimitar. *Melee Weapon Attack:* +3 to hit, reach 5 ft., one target. *Hit:* 4 (1d6 + 1) slashing damage.

Light Crossbow. *Ranged Weapon Attack:* +3 to hit, range 80 ft./320 ft., one target. *Hit:* 5 (1d8 + 1) piercing damage.

Figure 2: Stat block for bandit

DIRE WOLF

Large beast, unaligned

Armor Class 14 (natural armor)

Hit Points 37 (5d10 + 10)

Speed 50 ft.

STR	DEX	CON	INT	WIS	CHA
17 (+3)	15 (+2)	15 (+2)	3 (-4)	12 (+1)	7 (-2)

Skills Perception +3, Stealth +4

Senses passive Perception 13

Languages —

Challenge 1 (200 XP)

Keen Hearing and Smell. The wolf has advantage on Wisdom (Perception) checks that rely on hearing or smell.

Pack Tactics. The wolf has advantage on an attack roll against a creature if at least one of the wolf's allies is within 5 ft. of the creature and the ally isn't incapacitated.

ACTIONS

Bite. *Melee Weapon Attack:* +5 to hit, reach 5 ft., one target. *Hit:* 10 (2d6 + 3) piercing damage. If the target is a creature, it must succeed on a DC 13 Strength saving throw or be knocked prone.

Figure 3: Stat block for Dire Wolf

ELK <i>Large beast, unaligned</i>					
Armor Class 10 Hit Points 13 (2d10 + 2) Speed 50 ft.					
STR	DEX	CON	INT	WIS	CHA
16 (+3)	10 (+0)	12 (+1)	2 (-4)	10 (+0)	6 (-2)
Senses passive Perception 10 Languages — Challenge 1/4 (50 XP)					
Charge. If the elk moves at least 20 ft. straight toward a target and then hits it with a ram attack on the same turn, the target takes an extra 7 (2d6) damage. If the target is a creature, it must succeed on a DC 13 Strength saving throw or be knocked prone.					
ACTIONS					
Ram. <i>Melee Weapon Attack:</i> +5 to hit, reach 5 ft., one target. <i>Hit:</i> 6 (1d6 + 3) bludgeoning damage.					
Hooves. <i>Melee Weapon Attack:</i> +5 to hit, reach 5 ft., one prone creature. <i>Hit:</i> 8 (2d4 + 3) bludgeoning damage.					

Figure 4: Stat block for elk

GHOUL <i>Medium undead, chaotic evil</i>					
Armor Class 12 Hit Points 22 (5d8) Speed 30 ft.					
STR	DEX	CON	INT	WIS	CHA
13 (+1)	15 (+2)	10 (+0)	7 (-2)	10 (+0)	6 (-2)
Condition Immunities poisoned Senses darkvision 60 ft., passive Perception 10 Languages Common Challenge 1 (200 XP)					
ACTIONS					
Bite. <i>Melee Weapon Attack:</i> +2 to hit, reach 5 ft., one creature. <i>Hit:</i> 9 (2d6 + 2) piercing damage.					
Claws. <i>Melee Weapon Attack:</i> +4 to hit, reach 5 ft., one target. <i>Hit:</i> 7 (2d4 + 2) slashing damage. If the target is a creature other than an elf or undead, it must succeed on a DC 10 Constitution saving throw or be paralyzed for 1 minute. The target can repeat the saving throw at the end of each of its turns, ending the effect on itself on a success.					

Figure 5: Stat block for Ghoul

ORC <i>Medium humanoid (orc), chaotic evil</i>					
Armor Class 13 (hide armor) Hit Points 15 (2d8 + 6) Speed 30 ft.					
STR	DEX	CON	INT	WIS	CHA
16 (+3)	12 (+1)	16 (+3)	7 (-2)	11 (+0)	10 (+0)
Skills Intimidation +2 Senses darkvision 60 ft., passive Perception 10 Languages Common, Orc Challenge 1/2 (100 XP)					
Aggressive. As a bonus action, the orc can move up to its speed toward a hostile creature that it can see.					
ACTIONS					
Greataxe. <i>Melee Weapon Attack:</i> +5 to hit, reach 5 ft., one target. <i>Hit:</i> 9 (1d12 + 3) slashing damage.					
Javelin. <i>Melee or Ranged Weapon Attack:</i> +5 to hit, reach 5 ft. or range 30/120 ft., one target. <i>Hit:</i> 6 (1d6 + 3) piercing damage.					

Figure 6: Stat block for Orc

MERFOLK <i>Medium humanoid (merfolk), neutral</i>					
Armor Class 11 Hit Points 11 (2d8 + 2) Speed 10 ft., swim 40 ft.					
STR	DEX	CON	INT	WIS	CHA
10 (+0)	13 (+1)	12 (+1)	11 (+0)	11 (+0)	12 (+1)
Skills Perception +2 Senses passive Perception 12 Languages Aquan, Common Challenge 1/8 (25 XP)					
Amphibious. The merfolk can breathe air and water.					
ACTIONS					
Spear. <i>Melee or Ranged Weapon Attack:</i> +2 to hit, reach 5 ft. or range 20/60 ft., one target. <i>Hit:</i> 3 (1d6) piercing damage, or 4 (1d8) piercing damage if used with two hands to make a melee attack.					

Figure 7: Stat block for Merfolk

GNOLL

Medium humanoid (gnoll), chaotic evil

Armor Class 15 (hide armor, shield)

Hit Points 22 (5d8)

Speed 30 ft.

STR	DEX	CON	INT	WIS	CHA
14 (+2)	12 (+1)	11 (+0)	6 (-2)	10 (+0)	7 (-2)

Senses darkvision 60 ft., passive Perception 10

Languages Gnoll

Challenge 1/2 (100 XP)

Rampage. When the gnoll reduces a creature to 0 hit points with a melee attack on its turn, the gnoll can take a bonus action to move up to half its speed and make a bite attack.

ACTIONS

Bite. *Melee Weapon Attack:* +4 to hit, reach 5 ft., one creature. *Hit:* 4 (1d4 + 2) piercing damage.

Spear. *Melee or Ranged Weapon Attack:* +4 to hit, reach 5 ft. or range 20/60 ft., one target. *Hit:* 5 (1d6 + 2) piercing damage, or 6 (1d8 + 2) piercing damage if used with two hands to make a melee attack.

Longbow. *Ranged Weapon Attack:* +3 to hit, range 150/600 ft., one target. *Hit:* 5 (1d8 + 1) piercing damage.

Figure 8: Stat block for Gnoll

SKELETON

Medium undead, lawful evil

Armor Class 13 (armor scraps)

Hit Points 13 (2d8 + 4)

Speed 30 ft.

STR	DEX	CON	INT	WIS	CHA
10 (+0)	14 (+2)	15 (+2)	6 (-2)	8 (-1)	5 (-3)

Damage Vulnerabilities bludgeoning

Condition Immunities poisoned

Senses darkvision 60 ft., passive Perception 9

Languages understands all languages it spoke in life but can't speak

Challenge 1/4 (50 XP)

ACTIONS

Shortsword. *Melee Weapon Attack:* +4 to hit, reach 5 ft., one target. *Hit:* 5 (1d6 + 2) piercing damage.

Shortbow. *Ranged Weapon Attack:* +4 to hit, range 80/320 ft., one target. *Hit:* 5 (1d6 + 2) piercing damage.

Figure 9: Stat block for Skeleton

Monsters:
skeleton
elk

Time: 6.5160
Winner: JinJerry

Game 1 of 10
Party Size 2

Monsters:
orc
merfolk

Time: 1.7018
Winner: Tie

Game 2 of 10
Party Size 2

Monsters:
direwolf
ghoul

Players:
direwolf1
ghoul1
Time: 15.7640
Winner:Tie

Game 3 of 10
Party Size 3

Monsters:
bandit
gnoll
skeleton

Time: 125.5409
Winner: Tie

Game 4 of 10
Party Size 2

Monsters:
orc

ghoul

Time: 28.1922

Winner: Tie

Game 5 of 10

Party Size 3

Monsters:

elk

ghoul

merfolk

Time: 20.0030

Winner: JinJerry

Game 6 of 10

Party Size 2

Monsters:

skeleton

bandit

Time: 61.7809

Winner: Tie

Game 7 of 10

Party Size 2

Monsters:

gnoll

ghoul

Time: 111.7872

Winner: Tie

Game 8 of 10

Party Size 4

Monsters:

orc

skeleton

ghoul

gnoll

Time: 166.1774

Winner: JinJerry

Game 9 of 10
Party Size 2

Monsters:
orc
elk

Time: 89.9569
Winner: JinJerry

Total results:
JinJerry: 5
Random: 0
Tie: 5

A.2 JinJerry Against Aggressive

JinJerry with Depth 40

Game 0 of 10

Party Size 3
Monsters:
orc
elk
gnoll
Time: 15.2008
Winner: Aggressive

Game 1 of 10:

Party Size 3
Monsters:
bandit
skeleton
bandit1
Time: 21.3690
Winner: Aggressive

Game 2 of 10:
Party Size 2
Monsters:
bandit
orc
Time: 23.7866
Winner: Aggressive

Game 2 of 10:

Party Size 4
Monsters:
skeleton
skeleton1
ghoul
ghoul1
Time: 104.3177
Winner: JinJerry

Game 4 of 10:
Party Size 2
Monsters:
merfolk
skeleton
Time: 50.7113
Winner: JinJerry

Game 5 of 10:
Party Size 2
Monsters:
bandit
bandit1
Time: 141.2515
Winner: Tie

Game 6 of 10:
Party Size 2
Monsters:
direwolf
gnoll
Time: 148.0730
Winner: Tie

Game 7 of 10:
Party Size 4
Monsters:
merfolk
skeleton
gnoll
skeleton1
Time: 192.6523
Winner: JinJerry

Game 8 of 10:
Party Size 2
Monsters:
merfolk
ghoul
Winner: Tie

Game 9 of 10:
Party Size 2
Monsters:
gnoll
merfolk
Time: 113.3696
Winner: Tie

Total results:
JinJerry: 3
Aggressive: 3
Tie: 4

B Shyne Vs. Aggressive

Shyne depths: 0, 10, 20, 30, 40

Game 0 of 10
Party Size 4

Monsters:
bandit
bandit1
gnoll
ghoul

Time: 13.4276
Winner: Aggressive

Game 1 of 10
Party Size 3

Monsters:
ghoul
orc
gnoll

Time: 13.9778
Winner: Shyne

Game 2 of 10
Party Size 4

Monsters:
elk
skeleton
ghoul
bandit

Time: 58.3937
Winner: Shyne

Game 3 of 10
Party Size 3

Monsters:
bandit
bandit1
merfolf

Time: 38.9060
Winner: Shyne

Game 4 of 10
Party Size 3

Monsters:
direwolf
ghoul
bandit

Time: 112.9775
Winner: Tie

Game 5 of 10
Party Size 4

Monsters:
bandit
gnoll
direwolf
bandit1

Time: 228.9976
Winner: Shyne

Game 6 of 10
Party Size 4

Monsters:
merfolf
ghoul
gnoll
ghoul1

Time: 131.4392
Winner: Shyne

Game 7 of 10
Party Size 2

Monsters:
gnoll
ghoul

Time: 58.8480
Winner: Shyne

Game 8 of 10
Party Size 2

Monsters:
ghoul
ghoul1

Time: 85.4963
Winner: Tie

Total:
Shyne: 6
Aggressive: 1
Tie: 1

References

- [1] Diego Perez-Liebana et al. "The 2014 general video game playing competition". In: *IEEE Transactions on Computational Intelligence and AI in Games* 8.3 (2015), pp. 229–243.