Dungeon Crawl Stone Soup as a Goal Reasoning Challenge Problem

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GRW @ ACS - 11/15/2021

Outline

Dungeon Crawl Stone Soup (~17 min)

DCSS as an AI Challenge Problem and GR Problem

Thoughts on Building an AI to Win DCSS

The API: *DCSS-AI-Wrapper*

What is Dungeon Crawl Stone Soup?

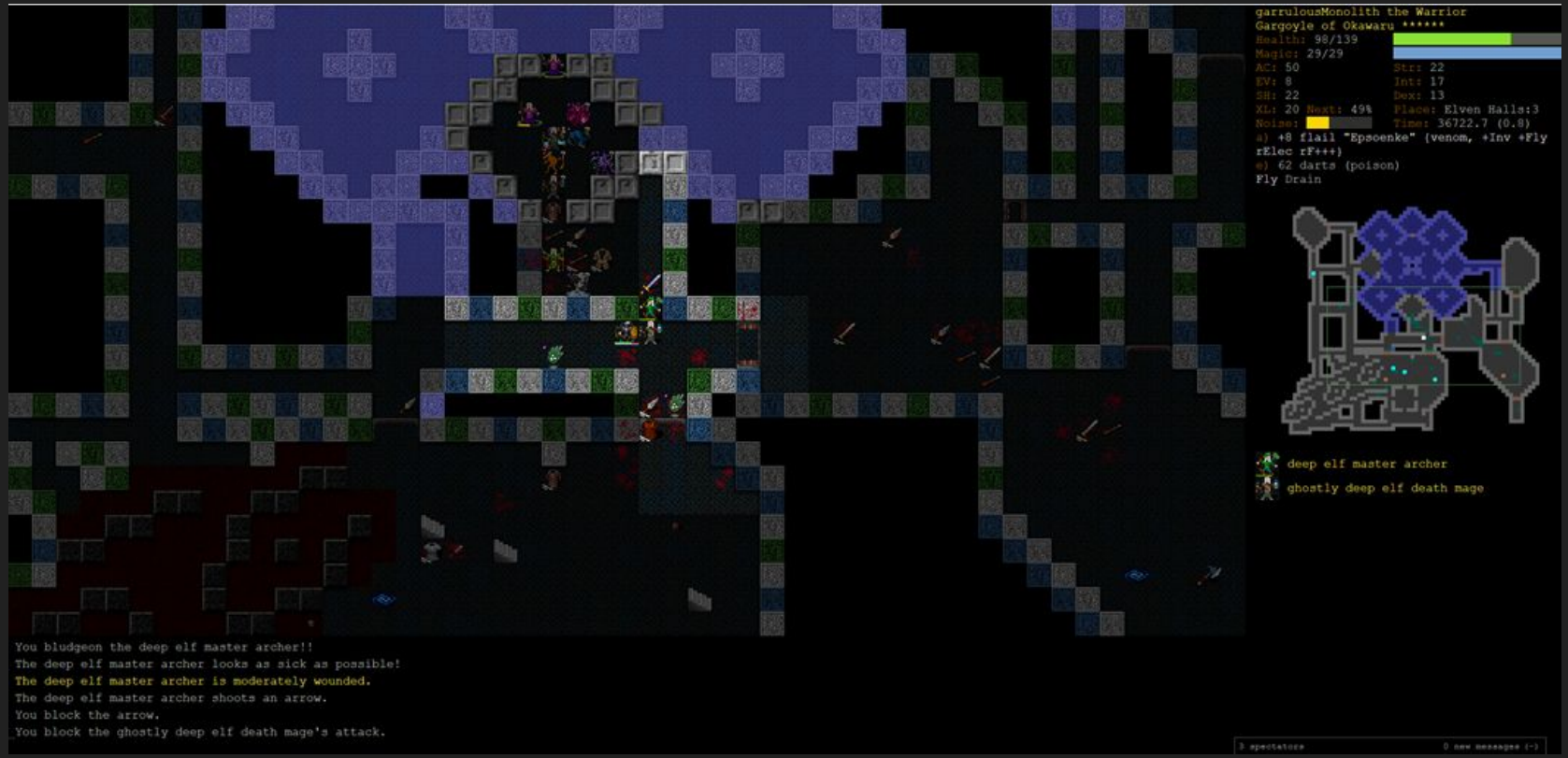
Rogue-like video game under active development since 2006

Game Objective: Navigate your character through a series of 2D grid-based levels to retrieve the Orb of Zot, and return to the entrance.

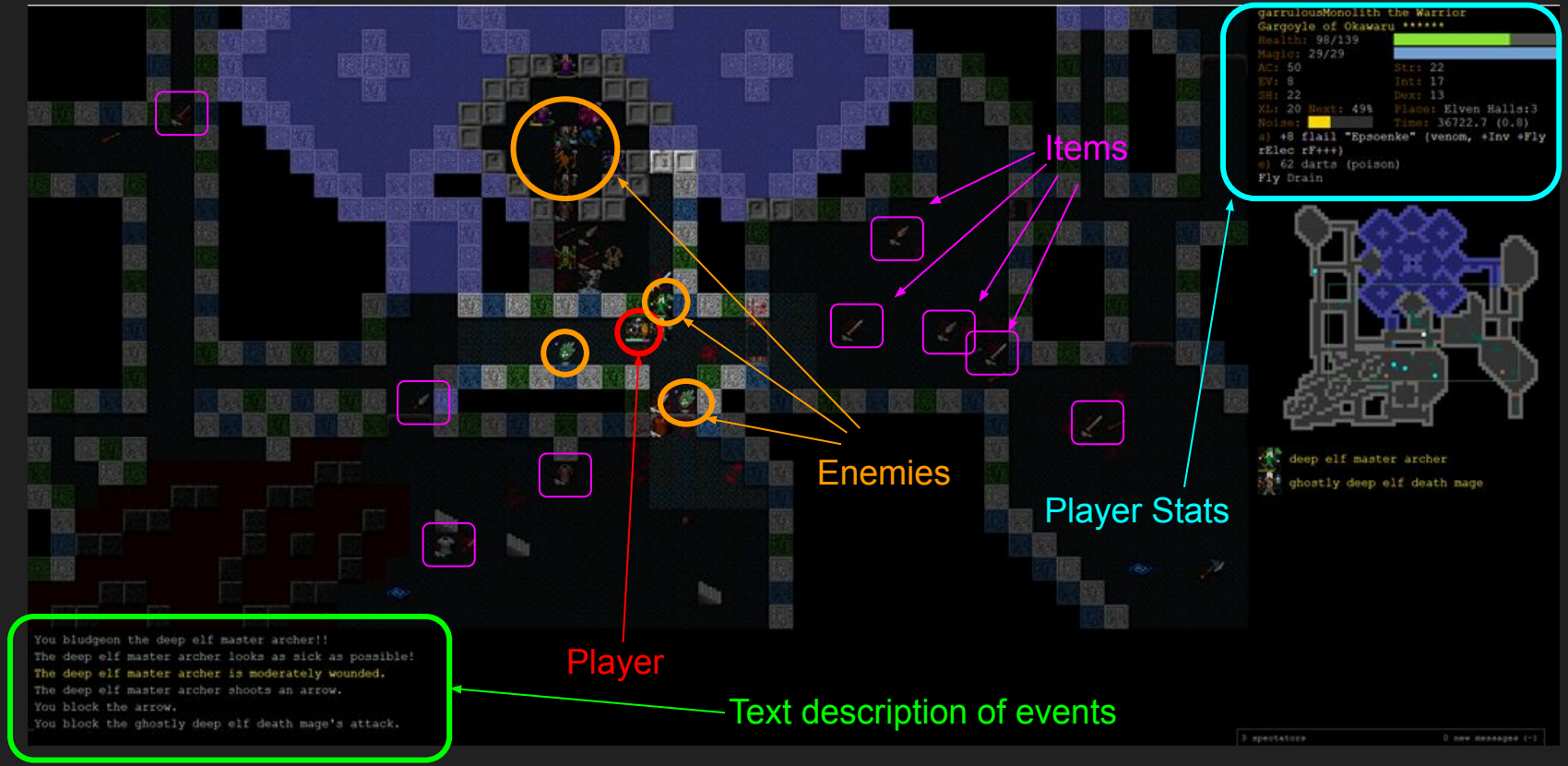
Open-source, available on Github: https://github.com/crawl/crawl

Often referred to as Crawl or DCSS

Screenshot of DCSS



Screenshot of DCSS (annotated)



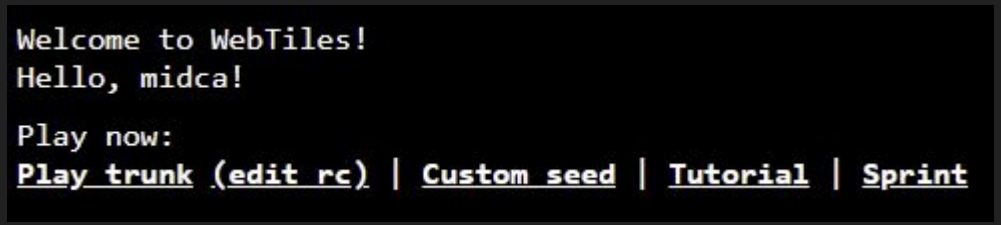
Game Modes

4 primary modes:

- Trunk (*main game mode)*
- Trunk w/ Seed
- Tutorial
- Sprint

Game Mode Selection in Desktop Client:

Browser:



Picking your starting character

Starting the Game (GIF)

Actions

Movement: Melee

To move in a direction or to attack, use the numpad (try Numlock off and on) or vi keys:

```
 7 8 9      y k u
  \|/        \|/
 4-5-6      h-.-l
  /|\        /|\
 1 2 3      b j n
```

Other Gameplay Actions: Magic

a : use special Ability (a! for help)
z : cast spell, abort without targets
Z : cast spell, no matter what
I : list all memorised spells
M : Memorise a spell from your library
t : tell allies (tt to shout)

Rest: Do-nothing

. : wait a turn (also s, Del)
5 : rest and long wait; stops when Health or Magic become full or something is detected. If Health and Magic are already full, stops when 100 turns over (numpad-5)

Dungeon Interaction and Information:

O/C : Open/Close door
</> : use staircase
; : examine occupied tile and pickup part of a single stack
x : eXamine surroundings/targets
X : eXamine level map (X? for help)

Item Interaction:

{ : inscribe item
c : Chop up a corpse on floor
e : Eat food (tries floor first)
f : Fire next appropriate item
F : select an item and Fire it
Q : select item slot to be Quivered
q : Quaff a potion
r : Read a scroll (or book on floor)
w : Wield an item (- for none)
' : wield item a, or switch to b (use = to assign slots)
v : eVoke power of wielded item
V : eVoke wand and miscellaneous item
W/T : Wear or Take off armour
P/R : Put on or Remove jewellery

Sensing Actions

Everything in the game has a text description.

Sometimes additional information too.

Pressing x switches to examine mode

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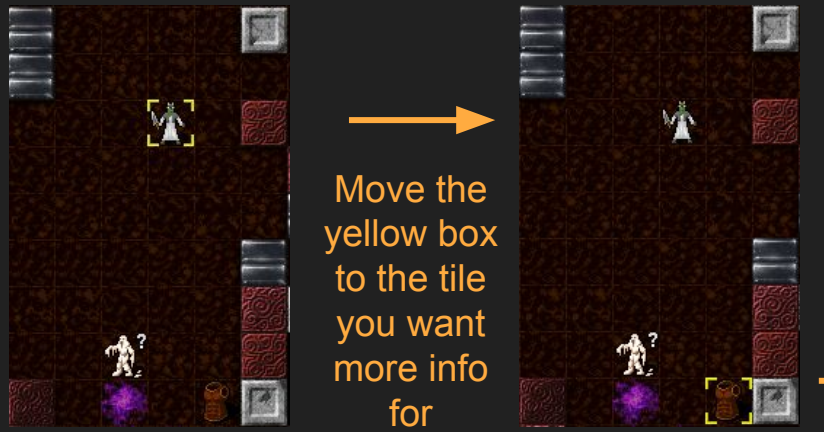
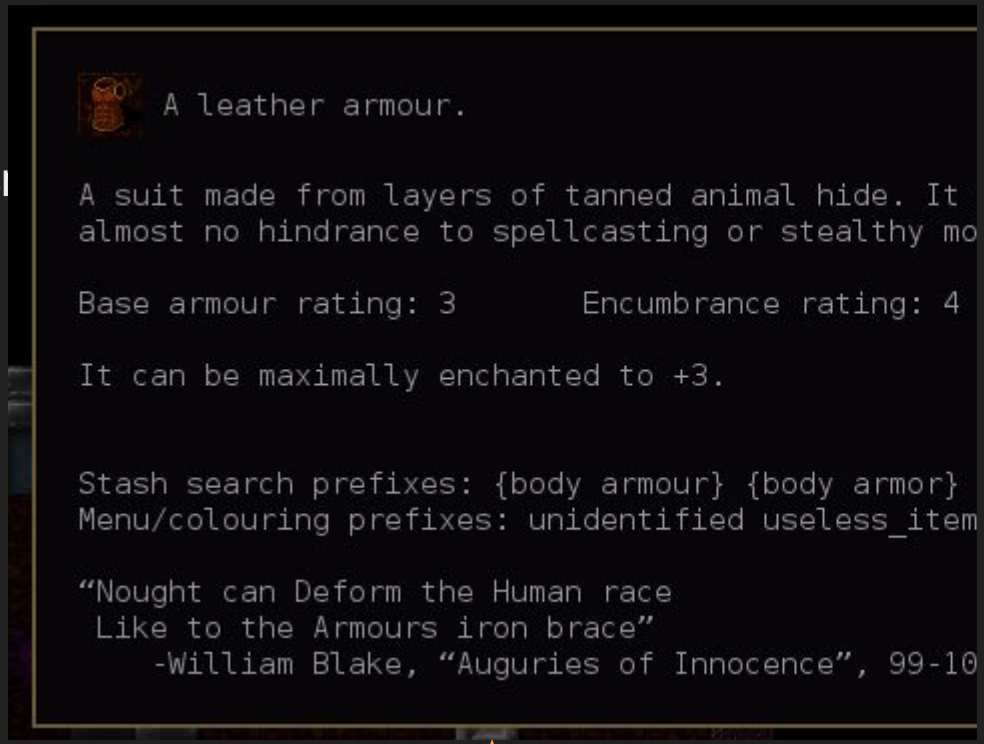
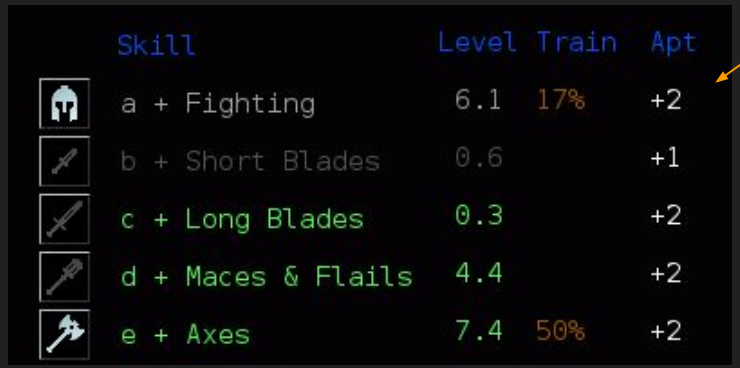




Leveling up in DCSS - Skill Points

Defeating an enemy provides experience

Wiki: “Allocating your XP to align with your aptitudes, available equipment, and playstyle will make or break your character.”



Characters have 33 Skills

Inventory Management

52 Slots in Inventory; Permanent vs. consumable items

Combat

Primary activity of the game

Many different play styles

- Melee
  - Stealthy backstabber
  - Antimagic berserker worshipping Trog
  - Ranged character
- Spells
  - Situational magic: traps and clouds
  - Transformations - become a dragon, etc.
  - Summoning - control a horde of zombies, orcs
- Hybrid
  - Battlemage

A Difficult Combat Situation

Situation

Character stats and inventory

Solutions recommended by other players:

- Use a Phantom's Mirror
  - Must have in inventory
  - Requires sufficient evocations skill
- Use a Scroll of Summoning
  - Must have in inventory
- Use a Wand of Scattershot
  - Must have in inventory
- Fight directly if AC > 30 and mid-tier weapon
- Summoning Scroll + Immolation Scroll
- Invis potion + run north + wall jump boost to slow "Lernie"
- Run away?
  - Are you fast enough?
  - How close are the nearest stairs?

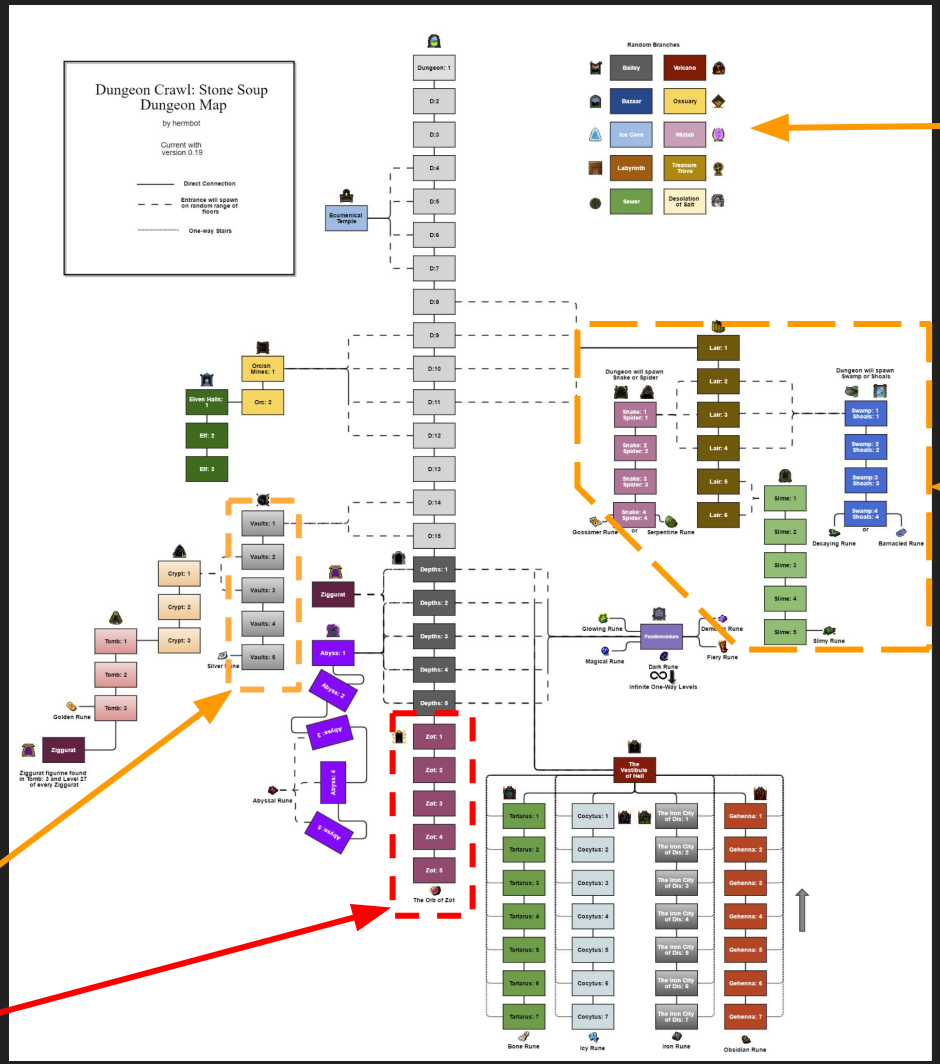
https://www.reddit.com/r/dcss/comments/o79cfm/need_help_fofi_in_swamp_with_lernie/

Dungeon Map

- More than 100 Levels
- 17 possible runes
- 3 runes needed to enter Zot

2 infinite realms:

- Pandemonium
- Abyss



8 Random Branches

Easiest runes

Easier rune

Orb of Zot

DCSS as an AI Challenge Problem

Features of Dungeon Crawl Stone Soup

- Stochastic Actions and Events
  - Ex: melee attacks may miss, hit for partial health, or kill a monster
- Non State Changing Sensing Actions
- Partially observable, unknown until explored
  - Line of sight is 7 tiles in all directions
- Procedurally Generated World
  - Unique every playthrough except if seed value specified
- Complex State Space
  - Minimum requirements to win include visiting ~70k tiles, thousands of monsters and items
  - 2 levels are infinite, change with every turn (abyss, labyrinth)
  - 650+ types of monsters
- Complex Action Space
  - More than 100 spell and melee action types, many actions requiring choosing targets
- Permanent Death

State Space Complexity - Lower Bound, 3-rune Game

Assumptions:

- 70,000 Tiles
- 900 Items
- 2000 Monsters

$$|S| = 70000^{2900} \approx 10^{14000}$$

DCSS has an infinite number of tiles, although visiting the infinite realms is not required to complete the game

Action Space Complexity

~50 action types

- 24 directional move / attack actions
- 2 macros for moving and fighting (o, tab)
- 2 resting actions
- 18 item actions (firing a missile, equip armour, evoke)
- 4 dungeon interaction actions (doors, stairs)

Players can learn up to 21 spells; carry multiple ranged weapons

Most spells and ranged weapons can target any creature in Line of Sight (7 tiles)

- Therefore up to 225 targets for a spell, including player tile

Result - upper bound could be ~30 types of ranged attacks… yielding 6750 possible instantiated actions

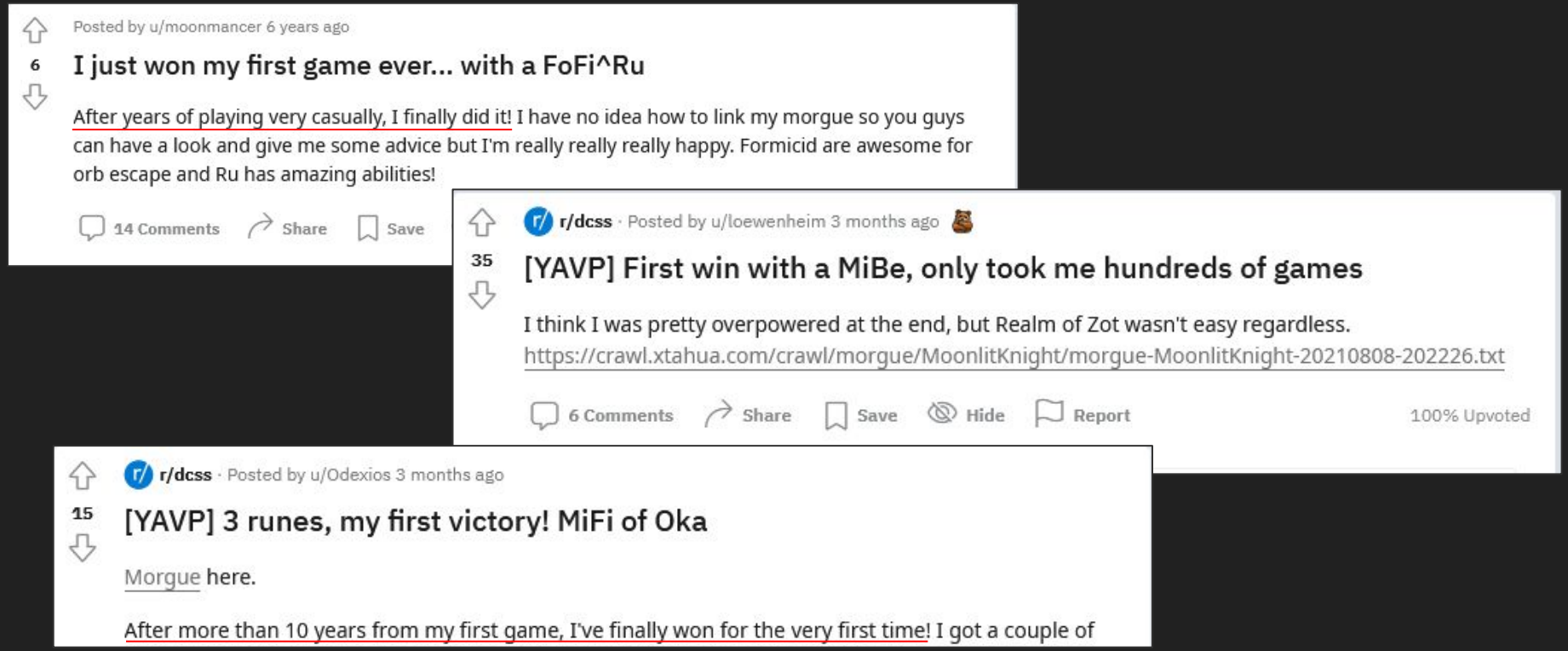
Features of a Good AI Challenge Problem

- Challenging
- Popular
- Available
- Easy to start
- Supported and maintained
- Publishable

Rogue-like Games as an AI Challenge Problem

Property	Dungeon Crawl Stone Soup	Nethack
Challenging	Currently Humans > AI	Currently Humans > AI
Popular	Active subreddit, IRC, wiki, discord	Active community
Available	AI API: ***dcss-ai-wrapper***	AI API: ***Nethack Learning Env.***
Easy to Start	Yes - tutorials available	Yes - tutorials available
Supported and maintained	Yes - under development (me) ***Open invitation to contribute!***	Yes - supported by Facebook AI Research
Publishable	Yes	Yes

Additional Benefit: It's hard for most humans



Features of a Good **Goal Reasoning** Challenge Problem

- Multiple Types of Goals
  - Achievement goals
  - Maintenance goals
  - Learning goals
- Goals over varying time horizons
  - Near term and long term goals
- Rich goal space
  - Many specific state features are desirable as goals
    - Not just a short list of goal types that a human provides (such as navigation)
- Pursuing more than one goal at a time improves performance

Achievement Goals in DCSS

A non-exhaustive list:

- Exit the dungeon with the orb of Zot (Highest goal)
- Obtain a rune (direct pre-req. to get orb)
- Acquire strength in:
  - Player stats / skills / weapons & armour
- Defeat a monster
- Acquire items
- Navigate to a tile

Maintenance Goals in DCSS

A non-exhaustive list:

- Keep health points high
- Keep magic points high
- Keep other player stats high
- Piety
- Stealth

Knowledge to Learn in DCSS

State Transitions:

- Player’s actions
  - Only living monsters will follow you up stairs
- Events
  - Fire spells over water may produce steam
- Processes
  - The rate at which health regenerates
  - Damage from actions change as you get stronger

Strategy:

- Bees travel in groups, most characters cannot outrun bees
- Bladed weapons against hydras will make them stronger unless they are branded with fire
- It is often easier to fight many enemies in a hallway 1v1 than in large open areas

Fighting in a hallway (GIF)

Winning DCSS

Some speculative thoughts

Learning as a Requirement

Intractable to human-author a complete, accurate model

- Hint: It's always changing

Any AI that's going to solve DCSS must be a learning agent

Which approach is best to solve DCSS:

Cognitive System approach? Or Deep RL End to End system?

Measuring Performance in DCSS

Well-known Metrics:

- # of wins / attempts
- Efficiency of wins
- Resources required for training (simulations, etc.)

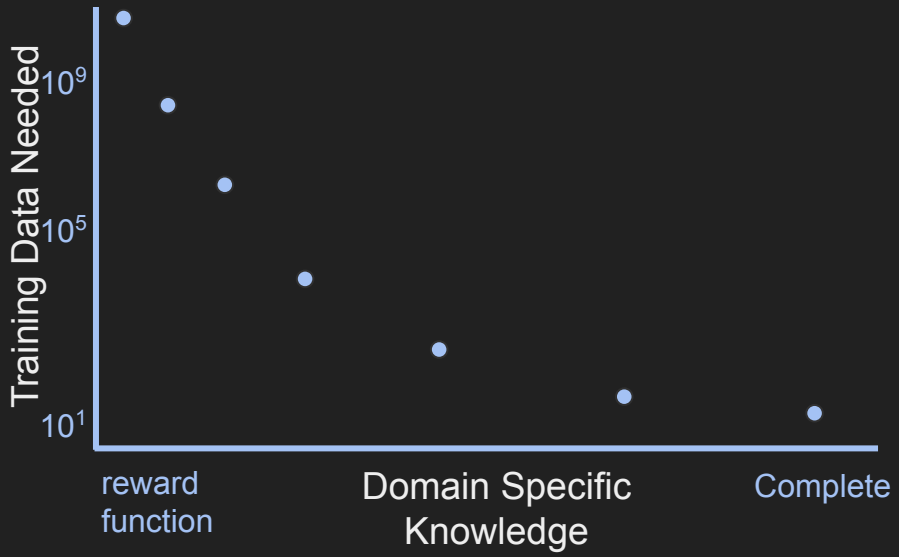
Less-obvious, critical metrics should address:

- How much knowledge is given to the agent?
- How much human time is spent encoding the knowledge to the agent?
  - *Wishful thinking?*

Measuring Human-Authored Knowledge

How much knowledge has been given to the agent?

Speculative Hypothesis:



Common phrase heard from cog. sys. folks:

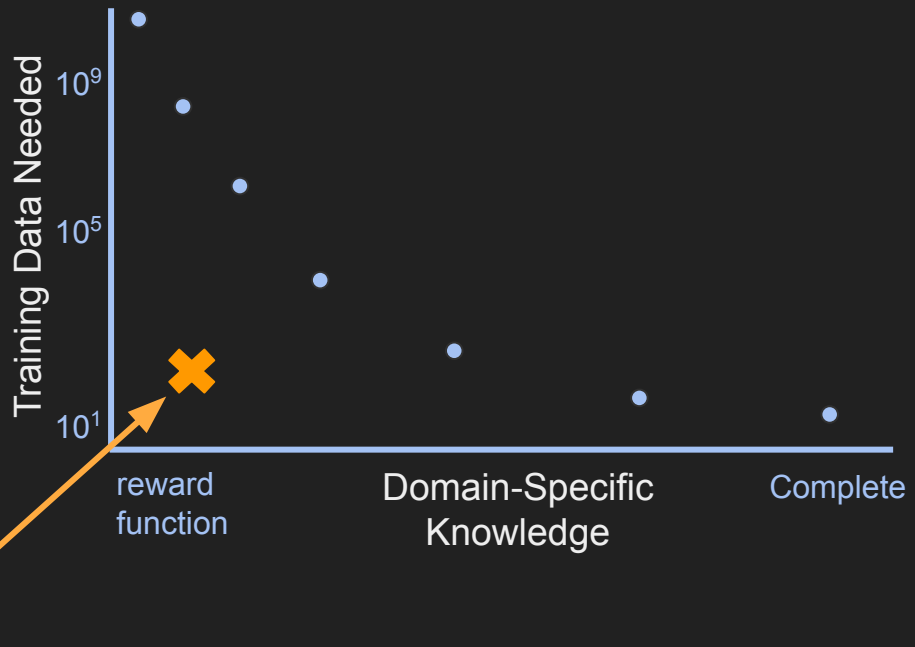
"With just a little bit of knowledge, it could learn way faster. After all, humans don't need so many examples"

DCSS-AI-Wrapper seeks to measure this precisely!

<u>Types of Knowledge to Measure:</u>

- Reward functions (incl. curriculums)
- Action / Event / Process Models
  - Varied by accuracy and completeness
- Strategy Knowledge
  - May take many forms
    - Schedules
    - Sub-goal Trees
    - Facts (ex: monster X weakness)

Bigger Goal: Can we do better?

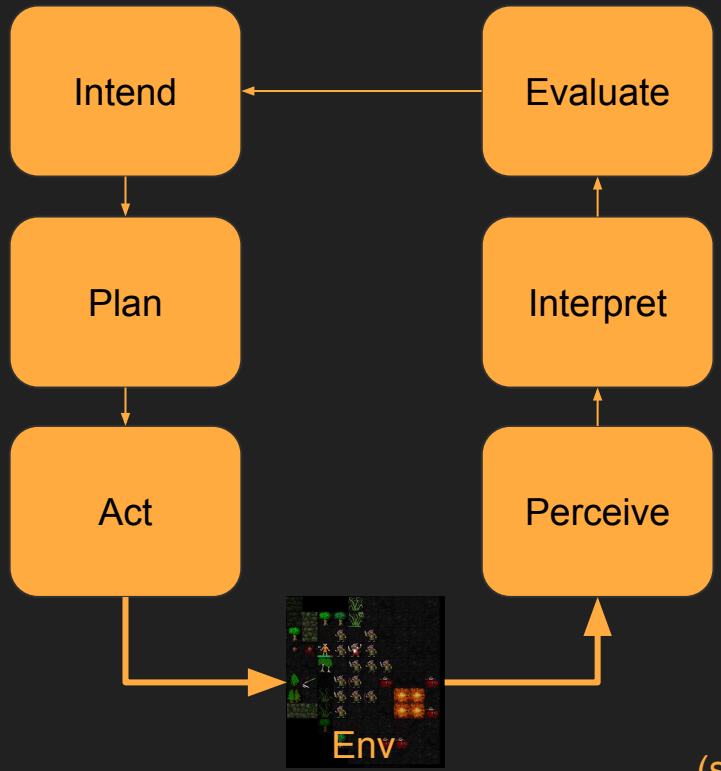


Learning as a Metacognitive Process

Cognition is Reasoning About the World

Examples:

- Beliefs and Goals are World States
- Actions change world states
- Interpret detects anomalous world states

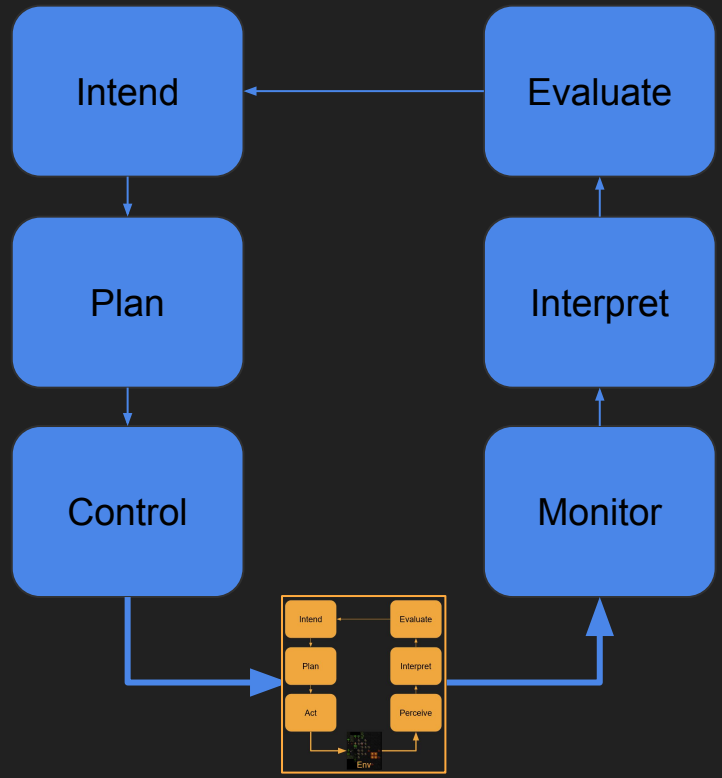


MIDCA
(see Cox, et al. 2016)

Metacognition is reasoning about Cognition

Examples:

- **Monitor** perceives the state of cognition
- **Interpret** detects anomalies in cognition
  - Failure to explain
  - Failure to plan
  - Failure of cyclic behaviors
- **Control** modifies cognition
  - Change parameter of an algorithm
  - Change algorithm
  - Change knowledge



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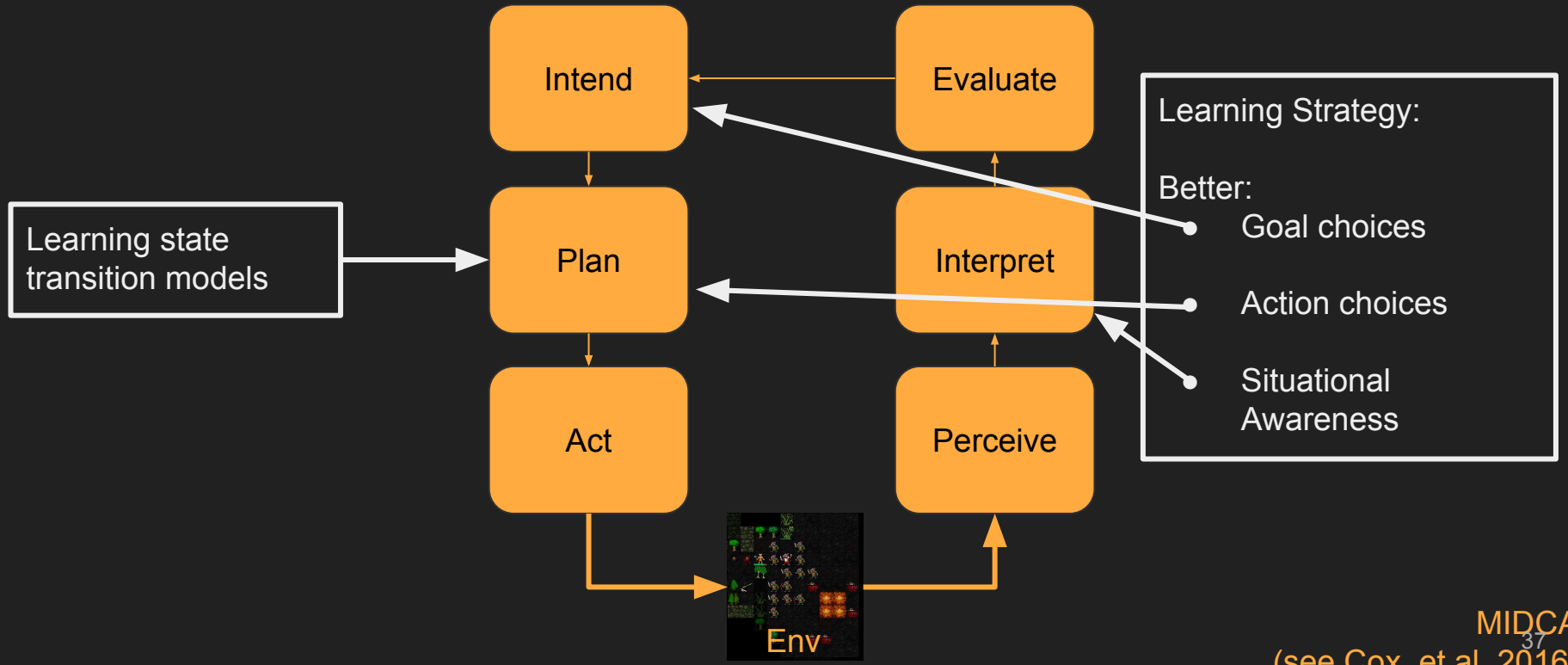
Changing Knowledge in MIDCA



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DCSS-AI-Wrapper

DCSS-AI-Wrapper

An AI-friendly API to DCSS

Goals:

- Make it easy for AI researchers to use DCSS as a test environment
- Preserve the DCSS game engine

Motivation:

- Push the field to use more complex domains as testbeds in every-day research
  - Only as an addition, not to replace other domains!

Features of the DCSS-AI-Wrapper

- Multiple state representations
  - Currently vector-based representations and PDDL 2.2
  - Low-effort to add new representations (such as other PDDL variants)
- An approximate, high-level PDDL domain file
  - ~2100 lines, includes all types of objects, monsters, spells, items, etc. & basic actions
  - Currently works with the FastDownward planner
- Cross-platform - works on Windows, Mac, Linux
- Support for running many experiments
  - Configuration options to easily set parameters
    - Auto-restart a game
    - End a game after X actions

Code to create an agent

```python
from dcss.agent.base import BaseAgent
from dcss.state.game import GameState
from dcss.actions.action import Action

class MyAgent(BaseAgent):

    def __init__(self):
        super().__init__()
        self.gamestate = None

    def get_action(self, gamestate: GameState):
        self.gamestate = gamestate
        # get all possible actions
        actions = Action.get_all_move_commands()
        # call your planner or policy instead of random:
        return random.choice(actions)
```

Only Requirements:

1. Subclass BaseAgent
2. Override get_action()

Code to run an agent

```
1   from dcss.websockgame import WebSockGame
2   from dcss.connection.config import WebserverConfig
3
4   def main():
5       my_config = WebserverConfig
6
7       # set game mode to Tutorial #1
8       my_config.game_id = 'tut-web-trunk'
9       my_config.tutorial_number = 1
10
11      # create game
12      game = WebSockGame(config=my_config,
                           agent_class=MyAgent)
13      game.run()
```

Option to set configuration values when running

Set your agent here

game.run() is a blocking call

Planning Agent Demo

Hallmark of DCSS-AI-Wrapper: Both Vectors & PDDL

Vector Based Representation

- Player stats (vector)
- Player inventory (vector)
- Player spells (vector)
- Player abilities (vector)
- Player skills (vector)
- Map data Line-of-Sight (LOS) (vector)
- Map data current level (vector)
- Map data all (vector)

PDDL State Representation

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- Map data current level (PDDL)
- Map data all (PDDL)
- Static Background Knowledge (PDDL)

PDDL Model of the game (~2k lines):

- Works with the FastDownward planner
- In the repo: **models/fastdownward_simple.pddl**

https://dcss-ai-wrapper.readthedocs.io/en/latest/usage/state_representation.html

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The map data LOS vector is comprised of 225 tile vectors, with each tile vector length 30

(total vector size being 6750)

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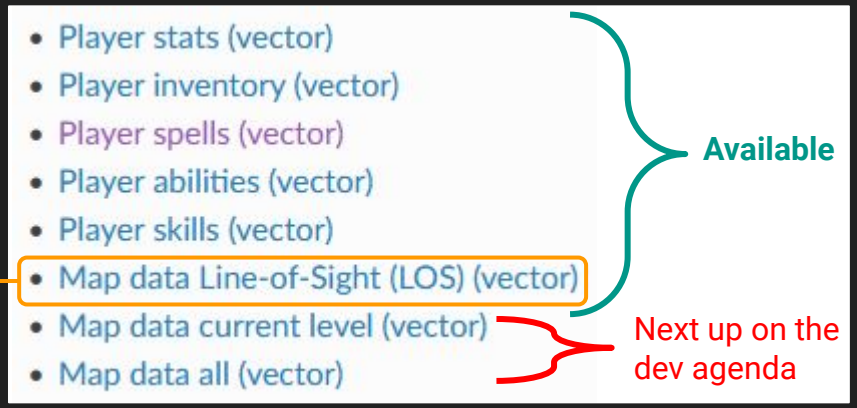

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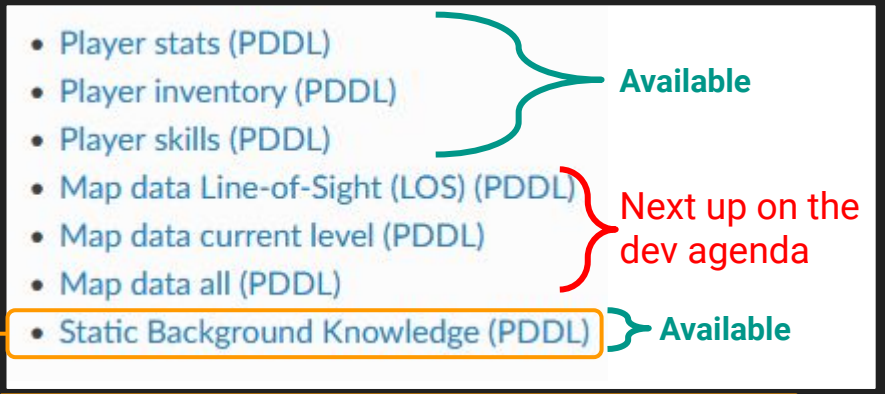

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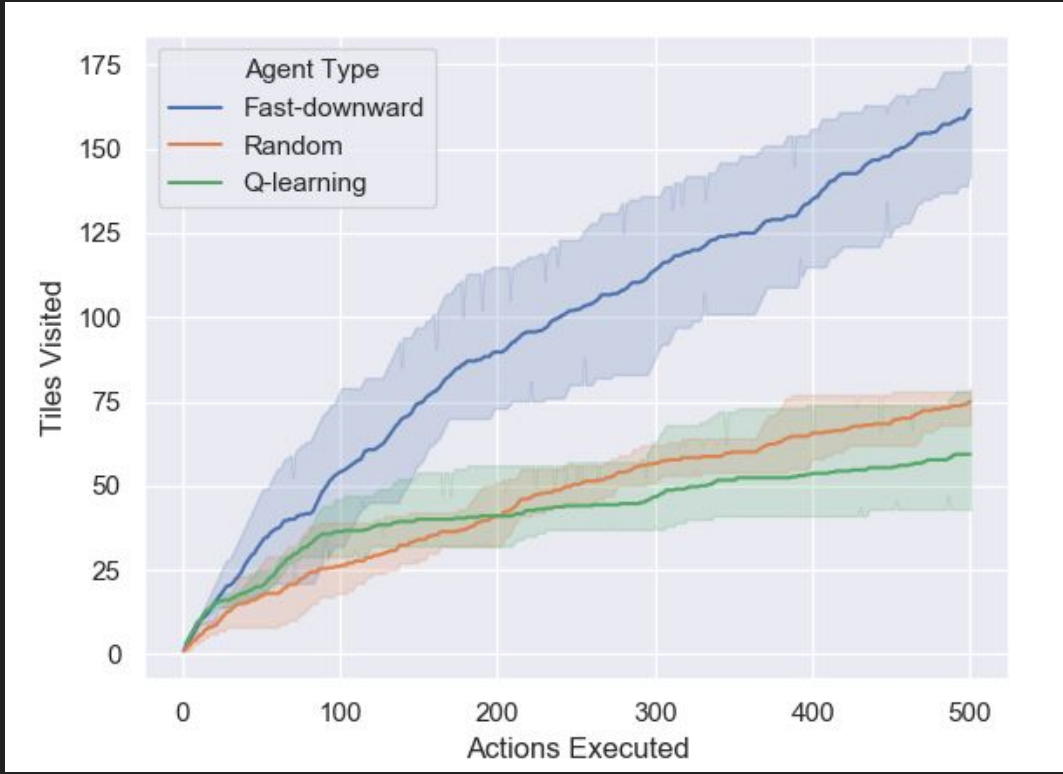
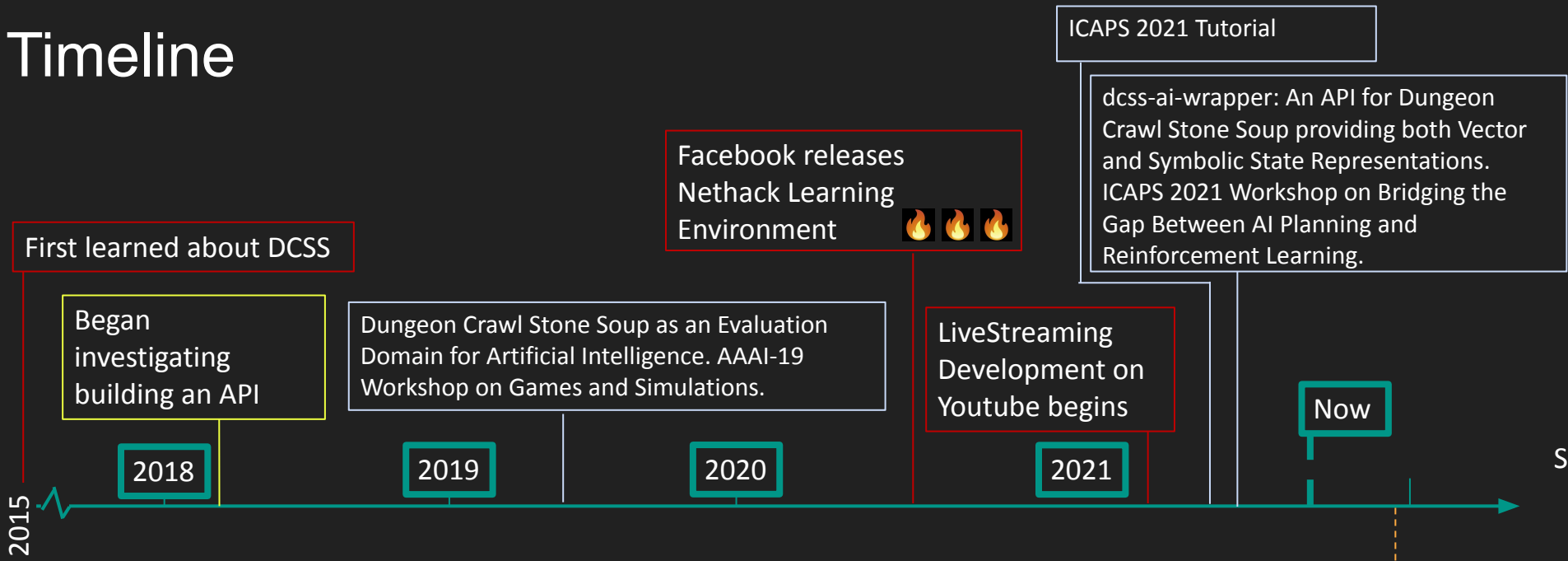
Comparing Diverse Agents



Data collected from agents using the dcss-ai-wrapper API

Timeline



Near-term Goals

- **Add monster details to API**
- **Finish PDDL API**
- **Optimize terminal mode**
- **Refactoring & polishing**
- **… agent development??**

Getting Started

Code:

Github: dcss-ai-wrapper & Documentation

Resources:

Recent ICAPS Tutorial Documentation

ICAPS Tutorial Youtube Video

Join the conversation and ask questions at the Gitter

Thank you to my collaborators

Michael W. Floyd @ *Knexus Research Corporation*

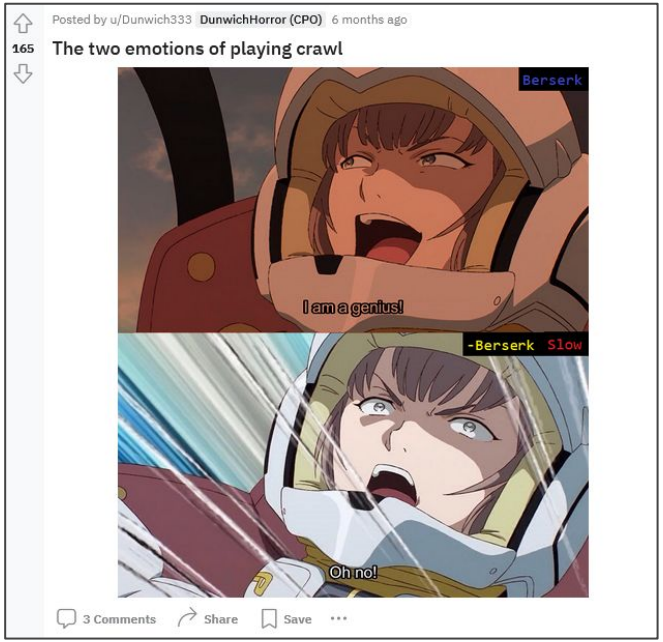
Zohreh A. Dannenhauer @ *Knexus Research Corporation*

Adam Amos-Binks @ *Applied Research Associates*

Jonathan Decker @ *Naval Research Laboratory*

David Aha @ *Naval Research Laboratory*

Noah Reifsnyder @ *Lehigh University*



End