# General Intelligence through playing games?

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This workshop aims to stimulate theoretical and practical advances in the development of machines endowed with human-like general-purpose intelligence, focusing in particular on benchmarks to train and evaluate progress in machine intelligence. The workshop will feature invited talks by top researchers from machine learning, AI, cognitive science and NLP, who will discuss with the audience their ideas about what are the most pressing issues we face in developing true AI and the best methods to measure genuine progress. We are moreover calling for position statements from interested researchers to complement the workshop program (see below).

# Are we generally intelligent?

- **No**

- Programmed for decades for doing some small range of tasks, using curricula developed for centuries by society

- We “could” solve any task, but it takes ages for society to reprogram us to do it

- Turing-completeness is irrelevant

# General intelligence

According to Legg and Hutter: universal intelligence is the sum of the performance of an agent on all possible problems, weighted by their simplicity

$$\Upsilon(\pi) \ := \sum_{\mu \in E} 2^{-K(\mu)} \, V_\mu^\pi .$$

# What kind of general intelligence?

- Human-like? (Which human?)
- Human-relevant?
- Abstract and incomprehensible?
- How dependent is the definition of general AI on the description language of tasks/problems?

# Games as AI benchmarks

- Old and obvious idea
- Faster, cheaper and technically easier than robots
- Games are made to challenge human thinking
  - “Fun” comes largely from our ability to learn the game as we play
  - Well-designed games should therefore be relevant test for AI

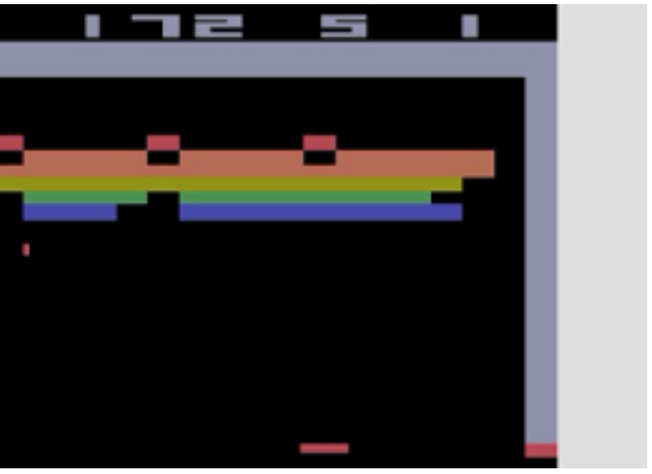
# Me, 2006: Train general AI in video games

evolving neurocontrollers and sensor setups for successfully competing against another car, and we hope that our results will be useful both for game developers looking to automatically create racing game AI, and computational intelligence researchers seeking to use games and game-like environments to evolve ever more general and complex intelligence.

REMOVE

## 1.1 Co-evolution

In our previous research, a controller's fitness was defined as the progress a con-



# Game-based AI benchmarks

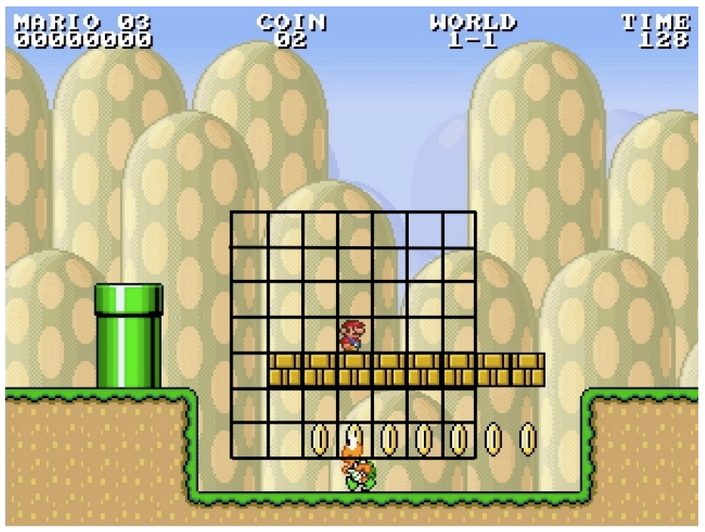
- Simulated Car Racing
- Mario AI
- StarCraft


- Unreal 2k4/BotPrize

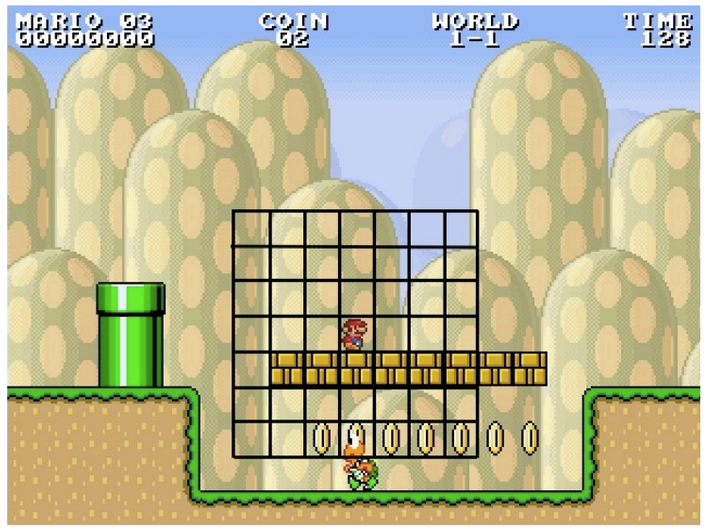
- General Game Playing
- Arcade learning environment
- FAIR Torchcraft

- Minecraft/Malmö
- DeepMind Labs
- OpenAI Universe

# Problem: overfitting



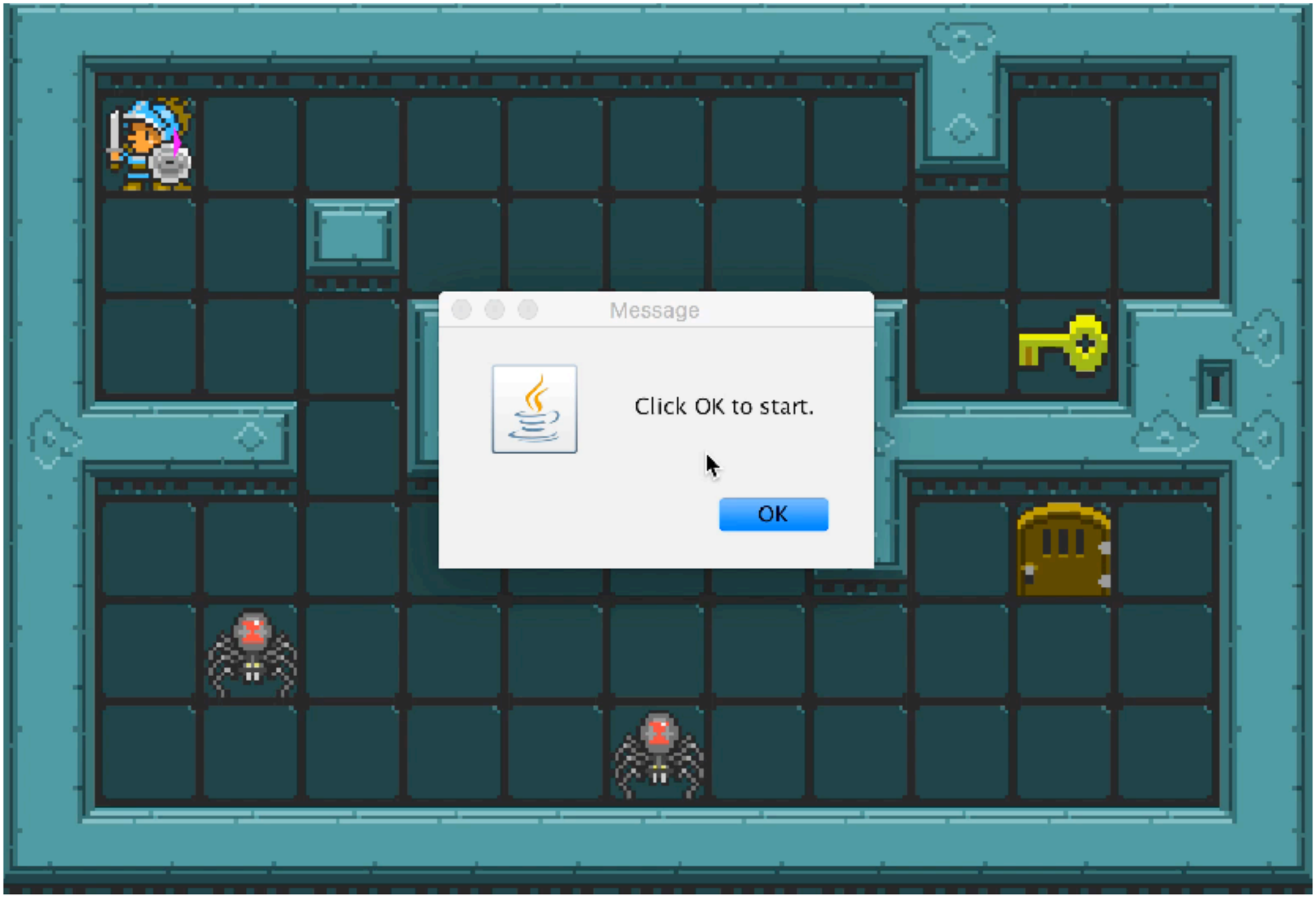

# Solution: many, unseen games



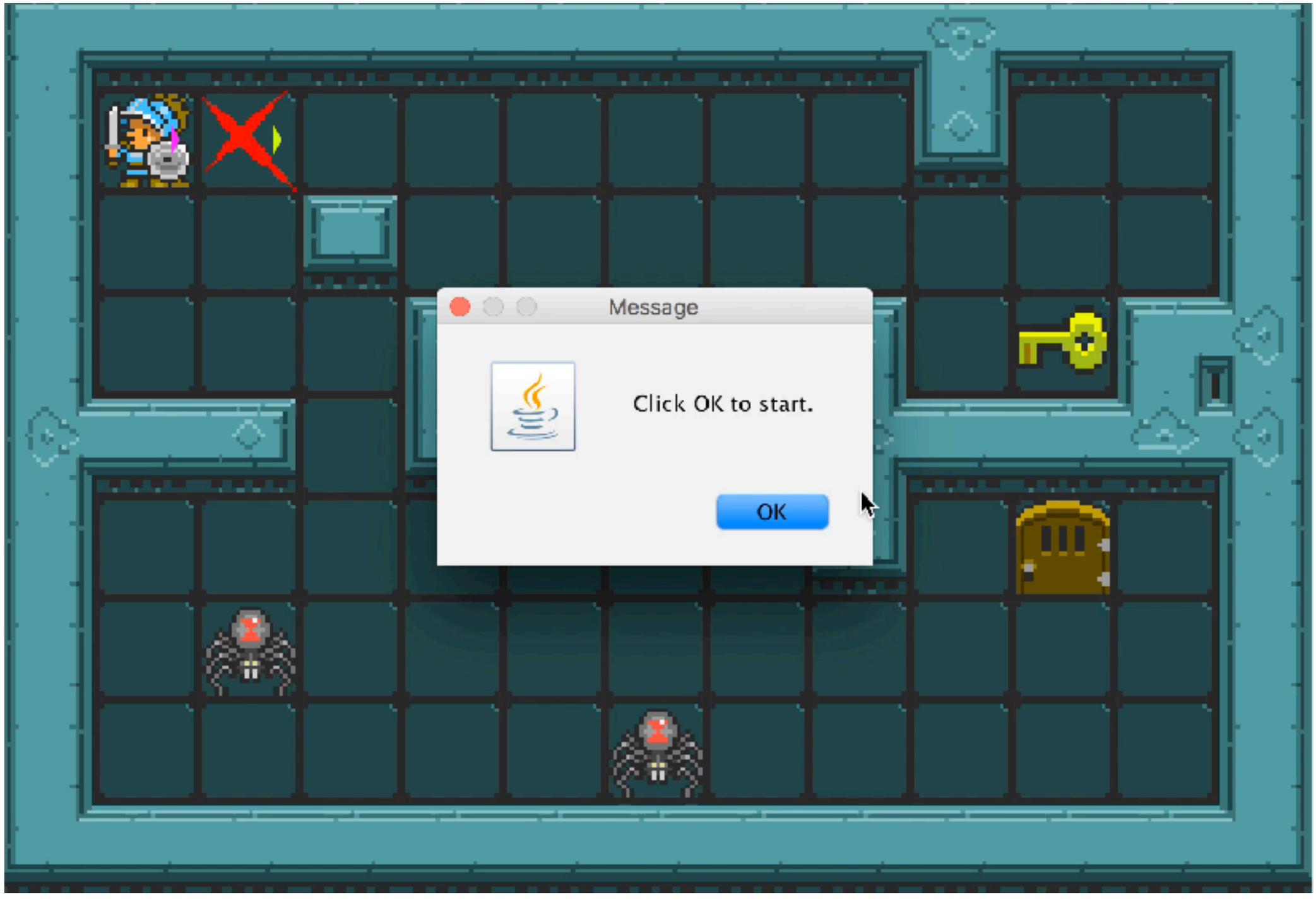

# General Video Game AI

- Video game-based AI testing framework with currently about 100 games
  - Most of them modeled on 70s and 80s games
- Agents are submitted to a server, and tested on *unseen* games
- Agents are written in a description language
  - Easy to write for humans, possible to generate!

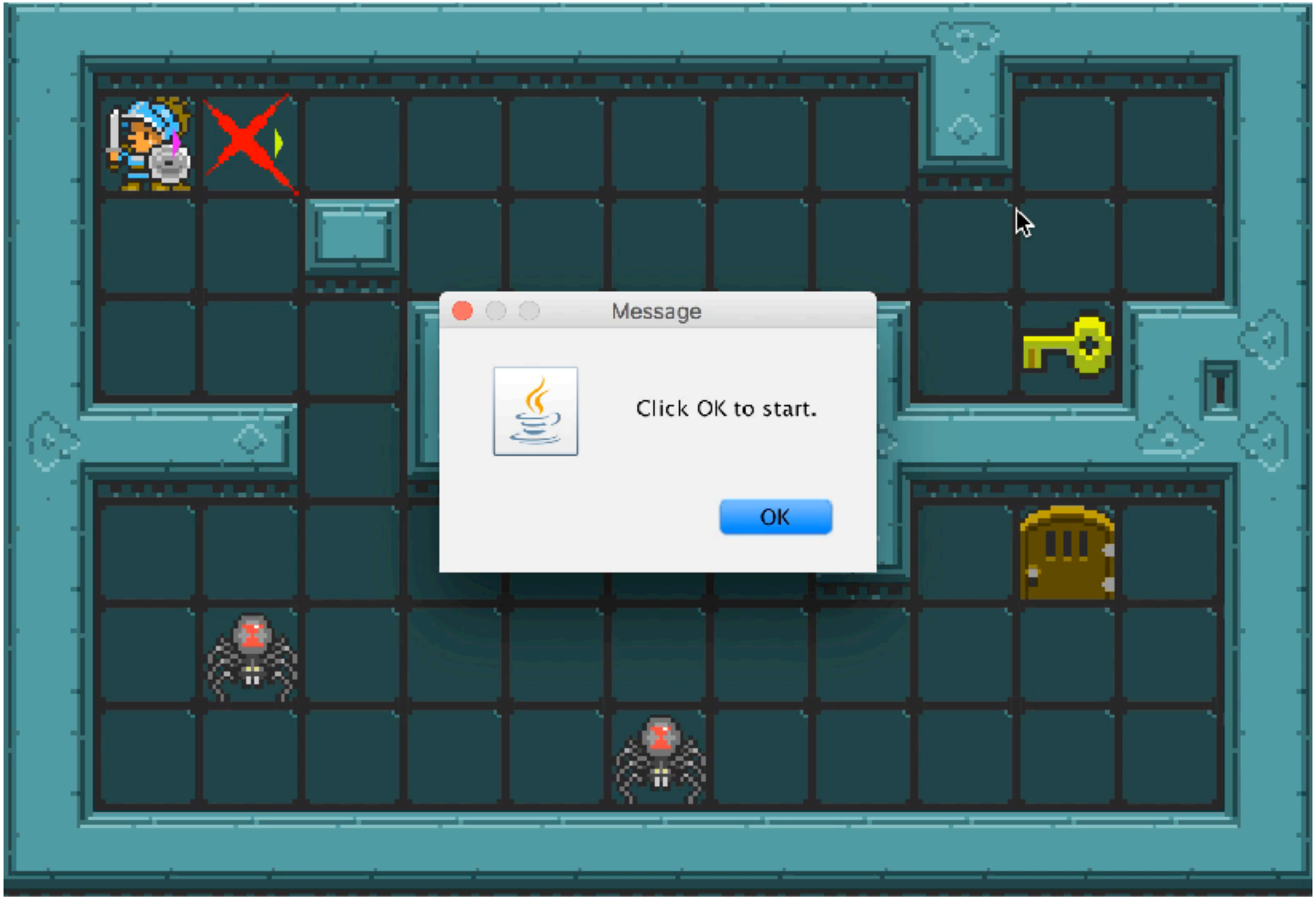
# Zelda: Human



# Zelda: Random



# Zelda: OLETS

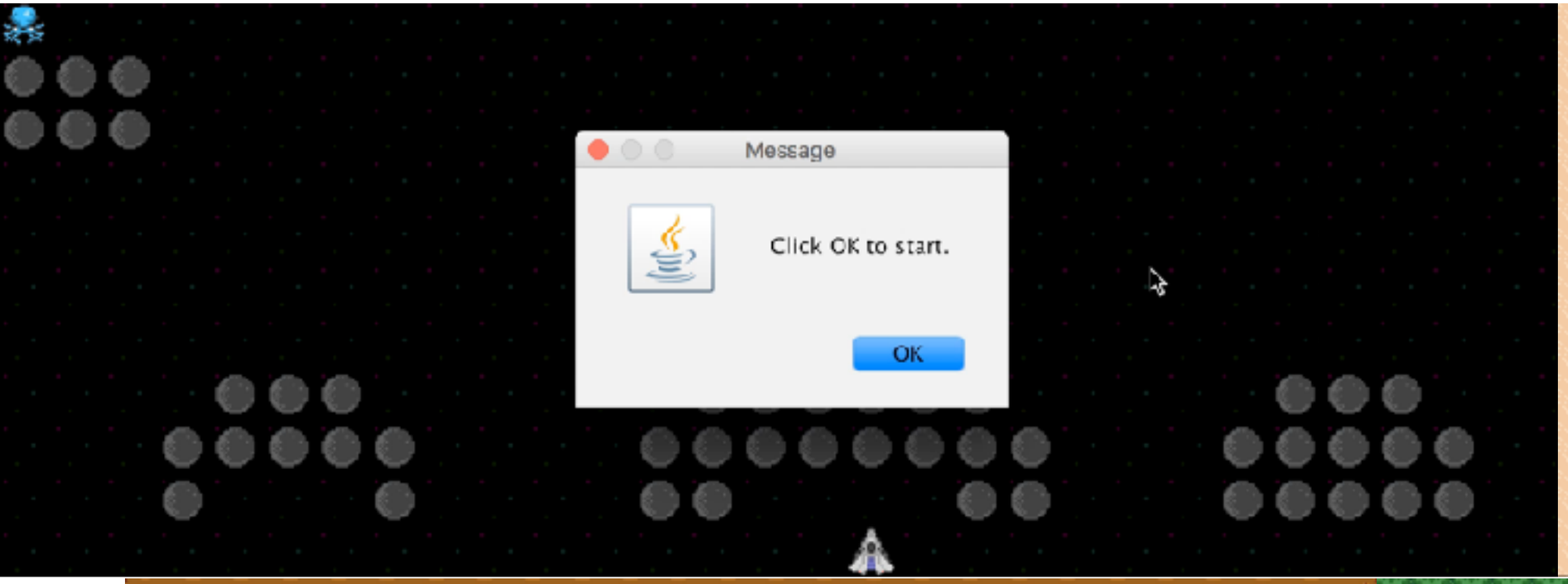


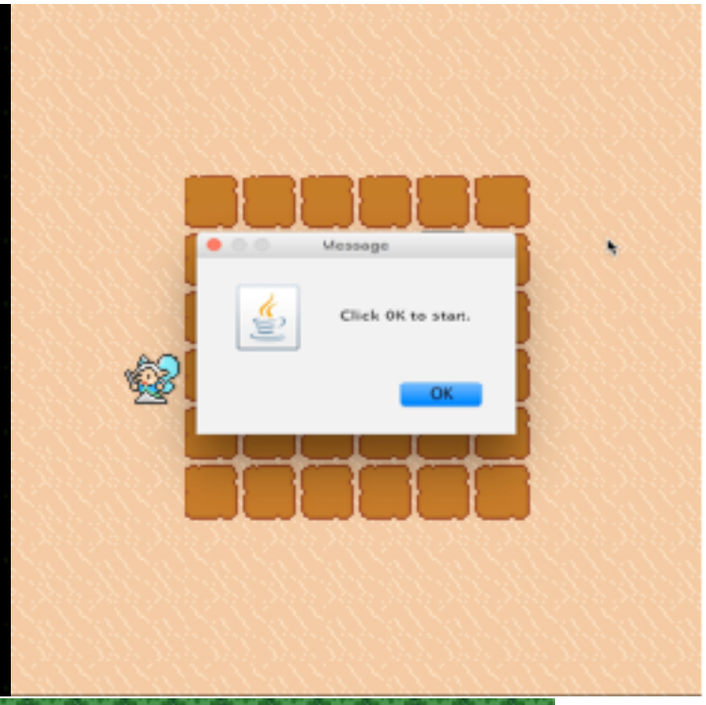
# Video Game Description Language

```
BasicGame
  SpriteSet
    goal  > Door color=GREEN img=goal
    key   > Immovable color=ORANGE img=key
    sword > Flicker limit=5 singleton=True img=sword
    movable >
      avatar  > ShootAvatar   stype=sword
        nokey   > img=avatar
        withkey > color=ORANGE img=alien
      enemy >  img=monster
        monsterQuick > RandomNPC cooldown=2
        monsterNormal > RandomNPC cooldown=4
        monsterSlow > RandomNPC cooldown=8

  LevelMapping
    G > goal
    + > key
    A > nokey
    1 > monsterQuick
    2 > monsterNormal
    3 > monsterSlow

  InteractionSet
    movable wall  > stepBack
    nokey goal    > stepBack
    goal withkey  > killSprite scoreChange=1
    enemy sword > killSprite scoreChange=2
    avatar enemy > killSprite scoreChange=-1
    key  avatar   > killSprite scoreChange=1
    nokey key     > transformTo stype=withkey
  TerminationSet
    SpriteCounter stype=goal   win=True
    SpriteCounter stype=avatar win=False
```

```
wwwwwwwwwwww
wA        w  w
w  w         w
w   w   w +ww
www w2  wwwww
w       w G w
w 2         ww
w     2     ww
wwwwwwwwwwww
```

# MOAR GAMES


Message
Click OK to start.
OK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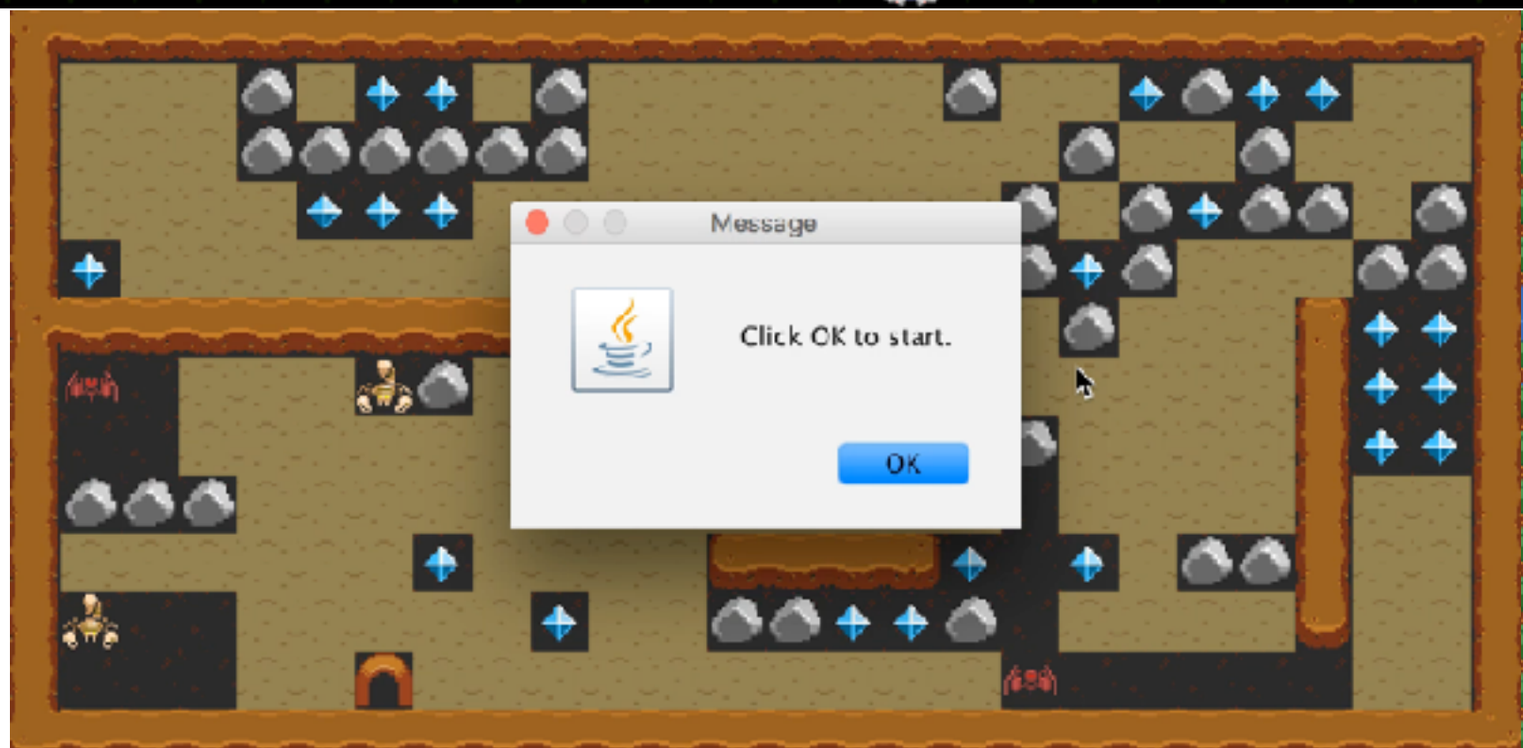
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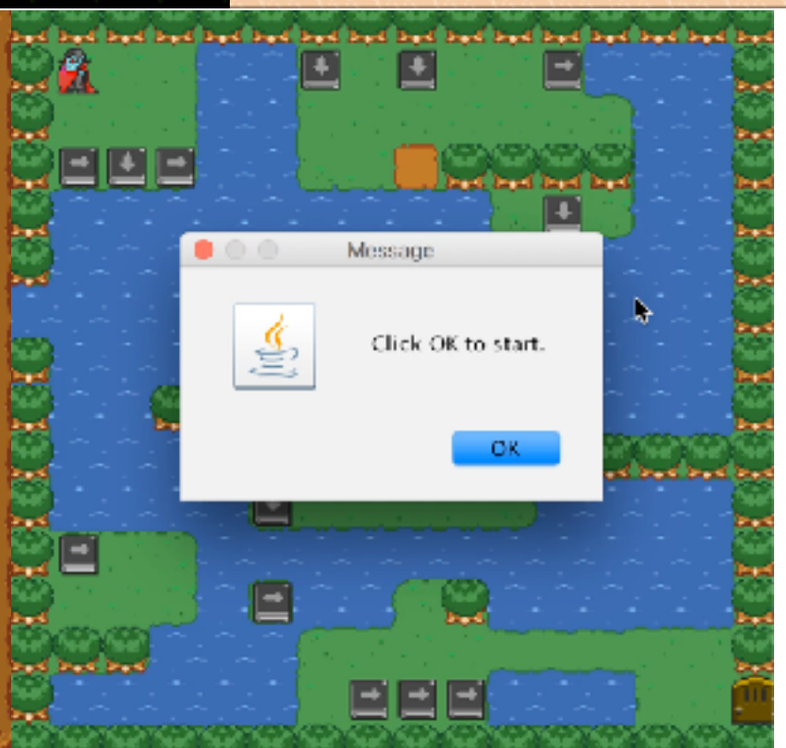

Message
Click OK to start.
OK

# GVGAI is ~~better~~ different because…

- Can be used with or without forward models
- No pixel parsing necessary
- Games are unknown
- Infinite game supply (potentially generatable)

# What works in GVGAI?

- Tree search
  - MCTS and friends
    - Iterative width / novelty pruning
- Evolutionary action selection
- Hyper-heuristics / algorithm selection

Controller Performance

aliens butterflies painter whackamole surround factorymanager infection camelRace firestorms frogs waitforbreakfast solarfox chase pacman crossfire portals labyrinth zelda overload escape jaws seaquest plaquesattack missilecommand modality survivezombies racebet2 bait brainman eggomania tercio ihtesiadel sokoban boulderchase boulderdash roguelike chipschallenge zenpuzzle bolocadventures digdug superman realsokoban realportals lemmings firecaster catapults plants defem rceandfire

Controllers (Algorithm)

sampleRandom (R)
simulatedAnnealing (SA)
hillClimber (HC)
depthFirstSearch (DFS)
sampleonesteplookahead (LA)
iterativeDeepening (ID)
breadthFirstSearch (BFS)
mrtndwrd (MCTS)
sampleGA (GA)
evolutionStrategies (GA)
aStar (A•)
roskvist (MCTS)
SJA86 (MCTS)
sampleMCTS (MCTS)
MnMCTS (MCTS)
AIJim (MCTS)
TeamTopbug (GA)
jaydee (GA)
Rooot (LA)
SJA862 (Minimax)
MH2015 (GA)
NovTea (Iterative Width)
adrienctx (MCTS)

25
20
15
10
5
0

Games

# Planning vs learning

- If you have a forward model, why not use it?
  - Enables use of heuristic search / planning
- Most physical world problems do not have forward models, but they could (easily?) be learned!
- Most computer-based problems allow (easy?) extraction of a forward model
- GVGAI planning track: forward model, no learning time
- GVGAI learning track: no forward model, learning time

# Pixels versus object data

- If you have nicely processed data, why not use it?
- For most computer-based problems, we have such data
- For most physical world problems, we could learn a model that parses the pixels

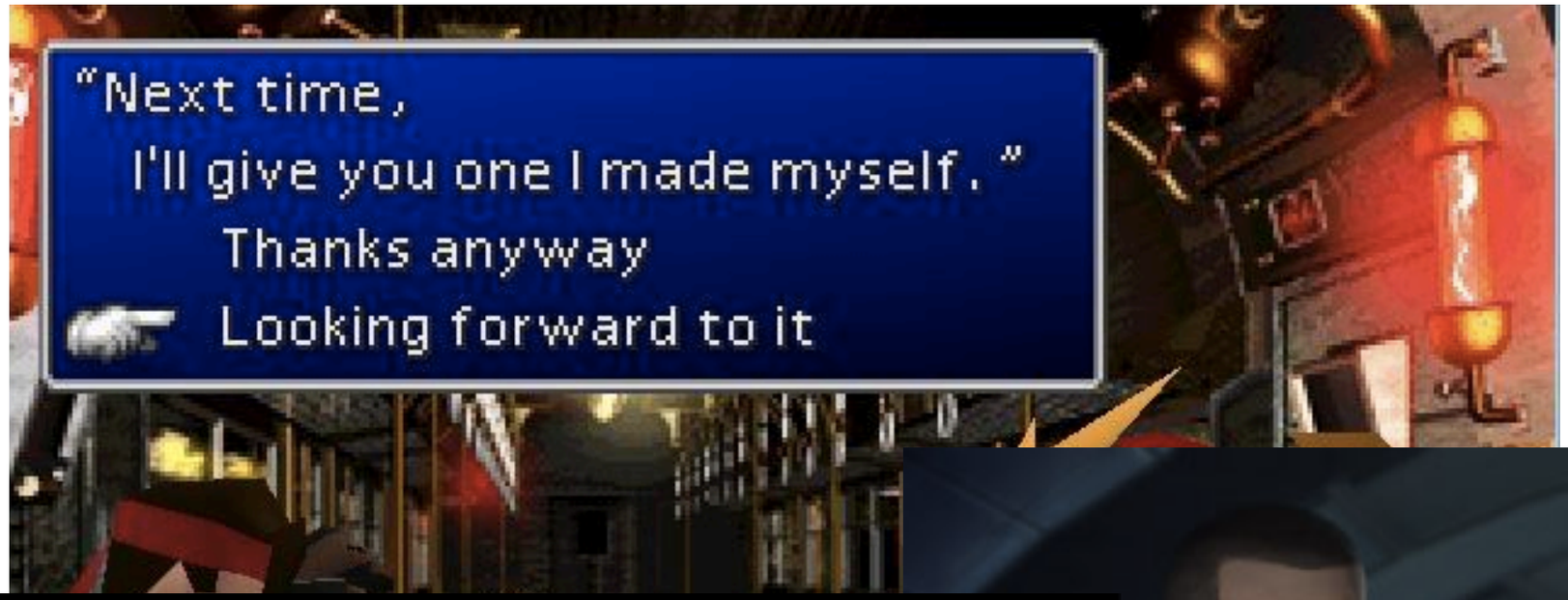
# General Intelligence through GVGAI?

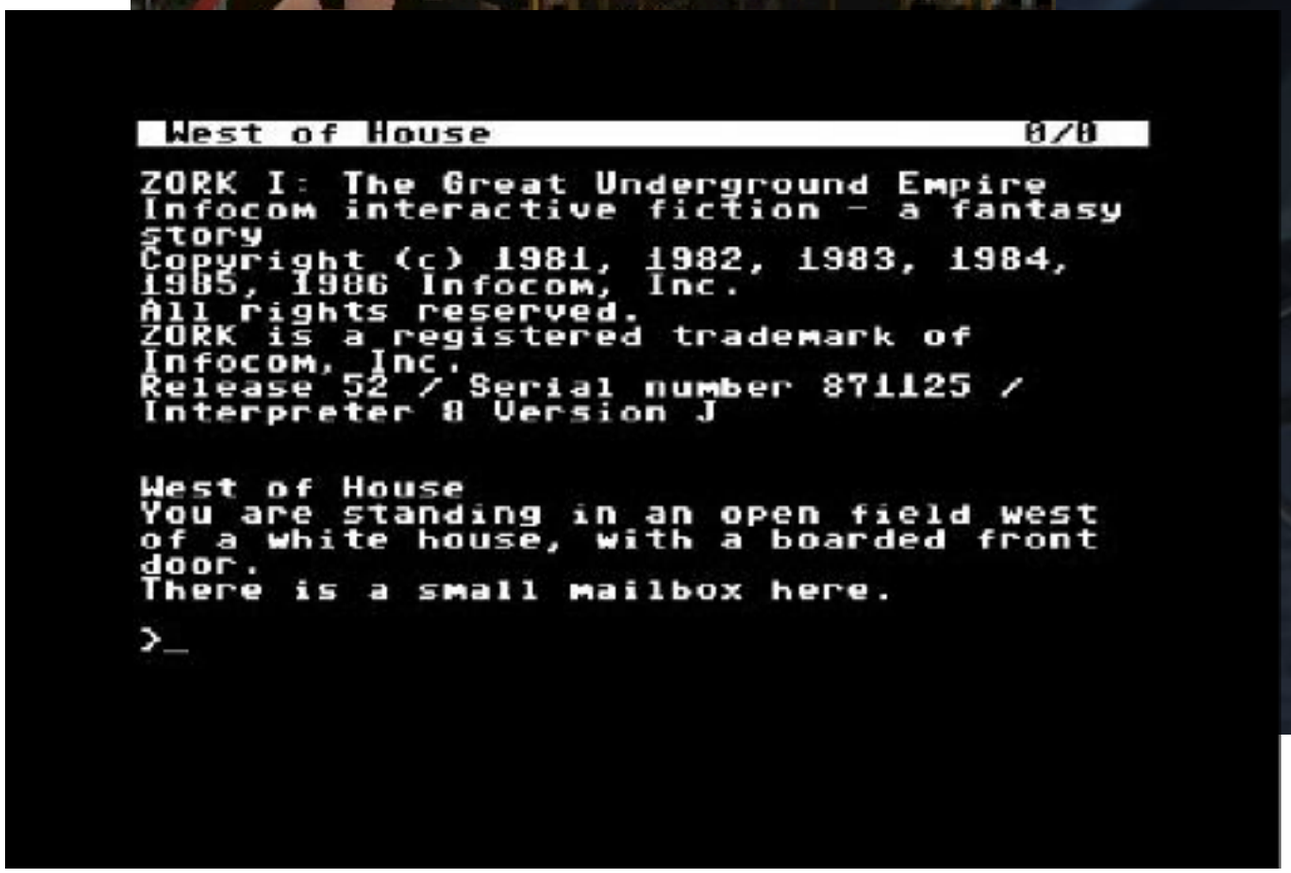
- Incremental/gradual learning: start on simple levels of a single game, go on to harder
    - Start on simple games, go on to harder ones
- Learning to learn: given many games that need to be learned, this seems to be an advantage

# What kind of intelligence do you get from only playing games?

- Capacity for linguistic interaction?
- Bodily awareness?
- Empathy?
- …

# Games are also this




# Still wanna play?

- *Sure*
- Games are less bad than other AI environments, and we need environments
  - We need *unseen* games and *generation* though
- By gradually increasing the types of games we test on, we include more “intelligences”
- The only way to figure out what general intelligence is is to build it

# Further reading

- Tom Schaul, Julian Togelius and Jürgen Schmidhuber (2011): *Measuring Intelligence Through Games*. arXiv: 1109.1314

- Julian Togelius (2016): *AI Researchers, Games Are Your Friends!* Computational Intelligence, Springer.

- Diego Perez, Spyridon Samothrakis, Julian Togelius, Tom Schaul, Simon Lucas, Adrien Couetoux, Jerry Lee, Chong-U Lim and Tommy Thompson (2015): *The 2014 General Game Playing Competition*. IEEE TCIAIG.

- www.gvgai.net