Mario AI Competition
@ CIG 2009
Sergey Karakovskiy and Julian Togelius

http://julian.togelius.com/mariocompetition2009
Infinite Mario Bros

- by Markus Persson
- quite faithful SMB 1/3 clone
- in Java
- random level generation
- open source
Making a benchmark

- The control loop rewritten
- Tunable FPS, up to 1000 times faster than real-time
- Created an interface for any type of agents or controllers
- Removed stochasticity and unpredictable randomness in behaviour of the benchmark
Develop a controller/agent (based on AI/machine learning?) for “Super Mario Bros”

Score: 13998.645
Levels cleared = 9
Total time left = 6780
Total kills = 87
Mario mode = 32
TOTAL SUM = 20906.645
Interface

- Each time step the agent gets a representation of the environment
  - Enemies and “blocks” around Mario
  - Fine position, jumping state
  - If Mario is carrying a shell
- And returns an action
  - 5 bits: left, right, down, A, B
Environment Interface

- 22x22 arrays describing
  - landscape features (e.g. walls, cannons, gaps)
  - creatures
  - Fine position of Mario and creatures
  - Booleans: mario is on the ground, may jump, is carrying a shell, is small/big/fire
Agent Interface

- `getAction(Environment environment);`
Very simple rule-based agent

```java
public boolean[] getAction(Environment observation) {
    action[Mario.KEY_SPEED] = action[Mario.KEY_JUMP] =
    observation.mayMarioJump() || !observation.isMarioOnGround();

    return action;
}
```
Media

- Reddit
- Slashdot
- New Scientist
- Le Monde
- Discovery Channel / MSNBC
- lots of blogs, gaming news sites etc.
Agent goals

• Develop an agent that gets as far and as fast as possible...

• ...on as many levels as possible...

• ...which are previously unseen

• Scoring: progress on 40 randomly generated levels (of different difficulty, length, type) with seed 17564

• If two agents complete all the levels: tiebreakers
Tiebreakers

- Total time left (in Marioseconds)
- Total kills
- MarioMode sum (small, large, fire)
Rules

• Implement the Agent interface (or connect to the TCP ServerAgent)

• Use only information from the Environment interface

• Don’t take more than 40 ms per time step in average
Agent challenges

• Handle a large state/observation space
• Handle very different situations (unlike e.g. car racing)
• Tactical tradeoffs (go back and get the power-up?)
Presentations of competitors
(in alphabetical order)
Robin Baumgarten
Using path-finding to find the optimal jump

AN A* MARIO AI
IDEA

- Analyse Mario’s physics engine to obtain movement equations for all objects
- Create our own physics engine that can predict next world state
- Plug engine into an A* algorithm to evaluate fitness of each node
- Heuristic: How long before Mario reaches goal?
- Penalty for falling into gaps or being hurt
- Ignore coins, enemies, power-ups (for now!)
A* ALGORITHM

- Best-first graph search algorithm
- Need heuristic that estimates remaining distance
- Keep set of “open” nodes (initially: start node)
- While open set not empty:
  - Pick node in open set with **lowest estimated total distance from start to goal**
  - If node == goal: finish. Create path by backtracking through ancestors.
  - Generate child nodes, put them into open list (only if better than existing nodes for that location)
- If heuristic admissible (always underestimating), we then have the shortest path to goal.
A* IN MARIO: CURRENT POSITION

Goal: right border of screen

current node
A* IN MARIO: CHILD NODES

current node

left, jump, speed

jump

right, jump

right, speed

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A* IN MARIO: BEST FIRST

**current node**

**right, speed**
A* IN MARIO: EVALUATE NODE

current node

right, speed
A* IN MARIO: BACKTRACK

current node

right, jump, speed

right, speed
A* IN MARIO: BEST FIRST

current node

right, jump, speed

right, speed
A* IN MARIO: EVALUATE

current node
A* IN MARIO: CREATE CHILDREN

current node
A* IN MARIO: BEST FIRST

current node
HEURISTIC

- Using Mario’s current speed and acceleration, how long does it take to reach the goal?
- Assume maximum acceleration and no obstacles (admissible heuristic!)

\[
\begin{align*}
xa &= xa + 1.2 \\
x &= x + xa \\
xa &= xa \times 0.89
\end{align*}
\]

- Optimisation: Find a closed form for this.
HANDLING NEW EVENTS

- Plan ahead for two ticks (=1/12 sec)
- Synchronise internal world-state with received enemies and object positions.

Possible Improvements:
- Keep & update old plan instead of starting from scratch each time
- Collect coins & power-ups (e.g., using a high-level planner that pans out the route between power-ups)
VIDEO
Trond Ellingsen

- Rule based agent. Estimates the danger of a gap, enemies and tries to avoid them.
Matthew Erickson

- Genetic programming and some simple hard coded detectors.

- Nodes arithmetic if-then, detectors (e.g. closest enemy, next pit)

- Population 500 was used; 90% crossbreeding, 9% cloning and 1% mutation

- Lots of room for improvement, e.g. no detector for blocks yet.
Glenn Hartmann

- Modified version of one of the heuristic agents that came with the software
- Move forward
- Jump if in danger of falling
- Jump over enemies if safe
- Shoot continuously
Douglas Hawkins

Peter Lawford

- A-star search to maximize x position
- Partial simulation to anticipate future positions (recalculated if simulation goes out of sync)
- Some pruning of search tree
Sergio Lopez

- Rule-based system, to answer 2 questions: “should I jump?” and “which type of jump?”

- Evaluates possible landing points based on environment info and heuristics (no simulation)

- Calculates “danger value” for each action, and “need to jump”

- Special situations, e.g. waiting for flowers and bullets to go away, climbing “stairs”
Rafael Oliveira

- Did not submit any documentation
- Seems to be an elaborate heuristic of a reactive agent.
• State machine with 4 states: walk_forward, walk_backward, jump, jump_hole
• Subsumption-type controller: later layers can override the action of earlier layers

• Each layer either a method or a state machine
Andy Sloane

- Joint work with Caleb Anderson and Peter Burns
- Based on A*
- Separate simulation of the game physics (not using the game engine)
- (imperfect) prediction of enemies’ movements
- Working towards propagating penalties in the tree
Erek Speed

- Rule-based system
- Maps the whole observation space to the action space
  - antecedent: 22x22 array, consequent: 5 bits action
- put in hash table
- Evolved with a GA
  - Genome as > 100 Mb XML file!
Spencer Schumann

- Simulates Mario's motion
- Converts observation into a vectorized format containing walls, floors, and ceilings
- Limited search space: sorts the floors from right to left, and tries to calculate a jump
- Calculates time needed to run from the current position to left edge of target floor
- For each jump button hold time (0 – 7), calculates when to jump to land on edge
Alexandru Paler

- Trained by a human player NN that should have learned the inverse function of the Mario movement.
- The net gets as input the distance to be traveled by Mario and returns the number of presses one should use to move Mario.
- A* to find the route to the margin of the screen. After route discovery decision on where to move Mario is made.
Sergey Polikarpov

• Based on “Cyberneurons”
Results
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Observations

- The best-performing agents take much longer time per time step (frame)
- This is due to usage of A* search!
  - ...works well because of completely observable states and lack of dead ends
- But some heuristic controllers do very well
- Not many learning/optimization techniques (though many competitors claim to be working on it)
After the competition

- Competition web page will remain, complete with competition software
- ...which you can use in your teaching or research!
- Complete source code of all submitted controllers
The future of the Mario Competition

- Mario AI Championship 2010
- Run at 2 to 4 different conferences, including EvoStar and CIG
- New physics: levels with water?
- More than one track, ideas include:
  - Standard track with more evil levels
  - Online learning of unseen level track
  - Personalized level generation track
  - (your ideas are welcome)
- Should let learning algorithms be more competitive.

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