Combining Cooperative and Adversarial Coevolution in the Context of Pac-Man

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What is Pac-Man?

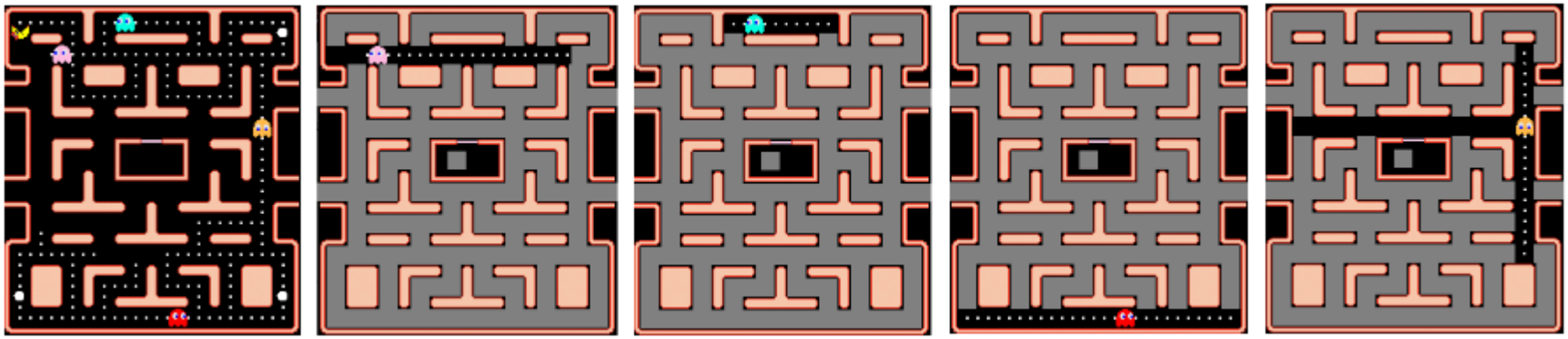
- Pac-Man is an arcade video game released by Konami in 1980.
- It yielded the second highest cross revenue of all arcade games (approx. 7.27 billion dollar).
- Pac-Man is the best known video character among American customers [source].

Pac-Man's Goals

- Pac-Man's task is to traverse a maze and eat all the pills.
- Four ghosts will hunt and try to stop him.
- Eating one of the our power pills will allow Pac-Man to eat ghosts for a short duration.
- Each of those actions scores Pac-Man points.
- After all pills were eaten, the next level starts.
- The game ends when no continues remain, after Pac-Man was eaten by a ghost.

Mrs. Pac-Man vs. Ghost Team Competition

- Since 2007 the Mrs. Pac-Man vs. Ghost Team Competitions.
- This work is part of this years competition, which features partial observation.
- The competition allows to program agents for Mrs. Pac-Man and the Ghost Team.
- In contrast to previous installments, agents will only receive information about objects in line of sight or general information about the map.



Related Work

- Previous Competition installments included agents based on:
  - State Machines [Gallagher and Ryan]
  - MCTS [Robles, Tong, Nguyen]
  - Neural Networks [Gallagher and Ledwich]
  - Ant Colony Algorithms
  - Genetic Programming [Alhejali, Brandstetter]

- It is not clear how well those solutions translate to the partial observation scenario!

Genetic Programming

- The behavior of each individual is encoded by a tree.
- The tree includes simple control structures using input by the game and points to an appropriate output.
- Evolutionary Algorithms are used to create a diverse set of trees while trying to improve the fitness of applied trees over time.
- Mutation and Crossover operators are used to modify parts of the trees.

Genetic Programming for Ghost Agents

- Implemented nodes should give access to all capabilities of the API, while being as general as possible.
- We differentiate function nodes, data terminal and action terminals.
- **Function Nodes:** include basic control functions (e.g. If…Then…Else…-nodes), and Boolean or Numeric operators
- **Data Terminals:** queries the API and the internal memory
- **Action Terminals:** perform a basic action, which is provided by the API

Mrs. Pac-Man Data and Action Terminals

Data Terminals:
- IsPowerPillStillAvailable
- AmICloseToPower
- AmIEmpowered
- IsGhostClose
- SeeingGhost
- DistanceToGhostNr<1,2,3,4>
- EmpoweredTime

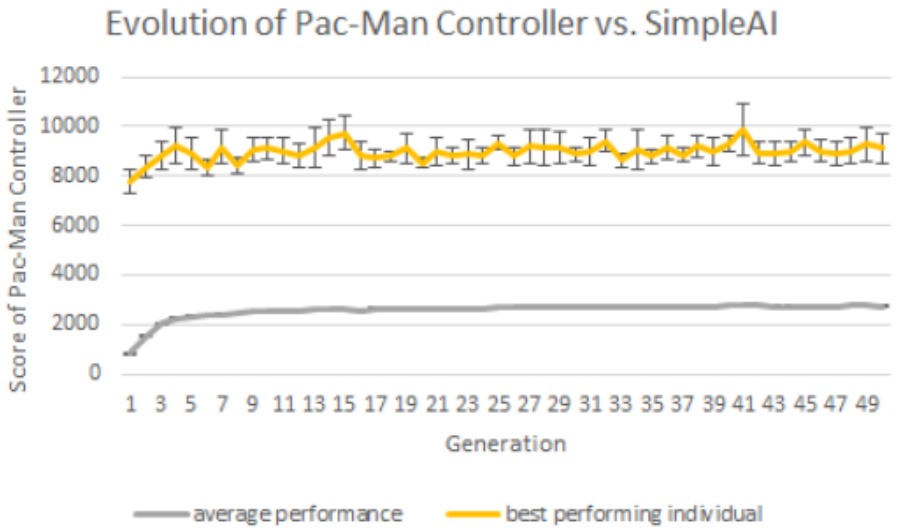
Action Terminals:
- FromClosestGhost
- ToClosestEdibleGhost
- ToClosestPowerPill
- ToClosestPill

This approach was adapted by previous competition submissions!

Due to partial observation restrictions we extended most Data Terminals with a short term memory:
- Remembers the last seen position of a ghost
- and simulates its behavior for a few ticks
- after a tick threshold is reached, the memory is cleared

Evaluation in a Partial Observation Scenario

- We first validated if the Genetic Programming works with partial observation.
- A ghost team of simple state machine agents were used as contrahent for evolved Pac-Man agents.
- The average performance as well as the performance of the best Pac-Man improved only slightly over time.



Ghost Team Data and Action Terminals

Data Terminals:

- SeeingPacMan
- IsPacManClose
- IsPacManCloseToPower
- IsEdible
- IsPowerPillStillAvailable
- DistanceToOtherGhosts
- EstimatedDistance

Action Terminals:

- ToPacMan
- FromPacMan
- FromClosestPowerPill
- ToClosestPowerPill
- Split
- Group

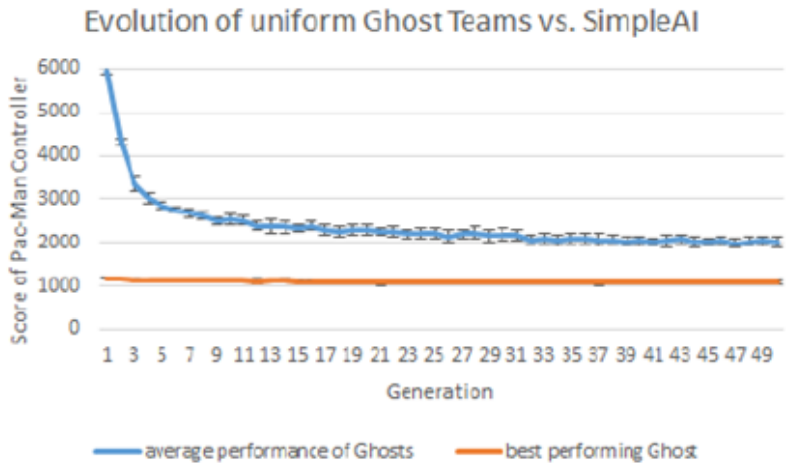
Evaluating Genetic Programming for Ghost Teams

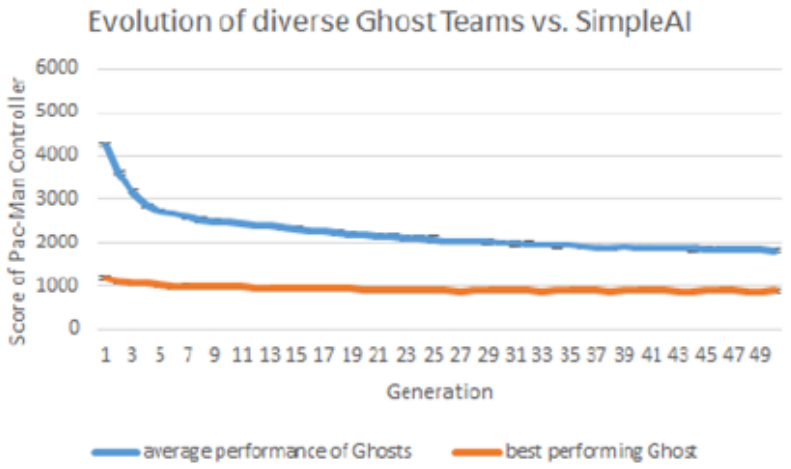
- Two Pac-Man agents were used as contrahents for evolved ghost teams.
  - SimpleAI = state machine agent
  - MCTSAI = Monte Carlo Tree Search agent

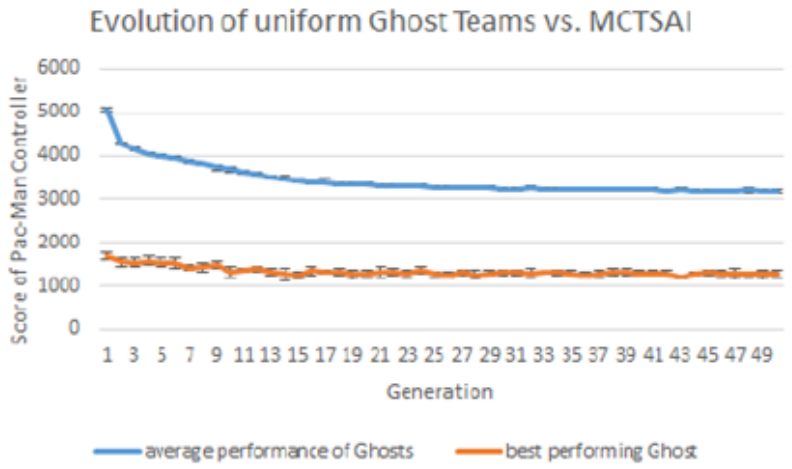
- Two approaches were compared:
  - uniform:
    - Ghost tTeams are made of four instances of the same individual
    - all individuals share the same population
    - ➢ single evolution

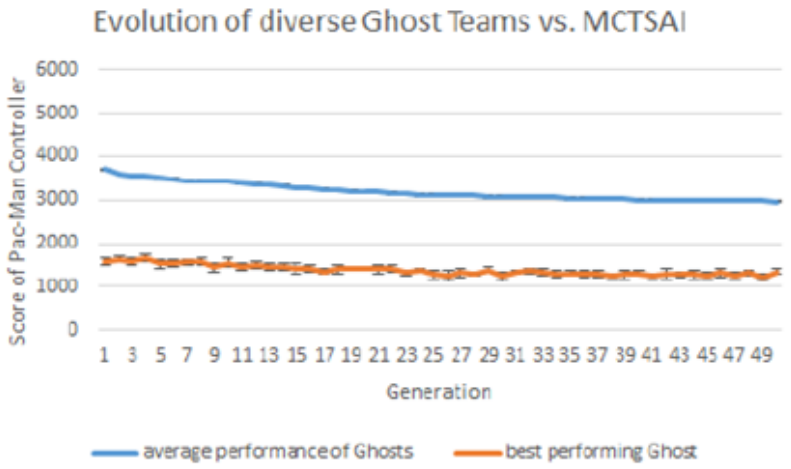
  - diverse:
    - Ghost Teams are made of four instances of different individuals
    - each individual is of one from four populations
    - ➢ cooperative coevolution

Single Evolution vs. Cooperative Coevolution









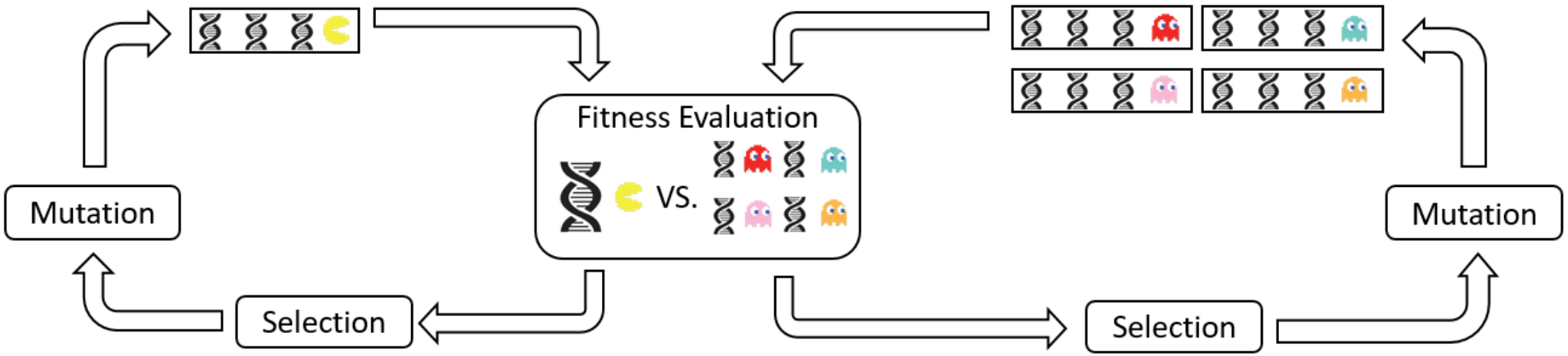
Genetic Programming Summary

- Agents for both agent parties can be learned using genetic programming.
- However, we need a suitable contrahent to assist the generation of complex behavior.

- Contrahents need to be hand-coded in the current framework.
  - Time consuming
  - Can miss possible strategies
  - Can be limited in the play-strength

- How can we combine both genetic programming procedures to get suitable Pac-Man agents **AND** Ghost Team agents?

Combined Coevolution Framework

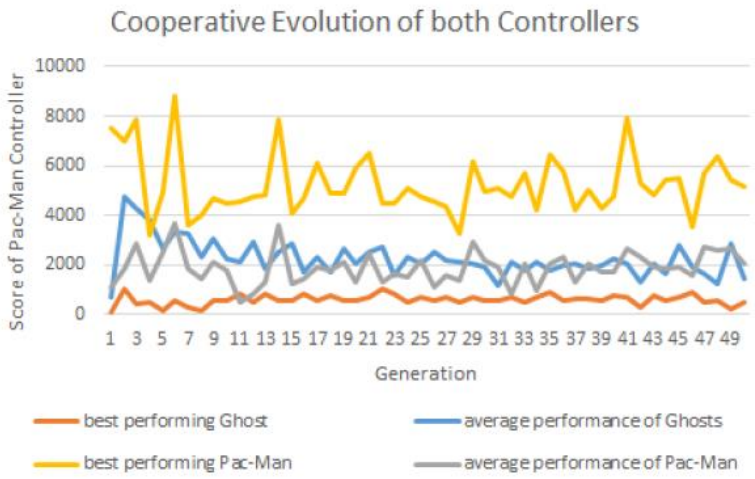


- Mrs. Pac-Man agents have one population

- Ghosts are split into 4 populations
- Each population exhibits its own strategy
- The best individuals per population will survive

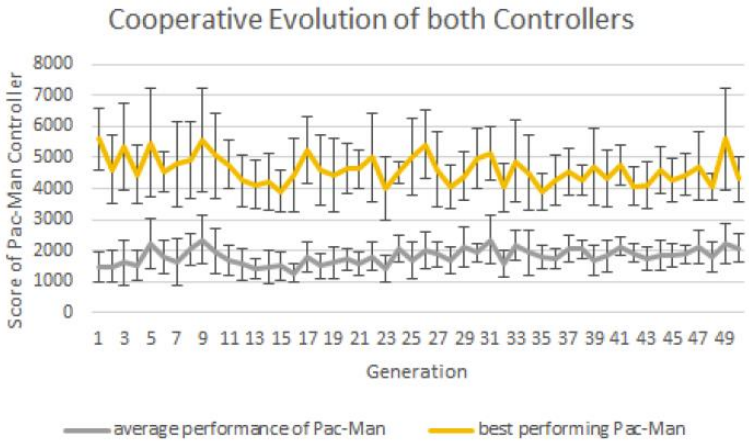
Combined Coevolution Framework

- The general idea:
  - ➢ When one agent type becomes stronger, their opponents need to react
- From our evaluation we can see bumps in Pac-Mans fitness values, which degrade over time
  - Those correspond to faster strategy changes in the beginning
  - And higher complexity in the end of the evolutionary process

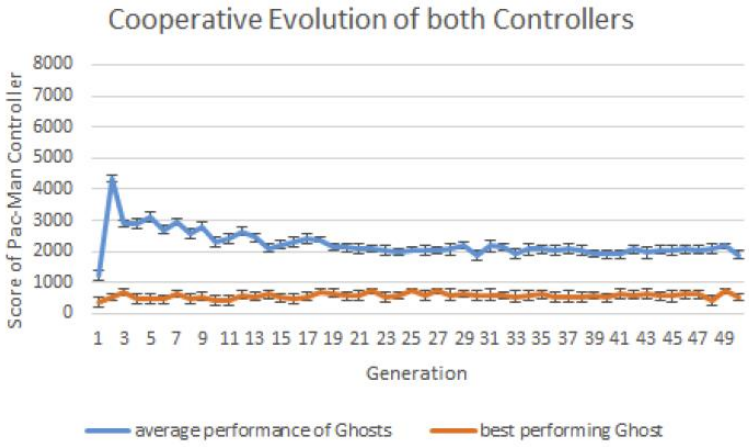


Combined Coevolution Framework

- We repeated the learning process 10 times to get insights in the general behavior of this learning process
  - Average points of Pac-Man and the Ghost Team converge over time
  - Best individuals per population quickly foster new strategies in the next generations
  - Overall complexity increases very slowly



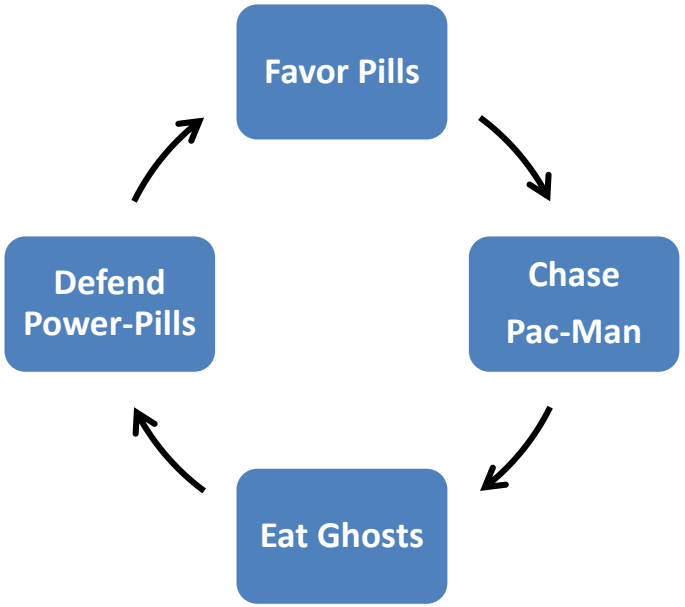
(a) Evolution of Pac-Man Controllers



(b) Evolution of Ghost Controllers

Insights

- The combined genetic programming reaches the same levels of complexity compared to single evolutionary processes.
  - …, but is increadible slow in doing so.
- Why does the complexity increase so slow?
  - Due to the scoring of the game, few basic strategies have a high return
  - This cycle dominates the first generations
- Open Question:
  - How can we promote complexity?



Conclusions

- Genetic Programming proved to be capable of generating simple and complex behavior in agents.

- Using four diverse ghost controllers was better and converged faster than using only one kind of ghosts
  - Either it is generally better to have mixed ghost teams
  - … or individuals from the single population need more time to built up comparable complexity

- Combining both genetic programming procedures potentially removes the need of creating suitable opponents.

Limitations and Open Research Questions

- Strategy loops hinder the combined framework in creating more complex strategies
  - Can those loops be detected during the evolutionary process?
  - Can we promote more complex solutions?

- Local maximas hinder the process
  - Exchange game induced scoring
  - Use a dynamic scoring function, which takes current strategies into account?

- How can other agent types be included, e.g. learning a multi-objective MCTS score function?

Thank you for your attention!

Check on Updates on our project at:
http://fuzzy.cs.ovgu.de/wiki/pmwiki.php/Mitarbeiter/Dockhorn
(Download of our project files will be made available soon)

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