Generative design of bionic partition for airplane cabin interiors by AlphaZero algorithm and finite element analysis

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Project GitHub page: https://github.com/gigatskhondia/Reinforcement_Learning_and_FEA
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1. Background and Rationale

Please see appropriate chapters in [1-3].

2. Methodology

a) Finite element model

For the finite element model I have used the Space Frame Element from [4].

b) AlphaZero algorithm

AlphaZero is a computer program developed by artificial intelligence research company DeepMind to master the games of chess, shogi and go. The algorithm uses an approach similar to AlphaGo Zero. On December 5, 2017, the DeepMind team released a preprint introducing AlphaZero, which within 24 hours achieved a superhuman level of play in these three games by defeating world-champion programs, Stockfish, elmo, and the 3-day version of AlphaGo Zero, [5].

c) Finite Element Environment to AlphaZero algorithm

The finite element model represents an environment to which an agent applies actions and from which it gets rewards. The agent uses AlphaZero algorithm to decide on its actions. Actions change geometry of the structure of an aircraft component; the resulting geometry is then subjected to FEA. The agent gets rewards if it meets the optimization objective of minimizing (weight of the component) and maximizing (stiffness of the structure) target values. The outcome of the modeling (produced “online” during the “game” after the training of AlphaZero algorithm) is an optimized design of the component.

3. Model Details

In this work, I made an agent do actions of drawing elements between grid nodes. For 5x5 grid, there were 72 possible elements (actions). I applied AlphaZero algorithm in a game between two players. Rules of the game were as follows: whoever drew a structure that passed through certain nodes (checkpoints), produced connected structure, had at least two neighbors for each node and an improved strength and weight compared to the previous move, won.

I decided to apply the algorithm in a form of a game between two players because of the ability to replace one player with a human engineer to assist an RL agent in engineering design, and

because I was interested in how the agents will behave (when creating a structure) in competitive game from the standpoint of the game theory.

The overall objective of the agents was to minimize the structure's weight while maximizing its strength. It took a while to train AlphaZero algorithm for about 250 iterations.

4. Final Words

AlphaZero player after appropriate training is much smarter than pure MCTS player (it has much more wins than pure MCTS). Typical game between AlphaZero and MCTS players takes on average more steps than a random play.

Results of the modeling (the game between AlphaZero and MCTS players) show that agents are usually capable of producing valid outcomes within 45 game steps (win limit).

Codebase for the model can be found at my GitHub page (see the link at the beginning of the paper). I took the code for the AlphaZero algorithm from this GitHub repo [6].

5. Bibliography

[1] On Engineering Design by Finite Element Analysis and Deep Reinforcement Learning, Tskhondiya Georyg, https://github.com/gigatskhondia/Reinforcement_Learning_and_FEA/
[2] Generative design of bionic partition for airplane cabin interiors by reinforcement learning and finite element analysis, Tskhondiya Georyg, https://github.com/gigatskhondia/Reinforcement_Learning_and_FEA/
[3] Generative design of bionic partition for airplane cabin interiors by Monte Carlo tree search and finite element analysis, Tskhondiya Georyg, https://github.com/gigatskhondia/Reinforcement_Learning_and_FEA/
[4] MATLAB Guide to Finite Elements. An Interactive Approach, Peter I. Kattan, 2nd edition
[5] https://en.wikipedia.org/wiki/Monte_Carlo_tree_search
[6] https://github.com/junxiaosong/AlphaZero_Gomoku