ABSTRAK

ANALISIS KOMPARATIF ALGORITMA KECERDASAN BUATAN PADA PERMAINAN LAST STANDING COIN

Permainan *Last Standing Coin* merupakan permainan strategi deterministik bertipe *subtraction game* dengan himpunan pengurangan {1, 2, 3} dan aturan *misère*, di mana pemain yang mengambil koin terakhir dinyatakan kalah. Permainan ini menjadi objek yang ideal untuk menguji tingkat optimalitas berbagai algoritma kecerdasan buatan karena memiliki solusi analitis matematis yang terverifikasi secara teoritis. Penelitian ini bertujuan untuk melakukan analisis komparatif terhadap efektivitas lima pendekatan algoritma yang diimplementasikan secara mandiri, yaitu *Rule-based*, *Monte Carlo Tree Search* (MCTS), dua variasi *Policy Network* (*Fast* dan *Strong*), *Q-Learning*, dan *Deep Reinforcement Learning* berbasis *Advantage Actor-Critic* (A2C). Konfigurasi permainan menggunakan 30 koin awal dengan pilihan aksi 1 hingga 3 koin per giliran. Setiap model dievaluasi berdasarkan tiga metrik utama: tingkat kemenangan (*win rate*) melalui skenario *cross-play*, skor optimalitas langkah terhadap solusi matematis modulo 4, serta efisiensi komputasi selama fase pelatihan. Hasil penelitian menunjukkan bahwa lima model — *Rule-based*, *Fast Policy*, *Strong Policy*, *Q-Learning*, dan A2C — berhasil mencapai *win rate* dan skor optimalitas sempurna sebesar 100%, membuktikan kemampuan masing-masing dalam menyamai solusi analitis matematis secara konsisten. MCTS menunjukkan performa kompetitif dengan rata-rata *win rate* 93,8% dan skor optimalitas 93,26%, sementara model *Random* menjadi *baseline* terendah dengan skor optimalitas 33,68%. Dari sisi efisiensi komputasi, *Q-Learning* unggul sebagai model paling optimal dengan waktu pelatihan hanya 5,33 detik dan konsumsi memori terendah sebesar 207,43 MB, menjadikannya pilihan terbaik dari sisi keseimbangan antara performa dan biaya komputasi.

Kata Kunci: *Last Standing Coin*, *Rule-based*, *Monte Carlo Tree Search*, *Policy Network*, *Q-Learning*, *Deep Reinforcement Learning*, Teori Permainan Kombinatorikal.

ABSTRACT

COMPARATIVE ANALYSIS OF ARTIFICIAL INTELLIGENCE ALGORITHMS IN THE LAST STANDING COIN GAME

Last Standing Coin is a deterministic strategy game of the subtraction game type with a subtraction set of {1, 2, 3} and the misère rule, in which the player who takes the last coin loses. This game serves as an ideal testbed for evaluating the optimality of various artificial intelligence algorithms, as it possesses a theoretically verified mathematical analytical solution. This study conducts a comparative analysis of five independently implemented algorithmic approaches: Rule-based, Monte Carlo Tree Search (MCTS), two variations of Policy Networks (Fast and Strong), Q-Learning, and Deep Reinforcement Learning based on the Advantage Actor-Critic (A2C) architecture. The game is configured with 30 initial coins and a legal action set of 1 to 3 coins per turn. Each model is evaluated across three primary metrics: win rate through cross-play simulation scenarios, move optimality score relative to the modulo-4 mathematical solution, and computational efficiency during the training phase. Results demonstrate that five models — Rule-based, Fast Policy, Strong Policy, Q-Learning, and A2C — achieved a perfect win rate and optimality score of 100%, confirming their ability to consistently match the mathematical analytical solution. MCTS exhibited competitive performance with an average win rate of 93.8% and an optimality score of 93.26%, while the Random model served as the lowest baseline with an optimality score of 33.68%. In terms of computational efficiency, Q-Learning emerged as the most resource-efficient model, requiring only 5.33 seconds of training time and the lowest memory consumption of 207.43 MB, making it the optimal choice in balancing performance quality against computational cost.

Keywords: *Last Standing Coin, Rule-based, Monte Carlo Tree Search, Policy Network, Q-Learning, Deep Reinforcement Learning, Combinatorial Game Theory.*