ABSTRAK

Agen musuh pada *game Bomberman* umumnya menunjukkan tingkat koordinasi yang rendah ketika dilatih secara independen, sehingga perilaku yang dihasilkan cenderung tidak sinergis dan tingkat kesulitan *game* menjadi terbatas. Kurangnya koordinasi menyebabkan agen bergerak secara redundan dan gagal membentuk pola pengepungan yang konsisten terhadap pemain. Oleh karena itu, diperlukan pendekatan pembelajaran yang mampu mendorong terbentuknya kerja sama antar agen secara kolektif.

Penelitian ini mengusulkan penerapan *Multi-Agent Reinforcement Learning* (MARL) dengan skema kooperatif berbasis *shared policy* menggunakan algoritma *Proximal Policy Optimization* (PPO). Eksperimen dilakukan dengan membangun simulasi game Bomberman menggunakan *Unity Game Engine* dan *Unity ML-Agents*. Penelitian membandingkan dua pendekatan, yaitu *Independent Reinforcement Learning* dan *Cooperative Reinforcement Learning*. Tingkat koordinasi agen dievaluasi menggunakan tiga metrik utama: waktu penangkapan, *coverage* (sebaran posisi agen di sekitar target), dan *overlap rate* (tingkat tumpang tindih pergerakan antar agen).

Hasil penelitian menunjukkan bahwa pendekatan kooperatif menghasilkan penurunan rata-rata waktu penangkapan, peningkatan *coverage*, serta penurunan *overlap rat*e dibandingkan pendekatan independen. Temuan ini mengindikasikan terbentuknya koordinasi spasial yang lebih baik antar agen dalam *game*. Meskipun demikian, performa agen masih menunjukkan keterbatasan ketika lingkungan berubah secara cepat dan dinamis, yang menyebabkan perilaku agen cenderung reaktif terhadap kondisi lokal.

Kata Kunci: *Bomberman*, koordinasi, *Multi-Agent Reinforcement Learning*, PPO, *Game*, *Reinforcement Learning*, kooperatif.

ABSTRACT

Enemy agents in the Bomberman game commonly exhibit low coordination levels when trained independently, resulting in unsynergistic behavior and limited game difficulty. The lack of coordination leads to redundant movements and the failure to consistently form encirclement patterns around the player. Therefore, a learning approach capable of encouraging collective cooperation among agents is required.

*This study proposes the application of Multi-Agent Reinforcement Learning (*MARL*) using a cooperative shared-policy scheme based on the Proximal Policy Optimization (*PPO*) algorithm. The experiment was conducted by developing a Bomberman game simulation using Unity Game Engine and Unity ML-Agents. Two learning approaches were compared: Independent Reinforcement Learning and Cooperative Reinforcement Learning. Agent coordination was evaluated using three primary metrics: capture time, coverage (spatial distribution of agents around the target), and overlap rate (movement redundancy among agents).*

The results indicate that the cooperative approach reduces the average capture time, increases coverage, and decreases overlap rate compared to the independent approach. These findings demonstrate improved spatial coordination among agents in the game. However, performance degradation was observed in highly dynamic environmental changes, where agents tended to react locally rather than maintain broader strategic positioning.

Keywords: *Bomberman, Coordination, Multi-Agent Reinforcement Learning,* PPO*, Game, Reinforcement Learning, Cooperative*