

Title	遺伝的アルゴリズムを用いた2Dシューティングゲームのステージ生成
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Research in artificial intelligence (AI) for games has been popular in past decades. Among the research, creating strong computer game players, or AI players, has achieved remarkable results. The achievements were demonstrated by AI players' superhuman levels of plays in many games. Thus, we expected the importance to increase for other research in game AIs than creating strong players. More specifically, this research focused on entertaining human players and studied procedural content generation (PCG) with the use of AI players.

PCG can be used to create game content massively and reduce the costs of making games by applying optimization or machine learning algorithms. Thus, it attracted attention from both academia and industry. The term "game content" covers various components in games such as graphics, music, and dungeons. In this research, we targeted at "stages" (i.e., the arrangements of enemies and obstacles) for a "shoot 'em up" game (STG).

In classical STGs such as Xevious, players control their spacecraft to attack enemies by ranged weapons while avoiding enemies' attacks and obstacles. The interestingness and the difficulty of stages crucially depend on the arrangements of enemies and their patterns of attacks. Usually, STG stages are elaborated by human experts and thus demonstrate their preferences and creativity. The design can be considered as a kind of art; however, the numbers of stages that can be made are limited. As a result, players may get bored easily since they can find good strategies to play after practice even for the stages thought difficult at first glance. Playing in new stages every time, which involves randomness, is desired by some players and is also important for entertainment. Even so, just randomly generating stages is impractical since many improper stages may be created. By improper stages, some examples are those too difficult for players to clear, those too easy that players can clear no matter how they play, and those without various patterns for enemies' actions but keep players busy all the time.

This research aimed to clarify "how to estimate the difficulty and the enjoyment of STG stages to human players" and "what features should test AI players have to achieve this." The goal was to generate stages that have proper difficulty such that human players can enjoy playing.

First, to evaluate STG stages, we proposed six features that were composed of three factors and two viewpoints. The three factors were difficulty, tenseness, and diversity. The two viewpoints were macro and micro, which represented an overall evaluation of a stage and evaluations of sections of a

stage, respectively. We then applied a genetic algorithm (GA) to optimize randomly initialized stages so that the evaluations from test AI players were maximized. To make the generated stages suitable for human players, the test AI players should be “human-like.” For this purpose, the test AI players performed the same actions for several continuous frames, did tree searches with considering the positional relations to enemies and borders of the screen, and tried to avoid possible enemies and bullets by enlarging the ranges for collision judgment.

To control the micro level of diversity of STG stages, we grouped enemies so that those in the same group slightly differed in the positions and the appearance time. Groups were set as the minimal composition of enemies and were represented by genes in GA. The generated stages were evaluated by test AI players, where the play results were inputted into a heuristic fitness function, and the values were used as evaluations. Furthermore, to control difficulty and tenseness, we defined appropriate ranges for some additional criteria, such as indicators of how the players cleared the stages, the numbers of enemies and bullets in each section, and the ratios of time that the players had no actions. For comparison, we increasingly included the criteria for the fitness function. From the results, for all of the seven proposed criteria (further divided into 23 by segmenting two of the criteria), the values fell into the defined ranges. The results demonstrated our success in generating stages where the designed fitness function was properly reflected.

The experiments were conducted on a simplified STG platform made by ourselves. To enable both doing subject experiments and speeding up AI players’ plays, we prepared two modes, where one had real-time inputs, outputs, and screen display while the other had no screen display for high-speed evaluations.

Finally, to evaluate our approach, a simple subject experiment was conducted. We asked seven human subjects to watch videos where an AI player played in eight different stages. The stages were either randomly generated or generated by our approach. We displayed two each of the stages from different approaches and asked human subjects to rate the interestingness and the difficulty of each stage in five-grade evaluation (1, 2, 3, 4, and 5). From the results, randomly generated stages received interestingness of 2.43 and difficulty of 5.00 on average. In contrast, stages generated by our approach received interestingness of 3.86 and difficulty of 3.08 on average. The experiment confirmed the effectiveness of our approach.