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Procedural Content Generation on 2D Game Maps that Guide Players Naturally

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Artificial intelligence (AI) has been actively researched in various fields and benefited human society. For games, creating strong AI players has been mainly researched, and AI players have already achieved superhuman levels of plays in many games (e.g., AlphaGo for the game of Go). In addition, research on teaching, entertaining, and supporting human players is widely investigated, one of which is the automatic generation of game content.

Since video games have become more complex and diverse, development costs have increased significantly in recent years. In order to reduce development costs, a framework of automatic content generation, well known as Procedural Content Generation (PCG), has attracted attention from academia and industry. In the field of games, the term content covers various components such as maps and characters. Although PCG was researched for many game genres, research on role-playing games (RPG) is relatively few.

RPG is a classical genre in which players generally enjoy exploring maps, fighting with enemies, and growing characters. In many cases in RPGs, game designers provide guidance for players exploring maps to lead the players to appropriate directions, aiming to increase the fun of playing. However, too obvious guidance harms the excitement of exploring maps. Thus, it is better that RPG maps give players freedom in exploring while controlling their behaviors *naturally*. By natural, it means that players do not notice the control or guidance. Creating such desirable maps usually needs many game designers' efforts and time, making the development costs high.

This research aimed to clarify "what elements in maps influence the players' behaviors" and to generate two-dimensional maps that guide players naturally based on the clarified findings. Considering the complexity of RPG maps that contain many elements such as items and enemies, we targeted two kinds of simplified maps where elements were included step by step. The first target is mazes that contain only passages and walls but no items, enemies, or NPCs. The second target is dungeons that contain passages, walls, and rooms. For the dungeons, items and hit points (HP) were introduced to make the environment closer to RPG maps. We analyzed and predicted human players' behaviors when exploring maps and proposed a method to automatically generate maps that guide players naturally.

Our proposed method mainly consists of the following four phases: (1) Collecting play logs of human players, (2) Investigating human players' behavioral tendencies and predicting their behaviors by supervised learning, (3) Creating a test player considering human-likeness using the learned model, and (4) Generating maps by using playing results of the test player. This paper works on phases (1) to (4) for mazes and only (1) and (2) for dungeons.

For mazes, specifically, we aimed to automatically generate mazes with adjusted difficulty considering human players' path selection tendencies at branch points. In the first phase, we conducted subject experiments to collect play logs. A total of 20 players participated in the experiments. We used the play logs as training data for supervised learning and built a regression model to predict the human players' selection probabilities of proceeding directions at branch points. The model was based on the LightGBM, a decision tree-based gradient boosting model. The prediction results showed that the Pearson correlation coefficient between the predicted probabilities and actual values was 0.74, indicating a highly positive correlation. Although the prediction accuracy still had room to improve, we concluded that the prediction model was reliable to some extent.

Using the prediction model, we created a test player that simulates human players' behaviors. Furthermore, we automatically generated mazes with difficulty based on the number of steps that the test player played the mazes. The difficulty was classified into five groups such as "easy", "moderate", or "difficult". We conducted new subject experiments to evaluate whether the difficulty is suitable for human players. A total of 10 players, who were different from those in the previous experiments, played 35 prepared mazes. The experimental results showed that the estimated difficulty by the test player matched the play results of human players in general and that there were statistically significant differences between each difficulty group. From the results, we concluded that mazes generated with adjusted difficulty by our method were generally suitable for human players' playing in terms of the number of steps.

As the next step, we changed the target maps to dungeons. We assumed that only focusing on behaviors at branch points is not enough to properly guide players in dungeons because the maps contain not only passages and walls but also rooms and items. Thus, in addition to a prediction model for branch points, we built another two types of prediction models: one predicts the human players' selection probabilities of proceeding directions at rooms, and the other predicts probabilities that players turn back (turn back model).

We conducted new subject experiments to collect play logs for dungeons. A total of 18 players participated in the experiments. We used the play logs as training data for supervised learning as we have done for mazes. The correlation coefficients between the predicted probabilities and actual values for the branch point model and the room model were 0.62 and 0.67, respectively. Although each value showed a positive correlation, the prediction accuracy was lower than the case of mazes. The results indicated that human players' behaviors would change by just adding a few elements such as items and HP, making it difficult to predict.

We also checked the accuracy of the turn back model. To know whether the model's predictions are similar to human players' behaviors, two important points are "places to turn back" and "the frequency to turn back." We first checked "the frequency to turn back." We obtained human players' frequency from the play logs and calculated the prediction model's frequency. The results showed that both of them turned back once out of approximately 20 actions. Furthermore, we observed that human players generally turned back at places with higher predicted probabilities and did not turn back at places with lower ones. From the results, we concluded that the outputs of the turn back model were similar to human players' behaviors in general.

Finally, we summarize this research. The results of mazes showed that our PCG method was effective in generating two-dimensional game maps that guided players naturally. Furthermore, from the results of dungeons, we verified that the method had room to improve in each phase. For example, the method would be enhanced using other types of techniques such as deep learning to build the prediction models.