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Abstract

The recent success of AlphaGo and DQN by DeepMind shows that the strength of computer game players has surpassed that of human players. However, we believe that strength does not solely promise the entertainment of games. Let's assume that a strong but not-human-like computer player is employed in a real-time fighting game and that it can react one frame after human players' actions, and can avoid human players' attacks by one pixel. Such quick reactions or accurate avoidance cannot be executed by human players. Then human players will be beaten even when the computer player's tactics are not very elegant. In such a case, human players will complain and may not play/practice the game any longer. Research on "human-likeness" is necessary not only for making opponent computer players but also for making cooperative computer players, coaching human players, procedural content generation (PCG), etc.

While a human plays a game, the decisions may not be optimal ones. Human players make decisions based on not only game information but also outside factors. For example, sometimes the behaviors of human players change due to their emotions. Even when human players try to perform optimal actions, sometimes they still make mistakes because of physical limitations such as tremor, reaction delays, and fatigue. Also, it is commonplace that human players set their own "sub-goals" for fun. Typical examples in Super Mario Bros. are to collect as many coins as possible, to kill as many enemies as possible, and to find hidden items, though the given goal is just to reach the final flag. These kinds of behaviors are considered as human-likeness and very significant for enhancing the entertainment of games.

Many research topics on human-likeness have been discussed. However, there are still no clear definitions of human-likeness which are commonly shared/used. Many different interpretations were given in different papers and the research was conducted under some specific situation. Especially, research in human-likeness becomes extensive and tends to increase acceleratedly in recent years. The first contribution of the thesis is to systemically survey many articles about human-likeness and cluster such papers in three ways, 1) the purpose of use, 2) the aspect of human-likeness, and 3) the method to realize. The goal is to understand the current situation of research in this field and whether there is any essential but less studied aspect of human-likeness which is worthy to reproduce. The review shows a broad area of studies.

Also, we explore three topics on human-likeness, which we believe is necessary for enhancing the entertainment of games.

As the first topic, we discuss several behaviors affected by humans' internal information such as emotion. Of course, game states are essential information for human players in the decision-making process. However, some internal factors such as current emotions are also important. For example, in Super Mario Bros., when the character (Mario) gets closer to an enemy, the player may want/try to keep some distance and avoid the collision with the enemy by jump because of the fear of being damaged. Another example is that, when the time almost runs out, the player may feel anxiety about remaining time more than the fear of being damaged. Thus he/she may take more risks to clear the game as soon as he/she can. These changes in behaviors are common to many human players. Thus, we attempt to create a computer player of Super Mario Bros., whose behavior changes and looks like a human just as his/her behavior changes based on his/her emotion.

We propose three local behavior models representing "safety play", " hurry play", and " rewards greedy play". These behavior models are implemented by heuristic methods based on the A* algorithm. In our experiments, the behavior of the "safety" model receives an average

score of 3.32 in a five scale rating Turing test, while a human player who tries to play as safe as possible receives 3.65. The results show that the safety behavior looks like a human player. We also try to switch these three behavior models by using if-then rules, though this player does not receive a higher score than the safety model.

As the second topic, we discuss how human players utilize game actions for different purposes from the original ones. For example, in some first-person shooter games where voice communication and text communication are limited, players may use some special actions to warn or notify other players. Shooting at walls is not rewarded by game rules, but is often used as the signal from a scout player to his/her teammates. We collect a lot of such examples and divide them into seven groups, i.e., warning, notification, provocation, greeting, expressing empathy, showing-off, and self-satisfaction. We then analyze each group to understand the characteristics, conditions to emerge, and whether such behavior should be reproduced by computer players or not. Besides, we simulate an emergence of notification behavior using actions that were not designed for notification.

We employ a Q-learning algorithm to play a hunting game where two agents should cooperate and catch a target. In the game, agents' sights are limited, direct communication with the other agent is prohibited, and each agent needs to find the target by itself. In our experiments, when two previous actions of the other agent are also provided as state information, the Q-learning agents successfully emerge a notification behavior, by moving right-left (or up-down) repeatedly after finding the target. The behavior increases the success rate of hunting by 40%, compared to the case without such additional information.

As the third topic, we investigate how to generate pseudorandom sequences which look random for human players. Pseudorandom number generators are used in many digital games in which randomness is needed, e.g., Poker and Mahjong. Human players often feel dissatisfied with the given random numbers, especially when they are at a disadvantage due to unlucky. Many players complain about the randomness even though an excellent algorithm is used to simulate the true randomness. Thus we propose a method to generate pseudorandom numbers/sequences where human players believe that it is random. In other words, our approach tries to understand human players' cognitive biases and match it. We firstly let human subjects write down 100 numbers which seem to be random from their viewpoint. We analyze the obtained sequences by 15 statistical features and compare the values to theoretical ones. Then, we propose a method to generate pseudorandom sequences by a local search, so that each sequence has similar statistical values to human players' values.

As a result, we successfully generate random sequences that human players feel truly random. Evaluation of naturalness is done by five scale rating questionnaire. The average score of the proposed method is 3.21, while that of the famous Mersenne Twister generator is 2.58. To assure the capability of the proposed method and the generated sequences, another evaluation of naturalness is conducted using a game called Sugoroku. The result shows that the set of sequences which is highly evaluated in the previous experiment is also highly evaluated in Sugoroku game, and vice versa. We can say our random sequences are more natural than conventional sequences and can reduce the dissatisfaction of common human players in practical use.

These three approaches presented in this article deal with only a part of aspects of human-likeness. However, we believe that the issues we discuss are essential to produce computer players and game environments which can entertain human players, and useful for further studies.

Keywords: Human-likeness, Computer player, Emotion, Sub-purpose, Pseudorandom, Biases