REVIEW

RAPID ADAPTATION OF VIDEO GAME AI

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When we think about artificial intelligence (AI) in the context of game playing, we usually focus on the so-called classical games such as chess, checkers and Go. These games are hard for humans to master and therefore have challenged researchers from the very beginning of artificial intelligence. Now that computers have finally accomplished what was long considered impossible by many, namely consistently defeating the best humans in chess and checkers, it is time to evaluate these accomplishments in the broader context of artificial intelligence. In the year that the IBM computer WATSON defeated the best human contestants in the popular American quiz show Jeopardy! and with the game of Go, the last bastion of human intelligent game playing, under siege, we suddenly realize that while computers have surpassed humans in some of the more difficult intellectual challenges, humans still dominate many less demanding domains.

In his thesis, Sander Bakkes addresses one such domain: video games. In computer programs that play classical games, all efforts are directed towards creating the smartest artificial intelligence that can make the best decisions in order to win the game. However, in video games most of the effort is spent on making the graphics as spectacular and realistic as possible. Hardware developments in graphics boards with dedicated chips for texture mapping, polygon rendering, shading, intra-frame prediction, motion compensation, etc., are frantically trying to keep up with the ever increasing demands from video-game developers. Recent animated movies such as Toy Story 3 fuel the demand for even more realistic real-time graphics in video games. This extreme focus on appearance comes at the expense of the intelligence in video games. In other words, the characters controlled by the computer are pretty dumb and stupid. Their behaviour is predictable, which makes them relatively easy to defeat by a human opponent. Even though the graphics of modern video games have improved by many orders of magnitude over early video games such as PAC-MAN, the intelligence of today's computer-controlled characters (generally referred to as NPCs: non-player characters) is comparable to that of the ghosts that chase PAC-MAN through the maze. To avoid that the game would become too difficult to play, PAC-MAN creator Toru Iwatani designed each ghost with a distinct (pre-programmed, rule-based) behaviour (personality). On 'The Pac-Man Dossier' website, Jamie Pittman describes these behaviours which were determined by reverse-engineering the game. This deliberate dumbing down (or should we say 'virtual lobotomy'?) of computer-controlled adversaries is also motivated by the concern that game developers have that unpredictable behaviour can lead to uncontrollable behaviour.

Fortunately, in recent years game developers have recognized the need for more intelligent behaviour of NPCs. They accomplish this mainly through incremental adaptation, which Bakkes describes as follows: "To adapt to circumstances in the current game, the adaptation process is based only on observations of the current game. Naturally, a bias in the adaptation process may be included based on domain knowledge of the experimenter. In addition, to ensure that AI is effective from the onset of a game, it is common practice to initialize adaptive game AI with long-time proven behaviour." Experiments that Bakkes performed using incremental adaptive AI in the game of QUAKE III revealed some of the weaknesses of this approach. Specifically, the requirement of high-quality domain knowledge and the large number of trials needed to improve character behaviour. He concludes that "the characteristics of incremental adaptive game AI prohibit our goal of establishing game AI capable of adapting rapidly and reliably to game circumstances." Therefore, he proposes an alternative approach to adaptive AI: case-based adaptive AI.

Case-based adaptive AI was inspired by case-based reasoning. "Case-based reasoning (CBR) is a methodology for interpretation and problem solving based on the explicit storage and reuse of experiences (or their generalizations). An observation on which problem solving is based in CBR, namely that similar problems have similar solutions, has been shown to hold in expectation for simple scenarios, and is empirically validated in many real-world domains." The idea is to "generate character behaviour and player models automatically, readily fitted to circumstances in actual, online play, on the basis of previous gameplay experiences. Case-based reasoning provides a strong starting point for realizing this desire in the form of a proof of concept." This approach requires three main components: an evaluation function, an adaptation mechanism, and opponent modelling. Bakkes devotes an entire chapter to each of these components.

The first component is the evaluation function which rates the current state of the game and serves as a predictor for the final outcome of that game. Bakkes designed an evaluation function for SPRING, an open-source complex real-time strategy (RTS) game formerly known as TOTAL ANNIHILATION: SPRING, which is played online in multi-player matches. Chapter 5 ends on this high note: "we may conclude that our evaluation function predicts accurately the outcome of a SPRING game." The second component is the adaption mechanism which must rapidly and reliably adjust the game AI to the game circumstances. It uses a case database of observations gathered from earlier games. The conclusion of Chapter 6 is also positive: "we may conclude that the mechanism for case-based adaptation of game AI provides a strong basis for adapting rapidly and reliably the player's behaviour in an actual, complex video game: SPRING." The third component is opponent modelling in which a model of the opponent is created that can be exploited in actual play. In 2003, Jeroen Donkers wrote a great thesis on this very topic (Nosce Hostem – Searching with Opponent Models). Again using SPRING as the test domain, Bakkes distinguishes four aggressive and three defensive opponent models. After several experiments in obtaining and exploiting opponent models, he concludes: "Experiments with establishing opponent models in the complex SPRING game revealed that for the game relatively accurate models of the opponent player can be established. Furthermore, an experiment with exploiting opponent models showed that in the SPRING game, exploiting the established opponent models in an informed manner leads to more effective behaviour in online play. From these results, we may conclude that opponent modelling may successfully be incorporated in game AI that operates in a complex video game, such as SPRING."

Regarding the practical applicability of case-based adaptive game AI, Bakkes discusses four issues: scalability, dealing with imperfect information, generalization to different games, and acceptance by game developers. On this last topic he notes: "Game developers often emphasize that advanced game AI is needed to create game characters that are able to operate consistently in modern video-game environments (i.e., react believably, in a human-like manner). As game environments are becoming more complex and more realistic, an ineffectiveness of the game AI will become directly apparent to the player. For instance, a recent trend in many games is that of deformable or dynamically changing terrain. As a result, game developers strictly require the ability of game characters to adapt adequately to changing circumstances." In a footnote Bakkes indicates that AI techniques may save game developers an enormous amount of time: "at the time of writing, the game STARCRAFT II is being fine-tuned for already nearly two years. AI techniques, such as automatically generated evaluation functions to express the strengths and weaknesses of units, may assist game developers in this important and time-consuming task." When STARCRAFT II was finally released on July 27, 2010, more than 1.5 million copies were sold in the first two days, making it the fastest-selling strategy game of all time. By February 2011, nearly 4.5 million copies had been sold. You would think that Blizzard Entertainment can afford to invest a few bucks in rapid adaption of video game AI. Meanwhile, they can download a free copy of Sander Bakkes' wonderful thesis from: http://sander.landofsand.com/phdthesis/Sander_Bakkes_-_PhD_Thesis_Camera_Ready_Copy.pdf