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Case History: The Evolution of Artificial Intelligence in Computer Games

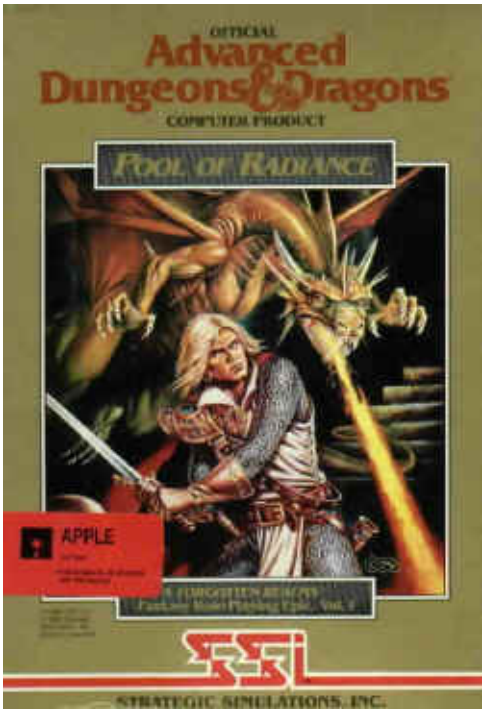
Computer games within the last 25 years have spanned the spectrum from simple 2D renditions of popular board games to fully immersive real-time 3D environments. Much of the focus early on in the development of computer games was on better graphics, better interfaces, and better gameplay under limited computing conditions. As graphics and computing hardware steadily increased in processing power, the graphics and interface issues seemed to be increasingly well under control, and game developers began to recognize more and more that improving gameplay was greatly facilitated by improving in-game artificial intelligence. As computer game AI techniques became more advanced, the field of game AI also began to affect the computer game genres that were emerging.

Computer game AI has its roots mainly in early applications of digital processing power to classical board games. Computer artificial intelligence applied to games can be traced way back to 1950, almost as soon as computers became programmable, when Claude Shannon and Alan Turing were writing AI for chess programs. In 1952, Arthur Samuel of IBM developed a checkers-playing program that took the novel approach of learning by playing against itself, and the program was able within just a few days to compete well against strong players.

Games like chess and checkers were a logical choice for early AI experiments, because board games are usually games of perfect information, meaning that the entire state of the game is easily accessible to the computer.[1] Also, such games are usually not trivial search problems with well-defined paths to solutions, since they involve an opponent which adds an element of uncertainty to the equation. Thus, computer board games emerged as a natural test bed for new AI algorithms and areas of academic research, and in modern times remain as such.

Modern advances in AI techniques and computing hardware have led many people to consider many of the classical board games "solved" (there are of course traditional board games that have not been solved by computer AI, such as Backgammon and the Japanese game "Go"). Usually the notion of "solving" such games means that algorithms and systems exist that can routinely beat an expert player within given time constraints, or sometimes may even be proven to never lose. For example, a computer program called Logistello beat the world champion *Othello* player, Takeshi Murakami of Japan in 1997 with a score of 6-0, and today humans generally refuse to play against computer opponents in tournaments.[2] In chess, the famous "Deep Blue" computer beat chess Master Garry Kasparov in 1997 in a highly publicized match, representing a culmination of AI techniques and processing power.

Other adaptations of traditional genres that spurred computer AI work were the development of role-playing games and turn-based strategy simulations on the computer. Computer turn-based strategy games generally had their roots in military strategy board games, and were adapted in the early 1980's by Strategic Simulations Inc. for the personal computers that were becoming more widespread at the time. SSI also made the most significant contribution to the RPG genre in the late 1980's when it reached an agreement in 1987 with TSR to be the sole producer of Dungeons and Dragons games for the computer.[3]



The level of artificial intelligence in these games was not very complex and usually consisted of a simple rules-based system, where the computer opponent had a few core rules as to what it should do in limited situations. During the birth of the RPG genre, AI was usually only important for enemy combat strategy, since the task of creating believable characters was handled by scripted storylines. Computer opponents in early computer turn-based strategy games usually had full knowledge of where the player's units were on the map, which simplified the decision-making that the computer player (CP) had to make and reduced the need for advanced AI. However, since personal computers at the time were still something of a wonder to most people, players commonly interpreted the computer's decisions in the context of human behavior, projecting emotions and deep strategy upon the CP's actions when they were just the results of simple rules-based systems.[4]

While the early games in each of the above genres made limited use of developing artificial intelligence techniques, it wasn't until the explosion in growth of computer graphics systems and personal computer processor power that AI started to become a more important feature of these types of games. Role-playing and turn-based strategy games in particular started to incorporate more advanced AI techniques to meet the demands of gamers that wanted a richer gaming experience.

The introduction of *Dune II* in 1992 by Westwood Studios defined a new genre of computer games: real-time strategy. The RTS genre created all kinds of new issues for artificial intelligence, and continues to do so even more-so to this day. First of all, the mere notion that the games needed to run in "real-time" was a huge break away from the turn-based games that dominated the previous decade, and required the use of efficient AI techniques and even the development of some new ones. The earliest RTS games such as *Dune II* and *Warcraft* (1994) didn't have very impressive AI, as they were still defining the genre and dealing with other core gameplay issues, but within a few years the genre started to focus heavily on AI. By 1997, with 2 games in each of the Warcraft and Command & Conquer series released, the genre was well-established and developers started to take a serious stance in regards to game artificial intelligence as the new defining feature. At a 1997 GDC roundtable discussion, developers recognized the serious need for improved AI if their RTS games were to improve. "Many felt that these games were more puzzles than war games at least in the single player mode. One reason for this 'feeling' of puzzle in such games was ascribed to the failure of the artificial player (or artificial intelligence). However, it was felt that the industry was finally recognizing the need for good AI in games and resources were being invested to solve this problem."[5]

Dune II (screenshot from GameSpot online)

Game developers specializing in AI that met at the 2000 Game Developer's Conference said that AI was allotted 25% or more of CPU resources, which is a huge jump from the previous figures of less than 10% that AI was getting in 1998, and under 5% in 1997.[6] This is especially remarkable considering that's 25% of the CPU for computers that were about twice the speed of computers in 1998. AI developers are also getting more say in the game development process and AI development is no longer saved until the end of production, but is rather a more modular and dynamic process throughout development. 80% of Game developers reported in 2000 that they had at least 1 person in their team working full time on AI development, and one-third of that group reported at least 2 people dedicated to AI. Some developers are even making high-level design decisions in favor of AI features over graphical features—some are quoted as saying, "New graphics features are fine, so long as they don't slow down the AI." [7]

This represents a dramatic shift in an industry that has been until recently narrowly focused on graphics. It is very interesting to note that what many people regard as the beginning of the "modern era of 3D acceleration" (the release of the first Voodoo boards) took place in October of 1996.[8] Given this information, the very close correspondence between the increase in graphics hardware and increase in resources available to AI after 1997 make a lot of sense. With the prevalence of advanced 3D graphics cards, graphics programmers simply didn't need as much of the CPU as they used to.

This transition from haphazard AI development to a development process in which AI is given full attention and ample resources is a remarkable one. By 1997, game developers in most genres were coming to realize that improved AI development had become one of the foremost deciding factors in improved gameplay.

Real-time strategy games changed dramatically as a result of better AI. Creating "intelligent" opponents has been one of the main applications of AI since its beginning, and was the main focus and challenge for the games mentioned above. Within the few years following 1997, real-time strategy games made innovative advances in AI that continued to shape the genre. While computer opponent AI slowly improved, RTS games became noticeably more playable in general in the face of better pathfinding and better unit control. The A* algorithm has been the method of choice for years in terms of pathfinding, but new methods of hierarchical optimizations and dynamic path recalculation have continued to be developed. Even with the dramatic increase in

multiplayer modes for RTS games, good AI has remained an important feature to facilitate better unit control and hence a more playable game.

The addition of the third dimension to many RTS games has resulted in new areas of computer game AI development so that computer opponents can make effective use of the added dimension. One of the earliest strategy games to place great emphasis on the third dimension was *Myth* (1997), a combat-oriented strategy game that relied heavily on unit control and effective use of different unit tactics. Besides requiring a computer opponent that made the game fun and difficult by factoring different terrain into battle strategies, the game also added greater unit control through the notion of unit formations. Ensemble Studios' *Age of Empires II: The Age of Kings* (1999) took intelligent unit formations to the next level, in a system in which the stronger melee units would automatically fall in line around the ranged units to protect them.[9] While the ranged units were free from danger, the melee units might wander off to attack enemy units, but if the ranged units were in trouble they would to return to defend them. *AoK* also made use of genetic algorithms that would pit various AI scripts against each other and allow the AI to "evolve" into a stronger one.

Age of Empires II: Age of Kings (screenshot from Gamasutra)

Another genre that has advanced remarkably thanks to improved AI is the first-person shooter (FPS). Valve Software's *Half-Life* (1998) featured an innovative AI system that raised the standard in FPS single-player AI. Although based upon the long-standing technique of finite state machines, Valve layered the technique in a way that created amazing complexity through a system they called a "schedule-driven state machine."[10] This system allowed them to create such effects as enemy squads that moved in formation and provided covering fire, fetched reinforcements when low on health or numbers, and even stage ambushes. The *Half-Life* scripting code also allowed for complex interactions between the player and the non-player characters that moved the story along fluidly, and these NPCs occasionally provided humor through their idiosyncrasies and reactions to the environment (it definitely added a new element to combat when you'd be leading a scientist somewhere and they started cowering or getting in the way when monsters were nearby, or when you were assisted by a friendly guard who would boast about his last kill and talk of placing it on his mantle, only the next instant to see him

picked up by some massive tentacle and be yanked away screaming). This type of fun immersive environment realized through AI is arguably the most important thing games strive to achieve, and this realization has served to add richness to the genre.

Half-Life (screenshots from Valve Software website)

The role-playing genre has also continued to evolve by developing more advanced AI. Games in the RPG genre have always strived to convey the sense of a real environment and real characters within a compelling, imaginative world. Good monster and non-player character AI in a role-playing game is essential if the game is to convey a sense of realism, and in many cases critical to the game experience. For example, in Massively Multi-Player Online RPGs, a relatively new branch in the RPG genre, nobody wants to play the commoners or workers that are a boring but necessary part of the world, but when a game gives personality to these characters it only benefits the game by adding to the experience and immersion.

These types of design features based around better AI have changed RPGs dramatically—games in the genre are becoming much more dynamic compared to its earlier members. *Ultima Online* (1997) is a good example of a game that made a strong effort to incorporate better intelligence in its NPC characters. NPCs are able to accompany the player on quests, give useful information, and even "remember" what other players they have met recently. NPCs even have their own agendas, desires, and goals, increasing the opportunities for interesting interaction with players.[11] *UO* and other similar games also made advances in A-Life (artificial life) technology, which attempts to create a realistic dynamic environment with which the player interacts. Examples of such features are wolves that hunt in packs and stay mainly in forested areas, animals that are scared of humans and flee from them, and dragons that are solitary, hoard treasure, and stick to mountain areas until food runs out, at which point they might migrate or raid a village. With the focus of game developers on the development of better AI, RPGs have become less linear and able to give the player a more realistic, unique experience than was previously possible.

Some games, mainly RPGs, have included the feature of "extensible AI." Under this system, players may enhance or replace the AI for the NPCs in their adventuring party, usually through a programmable script-based system. The flexibility and power allowed by such systems varies greatly between games—*Baldur's Gate* (1998) allowed for user-customizable scripts for their NPCs and characters,[12] while other games such as *Quake* (1996) and *Unreal Tournament* (1999) provide a full programming interface enabling programmers to rewrite all monster AI and add new gameplay features.[13]

Unreal Tournament (screenshot from Unreal Tournament website)

The extensible AI features that many games started providing in the 1990's, along with the widespread growth of the Internet accompanied by a surge in the amount of multiplayer games, led to a distinct online game culture trading AI scripts and creating and distributing new bots for commercial games. The use of extensible AI in games has also encouraged many independent developers to basically invent a new genre of computer games based on this idea. These games usually revolve around presenting a facility for the user to create advanced scripts for some sort of unit, and then pit their unit in battle against other AI units, usually over the internet. One such game is called *AI Wars*, which allows you to develop AI for a mechanized bug-like unit that does battle against your other creations or against other units created online.[14]

In fact, it appears that many game genres have evolved almost exclusively as a direct result of AI development. The extremely interesting *Creatures* series (1996) is an interactive experiment in genetic algorithms and neural networks. The player receives the game with six eggs each with its own unique "digital DNA." The player interacts with the creatures that hatch from the eggs (called Norns), and interact with them throughout their lifespan, teaching them what is allowed, punishing them for what is not allowed, and participating in all kinds of other types of interactions. Adult Norns may lay eggs, and these eggs acquire much of the same digital DNA that the parents pass on to them, plus the odd mutations. A fairly extensive game community has developed around the *Creatures* series, in which players trade eggs over the Internet, exchanging different Norn character traits and distributing the gene pool.[15] Games like *Creatures* represent an emerging genre of computer simulations that revolve primarily around AI. Whereas games in

the late 80's and early 90's had very simplistic intelligence models, newer games fully expose the complex artificial intelligence system to the user and encourage the study of it.

Creatures 3 (screenshot from www.gamesdomain.com)

AI has become an important marketing tool for developers, along with the traditional, "Great graphics, killer sound." On the business side, some companies learned the hard way that no matter how feature-rich their 3D-engine may be, AI can make or break your game. Nothing can be substituted for good gameplay, and good AI usually goes hand-in-hand with good gameplay.

Developers are allocating more time to AI development, and game companies have been placing more emphasis on their game AI as a core feature and selling point. For example, the popular real-time strategy game *Age of Empires* developed by Ensemble Studios (1997) was a big hit, selling over 3 million copies worldwide, but still drew sharp criticism in the two major areas of computer opponent AI and unit pathfinding.[16] The developers made these two areas a major focus in the development of their sequel to the game, *Age of Empires II: The Age of Kings*, bringing in an industry veteran to do a complete overhaul of the Computer Player AI and unit movement and pathfinding. The hard work paid off and the game received a noticeable amount of praise for the enhanced gameplay due to the greatly improved AI.

It's important to note that computer games bring a whole new meaning to what makes "good" AI. Good AI in games is not necessarily the best, most difficult to play against opponent. Computer games are targeted at a wide audience, and those players constitute a wide range of skill levels. A good AI incorporates adaptability, both in terms of improvement and learning, and

in terms of keeping the game a blowout. This problem can be solved by incorporating skill levels into a game, or in the innovative approach that one academic research group took with a game like *Unreal Tournament*, can be solved by creating an AI system that adapts its level of play to meet that of its opponent.[17] This generally creates games with long-term playability that is at a consistent level with the player.

It is also interesting to note the amount of interaction that has historically occurred between the entertainment industry and Academia. Traditionally, the two parties have been pretty separate, the game developers generally considering academic work mostly inapplicable to their own work, and academics generally paying little attention to entertainment work. However, the two fields have begun to interact more closely—in the year 2000 one source reported that there were "at least five AI Ph.D.s at game companies."[18] Some academics actually consider the game industry to be "light years ahead of academia in producing practical, working AI solutions to some very tough problems."[19] It is indeed very exciting to see what AI solutions appear in the near future.

[1] ***Artificial Intelligence, A Modern Approach***. Stuart Russell and Peter Norvig, 1995, Prentice-Hall, Inc. pg 122-139.

[2] "Classic Games and AI." Steven Woodcock. http://www.gameai.com/

[3] "Strategic Simulations." http://www.classicgaming.com/gotcha/ssi.htm (image from this site as well)

[4] Will Wright, *STS145* Guest Lecturer. Feb. 14, 2002.

[5] "Whither (or Wither) War Games." Mark Baldwin, April 1997. http://www.gamasutra.com/features/gdc_reports/cgdc_97/baldwin.htm

[6] "Game AI: The State of the Industry (2000)." Steven Woodcock, 2000. http://www.gamasutra.com/features/20001101/woodcock_01.htm

[7] "Game AI: The State of the Industry (2000)."

[8] "7 Years of Graphics." Thomas Monk, March 2002. http://accelenation.com/?doc=123

[9] "Postmortem: Ensemble Studios' *Age of Empires 2: Age of Kings*." Matt Pritchard, March 2000. http://www.gamasutra.com/features/20000307/pritchard_01.htm

[10] "Game AI: The State of the Industry (1998)." Steven Woodcock, 1998. http://www.gamasutra.com/features/19981120/gameai_01.htm

[11] "Games Making Interesting Use of Artificial Intelligence Techniques." Steven Woodcock, http://www.gameai.com/

[12] "*Baldur's Gate II*: The Anatomy of a Sequel." Dr. Ray Muzyka, 2001. http://www.gamasutra.com/features/20010502/muzyka_01.htm

[13] Postmortem: Epic Games' *Unreal Tournament.*" Brandon Reinhart, 2000. http://www.gamasutra.com/features/20000609/reinhart_01.htm

[14] AI Wars homepage: http://www.tacticalneuronics.com/content/prod_aiw.asp

[15] "Games Making Interesting Use of Artificial Intelligence Techniques."

[16] "Postmortem: Ensemble Studios' *Age of Empires 2: Age of Kings*."

[17] "Game AI: The State of the Industry, Part Two (2000)." Dave C. Pottinger, 2000. http://www.gamasutra.com/features/20001108/laird_01.htm

[18] "The Future of Game AI." John E. Laird, 2000. http://www.gamasutra.com/features/20001108/laird_03.htm

[19] "Game AI: The State of the Industry (1999)." Steven Woodcock, 1999. http://www.gamasutra.com/features/19990820/game_ai_04.htm