

Artificial Intelligence in Games:

**A look at the smarts behind Lionhead Studio's "Black and White" and
where it can and will go in the future**

James Wexler
University of Rochester
Rochester, NY 14627
jw005i@mail.rochester.edu

Keywords: artificial intelligence, entertainment, gaming, "Black and White"

Abstract

With its latest release "Black and White", Lionhead Studios has set the new standard for artificial intelligence in games. Creatures in this game have an incredible ability to learn that is implemented through a variety of AI algorithms and techniques. There is much that could be added to the game given ample time and computing resources. These additions include a partial order planner for creatures' actions, a game-state search algorithm and planner for a computer-controlled opponent, and a dynamic lookup table to create better battling creatures.

Written for Professor Brown
CS242 – Artificial Intelligence
May 7th 2002

Introduction

There are many types of computer programs that use AI. Market simulators, logic systems, and economic planners are some of the different fields of computer software that rely heavily on elements of artificial intelligence. These elements include situation calculus, tree searching, problem solving, and decision-making. But one genre of software programming has been slowly borrowing more and more from the field of AI is video gaming.

Video games have gone through drastic improvements in the past ten years. It seems as if Moore's law applies to video games as well as processor speed. Video games seem to get twice as complex in some ways every eighteen months. As these games get more complex they also get more interesting and engaging. Video games are no longer just a distraction from work or a thirty-minute escape from reality. They are becoming an artistic form of expression for the programmers and developers and a serious hobby and undertaking for the players. One relatively new game that shows this drastic advancement in the complexity and beauty of video games is "Black and White" by Lionhead Studios. "Black and White" has made its mark on the video gaming industry through its remarkable implementation and manifestation of artificial intelligence.

History of Video Games and Their Use of AI

Physicist Willy Higinbotham created the first video game in 1958. It was called "Tennis For Two" and was played on an oscilloscope. The first game to

run on a computer was “Spacewar” by Steve Russell from MIT. The graphics were ASCII characters and it ran on a Digital PDP-1 mainframe. In 1970 the future founders of Atari, Nolan Bushnell and Ted Dabney released the first video arcade game, “Computer Space”. In the next ten years companies such as Atari, Coleco, and Magnavox all released home video game console systems. In 1980, Battlezone, the first 3-dimensional game ever, was released. It went on to be used by the US government for the training of military forces.

Four years later, the Nintendo Entertainment System was released, marking the beginning of the modern gaming era. Home computers were starting to become practical and popular. Video games designed for home computers started being developed. The fact that home computers had more storage and computing power than cartridge-based console systems allowed for more complicated games. The console industry caught back up in 1995 when Sony brought the PlayStation to the United States. It was the first practical CD based system and a huge step forward. Currently, both console systems and computer games are pushing the limits of modern processors. Real-time 3D rendering, movie-quality video and sound, and intelligent computer agents all continue to amazing gamers worldwide [1].

The history of artificial intelligence in video games dates back to the mid-sixties. Before that, games were either two-player (meaning that there was no computer opponent) or any non-human objects were hard-coded. An example of hard-coded video game objects are the little aliens in “Space Invaders” that swoop down at the human player. The human player must shoot the aliens

before they reach the bottom of the screen. The manner in which these aliens move is explicitly coded into the game and is not determined at runtime by any precepts. The earliest real artificial intelligence in gaming was the computer opponent in “Pong” or variations thereof (of which there were many). The computer paddle would do its best to block the ball from scoring by hitting it back at the user. Determining where to move the paddle was accomplished by a simple equation that would calculate at exactly what height the ball would cross the goal line and move the paddle to that spot as fast as allowed. Depending on the difficulty setting, the computer might not move fast enough to get to the spot or may just move to the wrong spot with some probability.

For a long time no video game AI was not much more intelligent than the “Pong” AI. This was because the games were relatively simple and most often played with a second player instead of a computer opponent. Atari sports games AI agents were basically goal-oriented towards scoring points and governed by simple rules that controlled when to pass, shoot, or move. The advent of fighting games such as “Kung Foo” for Nintendo or “Mortal Kombat” for Sega Genesis saw only a slight improvement in AI. The moves of the computer opponents were determined by what each player was currently doing and where they were standing. In the most basic games, there was simply a lookup table for what was currently happening and the appropriate best action. In the most complex cases, the computer would perform a short minimax search of the possible state space and return the best action. The minimax search had to be of short depth since the game was occurring in real-time. Real-time game play has always been

major setback for AI in video games. There is very little time to compute actions and possible future states when the action never stops.

The last ten years has seen great strides in the field of AI in gaming. Most of these strides have been made in computer (as opposed to console) games because of their raw computing power and memory capacities. Currently, driving games like “Nascar 2002” have computer controlled drivers with their own personalities and driving styles. Pass one of these guys while they are having a computer-controlled “bad day” and they will be riding your bumper for miles, trying to take you out. Strategy games like “Warcraft 3” call for users to create an army to defeat one or more computer-controlled villages with armies of their own. These villages will form alliances, scout surrounding areas, and devise appropriate battle plans to do their best to be the last village standing. “The Sims” has reinvented artificial life in gaming. The game starts with the user controlling one person. Eventually the character may marry and then the user can control the spouse also, and then the children. These “people” are wonders of AI. They all have their individual characteristics, wants, and needs. They have the ability to fall in love, make friends, enemies, become hermits, strive for more in life, etc, and will act on their feelings at will. But, there is one recent game that yields an even more impressive use and understanding of artificial intelligence than all of the games listed above. That game is “Black and White” by Lionhead Studios [15].

Black and White

“Black and White” is based upon a simple premise. The game player is god. The game is set on Eden Island, which is inhabited by eight different sets of villagers (Celts, Greeks, Aztecs, and so on) and some non-human creatures. The different tribes all have different beliefs, hobbies, and spiritual powers. At the beginning of the game, the user selects one creature to do its bidding. This creature becomes somewhat of the main focus of the game. The user must train and take care of this creature like a parent looks after and helps a child. The point of the game is to make as many villagers as possible obey the user as their god. Worship can be obtained either through adoration or fear of the user-controlled higher being. Their worship provides the user with the power they need to cast spells and control more villagers. There is a rival god that threatens to destroy everything the user has built up and it is the player’s responsibility to destroy this god through pre-defined missions. There are small, mini-missions along the way such as helping a villager find her lost husband that the user completes using their creature [12]. Boiled down to simplest terms, “Black and White” is much like strategy/omnipotent-user games that have come before it such as Sid Mayer’s “Civilization” and “Command and Conquer” in that the point is control as many people and have as much power as possible. The thing that sets apart “Black and White” from any other game before it is its advanced use of artificial intelligence.

There are two types of agents in the game that can be perceived as intelligent. The first type is the community of villagers. The more of the villagers

that obey the game player as a god, the more powerful that player gets. Therefore, it was important for the game developers to make these villagers intelligent so that they the user could appreciate the challenge of winning the villagers over. Compared to computer-controlled agents from other recent games, such as “The Sims”, these villagers are incredibly simple-minded. All of their knowledge, beliefs, and desires are represented in large tables and situation calculus. If left alone, they will do what is best for the village. This may be chopping wood, mating with a member of the opposite sex, or building a shrine. If the user wants one of these villagers to do a specific task such as chopping wood, all they need to do is place them next to a tree. They can easily deduct from a lookup table that if their god places them next to a tree, then he wants them to chop wood for the village. The villager will then chop and deliver wood to the village until he dies if not interrupted. In reality the intelligent agent isn't the individual villager but instead the entire village. The villagers act as a whole to complete all the necessary tasks to satisfy their table-driven desires. The village is a simple, but nonetheless intelligent artificial agent.

The artificial agent that makes “Black and White” such an incredible achievement in AI is the creature. As previously explained, the creature is used by the game player to do its bidding. It can also be seen as a child for the game player to both nurture and train. The chief AI developer for the game, Richard Evans, provided the gaming website www.gameai.com with some simple documentation of the game design. The desire that the developers had for the creatures was that they would be both very human-like and useful. To be

human-like, the creature had to be “plausible, malleable, and lovable”. To be useful it had to be able to learn how to satisfy its master and know how to correctly act based upon its beliefs and percepts [7]. Many recent games, such as “The Sims”, have made very human-like toy agents and many other recent games, such as “Daikatana”, have made incredibly useful agents; but no game before “Black and White” was able to combine the two elements into one seamlessly intelligent and empathetic agent [4].

The main aspect of the game’s AI that makes it so powerful is its mixture of different approaches of representing intelligence. Given a variety of techniques, the one that is most suitable for any certain task can be used for that task on the fly. This idea was taken from Marvin Minsky’s years of research about AI at Massachusetts Institute of Technology [10]. In particular, three representations were used. Symbolic attribute-value pairs are used to represent a creature’s belief about any individual object. An example of this type of representation is:

```
Strength of obstructions to walking:  
  object.man-made.fence->1.0  
  object.natural.body-of-water.shallow-river->0.5  
  object.natural.rock->0.1
```

This method is used alongside with rules-based AI (situational calculus) to give creatures their basic intelligence about objects. This scripted-AI is the most popular form of artificial intelligence found in games today [2]. Decision trees represent agents’ beliefs about general types of objects. Finally, neural networks of perceptrons represent desires [5].

There are numerous skills involved with learning and a large variety of ways in which a creature can learn. Creatures learn facts about its surroundings, how to do certain tasks, how sensitive to be to its desires, how to behave to or around certain objects, and which methods to apply in certain situations. After a creature completes a task, the game player can zoom in on the creature and using the mouse either stroke the creature lovingly or give it one or more strong slaps. The creature's belief in the how good of an idea that action was will be altered accordingly, just as scolding a child after he does something wrong will make him think twice about doing it again. Simply giving the creature a specific task will cause it to think that that task is a beneficial one. If the user repeatedly tells their creature to attack a specific type of villager, the creature will learn that it is a good idea to attack that type of villager and may do so on its own in the future. The creatures also learn by simply observing their peers. It might emulate anything that it sees a villager, another creature, or the user (its god/parent) doing. The fact that the creatures can learn by watching the user gives the creature an interesting distinction from any other artificial agent ever created for a commercial game. A creature will keep a symbolic representation of its god. It learns the personality of the user and uses that information to determine what actions would most please the game player. Lastly, creatures learn from reflecting own their own experiences. After a creature completes an action to satisfy a certain desire it will look at how well that desire was satisfied and adjust its internal weight structure accordingly [4]. For example, a creature knows from birth that eating will satisfy its hunger. That is a natural instinct. But,

it does not yet know what type of object satisfies its hunger best. It may see a fence and instantly walk over and take a bite out of it. It will then realize that the fence did not satisfy its hunger well and tasted horrible in the process. The creature will alter its internal food decision tree as to keep it from eating fences in the future [14]. Here is a specific example of exactly how a creature dynamically builds a decision tree:

If a creature was given the following feedback after attacking enemy towns:

What he attacked	Feedback from player
Friendly town, weak defense, tribe Celtic	-1.0
Enemy town, weak defense, tribe Celtic	+0.4
Friendly town, strong defense, tribe Norse	-1.0
Enemy town, strong defense, tribe Norse	-0.2
Friendly town, medium defense, tribe Greek	-1.0
Enemy town, medium defense, tribe Greek	+0.2
Enemy town, strong defense, tribe Greek	-0.4
Enemy town, medium defense, tribe Aztec	0.0
Friendly town, weak defense, tribe Aztec	-1.0

Figure 1. Table of feedback given to creature after attacking town [4]

Then the creature would build a decision tree for Anger like this:

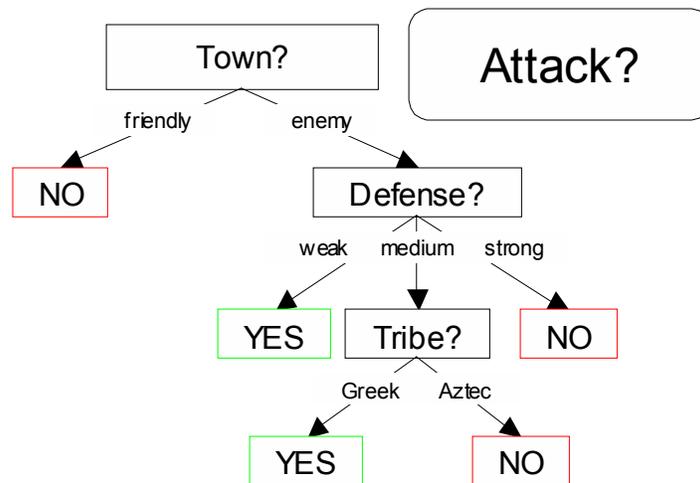


Figure 2. Corresponding decision tree

In his review of the AI system he created for “Black and White”, Richard Evans writes, “A decision tree is built by looking at the attributes which best divide the learning episodes into groups with similar feedback values. The best decision tree is the one that minimizes entropy, a measure of how disordered the feedbacks are. The algorithm used to dynamically construct decision-trees to minimize entropy is based on (Ross) Quinlan’s ID3 system.” [4]

The creators of "Black and White" did a good job integrating a strong AI, beautiful graphics and 3-d rendering, a powerful yet simple control scheme, and much more into a final product that ran fast and smooth. Obviously there had to be some shortcuts and omissions from the creatures' artificial intelligence in order to allow it to make real-time decisions without slowing down game play. If given the task to improve the game's AI for a sequel there are many improvements one could picture, although without an increase in processing power such improvements might hinder game play.

Black and White 2 – New Concepts

As previously stated, there are some shortcuts in the creatures' brains that were necessary due to time constraints and limited processing power. One drastic omission was the idea of creatures planning sequences of their actions to satisfy their desires and goals. The game uses a simple lookup table to find the correct action to satisfy a creature's current desire. For example, if a creature were hungry, it would look up hunger in its action lookup table and discover that the best response is to find something to eat. A huge improvement in the creatures' intelligence would come by incorporating a partial-order planner into its brain. Instead of a simple lookup table, the creature would have a list of states that it or any other object could be in at any time and a list of rules that equate changes in these states to certain actions. UCPOP (a pre-existing partial order planner) or perhaps a homemade partial-order planner could easily be integrated into creatures.

This idea of a planner would make creatures much more powerful. Instead of giving creatures one command at a time and having to wait for that task to be completed to give the creature another command, the user could simply create a list of goals that it wishes for the creature to complete [3]. Individual goals could be given importance values that give the creature an idea of what goals should be more immediately met. In addition to listing goals and importance, the user could specify a specific search function and search limit so that the planner doesn't waste too many cycles chasing after impossible goal states. Once all the goal state information is listed the planner could run in the

background and upon completion return the best sequence of actions that satisfy the user's needs. This list could then be sent from the user to the creature so that the creature could get to work on its newly created plan of actions. A planner would give the user more time to spend helping its villagers or doing missions since its creature could be given a plan that may take a considerable amount of time and accomplish many tasks. Of course, there would have to be restrictions in the actions that the planner can give to the creature. Otherwise the user could give the creature a list of actions that may train the creature very efficiently and that would take the fun and challenge out of having to manually train and nurture one's creature. One possible solution is that the planner could be a special tool that is only unlocked once a user's creature has reached a certain intelligence level.

Perhaps the biggest gaping hole in the design of "Black and White" is the absence of an intelligent computer-controlled opponent. The villain is hard-coded into the game and the only interaction the user has with the villain is through pre-programmed missions. According to an interview with Lionhead president Peter Molyneux, the game had no intelligent opponent since that would take away from the time that the user could spend nurturing and training their creature. This is quite true but probably not the only reason. Early designs of the game were bug-filled and development was constantly behind schedule [11]. It is possible that an intelligent opponent was left out due to time constraints. After all, it is much better to have a small game domain that runs perfectly than a large game domain that is buggy and poorly assembled.

The addition of a computer opponent god would be a heavy strain on a computer's resources but would give "Black and White" more replay value by adding variety from game to game. The computer opponent would be not unlike the human player. It would have a creature and have control over villagers. The idea would be eliminate the other god by converting all his villagers to your side. This computer opponent would make decisions using a breadth-first searching algorithm. The fastest method would most likely be breaking up the computer's decisions into broad goals. The breadth-first style search would go a few layers deep and explore some very general ideas. At the bottom of the tree, a static evaluator would compare the statistics it keeps on its own progress and the expected value of its new moves versus the statistics it has been able to gather from the human player's faction. This general search would return an optimal goal to help advance the computer's civilization, not simply a next move. Such goals could be "teach creature spell", "convert villagers", or "collect wood". The idea that the search returned would then be put into a planner (explained above for the creature) so that the best way to accomplish this goal would be implemented.

By integrating a very general and broad search and a partial-order planner, much time is saved. If this computer player were implemented with search on all possible combinations of many sequential actions, the branching factor would be humongous. The branching factor needs to be small since the search is running in the background of a real-time game. The search needs to

be short in time and cannot slow the game play down. The integration of a broad-goal-based search and a planner accomplishes this goal.

An important aspect of this search is the static evaluator. It would evaluate its own situation based on how many spells it can cast, how many villagers obey it, and how advanced its creature is. The evaluation of the human player would be more complex. In order to be a good strategy game, the computer opponent should base its evaluation solely on information it has collected through things that its creature or villagers have observed of the human's faction. Omniscient computer opponents are frowned upon in the gaming world since it creates a discrepancy in the styles of which the computer and human use. The static evaluator would have to take the limited information it has discovered about the other side and extrapolate to determine how advanced it considers its enemy.

One last possible AI-related addition to a sequel to "Black and White" would be a more sophisticated battle implementation. Currently, a player's creature can battle against other creatures in order to gain experience and strength or in self-defense. The battles themselves are very basic. A player can attack certain parts of the rival creature by clicking on parts of their body. By clicking multiple spots in succession, the creature will attack with a series of connected moves. Creatures also have special moves that they learn as they grow older and gain experience. These moves can be implemented by double-clicking certain parts of the screen. Lastly, creatures can block using buttons on the keyboard. The opposing creatures are controlled by hard coded sequences

of instructions and lookup tables that determine the best response to all possible actions. The creatures get smarter and better at fighting as the game moves along but overall, all of the fighting in the game is quite stale and boring.

A good way to spice up the action would be making the enemy creatures more intelligent. A constantly updating lookup table that keeps track of different fighting styles would make fighting more difficult and therefore more interesting. As the enemy creatures fight the human-controlled creature they would keep track of what types of moves the human-controlled creature used in certain situations. The creature would then be profiled by these actions. This profile would be used as the key in the lookup table and the best strategy of moves against that type of player (or against the closest known type of player that profile represents) would be returned. During the fight, if the computer player were doing poorly it would alter the best strategy against that style of fighter and continue on. If the human-controlled creature's style changed suddenly, the new best strategy would be implemented. If the strategy used were not in the table, it would be added at the end of the match and the strategy that fought best against it would be placed in the corresponding best-strategy spot in the table.

With a dynamic lookup table implementation of battling, fighting against other creatures would be much more interesting than in the original version. A player could not just use one style over and over again to defeat computer creatures since the computer would over time learn the best way to defeat a creature using that style. This keeps the game player on their toes when it

comes to fighting other creatures. Battling would no longer be the aspect of the game that gets in the way of all of the more interesting aspects.

Conclusion

“Black and White” is an extraordinary game that pushes the envelope when it comes to artificial intelligence in entertainment. Creatures from “Black and White” are the most realistic representations of living, learning things to ever come out of the gaming industry. Even though this game broke down barriers, there is still much more possible when it comes to integrating AI into video games. Given enough computing resources, there are three AI techniques that could be implemented in “Black and White” in order to make it a better and more powerful game. Incorporating a partial order planner into the creatures’ minds would make them more powerful and intelligent. A computer opponent powered by a breadth-first search and a partial order planner would make the game more difficult and engaging and therefore give the game more replay value. Using a dynamic lookup table to drive computer-controlled creatures in battle would make the battling aspect of the game more interesting and challenging. “Black and White 2” is currently in production and many of its new features are shrouded in secrecy. No matter what is added or improved, the game is sure to be another breakthrough in the use of artificial intelligence in gaming.

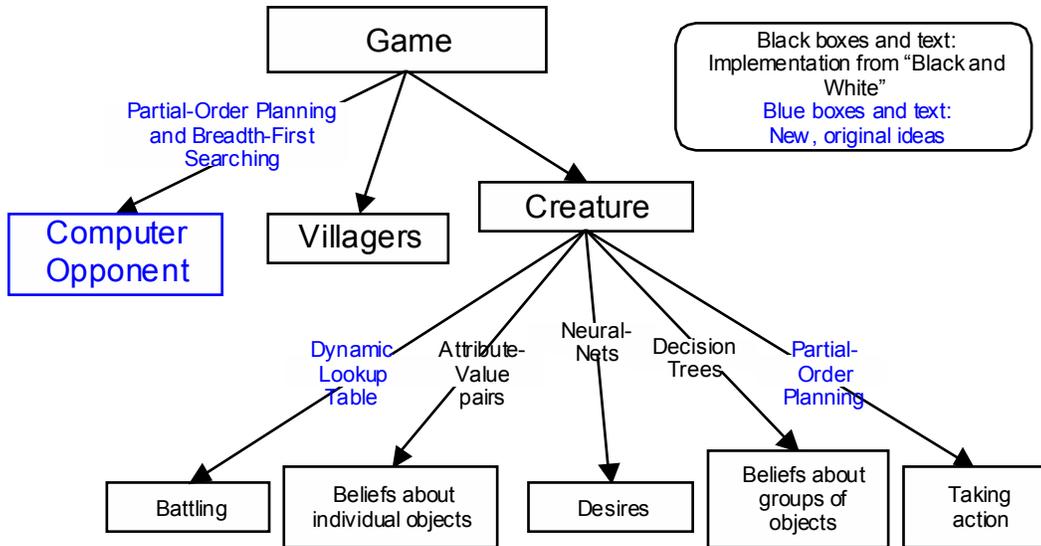


Figure 3. Tree describing aspects of the original game and new ideas for a sequel

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