THE NPC AI OF *The Last of Us*: A CASE STUDY

Harsh Panwar
School of ELectronic Engineering and Computer Science
Queen Mary University of London
London
h.panwar@se21.qmul.ac.uk

Abstract: *The Last of Us* is a game focused on stealth, companionship, and strategy. The game is set in a post-apocalyptic world after the pandemic and thus it needs AI companions to gain the interest of players. There are three main NPCs the game has - Infected, Human enemy, and Buddy AIs. This case study talks about the challenges in front of the developers to create AI for these NPCs and the AI techniques they used to solve them. It also compares the challenges and approach with similar industry-leading games.

Keywords NPC, GameAI, Infected, Ellie, PS4

1 Introduction

*The Last of Us* is a third-person shooter (TPS) action-adventure made by *Naughty Dog* and distributed by *Sony Computer Entertainment* developed majorly for *PlayStation 3* and later on remastered for *PlayStation 4* in 2014 [1]. Since its release the game has received amazing reviews by game developer critics [2] [3] [4] as well as by the gaming community and is considered as the best game of the decade as per Metacritic [5].

The game is set in post-apocalyptic America after the parasitic *Cordyceps* fungus [6] has wiped out majority of the humanity as we know it and divided the entire world into the infected and the survivors. In the nature this species of fungus [7] can be seen attacking on the ants and taking control of their brains [8] forcing the ants to lose control and become a useless creature with only one job left - become host for the fungus, generating a massive sprout which eventually shoots out of their head and infect others eventually. Inspired by this natural phenomena, the creators of *The Last of Us* thought of a scenario where a similar fungus affected the human body.

This paper is further organized into various sections where Section 2: Challenges summarizes the various challenges faced by developers while creating the NPC AI. Section 3: Skills and Behaviours discusses the Skills and Behaviours AI system used in the game, Section 4: AI Perception presents the AI perception used and compares it with other games. Section 5: Follow Positions presents the AI technique for follow positions. Section 6: Cover and Posts presents the AI technique used for cover and parts. Finally, Section 7: Conclusion concludes this paper.

2 Challenges

There are mainly two types of people left after the pandemic has affected the entire world in *The Last of Us* - The Infected and the Survivors. The pandemic in *The Last of Us* has left most of the population disfigured and aggressive and those who have been overcome by the fungus are declared as Infected. The infected lacks any humanly characteristics such as compassion or self-preservation and are mainly driven by the instincts of the fungus. Then there are the survivors who survived the pandemic and now lives in quarantine zones and are at constant threats of the Infected and other predatory survivors known as Hunters. And there are also half a dozen of survivors which are companions of Joel, the main character, and help him travel in the lonely world. The developers had to majorly work on these three groups - The Infected, The Human Enemy, and the Buddy companions. The developers chose to develop them using AI as such a system creates an environment closest to the real world. The players want the non-player characters (NPCs) in the game to be intelligent and just a simple glitch like an NPC running into a wall or trying to hide in plain sight can result in player's disinterest in the game. In a study done by Tremblay et. al. [9] they found that the adaptive AI companion has
The NPC AI of *The Last of Us*: A case study

(a) Ellie, a 14-year old teenage girl who accompanies Joel in most part of the game and is dependent on him.  

(b) Elizabeth, who reveals special abilities and has a complex background story.

Figure 1: Screenshot from the games showing the companion AIs in (a) *The Last of Us* and (b) *Bioshock: Infinite*

more influence over the player’s experience and it is a step forward in developing meaningful and engaging games. But each of these groups have their own challenges when it comes to developing the AI for them and they are discussed below in brief:

2.1 The Infected

One basic understanding of AI in Games is to make the NPCs intelligent and smarter. This simply can’t be done for the Infected AI as they have been made dumb by the fungus. This was one of the biggest challenges for the AI Developers in *The Last of Us* as they had to make them seem chaotic and alien unlike Hunters which work in groups and coordinate with each other. Our understanding of intelligence is more closely related to humanly behaviours such as togetherness, coordination, expressions etc. which were not allowed to be use for the Infected.

The Infected also because of the fungus were left to be sightless and had to rely mostly on hearing. This made it even more difficult to make them seem more real as otherwise it’ll become very easy to tackle them and the player could lose interest in the game. Just like in the actual world if you become blind or lose one of the 5 senses then the other senses
The NPC AI of *The Last of Us*: A case study

for example hearing becomes stronger \[10\], the developers had to make sure that their AI is really smart when it comes to actions and reactions using the ability of hearing.

2.2 Human enemy

The primary challenge while creating the Human AI was how to make an NPC so impactful that killing that NPC will have a effect on the player which will make the game interesting. Unlike in *Alien:Isolation* where the Xenomorph, primary antagonist, has two main AIs - main control itself using behavior trees which is very common in AAA games and an AI-director just like *Left 4 Dead* \[11\] which mainly manages the pacing of the game and the main focus was on Sense, Menace and Speed \[12\]. The Human Enemy AI in *The Last of Us* had to be focused mainly on Cover, Stealth and Flanking to make them look more like real humans and work in groups to give a feel of fighting against actual humans.

2.3 Buddy companions

The companion AI is one of the key factor in making a game like *The Last of Us* interesting since in a post-apocalyptic world which is full of Infected alienated creatures it’s essential that the only friend we have is intelligent and also compassionate. In an online survey done by Emmerich et. al. \[13\] on players they found out that most players prefer to have a companion and the most important characteristics they look in the companion are - Personality \((M = 3.82)\), Context Sensitivity \((M = 3.53)\) and Story Significance \((M = 3.70)\) on a Mean scale: 0 – 4. Elizabeth is a companion AI in *Bioshock: Infinite* \[14\] but is very different from Ellie in a way that Elizabeth has special abilities to help the player while Ellie is more dependent on the player. Since in *The Last of Us* the characters lacks any superpower or mysterious abilities, Ellie who’s just a 14-year old teenager is very difficult to be developed as someone who the player will find useful and not a liability who has to be escorted. Making a character that we as a player cared for was the key to the success of the game.

The pandemic in *The Last of Us* has left most of the population disfigured and aggressive and those who have been overcome by the fungus are declared as Infected. Although the AI for the Infected and the Hunters are similar, the developers have made the architecture modular which helps to make changes to the decision-making logic which makes the Infected feel fundamentally different than the Hunters \[15\].

3 Skills and Behaviours

The AI System used in *The Last of Us* mainly comprises of high-level decision logic known as the skills and low-level capabilities known as behaviours. The skills are used to decide what the character should do while the behaviours are used to implement those decisions. This sort of model helps in re-using the same low-level behaviours for multiple high-level characteristics. The skills are stacked in a priority queue which tells us which skills can interrupt other skills. The examples for skills for the infected are - *chase*, *search*, *follow*, *sleep*, *wander*, etc. and for human enemy the skills are - *panic*, *advance*, *melee*, *gun combat*, *hide*, *investigate*, *scripted* and *flank*. Since the skills are high-level they don’t change the animations or pathfinding systems. These changes are instead made by behaviour object using a behaviour stack. Examples of behaviour are *MoveToLocation*, *StandAndShoot* and *TakeCover*.

Most of the skills are common between the different characters for ease of adding new characters at any stage of development. There are 4 types of Infected - *Runner*, *Stalker*, *Clicker* and *Bloater* and only two skills are unique to single characters - *ambush* skill by the *stalker* and *throw* skill by the *bloater*. Now we will explain some of the major skills in detail:

3.1 Search Skill

The hunters are more intelligent beings and can communicate with each other to gather knowledge about the player’s position. The infected on the other hand lacks this and also can hardly see. So a requirement was there for a special search skill for the infected. This skill is in low priority compared to the *chase* skill and thus becomes valid when the infected loses track of the player during *chase* phase. The search by the infected should look unplanned and random while also covering a large amount of area. The search points \[16\] can be anywhere on the navigation mesh and hence the search area scan be of arbitrary size and shape. To solve this *infected-canvas* behaviour was developed as shown in fig \[2\] and the steps are explained below:

1. With the Infected in the center we place a logical grid on the covered area by the *canvas radius*. 
The NPC AI of *The Last of Us*: A case study

Figure 3: The initial vision cone developed for *The Last of Us* which was unable to look at players standing right next to the NPC.

2. Any obstacle that comes in the way and the entire area outside is fixed as seen and the rest of the cells needs to be checked.

3. Multiple possible animations are given to the behaviour by the invoking skills. Location and orientation of the Infected after these animations is looked at.

4. The number of unseen cells is computed for every animation.

5. We play the most desirable animation generally by counting the number of unseen cells and ignore the animations that were played recently.

6. After the completion of the wedges they are marked as seen and the process is repeated from step 3.

4 AI Perception

AI perception is one of the key factors in determining the success of any Game AI. Especially in a game like *The Last of Us* which is heavily based on stealth it’s important to know the position of other characters. The developers initially decided to use Vision Cone which is a very common way of visualising how the enemy sees the world and has been used in games like *The Uncharted* [17] and *Alien: Isolation*. As seen in Fig. 3 using a Vision Cone is very effective in finding player which are at a distance but fails to register player which is at close proximity to the NPC or standing right next to the NPC. This lead to the NPC acting very dumb and unaware of the surrounding which made it easy to full them and lead to the players losing interest in the game. One way to solve this is to have multiple Vision cone similar to the ones used in the *Alien: Isolation* Xenomorph AI [12]. It uses 4 different view cones namely - normal, focused, peripheral and close as seen in Fig. 4(a). The developers of *The Last of Us* came up with an even better and complex form of Vision cone with a simple rule that the angle of view is inversely proportional to the distance between the NPC and the player as seen in the Fig. 4(b).

5 Follow Positions

It’s essential for the Buddy AI, *Ellie*, to follow the player and stay close to him to not be responsible for raising any alerts to the enemy or even if something bad happened it can be related to the players on mistake since they both were close to each other and the player shouldn’t have been that exposed in the first place. To bring this in the game a follow system was developed which generates a number of candidate follow positions which are evaluated for quality. This generation was done by casting raycasts as seen in Fig. 5.
The NPC AI of *The Last of Us*: A case study

![Xenomorph Vision](image1)

(a) Four Vision cone used for the Xenomorph in the *Alien: Isolation* - normal (Blue), focused (Red), peripheral (Green) and close (Pink).

![NPC Vision](image2)

(b) The final complex vision cone used in *The last of Us* which is easily able to see the player in close proximity.

Figure 4: Screenshot from the games showing the companion AIs in (a) *The Last of Us* and (b) *Bioshock: Infinite*

![Pathfinding Raycasts](image3)

Figure 5: Pathfinding raycasts for follow positions (a) for generating candidate positions (b) for checking forward location (c) for checking future position

- First the raycasts are sent from the player to the follow region to make sure of a clear path between the player and the Buddy AI. Every raycast that successfully reaches the follow region is considered as a candidate. See fig. 5(a)
- Secondly new set of rays are shoted forward from every candidate to avoid any walls. See fig. 5(b)
- And finally from the players position rays are cast to each forward position to ensure obstacle free-movement. See fig. 5(c)

6 Cover and Posts

*The Last of Us* is a cover-based TPS [18] and the main focus is on stealth based attacking and strategising each move. For the AI to look and feel human-like it’s a very important decision of where to stand or take cover and is a fairly complex problem. For establishing proper covers we first need to recognise a set of potential locations which we’ll call *posts*. There are two different kind of *posts* - cover and open. The cover *posts* were formed around the NPC’s location while the open posts were around the player. Each NPC would be assigned 20 cover *posts* and in each frame 160 raycasts were thrown to them. The *posts* where every ray was rejected out of the 4 were rejected as shown in Fig. 6. The posts an NPC should use would be determined by different criterion written in LISP [19] using *post selectors*. After the development of the game there were 17 different *post selectors* with the most important one being *ai-criterion-static-pathfind-not-near-player* [20]. This was used when the path to the post required the human enemy to cross the player as shown in Fig. 7. This wouldn’t make sense and will lead to the player easily killing the human enemy and making the difficulty easier. Each of the criterion would give some value in float numbers and the product of the criteria for a given post selector and a given post in a value which would be used as the rating for that post. Then all the *posts* would be ranked accordingly and the one with the highest score would be chosen for that NPC as shown in Fig. 8.
The NPC AI of *The Last of Us*: A case study

Figure 6: Raycasts being generated for coverposts.

Figure 7: Some of the best cover could have a path which leads to the player before reaching the cover.

Figure 8: Ranking for each posts calculated based on AI criterion written in LISP.
7 Conclusion

The Last of Us was a complete success and received love from the players mostly because of how close to reality the game tried to go thanks to it’s AI. The game was in a sense first of it’s kind where the difficulty of the game didn’t lie in making the characters hard to kill but by increasing the co-ordination between the NPCs and thus increasing the intelligence in the game characters. Through the AI used in Ellie the players were able to create an actual relationship with her and each and every gesture performed by her made a meaning to the player. This leads us to question what we consider as human-like and can we make a companion AI in video games that will feel like an actual human being. The level of determination that the developers of The Last of Us went to can be seen when they talk about "her personal space" and "her choices" in one of the papers they have written on the character. The developers also avoided cheating in most ways with things like only using Teleportation when extremely necessary and in a way that the player don’t realize makes us understand that why the game feels so engaging to the players.

References

[1] Naughty Dog. The last of us. *Sony Computer Entertainment*, 2013.
[2] hrej.cz. The last of us. URL https://hrej.cz/article/the-last-of-us-3
[3] Václav Rybář. The last of us - recenze, Jun 2013. URL https://games.tiscali.cz/recenze/the-last-of-us-recenze-225826
[4] iDNES.cz. Recenze: The last of us je, Jun 2013. URL https://www.idnes.cz/hry/recenze/the-last-of-us-recenze-A130605_094544_bw-ps3-recenze_vdp
[5] Michael Harradence. The last of us is metacritic users’ game of the decade. Jan 2020.
[6] Chelsea Stark. The creepy, real science behind ‘the last of us’, Mar 2022. URL https://mashable.com/archive/the-last-of-us
[7] Harry C Evans and Robert A Samson. Cordyceps species and their anamorphs pathogenic on ants (formicidae) in tropical forest ecosystems i. the cephalotes (myrmicinae) complex. *Transactions of the British Mycological Society*, 79(3):431–453, 1982.
[8] Nigel L Hywel-Jones. Cordyceps myrmecophila-like fungi infecting ants in the leaf litter of tropical forest in thailand. *Mycological Research*, 100(5):613–619, 1996.
[9] Jonathan Tremblay and Clark Verbrugge. Adaptive companions in fps games. *FDG*, 13:229–236, 2013.
[10] Christina M. Karns, Mark W. Dow, and Helen J. Neville. Altered cross-modal processing in the primary auditory cortex of congenitally deaf adults: A visual-somatosensory fmri study with a double-flash illusion. *Journal of Neuroscience*, 32(28):9626–9638, 2012. ISSN 0270-6474. doi: 10.1523/JNEUROSCI.6488-11.2012. URL https://www.jneurosci.org/content/32/28/9626
[11] Niall Kitson. Left 4 dead. *Irish Gothic Journal*, (6):76, 2009.
[12] 2020 Tommy ThompsonBloggerMay 20. Revisiting the ai of alien: Isolation, May 2020. URL https://www.gamedeveloper.com/design/revisiting-the-ai-of-alien-isolation
[13] Katharina Emmerich, Patrizia Ring, and Maic Masuch. I’m glad you are on my side: How to design compelling game companions. In *Proceedings of the 2018 Annual Symposium on Computer-Human Interaction in Play, CHI PLAY ’18*, page 141–152, New York, NY, USA, 2018. Association for Computing Machinery. ISBN 9781450356244. doi: 10.1145/3242671.3242709. URL https://doi.org/10.1145/3242671.3242709
[14] 2k. Bioshock-infinite. URL https://2k.com/en-US/game/bioshock-infinite/
[15] Mark Botta. Infected ai in the last of us. In *Game AI Pro 360: Guide to Character Behavior*, pages 1–12. CRC Press, 2019.
[16] R Straatman, A Beij, and W Sterren. Dynamic tactical position evaluation. *AI Game Programming Wisdom*, 3 (5.2):389–403, 2006.
[17] Naughty Dog. *The art of the Uncharted Trilogy*. Dark Horse Comics, 2015.
[18] Max Dyckhoff. Ellie: Buddy ai in the last of us. In *Game AI Pro 360: Guide to Character Behavior*, pages 25–36. CRC Press, 2019.
[19] Guy Steele. *Common LISP: the language*. Elsevier, 1990.
[20] Travis McIntosh. Human enemy ai in the last of us. *Game AI Pro 2: Collected Wisdom of Game AI Professionals*, page 419, 2015.