Modelling Player Combat Behaviour for NPC Imitation and Combat Awareness Analysis

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***Abstract*—NPC [non-player characters] have progressed over the past two decades, they fulfil a number of different roles, each with different problems and development techniques. When fulfilling the role typically reserved for human-players, a problem occurs because they can be identified as NPC by observing their gameplay behaviours. This has negative consequences when deployed in a team-based game where eliminations impact game objectives. This research investigates the key combat characteristics exhibited by players during certain scenarios, analysing the data acquired through experiments to determine where generalised patterns emerge. It also explores the combat awareness of players when NPCs have overly tuned combat skill, and determine how effective standard game industry techniques are for creating believable NPCs.**

Keywords—NPC; Player Modelling; Gaming; Behaviour; Gameplay

I. Introduction

This paper explores the combat behaviour of human players in a FPS [first person shooter] game, and to determine what elements of their combat can be modelled for NPC [non-player character] imitation. It also examines how much combat awareness players have when NPCs are not modelled to imitate human behaviours.

This paper details two experiments, Firstly, an experiment was undertaken to capture how subjects reacted to common FPS combat situations, these range from suddenly appearing targets to varying target size. The second experiment focuses on the combat perception of NPCs when modelled using current standard techniques; those commonly used in the games industry, with emphasis on fast reaction speed and accuracy.

These experiments help show that players exhibit generalised patterns of behaviour that can be modelled in NPCs to imitate human players, this would present a novel approach to NPC development. It also highlights the potential impact of poorly modelled NPCs and when NPCs fulfil a player role, when they do not exhibit the same behaviours as players, it has negative effect on immersion and entertainment.

II. Background

A. Non-Player Character

Non-player characters have been an important aspect of gaming since the birth of the video game industry; they fulfil an array of different roles and are an important entity for most video games. In the FPS genre, enemy NPCs often fulfil one of the following roles;

- Boss: These NPCs have a variety of mechanics and tactics; they should present a challenging experience and have a prominent presence in the title.
- Elite Mobs: These NPCs are strong enemies that require more attention than trash mobs and often have more health and/or strong weapons.
- Trash Mobs: These NPCs are the most frequent type of enemy; they are individually the weakest category of enemy in the title.

The purpose of an NPC in a title can vary, but generally they can only fulfil one of the following stances toward the player at a given time;

- Friendly: When an NPC is friendly, this often means they are an ally and a non-threat.
- Neutral: An NPC with a neutral stance will not attack the player unless attacked or some in-game situation causes a change.
- Enemy: An enemy is an NPC that will attack the player and are seen as a threat.

Finally, there are NPCs that fulfil the role normally reserved for a human-player; these NPCs are expected to provide the same amount of challenge that is experienced when playing against human opponents. These NPCs can be employed in team-based games should one side have more players than the other; thus, evening the teams. Other application for these NPCs are for when the player wants to experience the multiplayer game, but does not necessarily want to play against actual human-players, these type of NPCs are often referred as bots.

B. NPC Modelling Techniques

There are a number of common techniques used in the gaming industry for developing the mechanisms necessary for NPCs. Depending on the action of the NPC will in part determine what type of solution will be required;

- A* Algorithm: Traversing the environment is an important function for an NPC, A* algorithm provides heuristic approach for the path finding.
- Finite-State Machine: Ensuring NPCs are actively pursuing an objective, it is important that NPCs can switch between tasks depending on the current situation. FSM [finite-state machines], provide a good solution as the NPC can only occupy one state at a time, and can transition to a new state when the condition requirement is met.
- Scripting: Scripting is a powerful tool for NPCs because scripts can be used to run exclusively for the NPC, they can be used to obtain external data, such as scanning for

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enemies. It can also monitor internal data, for example, keeping track of health and ammunition.

- Behaviour Tree: BT [Behaviour Tree] can be used to model NPC behaviour; they are particularly powerful when creating complex behaviour for decision making. BTs can also be influenced through event-driven mechanisms, this makes BTs a very powerful tool which can be visually illustrated and quickly implemented.

It should be noted that there is a number of techniques for NPC development; with the role they will fulfil influencing which techniques will be most suitable.

C. *Modelling Player Gameplay*

The patterns and combat characteristics of players can be modelled by observing how they react and respond to commonly occurring situations and recording the combat efficiency as the fight unfolds. The core attributes for combat are;

- Reaction Time: This is how long it takes for the player to respond to a situation as it occurs. For example, when an enemy suddenly appears, this can be modelled by timing how long it takes for NPCs to react.
- Accuracy: Combat accuracy is a crucial aspect of combat efficiency because higher the accuracy, the faster they can eliminate the target and it helps determines skill level. Modelling accuracy can be achieved by adjusting the probability to hit the target based on skill and situational data.
- Combat Awareness: While combat awareness is an abstract notion and can be quite vague, it can be modelled by comparing the data variance between difference scenarios which are likely to occur during play. The patterns that emerge could then be used in the model to display situational human-like combat gameplay.

While these combat attributes are important, it is also vital to determine what mechanisms influence these attributes and what affect they have on generalised patterns.

D. *What is Gameplay?*

The term gameplay can be quite ambiguous and so when trying to model gameplay it presents a problem as to what needs to be modelled. Fabricatore [1] describes gameplay as the actions completed by a player as the game unfolds; this is supported by Sedig et al [2] that suggests gameplay is the emergence of experience from the actions of a given player. For the purposes of this paper, gameplay should be extended to include that of NPCs and therefore define gameplay as;

> 'Actions or decisions taken by an entity, within the parameters of the specific game mechanisms and rules'

This statement suggests gameplay is therefore derived from the mechanisms of a game, and the gameplay emerges when actions are performed with the constraints of the rules.

III. MOTIVATION

While NPCs fulfil a vast variety of roles, when tasked with standing in for a human player it is vital they are capable of imitating the general characteristics of a player. When NPCs are easily identified by an opposing human player, they can become the primary focus for the opposition, especially if the combat behaviour of the NPC performance is low or predictable. When there are consequences attached to dying, such as in a death match where the objective is to get more eliminations than your opposition, having a poor performing NPC can impact the overall enjoyment of the game. This presents a unique problem, having a poorly modelled NPC can impact enjoyment, but also having uneven teams can be a negative and unfair experience.

We believe to have an engaging multiplayer experience where NPCs have the capability of fulfilling player roles; they should ideally be indistinguishable from human participants. This type of NPC needs to be flexible in combat behaviour; similarly to how randomly selected players will have random skill levels. They could also have a positive impact on single player experiences as well, because NPCs modelled on the performance of an individual and scaled to match the ability of the player, would provide a more challenging experience.

IV. RELATED RESEARCH

A. *Non-Player Character AI Techniques*

While traditional techniques are often used in the gaming industry, research into applying complex AI [artificial intelligence] techniques have been undertaken. With regards to believability and fulfilling a player role, Pfau et al [3] have explored using deep learning to simulate player behaviour by using DPBM [deep player behaviour modelling]. In this research they applied DPBM by generating an action based off its current state description using a neural network where the weighted choice is based of real-time feedback and previously captured human player gameplay. Their results yielded promising progress with a significant selection of subjects finding the NPCs to be undistinguishable from human players.

Research undertaken by Galvin and Madden [4] focused on using RL [reinforcement learning] to gradually train the NPC to improve its skill, cataloguing the skill in intervals as it is progressing, then enabling the NPC to dynamically select a desired skill level in real-time, which they called the skill experience catalogue. When experimenting with combat behaviour, they successfully created a skill timeline with five milestones; each milestone matched the proficiency of a fixed-strategy opponent with varying skill.

B. *Believability Identification*

Research by Warpefelt [5] stated that NPCs have significantly improved in believability over the past generation; however, further research is required. They developed a matrix called GAM [Game Agent Model]; this builds upon the Carley & Newell fractionation matrix, by categorising NPCs in five levels of social complexity. Their findings show that the higher the complexity the more likely the illusion of believability fails and when an NPC fails to be believable, it can cascade across the GAM.

Hinkkenen et al. [6] created a framework to evaluate the believability of NPCs in a game, using player based perception. They propose that NPCs believability can be reduced to three key aspects, movement, behaviour and animation and by improving these will improve believability. Similar research conducted by Togelius et al. [7] suggest that to evaluate believability in NPCs, it is more accurate to use an external observer, who are impartial to the game, which form the basis for the Turin test for bots.

Kersjes and Spronck [8] argue that using only techniques such as decision trees and finite-state machines is detrimental to believability and that when adding emotion to NPCs it can create more individualistic and diverse NPCs. This is somewhat supported by Hamdy and King [9] who argues that to imitate human players, NPCs must exhibit traits intrinsic to humans, such as, emotion, interpretation and memory, and to use a MARPO-type architecture for modelling NPCs.

C. *NPC Behaviour*

Bakkes et al. research [10] into rapid adaptation AI show that NPCs were able to adapt to current situations by gathering information of its domain and exploiting it accordingly in a case-based system. This enables NPCs to adapt its behaviour based on its opponent by accessing previously stored gameplay samples and then producing a suitable behaviour. They show that in strategy situations, their approach proved effective for enabling NPCs to adapt to its current condition and when combined with scaling difficulty able to define the effectiveness of NPCs.

This is supported by Delatorre et al. [11] who highlight the negative impact of overly difficult NPCs and that their study shows players are more immersed when the rules are unknown. This can be interpreted for NPCs as a whole, and so when NPCs are predictable or overly difficult, it significantly affects the player perception and enjoyment.

V. EXPERIMENTS

In order to accurately model the combat behaviour of human players, a number of experiments were performed to understand some of the parameters of this behaviour. The following section details the combat experiments by having subjects complete a series of scenarios and by playing against NPCs with no dedicated combat modelling. The purpose of the first experiment is to determine if subjects exhibit generalised patterns in their gameplay, and to evaluate the main mechanisms that influence combat behaviour. The second experiment analyses the combat awareness subjects possessed when facing NPCs that were over tuned to have unrealistically fast reactions and accuracy, this will help identify just how observant players are of their opposition and the effects of poorly modelled NPCS.

A. *Experimantal Environment*

All experiments were developed using Unity3D and all subjects were selected anomalously. Subjects were required to download and run the experiment on their system and use their peripherals. After experiment completion, data was sent and stored on an online database.

B. *Combat Experiment*

This experiment consists of four scenarios, each with five stages, as subjects progress through the stages the difficulty increasing by tweaking the constraint.

a) Single Target

This scenario consists of targets spawning individually, the objective is for the subject to move their cursor and left click over the target to eliminate it before it self-destructs (figure 1).

Fig. 1. Single Target Example

The initial self-destruct time was set to 2.5 seconds, with a reduction of 0.5 seconds per stage; in the final stage self-destruct was at 0.5 seconds. This experiment was intended to find the base reaction time to respond to a target suddenly appearing at a random location. The distance between the cursor and target was recorded to account for any effect distance has on time to click.

b) Increasing Spawn Rate

This scenario was designed to simulate the effect of new targets suddenly appearing while one or more targets are still active. The initial spawn rate was set to 1.12 seconds, then as the subjects progress, the spawn timer reduced by 0.225 seconds, with the final stage spawn rate at 0.275 seconds. The targets have a flat 2 second self-destruct time, which does not change throughout the scenario (figure 2).

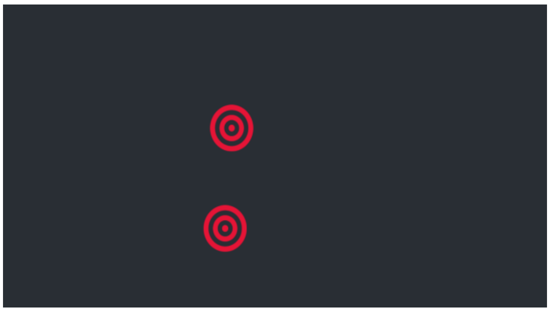

Fig. 2. Increased Spawn Rate Example

The experiment was intended to determine if subjects have targeting sequences and if patterns emerge in their targeting techniques as more targets are present on the screen. This is an important scenario because it is not unusual for new targets to appear during combat.

c) Grouped Targets

This scenario analyses the targeting patterns exhibited when a group of targets spawn at a given time. The initial stage consisted of three target, with an additional two targets added per stage, therefore, the final stage will have eleven targets (figure 3).

Fig. 3. Grouped Targets Example

Targets will self-destruct after 5 seconds, with the time and distance to targets recorded as in previous experiments. Targeting decisions are an essential aspect of combat behaviour, this scenario aims to identify if subjects employ personal techniques to increase efficiency.

d) Varying Size

Size is a crucial aspect of a 3D game, because size can denote distance to the target, this means targets of various sizes are likely to be presented to the player. The initial size is set to 0.6 inches, with the size decreasing by 0.1 inches per stage; the final stage has a size of 0.2 inches (figure 4).

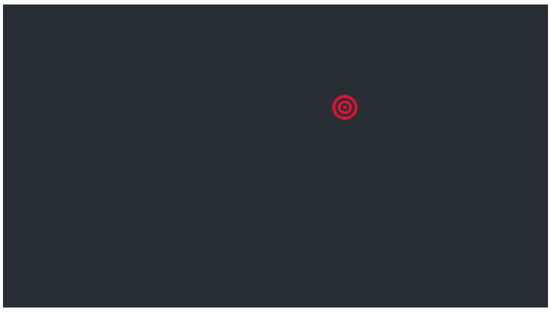

Fig. 4. Size Targets Example

Targets spawn every 2 seconds and have a self-destruct timer of 2 seconds. The scenario will determine if there is a performance drop as the target size decreases, and if size has a detrimental effect to combat efficiency.

C. Combat Awareness

This experiment is a general DM [death match] scenario, there are two NPCs and the winning criteria are to obtain five eliminations before the opponents. The map consists of a large reception area with eleven rooms; there is a slight variance in room sizes (figure 5).

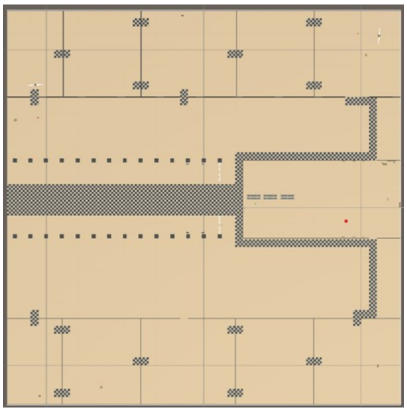

Fig. 5. Increased Spawn Rate Example

There is only one weapon which has one automatic fire mode, jumping has been disabled to simplify the experiment. There are two types of collectables, a medic-pack which increases the players health by 50% and an ammunition-pack which adds one clip worth of ammunition to the players overall stash.

The main purpose of this experiment is to gauge the feedback from subjects with regards to how human-like the NPC combat gameplay appears when using those basic techniques which are commonly employed. Another purpose is to determine to what extent subjects are aware of their opponents combat skill, and what impact this has on overall enjoyment of the experience.

a) NPC

The NPCs were designed to have unrealistic combat skill, they have instant reactions and perfect accuracy, this high degree of performance was chosen to fully evaluate player awareness. NPCs scan for opponents by constantly checking the viewport of the attached camera, it cycles through opponent world position to calculate if the opponent is in front of them, then using 'line casts' to determine if the target can be seen. When the NPC successfully identifies a target, the scanning is paused and the NPC engages in combat, when combat ends the scanning is resumed.

During combat the NPC will only attack when the target is in range and can be seen, they move towards the target when out of range and begin attacking when the range threshold has been crossed. If the target flees out of sight, the NPC will resume scanning and continue to roam the map. Reloading only occurs when the NPCs clip is out of ammunition during combat, or if reloading can be performed when out of combat.

For navigation, a standard slighted weighted A* algorithm was used, with increased cost for walkable nodes close to non-walkable nodes. Figure 6 shows the A* grid (left) and the map (right), the darker the shade of grey the more cost to use the node.

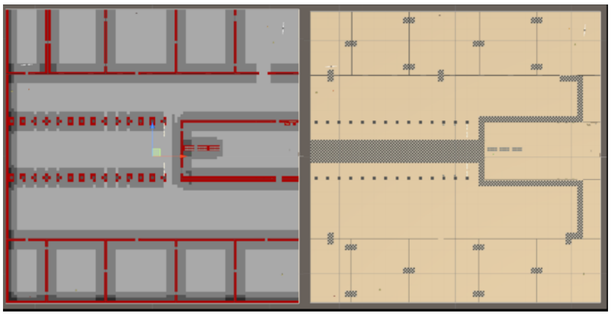

Fig. 6. A* Algorithm Grid and Map

When roaming NPCs create a list of locations they are going to visit, this was done by placing points of interest throughout the map, these points are used to create a list starting with the closest, then closest to the previous item in the list. When all points are in the list the NPCs creates a route to the first item, when a point has been reached, it is removed from the list and a new route is created to the next item. As roaming is the default navigation behaviour, all other activities have higher privilege, when roaming is stopped and then restarted, a new list is created.

Decision-making uses FSM [finite-state machines] with a BT [behaviour tree] philosophy, this was done by giving activities a priority order and transitions to different states can only occur when the behaviour tree is satisfied. The FSM uses a static methodology, transition conditions to other states are always the same, for example, when the NPCs health is below 50%, they will stop roaming and go to a medic-pack location.

An NPC manager was created to enable combat, navigation and decision-making scripts communicate, and to store crucial data about the NPC, such as health.

The NPC also monitored itself and depending on its current situation can cause transitions to a different state, this method of control enabled the NPC to ensure it is always had a state occupied and to perform subtle tasks, for instance reloading.

b) Collectables

Collectables were achieved by attaching a collision box to a game object, the boundary of the collision box was increased so the player does not need to run through the object but pass by very close. When the players collision box intersects with the collectables collision box, a check is performed to determine if they player can use the item and if so the item is destroyed and correct stats added to the player. The collectable respawns 5 seconds after collection in the same place; all collectables have a set location which does not change.

Collectables will only be taken if they can be used and will not increase the maximum health or ammunition of a player. Therefore, if a player has 1 health point missing and they pick up a health-pack they will only receive 1 health point. If a player passing through a collectable that they cannot use, the collectable is not collected or destroyed.

c) Constraints

A series of constraints were added to simplify the process so more focus could be applied to the main objective of the experiment. Jumping can be a key identifier of human-controlled character but they sometimes jump unnecessarily, and as there are no pitfalls in the experiment, jumping is not required.

There is only one weapon, all players start with an assault rifle which has one automatic fire mode, this was decided as it removes the need to balance weapons and combat strength to ensure a fair fight. No scopes were added, but a crosshair was added to help assist subjects as they were effectively shooting off the hip.

d) Environment

The environment of the map is all static and non-interactive, there are no doors and lighting is ambient only. Bullet holes are shown on walls and ceiling, this provides feedback when shots missed their target.

As it was important a smooth experience would yield more accurate results, it was decided limiting the number of non-player to player potential actions would be beneficial.

VI. Results

The results show there is conclusive evidence to suggest that player combat behaviour can be modelled and when NPC combat is modelled poorly, it can have a negative effect for players.

a) Modelling Player Combat Behaviour

The results from the reaction experiments show that patterns do emerge with regards to player combat behaviour, these behaviours could be modelled to develop human-like NPCs. Figure 7 displays the result of the single target experiment, the average reaction time was 0.73 seconds with a standard deviation of 0.42.

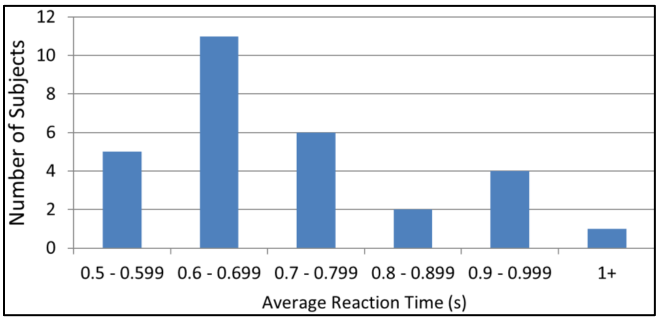

Fig. 7. Single Target Average Reaction Time

While there was some dispersion amongst the individual results, the majority of the successful hits were clustered between 0.6 – 0.8 seconds, this provides a good basis for the average responsiveness for NPC in a model.

When targets were spawning at an increased rate, it had a noticeable effect on reaction time, and suggests that when more targets are in view of the player, it can often have a negative effect on combat efficiency on that player. Figure 8 shows the reaction time for the increased spawn rate, the average reaction time was 0.81 seconds with a standard deviation of 2.83. This is an important behaviour and it could be argued when targets appear during combat, it has a slight effect on reactions because the player needs to factor the new target into their current strategy.

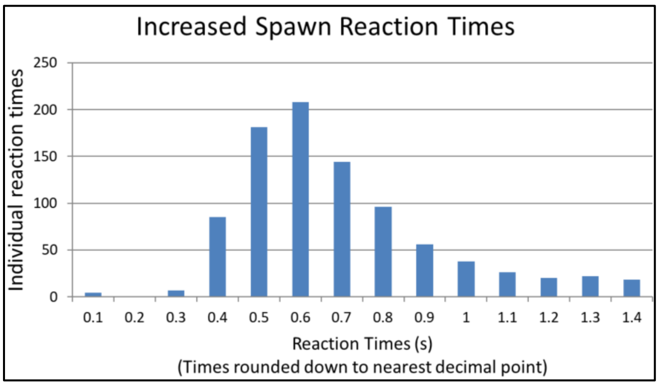

Fig. 8. Increased Spawn Rate Reaction Time

The analysis of the grouped experiment suggest subjects capable of formulating a strategy for attacking the targets, while tactics varied, the majority of the subjects first attacked the targets that spawned to form clusters, and then targeted the solo targets. When comparing the average reaction time between single target and grouped targets, there is a significant difference, there was better efficiency when multiple targets spawn than when they spawned one at a time (figure. 9).

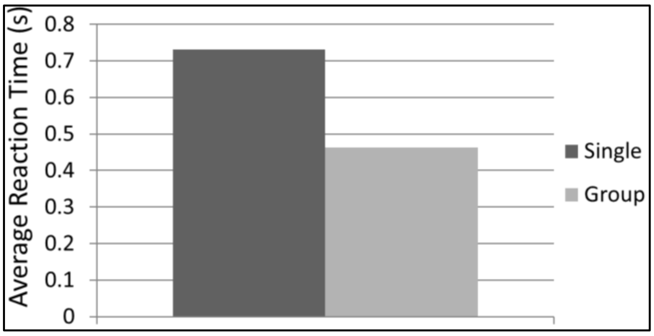

Fig. 9. Comparison Reaction Time

This is an important discovery because it suggests that there is a slight overhead when formulating a response, and that the initial number of targets does not have a noticeable time effect when formulating this response. It is also interesting when comparing with the increased spawning because in that scenario the strategy needed to be frequently updated, this proves that there is some overhead time needed to calculate a strategy.

When evaluating the effect size had on reaction time, there is a noticeable increase in average reaction time as the target got smaller. Figure 10 shows the reactions time of the large target (0.6 inch) and the smallest (0.2 inch), the cluster of results clearly show subjects were able to dispatch the large targets faster than the smaller targets.

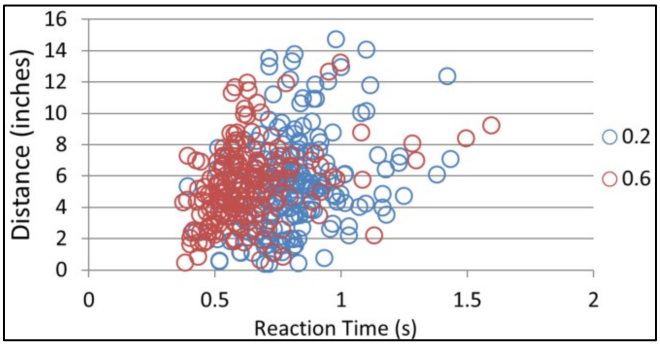

Fig. 10. Size Reaction Time Correlation

The importance of this finding is that it proves precision has an effect on reaction time, and with a difference of 0.19 seconds, which mean it can be modelled. It should also be noted that target distance from cursor did not have a noteworthy effect, and it was precision that the biggest effect. It could also be argued that precision will have an exponential negative effect on reaction time, the smaller the target becomes, the more precise and thus longer it will take to dispatch.

A pattern also emerged when analysing the targeting sequence when multiple targets appeared at separate times, figure 11 highlights the results when three or more targets were present on the screen.

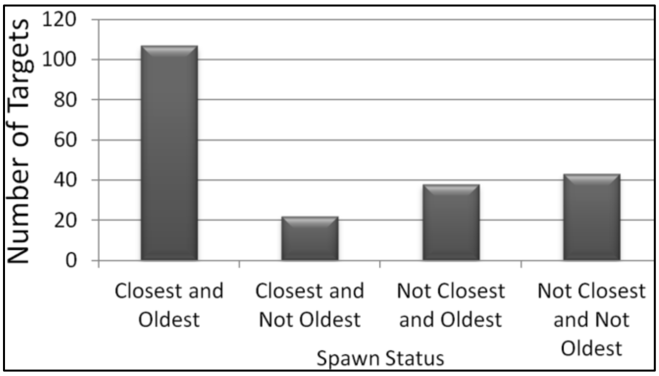

Fig. 11. Three or More Target Sequence

While the majority seem to stick to the strategy of targeting the oldest target, there were some subjects that were target switching as the number of targets grew. This implies flexibility in the combat gameplay for some subjects, and the ability to adapt to changing situations needs to be modelled for NPCs.

Lastly, when analysing the results for missed shots, there was evidence to conclude that when subjects missed a target they responded by rapidly taking more shots. This scatter shot behaviour did not seem to be present during the easier stages, but was more visible in the latter. This further show the adaptiveness of human-players and it is important NPCs are not static in their behaviour but able to employ different tactics when needed.

b) Player Combat Awareness

The results from the combat awareness experiment show a high degree of awareness from subjects, and when NPCs are overly tuned in combat efficiency, it can have a negative effect on enjoyment. Figure 12 shows the general perception of the NPCs in relation to how human-like they appeared.

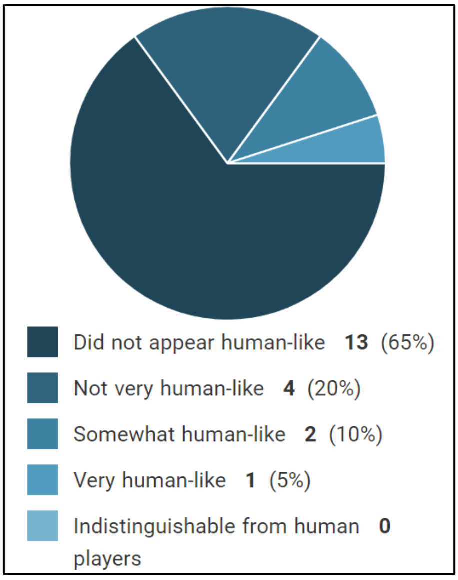

Fig. 12. How human-like did the NPCs appear

The result provides a good indication that when NPCs are not modelled to imitate human-players they can be clearly identified as non-human controlled, despite having the same combat actions available. When evaluating where the combat failed to appear human-like, figure 13 highlights that both reaction speed and accuracy were selected by most subjects. This is interesting because it proves players do have a good understanding of the combat efficiency of their opposition and when this efficiency is higher than usual, it is detected.

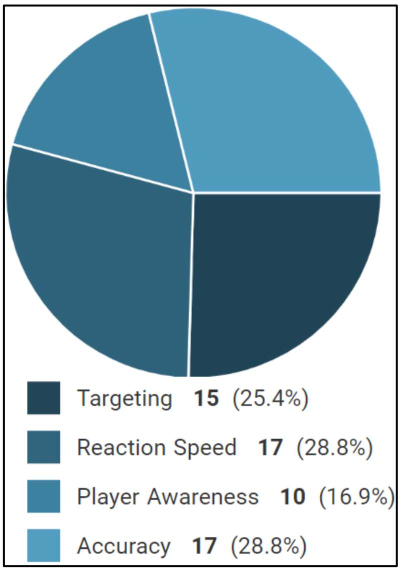

Fig. 13. Combat Awareness Identification

When analysing the feedback of the overly tuned combat efficiency, the general consensus is focused on the fact that the NPCs had perfect aim (figure 14). This supports the claim that players have good perception of combat awareness, and that poorly modelled combat can have a detrimental effect on overall enjoyment.

the aim
Nothing i can think of.
The fact that they never miss even when you strafe the shots
the snapping to me
Their movement system, there was no strategy to it, it seemed to be random
They had perfect aim and response times
Didn't see much movement but was killed as soon as I saw them
the movement around the map was believable
bot accuracy
Bot like accuracy of the NPCs when they are tiny specs on the screen.
Comabat
Movement
Shooting
fast reactions
Everything
fighting

Fig. 14. Combat Awareness Feedback

It should be noted that subjects were aware that they were playing against NPCs, judging by the tone of the feedback, if this combat model was used in a multiplayer title, there could be accusations that cheaters were prevalent in the game, which is expressed in some of the comments. This is a vital discovery because it suggests NPCs that are too skilled have the appearance of cheaters, and the perception of cheaters has a profound negative effect on the game reputation and player entertainment [12].

This survey was necessary because it shows there is a problem when using industry standard techniques for developing NPCs to imitate human players. It shows that players are acutely aware of the combat behaviour of their opponent and when displaying behaviours that are not commonly identified in human players, it influences their opinion of that opponent.

The data acquired from the survey could be used as a guide as to what areas of combat have the biggest impact on believability of the NPC. For example, when modelling the targeting and reaction speed of NPCs, it is imperative that they resemble human players as this perception was identified as a key area where believability failed.

This survey along with the data acquired from the combat experiments could be used to model the core combat attributes for NPCs. For instance, by implementing a skill based attribute, NPCs accuracy and reaction speed could be controlled individually to resemble that of a human player around the same combat skill level.

VII. Conclusion

This paper has shown that there is a quantitative element to generalised player combat efficiency and patterns emerge which can be modelled. Target distance did not have a noticeable effect on reaction time; however, there was an overhead cost for precision which did have a clear effect on reaction time. Subjects exhibited targeting strategies when numerous targets spawned together, and when new targets were spawning before old targets had been dispatched, there was evidence that it had a slight effect on combat efficiency.

Subjects had a clear awareness of the increased NPC combat efficiency; this had a profound negative effect on how human-like the NPC appeared, with the majority of the responses indicating accuracy and reaction time to be the cause. A number of responses also highlighted that the combat efficiency was reminiscent to that of cheating players; this paper believes the impact of overly potent NPC skill could have negative consequences towards overall enjoyment.

VIII. Future Work

While it was clear patterns in combat behaviour emerged, future work needs to be undertaken to model the patterns for NPC development, an analysis completed to determine the effectiveness of the model. Furthermore, combat is one part of gameplay, to provide a complete model; experimentation will be required in navigation and decision-making with the final objective to undertake a Turing-test for bots.

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