

A Comparison of Automatic versus Manual World Alteration for Network Game Latency Compensation

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ABSTRACT

Cloud-based game streaming services add network latency to even single-player games, making them harder to play. World alteration has the potential to mitigate the effects of latency by adjusting the game world to keep the difficulty similar to that with no network delay. This paper presents results from a user study evaluating world alteration as a latency compensation technique. Data from 18 users show world alteration does not totally overcome network latency, but improves performance and quality of experience over an uncompensated game.

CCS CONCEPTS

• **Applied computing** → **Computer games**; • **Human-centered computing** → *User studies*.

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Author's Keywords

Video Games; World Alteration; Latency Compensation

1 INTRODUCTION

In online multiplayer games, game data must travel across networks to servers and other clients – computers that are possibly on the other side of the world – degrading player performance and Quality of Experience (QoE) [10]. High levels of latency can make games feel unresponsive and make it difficult for players to respond fast enough for time-sensitive input.

In order to mitigate the effects latency on QoE, game developers typically use latency compensation techniques [1]. While many such techniques are hidden from the player – e.g., predicting the location of an opponent before getting their input – world alteration [5] explicitly adjusts the game world in the presence of latency. In world alteration, instead of hiding latency, the game is made

easier so that the difficulty is similar to that with no network latency. For example, in a shooting gallery game, the targets could be made larger and/or move more slowly in the presence of latency. Manual world alteration has long been present in non-networked, single player games in the form of difficulty adjustments – e.g., easy, medium, hard – where a player can choose the setting whereupon the game automatically adjusts the game world to fit the chosen difficulty level.

However, world alteration can be difficult to implement, and even inappropriate, in a multiplayer network game since players with different latencies would see the different world adjustments, even if the world was shared by all. But the emergence of cloud-based game streaming services (e.g., Google Stadia [8]) means that even single player games are affected by network latency – all player input needs to travel back and forth from the client to the cloud-based server – and this provides an opportunity for an effective use of world alteration.

This paper presents an evaluation of world alteration on a game with latency, specifically measuring player performance and QoE both with and without world alteration. Two methods of world alteration are explored: automatic, where the game adjusts the game world based on measured network latency, and manual, where the player adjusts the game world in response to latency, similar to difficulty settings (easy, medium, hard) common in many single-player games. We modified an open source version [12] of the game Flappy Bird [2] to: 1) incorporate our latency compensation techniques, 2) emulate a cloud-based streaming version of the game by controlling the amount of latency the player experiences, and 3) record player game data and administer QoE surveys during experimentation.

A user study with 18 participants provided performance and QoE data on the impact of manual and automatic world alteration. Analysis of the data shows that while world alteration does not provide for an experience akin to that of no network latency, both manual and automatic world alteration do improve player performance (up to 8x) and provide a better QoE (about +10%), on average.

This work represents the first step in our goal of incorporating world alteration as a latency compensation technique not just for a single game, but rather as a technology supported by a game engine (e.g., UE4) in order to make it available to game designers.

This rest of this paper is organized as follows: Section 2 describes related research; Section 3 details our methodology; Section 4 analyzes our user study results; and Section 5 summarizes our conclusions and possible future work.

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2 RELATED WORK

Even small delays have been known to degrade player QoE [4]. Chang et al. [6] found latency had a negative effect on a game’s QoE, but that effect could be mitigated through compensation.

Methods to combat network latency have often incorporated manipulation of the game world, either predicting object positions or rolling back virtual time to previous states [1]. Many compensation techniques have drawbacks, such as adding additional computation overhead or sacrificing consistency for responsiveness, prompting other techniques to mitigate some drawbacks [6, 7].

Experiments show a latency compensation technique that does not hide latency, as is the case with world alteration, can still improve QoE [11]. In this vein, other work [5] explores the potential for world alteration to compensate for latency. While their work focused on the objective scores players achieved with world alteration, our work evaluates the effect world alteration has on performance and QoE.

3 METHODOLOGY

3.1 Flappy Bird

We chose Flappy Bird as the game for our study. In Flappy Bird [2], the player tries to steer a bird through a series of openings narrowed with pipes by flapping the bird’s wings at the appropriate time. The game ends when the bird crashes into the pipes or the ground. The player’s score is based on how far the bird flies before crashing. The gameplay in Flappy Bird is simple, so readily learned by users for our study. Moreover, the game action is time-sensitive and so is affected by latency.

3.2 Modifications

We modified a Python-based FlapPy Bird [12]¹ for our user studies. Four major modifications were made to study world alteration: 1) Network latency was emulated by adding a controlled amount of delay before applying a button press; 2) World alteration was enabled by changing the strength of gravity, the power of the flapping wings and the size of the gaps between the pipes. The gap size was chosen to reduce the accuracy needed to proceed through the game, and the strength of flapping and gravity were chosen to require fewer actions per second; 3) Automatic latency compensation was added to do world alteration based on the latency, and manual latency compensation was added to allow the user to manually specify one of 5 levels of difficulty; and 4) automated data collection was put in to record player scores and input events, as well as the test configurations for each game (i.e., added latency and compensation method - automatic, manual or none).

3.3 Pilot Studies

Pilot studies were done to first ascertain a range of latencies for testing that had noticeable impact on gameplay without compensation and are readily encountered in real-world networking environments [3]: 10ms, 100ms, 200ms, and 400ms. Then, additional pilot studies were done to tune the world alternation settings so as to keep the game difficulty with latency comparable to the game without latency. We played many games of the unaltered FlapPy

¹With an MIT license.

Table 1: World alteration by latency amount.

Latency	Gravity Power	Flap Power	Gap Size	Gap (in)
10 ms	100%	100%	100%	1.3
100 ms	80%	89%	110%	1.4
200 ms	75%	80%	130%	1.7
400 ms	60%	72%	200%	2.6
Manual	40%	67%	240%	3.1

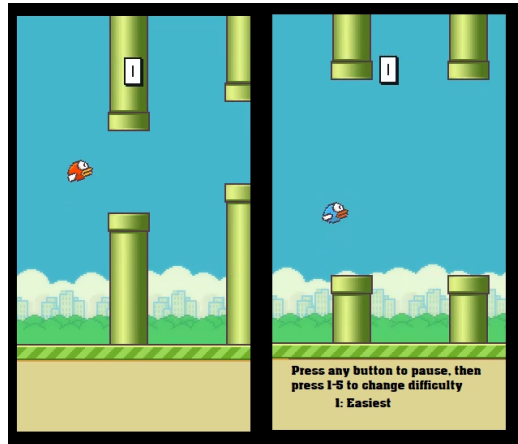


Figure 1: FlaPy Bird with minimal latency (left) and starting manual settings (right).

Bird to get an average score, then repeatedly played FlapPy Bird with different world alteration adjustments until the average score for each latency chosen was within one point (about 5%) of the unaltered game.

Table 1 shows the final world alterations used. Each row shows the game settings given the latency, with the last row showing the initial settings when manual world alteration is enabled. The final two columns are corresponding measurements based on a 15.5" screen at 1920x1080 resolution.

Figure 1 shows two screenshots of the modified FlaPy Bird, with the left side with minimal latency and the right side with the initial manual difficult setting.

3.4 Surveys

In-game surveys were used to assess QoE, provided only once for each (compensation, latency condition). Users rated four aspects of the previous game on a scale from 1-low to 5-high:

- (1) How challenging was it to play this version of Flappy Bird?
- (2) How much of an impact did latency have on your gameplay?
- (3) How difficult was it to get into a rhythm while playing?
- (4) How enjoyable was it to play this version of the game?

QoE was assessed from the fourth question, though other questions were also analyzed [9].

A post-game demographic survey ascertained age, gender, game-play habits and game experience. The exact text can be found online.²

3.5 Test Procedure

Participants were first given a brief verbal explanation of the test and signed an informed consent form. They were verbally informed that some games would allow them to control the difficulty of the game, and received in-game notifications when those games were played. The first three games of FlapPy Bird were unaltered in order for participants to become acclimated to the game. After that, the participants played through 12 versions of the game (4 different latencies, 3 latency compensation configurations) in a random order, with each version encountered three times. Mid-game surveys were administered after the second playthrough of each compensation-latency combination. Post-game surveys were administered at the end of the final game.

3.6 Testing Locations

The first 12 users all tested in dedicated computer labs on campus, with hardware more than adequate to support the game. Due to the COVID-19 outbreak, the 6 subsequent users were tested in their homes without a test proctor.

4 RESULTS

We had 18 users participate in our study. The sample skewed young and male – 12 males and 6 females, 10 users under the age of 21 – similar to the demographics of our home university. Most were gamers, with 67% reporting playing games more than 6 hours a week on average. 83% had played the original Flappy Bird [2] previously. There was a positive relationship between playtime and score, with median scores for those that played games for 12+ hours per week about twice as high as those that played for only 3-5 hours per week.

4.1 Player Performance

Figure 2 shows the average score (y-axis) versus the added latency (x-axis). The none, automatic and manual modes are grouped, with each point connected by a line representing the mean for that group, shown with 80% confidence intervals. Visually, the manual compensation modes had much higher performance, likely attributable to the default setting that was as easy as possible and the fact that often (35% of the time) users did not change the game from this setting. The automatic latency compensation modes are generally higher than the non-compensated modes.

4.2 QoE

Figure 3 shows the QoE versus added latency. The none, automatic and manual modes are again grouped, with the same colors as in Figure 3. Each point connected by a line is the mean for that group, shown with 80% confidence intervals. From the graph, there is a downward trend in QoE with an increase in latency but no clear difference in QoE for the compensation methods. The games with no added latency had an average user rating of 3.4, while games

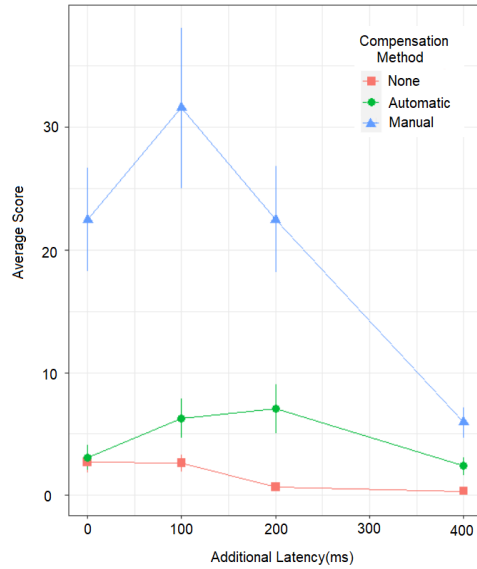


Figure 2: Score versus latency, grouped by latency compensation.

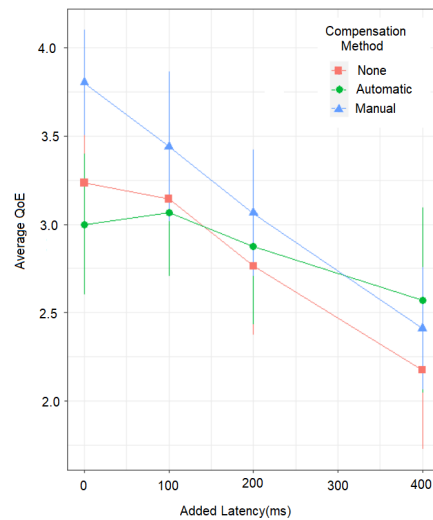


Figure 3: QoE versus latency, grouped by compensation method.

with automatic compensation had an average of 2.85 and manual compensation had an average of 2.9. According to ANOVA tests [F(2,140)=0.615, p=0.542], there was no statistically significant QoE difference between the compensation methods.

4.3 Summary Results

Figure 4 summarizes the QoE and player performance in one graph. The x-axis is the average score and the y-axis is the average QoE. Each point is a latency and game mode combination, with both QoE and score averaged across all users. The horizontal and vertical

²<https://web.cs.wpi.edu/~claypool/ms/world-alteration/>

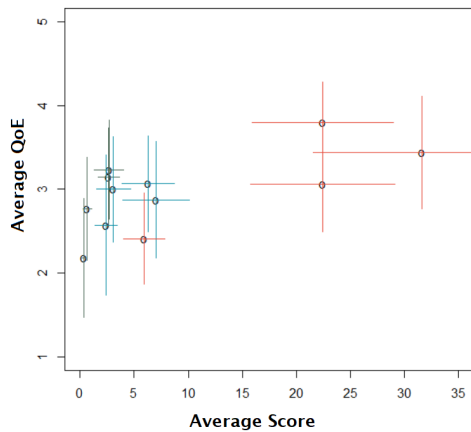


Figure 4: QoE versus score.

bars around each point are 95% confidence intervals. The manual compensation points are all on the right side, owing to the easier mode that was the default. Visually, there appears to be a positive relationship between QoE and performance, and statistically, the correlation is moderate $r = 0.64$.

5 CONCLUSION

The growth in cloud-based streaming game systems bring the challenge of latency but opportunities for new latency compensation

techniques. World alteration is one such technique. In world alteration, the game world is adjusted to make the game easier to play in response to latency.

This paper evaluates the potential benefits of world alteration by comparing no compensation to automatic world alteration – adjusting the world without user input – and manual world alteration – where the user can change the game difficulty. This study focused on the effect world alteration had on QoE, a previously unexplored aspect of the compensation technique. A 18-person user study provided data comparing player performance and QoE for the three compensation cases across 4 latencies.

The results show that while all compensation methods are still affected by latency, world alteration reduces the latency impact by about 50% on average. Users perform much better in manual world alteration because they can set and keep the game at the easiest setting; however, automatic world alteration also improves performance over no compensation. There is a positive correlation between player performance and QoE, suggesting the benefits to world alteration in keeping the game from being too difficult in the presence of latency.

Future work is to continue evaluation with more users, perhaps with broader demographics that better represents gamers. The work is also the first step in a research agenda to support world alteration in a game engine (e.g., UE4), allowing game designers to enable world alteration for cloud-based games by specifying what parameters of the world should be scaled with latency.

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