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Investigating a Level Of Detail-technique for crowd simulators

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Abstract

Crowd Simulators are used to see how large virtual crowds behave. They are mostly used to simulate crowd behaviors. One of the constraints with crowd simulators is the level of detail that should be used to still have a realistic simulation. This thesis explores the idea of using imposters as a method of lowering the level of detail. Imposters are 3D-models in a scene that are only rendered as two-dimensional objects when they are far enough from the camera. The general problem statement of this thesis is to see how well people can differentiate between 3D-models and imposters. This is tested with the underlying problem how presentation affects how one interpret imposters. Presentation is tested in regards to the distance the camera have from the imposter and from what angle you look at imposters from. Using Unity 3D, an implementation of imposters was created that can capture an imposter, render an imposter and make the imposter move in different camera angles. A user study was conducted to test how well this implementation works in regard to presentation. The study consisted of several movie clips showing an imposter and its original model walking down a road. Users had to push a button when they saw through the imposter. From the user study, it was shown that distance from the camera do affect how one sees an imposter. Almost all of the other factors does not have a significant difference from each other. Users attest to that they were specifically looking for any visual artifacts and aliasing in the imposter to find any faults in them. It would have been interesting to try this implementation in a real crowd simulator. It would help to enable using other camera angles as factors to have more extreme cases to compare to. The recommendation is to try to not use imposters outside of crowd simulators, as it is too easy to see a difference between imposters and their models if the imposter is too close.

Sammanfattning

Simulatorer av folkmassor används för att se hur stora virtuella folkmassor beter sig. De används främst för att testa hur folk beter sig i verkligheten. En av begränsningarna med denna typ av simulatorer är att kunna välja hur mycket detaljer man vill begränsa i scenen. Simulationen måste gå fort men samtidigt bibehålla realismen. Detta arbete har utforskat imposters som metod för att sänka detaljer i scener. Imposters är 3D-modeller som renderas som tvådimensionella objekt när de är tillräckligt långt bort ifrån kameran. Det generella problemet som presenteras i denna rapport är att se hur väl man kan se skillnad mellan 3d-modeller och imposters. Detta testas med det underliggande problemet, hur det påverkar presentationen av imposter hur man tolkar dessa. Tolkningsfaktorer är hur långt ifrån kameran är från imposters samt vilken vinkel man ser imposters från. Studien gick till så att användare tittade på ett antal klipp som visar en imposter och dess normala modell som går på en väg. Användare skulle trycka på en knapp när de trodde de såg igenom impostern. Resultatet från studien visar att avståndet från kameran påverkar hur man synar en imposter. Nästan alla andra faktorer har ingen signifikant skillnad mellan varandra. Användare menar att de tittade specifikt efter visuella bieffekter (så som aliasing och visual artifacts) för att se några fel i imposters. Det hade varit intressant att testa denna implementation i en äkta simulator för folkmassor. Detta hade kunnat göra så flera andra kameravinklar hade kunnat användas som faktorer, något som hade skapat mer extrema fall att jämföra med. Rapportens rekommendation är att inte använda imposters utanför simulatorer av folkmassor, då det är för enkelt att se skillnaden på en imposter och dess modell om impostern är för nära.

Contents

Chapter 1

Introduction

1.1 Background

Crowd simulators are computer programs made to simulate how a crowd is acting. Simulating large and dense crowds is important. In entertainment, a large crowd that acts realistically can help give life to a scene. For research, simulating crowds can be valuable in understanding how people in a social environment are acting in different situations.

There has however been a long running problem of understanding how to run crowd simulations as realistic as possible. Previous research has been focusing on different methods used to improve simulations, for example by trying to make a crowd seem more realistic by making them move in crowds [1]. However, there is a problem. Making realistic crowd simulators demands heavy computing power.

One of the problems is that rendering every single virtual character in the scene is time consuming if we have to render a 3D model for all virtual characters. One of these solutions are Level of detail (LOD) techniques. Different types of LOD is commonly used to be able to have a realistic environment that also runs smoothly [4]. The main problem is to find methods to lower the LOD of the simulation without affecting the usability of the simulation.

One way to lowering LOD is the use of so called imposters. These are less important virtual characters that are rendered as 2D-textures while still looking like a real model. This process is detailed [3] into two steps. The first step is to capture images for the imposter to have as many images from as many angles as possible to use. The second step is rendering the imposter, where you by using different types of projection methods render the 2D-texture in such a way that it looks like 3D.

1.2 Problem statement

Imposters as a LOD-technique only works as long as the user is not able to see through the illusion. Therefore, it would be interesting to understand how well imposters as a method work. This in regards with comparing how well it works against the 3D-base model and how different presentation and factors affects the imposter. The aim of the article is to investigate how users can detect any faults in an imposter. It is about comparing the factors that could be affecting the visual appearance of an imposter. The goal of the article is to
answer this problem statement:

To what degree can people see the difference between an imposter character and its 3D model?

This is the general problem statement. This is significant because this gives an indication on how well imposters work as a LOD-technique. Seeing as this is something that have already been tested and implemented before, this question is focusing more on confirming this.

To be able to answer the general question, three more detailed problem statements are used to support it:

Does the presentation of the imposters affect how users interpret them?

This is important because if the presentation does not affect the interpretation of an imposter, then it should lead to it being much harder to differentiate imposters from their models.

The other two questions focuses on how you present imposters:

1. Does the resolution affect how users interpret imposters?

2. Does the camera placement, in regard to distance from the imposter and the angle shown, affect how user interpret imposters?

To have some way of testing presentation, these factors were decided to be tested in regard to how one would present imposters. Each of the questions will be answered by analyzing the results from a user study.

1.3 Overview of the thesis

This article will start by introducing earlier attempts to use imposters in crowd simulators, with imposters and clones being specified. Then, details about the process of designing the system for the imposters will be presented. First this will be done by going into detail about the process of capturing and rendering an imposter. Then by explaining how the evaluation of the system will be handled. This is done by explaining about the user study that was conducted to help answer the research question. Next, the results of the evaluation will be presented, before going into a discussion about the results. The report will then end with a conclusion to summarize the most important parts of the article.

Chapter 2

State of the art

This chapter is meant to present some of the earlier research that has been done. The main focus is how imposters are being used today and some examples of how crowd simulators work.

2.1 Imposters and clones

2.1.1 Imposters as a LOD-technique

The idea of using imposters is that you take 'snapshots' of the model and put them in an 'image cache' that keeps track of the current picture of the model that is used by the imposter. If you need a new motion, you only need to take a new snapshot. One upside of this being that you are able to manipulate the 2D-object using 2D transformations. [2]

There are several problems with the visibility of the objects. Issues with popping effects, for example where body parts do not connect well together for one frame, before fixing itself the next. There are a few solutions to this, one is skipping frames where objects collide with each other. Another is to check the depth of the objects. Another problem is that if the simulation miss details in the animations, the animation can look sluggish and ruin the realism.

2.1.2 Implementation of imposter

One approach of implementation is brought forward by switching between the two rendering techniques using a "pixel to texel" ratio. [3] The algorithm for how this works is explained next.

- Generate the image
  - Generate images from 17 by 8 camera viewpoints.
  - Encode the imposters detail image by setting specific alpha-values at each pixel, which allows for variety
  - For a set frame of animation, put every image into a single image, one for each key frame in an animation
- Switch between virtual characters with imposters
  - Calculate an imposters image's pixel size with (2.1)
  - Calculate an imposters 'texel-size' (TEXtured ELement, the measurement for texture mapped 3D objects) with (2.2)
  - Calculate a 'switch' threshold value, that checks if the aliasing of the imposter is too much (mean when the texel size is greater than the pixel size) with (2.3)
- Implement a shader for the imposter
  - Calculate the light vector for a set vertex using (2.4)
  - Use the light vector with the mapped imposter to generate how it should look
- Add color to an imposter
  - Using the shaded map, use the alpha values to generate a color map that can be used to match the outfit of the character using (2.5)

$$Pixel_{size} = \frac{tan^{-1}(\theta/2) * 2 * d_{cam}}{x} \tag{2.1}$$

$$Texel_{size} = \frac{2 * d_{nearplane} * tan^{-1}(\theta/2)}{x} \tag{2.2}$$

$$d_{switch} = \frac{d_{nearplane} * Texel_{size}}{Pixel_{size}} \tag{2.3}$$

$$\begin{aligned} Vertex_{color} = Ambient_{LightModel} * Ambient_{Material} + \\ MAX((Vector_{light} \cdot Normal_{Vertex}), 0) \\ * Diffuse_{light} * Diffuse_{Material} \end{aligned} \tag{2.4}$$

$$\begin{aligned}Pixel_{Color} = {} & Ambient_{LightModel} * Ambient_{Material} + \\ & MAX((Vector_{light} \cdot Normal_{Map}), 0) \\ & * Color_{map} * Diffuse_{light} * ImposterDetail_{Map}\end{aligned} \tag{2.5}$$

2.1.3 Clones in a crowd

One way to use imposters is to easily make a lot of clones in a crowd. It is possible to use a lot of clones that have the same appearances or using the same motion capture to save memory, but with the drawback of breaking the illusion if it is too easy to distinguish the clones. A user study shows that it is easier to distinguish clones who uses the same clothes or model and harder to see those who use the same motion captured animations. [5]

2.2 Crowd simulators

While the aim is not to create a crowd simulator, there are a lot of different optimization methods being research. Some of the more interesting ones are presented here.

2.2.1 Unilateral Incompressibility

One of the methods used for path finding in crowd simulators is unilateral incompressibility (UIC), making the crowd as a whole move and behave like a sort of liquid. This algorithm lets the simulation run a large number of virtual characters at once [6].

2.2.2 Groups in crowds

The idea of pedestrians walking together in groups is normal in a social setting, but could be something that is easy to miss in a simulation. Creating a group consist of making a navigational system that is based on a two-level method, one group agent and one pedestrian agent [1].

They are able to navigate a group of virtual characters through the environment and make them react to objects like street crossings.

Using these two ideas, it was shown [7] that it is possible to make characters in a crowd to walk within groups. This was to show how it changed the performance of the simulation, but also to see how realistic groups in a simulated crowd looks. Groups ended up being a small constraint on the performance. A user study was conducted that showed that if a crowd is compact enough, it will make it harder to see groups.

Chapter 3

Method

3.1 Implementation

To create the different parts for the system, Unity 3D was used. Unity is a game engine mainly used for development of 3D and 2D video games and simulations.

Based on earlier research [3], the implementation of the system is divided into two parts.

3.1.1 Capturing

A system that captures images of a 3D-model was written. These images are 2D-textures showing the model from different angles.

For the capture, a virtual camera is used to take snapshots of the model from different angles. For each angle, a whole animation cycle is captured. This is done by taking one snapshot of each key frame in the animation. For sake of simplification, the implementation is using 32 viewpoints around the model ($360°$ around the model) and 9 viewpoint angled downwards ($90°$ upwards).

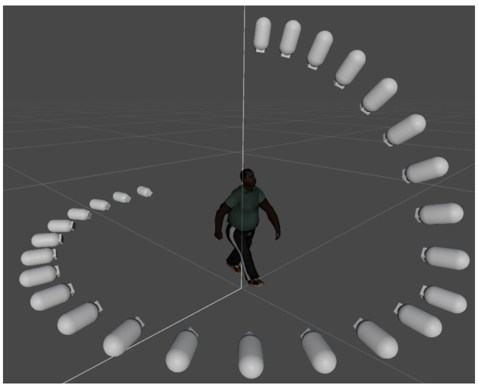

Figure 3.1: Visualization of where the camera position for the capture camera would be in two different axes. 17 viewpoint are used in this example.

(see Figure 3.1) This is to make sure that mirroring the image will not be an issue. All of these images can later be used for rendering the imposter.

To sort through all the viewpoints for each of the 10 frames of animation, a classification system for each captured image was created. Each frame of animation is given two angle based on what angle the snapshot was from. This is then saved into memory for later use. This made it possible to get the specific image by using the correct angle as input.

3.1.2 Rendering

A system for rendition of the scene was created. This system has two parts. First, there was a need to preload all of the images captured from the last process. Next, a quad is used to show the current texture. The quad is rotated to always be facing the main camera. Based on where in the animation cycle the imposter is and what angle the user is looking at the imposter from, the corresponding image of that angle is shown. These two parts together are able to choose what texture to show for the user in runtime. (see Figure 3.2)

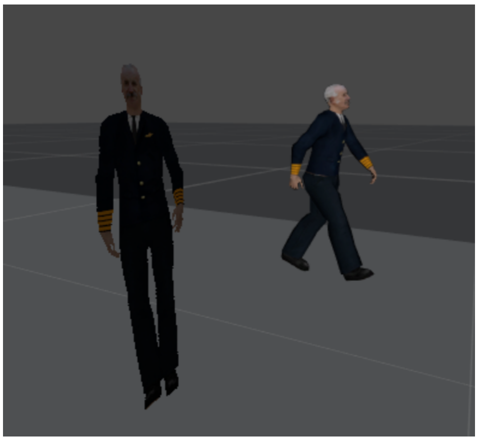

Figure 3.2: Example of a render from another angle. The imposter is rotated towards the main camera.

Not everything from the original implementation was created. No part of this implementation considers if it should render a model or an imposter, like how it should behave in a crowd simulator. The only focus was to determine what angle we are looking from and what part of the animation is playing.

3.2 Evaluation

To help answering the research question, a user study was conducted to be able to test the implementation. The user study was formed as a within-subjects study to be able to compare factors to each other.

3.2.1 Participants

There were 10 participants (6 male, 4 female) in this study. They were in the age span of 19-30 years. All of the participants were students. The majority of them were from KTH. They were asked to be part of the study by word of mouth or by filling in a time slot in a poll.

3.2.2 Stimuli

Variations		
Screen Resolution	Distance from camera	Camera Position
Low(1000x576)	Close to cam	In front of cam
Low(1000x576)	Close to cam	At 45° angle above
Low(1000x576)	Close to cam	At 45° angle to side
Low(1000x576)	Far from cam	In front of cam
Low(1000x576)	Far from cam	At 45° angle above
Low(1000x576)	Far from cam	At 45° angle to side
High(1920x1040)	Close to cam	In front of cam
High(1920x1040)	Close to cam	At 45° angle above
High(1920x1040)	Close to cam	At 45° angle to side
High(1920x1040)	Far from cam	In front of cam
High(1920x1040)	Far from cam	At 45° angle above
High(1920x1040)	Far from cam	At 45° angle to side

Table 3.1: All of the variations of stimuli that is shown to the user.

The stimuli is based on the scenario of an imposter and its model walking down a path. It consisted of clips with the variation in table 3.1. They are meant to showcase different types of factors that could be affecting how the user could differentiate between models and imposters. Each clip ranges from 10 seconds to 30 second, depending on if the models are far away from the camera or not (see figure 3.3).

Figure 3.3: The six different variations. From left to right, angle above, in front and to the right.

Figure 3.4: The actors used in the clips.

To minimize the risk of recognizing any patterns in visual artifacts, each clip uses a set of 6 different actors. Each actor is randomized throughout the clips. Each of the clips also randomizes which position the model and the imposter is in (see figure 3.4).

3.2.3 Task

The participants were asked to watch the presented clips. For each clip, the task was to determine which models was of lower quality. The participants would choose the lower quality model by pressing a corresponding key. This would then show a new clip.

To be able to conduct a within-subjects study, the clips were ordered with resolution as the outer factor. The first clips presented were all of the clips for the low resolution, then all the clips for high resolution.

After every single clip was shown, the participants were asked what they were thinking was of lower quality in the imposter.

The recordings were presented using 6 different permutations for each of the resolutions. This lets the user look through 36 different clips of the actors walking. There was a risk with this. The user could get used to look for a specific pattern throughout the study. To minimize this risk, each clip both randomized the position of the models and had a randomly chosen actor presented.

3.2.4 Procedure

Each participant was welcomed to the computer lab. They got to fill in a questionnaire (See appendix A) to give some basic information about them. This consent also was detailing the moral aspect of this study, as everyone had to give consent to be part of the study. Essentially, it was detailing that the study is anonymous and voluntary for the participants. Next, they got some time to read the instructions (See B) for the task. They got some time to ask any questions they had before starting. Then they got to watch all of the clips. The sequence was randomized beforehand. Each clip was presented in 6 different permutations. Finally, the participants got an explanation to what an imposter was before asking the last questions about quality.

3.3 Hypotheses

The research question focuses on how presenting the imposter can affect how you view the imposter. To connect the user study to the research question, two set of hypotheses was described.

To start with, it is of interest to see how comparable imposters are using different factors. Therefore, a two-way ANOVA test with replication is used to determine any significant differences between the factors.

First of all, to determine if the camera angle and resolution affect how quick the users can see through the imposters These null-hypotheses were used:

Hypothesis H_0: All the different resolution have equal mean response time.

Hypothesis H_1: All the different angles have equal mean response time.

Hypothesis H_2: The factors are independent.

Next, to determine if the distance from the camera and the resolution affect how quick the users can see through the imposters These null-hypotheses were used:

Hypothesis H_0: All the different resolution have equal mean response time.

Hypothesis H_1: Any distance from the camera have equal mean response time.

Hypothesis H_2: The factors are independent.

Chapter 4

Results

4.1 Collapsing and outliers

To start with, the data was collapsed. A lot of users actually were able to answer the majority of the models to be imposters. Specifically, most of the participants in the study only answered incorrectly on the very first imposter they saw. To make sure there is not any statistical errors, the first permutation of the test was removed from the data.

Next, each set of data was compared to an outlier detection criteria. This was created by calculating inner and outer fences using quartiles. Any data point that were outside of the fences were marked as an outlier.

4.2 Mean Response Time from participants

Figure 4.1 shows how the different variations affected response time from users. The response time is not only longer when the resolution is lower, it is also has a larger standard deviation per variation. This is pointing to a much bigger spread on data.

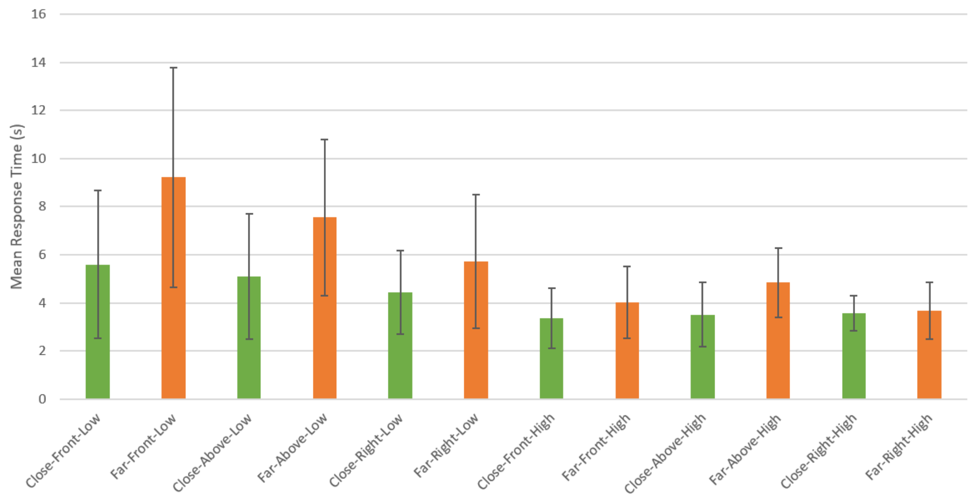

Figure 4.1: Mean response time (and standard deviation). Divided into each of the 12 variations.

4.3 Test of hypotheses

4.3.1 Resolution vs. Camera angle

The two-way ANOVA test gave these results:

Factor	F	F-crit	p-value
Resolution	29.94587933	3.924330485	2,66951E-07
Angle	2.431158881	4.257342048	0,092482048
Interaction	12.65769626	3.075852636	0,13061214

Exact values for calculations can be find in appendix C.

By comparing the F-value to the F-crit value, the data says that Hypotheses H_0 and H_2 should be rejected.

The test was done with a 95% significant level. There is a statistically significant interaction between the resolution and angle (F(2,114) = 12.65769626, p = 0.13).

For post-hoc analysis, the least significant difference (LSD = 1.23134862) was used to find any significant differences between two angles. There is no significant difference for any of the factors. (front vs. above diff = 0.313797055) (above vs. right diff = 1.176637494) (front vs. right (diff = 0.862840439).

4.3.2 Resolution vs. Distance from camera

The ANOVA test gave these results:

Factor	F	F-crit	p-value
Resolution	32.24717384	3.922879362	1.02095E-07
Distance	12.34709273	3.922879362	0.000630691
Interaction	4.224242477	3.922879362	0.042095677

Exact values for calculations can be find in appendix D.
By comparing the F-value to the F-crit value, all hypotheses should be rejected.

The test was done with a 95% significant level. There is a statistically significant interaction between the resolution and angle ($F(1,116) = 4.224242477$, $p = 0.042$).

For post-hoc analysis, the least significant difference (LSD = 0.978127752) was used to find any significant differences between the two distances. There is a significant difference for close vs. far (diff = 1.526840678).

4.4 Outcome of the study

Based on the comments from the users, the outcome of the study is presented here.

The outcomes from the result varied from participants. By asking them about what they thought made them guess, some common trends showed up. First, the three most common traits they started to look for was aliasing on the imposter and the stuttering animation from the imposter. The aliasing gave the imposter a pixelated outline, something the 3D-model did not have. The imposter is rendered with 10 key frames, meaning that there was much more stutter in the imposters animation than the 3D-models. In any case, all of the participants had a hard time differentiating these traits if the models were far away.

A lot of participants were confused about what 'low quality' meant. There are several things in the scenario that can be considered low quality. Other than animation and aliasing, the low resolution in itself made users unsure about the quality. This is due to the fact that the 3D-model gains some faults itself. One participant pointed out that they had to try to think which was was worse in terms of quality. Any uncertainties about low quality faded away during the study, especially when the high resolution clips started.

Some participants mentioned that they did not even notice that the resolution changed. There are not any clear indications for what this could mean. Especially since a few other participants mentioned that they did notice the change of resolution.

Chapter 5

Discussion

5.1 Analysis of results

The further away an imposter is, the more difficult it is to distinguish it from the model. This can be seen clearly in the data. Every camera angle correlates to users being slower to respond if the models are far away. This is obvious. Objects that are far away have less detail. Meaning it is much harder to find any difference between two very similar objects.

In regards to resolution, the participants had a much easier time if the resolution was higher. It is much easier to understand what one is supposed to look for in a clean environment. Even if participants mentioned that they either did notice the change or resolution or not. This is because there are less visual artifacts when the resolution is higher. In those circumstances, it is easier to understand what is happening in a scene.

Next, it is interesting that all the hypotheses are discarded and the post-hoc analysis shows something else. It is certain that distance from the camera does affect the response time, and that all of the factors does have some form of interaction with each other. However, the fact is that there were few participants. One reason to not trust the data is that the distribution of the data is not as normally distributed as it could be. The hypotheses should only be used to strengthen the factor of distance from camera, as all the other factors still have their hypotheses standing.

There is one thing that stands out in the data that can explain all of this.

If you compare the data between the resolutions, the standard deviation is much higher in data points containing low resolution. This is because of ordering effects. The users were interpreting the instructions of the assignment in different ways. From the comments the users made, the users had a problem were they did not understand what 'low quality' means. This means that they could be looking for anything that stands out. The outcome of this is that they spend more time looking at the scene and make a decision until they can confirm what they already know. This helps to strengthen why there is no significant difference between the majority of the angles shown. The participants are not being affected by the angles as much as distance and resolution.

5.2 Limitations

One of the problem with the implementation is how easy it is to encounter visual artifacts. This was one of the expected flaws with the study. While effort was given to make sure to correct this as much as possible, some form of visual artifacts was still able to slip by. One more factor is during the start of the study, the users watched clips of lower resolution. This does show that the user had some form of uncertainty with the assignment, giving us much more spread out data points. Utilizing [3] in more detail could have helped. As soon as any form of aliasing is seen, the imposter should not be seen by the observer anymore.

To expand on this, not enough imposters were used in the clips. Participants mention that they can easily see patterns in the clips. Meaning that they have started to recognize all of the imposters presented to. As [5] mentions, clones are easier to distinguish if they use the same clothing or animations. Using one unique model for each clip could have solved this. However, both time and resource constraints did hinder to solve this.

Between all of the factors, one problem was that the only angles chosen were static camera angle. Using a static camera angle means that the scenario only could be seen from a decided angle. While one would know exactly what the camera shows, there is no feasible way of knowing what exactly the user is looking for in a scene. Essentially, every chosen camera angle had the same effect on how observers perceive the scene. The only exception is the angle with a significant different, the right angle.

Lastly, the thesis only focused on imposters as a method and not so much on their role in a crowd simulator. This has to do with time constraints. While this goes against how imposters should be used, it made it easier to conclude results that are needed for the research question.

5.3 Future work

Most of the limitations describe what in the crowd simulator could be implemented and how they could affect the result if they were implemented. One of the bigger problems was that the choice to not use a bitmap to save the textures for the impostor took a tool on the performance of the imposter simulations. This means that it was almost impossible to conduct any form of study with a crowd of imposters, meaning that you are losing the condition of how dense a crowd could be before an impostor could be seen. The first recommendations is to not test imposters by themselves. Aliasing is too much of an disturbance in the scene that letting an imposter get too close will break the immersion.

Testing imposters in crowds would help the problem of having too few actors. Clones in a group with different animations and different clothing [5] is shown to work. This would have been an interesting factor to look closer into.

In regards to the static camera, a moving camera would be interesting to use as a factor. There are three options here. One is a constant moving camera. Either moving forwards the imposter or around the imposter. This would be the simplest idea to implement. Another idea is the use of a free camera that the observer can control would be an interesting factor to investigate. It would mean that observers can look at whatever they want in the scenario. However, they would need to understand how to use and control the camera. The user would also need to have an even clearer understanding of what the presented scenario is.

Another option would be the use of Virtual Reality. The primary advantage of this would be that it would be the most natural way of looking at the scenario, while also limiting the user to how they could move around the scenario. However, any control the user has over the scene can create unexpected technical difficulties. It would also be harder to determine what the controllable variables would be.

One way to solve the problem of knowing where the user is looking at the screen would have been to implement eye tracking technology. It would mean that you would get data of what exactly the user is looking for in the scenario. This would have helped answering when the user had a hard time comparing the imposter with the model.

Chapter 6

Conclusion

In regard to how the imposter is presented, imposters need to be as far away as possible to not affect how one can see it. It is harder to determine if from what angle imposters are presented do affect their presentation. This means that when using imposters as a LOD-technique, camera placement have a certain factor to how well imposters work. Further research would help detail this. It is also important to present an imposter in its intended resolution to not create any confusion with 3D models. The two most important factors could be seen as distance from camera and the resolution, both of which affect how users see imposters. Presentation of imposters is important to make them work well. Lastly, without being able to test this implementation of imposters in a real crowd simulator it is hard to determine how people see the difference between imposters and its 3D model. While it is easy for users to see an imposter if it is close, it should never be close to the camera anyway. Only presenting imposters with its model makes it very easy for the user to see the difference between them. The recommendation is to test this approach within a crowd simulator to have a less predictable environment.

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Appendix A

Questionnaire for User Study

Questionnaire - Basic Information

Fill in this information about yourself.

Specifically, read through the section about consent properly.

If you have any question, talk to the observer.

1. **ID**

   ____

2. **Age**

   ____

3. **Gender**

   Mark only one oval.

   - ◯ Female
   - ◯ Male
   - ◯ Prefer not to say
   - ◯ Other: ________________________________

4. **How well would you rate your vision? (1 = bad, 5 = excellent)**

   Mark only one oval.

1	2	3	4	5
◯	◯	◯	◯	◯

Consent - Please read through this proplerly

The purpose with this user study is to gather data. This data will be used to answer a scientific queston. The data collected is entirely anonymous and cannot be connected to you in any way. Participating in this study is entirely voluntary. You are allowed to stop being part of the study at any point, both during the experiment and afterwards. All data collected will be erased after the study is completed.

5. **By filling in this box, you consent to being part of the user study**

   Tick all that apply.

   - ☐ I consent

Please tell the observer when you are done

You will then get to start the user study

Questionnaire - Afterward

What you were looking at was called an imposter. They are built by first taking photographs of a model in as many angles as possible, then only showing the photos from the appropiate angle.

Please answer your opinions about the study down here

For the first set of videos, where the videos were shown in a lower resolution...

1. **When did the imposter lose its sense of realism?**

2. **Can you describe what gave away the illusion?**

For the second set of videos, where the videos were shown in a higher resolution...

3. **When did the imposter lose its sense of realism?**

4. **Can you describe what gave away the illusion?**

Appendix B

Instructions for User Study

Instructions

In this study, you as the user will be shown a set of movie clips.

These movie clips portray *a man and a clone of the man* walking down a path. These movie clips will be shown using different actors, in different angles and at different distances.

The only significant difference between the man and the clone is that the clone is *presented in a worse quality* than the other.

In each clip, it is randomized which man is of what quality.
***Your goal** is to determine which one of the men is of lower quality.*

You are able to press the **left and right key** on the keyboard. If you think the left one had lower quality, press left. If you think it is the right one, press right.

As soon as you press a key, you will be shown a new clip. This will keep on going until the program tells you that the study is over.

There is no rush to do this test quickly. Just make sure you feel certain about your pick before choosing.

If any clip runs to its end, the video will pause. You can still make a choice and the study will keep going.

To start the test, you can press *Play Movie*. All of the other clips will play automatically.

You can ask questions to the observer before and after the study, but not during.

Appendix C

Two-way ANOVA for camera angle and resolution

Low Resol.	Front	Above	Right	Total
Data Sets	20	20	20	60
Sum	147.2452749	126.5949947	101.5332018	375.3734714
Mean	7.362263744	6.329749735	5.076660092	6.256224524
Variance	16.59376359	9.77751077	5.537313076	11.16381662

High Resol.	Front	Above	Right	Total
Data Sets	20	20	20	60
Sum	73.49192202	81.59031997	72.13849527	227.2207373
Mean	3.674596101	4.079515998	3.606924764	3.787012288
Variance	1.801196672	2.035272062	0.903112341	1.570586223

Total values	Front	Above	Right
Data Sets	40	40	40
Sum	220.7371969	208.1853147	173.6716971
Mean	5.518429922	5.204632867	4.341792428
Variance	12.44854286	7.053292116	3.691520571

ANOVA	Sum of Squares	df	Mean Square	F	p-value	F-crit
Resolution	182.910272	1	182.910272	29.94587933	2.66951E-07	3.924330485
Angle	29.69917346	2	14.84958673	2.431158881	0.092482048	3.075852636
Interaction	25.31539252	2	12.65769626	2.072304855	0.13061214	3.075852636
Within	696.3152018	114	6.108028086	-	-	
Total	934.2400397	119				

Table C.1: Result of Two-Way ANOVA test for finding if resolution and angle have a significant difference between each other.

Appendix D

Two-way ANOVA for distance from camera and resolution

Low Resol.	Close	Far	Total
Data Sets	30	30	60
Sum	151.3367056	223.9340436	375.2707492
Mean	5.044556854	7.46446812	6.254512487
Variance	6.210931932	13.45857718	11.15686987

High Resol.	Close	Far	Total
Data Sets	30	30	60
Sum	104.1038173	123.11692	227.2207373
Mean	3.470127242	4.103897333	3.787012288
Variance	1.196441082	1.791131995	1.570586223

Total values	Close	Far
Data Sets	60	60
Sum	255.4405229	347.0509636
Mean	4.257342048	5.784182726
Variance	4.271122821	10.36683231

ANOVA	Sum of Squares	df	Mean Square	F	p-value	F-crit
Resolution	182.656717	1	182.656717	32.24717384	1,02095E-07	3,922879362
Distance	69.93727371	1	69.9372371	12.34709273	0.000630691	3.922879362
Interaction	23.92725225	1	23.92725225	4.224242477	0.042095677	3.922879362
Within	657.0553836	116	5.664270548	-	-	
Total	933.5766266	119				

Table D.1: Result of Two-Way ANOVA test for finding if resolution and distance have a significant difference between each other.