CSCI 5611 Animation & Planning in Games Final Report

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Storyline

The storyline of our animation plays with the plot of the movie *The Ring* which deals with watching an unmarked VHS tape and immediately after getting a scary phone call that the girl with long black hair is coming in 7 days. Our story follows a mullet man skipping class to watch an unmarked VHS tape, a worried girl asking if he got a phone call, to which the mullet man claims he doesn't have his phone on him today. This hints at the motivation of the animation, as the mullet man didn't have his phone on him, so the girl from the movie *The Ring* had to show up herself instead of reaching him over the phone like in the movie. Her showing up is left slightly open ended. Was it to give him the message that she was going to show up in 7 days? Was it to kill him 7 days early? Those definitely sound like choking noises at the end, but it wasn't coming from the mullet man. Or was it to simply make some new friends on her first day or school? We wanted a playful aspect of "*The Ring* girl" being the new girl at school, giving a contrast between a lighthearted conversation between schoolmates and an intense heavy-breathing creature.

Mullet Man: I'm such a rebel, I skipped class and hung out in the library
Worried Girl: You skipped English class to go read?
Mullet Man: Nah, I snuck in the back and watched TV. I found this unmarked VHS tape.
Worried Girl: Uh- wh- Have you gotten a phone call by any chance?
Mullet Man: No, I don't have my phone on me today, why do you ask?
Person Who Just Walked In: Hey, have you guys seen the new girl?

Approach and Key Algorithms

To summarize, our final project is a short animation that takes place in a school hallway. We start searching the hallways in an empty school. There are two students walking down the hallway having a conversation about their day. Another student then enters the hallway through a classroom door to ask the others a question. Next, the creepy girl from the movie *The Ring,* henceforth referred to as "*The Ring* girl", walks down the hall in slow motion. Her hair blows softly in the wind created from the walk. As "*The Ring* girl" walks down the hallway, the students turn to face her and appear scared when they see her. The camera switches to facing "*The Ring* girl", finally an answer to the question of who the "camera person" is. To animate and render this short film, our group used Blender. In the rest of this section, we will cover in depth all of the approaches used in the project. First, how keyframing played a large role in the development of our project. It was used as the method to make "*The Ring* girl" walk down the hallway, animate the side characters walking, and show side characters talking and changing their expressions. Second, we will discuss how inverse kinematics was used for focusing the eyes of the side characters on *"The Ring* girl" as she entered the scene. Afterwards, we will cover how audio was utilized to make the characters hold a conversation. Our teammate Amelie recorded all of the conversation audio herself, based on topics from the film *The Ring*. Finally, the particle system approach used on the hair on the main character will be discussed.

Keyframing

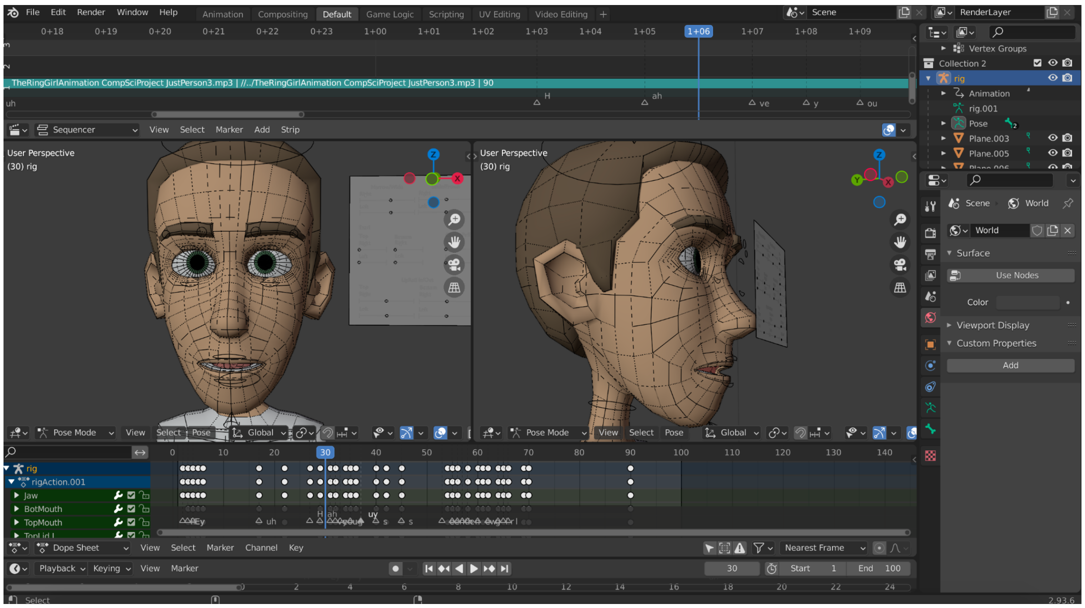

Figure 1: Screenshot from keyframing process to animate a character's face.

Keyframing was one of the most significant approaches we used in our project for all of our characters. While we could have accessed downloaded animations already containing keyframes from the internet, we decided that implementing our own keyframes was an important approach to the project since we only briefly talked about it in class. Doing the keyframing ourselves allowed us to have a hands-on exploration of a technique that was not heavily used in one of our class projects.

First, for the character based on *The Ring*, we keyframed her walk to be slightly creepy and ominous. It was important to us that she walk slowly to build some suspense, but not too slow or stiff. We also had to figure out how to marry her walking with her hair movement. This was crucial because her hair is very sensitive to movements like jerks or glitches, so we spent a lot of time making the walking motion smooth. It was especially difficult to make the walk flow nicely since the character mesh and armature were downloaded from the internet, making it harder to know which bone controlled what part of the skin. Additionally, there was almost an excessive amount of bones compared to the characters that we created ourselves in Blender. This caused the keyframing to be tedious as a multitude of bones had to be repositioned each keyframe.

Second, for the student that enters from a side door at the far end of the hallway and has his mouth animated, we used keyframing for both his walking and speaking. We were able to find a character online with a full face and body rig, which made the keyframing more doable. Next, we recorded the conversation audio for the scene ourselves, and then uploaded it into Blender. Following this, we used markers and keyframes to animate his face syllable by syllable to make it appear like he was speaking the words from the recorded audio. This was a lengthy process, as the human face moves significantly during each syllable of the speaking process. A multitude of the lip sync keyframing didn't make it into the final cut due to frame rate decisions. Finally, for his walk we used a similar keyframing approach as the girl from *The Ring*, however his walk is regular, and not slow or creepy in any way.

Third, the additional two characters, one in a red shirt and the other in green pants, are having the main conversation. Our group utilized keyframing to animate them walking down the hallway. An interesting difference between the approaches for the mullet man (character in red shirt) and the girl in green pants is that we keyframed the mullet man's actual movement walking so the walk couldn't be copy-pasted as it was in a different location each cycle. For the girl in the green shirt however, we allowed more time given to details in her posing since we were animating her walking in place, so the walk cycle could be copy-pasted after the initial two steps were keyframed. Afterwards, in the integrated hallway scene file, we keyframed her beginning position being at one point in the hallway, and her end position being in front of the door the other character walks out of. The purpose of this was to give the illusion that she is truly moving instead of walking in place. Once "*The Ring* girl" approached all of the characters, we used keyframing to have them all turn towards her and change their facial expressions to be scared. Further discussion will occur later in the Inverse Kinematics section for the girl with green pants, as a majority of her head turns were from our implementation of damped tracking, and eye movements from inverse kinematics.

We also employed keyframing for the camera movement throughout the scene. This is significant as the camera takes the role of a character in the scene instead of watching third person. At first, we tried to create a path for the camera to follow using the "Follow Track" tool in Blender, but this became hard to handle exactly where the camera was pointing. It was default to follow the path in terms of pointing from ceiling to floor and back to ceiling. Really what was desired was for the camera to continually point down the hallway, and only move up and down to emulate the POV's limping. To accomplish this, we placed the character into the scene to analyze its limping, and then keyframed the camera at different points along the somewhat-sinusoidal path, with the camera being at eye-level position with the main character.

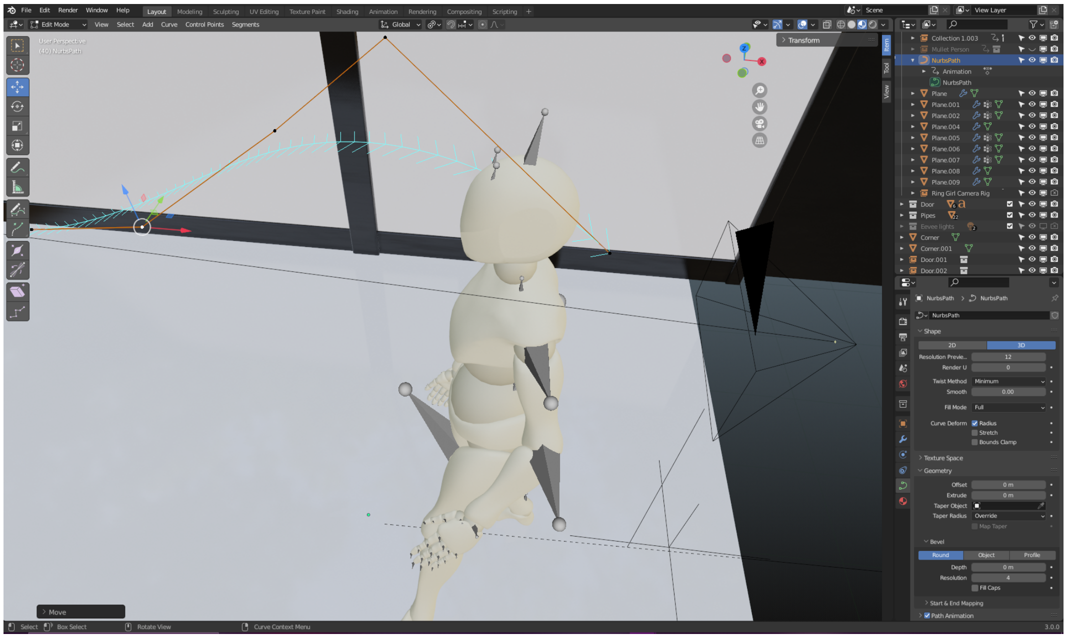

Figure 2: Process of mapping out the limping motion for the camera.

There are many benefits to working with keyframing as opposed to other methods of character movement. First, there are computational benefits. Since we are developing the keyframes by hand, there are not nearly as many background calculations to calculate positions as there would be if we were trying to hard code all the movements and positions with another method such as inverse kinematics. Blender has a user-friendly interface for developing keyframes, however it was much more challenging to figure out how to add our own inverse kinematics code. Thus, inverse kinematics uses were kept to a minimum. Second, creating our own keyframes allows us to determine the speed at which the characters move instead of relying on speeds calculated from fixed keyframes downloaded from the internet.

The difficulties and bottlenecks to this approach were that we could not get everything as perfect as we wanted it to be, since we did the keyframing by hand. More exact results could have been achieved if we had hard coded the facial movements or programmed the walking, however this would have resulted in longer computation times and a less accurate rendering. Additionally, this would have taken us much longer to develop overall which would have resulted in a less exciting final project. If we were to scale this animation to 10x what it currently is, a limiting factor would be the time that it takes to keyframe and the human effort that would need to be put in to make a longer animation work. It took a lot of hours to keyframe this short animation with a few characters, so to extend that would take a lot of extra time. If we were to have hard coded the movements, it would not be nearly as much of a limitation to move the characters for longer and scale up the project. Another computational bottleneck in our animation was the hair on *"The Ring* girl". Having thick hair with a lot of strands, calculating collisions, and how it moved all caused the rendering to be extremely slow. This made it hard to check the progress of the animation because every time the animation was rendered it took up to five hours. Scaling this up would cause the rendering time to be even greater.

We discussed the concept of keyframing in class, and it was addressed as a pretty significant and effective way to animate characters. We also explored linear interpolation and representing rotations with matrices, which we did not hard code or directly use in our project. However, we did use something similar to blendshapes using Blender and keyframes, which allowed interpolating between shapes within the program. When we have two keyframes, Blender blends them together behind the scenes by interpolating between the two key positions that we have established. Additionally, using blendshapes for facial animations was highlighted in class. We also did this in this project by establishing keyframes and having the program interpolate between them to give the appearance of realistic facial expressions. Keyframing was an immensely significant part of our project, and it was also touched on in class. Blender interpolates between shapes and positions in keyframes, which we talked about in class as a process called tweening. In lecture, we examined how to code for interpolating keyframes, which is different from what we did in our project. Blender allowed slight access to the tweening though, letting us choose between linear or different exponential graphs for the interpolation which ideally would allow for the animation fundamental of ease in and ease out, but it wasn’t visually obvious. Another animation fundamental we talked about in class that could have enhanced our animation was squashing and stretching, as it would allow for our characters to be more expressive.

Hair Animation

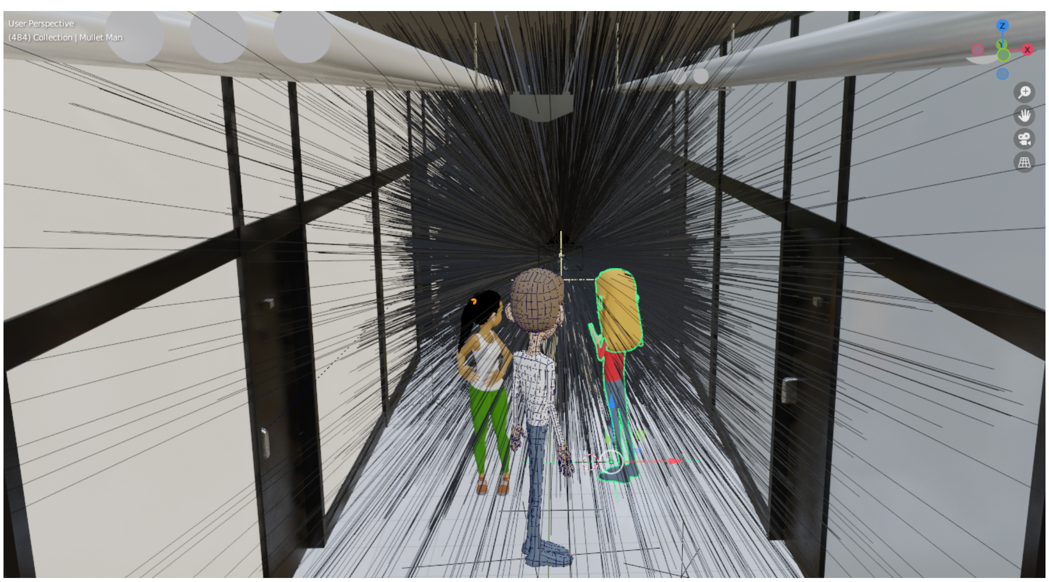

Figure 3: In progress image of our hair animation before we implemented all the properties.

To create and animate the hair of *"The Ring* girl", we employed a method that displayed the hair as a collection of individual strands blended together. This process started with a particle system along the scalp, and then each particle was extended to be the length of hair (0.75 m) and segmented into 30 segments. This segmentation allowed for bending in the hair instead of remaining in rigid straight lines. We also applied a gravitational force to help the hair settle from its initial state of sticking straight up. Unfortunately, this caused the hair to fall through the character's body, so collision detection between each particle and the character's body was introduced. For the collision detection, we altered the parameters to have a damping force of 1.0 and a friction force of 80.0. Finally, to fill out the scalp of hair further, we interpolated children nodes from our parent particle nodes.

This hair animation technique was applied to our main character, *"The Ring* girl". The hair was critical to creating an animated character that embodied the girl from the movie, so we found it significant to explore an accurate way to render hair. The team chose to hang it over her face as this more accurately represented the movie character. Additionally, this allowed the viewer to see more of the hair, specifically how it moved and interacted with the body. If the hair was not covering her face it would have looked less like the character we were going for, and would not have emphasized hair and body interactions or hair and air interactions. The rest of the characters in the scene have stationary hair as we didn't think their hair or movement was as significant to the scene.

Initially, we started with our character having much thicker hair, however we decided to change this for two reasons. First, this was very computationally inefficient. Second, the viewer was not able to see the movement of her body or her hair as clearly. Decreasing the amount of hair was computationally beneficial, as the rendering was not lagging nearly as much. We believe it is also more beneficial than a cloth rendering would have been, as the cloth has more ropes that are connected, which in general led to more computation and slower rendering.

The biggest difficulty we faced with the hair simulation was the time it took to detect collisions and render. Initially, when we had a very thick head of hair, the simulation would constantly glitch, and we were not able to visualize the actual movement of the hair. It caused other parts of our program to also lag, and ended up setting us back as we could not test how the rest of the animation was working. Computing individual values for that many strands, as well as detecting collisions, took a significantly long time. Another difficulty that we encountered was getting the gravity and wind to work properly as sometimes the hair was extremely bouncy, or appeared as though it was floating. It took us a while to decide what parameters worked the best for our simulation to make the hair look as realistic as possible.

In class, we did not do a deep dive into the topic of hair simulation, just briefly touched on the fact that it is known as a very complicated and difficult task in computer animation. It was also noted in lecture that hair could be rendered, in its most basic form, as a cloth simulation. In researching this topic, it was found that this is a common way to render hair. We discussed how to animate cloth and it's motion with ropes, and how to factor in things such as air resistance and gravity. Additionally, we covered how changing the different string parameters affected the animation of the strings. Our method is only slightly similar, in that we are using individual strands of hair that could be compared to ropes. They each have actions independent of their neighbors, and collision detection is very important for both. They are different in that we did not connect our strands with cloth, and instead used a particle system that we extended. Most of the information we learned about rendering hair was from the internet, specifically tutorials, however having the knowledge of how the cloth simulation worked greatly helped us design the hair.

Inverse Kinematics

We wanted to incorporate the interesting and largely applicable topic of inverse kinematics into our animation. As a topic covered in class and in one of our projects, we wanted to explore how we could apply inverse kinematics in our animation. To indicate the attention being given to *"The Ring* girl" by the bystanders, we decided to use inverse kinematics to move the head and eyes of the bystanders so that the direction of their heads were directed towards *"The Ring* girl" as she approached them.

Forward kinematics is the movement of limbs based on given limb lengths and joints. We used forward kinematics to predict where the end-effector, or the limb in question, would be located. Inverse kinematics, as the name suggests, is the problem of calculating the locations of limbs and angles of joints of a skeleton of bones given a position where the end-effector should reach towards. It is used to move limbs and rotate joints in a manner such that an end effector can be moved towards a targeted position. This has many applications in the broad world of robotics, character animation, and motion planning. This problem becomes complex due to the many constraints needed on top of this problem, including the range of motion of robot arms, the flexibility of characters to produce realistic simulations, and collision avoidance with other limbs, to name a few examples.

In our project, we aimed to use inverse kinematics to direct the head and eyes of the girl walking down the hallway towards the other bystanders present to display her engagement in their conversations. The Blender file of the girl luckily came with a skeleton rig which we could apply inverse kinematics on to manipulate the movements of her character. Blender comes with a built-in inverse kinematics option for character bones, so there was no need for us to use our own inverse kinematics scripts to apply on the characters. During the project, we decided to switch from inverse kinematics to damped tracking for her eyes as it made it easier to make our simulation look more realistic. The damped tracking constraint in Blender is a constraint that simply moves one bone towards a specified target object, which fit perfectly for the case of the eyes. There were no computational issues with the inverse kinematics and damped tracking, and everything ran very smoothly.

Some difficulties we ran into involving inverse kinematics were the change in targets from the mullet man to the other man, and the orientation of the girl's rig we were working with. In the middle of the animation, we wanted to move her attention from the mullet man to the man stepping into the hallway. However, this was difficult as simply changing the target from the mullet man to the other man in the middle of the animation made the change rather abrupt. We wanted to slowly change her focus of attention to make the animation look more realistic. Our solution to this problem was keyframing, a property variable, and the influence parameter of the inverse kinematics. The inverse kinematics in Blender has a number of fields that can be manipulated and includes a variable named "influence". This variable helps determine how much the inverse kinematics affects the motion of a given bone. Our idea was to create two inverse kinematics constraints and a property variable coined "prop" that would linearly interpolate from 0 to 1 in order to slowly shift the influence of one of the inverse kinematic constraints to the other. We performed the gradual increase of this variable from 0 to 1 using keyframing in the animation. A second area of difficulty was the orientation of the end-effector being manipulated. The rig was oriented in such a way that the end-effector was pointing towards the top of her head causing the resulting inverse kinematics in the head of the girl to become deformed by 90 degrees. To fix this problem, we used one of the fields in the built-in inverse kinematics called "pole-target". The inverse kinematics method in Blender has two different types of targets: target and pole-target. Target was the targeted position for the end-effector while the pole-target was the object for rotation. To give context, inverse kinematics can have many solutions as there are many limb positions and angle values that give the same end-effector position. The pole-target defines a second target that orients the end-effector so that the end-effector is facing towards the pole-target. By using a hidden object above the girl as the target and the other bystanders in the hallway as the pole-targets, we were able to achieve our desired motion of the head rotating to face the characters.

Blender's inverse kinematics features gave us a large number of options to manipulate and was very comprehensive for a built-in option. Using our own script would have given us more flexibility with the type of inverse kinematics algorithm used and more freedom in certain properties such as the speed of the movement and specific joint constraints. However, we believe the built-in option was much easier to work with than coding our own inverse kinematic equations, due to the unpredictability of combining our own inverse kinematics with the other tools we used in Blender.

Animation Audio

The setting felt important for the story, with a hallway that posed as a school hallway but held more ambiguity. Its tall ceilings and narrow composure made it feel formal yet claustrophobic. Thinking about the ways in which the room was made up helps in the process of applying the right sounds, so that you can truly feel like you're in the space in which you see. We kept in mind the ways in which sounds move – direct movement, bouncing off walls, refracting around a corner – while matching the audio to the visual. Essentially, we were Fowley artists. We played the video while another person watched, attempting to slide their shoes in the same fashion that the "camera person" aka "*The Ring* girl" is doing in the animation. We also had to attempt to swing open a door at around the same pace the doors open in the animation.

For this animation especially, it was a helpful asset to keep sound propagation in mind because for the first half of the animation, the viewer can't actually see any characters. This was a unique solution to our worry of having to keyframe the mouth movements for so much dialogue. The searching through the hallway at the beginning perfectly fit the horror genre. But still, we needed to introduce characters without having them be seen by the camera. To do that, having the dialogue come from a specific place off screen helped to designate a location of the voice, so something is learned of the character – where they are. It also gives the viewer suspense, as the "camera person" looks throughout the space to find the voices. The viewer is in the role of "*The Ring* girl" at the beginning, so the viewer can also mentally search for where the voices are coming from based on the sound propagation techniques being applied.

We used several softwares to emulate the sound dynamics. First, in the heavy breathing and choking noises at the end, we used Final Cut Pro to keyframe the audio movement from in front of the viewer to the left side of the viewer.

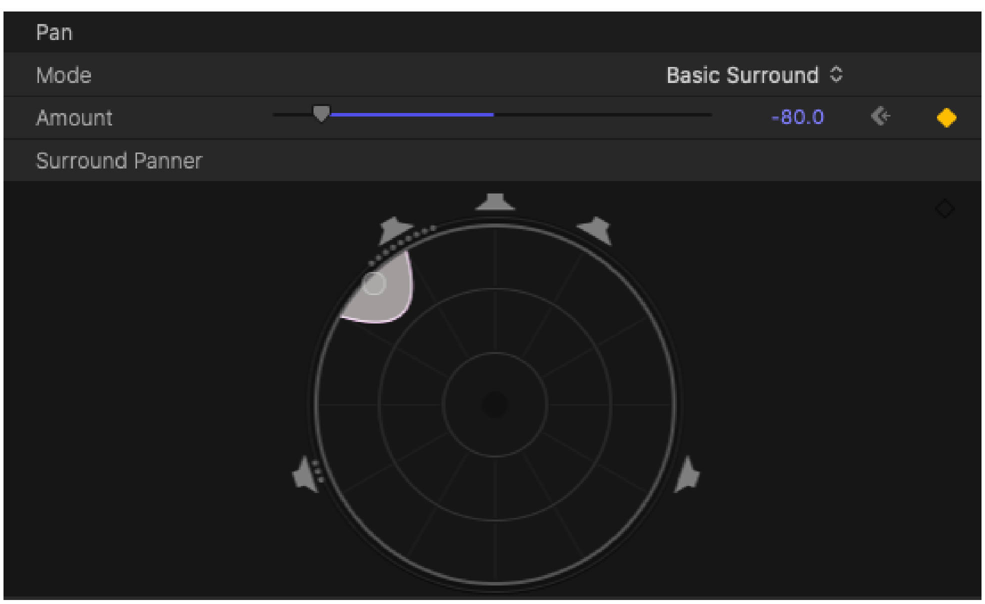

Figure 4: User Interface of Final Cut Pro to create the movement of the breathing noises.

Figure 5: User Interface of Logic Pro during the addition of sound propagation techniques to the dialogue.

Second, for the dialogue, we used the panning tool in Logic Pro to pan from left to right (and in between). The characters start talking right as "*The Ring* girl" enters into the intersection of the hallway, so the dialogue is happening directly to the left of her, via the pan left. Even though they are directly to her left, sound waves are still being bounced off of walls, and the distance they are at introduces a lapse in time between when the words are said and heard. Third, the plug-in EchoBoy has a preset for HallwayVocal that worked with our setting, and we made adjustments to the tuning of parameters on the plug-in– the Echo Time parameter dealt with time adjustments to the wavelength, the Saturation dealt with details to the wave, and the volume metrics dealt with amplitude.

Figure 6: User Interface of a Hallway echo simulation.

As "*The Ring* girl" turns to the right, looking at the doors on the far wall (but the wall closest to her at that moment), the audio changes to be more stereo centered, but quieter. Instead of the sound shooting directly into her left ear from the long hallway, it is heard being bounced off of the wall in front of her. Next, "*The Ring* girl" turns back to look around the corner, and the audio makes a shift in panning to come in through the right ear. We made this decision, as the left side of the screen is blocked by the hallway corner as if the left ear is being blocked. There is potentially some refraction still happening around the corner in reality, but we wanted to lean on the idea of her ear being blocked.

As "*The Ring* girl" starts her scary fast venture down the main hallway, we switch from using a Hallway echo to using a Tunnel echo (changing from Figure 6 to 7). The long, narrow composition of the hallway seemingly fit with a tunnel analogy. A different kind of echo applied during this section can indicate the change in space as well as put emphasis on a peculiar feeling, being a tunnel instead of a hallway. There is a decline in the "wetness" of the effect as we arrived at the people to show we are now hearing them more directly instead of from the sound waves that were bouncing down the hallway walls.

Figure 7: User Interface of a Small Tunnel simulation.

State of the Art Techniques

Hair Animation

Our initial intent when developing the hair in our simulation was to parallel our prior cloth simulation code to be applicable to hair. However, the way we learned to implement this in class would not look very visually compelling, as each rope is connected to form one single layer of cloth. Instead, as detailed above, we used a particle system along the scalp and edited it to look and behave like hair strands. This method allowed us to create something that not only looked realistic, but acted like hair as well due to the gravity, wind, and collision detection we implemented.

A very common state of the art technique to animate hair involves using a cloth simulation, similar to what we studied in class and exercised in project 2. A cloth is a good baseline for hair as it moves similarly to hair, and properties like gravity, wind, and collision detection can be invoked. However, there are a few setbacks, such as the fact that a cloth travels as one object, and while there are different nodes that interact separately, the nodes are still connected throughout. We saw in lecture and in further research, that while cloth simulations are accurate, there are limitations to looking accurate. For example, chunks of hair are not able to travel independently from one another as they would in real life. Another problem that was demonstrated in one of the papers that was presented in class was that a cloth simulation for hair has no volume right off the bat. If we were to implement it as a cloth, it would be one flat sheet, unlike hair, that has volume, different lengths, and different properties.

In one of the papers our group read, “Real-time Hair Mesh Simulation”, the authors implemented a new technique that was different from other hair and cloth simulations. The technique included volume, so while the hair was still acting as a singular cloth, it also had thickness. This helped turn a cloth into a more realistic looking hair simulation. One problem that the authors faced in their experiment that motivated their research was having chunks of hair act independently from one another. In this simulation from very experienced researchers, they were not able to get the hair to act independently, which is something that we really wanted to do with our project. Thus, we had to look for other resources to be able to render independently behaved hair strands. Another problem they faced, similar to us, was how much time hair simulations take to calculate and render. With only a cloth simulation it took them a very long time, especially with collision detection, to get their simulation to act in real time. This is another way that our project was different, in that using individual particle strands, our hair detects collisions, but is still able to render properly.

Our techniques are very different from state of the art techniques in that we do not do a cloth simulation or even a cloth with volume. A cloth simulation would have the hair all acting as one object, while our simulation involves a lot of separate particle systems that are all on the same head. According to the papers we read, even though our simulation still runs slowly due to the hair calculations, it has less problems than detecting collisions for a full cloth with volume. Despite being so different, our technique is still slightly similar to the state of the art processes. Particle systems are different from cloths, but they act similarly to the individual ropes that make up a cloth, like what we animated in class. They have similar actions in that they detect collisions, blow in the wind, and are affected by gravity. Therefore, our technique has a few overlapping ideas with the state of the art hair cloth techniques while still having its own unique characteristics.

Inverse Kinematics

Inverse kinematics (IK) is a state of the art technique for motion planning that allows us to determine what joint angles and limb positions allow us to move towards a given target, and is a problem commonly found in the realm of robotics and 3D animation. Notably, recent research into inverse kinematics in robotics has been focusing attention on animation tools to simulate algorithms and robots in virtual environments, specifically Blender. Blender is a popular option for motion planning, due to its support of many of the 3D tools needed, such as rigging, animation, simulation, rendering, and motion tracking, while also providing an extensive API for Python scripting that supports customization in applications. Most importantly, Blender has inverse kinematics functionality with a standard IK solver as well as an iTaSC solver, meaning that it has the framework needed to support other IK solvers.

There are many different inverse kinematics solvers that have been discovered and each of these solvers has their own property that makes them outstanding in a particular setting. Most of these IK solvers can be split into two different types: minimizing algorithms and predictor-corrector algorithms. One algorithm covered in this class was the cyclic-coordinate descent (CCD) which is a minimizer type algorithm, and is also currently the most popular method of inverse kinematics. CCD excels in fast convergence and has no issues with singular Jacobians. Another minimizer type algorithm that is especially used in movement in robotics is the iTaSC solver. The iTaSC solver is popular due to its focus on constraints and how best to tackle them. Another algorithm mentioned in class was the FABRIK algorithm which is a predictor-corrector algorithm also geared towards robotics.

We decided to use the auto-IK solver that Blender provides because our use of inverse kinematics was relatively simple and Blender's auto-IK solver has the additional functionality of having a pole-target, as previously mentioned. Unlike moving the arms or legs of the characters, turning heads and adjusting eyes using inverse kinematics was not a task that would be much different based on the inverse kinematics algorithm used. Another integral reason why we chose one of the IK solvers provided by Blender was its option of allowing us to choose a pole-target. A feature not talked about in class, pole-targets help limit the solution of the inverse kinematics problem in the 3D space by helping us choose an orientation out of the many possible solutions. This feature helped make the motion of the head more accessible. Since we would achieve the same result with any other inverse kinematics solver and our main concern with inverse kinematics was integrating it with our other features, such as keyframing, we decided that Blender's auto-IK solver was the best approach.

Animation

Figure 8: Still of "The Ring Girl" walking down the hallway from our video animation.

Figure 9: Still of the side characters' reactions to "The Ring Girl" walking down the hallway.

Link to Final Animation Video:
https://drive.google.com/file/d/19Z-ZTlhPP97lc0Bg3_o-a1acZZriBQQ9/view?usp=sharing

Limitations and Future Work

The main limiting factor to scaling up our project would be computation time. There are many very computationally slow components of our project. First, the lighting in the hallway reflects and bounces off of everything which creates a nice scene, but takes a long time to render. The hallway scene is very detailed, but as soon as we started using it over the basic scene everything slowed down significantly. Second, the hair of the main character has already been mentioned several times in this report for its very slow rendering. Hair itself, even in cloth simulations, has been known to be a very computationally heavy process, with collision detection adding a lot of extra time, specifically in our case to detect for each individual strand. In the future, this limiting factor could possibly be reduced in that we could work in a more professional program, or find a new method to implement hair that acts a lot quicker while still appearing accurate.

Another, more minor limiting factor, was keyframing and the accuracy that we were able to obtain through using it. While our characters' movements looked pretty accurate, there will always be small errors that we made as we were establishing the movements and positions by hand. It is very time consuming, and difficult to account for every body part that is in motion while a person is walking or talking. It is even harder to be extremely precise in moving each and every bone for each keyframe. While the rigs that we have are very detailed for many body parts, it is not as accurate as how a human would actually move in real life. We were able to get a lot of detail in our work with keyframing, which is why we chose the method, but compared to programming the movements, there will always be human errors and small inaccuracies in keyframing. A way that we could fix this in the future would be to use a more accurate method of keyframing, or possibly calculated programmed positions instead. This would allow us to be very accurate in the movement of our characters' bodies and faces.

Given more time, we would have further researched how to implement realistic hair that was more computationally efficient. Our hair took a very long time to render, however we could not find another equally realistic implementation method in the short time we researched it. While we could have done something more like cloth simulation, this is also known to take a very long time for computations, and the hair, as previously mentioned, does not act as individual strands, instead acts as one object. We found that the method we were able to implement not only became fairly computationally efficient when we decreased the amount of hair, but also looked very similar to real hair in that we were able to animate individual strands. It would have also been interesting to find more detailed methods of keyframing to make the movements very exact, and to have as much precision as possible to resemble real human movement.

In the future, we would like to extend the animation of our main character. Right now hair covers her face the entire time and she is just skin and bones. It would be exciting to add clothes and facial features to make her even more realistic to the girl from the movie she is based on. We could add more keyframing to her face to really illustrate the spookiness of the scene. Another thing we could do is add even more keyframes, so we get the exact body positions at each point in time to really make the simulation accurate. Finally, to really extend this project, more side characters could be added so that crowd evacuation could be utilized. It would add another dimension to the project if crowd evacuation was implemented and all of the side characters got scared, then exited through the various doors in the hallway.

Peer Feedback

The feedback given to us by our peers was very beneficial. The main point they brought to our attention was that our main character glitched a little in her walk at the end of our video. We immediately took this feedback and smoothed out the key frames for the main character. Her walk looks much more smooth and natural, as natural as it can be given she is a creepy dead person. Another piece of feedback that our group was given was that the hallway looked very empty. It was suggested that we add additional characters along the side in order to make the scene more exciting. We took this feedback and created an additional character and added them into the hallway. Additionally, we added more excitement to the characters by recording audio and lip syncing it to them. This added a conversation element to the animation. Finally, it was recommended that we feature "*The Ring* girl" more in the animation as she was only shown in the very beginning of the progress video, yet is the main focus of the entire animation. Our alterations are seen in the final video where we build suspense up until revealing her at the end of the video. Changing when "*The Ring* girl" appears in our video greatly alters the emotional feel and build up of the video.

In developing our project from peer and instructor feedback, we planned on switching the speed of our animation from 12 frames per second to 24 frames per second. We got feedback that our animation was a little slow, so we chose to do this to fix it. Unfortunately, we planned on doing this switch right in the end, and because we were following an audio storyline that all the movements were synched to, increasing the frame rate messed up this process. When we increased the framerate, all the movements and audio were off, and we found that it was going to require more work than was feasibly possible to complete to resync everything in the end as we were completing the finishing touches. Thus, we chose to ignore this point of feedback, honing in on the slow feel to the scene since hair in slow motion was our original idea.

Appendix[1]

1. "*The Ring* girl"
    a. https://www.mixamo.com/#/?page=3&query=walking&type=Motion%2CMotion Pack
2. Hallway Scene
    a. https://drive.google.com/file/d/1HDRrJR2z73GZjlaOb2dWZE8UY0aKsI51/view
3. Girl Side Character
    a. https://studio.blender.org/characters/5f1ed640e9115ed35ea4b3fb/v2/
4. Boy Side Characters
    a. https://www.blendswap.com/blend/2840
5. Hair Volume Paper Real-time Hair Mesh Simulation
    a. https://dl-acm-org.ezp2.lib.umn.edu/doi/abs/10.1145/2856400.2856412
6. Video Demonstrating How to Keyframe Facial Expressions
    a. https://www.youtube.com/watch?v=K0f3izO2muQ&t=667s
7. Video Demonstrating How to Create Hair Using a Particle System
    a. https://www.youtube.com/watch?v=p5K8GhLyPAs
8. PhysIK: Physics based Inverse Kinematics for Character Posing and Animation
    a. https://www.cs.rpi.edu/~cutler/classes/advancedgraphics/S19/final_projects/fred.pdf
9. FABRIK: A fast, iterative solver for the Inverse Kinematics problem
    a. http://andreasaristidou.com/publications/papers/FABRIK.pdf
10. Blender for robotics and robotics for Blender
    a. http://sol.cs.trinity.edu/~jhowland/class.files.cs357.html/blender/blender-stuff/robot-blender.pdf\
11. Blender for Robotics: Integration into the Leuven Paradigm for Robot Task Specification and Human Motion Estimation
    a. https://link.springer.com/content/pdf/10.1007%2F978-3-642-17319-6.pdf

[1]All of the Blender resources cited here are just base models that were downloaded to be used as a template. All of them were significantly altered before being added to the project.

Work Distribution

Amelie Elmquist

1. "*The Ring* Girl" hair, particle system/collision detection using Blender facets
    a. Every time after the long process of adding the hair, the bones would not synch with the skinning so I'd have to redo the hair if we wanted to change her motion's keyframes at all.
    b. Sometimes crashing would occur, as the hair slowed down our computers.
    c. It was hard to get the hair to cover the face properly, and it wasn't until after a several hour render that I'd realize only a couple strands of hair were in front of her face.
2. Keyframed walk cycle for "Worried Girl" (the girl in green pants)
    a. First I keyframed her with her arms swaying beside her like a typical walk, but she looked too confident, and giving off her emotion with her walk was vital since we weren't showing her facial expressions. So, I re-keyframed her arms and hands, having her fiddle with her hands in a timid fashion.
3. Keyframing camera movement
    a. I had to do this several times since at first I had her searching the hallway much more, but it would have taken too long, and for that I would need her moving fast. I later realized that her slow movement would be much more effective than a thorough search of the hallway so I re-keyframed the camera movement to follow a limping path. I tried to do a technique other than keyframing, creating a sinusoidal curve for the camera to track but it didn't turn out the way I wanted.
4. All audio
    a. I had too much fun voicing the Mullet Man (and the other characters)
    b. I wanted to be able to use code for the sound propagation, but in class we learned it can add a lot of time onto render and our render was already taking too long. So instead I applied knowledge learned in class about Sound Propagation to try to visualize the paths the sound waves would be taking, and that influenced my decisions for panning and volume adjustments, as well as echo plug-ins and their parameter tuning. From what I learned in class, I assume these plug-ins implement code, taking the input audio of my lovely Mullet Man voice and essentially performing linear algebra on the sound waves.
5. Final Compilation
    a. A nice way we were able to split up the work was having our own file for the character we were working on, and then be able to link the file into the big Blender file of the Hallway scene. I was the only one at the time who was at a desktop computer so I volunteered to be the person to link it all together. When I tried sending the file to other people, the characters wouldn't be linked in, so I had

to keep this role which led to stress in the final 24 hours of compiling and rendering issues. Tip: I did find out later on that if you have the same version of Blender and are given a folder file that has the Hallway scene and all of the character files (the exact ones I linked in), then the Hallway scene should open appropriately. That way I can send the final project to everyone now to have for their own keepsake.

6. Report
    a. I wrote some sections but Hazel and Bridgette were great about spending a lot of time on the report. For instance if there was ever a time when they didn't have something specific for the animation to do, they'd go work on the report for hours. I'm impressed.

Bridgette Sieffert

1. Keyframed the motions of "*The Ring* girl"
    a. I implemented a limp into the walk of the girl to make her look more dead and creepy looking.
    b. This was challenging to keyframe because I wanted the walk to be in slow motion. Thus, I had to make sure my keyframes were more spaced out and depicted less movement than the walking motion of the other characters.
    c. Everytime this file was shared between group members the bones of the rig separated from the mesh. This meant the motion keyframing and the hair had to be completely redone when we wanted to fix one small part.
2. Keyframed the motions of the "Scared Blonde Mullet" character
    a. This was a long process because for some reason there was a lot of slipping in this character. The way the premade rig was designed required a large number of joints to be manipulated to create the simple motion of walking.
3. Selected "*The Ring* girl" character skeleton and created the materials
    a. I found a skeleton character that looked simple yet zombie-like. Additionally, it had materials that were easy to manipulate.
    b. I designed the material colors to match the actual girl from the movie. We thought that basing this character off of an actual real life character would enhance the overall animation.
4. Found the Hallway scene
    a. After Hazel discovered that it would be very difficult to build our own hallway scene, I scavenged the internet for a free school hallway scene. This scene is eerie and perfectly fits our setting.
    b. I altered some of the lighting and camera settings to make the scene render faster.
5. Final Video Compilation
    a. I voiced over the second half of the project intro.

b. I compiled the project video that Amelie developed with all our files (she did an amazing job being the lead on the project animation!!) with the voice overs from myself and Hazel into the file product.
c. I added images from Hazel over the voice overs to make the presentations more interesting.

6. Report
    a. I wrote the Feedback and Limitations sections as well as outlined the Approach section and State of the Art sections.

Hazel Dunn

1. Keyframe the walking and talking of the side character 3
    a. This was a pretty large task, as this character's rig had many parts that all required a lot of manipulation to get the desired effect
    b. In order to get him to speak with the audio, I took Amelie's recording and had to make markers of each syllable for this character's lines. I slowly went through the audio, manipulating his facial expressions for each syllable that was spoken so it looked real, which I learned from videos.
    c. We decided that he would walk after I implemented the talking, so I had to rearrange my previous keyframes in order to fit the walking in in the correct amount of time. This caused a few issues, as I hadn't intended him to be moving in the first part, so all of the positions were off for the facial keyframes and I had to fix all of them a few times.
    d. The character's walk wasn't too bad, but took me many tries in order for it to look semi realistic. While the detail in the rig was nice, it was not possible to just move one part of the body and make it seem like he was walking.
2. Design Character 2, "Mullet Man"
    a. For character 2, we took the rig from the third character that speaks and changed his appearance to be a new character with the same rig. So "mullet man" and the other man in the animation are technically the same rig.
    b. I was responsible for designing the other man, which meant changing the materials of his clothes so he would look different, and finding a way to make his hair look different too.
    c. Because it was a full rig, changing his hair was unusually difficult, as it required a fair amount of messing around in order to look somewhat realistic. We ended up having to just drag the hair down in a certain way that it would look like a new hairstyle.
3. Hallway Scene
    a. In the beginning we could not find a pre-made hallway scene, so I had put a lot of time into creating a scene with shapes and characters in blender.

    b. We obviously found a scene that had a lot more detail, but doing this in the beginning took up a good chunk of my time.
4. Girl With Green Pants Character
    a. In the beginning, I considered having the girl as the main person talking, but we soon figured out that her facial rig was a lot more difficult.
    b. I worked for awhile on trying to animate her in the early stages of our project before Amelie and Matthew added a lot more details to her movement.
    c. We messed with her ponytail for a little while, and it took me a fair amount of time to search through and find good characters to use.
5. Final Video Compilation and Report
    a. We all wrote the script for our video, but I was responsible for finalizing it and preparing everything to be recorded.
    b. I voiced the first section of the video and was responsible for getting all the screenshots in the video over to Bridgette so she could compile everything.
    c. Amelie pretty much put everything together at the end and went through all the trouble of rendering everything multiple times, so she really brought the project together at the end.
    d. We all put in a lot of effort writing the report, and I was responsible for writing the bulk of the information about keyframing and both sections about hair. I also worked with Bridgette on the limitations section. We all put in work editing it and making it all come together.

Matthew Choi

1. Used auto-IK solver on the head of the girl with green pants
    a. The IK constraints were used to orient the girl's head towards the desired characters
    b. The IK constraints failed due to the rig orientation being messed up so I had to use the pole-targets in the IK-solver
    c. Created two IK constraints, one that targeted the "Scared Blonde Mullet" character, the other targeting the boy character
    d. Created a variable that would shift the influence from one of the IK constraints to the other IK constraint so that the girl would look at the "Scared Blonde Mullet" character to the boy character
2. Applied damped tracking constraint on the eyes of the girl with green pants
    a. Since the eyes and head bones were connected in an awkward way in the rig, it was better to separate the two bones
    b. Since the eye bones were disconnected from the head bones, a damped tracking constraint were used on the eyes so that it would track the desired targets
3. Keyframing the change in targets

a. A simple use case of keyframing on the variable that changed the target from the "Scared Blonde Mullet" character to the boy character